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COVER
A production line at one of LM Ericsson's factories for power supply units for telecommunication equipment

Power Units and Power Distribution in the BYB Construction Practice

Christer Boije af Gennäs and Ingemar Webrell

BYB is a mechanical construction practice for electronic equipment that is mounted on printed boards. BYB was originally developed for public telephone exchanges, but it is also eminently suitable for PBXs, transmission equipment and other communication equipment, as well as electronic equipment in general. In order to be complete, a mechanical construction practice for electronics must also comprise methods and equipment for power feeding. When designing BYB great attention was therefore paid to power units and power distribution. In this article the basic guidelines for power feeding are discussed, and the basic range of power equipments and their general design are described.

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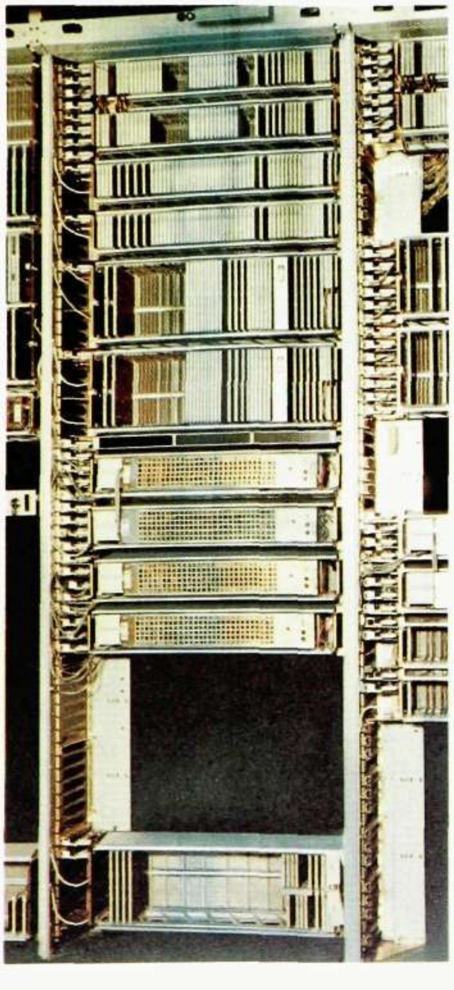
Fig. 1, left
Older construction practice with common power units for all units (electronic apparatus) in the rack

Fig. 2, right
BYB magazines with their own power units (to the right). Each magazine contains a d.c./d.c. converter for local feeding. The system voltage, 48 V, is fed through a bus cable that is branched and fused with a T-connector in each branching point



Earlier construction practices for electronic equipment have been based on construction practices for electromechanical equipment. The relay sets were replaced by electronic units for printed board assemblies. The cabling was still associated with the rack, fig. 1.

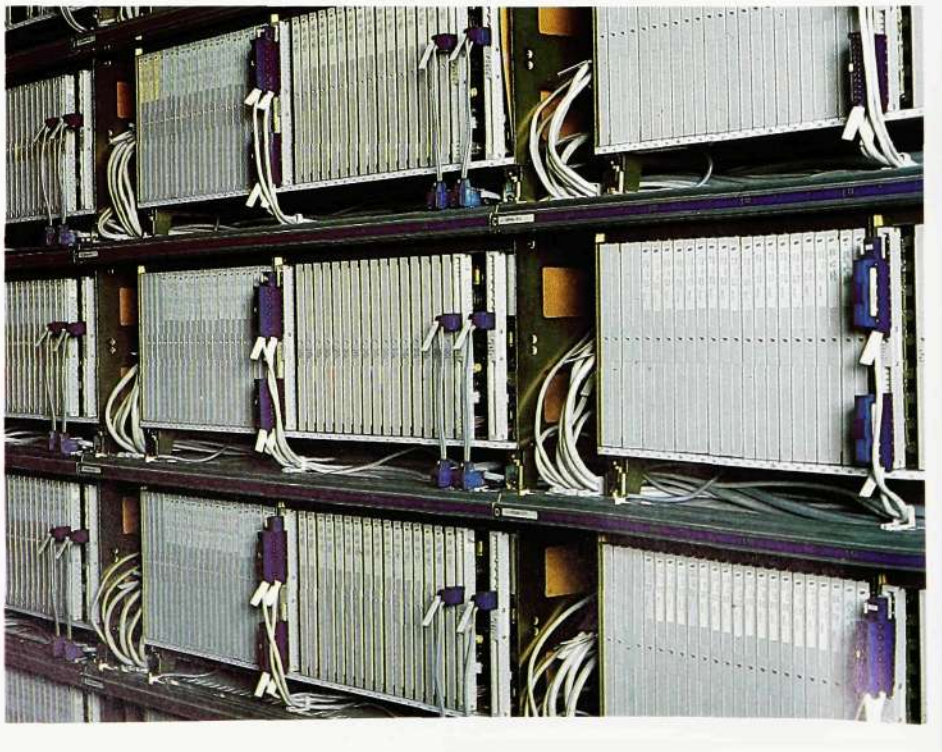
In the BYB construction practice[1] the cabling is entirely dissociated from the mechanical parts and the rack has been replaced by shelves, which permit arbitrary placing of magazines for printed board assemblies. This has made it possible to build up electronic systems of functional modules throughout. Telephone exchange system AXE 10 is a good example of a modular system.

In previous construction practices the power equipments have usually been assembled in one place in the rack, from where the power has been distributed via generously dimensioned conductors to function units placed in electronic sets. This layout was natural in systems where the rack formed the extension unit.

The extension unit in BYB is the magazine, fig. 2. It is available in 8 sizes, and thus each function unit can be given a magazine of its own. The magazines are delivered fully equipped, including a power unit. The power distribution can therefore easily be adapted to the system structure. This makes for a structure that is easy to handle at all stages, such as manufacture, delivery, installation, project planning, operation and maintenance. In this way the power distribution is also well suited for the structural features that are desirable from the point of view of reliability.

Uninterrupted power

The electronic systems for which the BYB construction practice is primarily intended require power feeding that is free from interruptions. The simplest and safest way of achieving this is to use some form of battery back-up. The battery is usually placed centrally and provides a system voltage that is either distributed straight to d.c./d.c. convert-



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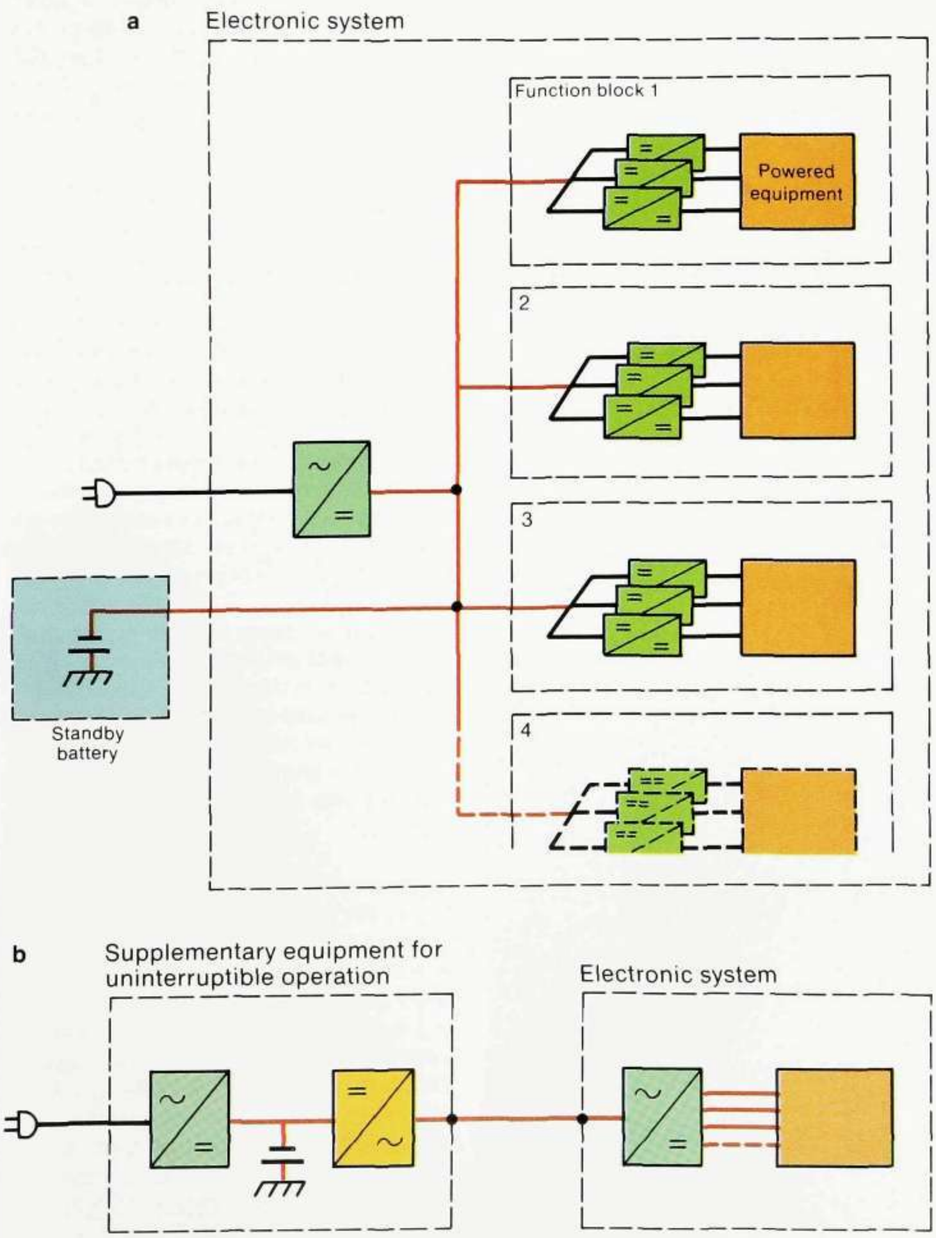


Fig. 3
Uninterruptible power feeding.
a. Electronic equipment which has been designed with the option of uninterruptible operation and with functional modularity. If the equipment is small, the battery can be placed in the equipment.
b. Electronic equipment which has not initially been designed for uninterruptible operation. A converter, battery and inverter must be added to obtain uninterruptible feeding

ers or is converted by inverters for a.c. feeding, fig. 3.

Both methods can be used in the BYB construction practice, but the d.c. feeding method is commonly used. It is more cost-effective because of its higher overall efficiency and smaller batteries. In addition it gives higher reliability since it has a simpler structure and allows the introduction of redundancy by means of parallel coupling.

Inverters are used, for example, to provide uninterrupted feeding of units intended for a.c. feeding, such as I/O devices and fans. However, fans are rarely used since the construction practice provides satisfactory cooling by means of natural convection.

Inverters are also used in equipment that is normally intended to operate without standby batteries in the rare cases where uninterrupted feeding is required.

Knock-out units

In BYB associated magazines can be placed together horizontally in a shelf or vertically in several shelves, fig. 2. Each magazine can contain one or several function units. The units can be dependent on each other or independent with respect to the system functions concerned. From the point of view of reliability the function units can be grouped in *knock-out units*. A knock-out unit consists of a number of interdependent units and is the largest unit that may be affected by a single fault.

A fault in a knock-out unit must not be propagated to other knock-out units. However, a fault in a function unit may interfere with the function of other units in the same knock-out unit.

The required immunity against interference is obtained by placing the power units in the function units and by individual distribution of the system voltage to the knock-out units, fig. 4.

The distribution and earthing of the power supply have been described in detail in a previous issue of Ericsson Review[2]. It describes how each knock-out unit has "high-ohmic" connection to the primary power source. A high-ohmic connection means basically that the resistance of each distribution cable is at least ten times that of the voltage source. The earthing is constructed so that it forms a fine-mesh network with very low impedance. Thus a short circuit in a knock-out unit cannot interfere with other units via the common voltage source or earth.

Like all other cabling in BYB the power cabling is independent of the load-carrying mechanical parts in the construction practice. The power cabling is installed after the shelves have been erected.

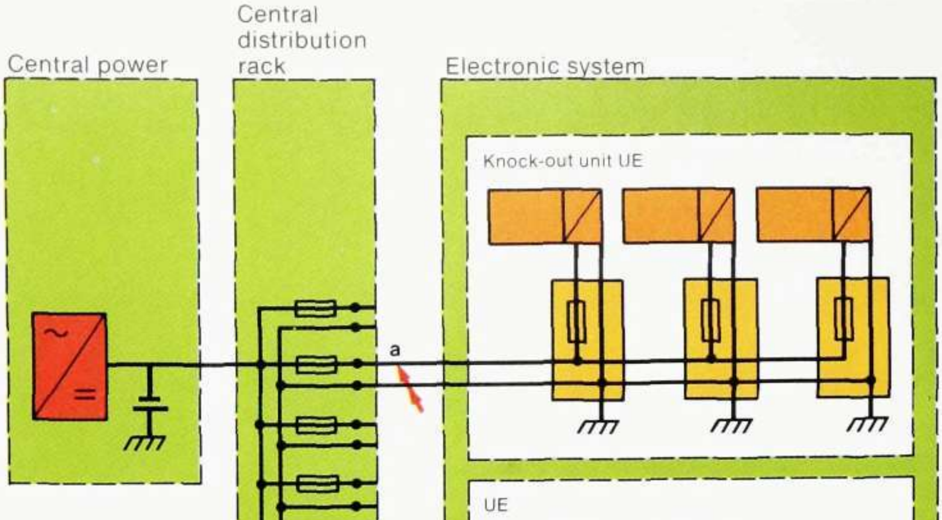


Fig. 4
The basic principles of the power distribution in BYB. One or more magazines form a knock-out unit, which is fed via a fuse in the distribution rack. The power units in the magazines are protected by a fuse in a connector, fig. 5

a — 48 V distribution via a power bus
Function unit containing a power unit
Branching unit with fuse

Distribution in BYB 101

BYB 101 is the variant of the construction practice that is primarily used for large systems. The power distribution consists of external distribution to and between the magazines, and also internal distribution within the magazines.

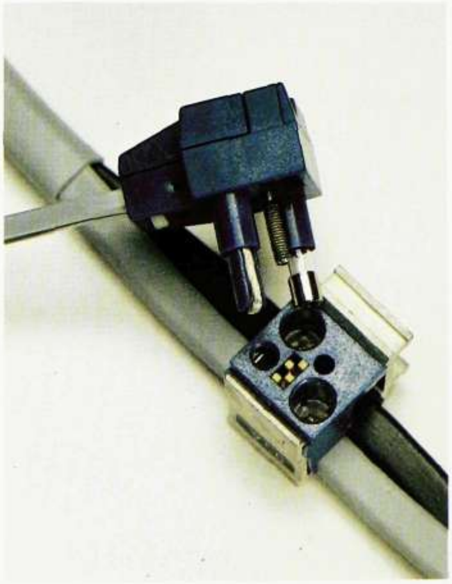


Fig. 5
Connector with fuse

External distribution

The external distribution consists primarily of the distribution of a centrally generated system voltage, usually −48 V. In special cases it also includes the distribution of voltages for electronic components, so-called electronic voltages.

Fig. 2 shows BYB magazines fed with 48 V via a power bus, with fuses placed in the connectors at the branching points, fig. 5. The power bus method has several advantages. The number of wires in the shelves is reduced to a minimum, which simplifies installation. The fuses are placed near the powered units, which almost completely eliminates the risk of making mistakes when changing fuses. Furthermore this distribution method does not take up magazine space.

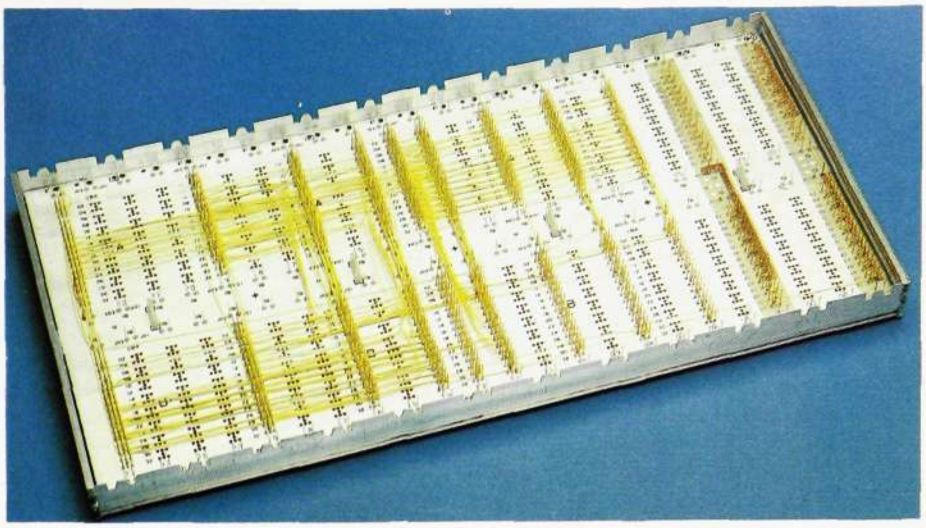
Internal distribution

The internal distribution can comprise both electronic voltages and the system voltage. Bars are used for the distribution from the converters to the printed board assemblies. The magazines can be equipped with up to four packages, each consisting of two bars. The bars are connected to the converters via printed boards and to the printed board assemblies via wire straps. In certain cases, where only small converters are used, the distribution can be done entirely with wired connections.

There are two types of earth distribution used in older magazines. When a signal earth plane in the form of copper foil is used, it is also used for the earth distribution. In magazines without any earth plane the earth distribution is carried out via bars paired with voltage bars.

A general earthing method is used for the latest version of magazines which have a back plane made of aluminium. In this version the printed board assemblies are plugged into connectors having a middle row of eight pins that are directly connected to the earth plane. If the earth is required somewhere else, connection can be made to these pins using wrapped joints. Fig. 6 shows an aluminium back plane with bar feeding and a printed board for connecting the converters to the bars. The signalling

Fig. 6
Aluminium back plane with feeding via bars, and 8 pins per printed board assembly for earthing



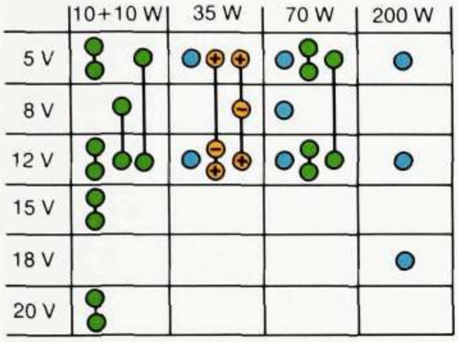


Table 1
DC/DC converters
- (blue) Units with one output voltage, floating relative the input voltage
- (green) Units with two output voltages having optional polarity
- (orange) Units with three output voltages having fixed polarity

connectors are constructed with eight earth pins per connector.

Several of the converters have a floating output, and the polarity can thus be chosen by earthing one or the other of the output poles.

Any distribution of the system voltages within the magazine can be carried out in the same way as the distribution of the other voltages. The system voltage is usually connected to the magazine via the d.c./d.c. converter, whose feeding voltage is taken through to the back plane. The converters usually also provide the possibility of connecting through another, optional voltage from the power connector at the front to the back plane.

Distribution in BYB 201

BYB 201 is the cabinet variant of the BYB construction practice. The system voltage is connected via a distribution unit at the top of the cabinet. The division into knock-out units can be done by running separate cables to the various units. The high-ohmic distribution method is used in this case also, in order to prevent any short-circuit transients from being propagated from one knock-out unit to another, fig. 7.

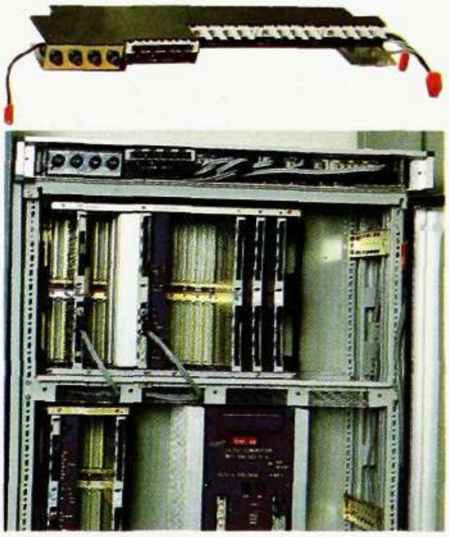


Fig. 7
A BYB cabinet with an electronic fuse unit at the top of the cabinet

With small systems it may be difficult to obtain a sufficiently low impedance in the feeding source to enable the high-ohmic distribution method to be used. In such cases an electronic fuse unit is used instead of the distribution unit. The fuse unit then serves as a current limiter and filter as well as a fuse.

The earthing element in the cables that connect the system voltage to the load is connected to mechanical earth close to the load.

The earthing in BYB 201 has sufficiently low resistance to meet the requirements of the high-ohmic distribution method.

The electronic printed board assemblies are connected to the d.c./d.c. converters via bars in the magazines in the same way as in BYB 101.

Power units

The most common types of power units for the BYB construction practice are
- d.c./d.c. converters, which convert the system voltage (usually 48 V) to d.c. voltages for feeding, for example, electronic components, relays or magnetic tape units
- rectifiers, which convert the a.c. mains voltage to a suitable system voltage
- inverters, which convert the system voltage to an a.c. voltage for feeding, for example, I/O devices.

The distribution of the low voltages takes place almost exclusively within the magazines. This provides the best solution for the system structure, and also helps to keep voltage drops and interference in check.

DC/DC converters

The d.c./d.c. converter is the predominant type of power unit. This is because the conversion to the feeding voltage is carried out in the magazine. Local conversion has advantages as regards modularity, reliability and cost. The number of d.c./d.c. converters manufactured each year is very large. In spite of great efforts towards standardization, the number of variants with different output voltage and power has also become considerable over the years. The basic range is shown in table 1.

In addition to the basic range there are a number of special variants and older units. These are gradually being replaced by newer types from the basic range wherever possible. New types have been made compatible with the old types as regards connections, whenever this has been practically possible.

Mechanical construction

The converters are normally constructed as printed board assemblies for placing in magazines. The only exception is the 200 W unit, which, because of its size, is constructed in the form of a magazine. Units larger than 200 W are not used in the system because of the trouble and cost the distribution of the power would entail. When greater power is needed for a magazine this is arranged primarily by dividing the load and secondly by connecting several converters in parallel. Both methods give better modular adaption and greater reliability then the use of larger units.

Standard converter designs, documented and with set printed board layouts, are used in cases where only low converter power is required. These converters usually form part of the printed board assembly that is to be powered.

Function

All d.c./d.c. converters in the standard range are of the switch type, with a working frequency within the range 20–50 kHz, and thus have high efficiency, fig. 8. The input voltage is chopped and pulse width regulated to a square wave which is transformed over to the secondary side, rectified and filtered.

The circuit design is conventional and does not differ greatly from the circuit design in the units that are available on the market. However, a considerably higher degree of reliability has been achieved, mainly by means of careful choice of components and consistent derating of the components used. Normal MTBF values for the converters are 60–200 years. High reliability is necessary in order to obtain a low repair rate in systems that contain a large number of units. The units are constructed for an operational life of 20–40 years.

Future trends

The number of converter types will increase in spite of all efforts regarding standardization. The strong general tendency towards increasingly more

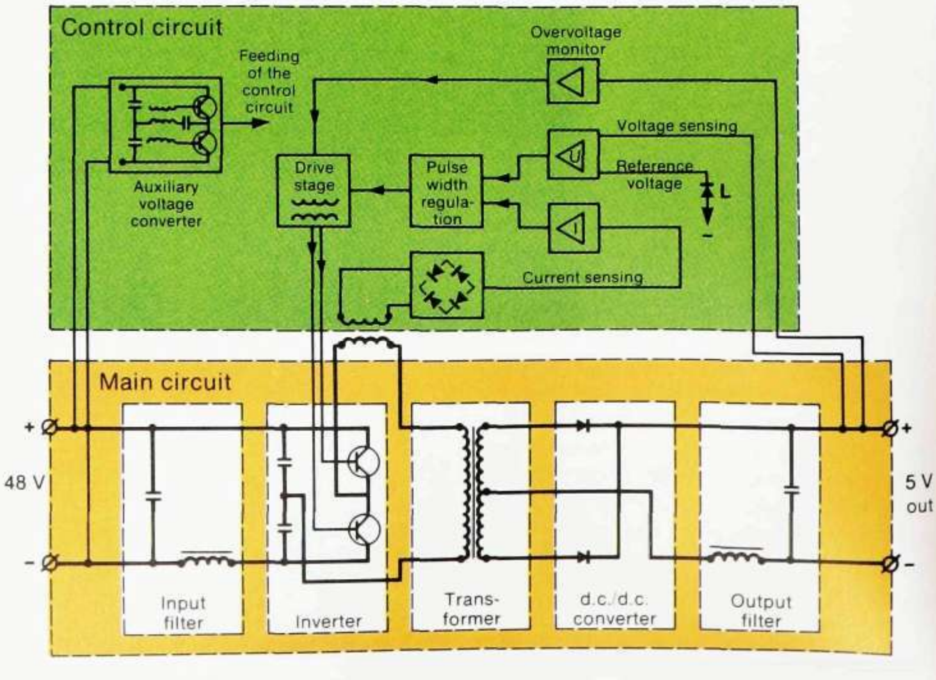
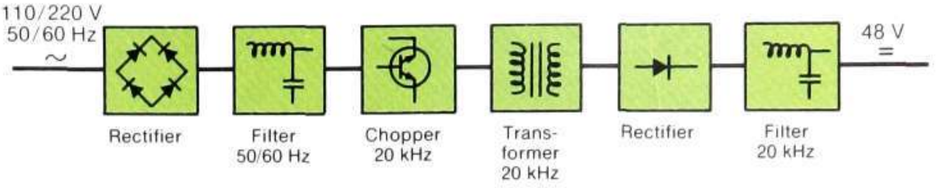


Fig. 8
A simplified diagram for a d.c./d.c. converter

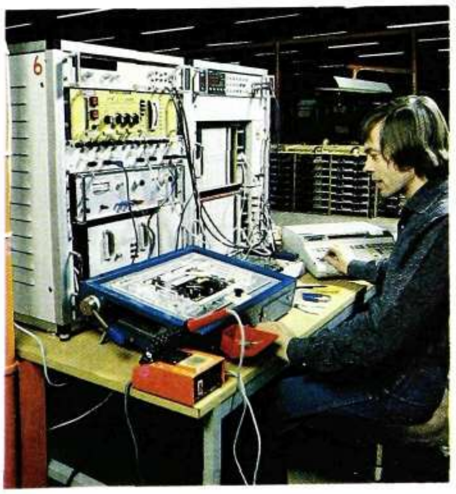
Fig. 10
Block diagram of the primary switched rectifier, DOL



	BFD 200007	BFD 200008	BMT 241	BMT 242	BMT 243
Baterry eliminator	Yes	Yes	Yes	Yes	Yes
Battery charger	–	–	Yes	Yes	Yes
System voltage	48 V	48 V	24 & 48 V	24 & 48 V	24 & 48 V
Current	4 A	4 A	4 A	10 A	25 A
Automatic charging	–	–	Built in	Ex-ternal	Ex-ternal

Table 2
Rectifiers

Fig. 9
Factory testing of a d.c./d.c. converter.
The d.c./d.c. converters are manufactured in large numbers. The experience and manufacturing resources provided by other large-scale production are then drawn upon. The testing is largely automatic, with computer-controlled test routines. The rational production and testing methods ensure a high and even quality



compact electronic equipment means that the designers of power units will be under great pressure to develop more compact d.c./d.c. converters with better performance.

Future units will utilize higher frequencies then present-day units. This will be made possible by new semiconductors, for example MOS-FET power transistors, and better magnetic materials. It is also necessary to achieve greater efficiency, since a more compact design would otherwise give increased power density and thus also higher temperature and lower reliability. In recent years new components and new circuit designs have helped to increase the efficiency from 70 % to 80 %.

Rectifiers

Rectifiers are usually used to convert the mains voltage to the standardized system voltage, 48 V, which is then distributed to the various functional units. Rectifiers for centralized feeding of large exchanges have been described previously in this magazine[3]. In this article only the rectifiers that are suitable for use in units in the BYB construction practice will be discussed.

The output data requirements for the rectifier differ, depending on whether the system is to operate with a battery back-up or not. Rectifiers that work with a battery require very precise voltage regulation and the ability to work for long periods with current limiting. It should also be possible to equip the rectifier with automatic charging, which gives the best battery life.

The requirements are not as severe for rectifiers that are not to work with a battery. This type of rectifier is often called a battery eliminator.

Table 2 shows the standard range of battery chargers and battery eliminators. All have a low-frequency transformer. The battery chargers are phase shift controlled by thyristors, and the battery eliminators have ferromagnetic regulation. All battery chargers for the BYB construction practice have good performance data both with and without batteries, and they can thus also be used as battery eliminators.

Future trends

A new series of rectifiers of the primary switched type, called DOL (Direct Off Line) will shortly come on the market. Their distinguishing feature is that the mains voltage is rectified immediately, after which the d.c. voltage is converted to a suitable value by means of a high frequency d.c./d.c. converter. Thus no magnetic components with mains frequency are required, such as transformers and chokes. The rectifiers can then be made smaller and lighter, and can be made to work almost noiselessly. One disadvantage is that they become more complex, a fact which has previously made it difficult to achieve sufficiently high reliability for sophisticated applications. However, recent developments, particularly in the field of semiconductors, have created new possibilities of obtaining high reliability even with DOL rectifiers, fig. 10.

Inverters

Inverters are used in the BYB construction practice to ensure uninterrupted operation of units that are designed for a.c. feeding. Some such units are recording instruments, tape recorders and fans, which contain various types of motors. AC motors are preferable to d.c. motors because they have a longer life. Moreover, units purchased in the market, such as I/O devices, are often not available in d.c. versions.

The units to be supplied with power have different requirements as regards the waveform and quality of the a.c. voltage. A simple square wave is often sufficient, for example for driving a motor. In other cases a good sinusoidal wave is required in order to obtain the necessary performance. Sinusoidal a.c. voltage, with its small harmonic content, causes less interference in the connected and adjacent equipment.

A phenomenon that often causes problems is the fact that most loading units with a.c. feeding draw a large momentary current when they are connected. Current surges of 100 A are not uncommon. The inverters cannot be dimensioned to maintain the output voltage during such current surges. They are instead often equipped with some type of current limiting. If several loading units

	BFD 200006/1	BMS 602
Input voltage	43–56 V	44–56 V
Output voltage	2×24 V	220 V ±5 %
Output power	2×60 W	500 VA
Wave shape	Square	Sinusoidal
Regulation	Unregulated	Magnetic stabilizer
Synchronization	–	Yes

Table 3
Inverters

are fed from the same inverter there is a risk that the connection of one unit will cause serious disturbances in the others. The best way of avoiding this is to connect only one loading unit to each inverter. This also conforms very well with the applied distribution method with knock-out units. Thus large inverters are not needed for the BYB construction practice. Table 3 shows the available inverters. The standard inverter for 500 VA has been described previously[4]. The highest required amount of power per loading unit is 1 kVA, which is obtained by means of a special type of parallel coupling of two 500 VA units.

Future trends

The present inverters contain transistor or thyristor switches, which operate at the mains frequency, followed by transformers and filters. In the 500 VA inverter the transformer is constructed as a ferromagnetic stabilizer in order to obtain the desired regulation characteristics.

Work on improving the characteristics of these magnetic stabilizers is going on all the time. Improved core materials and refined calculation will in the near future give both greater efficiency and smaller dimensions. For small inverter units, perhaps up to 200 VA, it will be possible to use high frequency technology. The principle is simple. The output voltage from a pulse width regulated converter is modulated by a low frequency sinusoidal voltage. The advantages of this method are, among others, better wave form through faster regulation and smaller dimensions, due to the fact that it is not necessary to use low-frequency transformers and filters. This technology has an obvious field of use in small inverters and ringing generators built up on printed boards. Hitherto there have been considerable practical difficulties with constructions of this type, but these are now on the way to being resolved.

Summary

Modern electronic systems, such as AXE 10, have the following main features:

- highly developed modular structure
- high reliability, partly through being built up of knock-out units
- great adaptability to new technology, such as new mechanical and electrical components and new system designs
- simple operation and maintenance routines.

The BYB construction practice and its power units are developed to suit such systems. The chosen range of power units and the methods selected for the distribution of power make this construction practice extremely suitable for all types of electronic equipment.

Many of the units can also be used in other construction practices, for example in BAF 201 for large power plants and in the common 19" construction practice.

These features mean that the BYB construction practice and its power units are well equipped to satisfy all requirements made on a construction practice, even in the rapidly changing technical environment of the 1980s.

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The Development of Custom Design Circuits

Gunnar Björklund, Jan Johansson, Lars-Anders Olofsson and Jackie Sundvall

This article is one of a series devoted to the activities of RIFA, a components manufacturer in the Ericsson Group. It describes the development of custom design circuits in monolithic and hybrid technique. The authors discuss the specification, design and evaluation of such special circuits.

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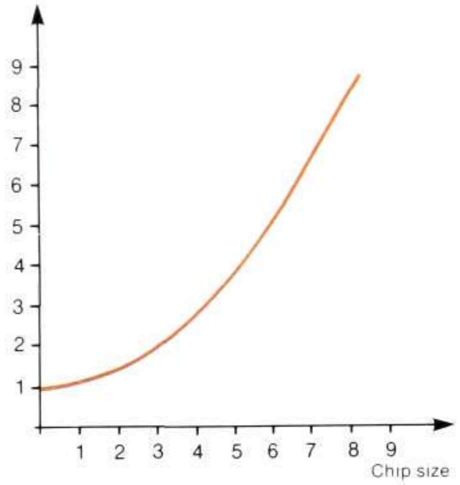

Fig. 2
The circuit cost as a function of the chip size

Special circuits that are adapted to the customer's system design are very important in modern electronic systems. The development of such circuits comprises five different stages.

Stage 1. *Specification*
- Functional description
- Requirement specification
- Quality specification

Stage 2. *Design and simulation*
- Design
- Circuit analysis and computer simulation
- Measurements on the bread-board model
- Layout design
- Checking the design
- Preparing the basic data for production measurements and circuit testing
- Preparing the basic data and tools for production

Stage 3. *Manufacture of prototypes*

Stage 4. *Evaluation*
- Measurements
- Tests
- Approval

Stage 5. *Series production*

This division into stages provides a good survey of the project, the customer can be kept well informed regarding the progress of the work and a natural checkpoint is obtained at the end of each stage. This article describes mainly stages 1 and 2, with monolithic and hybrid circuits treated separately.

Monolithic circuits

Specification

The specification stage is characterized by close contact between the circuit designer and the customer's technical staff. The purpose of this stage is to describe the function of the circuit and to inform the designer about the degree of freedom and the limitations. The first stage usually results in a requirement specification with a block diagram, fig. 1, and a list of external components.

All electronic designs must be adapted to suit the manufacturing method. This is particularly important for monolithic circuits, where unsuitable circuit engineering can result in high production costs. The encapsulation method, the chip size and the efficiency of the circuits are decisive factors as regards the production cost, fig. 2. The cost is reduced to a minimum through efficient design methods and the use of components that require very little chip area. Fig. 3 shows the chip area requirement of some components.

As can be seen from fig. 3, transistors require little chip area compared with resistors and capacitors. For practical and economical reasons it is therefore often necessary to leave certain components, such as large capacitors or high-value resistors, outside the circuit. Another reason for using external components can be the need to adapt to different markets.

One advantageous characteristic of

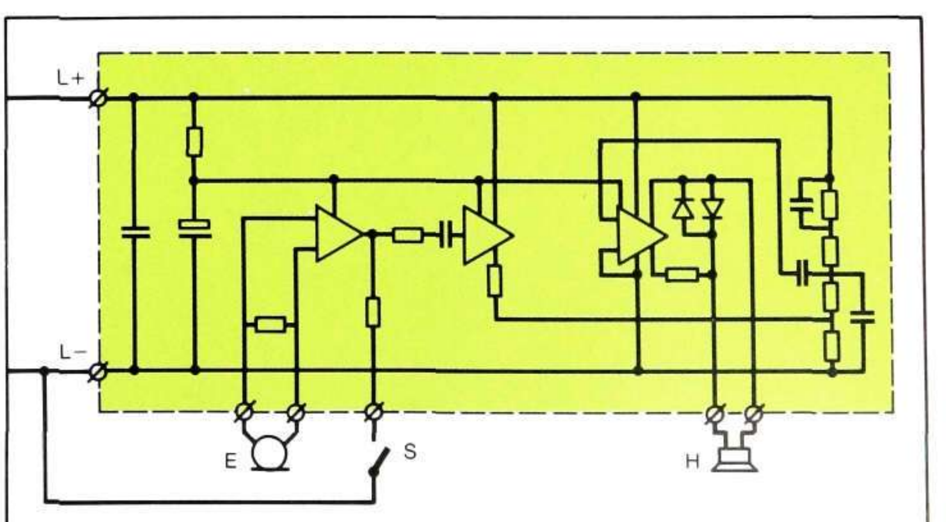

Fig. 1
A block diagram for an integrated circuit

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JAN JOHANSSON
LARS-ANDERS OLOFSSON
JACKIE SUNDVALL
AB RIFA

	Absolute tolerance	Relative tolerance
Resistor		
Resistance	±10–20 %	±0.2–2 %
Transistor		
Current gain	±25 %	±5–10 %
Current ratios	–	±1–5 %

Table 1
Tolerances for integrated components in monolithic technique

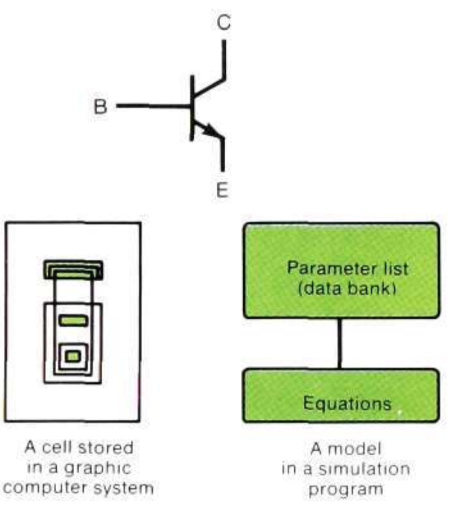


Fig. 4
Components stored in a data base

components manufactured using monolithic technique is that components which are geometrically alike are also almost identical from an electrical point of view. Table 1 gives some typical comparative values for absolute and relative tolerances. The small area requirement and good matching characteristics of transistors are utilized when designing circuits in monolithic technique, and give such circuits their characteristic feature, which may make them difficult to understand for somebody who is used to circuit engineering with discrete components. However, all circuit diagrams can be converted into block diagrams, which give a better picture of the circuit function.

Circuit design

On the basis of the first, rough block diagram and the specification, work is started on a more detailed diagram and the design of the blocks or sub-assemblies. Computerized aids are used, partly to provide verification and partly to simplify optimization and other calculations.

The monolithic technique gives the circuit designer great freedom of choice as regards the geometry of the components, but certain rules regarding spacing must be observed. However, the most rational way is to use standardized circuit elements with well documented electrical data as far as is possible. In certain cases new circuit elements are designed, for example when a circuit design requires special component data which cannot be obtained with standardized elements. A test circuit is manufactured in order to verify the data of the new components.

Standardized components, for example transistors, have been separately encapsulated for use in bread-board models. The geometrical data of such components are stored in a data base in an interactive graphic system for circuit layout, and their electrical data are stored in another data base for use in circuit simulating programs, fig. 4.

Transistors, including JFETs, diodes, thyristors, zener diodes, resistors and capacitors can all be manufactured using bipolar circuit engineering.

The detailed diagram design is verified by means of circuit simulations and by building a complete circuit with standardized components, fig. 5, a bread-board circuit. Electrical measurements are carried out on this circuit to check that its function is in accordance with the specifications and that the circuit design meets the given electrical data. After these measurements the design is discussed in detail with the customer, so that the latter can assess at this early stage whether the finished product will meet the set requirements.

The requirements for the components in the circuit are specified in detail in connection with the calculations for the

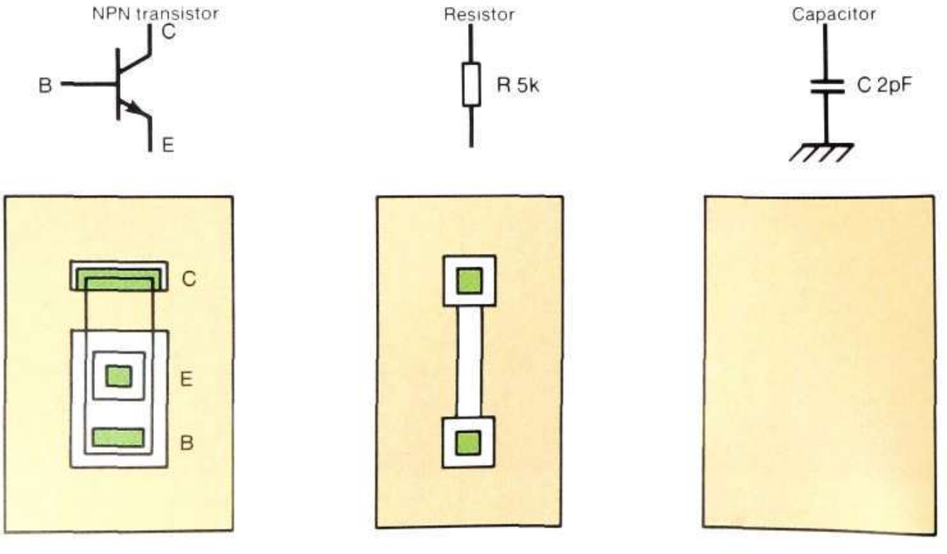


Fig. 3
The chip area requirement for some integrated components in monolithic technique

whole circuit. These data are compiled in a design report, which also includes the geometrical data for the components. The design report forms part of the basic data for the layout work and for the work on determining the permissible tolerances for the manufacturing process.

The design and design report are examined by at least two designers who have not previously participated actively in the work. The intention is to discover any weaknesses in good time and also to enable other designers to benefit from the experience gained from the design. An examination is also carried out together with the staff responsible for measurements and production.

Directives for the layout design are also compiled in connection with the design examination. They comprise a preliminary layout of the blocks in the circuit, the dimensions for the conductors with respect to the current density and descriptions of other freedoms or limitations.

The layout work is carried out in close collaboration with the circuit designer. This is essential, since a part of the function and the performance are determined during the layout work, for example by giving matching components the same orientation in relation to the crystal direction.

The first stage in the layout work is carried out manually, with schematic blocks of approximately the correct size as the smallest units. These blocks are connected together by a conductive pattern. The blocks are moved about and the wiring is changed until an acceptable packaging density with few conductor crossover points has been obtained. The detailed layout of the blocks can either be done manually or in a Computer Aided Design system, CAD, in which the component geometries are stored. The components vary in complexity from simple transistors to, for example, complete logic circuit units. This stage comprises extensive, interactive work which results in a first detailed circuit layout.

The various layers in the detailed layout are drawn in several colours on a drum plotter. The degree of magnification is usually between 200 and 400, fig. 6. The designer then scrutinizes this drawing against the circuit diagram as regards connections and electrical design rules. The CAD system carries out a computer check with regard to geometrical design rules.

After any corrections the production tools are manufactured. In this case they consist of one photographic mask for each stage in the production process. Each mask comprises a large number of the circuit pattern. These masks are used both for manufacturing the prototypes and for the series production of the circuit. A normal production process for bipolar integrated circuits contains between 7 och 12 different masks. The first prototypes are then made. This

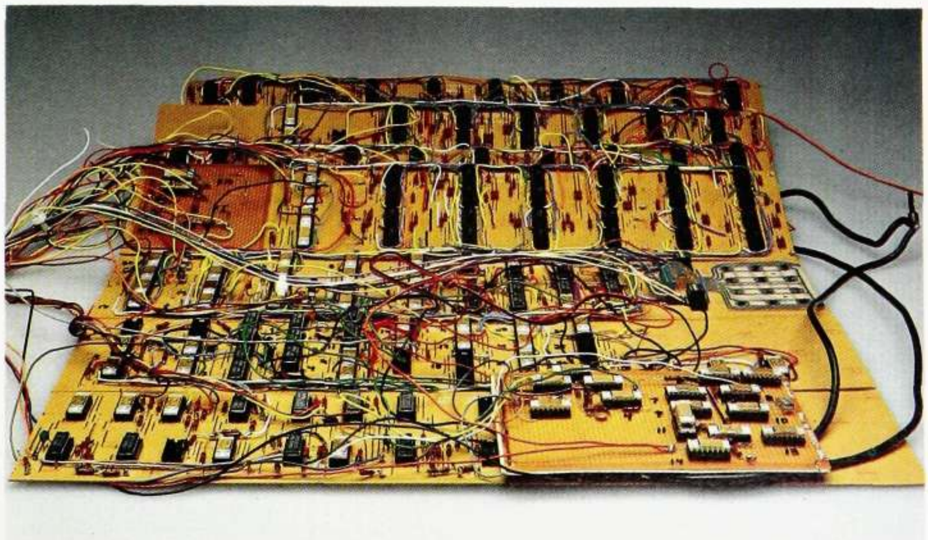


Fig. 5
A bread-board model of a monolithic circuit

batch usually comprises at least 10 silicon wafers, each containing between 100 and 1000 circuits.

The yield is normally between 10 and 80 % depending on the size of each circuit. Thus each silicon wafer can contain between 10 and 800 acceptable circuits. The large number of unacceptable circuits on a wafer makes it necessary to have an efficient measuring program with total testing of the individual circuits while they are still part of the whole wafer. The measuring methods and the basic data for the measurement program are adapted to the computer-controlled measuring systems used in the production. This simplifies the work of designing and manufacturing hardware and preparing software for the testing.

The measuring program is designed to give acceptable security against both functional faults and electrical parameter deviations. It is usually desirable to have a measuring method that can guarantee the function and parameters over the whole temperature range concerned by measuring only at room temperature. An increase or reduction in the feeding voltage of the circuit and the application of stricter measurement limits are often sufficient to simulate the worsening margins obtained at the limits of the temperature range. In special cases, with complex circuits, it may be necessary to carry out comprehensive measurements at the temperature limits in order to ensure correct function over the range.

Evaluation
The evaluation of a new circuit starts with measurements on the first prototypes of the circuit in order to check its function and electrical parameters. If the circuit meets the set requirements, the prototype is delivered to the customer for electrical evaluation and approval. At the same time that the circuit is being evaluated by the customer, its temperature dependence and design margins are measured and specified in detail. These measurements provide the basic data for the preparation of the measuring program in its final form and for optimizing the design before production.

This first stage of the evaluation is then documented and finally leads to an approval for a limited production series. The final approval for production is given after the optimization of the production yield, and after the type test results have been approved.

Circuit simulation
Analysing the electrical function of sizeable networks is very time consuming and can even be impossible to carry out manually. A transient analysis of networks that contain non-linear elements, such as diodes and transistors, is particularly difficult. Computers must be used for such analyses, and special computer programs for circuit simulation have been prepared. The designer is not usually expert in programming, and these programs must therefore be easy to handle and self-instructing.

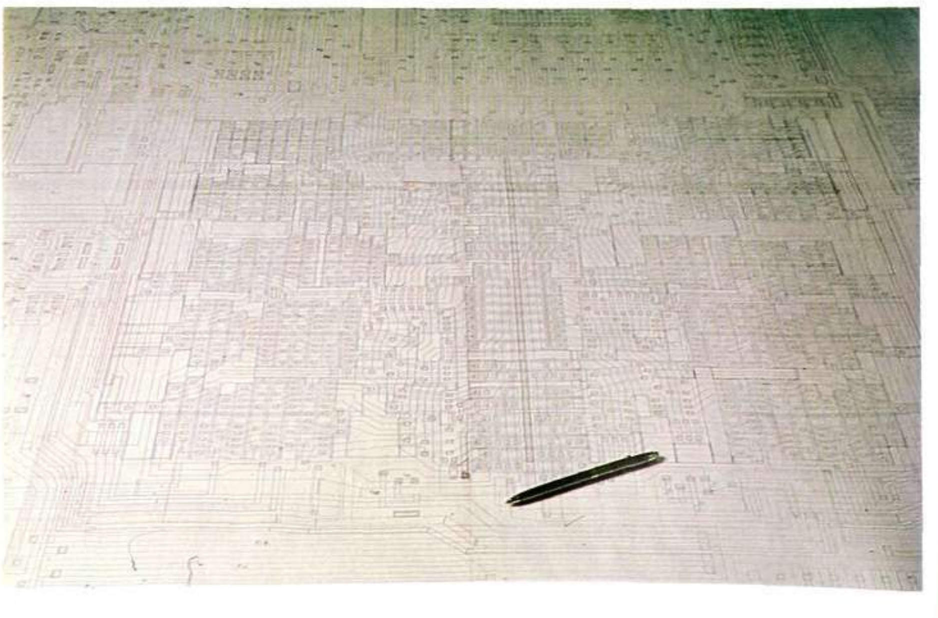


Fig. 6
A circuit layout for a monolithic circuit

The most common simulation programs are node analysis programs. In such a program the network is described as a number of numbered connection points, nodes, between which the elements in the network are connected. The network is described in the input data by specifying the nodes to which an element is connected, the type of element and its parameter values. The elements can be simple, such as resistors with a single resistance value, or more complicated, such as transistors with non-linear characteristics which are described by means of equations with some tens of parameter values. The designer specifies which type of analysis is to be carrried out, for example transient analysis, and which nodes and branches are to be analysed. The desired currents and voltages are listed and plotted in the output data as a function of time, frequency or temperature.

Circuit simulation is often used as early as when the first block diagram is prepared. The circuit function is then described by means of a number of simple blocks, each block being a simple model of a complex network. The analysis is done so quickly that many alternative circuit designs can be compared, for example with regard to sensitivity to defects in components or imperfections in amplifier stages. As the block diagram develops, the models of the different blocks can be made more detailed so that the requirements for each block can be determined.

Fig. 7 shows a detailed block diagram. When working out the detailed design of the blocks it has proved to be advantageous to carry out simulations and at the same time make measurements on a bread-board model. The general function can quickly be determined by means of the measurements, and simulation gives the properties of the true circuit, without the parasitic effects obtained in the bread-board model caused by stray capacitances and wire inductances. When checking temperature properties it is easy to introduce thermal coupling and matching between components in simulation, but it is almost impossible to do so on the bread-board model.

The parameter values of standardized components have been calculated and stored in a data bank. During the simulation it is then only necessary to specify the transistor type, and the program fetches the parameter values. The model for bipolar transistors is usually a modified version of the one originally described by Ebers and Moll[1]. The programs usually contain a macrofunction, i.e. the possibility of building network sections, which can be used in more than one place in the same circuit.

The programs described above give optimization because the designer assesses the result of a simulation, modifies the input data and carries out a new simulation. In certain cases this procedure is not sufficient. Special optim-

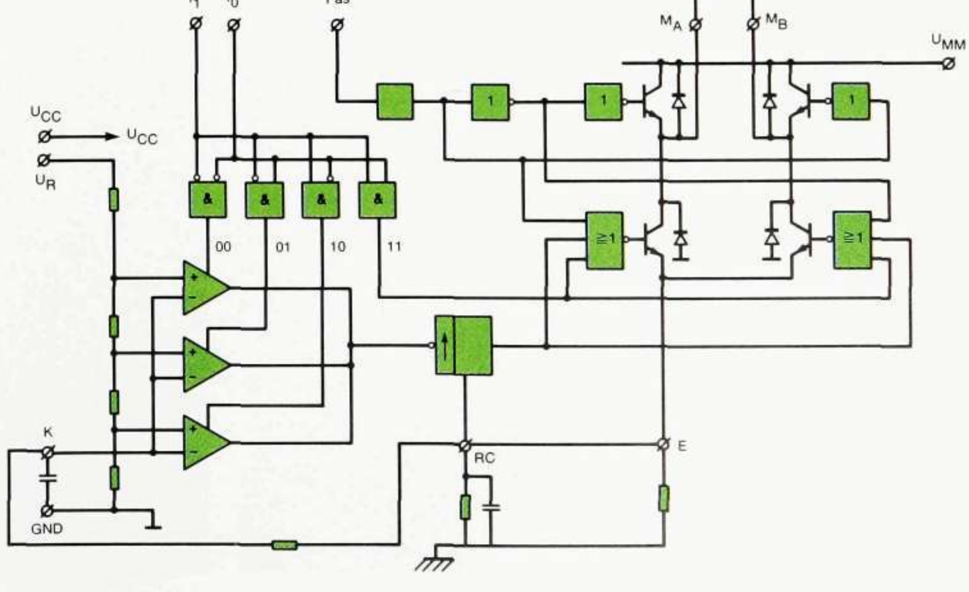


Fig. 7
A detailed block diagram for an integrated monolithic circuit

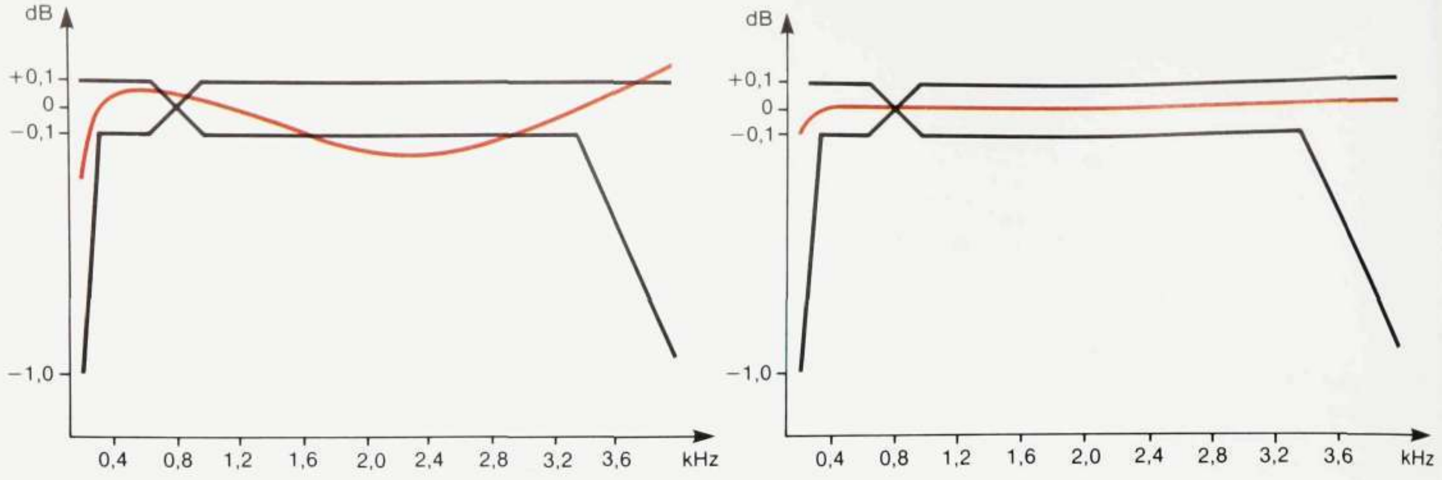


Fig. 8
Optimization of an integrated line interface circuit, SLIC
Left: Data before optimization
Right: Data after optimization

ization programs have therefore been developed. The input data for such an optimization program consist of a network description and also a requirement table and a list of the parameters that may be changed in the attempt to meet the requirements. The program automatically carries out iterations until the requirements have been met. This type of program is more difficult to handle and usually requires the user to have a certain amount of programming knowledge. Fig. 8 shows a printout from the optimization program FORNAP.

Hybrid circuits

Conditions

Hybrid circuits for telecommunication applications are usually manufactured using thick film technique, with high temperature sintering of both resistors and conductors on a ceramic substrate. The resistors are laser trimmed to tolerances better than ±1 %. Active and passive components are mounted on the circuits, which are then encapsulated and the final measurements carried out.

Efficient circuits can be obtained by combining several component types on the same substrate[2]. The types of components that are suitable for thick film hybrids are

- integrated circuits in both MOS and bipolar technique
- discrete components, e.g. transistors, diodes and thyristors
- chip capacitors, both the ceramic and the dry tantalum type.

The components can be mounted after they have been encapsulated, in which case they are soldered or glued to the substrate, or they can be mounted before encapsulation. This is then done afterwards, for example by encapsulation in plastic.

Both capacitors and semiconductors are mounted unencapsulated when a high packaging density is desired. Fig. 9a shows a hybrid circuits with the components glued on. The connections to semiconductors and tags is then carried out in a bonding machine using gold wire, chip & wire technique.

In the case of circuits with both active and passive components it is often advantageous to use a technique with only soldered components. All semiconductor components are then encapsulated individually, usually hermetically in ceramics but also in plastic. Chip capacitors are surface soldered on to the thick film substrate together with the semiconductor components. Fig. 9b shows a circuit in solder technique.

Fig. 9
Different hybrid circuits
a. Chip & wire technique, left
b. Solder technique, right

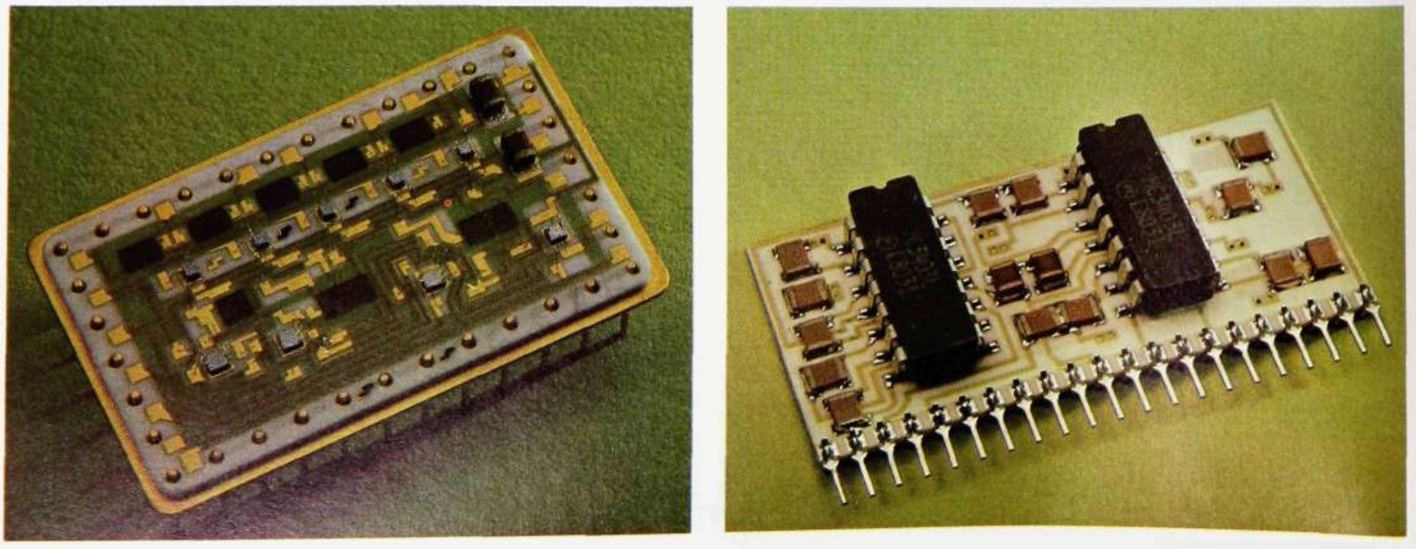
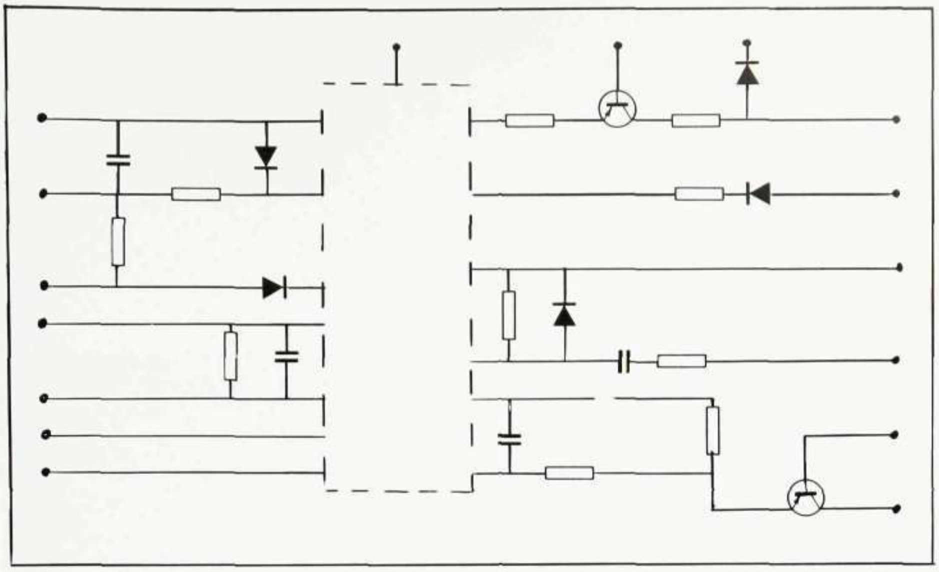
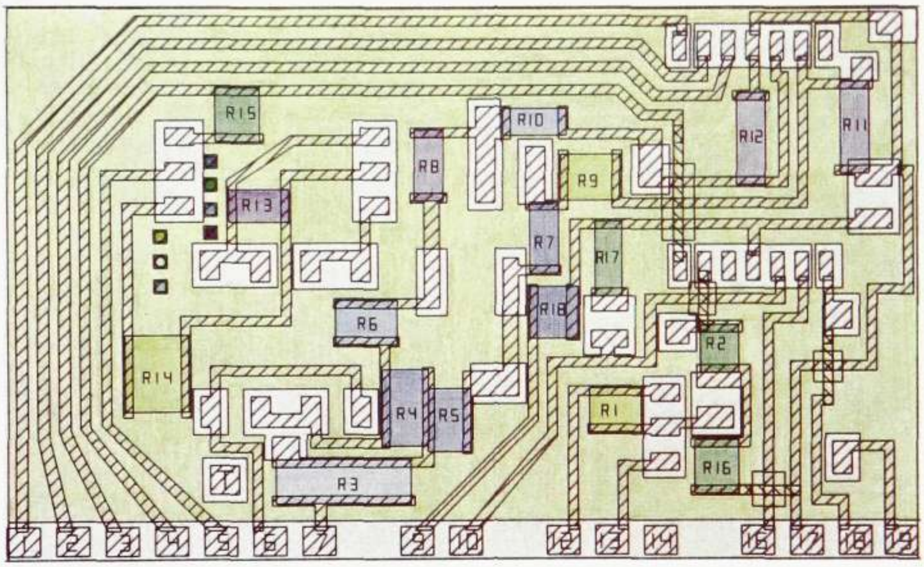


Fig. 10
Stages in the development of a hybrid circuit

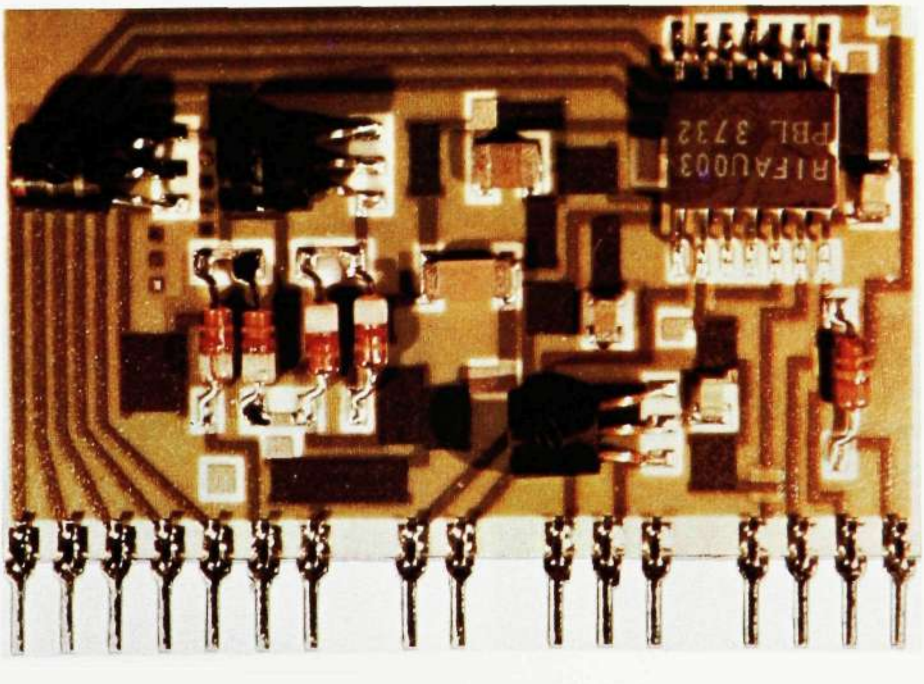


Electrical diagram

Circuit layout



Completed circuit



Specification

The specification for a custom design hybrid circuit describes the electrical and mechanical requirements for the circuit. The circuit specification is normally divided into three parts:

- an electrical requirement specification comprising limits and characteristic data for the circuit
- a mechanical specification comprising requirements for the encapsulation and the connections to the circuit
- a quality specification comprising tolerance and reliability requirements for the circuit.

The circuit specification has a considerable effect on the development and manufacturing costs. It is therefore advisable that the design staff of the customer and the manufacturer discuss in detail the factors that influence the costs, particularly for large hybrid circuit projects, before the development commission is placed.

Circuit design

The design work starts with a thorough examination of the customer's specification, and preparation of drafts for the circuit design. Preliminary drafts may have been made previously in order to estimate the circuit size and manufacturing costs. The various drafts are then assessed by means of calculations and measurements on a bread-board model. In the design work the range of tested and type approved components, which are already documented, are used wherever possible. When it is necessary to introduce new component types or use a new supplier, evaluation and testing must first be carried out.

When designing electrically complex hybrid circuits it is often necessary to use simulation of critical subfunctions and sometimes even simulation of the whole circuit function. In particular it may be necessary to study the temperature sensitivity, the ability to withstand high power and the sensitivity to drift in, for example, resistance values. In all essentials the equipment, programs and methods for simulation conform with those described in "Circuit simulation" in the previous section.

The final circuit design is evaluated using a bread-board model, which can

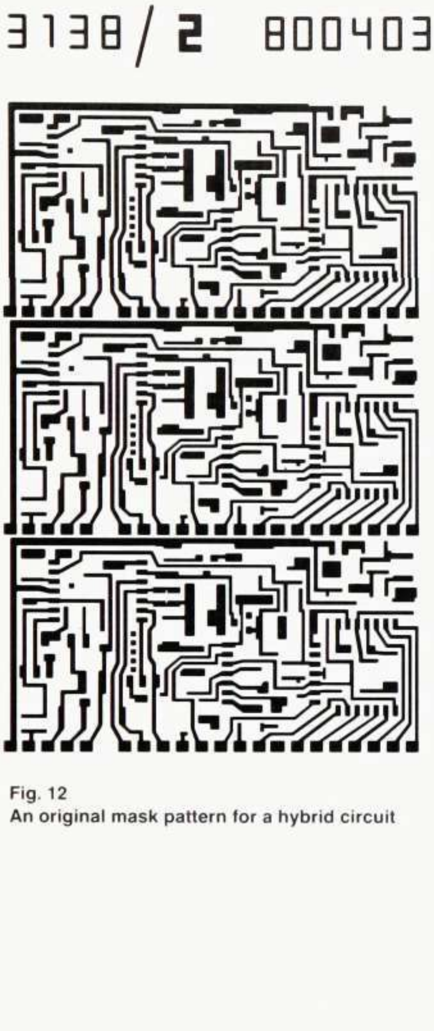


Fig. 12
An original mask pattern for a hybrid circuit

Fig. 11
Digitalization by means of a computerized graphic aid

be built up either on a printed circuit board or on a ceramic substrate. The circuit characteristics can be evaluated in detail by means of measurements on such a bread-board model. Factors that affect the layout, such as matching requirements, permissible tolerances and sensitivity to stray capacitances, can be assessed and the final choice of additional components can be made. Fig. 10 shows the development of a circuit from the electrical diagram to the final hybrid.

The layout work is based on documented rules that specify how the film pattern of the circuit is to be dimensioned in order to obtain the optimum values for the characteristics of the finished circuit. The electrical circuit design often leads to special requirements. Different circuit functions must be separated, for example because of their sensitivity to disturbances or to stray capacitances. The choice of voltage and the requirements regarding ability to withstand currents influence the choice of conductor widths and resistor areas. When positioning the additional components the designer must also pay attention to the power dissipation, the mounting facilities, terminal positions, substrate dimensions etc.

The layout work also includes calculating the dimensions of the resistors on the basis of the given resistance values, tolerances, power values, temperature coefficients and requirements for long-term stability. The designer must also try to achieve the most favourable combination of component placing and wiring. Components, conductors and resistors are placed on the substrate surface in a layout sketch which is then used to generate the pattern in a CAD system. The sketch that is to be input into the system is placed on a drawing board. Its data are fed into the computer store by means of commands together with digitalization of the position of the drawing board index, fig. 11. An original production master is then generated on the basis of the stored information, fig. 12.

The work on the final mechanical dimensioning of the circuit is carried out simultaneously with the layout work. A suitable mechanical circuit construction can provide considerable advantages, such as

- ability to withstand high power
- small dimensions
- simplified mounting
- ability to withstand extreme climatic conditions
- ability to withstand mechanical vibrations and shocks.

Figs. 13–15 show some hybrid circuits with different mechanical constructions.

Basic data for measurements and documentation

Series production of hybrid circuits requires documentation of

- the substrate manufacture including pattern printing and trimming
- component mounting
- pin mounting
- encapsulation
- final measurements and final checking
- type testing.

The designer prepares a circuit specification with supplementary data for the programming of the equipment for the final measurements. The staff responsible for the quality control and the design carry out a joint evaluation of the basic design data and the prototypes, so that the quality control work can start well in advance of series production.

The manufacturing documentation comprises complete manufacturing and flow descriptions, with material and component lists. The documents are

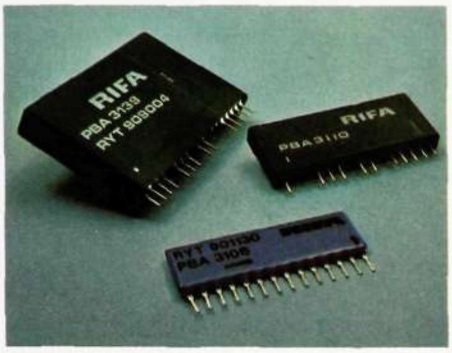


Fig. 13
Single-in-line circuits for mounting on printed circuit boards

prepared by the designer in charge and must contain all information that is required for the series production. In particular all production stages and checkpoints in the manufacturing process must be specified, with reference to the applicable manufacturing and checking regulations.

The stringent requirements that apply for the materials and components used in the manufacture of hybrid circuits mean that type testing and quality control are necessary before these materials and components can be used. The design section documents the requirements that apply for the purchasing and delivery checks.

Before delivery the hybrid circuits undergo a final check that is based on the circuit specification and the quality regulations. The quality control work has provided the basic documentation data for this check. The continuous quality control work is supplemented by periodic quality checks of the circuits. These measures provide a constant follow-up of both the quality of the circuits and their suitability for series production.

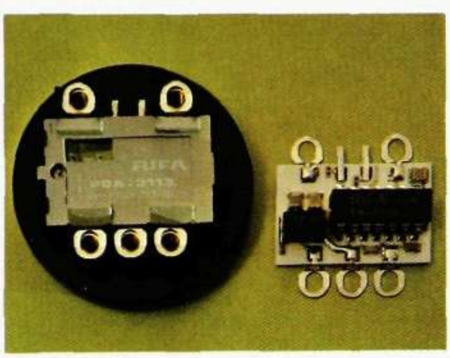
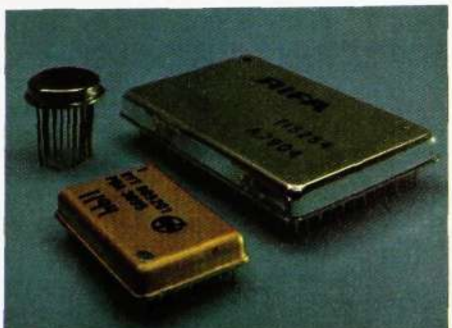


Fig. 14
Special encapsulations for screw mounting

Fig. 15
Hermetic encapsulation for military use



Future trends

Computer aided design systems will have to be used more widely and also be developed further if it is to be possible to develop integrated circuits with greater complexity and better performance. In fact, very shortly, in 1981, RIFA will be taking into service a new graphic CAD system intended for designing extremely complex circuits. One feature of the system is automatic layout checking, and its performance is considerably better than that of present systems.

During the 1980s there will be further development of automatic layout designing and checking, particularly for digital circuits. It will also be possible for the users of integrated circuits themselves to make use of these efficient design aids, partly because the design elements will be standardized.

The development of computerized aids for both simulation and circuit evaluation means that it will be possible to design and test increasingly complex micro-assemblies for use as circuit building blocks.

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Operational Experience of ARE 11 in Seinäjoki

Sakari Uitti

The Seinäjoki concession area comprises the whole of the Seinäjoki group of primary centres and a part of the Vasa group in western Finland. Seinäjoki contains six ARE 11 local exchanges (SPC system with crossbar switches) and a four-wire transit exchange. Control system ANA 30 is used for these exchanges. The operational experience has in all respects met the expectations of the operating staff. The ARE 11 system can interwork with different signalling systems and has a large traffic handling capacity. It provides many valuable operation and maintenance facilities, which can also be utilized for other exchanges in the group.

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The Seinäjoki Telephone Administration was formed in 1893. Its concession area covers 6400 km² and the number of subscribers is now around 33 000, fig. 1.

In 1951 the first automatic exchange was taken into service in the town of Seinäjoki, which is the zone centre. It was a 500-line selector exchange, system AGF from LM Ericsson. The exchange originally had 1500 lines. It is still in operation.

In order to provide better service for the subscribers, automatization of the 13 groups of terminal exchanges in the area was started in 1960. The system chosen was the automatic rural exchange system ARK 50, supplemented by transit exchange ARM 503 in the primary centres. Today about 21 000 subscribers are connected to 117 exchanges ARK 500.

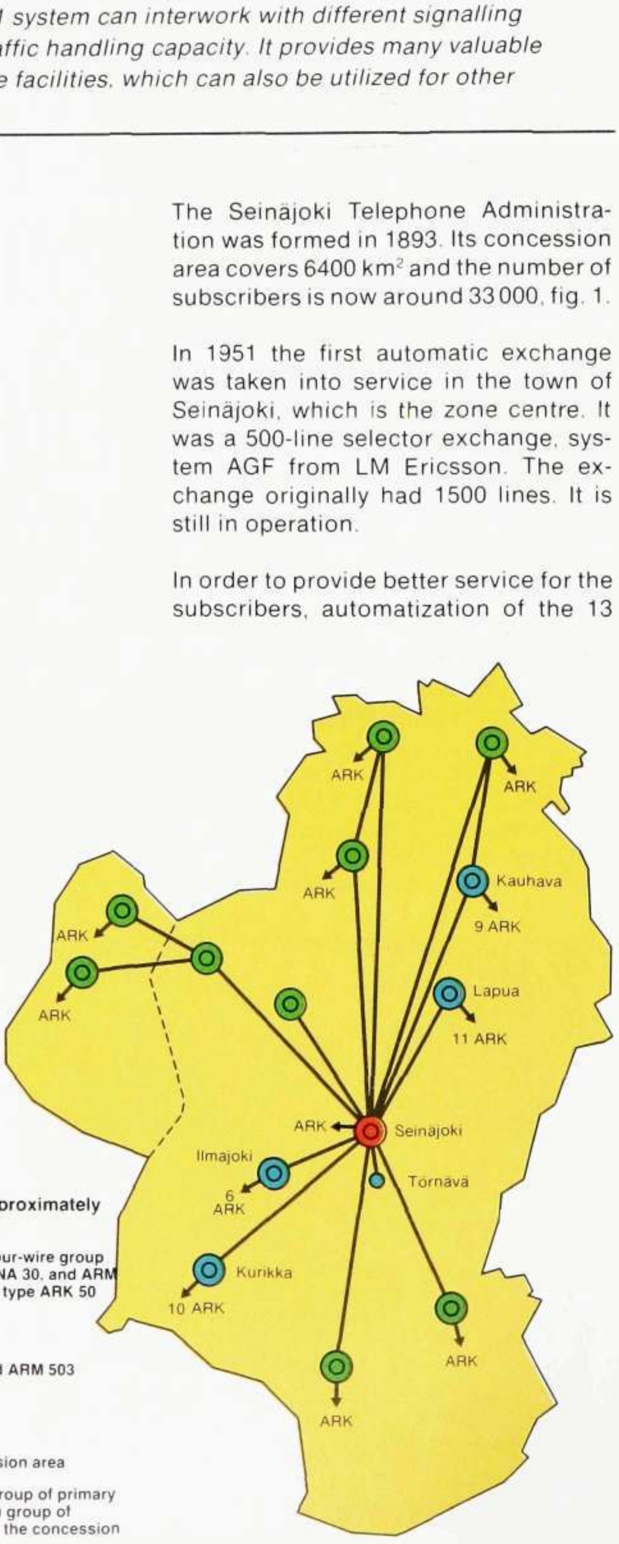

Fig. 1
Seinäjoki concession area with approximately 33 000 subscribers

- Zone centre with ARE 11 and four-wire group selector stage, controlled by ANA 30, and ARM 501 with terminal exchanges of type ARK 50
- Primary centre with ARE 11 and ARM 503
- Primary centre with ARK 50 and ARM 503
- Urban local exchange ARE 11 under Seinäjoki exchange
- Border of the Seinäjoki concession area
- Border between the Seinäjoki group of primary centres and the part of the Vasa group of primary centres that belongs to the concession area

In the 1970s it was necessary to replace the local exchange ARK 50 in the largest primary centres and to increase the capacity of Seinäjoki exchange, and after careful study of different exchange systems the Administration decided, in 1974, to install LM Ericsson's system ARE 11 and thus make use of the many advantages offered by SPC. ARE 11 was chosen because

- it provides smooth interworking with existing exchanges
- the basic version of the crossbar switch system had long proved to be very reliable
- the ARE 11 system is easy to understand and handle, and thus requires very little training and maintenance
- operation and maintenance can be rationalized throughout the whole group of primary centres by means of the facilities offered by ARE 11
- several new functions and services could be offered to the subscribers.

The first ARE 11 exchanges were put in operation in 1976. At the turn of the year 1979/80 six local exchanges and a four-wire transit exchange were in operation, table 1. In addition 6000 lines of ARE 11 have been ordered and are now being installed.

Operational experience of ARE 11

Table 2 summarizes the total number of faults and disturbances that occurred in 1978 and 1979 in all ARE 11 exchanges listed in table 1. Some comments on the figures in table 2 are given below.

The Finnish recommendations allow two faults per 100 numbers and year. The fault rate for 1979 is considerably lower than this.

The number of breakdowns was higher in 1978 than in 1979 because in 1978 control system ANA 30 for the control of the four-wire transit exchange in Seinä-

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Seinäjoki	Transit exchange	10×80 inputs	Successively during 1978/79
Seinäjoki	Local exchange	3000 lines	15.12.1976
Törnävä	"	2000 "	15.12.1976
Ilmajoki	"	2000 "	25.10.1977
Kurikka	"	2000 "	7.3.1978
Lapua	"	1000 "	10.7.1978
Kauhava	"	2000 "	13.3.1979

Table 1
The table shows when the exchanges were taken into service and also their capacity

Number of faults per year	1978	1979
Number of faults in the whole exchange, per 100 lines	–	0.36
Number of faults in ANA 30 only	21	14
Number of breakdowns caused by faults in ANA 30	6	3
Number of faulty printed board assemblies (of a total of 9000 assemblies)	14	12
Total breakdown time in hours	8.5	2.8

Table 2
The table shows the number and types of faults during 1978 and 1979

joki was installed, which caused operational disturbances. Thus seventeen ANA 30 faults were found in the Seinäjoki exchange in 1978. They constituted 80 % of the total number of such faults in the whole group of primary centres. In spite of this, the average breakdown time during 1978 and 1979 was

$$\frac{(8.5+2.8)\times 3}{5\times 2} = 3.4 \text{ hours per exchange and three-year period}$$

The calculations are based on the times given in table 1 which show when the six local exchanges were taken into service. This gives an average value of *five* local exchanges that were in operation during the *two*-year period in question.

The calculated average of 3.4 hours should be compared with the Finnish purchase recommendations for SPC exchanges, which permit a total breakdown time of up to 8 hours per exchange and three-year period.

As regards the faulty printed board assemblies the Administration themselves were able to repair 10 in 1978 and 9 in 1979.

The ARE 11 supervisory system also serves the interworking exchanges

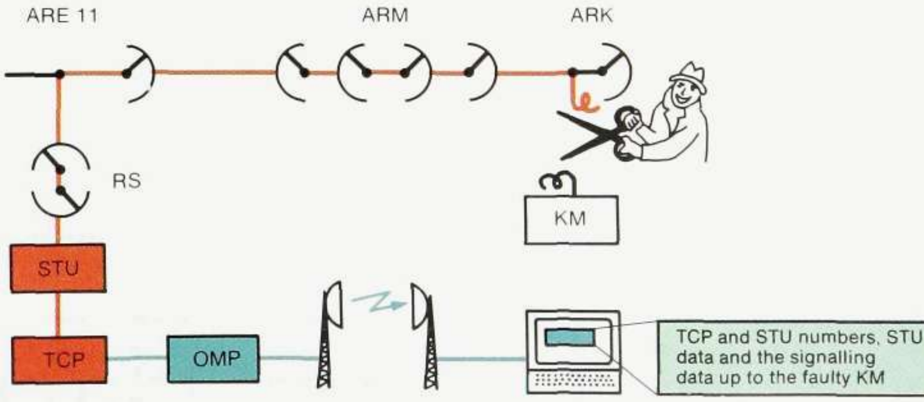
The continuous operational supervision of ARE 11, which also extends to the interworking with other exchanges, makes it possible to also improve the quality of service for the ARM, ARK and AGF exchanges in the whole group of primary centres.

For example, if a fault occurs on one or more circuits between a terminal exchange and a group centre, this is detected because ARE 11 supervises the alarm state in the transit exchange ARM 503. Other types of faults are detected by means of the error rate monitoring. An alarm is given if a limit value is exceeded. Certain devices in ARE 11 can then be marked so that the signalling can be traced even in traffic with ARK and ARM exchanges. Faulty connections can be analyzed and the exact position of the fault in the switched connection is shown on a visual display unit or a printer, fig. 2, It specifies the exchange and even the unit where the fault is located, so the repairman just reads off the information. This means that a fault can often be repaired before the subscribers notice it.

Personnel requirement with centralized maintenance

Three people within the Administration are specialists in ARE 11. They spend approximately 10 % of their time locating and clearing faults in all ARE 11 exchanges. In addition they are maintenance experts for all other exchanges in the group of primary centres and also handle certain operational matters.

The Seinäjoki exchange is the only manned exchange. The other ARE 11 exchanges are supervised from Seinäjoki via data links, fig. 3. The maintenance of the ARM and ARK exchanges has also been centralized successfully by means of the facilities offered by the ARE 11 supervisory system.

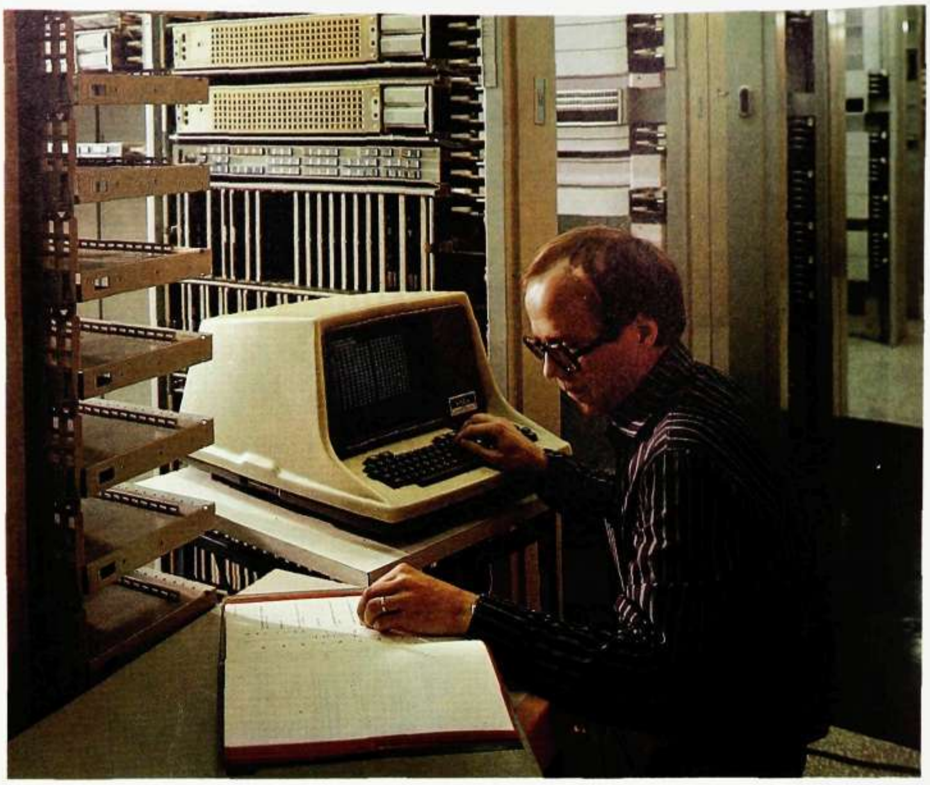


A fault is discovered in the signalling towards KM/ARK
a printout is obtained on the visual display unit

Fig. 2
Marking of the signal transfer unit, STU, in ARE 11 so that the signalling can also be traced in traffic with ARM and ARK. The example shows that a fault has occurred in the code receiver, KM, in an ARK exchange and a fault printout is obtained on a visual display unit in the maintenance centre

RS Line Finder
STU Signal transfer unit
TCP Traffic control processor
OMP Operation and maintenance processor
KM Code receiver

Fig. 3
All ARE 11 exchanges are supervised from Seinäjoki



Training

Seven people have received training in the ARE 11 system for the following posts in the organization:

- a manager for the operation and subscriber services section (engineer)
- a manager for the exchange operation and maintenance activities
- two maintenance technicians
- an exchange planning technician
- an installation and testing technician
- an installation supervisor.

The total training time for all seven participants amounted to 54 man-weeks, distributed in the following way:

- ARE 11 courses at LM Ericsson O/Y, Helsinki, 36 man-weeks
- ARE 11 course at LM Ericsson in Östersund, Sweden, 16 man-weeks
- Fault clearing course during the testing of an ARE 11 exchange, 2 man-weeks.

In addition the manager of the operation and maintenance activities has participated in the installation and testing of an ARE 11 exchange for two months. Each person has also further improved his knowledge of his own field during the course of his work.

ARE 11 can easily be adapted to new requirements

As time goes by the need arises to introduce new functions and services in ARE

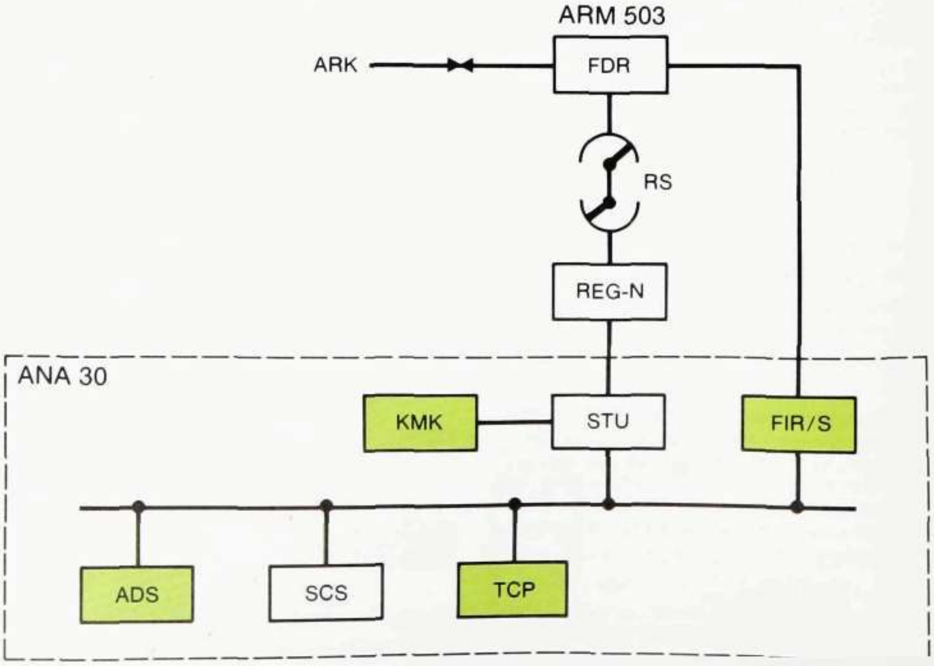


Fig. 4
Existing devices in ANA 30 in a primary centre can be used to provide the subscribers with new services in connected ARK 50 exchanges. (The relevant devices are coloured green in the figure). The subscribers connected to the ARK exchange can themselves change certain data in SCS and ADS

FIR/S	Sensor for hook signals when electronic charging is used
KMK	Tone receiver for push-button dialling
SCS	Subscriber category store
ADS	Abbreviated dialling store
FDR	Junction line relay set for duplex traffic
RS	Register finder
REG-N	Register for the group of primary centres
STU	Signal transfer unit
TCP	Traffic control processor

11. Thanks to the flexibility of the system this is easy to do. A few instances are described below.

Electronic charging and other new functions

The Administration intend to introduce electronic charging in all ARE 11 exchanges. The output from the charging data store can then be processed by computer, which will mean considerable savings. The program store of the existing operation and maintenance processor will be enlarged for this purpose. Among other services that can be introduced at the same time, the Administration has decided upon:

- subscriber-controlled changing of numbers for abbreviated dialling and connection and disconnection of certain subscriber facilities, such as absent subscriber's service and blocking of certain traffic routes
- supervision of the central alarm system and of external alarms, so that alarm information from ARM 503 to the maintenance centre can also be obtained via ARE 11
- a new I/O system, which enables up to 8 local I/O devices to be connected up, and which makes possible communication with the operation and maintenance centre via a data link etc.

The ARK 50 primary centres modernized by the introduction of control system ANA 30

Four primary centres in the concession area are equipped with ARE 11 in combination with ARM 503, fig. 1. In order to increase the life of these ARM 503 exchanges with the associated terminal exchanges ARK 50, the Administration would like to carry out technical improvements so that these exchanges will be almost equivalent to existing ARE 11 exchanges as regards operational functions and subscriber facilities.

Minor changes in the software of ANA 30 will enable the ANA 30 processors to also control ARM 503 and interwork with ARK 50. This has made it possible to realize the above-mentioned improvements. Thus the subscribers connected to ARK 50 can be offered new services, such as push-button dialling, abbreviated dialling and remotely controlled subscriber facilities, fig. 4. Electronic charging can also be introduced for the subscribers at these exchanges.

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Automatic Train Control

Anders Sjöberg

The Nordic Railway Administrations have decided to increase the safety of the railway lines by introducing automatic train control systems on lines carrying a large amount of traffic. The systems, which are based on LM Ericsson's system JZG 700, will provide assistance for the driver and, if necessary, brake the train. In this article the reasons, possible methods and safety requirements for automatic train control are discussed, and the functions and facilities of system JZG 700 are described. The emphasis is placed on the method for track-to-train transmission and the ways and means of using computers in safety systems. Finally a summary is given of the current installation programs.

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Fig. 1
The beacons are installed in pairs in order to increase the reliability of the system. The beacons are encoded so that the evaluation equipment can determine for which direction of travel the information applies

The low friction between wheel and rail means that the railway is a transport medium with low energy consumption, but it also means that the braking distances of trains are very long. A freight train at 100 km/h can have a braking distance of 1200 m. An express train at 130 km/h needs about 700 m to stop. In many cases the train driver's range of vision is less than that.

The driver is therefore informed about the situation ahead by means of light signals and signs. Knowing the characteristics of the train, such as the braking distance, he can then adjust the speed to provide safe and steady driving.

Safety systems ensure that the signals cannot give dangerous information even if a fault occurs. Thus, if the driver acts upon the signal information, no collisions can occur nor any derailment because of excessive speed.

Train drivers, like all other human beings, can make mistakes. How often depends on, for example, how complicated his job is. Increasing traffic volume, with more information to the driver, additional tasks and higher speeds, make the driver's job more difficult.

The railway administrations are introducing systems for automatic train control (ATC) in order to reduce the risk of accidents caused by the train driver. ATC systems must

- transmit information from the track to the train
- present the information in such a way that the driver's work is simplified
- supervise that the train is driven safely, warn the driver in the case of danger and, if necessary, brake the train.

Different types of ATC

ATC systems can work with continuous or intermittent transfer of information, and the amount of information can be small or large.

Continuous systems, where information is continuously transmitted from the track to the train, are comparatively expensive, but are suitable for underground railways and other tracks with a high traffic load. LM Ericsson have supplied continuous systems since 1950.

The predecessor of the ATC systems with intermittent transmission of information was mechanical train stops. LM Ericsson have delivered such systems to several countries. The transmission to the train is carried out by a lever which hits a brake valve on the passing train that is to be braked.

Nowadays the intermittent track-to-train transmission is usually inductive. The track is equipped with beacons, fig. 1. The previous beacon systems have only been able to send a few messages to the train, but both the demands and the available facilities are now greater.

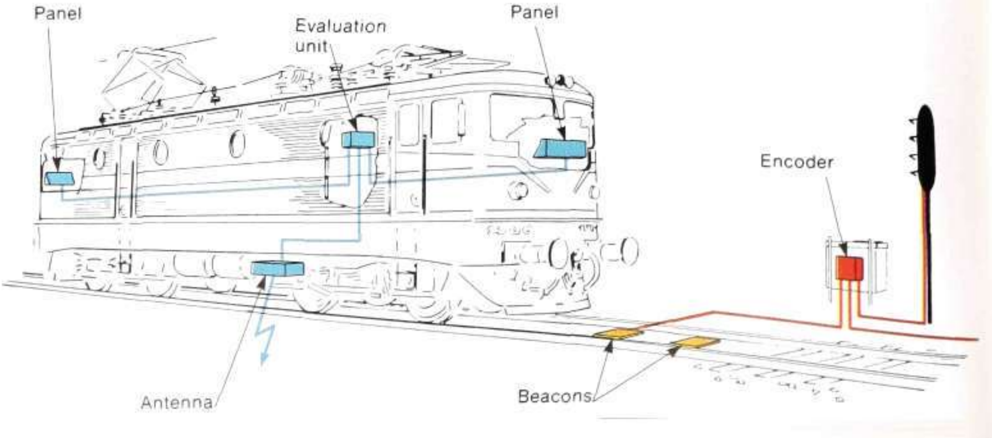

Fig. 2
The units in an ATC system that are installed in the track and the locomotive

ANDERS SJÖBERG
Signalling Systems Department
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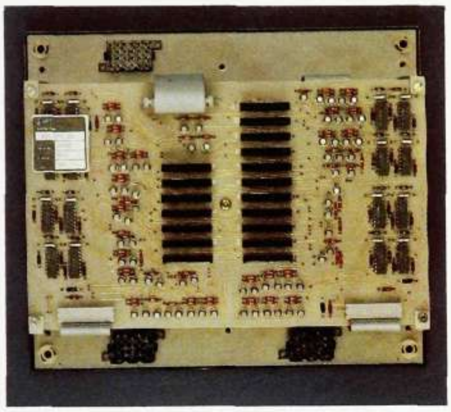


Fig. 3
Encoder

Demand regarding quantity of information

A modern ATC system must
- *warn or brake* in all situations that can be dangerous
- *not warn or brake unnecessarily*, since this would reduce the traffic capacity and reduce the driver's confidence in the system.

The ATC system must therefore handle approximately the same amount of information as the driver whose driving the system is to supervise.

JZG 700 has the required high information capacity. Furthermore it is possible to start by installing a simple system, which has certain limitations as regards traffic capacity. Later on, when the demand grows and experience has been gained, the ambition level can be increased and additional equipment installed, for example at a certain signal, along a line, for a certain type of locomotive or more generally throughout the system.

Safety requirements

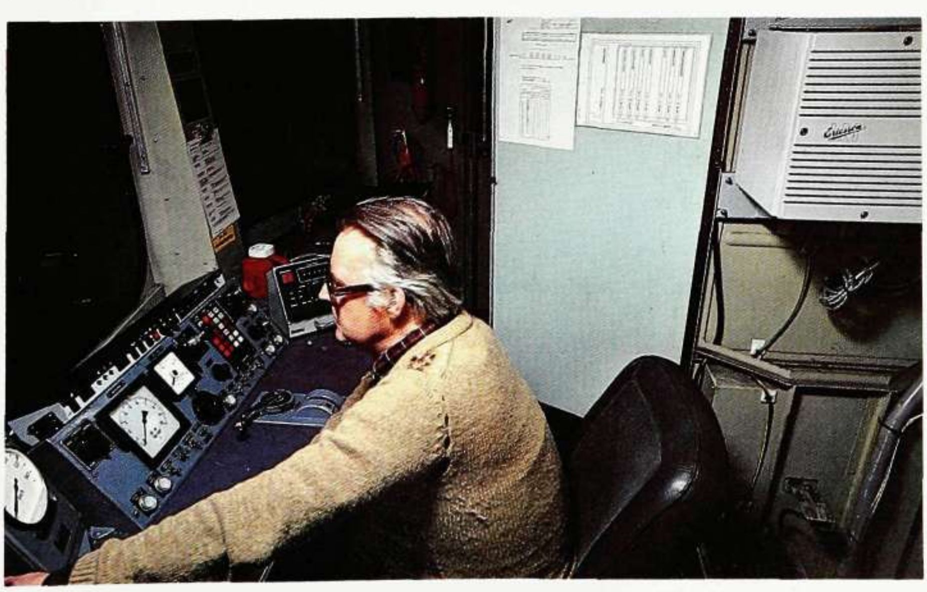
For reasons of safety the ATC system must never let trains be driven at a speed that exceeds the permissible limit. The system must be safe even if a fault occurs. This applies for all types of faults, including design and programming faults.

Fail safe does not mean freedom from faults. For example, if a fault occurs, the ATC system may interpret a "proceed" message as "stop" and brake the train. A stop message, on the other hand, must never be interpreted as "proceed". Availability, i.e. the amount of time when the equipment works accurately, and fail safe are to a certain extent in opposition. Redundancy in code words or duplication of equipment can be used to increase the safety, but it then reduces the availability.

Fail safe means that
- no probable fault, including secondary faults, may create a situation in which the train can be driven faster than would have been allowed if the fault had not occurred
- a fault must be detected and cleared so quickly that the probability is very low that another fault will occur which, in combination with the first, can lead to a dangerous situation.

The safety requirement determines how low these probabilities must be. The safety demands on an equipment mean that the design and manufacture become considerably more difficult and expensive.

Fig. 4
A driver's cabin with control panel and evaluation unit (top, right)



System JZG 700

JZG 700, the latest ATC system developed by LM Ericsson, transmits a considerable amount of information from beacons in the track, via an antenna on the locomotive, to the evaluation and presentation equipment in the locomotive. The system, fig. 2, consists of
- an *encoder* which senses the signal information
- *beacons* in the track, which transmit the information to the train. The beacons are powered by the passing locomotive
- an *antenna and transmission unit* on the locomotive, for scanning the track and receiving the information from the beacon
- an *evaluation unit*, which, on the basis of information received from beacons, panel, speedometer and braking system, supervises that the driver drives safely
- a *panel* for displaying information to the driver and for feeding information regarding the characteristics of the train to the evaluation unit.

Fig. 5
A driver's panel for the Swedish and Norwegian State Railways. The ATC panel is shown framed in white. The left-hand part of the panel contains digit displays that show the speed limits for the current line section and the next speed restriction. The right-hand part contains thumbwheels for entering data concerning the train, such as the maximum permissible speed for this particular train, its length and the reaction time and the retardation capacity of the brakes. It is also possible to enter whether the train may exceed certain types of speed limits. For example, future special high-speed trains may go through bends at higher speeds.

All units and the communication between them meet stringent safety requirements.

The ATC system is designed for interworking with train radio on the locomotives. The train radio can via the ATC system be provided with information regarding the position of the train and the radio channel number. Via the radio it is also possible to quickly inform the evaluation equipment about changes in the signal information, so that initiated braking can be interrupted. This eliminates the disadvantage of an intermittent system compared with a continuous system.

A fully electronic recording equipment can be connected to the ATC system. It records all relevant information, so that if an accident should occur, it will afterwards be possible to reconstruct the events before the accident.

Adaption to special requests from administrations

Traditionally the railway administrations have different signal aspects. These differences mean that adaption is required between signal and beacon, by means of different encoders. Furthermore the locomotives can have different braking systems, different power supply and different speedometers. In these cases also, adaption is required.

The administrations have different safety regulations and different opinions regarding the information to be provided for the train driver. This affects the panel design and computer program. The program in JZG 700 has a modular structure and is to a large extent written in a high-level language in order to simplify adaption to different requirements.

Function

The speed supervision in modern ATC systems is carried out by means of
- indication of the speed limit
- warning and braking when the speed limit is exceeded, fig. 6
- warning and braking when the driver does not reduce the speed sufficiently when approaching a lower speed limit, fig. 7
- emergency braking if the train passes a stop signal.

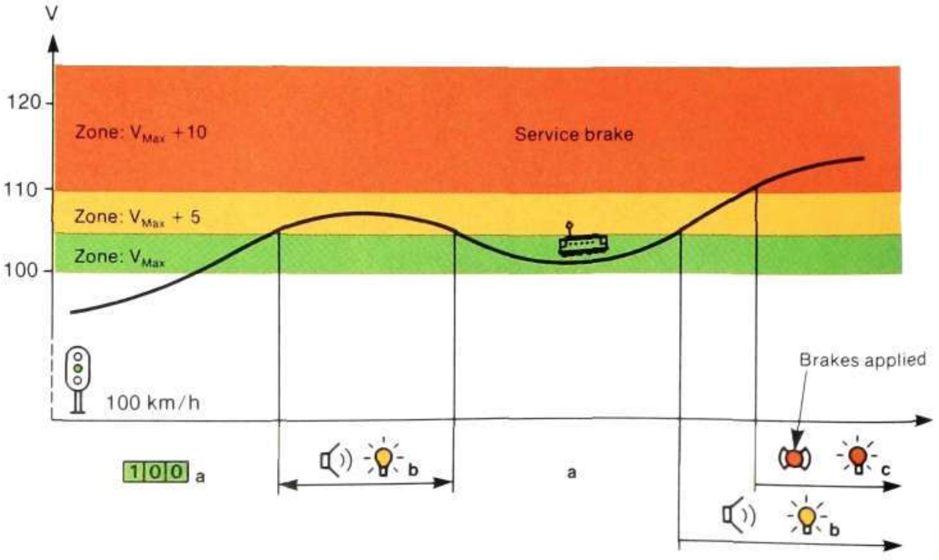


Fig. 6
Warning and braking when the speed limit is exceeded.
a. The display shows the speed limit (V_{Max})
b. Acoustic and visual alarms are given when the speed limit is exceeded by between 5 and 10 km/h
c. Automatic braking is carried out when the speed limit is exceeded by more than 10 km/h. The braking is indicated by a lamp. When the speed of the train is reduced to the permissible level the driver can cancel the braking by depressing a button

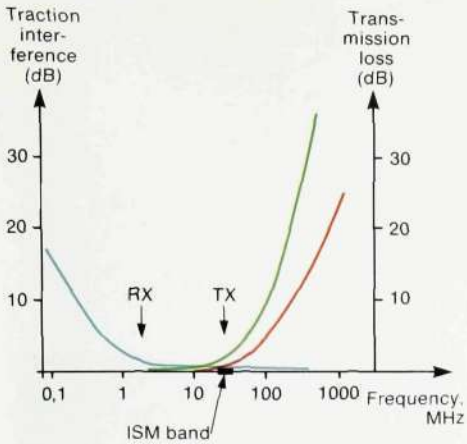


Fig. 8
Choice of frequencies for JZG 700

Relative interference level from the traction current
Attenuation by 10 mm iron ore concentrate
Attenuation by 100 mm water
RX Information frequency
TX Scanning frequency

Advance signals and signs along the line inform the train driver about speed limits on the following sections. Via encoders, beacons and inductive transmission to the locomotive the evaluation equipment receives the same information, supplemented by information regarding track gradient and distance to the beginning of the section with the new speed limit. On the basis of this information and the data regarding the braking characteristics of the train, which were fed in via the driver's panel before the train started, the equipment calculates when the train must be braked in order to slow down to the set speed limit at the beginning of the relevant section. On the Swedish and Norwegian State Railways this information is displayed for the driver when the train is at the normal braking distance (8 seconds before the ATC system intervenes). After that a warning that the train must be braked immediately is given 3 seconds before the ATC system acts. If the driver still does not apply the brakes, this is done automatically.

Track-to-train transmission

The demands made on the track-to-train transmission are severe as regards ability to withstand adverse environment, quantity of information and safety.

The *environmental requirements* are that the system must be able to withstand

- ambient temperatures between −40° and +70° C
- impact acceleration on the beacon up to 300 m/s^2 (30 *g*)
- blows on the locomotive antenna from bouncing gravel
- oil on the antenna and beacon
- 100 mm water or ice on top of the beacon
- the train antenna covered with ice or snow
- 10 mm iron ore concentrate on top of the beacon
- electrical and magnetic interference from the locomotive
- interference from radio transmitters.

These environmental requirements affect the choice of material and transmission frequency. Low frequencies suffer more from interference from the locomotive traction system. In addition low frequency means large dimensions. The choice of higher frequencies is mainly limited by the effects of water, dirt and ore on the beacons, fig. 8.

The telecommunications administrations accept the use of the internationally standardized ISM band at

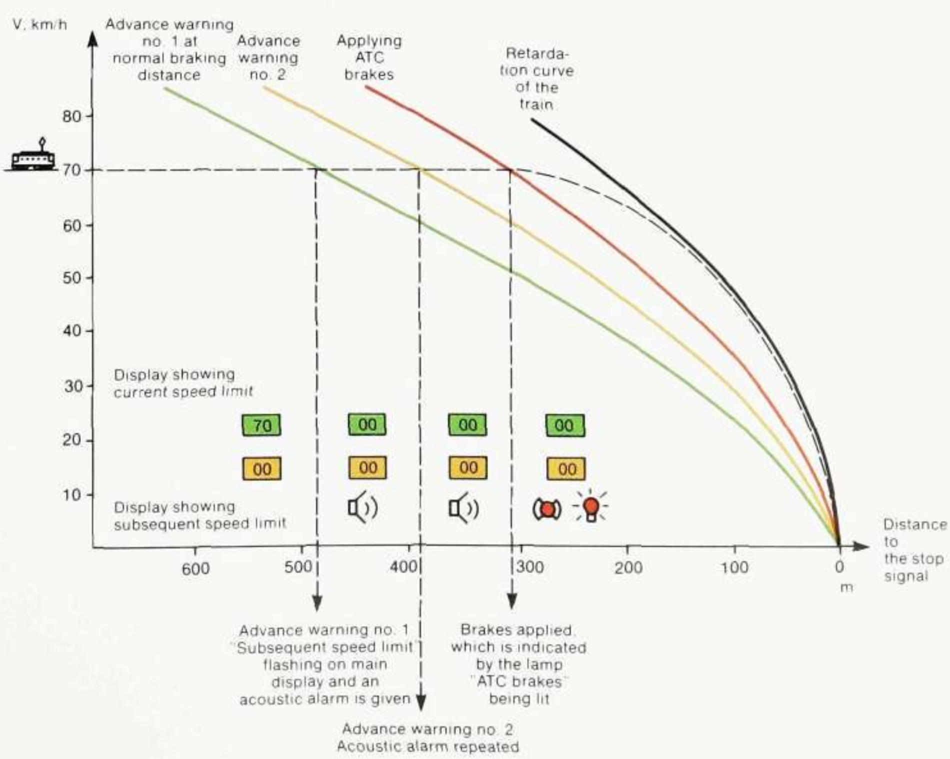


Fig. 7
The function of the ATC system on the Swedish state railways for a train at 70 km/h which approaches a stop signal without the driver applying the brakes.
S is the distance between the point where the ATC system intervenes and the beginning of the section with lower speed limit
S=the advance warning distance + the brake application distance + the braking distance

$$S = t_f V_T + t_b V_T + \frac{V_T^2 - V_M^2}{2b}$$

V_T The speed of the train
V_M The speed limit (in this case 0 km/h)
t_f Advance warning time
t_b The appplication time of the brakes
b The retardation of the train with full braking power, adjusted for track gradient and bad track conditions

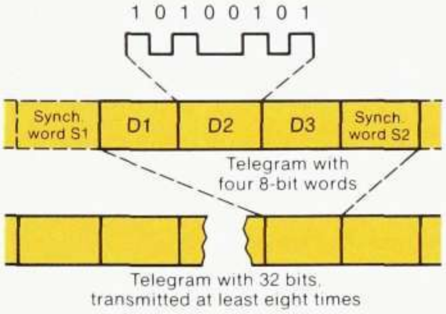


Fig. 9
The quantity of information per message. The message from a beacon consists of three eight-bit data words, D_1, D_2 and D_3, and a synchronization word, S_1 alternating with S_2. The *message must be transmitted at least eight times* while the locomotive travels over the beacon.

27 MHz for the scanning signal from the locomotive to the beacons. The frequency is at the upper limit for what is called inductive transmission.

The level of the signal from the beacon to the locomotive is so low that there is no risk of it causing interference. The locomotive motors cause more interference than this signal. A frequency of 4.5 MHz was chosen for this direction to avoid any disturbance from radio transmitters.

The *quantity of information* which it must be possible to transmit to the locomotive corresponds to more than 3000 different messages. This is achieved by sending 3 words, each with 4 information bits, from each beacon. Four redundancy bits per word are added in order to reduce the risk of errors. The 8-bit words thus obtained are encoded so that 4 bits in a word must be wrong if it is to be possible to mistake one code word for another.

In order to reduce the error risk further, the equipment in the locomotive will only accept messages that have been identical at least four times of the eight times it has been received during the passage over a beacon. Each three-word message is preceded and followed by different eight-bit synchronization word. These precautions mean that the risk of a message being misinterpreted is negligible.

As can be seen from fig. 9, more than 256 bits must be transmitted while the locomotive passes over a beacon. With train speeds of up to 300 km/h and a beacon and antenna size of only 0.5 m a transmission rate of 50 kbit/s is required.

The *safety requirements* demand that beacons must be detected and that it must be impossible to misinterpret a message. The risks of misinterpretation have already been discussed. The beacon is designed so that no individual fault or probable combination of faults can lead to the beacon transmitting a less restrictive message than the correct one.

The beacons are installed in groups of not less than two. If one beacon develops a fault the driver of a train that passes this beacon receives an alarm. The equipment in the locomotive checks that the beacon groups are complete and that the distance between adjacent groups is correct.

For reasons of safety and maintenance the transmission of information to the train has been made independent of batteries etc. in the track equipment. The energy for the beacon logic and the sig-

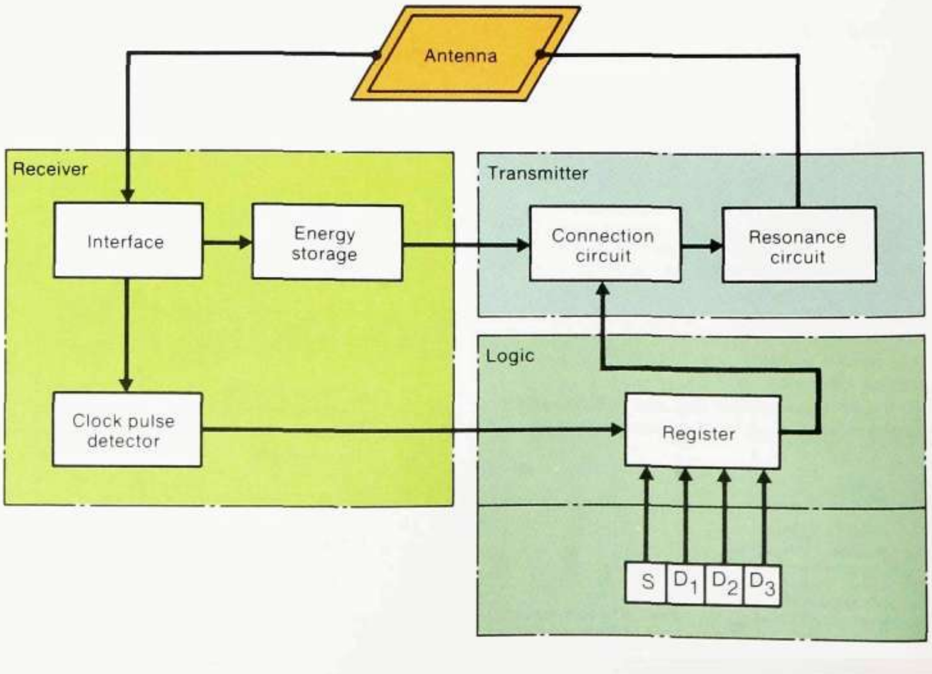


Fig. 10
A block diagram of the electronics in a beacon

Fig. 11
Antenna

The ATC system of the Swedish State Railways can transmit any of the following numbers of messages from the beacon to the antenna:

– current speed limit from main signal	14
– subsequent speed limit from advance signal, i.e. the speed the train must keep at the next main signal	14
– speed limit from speed limit signs (5 causes and 42 levels)	210
– subsequent speed limit from precaution signs, i.e. the speed the train must keep at the next speed limit sign	210
– distance between advance signal and main signal or between precaution sign and speed limit sign	210
– track gradient	15
– signal identity	2048
– radio channel number	196

nalling back to the train is transmitted from the train. The energy for the encoder electronics and its control signals to the beacons is taken from the power feeding to the lamps in the signals that the encoder is sensing.

Beacon design

Fig. 10 shows the block diagram of a beacon. The scanning signal from the locomotive is received by the receiving loop in the beacon. The scanning signal consists of a 27 MHz carrier, interrupted by 50 kHz clock pulses. The energy content of the signal is stored and the clock pulses are filtered out. The receive side of the beacon contains an energy output and a clock output.

Every clock pulse shifts the contents of a register in the beacon logic one bit forward. The register contains the message to be sent to the train. When the shift register output contains a zero the energy stored in the receive side of the beacon is fed out to a resonance circuit, whose inductance consists of the transmitting loop. The resonance circuit starts to oscillate at 4.5 MHz with decaying amplitude. No energy is fed to the resonance circuit if there is a one on the shift register output.

When 32 bits have been shifted out in this way, new information is read into the shift register in parallel. Fixed information, such as synchronization words and information regarding preset speed limits and distances, is obtained from strapped connections in the beacon. Information concerning signal-dependent speed limits is obtained from the encoder.

The beacon consists of a sheet of glass fibre armoured plastic with receiving and transmitting loops embedded in the rim. The electronic components are mounted on a printed circuit board placed in a box underneath the sheet. The printed board assembly is surrounded by a filling that protects the components against damp, reduces vibrations and prevents cracking by frost. A life of 40 years has been aimed at when designing the beacon. The beacons are only 22 mm high so that they are not damaged during snow clearing and other work on the track. Their width is 400 mm and the length 536 mm.

Transmission equipment in the locomotive

The carrier is generated in the transmitter printed board assembly in the evaluation equipment. The carrier is modulated by 50 kHz clock pulses which cut off the carrier for a few microseconds. The antenna equipment contains a power amplifier stage for the output signal. The antenna is shown in fig. 11.

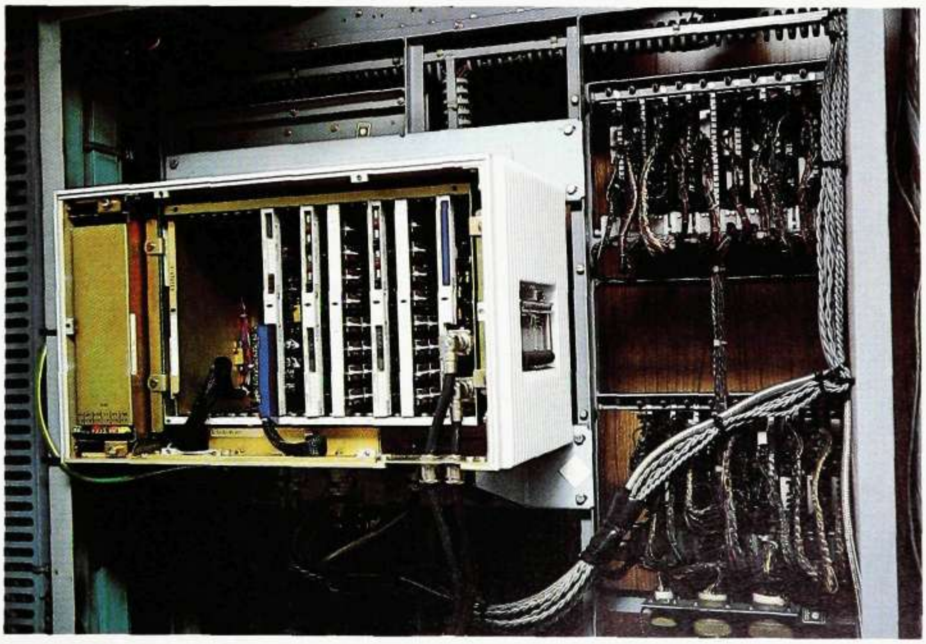


Fig. 12
An evaluation unit, mounted in a driver's cabin. The unit consists of a power unit and transmission, processor, data storage and interface units in the form of printed board assemblies. They are placed in a cabinet having the dimensions 400×300×325 mm. The problems with interference from the locomotive have been overcome by galvanic insulation and filtering of all incoming and outgoing conductors at the input to the evaluation unit. Communication with the panel takes place over two-wire lines, with data sent in series form.

The 4.5 MHz signal from the beacon is received by two loops in differential coupling in the antenna. This coupling suppresses the 27 MHz signal from the send loop, which is placed between the two receive loops. It also suppresses radio interference.

In order to ensure that the antenna and transmission function satisfactorily they are frequently tested by means of a test beacon placed in the antenna. This beacon can never be more sensitive or send a stronger 4.5 MHz signal than the faintest beacon which the equipment must be able to detect. The test beacon is activated every 50 ms by the computer in the locomotive. An alarm is given if no signal is then detected.

The evaluation equipment and its safety level

The evaluation equipment, fig. 12, has to process so much information that computers have to be used. Hitherto the use of computers in safety systems has been restrained, although development and experiments have been carried out in many countries. Solutions have been sought that make the systems safe in spite of the fact that components in the computers can develop faults. The fault types that must be considered in a computer system are

- hardware faults, such as random component faults, systematic component faults and interference
- software faults.

Much of the experience gained from relay and electronic systems without computers can be drawn upon to clear hardware faults in computer systems.

Two independent channels are often used for the processing of information in order to detect any random component faults. Checks that the results are the same are made at the channel outputs and at suitable points in the channels. If this checking is made frequently and is extensive enough, the risk is negligible that both channels develop the same, independent fault without it being detected.

Complex components sometimes contain systematic faults, i.e. faults that occur in all circuits of a certain type or in a certain production batch. For example, a certain combination of data can cause a functional fault since the component may be pattern sensitive. The risk of such faults affecting the function is small enough to be acceptable as regards the availability requirements for most systems, and the components are therefore sold in spite of the faults. In safety systems such faults must be rendered harmless.

In safety systems it is also important that dangerous output data are not produced even outside the specified temperature range, and thus faulty functions must also be considered in these areas.

Systematic component faults can be detected by designing the two calculation channels differently, or by not using them in the same way. Differences between the channels also mean that the results obtained will be affacted in different ways by any interference.

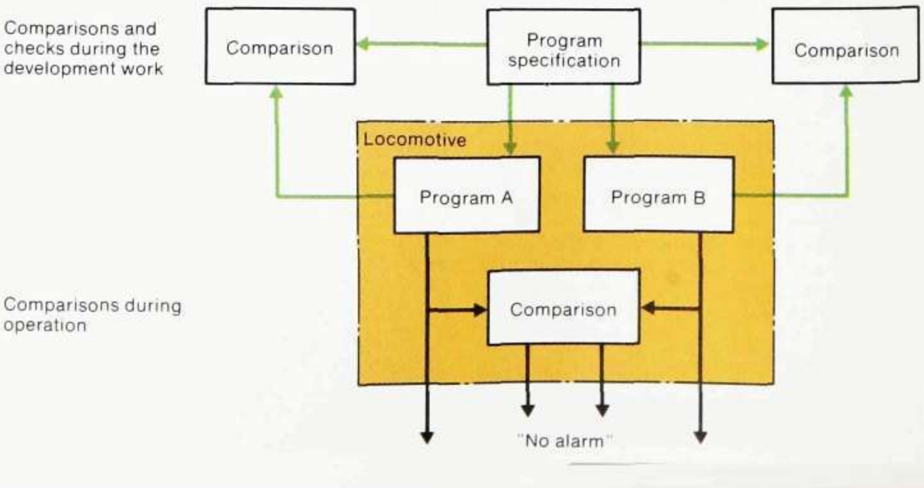


Fig. 13
The two-program method means that
- tests and checks are carried out at the specification stage in order to find any faults before the work is divided between the two teams of programmers
- each program is made so safe that the probability that both programs have the same, independent fault is negligible
- the interdependency of the two programs is at a level where checks and tests can be carried out
- faults in the programs are detected by comparison
- all possible cases are tested when they occur

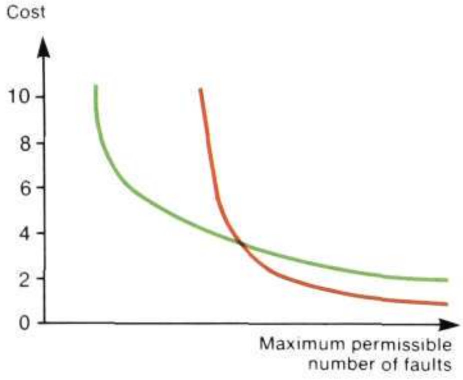


Fig. 14
The program cost as a function of the maximum permissible number of faults for one and two programs

2 programs
1 programs

Fig. 15
Installation.
The Swedish State Railways have made great efforts to get the ATC system installed and taken into service as quickly as possible. Several aids have been developed to simplify the installation in the track. The picture shows one of the three special vehicles that plough down the cables which connect the encoders and the beacons

Of all the possible types of faults in a computer system, software faults are most difficult to clear. It is well known that it is practically impossible to design faultless programs unless the programs are very simple. It is even more difficult to prove that they are faultless.

However, it is fairly easy to make a program function properly in normal situations, since any faults are quickly detected during functional tests in the real environment and during simulations. But safety systems require that the program functions properly even in abnormal situations. The safety requirements for ATC systems are about six powers of ten more stringent than the availability requirements.

Since there is no method or combination of methods that makes the program faultless, the system design must be such that residual program faults do not have any dangerous effects.

The method chosen by LM Ericsson for the programming of the ATC system is based on redundancy programming. Two independent programmer teams each design and test a program version that they make as safe as possible. When the two programs are executed, an alarm is given if any intermediary result or the final result differ, fig. 13.

Both these programs and the comparison program are stored in the equipment, and during the operation the programs are tested against each other for every combination of input data that is used. The ATC system is too complex to allow testing of all possible combinations of input data before it is put into operation.

The method using two programs means that any remaining faults are harmless. The faults that remain concern only very odd and abnormal situations, and thus they do not affect the availability of the system.

Installation and putting into operation

LM Ericsson designs and manufactures encoders, beacons, antennas, evaluation units and drivers's panels for ATC system JZG 700. In Norway and Finland, the countries that have most recently ordered ATC, LM Ericsson is the main contractor for the system and supplies all equipment. In Sweden and Denmark LM Ericsson supplies all ground and transmission equipment, whereas the majority of the evaluation equipment and panels are supplied by another manufacturer.

However, to put an ATC system into operation requires more than just the delivery of the described equipment. The input signals to the system must be generated and the output signals from the system must be dealt with. The equipment must be installed. The maintenance organization must be prepared to take on the ATC system. The train drivers must be trained. The cost of the auxiliary equipment and the work connected with the installation of ATC is approximately of the same order as the cost of the ATC equipment itself.

The Swedish State Railways calculate that the installation of the 1200 locomotive equipments will take about three years. The installation is contracted to different installation firms.

The State Railways themselves are carrying out the installation of the about 11 000 encoders and 40 000 beacons. The work is expected to take five years, but so far it has gone better than planned. Great efforts have been made to ensure that the planning and installation of the ground equipment proceed smoothly and efficiently without any of the safety aspects being neglected, fig. 15.

In Sweden, area after area are taken into operation and locomotive after locomotive is put into service as soon as the installation work is completed. All commuter train traffic in the Stockholm region will be equipped with ATC in 1981. The lines Stockholm–Malmö (south Sweden) and Stockholm–Gothenburg (west Sweden) will also be completed in 1981.

The first lines in Norway will be taken into service in 1981, in Denmark in 1983 and in Finland in 1984. Outside the Nordic countries an early variant of the system was put in operation in Taiwan in 1979.

Reference

1. Andersson, H.S.: *Railway Signalling Systems.* Ericsson Rev. *57* (1980):4, pp. 118–123.

Stored Program Controlled PABX, ASB 20

Lennart Nyberg

LM Ericsson have, in collaboration with their Italian subsidiary, FATME, developed a microcomputer-controlled PABX for up to 28 extensions. The PABX offers many facilities which have previously only been available in large PABXs. The revolutionary development in the semiconductor field has now made this economically feasible. Particular care has been taken to give the system a rational mechanical construction and make the operation and maintenance functions simple and efficient.

UDC 621.395.22
621.3.049.774

ASB 20 is a microprocessor-controlled PABX with programs and data stored in semiconductor stores. The PABX is designed for analog speech transmission. The switching elements in the switching network consist of semiconductors.

Conventional rotary dial and/or push-button telephones can be connected to ASB 20. Register access during a conversation is gained by pressing the recall button (R-button). ASB 20 can be connected to virtually all public exchange types available on the market via its programmable public trunk circuits. Signalling towards the public exchange can be achieved using different types of decadic signalling, alternatively by means of Dual Tone Multi-Frequency (DTMF)-signalling.

All sizes of ASB 20 can be supplied with an operator console. Alternatively, it is possible to use a conventional telephone to expedite incoming and outgoing calls.

The use of modern electronic components and stored program control have made it possible to equip the system with many valuable facilities such as DTMF-signalling, abbreviated dialling and automatic call back. The service supervision is also stored program controlled. An alarm is sent to the operator if a fault occurs.

Mechanically the PABX is designed as a compact unit with the power supply unit and the connection field as integral parts. ASB 20 can be equipped with one, two or three printed board assemblies depending on the desired number of extensions. The PABX is delivered from the factory completely assembled and tested.

On installation of ASB 20 the installer feeds in specific customer data via the operator console. Existing customer data can subsequently be changed or more added by the operator or other personnel at any time. No special training is required for this purpose. Alteration and addition of data can be made quickly and at short notice.

Fig. 1
Operator console and cabinet for PABX ASB 20

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System structure

ASB 20 consists of a telephony subsystem and a control subsystem. The exchange of information between them is carried out over a bus system. Fig. 2 shows a block diagram of the PABX. The units with solid outlines are always included in the PABX, whereas the units with broken outlines constitute auxiliary equipment, which can be provided if required.

Telephony subsystem

The subsystem consists of a switching network and the associated line circuits for the extensions and the operator, public trunk circuits, devices for tone sending and receiving etc.

ASB 20 has a single-pole switching network. The semiconductor elements that are used in the crosspoints are of the MOS type. The switching network has a bus structure and is divided into two

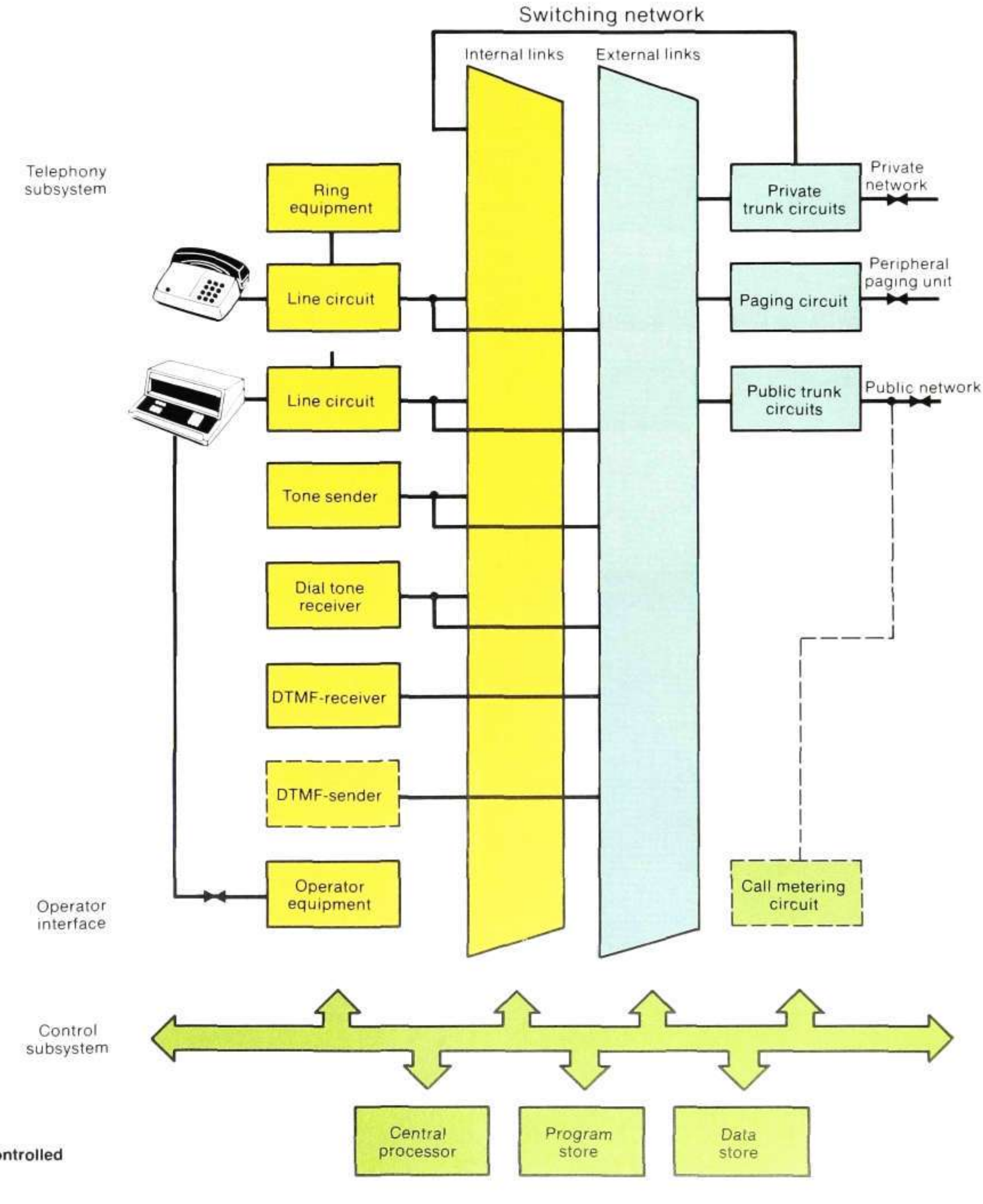


Fig. 2
Block diagram for stored program controlled PABX, ASB 20

groups of links, one for internal and one for external traffic. Each external link is connected to one public trunk circuit. The crosspoint matrices of the switching network are placed on the same printed board assembly as the telephony devices they serve. The switching unit is used not only to set up calls but also to connect the tone sender, dial tone receiver, DTMF-tone sender and DTMF-receiver. ASB 20 possesses up to four DTMF-receivers but only one tone sender, tone receiver and DTMF sender, all three of which are time-shared. The crosspoint in the switching network is used to generate the various tone cadences for dial tone, busy tone etc., fig. 3.

A call from an extension is detected in the line circuit fig. 2. The control subsystem, which regularly scans the line circuits, selects a free internal link, connects a DTMF-receiver and a tone sender for dial tone. The extension can then start dialling. The digits are analyzed in the control subsystem. If the dialled number corresponds to an internal number the DTMF-receiver is released, the ring signal is connected to the called extension (B-extension) and the ring control tone to the calling extension (A-extension). When the B-extension answers, both ring signal and ring control tone are disconnected and the speech path is through-connected.

If the extension is equipped with a rotary dial telephone, the digits are received in the line circuit and the DTMF-receiver is released after detection of the first break pulse.

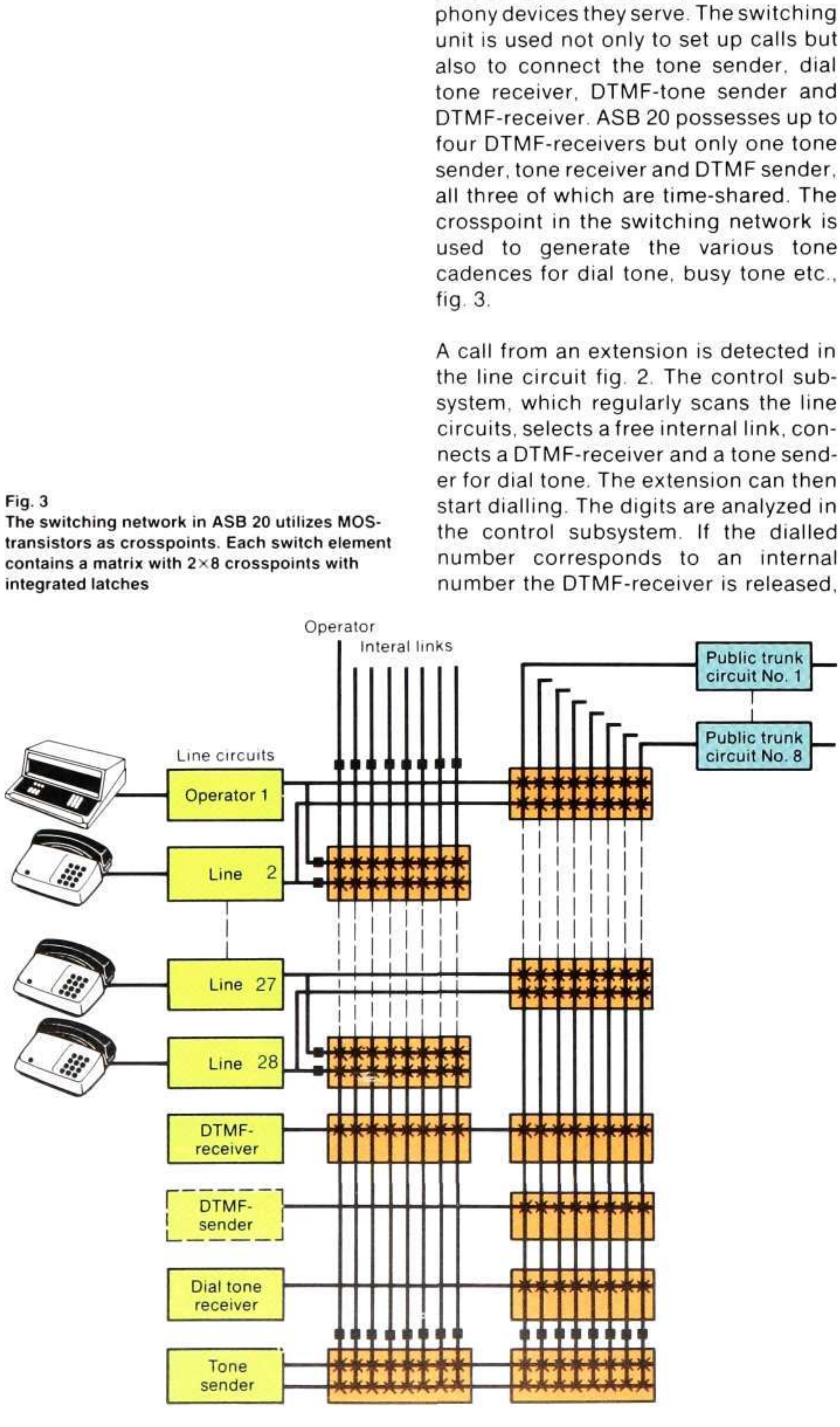
If the digit analysis shows that the extension has dialled the digit for external calls, a free public trunk circuit is selected, the public exchange is called and, using a time-division mode, the dial tone receiver scans the public trunk circuits in order to detect dial tone. After receipt of dial tone the extension dials the number of the external subscriber. The dialled digits are stored temporarily in the data store and under processor control are then sent towards the public exchange by decadic signalling or DTMF-signalling.

All external traffic can be subjected to Trunk Call Discrimination, TCD. Up to 5 digits are compared with a digit table compiled according to customer requirements and contained in the data store.

Incoming traffic can be handled in several different ways in ASB 20. An operator can answer the calls using either a console or a conventional telephone. Incoming traffic can also be handled without any operator, the calls being signalled on separate bells. Any extension can then answer a call by lifting the handset and dialling digit "8". It is also possible to assign individual extensions a public trunk circuit for exclusive use for both incoming and outgoing traffic.

From the point of view of traffic handling the alternative with a telephone operator and an operator console is recommended. The operator console makes it easier to deal with the incoming traffic and provides a good survey of the traffic situation. A speech link is reserved for the operator console, and the transmission of digits between the console and the PABX takes place over a separate data channel. This guarantees

Fig. 3
The switching network in ASB 20 utilizes MOS-transistors as crosspoints. Each switch element contains a matrix with 2×8 crosspoints with integrated latches



fast and congestion-free service for the operator. The information provided on the display panel in the console, in the form of digits, letters or symbols, is simple and easy to understand. A feature of interest is that the number of queuing calls is stated on the display panel.

Control subsystem

The central unit in the control subsystem is an 8-bit microprocessor with program and data stores, fig. 2. The program store consists of EPROMs which retain their information in the case of a power failure. The data store for the programmed system parameters, specific customer data and temporary storage of digits and other parameters consists of C-MOS RAMs. This store is supplemented by a battery which is charged during normal operation and which retains the stored information for about 100 hours in the case of a mains failure.

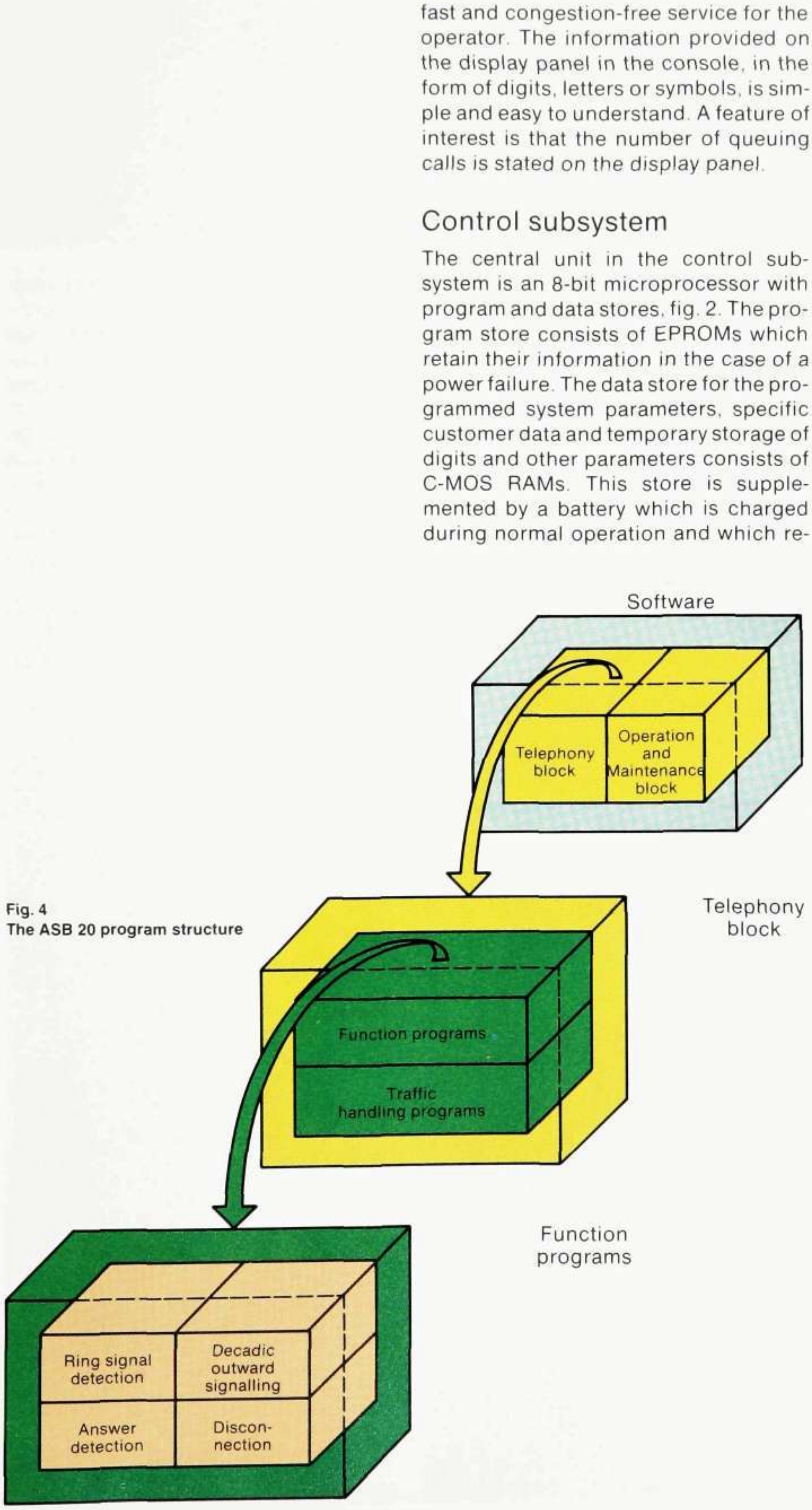


Fig. 4
The ASB 20 program structure

Fig. 4 shows the program structure. The main aim has been to produce a program system with small volume and rapid program execution. It comprises a block for telephony functions and a block for operation and maintenance programs.

The telephony block consists of function programs and traffic handling programs with defined signal relations. The function programs work direct with the hardware for the sensing and scanning of signal states and for operating the hardware. The traffic handling programs control the various traffic processes and facilities.

The operation and maintenance programs consist of interrupt programs and supervisory programs. The interrupt programs are controlled by different types of hardware signals and interrupt the ordinary program handling. When a PABX is put into operation for the first time an interrupt program is calles in, and using the basic system data it automatically starts the PABX, i.e. prepares it for traffic handling.

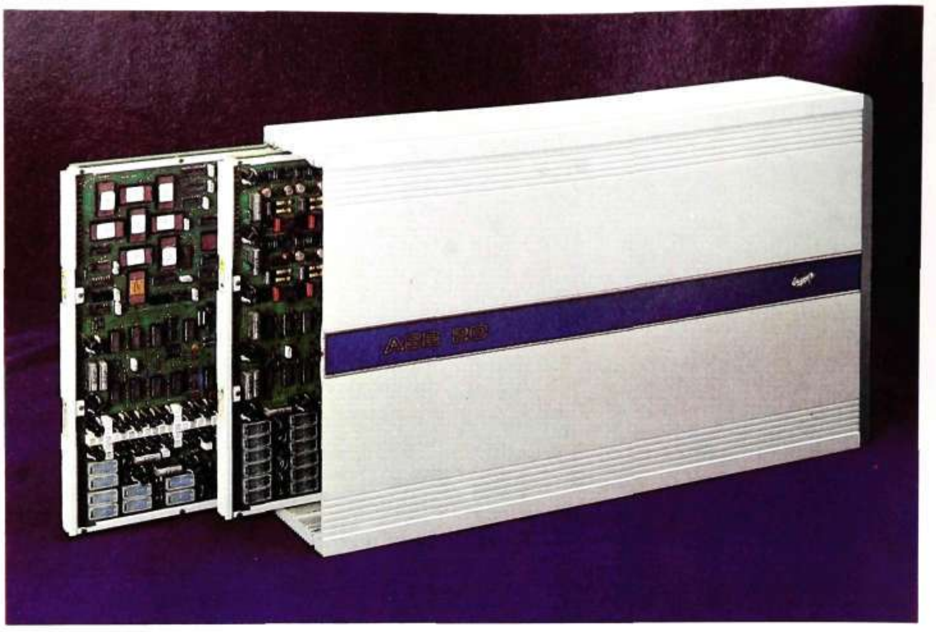
The supervisory programs monitor the functions of the PABX during operation. These programs utilize available processor capacity during pauses between the traffic programs and send alarm messages to the operator if a fault occurs.

Traffic functions and facilities

The PABX is supplied with complete software for all ASB 20 traffic functions and facilities. The hardware for the call metering and DTMF-signalling facilities is offered as optional equipment. ASB 20 has the following basic facilities:

Extension facilities:
- internal calls
- outgoing calls, direct or via operator
- incoming calls via operator, alternatively signalled on common bells and answered by an extension dialling digit "8" answer code
- inquiry during external calls
- call transfer, before or after answer

Fig. 6
The cabinet for PABX ASB 20 with two of the four printed board assemblies pulled out



- trunk call discrimination, by which the call possibilities can be limited for certain extensions. A maximum of 30 area codes are accessible to these extensions. Up to maximum 5 digits are used to define each of these area codes
- automatic call back on busy, by dialling suffix digit "6"
- common abbreviated dialling. A three digit number dialled by an extension results in the automatic transmission of a preprogrammed external number. A total of 36 such numbers with a length of 11 digits can be programmed by the operator. These numbers can be paired and combined to form numbers maximum 21 digits long
- extension group hunting to one group of 5 extensions. The hunt order can be on a fixed hunt basis or by cyclic stepping
- selection of individual public trunk circuit. Can be utilized by extensions and operator by dialling the circuit's individual number
- call waiting. A tone message is sent to a busy extension when the operator extends an external call. A tone message is also sent for each new incoming call or recall to an extension used as night service position, or to an operator equipped with a conventional telephone
- executive intrusion. Extensions assigned this facility can intrude upon an ongoing call. Warning tone is issued to all three parties
- common night service. To a predetermined, common, programmable extension
- universal night service. Incoming calls are signalled on separate bells and are answered by any extension dialling digit "8"
- extension exclusive trunk circuits. Can be assigned for the exclusive use of individual extensions by programming. Incoming calls are routed directly to the extension. Call transfer on such trunk circuits is permissible
- direct connection to publik trunk circuits on power failure. Maximum 4 trunk circuits are connected direct to predetermined extensions
- private trunk circuits to other PABXs. Each private trunk circuit occupies one public trunk circuit position, with through-connection possible on power failure, plus one line circuit. The function is programmed and requires no additional hardware. Traffic on tie lines utilizes decadic signalling
- DTMF-signalling towards the public network. Additional hardware is required
- peripheral paging unit. Connection of this requires one trunk circuit
- call metering. Utilizes pulses from the public exchange (50 Hz, 12 kHz or 16 kHz). Additional hardware is required.

Fig. 5
The operator console in ASB 20.
The upper panel contains alarm lamps, busy lamps for the trunk circuits and display with symbols for information on call progress. The lower panel contains busy lamps for the extensions, function buttons and a pushbutton unit

Operator console and operator facilities

Even the smallest ASB 20 version can be equipped with an operator console, figs.

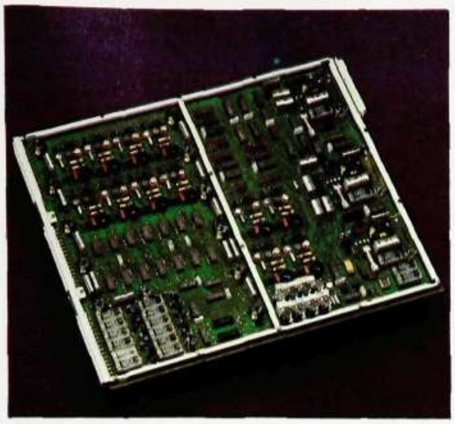


Fig. 7
A printed board assembly for ASB 20 containing power connectors in the far edge and connectors for bus cables and the cable to the connection field in the near edge

1 and 5. The operator console is easy to handle and provides a good overview of the traffic situation. An 8-window display unit allows the operator to follow the progress of a call quite simply. The display unit shows:
- call type
- number of relevant trunk circuit
- serial call marking
- extension number
- extension state
- amount of queuing calls

An explanatory symbol exists above each window. The information for all traffic cases is simple and unambiguous.

The operator console also contains individual busy lamps for each extension and trunk circuit plus two alarm lamps. The console is equipped with five function buttons each marked with a symbol, a volume control button for the call signal and a unit with 12 pushbuttons for dialling and programming.

Night switching of the console is achieved by the operator dialling a predetermined code or by not answering incoming calls.

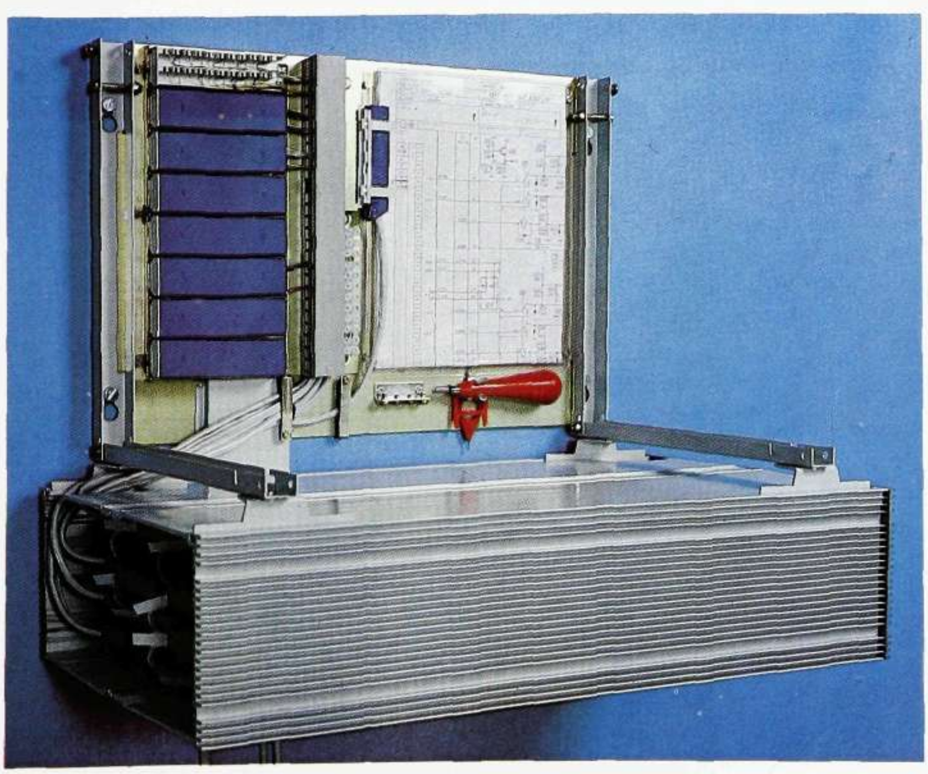
In addition to the facilities provided for the extensions the operator can:
- park calls
- camp calls on to busy extensions
- set up serial call procedures
- program system data
- read off system data
- read off metered call data.

The operator can program:
- extension classes of service
- common night service extension and universal night service
- call number for extension group hunting, extensions in the group and hunt method
- exclusive trunk circuits
- permitted area code numbers for extensions for trunk call discrimination
- external abbreviated numbers
- device blocking
- reading of call meters for extensions and public trunk circuits.

The operator's programming functions can be limited. The limitations are programmed by the installer of the PABX.

The operator console is normally connected direct to the exchange via a plug-in cable. The distance between console and exchange can be up to 25 m.

Fig. 8
The PABX cabinet dropped forwards with connection field fully accessible



Mechanical construction

Cabinet and printed board assemblies
The exchange cabinet is built up from three pairs of extruded aluminium sections. The main top and bottom sections are U-shaped and lock together. The end pieces are screwed to the top and bottom sections. The cabinet is hinged to a wall bracket and, when upright, covers the bracket, fig. 6. The connection field is also mounted on the wall bracket.

The top and bottom sections of the cabinet have four grooves for the printed board assemblies. Internal cooling flanges are fitted between the printed board assemblies. The heat dissipation in the cabinet is so good that forced cooling is not necessary.

The power supply unit is mounted at one end of the cabinet. The printed board assemblies are slid in from the other end and are plugged into the power supply unit via one connector for all power. The free ends of the printed board assem-

Fig. 9
The PABX cabinet, showing how the printed board assemblies are connected

blies are each equipped with three connectors. The upper two of these are used to connect the printed board assemblies together by means of plug-in bus cables. Via a plug-in cable to the third connector the printed board assembly is connected to the connection field, figs. 8 and 9.

Connection field

The connection field behind the PABX cabinet is readily accessible when the cabinet is dropped forwards, fig. 8. The terminal strips for the trunk circuits and extension lines have slots where the wires are pressed down between cutting tags without the insulation having to be stripped off. There is room in the terminal strip for lightning protectors for all lines. All trunk circuits are always supplied from the factory with lightning protectors.

The cable from the operator console is plugged into a jack in the connection field, which also contains a terminal box for fixed connection of power to the PABX. The remaining space in the bracket is occupied by a compartment for the documents concerning the PABX.

Power feeding

ASB 20 is delivered with a built-in power supply unit for mains connection to 110, 117, 127, 220, 230 or 240 V single-phase a.c. voltage at a frequency of 50 or 60 Hz, fig. 10.

The various operating voltages for the PABX are generated by transforming the mains voltage and then rectifying and regulating the voltages thus obtained. Each voltage is either current-limited or load-protected by fuses. The fuses are easily accessible from the rear of the PABX when it is dropped forwards.

The connectors for the power feeding to the printed board assemblies in the PABX are mounted on a printed board assembly in the power supply unit.

The power supply unit supplies 12 V. a.c. on a separate output to the operator console which contains the required rectifier and regulation circuits.

The power supply unit also contains two thyristor-controlled voltage outputs for the ring voltage. One output is used for the telephones connected to the PABX and the other is used for ringing on common bells. The ringing is at the mains frequency, and the connection and disconnection are controlled by the PABX software. The power supply unit can be supplemented with an extra printed board assembly for ringing at 25 Hz.

Fig. 10
The power supply unit (to the right) with the connectors for the printed board assemblies at the top

Technical data

Capacity

Extensions	4	10	16	22	28
Trunk circuits	2	3	5	6	8
Internal lines	7	7	7	7	7
Telephone operator	1	1	1	1	1
DTMF-receivers	2	2	3	3	4
Printed board assemblies	1	2*	2	3*	3
Traffic in erlangs per extension for a fully equipped system	0.2				

* One printed board assembly partly equipped

Telephones	Pushbutton telephone for DTMF-signalling in accordance with CCITT recommendations and with a recall button. Rotary dial telephone for a pulse frequency of 8–16 Hz and a pulse ratio of 30/70–50/50

Extension numbers	Two digits, fixed numbers	
Current feed resistance	ohms	2×400
Extension line		
loop resistance	ohms	1800 incl. telephone
leakage resistance	kohms	40
Attenuation at 800 Hz		
external circuit	dB	1
internal circuit	dB	7
Crosstalk attenuation at 1100 Hz	dB	>80
Power supply		
a.c. voltage	V	110, 117, 127, 220, 230, 240
frequency	Hz	50 or 60
power consumption	W	90 to 130
Ambient temperature	°C	+5 to +40
Relative humiditty	%	20 to 80
Dimensions		
height	mm	370
width	mm	645
depth	mm	146
depth with connection field	mm	193
Weight (fully equipped exchange)	kg	27

Installation and testing

ASB 20 is a compact unit which requires very little space. It works silently and is preferably placed in an ordinary office environment, near the telephone operator. The installation work consists of fixing the PABX to a suitable wall, connecting the telephone lines and power, programming the customer data and testing the functions. The installation time is short because:

- the whole PABX system, with supplementary printed board assembly and the operator console, is tested at the factory before delivery
- restrapping for adaption to different markets is done by means of movable U-links
- all connections are made by means of slot strips or plug-in connectors
- the customer data are programmed by means of commands. No programming is required for the basic system data. These data are read into the data store from the program store by an interrupt when the PABX is connected to the mains
- customer data can be programmed before installation if required. The data store with programmed customer data can withstand a transport time of 100 hours
- the software includes test programs which simplify fault locating.

Operation and maintenance

The operation and maintenance of ASB 20 is very simple since the system only contains one power supply unit and three types of printed board assemblies. If a fault occurs the test programs indicate the faulty printed board assembly. It takes only a minute or two to change the board. The data store battery should be changed approximately every fifth year. No other preventive maintenance is required.

Service supervision

The following circuits and functions are supervised automatically:

- data stores
- switch circuits
- short mains failures. If a failure is shorter than 100 ms all calls in progress will be unaffected
- too low working voltage for the microprocessor
- faulty program execution
- the content of the data store, i.e. whether it is still correct after a power failure.

If a fault occurs, an indication is obtained on the alarm lamp in the operator console. The operator can determine the type of alarm by means of special alarm read-out commands. The operator can also take a faulty device out of operation temporarily by blocking it. Any such blocking is indicated by a special lamp in the operator console.

Aids

All programming of ASB 20 can be carried out using the operator console or a pushbutton telephone. The operator console can also be used to read out stored data for checking. Two four-figure codes, "passwords", one for the installer and one for the operator, are used to switch the operator console into the programming mode. The codes are arbitrary and are selected during installation. The installer can also specify the programming facilities that are to be available to the operator.

Fault localization

Faults are located by means of test connections from any extension. The operator programs the desired extension. The extension can then be used to enter commands which specify the switching paths and devices that are to be tested, and thus to localize the fault to a certain printed board assembly. These test connections can be carried out without interfering with the normal operation of the PABX.

Command language

The command language used to communicate with ASB 20 is the same as used in LM Ericsson's other PABXs in the ASB series. It has been modified and simplified in some respects. A command consists of a two-digit command code and in certain cases also a parameter part.

Cable for Rural Networks

Thor Aarum and Arne Ernbo

The transmission section of the Headquarters of the Swedish Telecommunications Administration, LM Ericsson's division for transmission and local network systems and Sieverts Kabelverk AB have jointly developed a transmission package which is primarily intended for rural networks. It can be used for both coil-loaded physical circuits and 0.7 and 2 Mbit/s digital line systems. The package consists of the cable, housings for intermediate repeaters and loading coils, installation material and instructions for planning, installation, operation and maintenance. This article provides a description of the cable.

UDC 621.315.2

The main characteristics of telephone routes in rural networks are their length and the fact that they contain few circuits. The predominant transmission methods have hitherto been analog, often over physical circuits or 12-channel carrier systems on bare wire or small pair cables. The following conditions, which apply for the Swedish rural network, may serve to describe a rural network in general:

- Approximately 80 % of the routes in the network between, for example, primary centres and terminal exchanges consist of routes with a maximum of 12 circuits
- A considerable proportion of the small rural routes consist of bare wire circuits, usually with 3.5 mm iron wire
- The transmission quality of the bare wire network is poor. Phantom circuits can normally not be used, partly because of maintenance problems
- Digital transmission over side circuits in bare wire networks is technically difficult and economically unfavourable even if special equipment is developed
- The utilization of existing cables is in many cases technically and economically unsuitable because of the design of the equipment and the cable structure
- The routes are relatively long, normally 10–15 km.

However, the problem of maintaining existing cable networks, the need of more circuits, new telecommunication facilities and technical advances justify the introduction of digital transmission also in rural networks[1].

New cable

A cable that is particulary suitable for digital transmission, having only two pairs in the form of a star quad, has been developed in order to obtain a transmission medium that is technically and economically competitive. An evaluation of existing small-core standard cables has shown that they are unsuitable for digital transmission in rural networks. For example, the cheapest and smallest cable used in the Swedish network, a subscriber connection cable with a star quad and suspension strand (designated EVL 1S 0.6, ELKX 4×0.6 or TUKA), does not meet the technical requirements, mainly because different climatic conditions affect its transmission characteristics. This can be avoided, however, by equipping the cable with a screen made of aluminium foil.

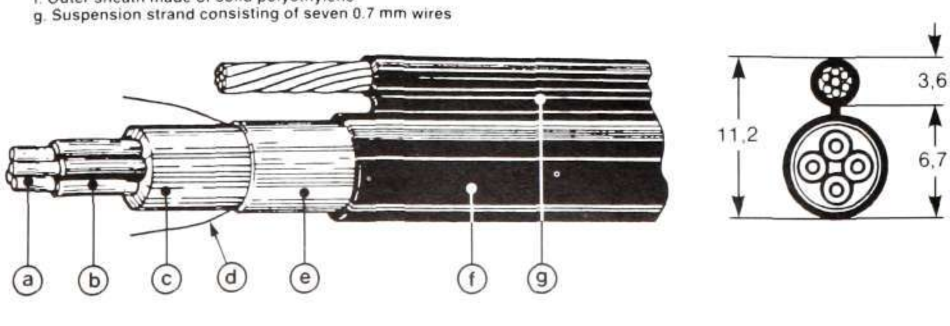
The screen acts as a moisture barrier and also greatly reduces the risk of interference from radio transmitters in the long and medium wave bands. The basic structure with a star quad, screen and suspension strand has been retained, because cost estimates have shown that this undoubtedly gives the lowest cable cost. The new cable is designated EEMEL 1S 0.6 or ELLALCE4×0.6 and is also called screened TUKA. The cable design is shown in fig. 1.

Cost optimization

The screened TUKA cable has been dimensioned so that the total line system cost has been reduced to a minimum. This cost consists of the cost of the cable, intermediate repeaters, terminal equipment and installation. In this connection the cost of an intermediate repeater can be considered constant since the repeater design is decided. The installation cost can also be considered to be independent of variations in the cable dimensions. The cable dimensions will of course affect the cable cost directly, but also influence the cable attenuation and hence the repeater spacing, i.e. the number of repeaters for a given route length, and thus also the overall repeater cost.

Fig. 1
Screened TUKA cable

a. Copper conductor, single wire
b. Insulation: pair 1 white and blue
pair 2 turquoise and violet.
The conductors are stranded into a star quad
c. Inner sheath made of polyethylene
d. Screening wires made of tinned copper
e. Aluminium screen
f. Outer sheath made of solid polyethylene
g. Suspension strand consisting of seven 0.7 mm wires



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An optimum cable can be dimensioned by minimizing the sum of the cable cost and the repeater cost. Calculations have shown that with set conductor dimensions the cost reaches a minimum at a certain pair capacitance. The position of this minimum is dependent on the ratio between the cable and repeater costs. Low cable costs and high repeater costs give a minimum at a low pair capacitance. High cable costs and low repeater costs, on the other hand, give a cost minimum at higher capacitances. These relationchips are illustrated in fig. 2. The upper curves apply for 2 Mbit/s systems, the lower for 0.7 Mbit/s systems. The diagram shows that the cost minimum for 2 Mbit/s is found at lower capacitances than that for 0.7 Mbit/s. Since the minima are rather flat it is possible to use the same cable dimensions for both systems. In this case the choice was a conductor diameter of 0.6 mm and a pair capacitance of 42 nF/km.

The other technical data are given at the end of the article. In Sweden loading coils are not used on cables with conductors smaller than 0.6 mm, and hence *the 0.5 mm conductor diameter was not* considered. This alternative would otherwise have given better handling characteristics and a slightly lower overall cost for 0.7 Mbit/s systems.

Attenuation and characteristic impedance

The attenuation of the cable must be calculated so that the repeater spacing can be decided in order to optimize the cost. A cable consisting of a star quad inside a metallic screen is a rewarding object for such calculations since its geometry is simple and well defined. The attenuation and characteristic impedance of the cable are calculated from its resistance, impedance, capacitance and leakage. These parameters in their turn are functions of the frequency, the geometrical dimensions of the conductors, the insulation and the screen, and the characteristics of the materials used for these.

A computer program, which is specially adapted for a star quad or pair placed centrally in a cylindrical cover made of a conducting material, was developed for the calculations. The program is used to calculate the characteristic impedance and attenuation of the cable in the frequency range 1 kHz – 10 MHz. Comparisons with later measurements made on a real cable show good agreement. The cable model used in the calculations is shown in fig. 1.

Operation

The repeater spacing will be limited by near-end or far-end crosstalk in the cable, by thermal noise or by crosstalk or the available amplification in the intermediate repeaters, depending on how the pairs in the cable are used for digital systems.

With single-cable, i.e. when both directions are transmitted over the same cable, near-end crosstalk is the major source of disturbance. The nominal repeater spacing is then 2.2 km for 2 Mbit/s and 4.4 km for 0.7 Mbit/s, corresponding to about 29 and 34 dB cable attenuation at 1024 kHz and 352 kHz respectively.

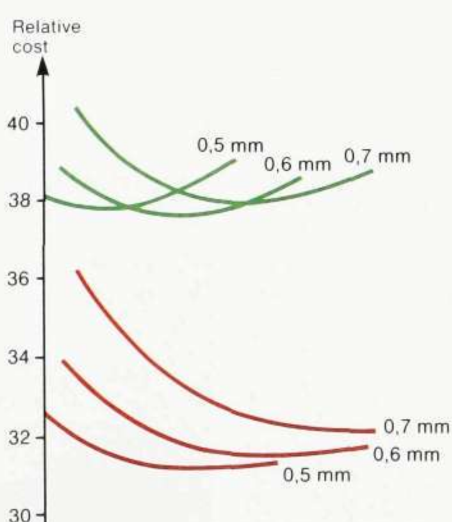


Fig. 2
The relative costs as a function of the pair capacitance for screened *TUKA cable*

2 Mbit/s system (green)
0.7 Mbit/s system (red)

Repeater housing

Intermediate repeaters for 0.7 and 2 Mbit/s systems or loading coils are installed in a housing that is jointed to the line cable. The housings are normally mounted on poles, but other methods may be used. A cylindrical housing has been designed for connection to screened TUKA cables. It is made of acidproof stainless steel, has a diameter of 150 mm and is 260 mm high.

Fig. 3
A pole with a housing for connecting a screened TUKA cable

The housing holds two two-way intermediate repeaters, i.e. amplifier for two screened TUKA cables, or alternatively loading coils for four pairs, and the required number of overvoltage protectors.

When connecting the housing to the cable the same tools and jointing materials are used as for ordinary cable joints. The housing is described in more detail in the following article[2].

Line construction

The TUKA cable is mounted on poles as an aerial cable. The same method and suspension devices are used for both screened and unscreened cables. The unscreened cable is delivered in lengths of 250 m and is run out either by hand or from a cable trolley.

The jointing of the screened cable is more complicated. This is because the extra jointing of the screen and because greater demands are made on the transmission characteristics. It is necessary to reduce the number of joints to a minimum, and the cable is therefore delivered in the greatest possible lenghts.

The chosen delivery length, 1100 m, corresponds to a whole loading coil section. Two lengths are required for a 2 Mbit/s repeater section and four lengths for a 0.7 Mbit/s repeater section.

Bare wire lines usually contain sections with aerial or buried cable. These cables can normally be retained when the bare wire is replaced by screened TUKA. A housing with overvoltage protectors and, if necessary, intermediate repeaters, is then connected in at the joint between the TUKA and the multi-pair cable.

Screened TUKA cable is normally used as line cable on existing poles. However, in certain cases it is advisable to continue with the TUKA cable right into the exchange. It can therefore be buried or run in ducts over short distances. The TUKA cable must not be used as station cable because of the fire risk, since its sheath is made of polyethylene.

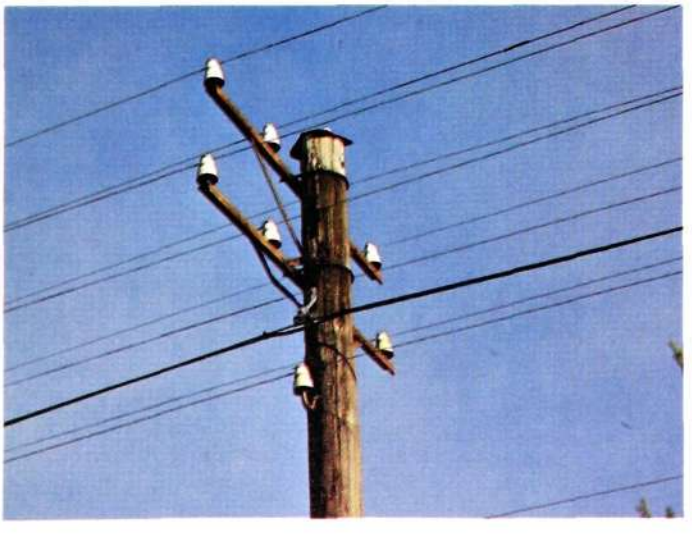
Field trials

The first field trial with a 2 Mbit/s system was started in the Swedish Telecommunications Administration's network in 1979. It is expected to be completed during 1981. The measurements carried out so far have indicated that the cable characteristics agree well with the specification. Climatic conditions have not influenced the transmission characteristics abnormally, neither at low nor high frequencies.

Further trials will be carried out in the Administration's network during 1980–81. They will comprise about 380 km screened TUKA cable with coil-loaded as well as digital circuits for 0.7 and 2 Mbit/s. Figs. 3–5 show details from one of the first installations.

Fig. 4, left
A pole with a suspension device for TUKA cable

Fig. 5, right
A joint on a screened TUKA cable



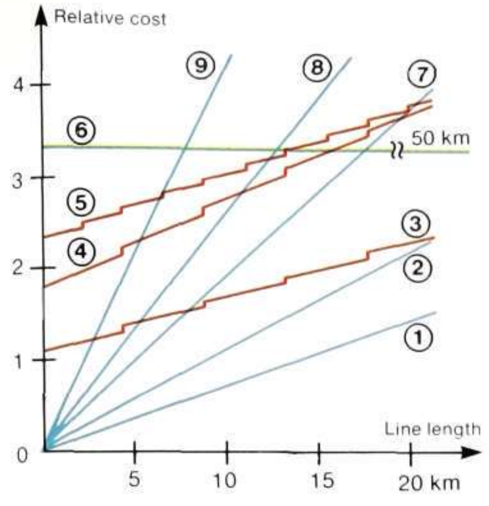
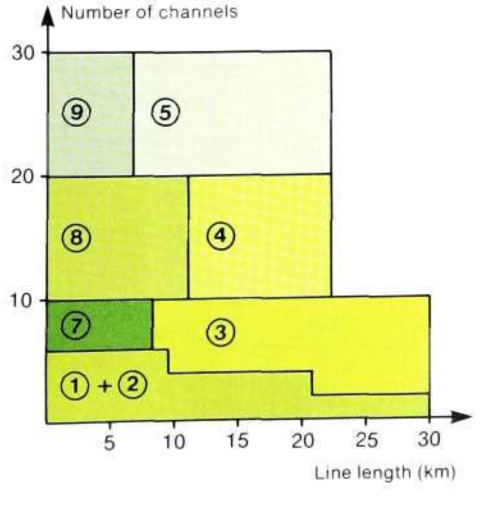


Fig. 6
The relative cost of new rural lines. The comparison concerns screened TUKA cable, PMOK cable and a 10-channel radio relay link, and applies for Swedish conditions.

1. Coil-loaded screened TUKA, 2 circuits, 1 cable
2. Coil-loaded screened TUKA, 4 circuits, 2 cables
3. One 0.7 Mbit/s system on screened TUKA, 1 cable
4. Two 0.7 Mbit/s systems on screened TUKA, 2 cables
5. One 2 Mbit/s system on screened TUKA, 1 cable
6. One 0.7 Mbit/system on radio relay link
7. 10-pair PMOK
8. 20-pair PMOK
9. One 10-pair and one 20-pair PMOK

Fig. 7
The limits of the most favourable cable alternatives with different line lengths and different numbers of speech channels for new lines in Sweden.
The diagram shows the economical limits for new lines. The limits may be different if consideration must be paid to voice frequency attenuation or loop resistance.
The digits 1–9 in the diagram mean the same as in fig. 6.



Cost comparison

It may be interesting to compare the cost of a new rural line using screened TUKA with the cost of other systems having equal transmission capacity. For this purpose the relative costs have been calculated for new lines with screened TUKA cables and another, new, plastic insulated trunk cable, PMOK, and a 10-channel digital radio relay link. The calculations, which apply for Swedish conditions, comprise the cost of cable, PCM multiplex equipment, signalling relay sets, line equipment or radio equipment, antennas and masts, installation and lining up. The two exchanges in which the line terminates are assumed to be of the analog type. The results are shown in figs. 6 and 7. These diagrams show that TUKA cable is a competitive alternative for rural networks.

If one exchange is digital and the other analog, the alternatives with 0.7 and 2 Mbit/s on screened TUKA cable are always cheaper when a new line is to be installed, since no signalling relay sets and multiplex equipment are needed at the digital exchange.

Summary

The recently developed screened TUKA cable can be used for different types of lines, from individual coil-loaded circuits up to 30-channel digital systems. The cable is light and thus easy to install on poles. Several cables can be run on the same pole line when greater capacity is needed. Screened TUKA cable is thus a very suitable transmission medium for rural networks.

Technical data
For EEMEL 1S 0.6 and ELLALCE 4×0.6

Conductor diameter	mm	0.6
Conductor insulation	polyethylene	
Inner sheath	polyethylene	
Moisture barrier		
Al-polyethylene sheath	mm Al	0.15
Outer dimensions	mm	6.6×11
Weight per 100 m	kg	7
Maximum loop resistance	ohms/km	136
Characteristic impedance		
at 352 kHz	ohms	129
at 1024 kHz	ohms	125
Attenuation		
at 352 kHz	dB/km	7.8
at 1024 kHz	dB/km	13
Near-end crosstalk attenuation better than		
at 352 kHz	dB	66
at 1024 kHz	dB	60
Effective far-end crosstalk over 500 m cable better than		
at 352 kHz	dB	59
at 1024 kHz	dB	50

References

1. Frizlen, H.-J. and Widl, W.: *10-Channel PCM System.* Ericsson Rev. *56* (1979):2, pp. 72–79.
2. Arras, J. and Danielsen, D.: *0.7 and 2 Mbit/s Systems for Pair Cable.* Ericsson Rev. *58* (1981):1, pp. 42–48.

0.7 and 2 Mbit/s Systems for Pair Cables

Juho Arras and Dagfinn Danielsen

Present-day telecommunication systems are characterised by the rapidly increasing use of digital transmission. The recent developments in the components field have made it possible to design digital transmission systems which are very attractive economically.
In this article LM Ericsson's new digital transmission systems for pair cables are presented. The systems transmit 10 and 30 PCM telephone channels and are mainly intended for use in the trunk and junction network and in certain parts of the subscriber network.

UDC 621.315.2
621.391.037.37

LM Ericsson's new digital line systems are intended for transmission over balanced pair and quad cables with a conductor diameter of 0.4–1.4 mm and a line capacitance of more than 25 nF/km. The new generation comprises:

- ZAD 2–4 for 2048 kbit/s, corresponding to 30 PCM channels and with fault localization in accordance with the fault detector method (one detector per repeater station)
- ZAD 2–5 for 2048 kbit/s, corresponding to 30 PCM channels and with fault localization in accordance with the loop connection method
- ZAD 0.7–1 for 704 kbit/s, corresponding to 10 PCM channels and with fault localization in accordance with the loop connection method.

All three systems can be connected for transmission of both directions in the same cable – single-cable operation. ZAD 2–4 also permits connection to different cables for the two transmission directions – two-cable operation.

As far as possible the same system design and equipment have been used for all three systems. This applies for the housings, device construction practice and terminal equipment among others. The systems are also designed so that they complement each other. They constitute an economically competitive alternative in both rural networks and city areas.

The digital interface D1 standardized by CCITT is used for 2048 kbit/s line systems. The 704 kbit/s line system has a corresponding interface designated D.

The basic principles of digital line systems and the operation of terminal equipment and intermediate repeaters have been described previously in Ericsson Review[1,2] and will therefore not be discussed here.

The new intermediate repeaters have lower power consumption than the old types. This has been achieved through the use of monolithic circuits having a high degree of integration. It has been possible to reduce the voltage drop across each repeater by about 40 %, which means 9.1 V per two-way repeater with a feeding current of 48 mA. This has also made it possible to greatly increase the distance between the power feeding points. Fig. 1 shows normal distances between repeaters and power feeding points.

Many administrations with older systems that contain partly equipped intermediate repeater housings wish to supplement these with new repeaters.

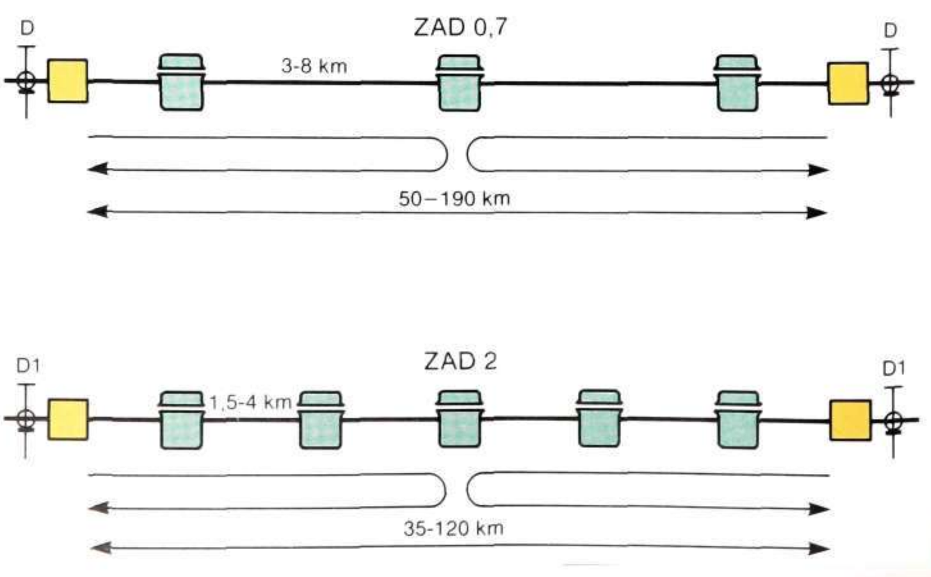


Fig. 1
Normal repeater and power feeding spacings with transmission over cables having a conductor diameter of 0.4–1.4 mm

JUHO ARRAS
DAGFINN DANIELSEN
Transmission Division
Telefonaktiebolaget LM Ericsson

Adapters have therefore been designed for complementing line systems ZAD 2–2 and ZAD 2–3 in this way.

Terminal equipment

The line terminating shelf used for ZAD 2–4 is the same as that used in ZAD 2–3[1]. An adapter has been designed for connecting the terminal repeater to the fault localization system. The adapter is connected to the alarm interface of the shelf and can easily be introduced in previously installed shelves.

New terminal repeaters and alarm units have been developed for ZAD 0.7–1 and ZAD 2–5. Since the systems have the same structure, one and the same line terminating shelf can be used for both of them, for example in small terminal exchanges or branching exchanges where both systems are installed. A block diagram of the line terminating equipment is shown in fig. 2.

Both the terminal and intermediate repeaters are dimensioned to allow cable attenuations up to 40 dB. The terminal repeaters also contain circuits for loop connection of the transmission signal for fault localization purposes.

The alarm unit monitors a number of system parameters and sends alarm indications if any values deviate from the specified ones. The front of the alarm unit is equipped with diode lamps for optical alarm indications. A derived systems alarm can be connected to external equipment, for example in a supervision room.

Changeover to a standby system

The line terminating shelves can be equipped with a switching unit which, in the case of an alarm in the receive direction, automatically switches over to a standby system. The automatic changeover can only be used with single-cable working.

The line terminating shelves can also be equipped with pattern generators for test purposes. The pattern generators are also used to provide the standby systems with a signal, so that they can be supervised in the normal way when they are not in use.

Intermediate repeaters

Modern semiconductor technology with a high degree of integration has been used for the new intermediate repeaters. Almost all active components are assembled in two identical monolithic circuits which are manufactured using bipolar technology. The block diagram of the circuit is shown in fig. 3. The fixed equalization network, BETA, the adjustable line building-out network, ALBO, and the selective tank circuit are all manufactured using discrete components. All elements that determine the frequency have been assembled in these networks, and identical monolithic circuits can therefore be used for the 704 kbit/s and 2048 kbit/s repeaters.

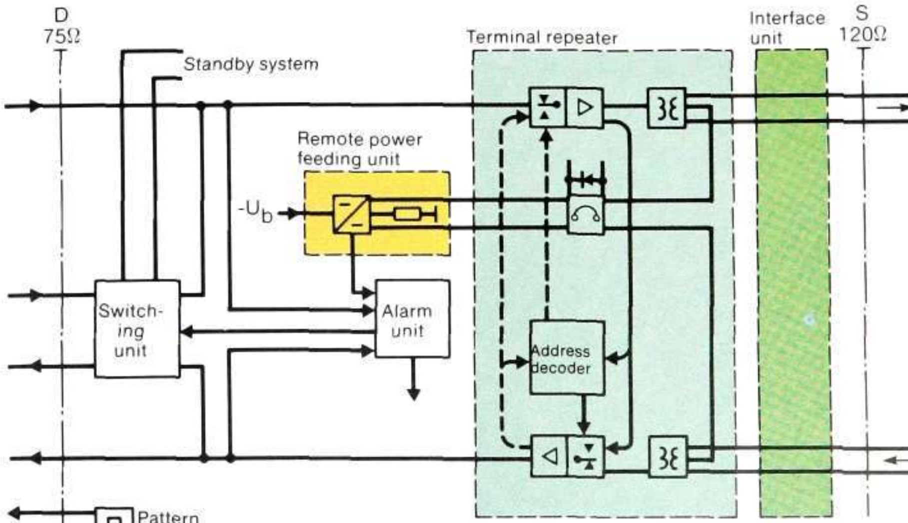


Fig. 2
A block diagram of the line terminating equipment for ZAD 0.7–1 and ZAD 2–5. The equipment can be mounted in a line terminating shelf, which holds up to four systems, in combination shelves or in digital branching shelves

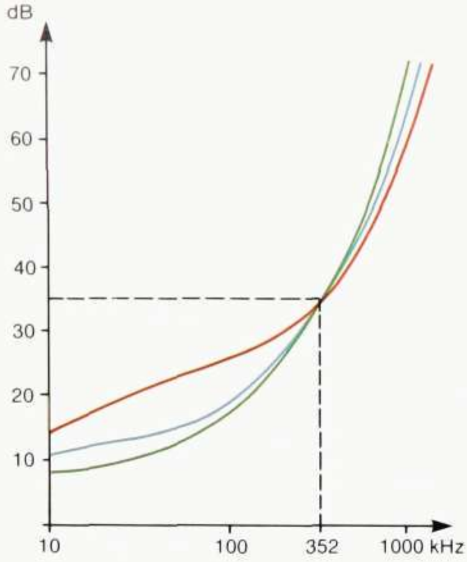


Fig. 4
The attenuation characteristics of three cable types in the frequency range that corresponds to transmission at 704 kbit/s

0.4 mm polyethylene-insulated cable
0.7 mm paper-insulated cable
1.2 mm paper-insulated cable

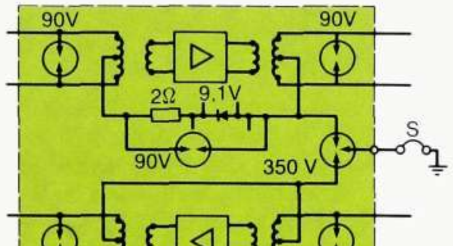


Fig. 5
Overvoltage protection for a digital repeater. It provides protection against longitudinal and transversal voltages and voltages between the two directions of transmission. The protection can be earthed via strap S in the housing if the safety requirements demand it

The transmission performance of a repeater is to a great extent dependent on its equalization characteristics. Considerable efforts have been made to optimize the equalization for the various cable types concerned. The attenuation curves for some cables with different conductor diameters and different insulation materials are shown in fig. 4. With transmission at 704 kbit/s equalization is difficult to achieve below 200 kHz because there are large deviations from the normal attenuation characteristic of $\sqrt{f}$.

The optimization of the performance of a repeater for a wide range of operational cases requires powerful computer aids. LM Ericsson have therefore designed an extensive simulation and optimization program, which can be used for any part of a transmission system. The program is fed with data concerning the relevant cable types, the desired operating range, repeater configuration, line code (AMI, HDB3) etc. The optimization program dimensions the equalizer so that the lowest possible error rate is obtained over the whole desired equalization range, with consideration paid to near-end and far-end crosstalk. The program selects a solution that takes all relevant cable types into account.

The equalization range is divided into two, corresponding to a line attenuation of 0–20 dB and 15–40 dB respectively.

The electrical environment for the repeaters is extremely varied. In rural areas with aerial cable and in areas with high earth resistance the repeater can be exposed to very high voltages in connection with lightning and short-circuits to earth in adjacent power lines. The equipment is protected by rare-gas tubes, connected in accordance with fig. 5, and by robust diode protectors on the inputs and outputs and in the power feeding path. All printed board conductors that are exposed to overvoltages have a width of 2 mm and the same isolation space. The connector contacts are gold plated and are of the same type as those used in the M4 construction practice. This type of contact has proved to have particularly good overvoltage and overcurrent characteristics.

A characteristic feature of the mechanical construction practice is that both the housing fittings and the repeater cassettes are made of plastic. This has given the repeater the ability to withstand such high overvoltages that there is no need to protect the repeaters with rare-gas tubes to earth. This has considerably reduced the risk of cable damage, since a striking rare gas tube can cause such large difference voltages relative earth in the cable that disruptive discharges can occur between the pairs.

The repeaters have been dimensioned to withstand surge voltages and currents from lightning strokes up to 5 kV

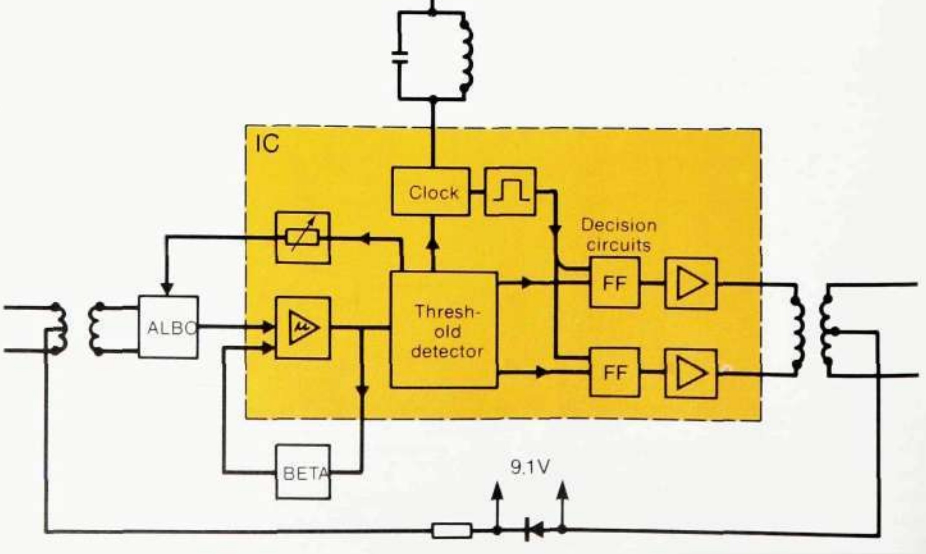


Fig. 3
One transmission direction in a digital repeater, not including the fault localization equipment and protective devices. The blocks within the broken outline are contained in the integrated circuit

and 200 A with a pulse shape of 10/700 μs (rise time and time to half value). They thereby meet even more stringent demands for overvoltage protection than those given in CCITT recommendation K. 17.

Very large currents at the mains frequency can momentarily be induced in the telecommunications network if a breakdown occurs in the power line network. All line systems have therefore been dimensioned to withstand 20 A r.m.s. for 0.5 seconds.

In many applications, particulary in urban networks, the high level of protection which has been described above is not necessary. A repeater variant has therefore been developed for ZAD 2−4 which meets the requirements of CCITT recommendation K.17 (1.5 kV and 37.5 A) as regards overvoltages and which can withstand induced currents of a magnitude of 5 A r.m.s. for 0.5 seconds.

Fig. 6 shows the mechanical construction of the intermediate repeaters. The choice of power feeding arrangement is made by means of soldered straps. The equalization range and fault localization addresses are set by means of plug-in U-links.

The cassette containing the repeater consists of two parts and can easily be opened without tools. Strapping and checking of the units can therefore be carried out quickly.

Housing

The new generation of line systems is complemented by a new series of cylindrical repeater housings, consisting of top and bottom parts of equal size. Each part has a flange, so that they can be made gastight and watertight by means of a ring seal and a number of bolts. The ring seal and bolts stay in place even when the top is removed, which simplifies installation and maintenance work considerably.

The housing is fitted with a holder made of expanded polystyrene, with the different repeater positions marked. The connectors and units are locked in place by a polystyrene disc placed in the top, and which is pressed against the units when the top is put on.

The stub cable is a 6 m lead-sheathed cable with an outer sheath of polyethylene and screened units with cross-stranded 0.5 mm PVC insulated pairs. In the housing the stub cable is connected to 10-pole connectors, which are plugged straight into the repeaters. The connection to the detector unit in the fault localization system is made with a sepa-

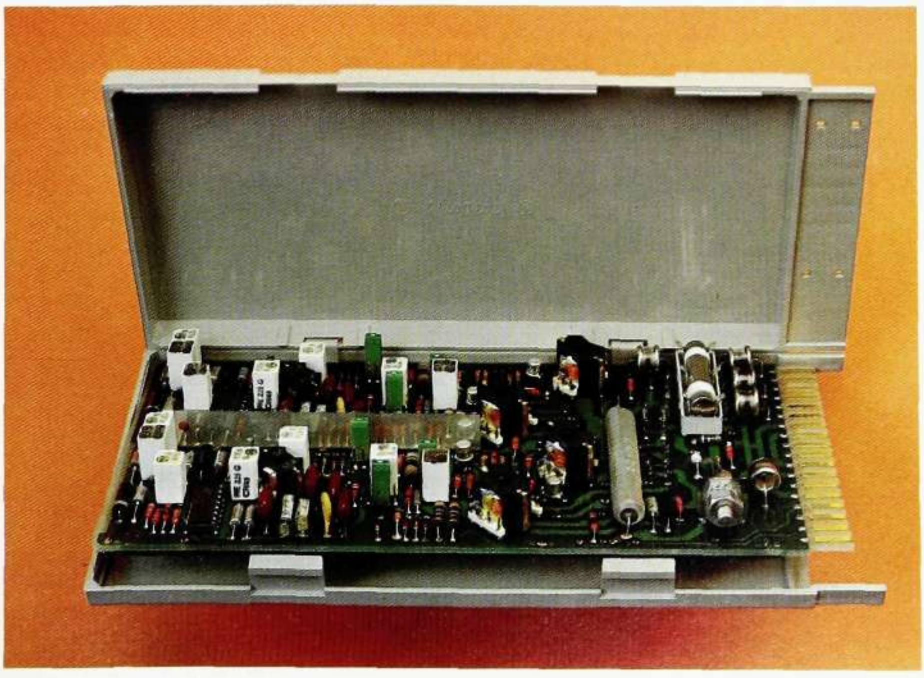


Fig. 6
A digital intermediate repeater for ZAD 2−4 with extra overvoltage protection. The dimensions of the cassette are 218×100×20 mm and it holds the equipment for both directions of transmission. The unit can withstand overvoltages of more than 5 kV without flash-over to the environment

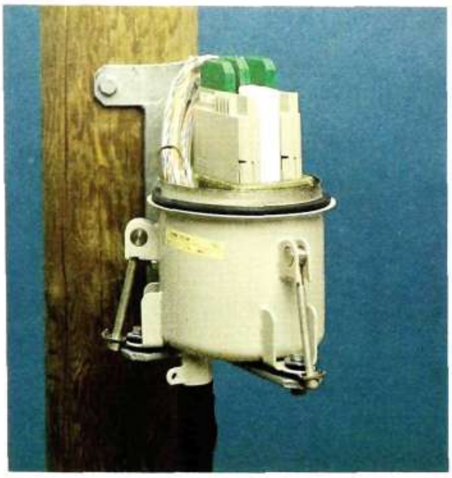


Fig. 7
Housing ZDD 53501 with the top removed. Holds 3 two-way repeaters for ZAD 0.7-1 or ZAD 2-5. Dimensions: Ø = 150 mm, h = 160 mm. Weight: approximately 10 kg when fully equipped, including the stub cable

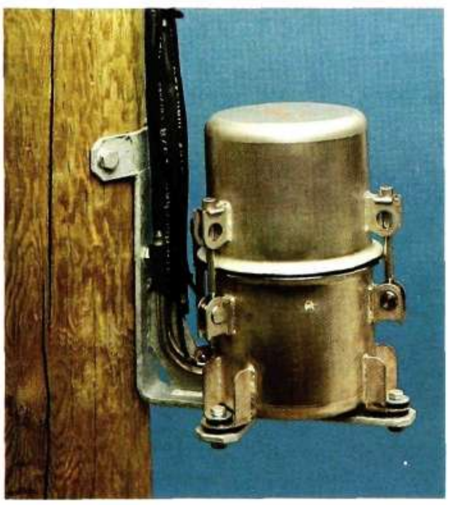


Fig. 10
Housing ZDD 53502 for jointing to TUKA cable. Capacity: 2 two-way repeaters for ZAD 0.7-1 or ZAD 2-5. Dimensions: Ø = 150 mm, h = 260 mm. Weight when fully equipped: approximately 3 kg

rate cable. This cable is equipped with four-pole connectors which are also plugged direct into the repeaters.

The housings are pressure-tight towards the cable and the environment and can be pressurized via the line cable or an external valve.

The housings are often placed in very corrosive environments, for example in manholes or concrete boxes which may at times be filled with polluted water. When placed above ground the housings can be subjected to temperatures between −40° and +50° C. All this puts great demands on the material and finish. The housings are therefore made of acidproof, stainless steel. Housings that are to be placed underground are coated with epoxy tar.

The choice of material has meant that the weight of the housing has been reduced by about 50 % compared with older housings, which facilitates transport and installation.

Three types of housings are intended for jointing to conventional cables, figs. 7–9. The two larger ones also contain a fault detector and a service unit. Brackets and sun shields are available for mounting the housings on wooden or concrete poles.

A similar housing is intended for jointing to TUKA cables[3], fig. 10. It is equipped with four input tubes for line cables. The cables are stripped of their sheaths in the housing and are jointed to the connection cables, which are equipped with 10-pole connectors. The jointing and sealing between the housing and the line cable are carried out in the same way and using the same tools as for ordinary jointing of the TUKA cables. This has meant considerable simplification and rationalization of the installation work. The jointing method was developed in close collaboration with the Swedish Telecommunications Administration.

All housings can be equipped with loading coil units for temporary re-loading or with through-connection units for testing the transmission pairs.

Fault localization

A reliable and efficient system for localizing repeater and cable faults is a prerequisite for economical maintenance of transmission systems. In view of the often very difficult installation conditions in cities it is necessary to be able to pinpoint the faulty equipment directly.

The trio method was long the most common fault localization method, but it proved to be very unreliable. The main reason for this was that the method was based on measurements of analog quantities, which were affected by many irrelevant factors. LM Ericsson have therefore developed fault localization methods that are based on digital condi-

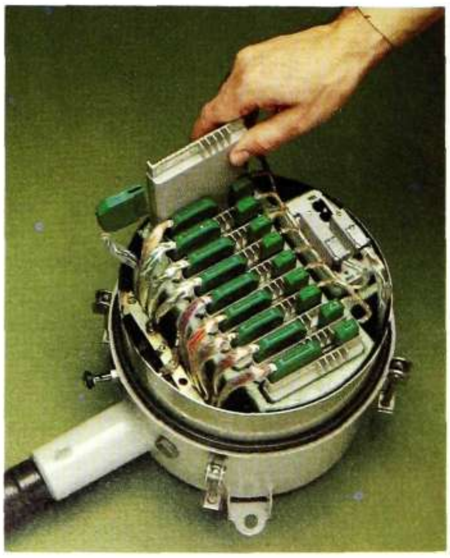
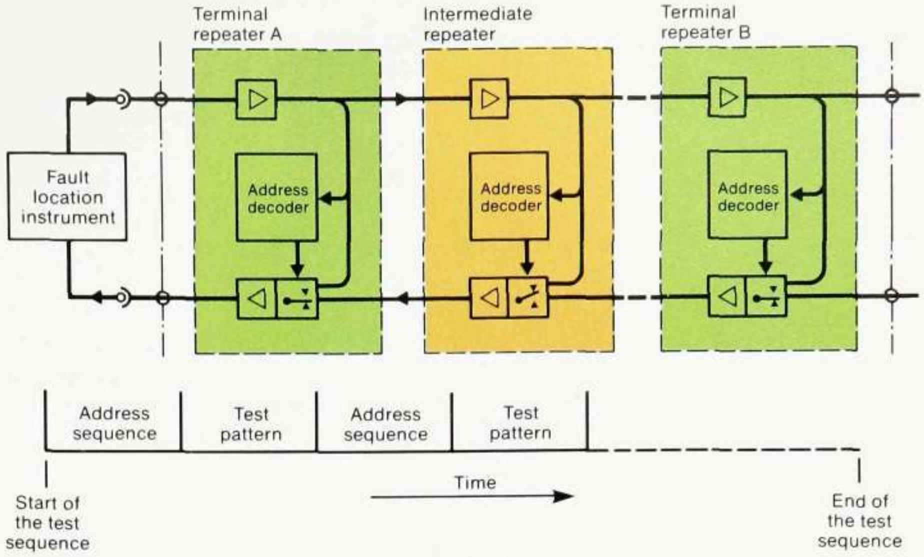


Fig. 8, left
Housing ZDD 53601 with the top removed. Holds 10 two-way repeaters for ZAD 0.7-1, ZAD 2-4 or ZAD 2-5. Dimensions: Ø 260 mm, h = 320 mm. Weight: approximately 24 kg when fully equipped, including the stub cable

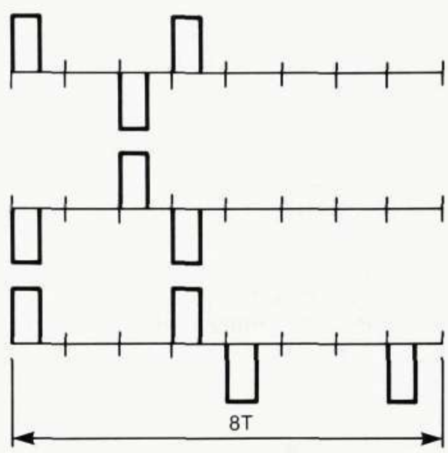
Fig. 9, right
Housing ZDD 53701. Holds 24 two-way repeaters for ZAD 0.7-1, ZAD 2-4 or ZAD 2-5. Dimensions: Ø = 400 mm, h = 320 mm. Weight: approximately 46 kg when fully equipped, including the stub cable

Fig. 11
Fault localization in accordance with the loop connection method



a. Block diagram

b. Test sequence



c. Pulse sequence

tions[1]. By means of one of these methods, the fault detector method, the error rate can be measured direct at the output of each individual repeater without interrupting the traffic. The method is well suited for computer control, and an automatic fault supervision system can be arranged. Line system ZAD 2–4 is adapted for connection to such a system.

However, the fault detector system constitutes a considerable part of the whole of the equipment for routes with only a few systems, and it requires an extra pair in the cable. A new fault localization system, using the loop connection principle, has therefore been introduced in line systems ZAD 0.7–1 and ZAD 2–5. Each individual line system is then autonomous as regards fault localization. Every two-way repeater is equipped with electronic contacts, which can loop connect the output of one repeater to the input of the other.

The connection is controlled by an address decoder on the repeater board. The address is strappable. The principle is illustrated in fig. 11a. The fault location instrument, which is connected to interface D in exchange A, is used to address one of the repeaters. The address is decoded, the repeater in question is loop connected and the signal received from the instrument is returned for analysis. The test sequence is shown in fig. 11b. The initial address sequence is followed by an arbitrary pulse pattern.

The address sequence is mainly based on repetition and combinations of pulse sequences, fig. 11c, and is designed so

Fig. 12
Fault location instrument
The front is equipped with
- thumbwheel switches for addresses
- error rate indicator, the rate being given by one digit
- switches for selecting the bit rate, 704 or 2048 kbit/s
- switches for selecting the line code, HDB3 or AMI
- connectors for outgoing and incoming signals and for external instruments

Technical data

Electrical data

	ZAD 0.7-1		ZAD 2-4 and ZAD 2-5	
Line signal	Interface D	Interface S	Interface D1	Interface S1
Bit rate	704 kbit/s		2048 kbit/s	
Code	HDB3 or AMI		HDB3	
Impedance	75 Ω unbal.	120 Ω bal.	75 Ω unbal.	120 Ω bal.
Pulse amplitude	±2.37 V	±3.0 V	±2.37 V	±3.0 V
Intermediate repeater				
Equalization range	0–40 dB at 352 kHz		0–40 dB at 1024 kHz	
Power consumption per two-way repeater, typically	48 mA/9.1 V		48 mA/9.1 V	
Temperature range	−40° C to +70° C		−40° to +70° C	
Power supply				
Primary current source	Battery 20–72 V Rectifier for 110, 127, 220 V (45–65 Hz)			
Feeding of the intermediate repeaters	Series feeding over phantom circuits			
Nominal regulated current	48 mA d.c.			
Maximum output voltage	±106 V bal.			
Fault localization			ZAD 2-4	ZAD 2-5
Method	Loop connection		Fault det.	Loop conn.
Number of station addresses	51		32	51
Mechanical data				
Line terminal				
Shelf dimensions	122×225×473 mm			
Capacity per line terminating shelf	4 systems			
Housing	ZDD 53501	ZDD 53502	ZDD 53601	ZDD 53701
Dimensions, Øxh, mm	150×260	150×260	250×320	400×320
Weight fully equipped	10 kg	3 kg	24 kg	46 kg
Number of two-way repeaters	3	2	10	24

Technical data

Fault location instrument ZTY 10101

Signal in/out	
At interface D	±2.33 V/75 ohms
At interface S	±3.0 V/120 ohms
Bit rate	512, 704 and 2048 kbit/s
Code	HDB3/AMI
Current/voltage at interface S	48 mA/11 V
Fault localization addresses	
Number	1–51
Test pattern	
PR signal with a cycle length of	$2^{15}-1$
Bit error rate	
The measurement is based on 10^6 clock periods of the input signal	
Maximum bit error rate	$9 \cdot 10^{-2}$
Resolution	$1 \cdot 10^{-6}$
Bit error count	
Maximum number of errors	99999
Power supply	
Primary current source	110 V/220 V a.c.
Primary power consumption	30 VA
Environment	
Temperature range	0° C to +45° C
Mechanical data	
Height×length×width	122×355×235 mm
Weight	6 kg

that it does not imitate any ordinary traffic signals. Furthermore the method is not subject to interference.

The fault localization system is controlled and the test signal analyzed by means of a portable instrument, fig. 12. In the instrument the output signal is combined with the repeater address in accordance with fig. 11b. The test pattern can consist of the pseudo random sequence generated by the instrument or of an optional external signal. Tests can thus be carried out using particularly interesting test patterns if the fault picture has to be studied in detail. The error rate is measured in the receive part of the instrument, which counts the number of code errors in the test pattern.

The instrument can also be used for making functional checks of repeaters in connection with the installation. The instrument is equipped with an internal constant current unit, which provides 48 mA. A loop connection adapter is used to connect the repeater to be tested to the 120-ohm interface of the instrument.

Cable faults are located in the way described previously, by reversing the polarity of the voltage from the remote power feeding unit and measuring the output current[1].

Summary

The main features of LM Ericsson's new line systems for 704 kbit/s and 2048 kbit/s transmission on pair cables are:

- a flexible network structure since the line systems complement each other
- efficient fault localization systems for both urban and rural networks
- ability to withstand high overvoltages
- equalization well adjusted to different cable types
- low power consumption
- high reliability through the use of modern circuit engineering
- new housings that withstand aggressive environments
- housings and intermediate repeater equipment are easy to install.

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Contents

COVER
Inspection of silicon discs for monolithic circuits. An intense, yellow light is used which makes it easier to spot any defects

Manufacture of Monolithic Circuits

Ulf Jerndal and Eva Novak

This article describes the manufacture of monolithic integrated circuits at RIFA, the Swedish components manufacturer in the Ericsson Group. The most important procedures are described with the aid of a flow chart and the requirements regarding the work environment are discussed. The construction of the RIFA factory at Kista, near Stockholm, is described briefly, with regard to the stringent requirements concerning ventilation and the gas and water supplies. Finally the production yield is considered, and also the methods used to control and check the production.

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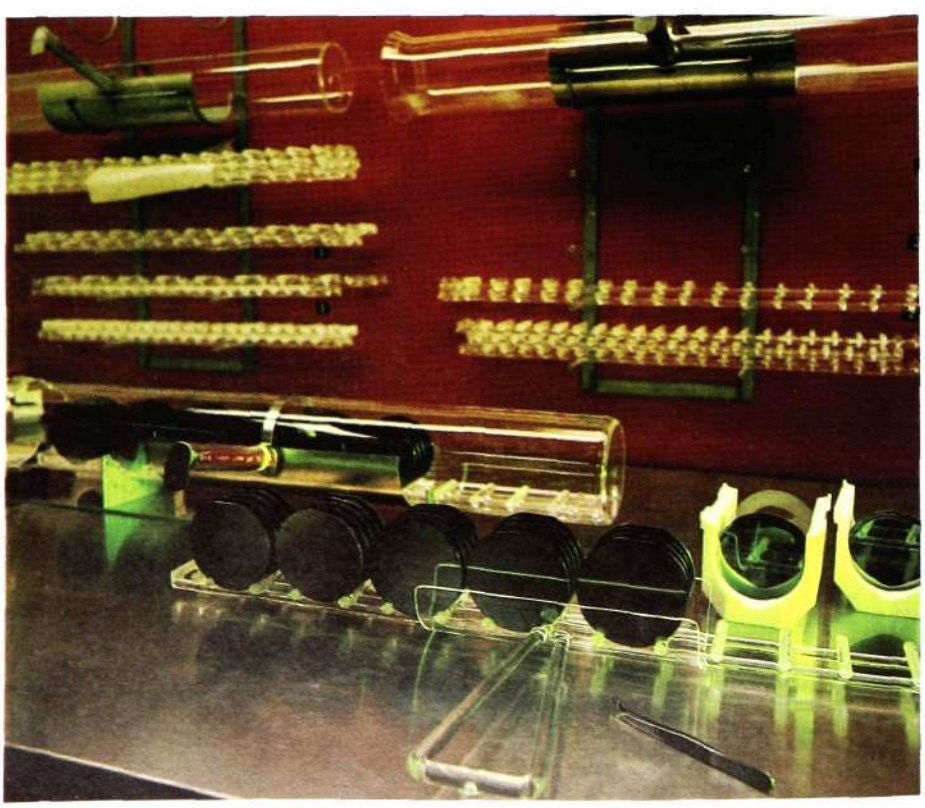
The build-up of the major types of micro circuits has been described in a previous article in Ericsson Review[1]. This article describes the manufacture of bipolar micro circuits in the RIFA factory at Kista, near Stockholm. Several different basic types are manufactured, and the production processes and number of stages vary. The flow chart of fig. 2 describes one such process.

Production process

The production of monolithic circuits comprises a large number of process stages, all of which require extreme accuracy and cleanliness. Batches of about 20 wafers are processed in each stage. All micro circuits, both bipolar and MOS circuits, are manufactured in similar processes. Details in the production process, the number of stages and their internal order are varied so as to obtain the structure that characterizes the desired type of circuit.

Fig. 1
Loading wafers for oxidizing



Basic material, dopants and impurities

The basic material for the manufacture of circuits is discs of silicon, wafers or substrates, which are approximately 0.3 mm thick and have a diameter of 75 mm. The discs are sliced off a single crystal rod at exactly specified angles in relation to the crystal axes, and are highly polished. The silicon is very pure but small quantities of dopants are added.

The dopants are elements from group 3 or 5 in the periodic table, whose presence in silicon in very small proportions drastically changes its conductivity. Some common dopants that give n-conductivity (surplus of electrons) are antimony, arsenic and phosphorus. The most comon dopant for p-conductivity (deficiency of electrons, hole conductivity) is boron. Substrates for bipolar circuits are usually p-conductive, with a conductivity of 10 ohmcm, corresponding to 10^{14} boron atoms/cm^3 (0.001 ppm).

All process stages require extreme cleanliness and careful checking that no impurities are present. For example, heavy metals, even in very low concentrations, constitute traps for electrons and holes and have an undesirable effect on the electrical conductivity of the silicon. Similarly, sodium, a common impurity in most chemicals, is harmful to the silicon oxide. The manufacturing process therefore requires very pure chemicals. Almost all process stages are preceded by a cleaning stage. Such cleaning is adapted to the subsequent process stage and can consist of mechanical cleaning and etching in different acids. The cleaning usually finishes with a thorough rinsing in deionized water. All air and water supply is controlled, and the air and water is cleaned so that no impurities are introduced.

Oxidation

The cleaned silicon wafers are oxidized by heating to approximately 1000°C in an atomosphere of nitrogen, oxygen and water vapour. Careful control of time and the composition of the at-

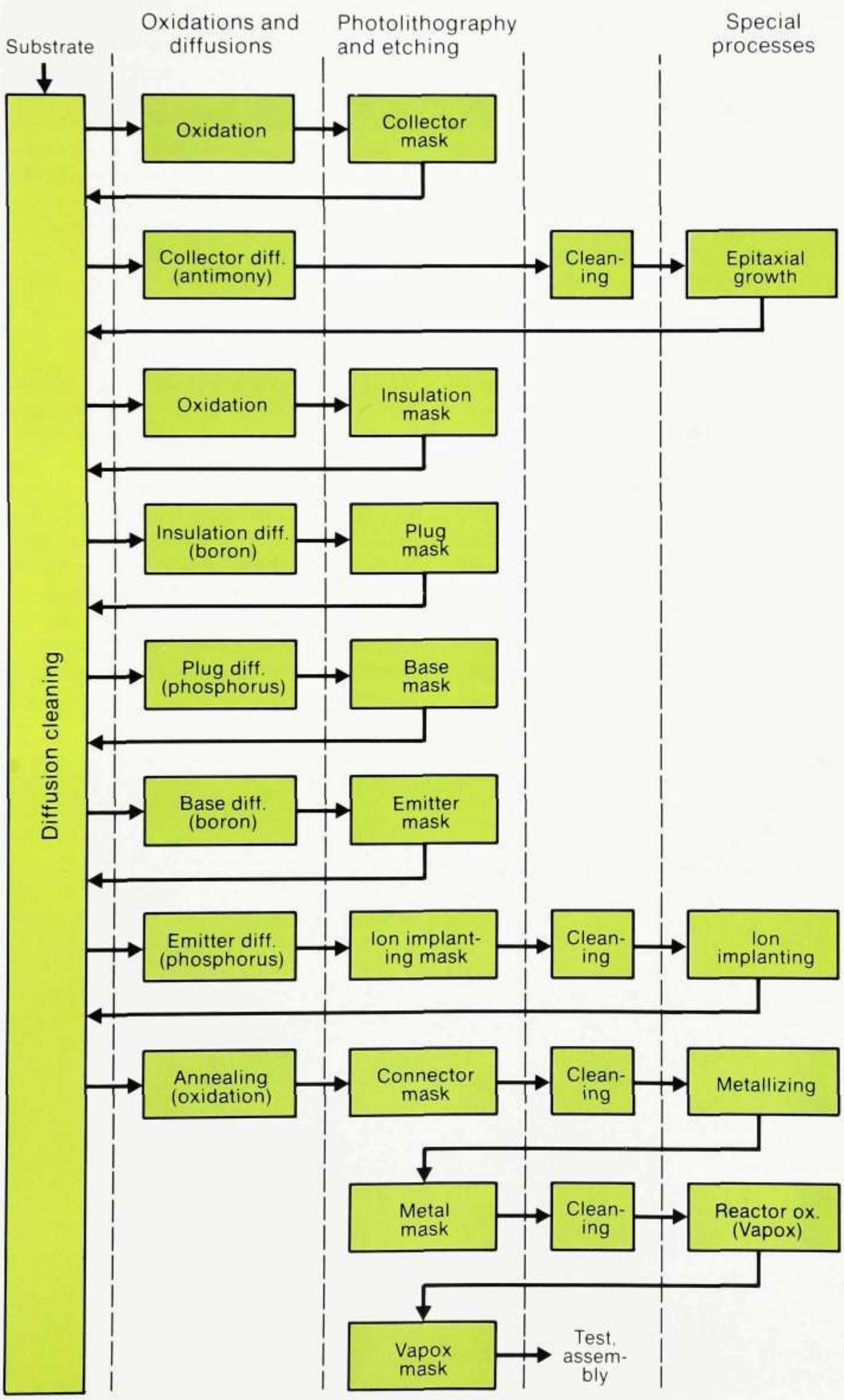
ULF JERNDAL
EVA NOVAK
AB RIFA

mosphere gives the desired oxide thickness, approximately 1±0.05 μm, fig. 1.

Photolithography

The various elements in monolithic circuits are very small, down to a few μm, and have dimension tolerances of the magnitude ±1 μm. The circuit pattern is defined and reproduced photographically. The circuit layouts for the different process stages are prepared with the aid of a computer and are transferred to masks, glass plates, which look like photographic negatives. The glass plates, which are first coated with a thin chrome layer, are then covered with a light-sensitive organic material called a photo-resist. A step camera, which can be programmed so that the glass plate is moved in exact steps, is then used to project a greatly reduced picture of the circuit layout on to the glass plate by means of ultraviolet light. When the plate is developed the photo-resist is removed from the exposed parts. The chrome layer is then etched away from these parts.

In a similar way the photomask pattern is transferred to the oxidized silicon wafer, which is first covered with a layer of photo-resist approximately 1 μm thick, fig. 3. The mask is copied on to the wafer in a contact or a projection pattern aligner using ultraviolet light. The wafer is then developed and etched. The manufacture of a bipolar circuit requires 8–11 photolithographic stages with the intermediate processes for treating the wafer. The accuracy in positioning any mask when copying it on the wafer is ±1μm in relation to the oxide openings from earlier mask stages. The pattern in the photo-resist is therefore checked in a microscope before it is etched out. Extreme cleanliness is also required. Above all there must be no dust particles. The photo-resist work is therefore carried out in a special room, called the yellow room, with very carefully filtered air, which is taken to the work position in a laminar flow.



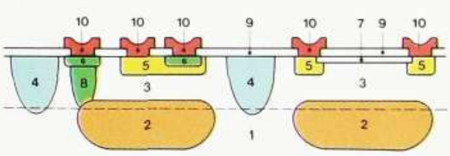
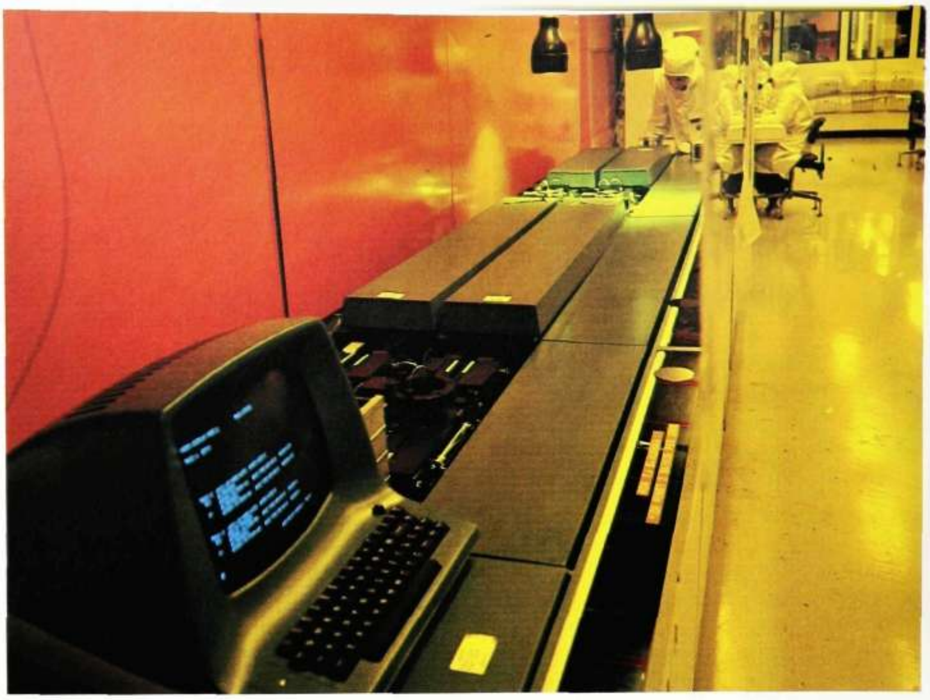


Fig. 2
A flow chart for the manufacture of a monolithic circuit

1. Substrate
2. Collector
3. Epitaxial layer
4. Insulation
5. Base
6. Emitter
7. Ion implanting
8. Plug
9. Oxide
10. Metal

Fig. 3
Equipment for applying photo-resist. At the rear a pattern aligner



Etching

Etched openings in the layer determine where the silicon surface will be conditioned in the different process stages, fig. 4. The oxide is fairly resistant to penetration *(diffusion)* by *dopants*. The openings in the oxide are etched out with hydrofluoric acid, whereas metals for conductor patterns are etched with other liquids. Dry etching methods have also been developed recently in which electric gas discharges at low pressure are used.

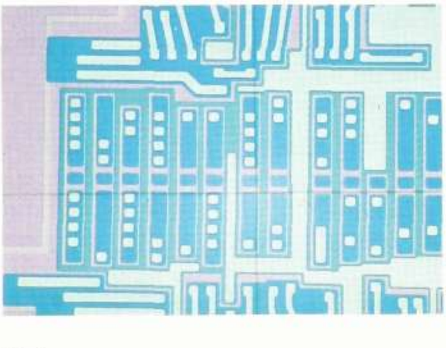


Fig. 4
Detail of a monolithic wafer after parts of the oxide layer have been etched off

Diffusion

Dopants are usually introduced into the silicon by means of diffusion. The manufacture of bipolar circuits comprises 4–5 different diffusion stages, with different concentrations and types of dopants, and diffusions are made to different depths in the exposed areas. All diffusions are carried out in a similar way. First the dopant is deposited in the etched openings on the silicon. This is done by heating the wafers to about 1000°C *in a tube type furnace* with a gas mixture of nitrogen, oxygen and a gaseous dopant, fig. 5. The actual diffusion takes place at a temperature of 1000–1200°C, at which temperature the dopant penetrates the silicon to the desired depth, varying from 1 to 25 μm. The gas mixture in the oven is then changed so that a new oxide is formed over the oxide-free surfaces, ready for the next mask stage. The diffusion processes require careful control of time, temperature ($\pm$2°C) and gas concentrations. Normally an accuracy for depth and conductivity of approximately 10% is achieved.

Fig. 5
Diffusion ovens in the RIFA factory

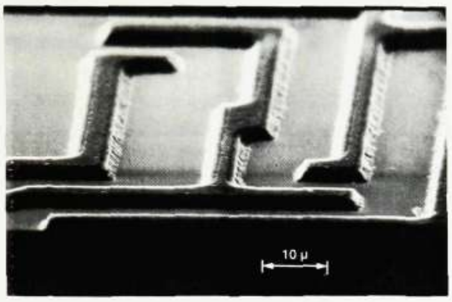


Fig. 7
Detail of an etched aluminium conductor pattern

Ion implanting

Alternatively the dopant can be introduced in the silicon by means of ion implanting instead of diffusion. The dopant is then gaseous in partial vacuum, and the atoms are ionized and accelerated in an electric and magnetic field and hit the silicon wafer, fig. 6. Since each ion has a certain electric charge it is possible to determine the exact dose of dopant by measuring the electric current of dopant ions. The field strength can also be adjusted accurately so that the ion energy can be regulated to a value within the range 10–200 keV. The depth of penetration into the silicon can be determined in this way. Normally an accuracy for conductivity of approximately 3% can be achieved with this method. RIFA uses ion implantation, for example, for manufacturing resistors and field effect transistors.

Epitaxial growth

By epitaxial growth is meant chemical deposition of molecular layers, for example of silicon on a silicon wafer, in the same crystal structure as the original substrate. Thus a new layer of silicon is built up, for example on npn transistors after the collectors have been made by means of diffusion. The unoxidized silicon wafers are heated to about 1200°C in the epitaxial reactor and are exposed to flowing gas composed of hydrogen and, for example, silicontetrachloride. The gaseous silicon compound decomposes on the silicon surface and new silicon molecules are deposited on the wafer. The growth rate is approximately 1 µm/minute. The type and degree of conductivity of the new silicon is controlled by the addition off gaseous dopants. The process is very sensitive to impurities both on the wafer surface and in the gases.

Reactor oxidizing

Whereas oxidation is used to coat open silicon surfaces after a process, reactor oxidizing is used, for example, to cover the completed circuit with a protective layer before it is encapsulated. The method, which is related to epitaxial growth, can also be used in other process stages. The gaseous silicon compound SiH_4 is dissolved at about 500°C in an oxidizing atomsphere. Silicon oxide is then formed and is deposited on the circuit. The oxide usually contains phosphor.

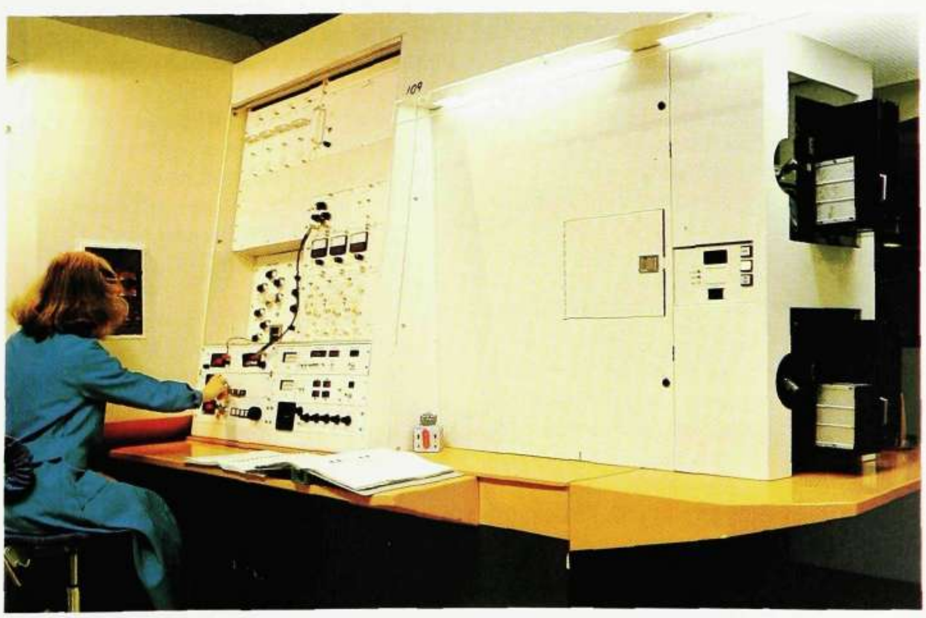
Metallizing

The monolithic circuit is coated with metallic layers, in which the connection pattern is etched out, partly in order to connect together the various circuit elements, fig. 7. The thickness of the metallic layers varies between 0.05 and 1.5 µm. The layers are applied by means of either cathodic evaporation or vacuum vaporization. The connection patterns are usually made of aluminium, but gold can also be used. Aluminium is vacuum vaporized to a thickness of about 1 µm. Other metals are used in thinner layers, platinum in the making of Schottky diodes and titanium as a separation layer to prevent the aluminium and silicon from forming an alloy.

Process testing

The microcircuit manufacturing processes are sensitive and the desired tolerances are close to the limits of what is technically possible. It is therefore necessary to carry out tests after almost every process stage. The process testing usually consists of measuring the physical or electrical characteristics of a special test wafer or an individual test circuit on a wafer. Some characteristics that are checked are the thickness of the oxide layers, the thickness and resistivity of the epitaxial layers, the resistivity of the diffused layers, the dimensions of the etched patterns, the quality of the metal layer and the param-

Fig. 6
Equipment for ion implanting



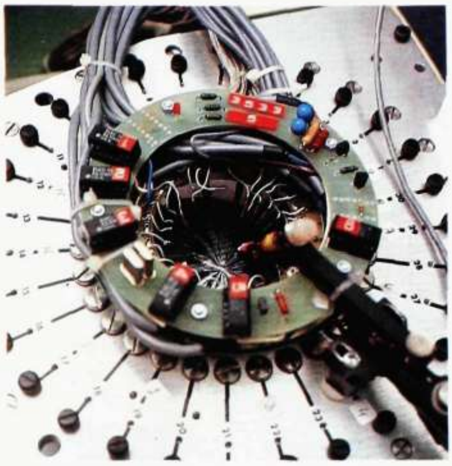


Fig. 8
Detail of a test station

eters of the test transistors. The results of the process testing are necessary to obtain the optimum settings for the various process stages.

Wafer testing, assembly, final testing
A silicon wafer contains 200–2000 identical integrated circuits, future chips. A certain proportion of them are acceptable. Since the subsequent mounting and encapsulation is costly, all ICs must be tested before the wafer is cut up. Stored program controlled test equipment is used to carry out mesurements at the test points on the ICs, fig. 8. A few hundred measurements is a typical number, and the total test time per circuit is between 0.5 and 2 seconds.

After microscope inspection the wafers are packed and sent for encapsulation. The encapsulation is carried out in factories in the Far East using materials and work routines in accordance with RIFA specifications. The chip packages are tested for gas-tightness and the final testing is carried out using stored program controlled test equipment. Any remarks concerning faults that have occurred in connection with the encapsulation are brought to the notice of the encapsulation factory. The long-term performance of the circuits is checked by means of accelerated testing with increased voltage and temperature.

The RIFA monolithic circuit factory

Fig. 9
A supply floor in the factory

When describing the various process stages it has been stressed that the production requires extreme cleanliness and also demands clean, filtered, cooled and dehydrated air, clean, deionized and filtered water and a large number of special gases, such as nitrogen, hydrogen and oxygen. These requirements are so stringent that they have greatly influenced the design and equipment of the RIFA factory for monolithic circuits. In addition the layout of the premises has been made as flexible as possible, in view of the rapid development of manufacturing techniques. The ground floor of the building contains plants for water purification and waste water treatment, cooling compressors and stores. Two floors are used for the manufacture of monolithic circuits and two for the supply of air, gases and liquids, fig. 9. Thanks to the separate supply floors it is possible to carry out most of the installation work for new machines without causing pollution of the manufacturing processes.

A separate part of the building contains fans, heat exchangers and filters for the air treatment. There is also supervision and control equipment that monitors the continuity and purity of the supply of gases and liquids.

Yield

The yield is a basic factor in all discussions concerning the manufacture of integrated circuits. It is defined as the proportion of accepted ICs out of the total number of circuits that it would be possible to manufacture from the material used. The yield for different stages can also be considered, for example from the handling, wafer testing, assembly and final testing stages.

It is desirable to be able to calculate the yield for a circuit in advance, so that the importance and effect of different construction parameters can be considered before production starts. Experiments, manufacture of prototypes and previous experience of similar designs are used to decide statistically the parameters that determine how the yield is affected by process techniques and design rules.

Wafer yield
A silicon wafer normally passes through 100–200 different substages during the manufacturing process. The wafers are often handled manually by different people and can be dropped, broken or scratched. Handling damage constitutes a not inconsiderable cost and one aim is therefore to automatize the processes to a greater degree.

Wafer probe yield
The production yield is determined by the size of the circuit and the fault rate, i.e. the number of imperfections per unit of area in the basic material and production masks, and by the number of faults that are introduced on the wafers during the manufacturing process. Faults occur in groups along the edges of the wafer and along surface scratches, as well as randomly. The larger the area of a circuit, the larger the probability that

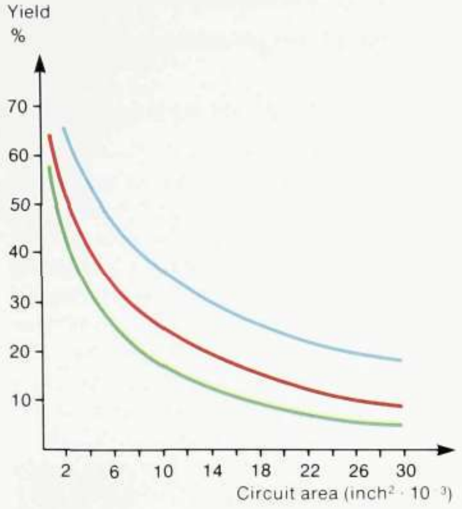


Fig. 10
The relationship between the wafer probe yield, circuit area and fault rate

100 defects/inch²
200 defects/inch²
300 defects/inch²

the circuit contains at least one fault and must be rejected. The relation between yield, circuit area and fault rate is illustrated in fig. 10.

Faults on a wafer can occur in the substrate, epitaxial layer, photo-resist process, diffusion, oxidation and metallizing. Pinholes in the oxide and irregularities in the crystal structure are some spot faults. Scratches and grinding marks caused by impurities during mechanical grinding are line faults.

The most common causes of rejection are random faults in photo masks and photo-resist processes. Such faults can occur in any stage in the manufacturing process because of impurities in the environment, careless handling or bad process control. However, new methods for manufacturing masks, using electronic beam exposure, do not automatically reduce the fault rate.

The yield can be improved by increasing the degree of automatization, by keeping the number of process stages low, by consciously aiming at a low fault rate, by improving production masks and processes in each stage and by improving the design of the circuit.

Assembly yield

The assembly yield is defined as the proportion of faultless chips that have successfully been mounted and encapsulated. The yield is determined by such factors as the type of package and number of pins. The bonding, i.e. the connection of the pins to the outputs on the chip, is the most labour-demanding part of the mounting. An assembly yield of 95% is normal.

Final test yield

RIFA carries out a final testing of the circuits after the mounting and encapsulation and before delivery. The final testing yield is the proportion of encapsulated circuits that finally meet all demands. It is normally about 95%.

Process control and supervision

The various processes that are today used in the manufacture of integrated circuits will for a long time remain the basic production processes. These processes already include a number of automatic substages. It is also possible to work with large batches. A million transistors can be built op on one three-inch silicon wafer, and a few hundred such wafers can be processed simultaneously in a diffusion oven.

The production cost consists primarily of the cost of investing in machines and equipment, and not of material and personnel costs.

The main production problems today are how to assemble data, compile data in an acessible form and evaluate them, control and supervise the processes and minimize the need of operators. In view of the large number of process stages and batches in production and the relatively long manufacturing time, it is necessary to have a very well developed control and follow-up system. Information is required concerning every batch, each type of product, the number of wafers in the batch, the equipment used for each individual process, when each process was carried out, measurements and test values, yields and machine utilization.

RIFA therefore intends to use an on-line process control and data collection system for its manufacture of integrated circuits. The yield can be improved when the process and product engineers have better access to the relevant data. The dependence on operators can be reduced by using microcomputers for process control as far as possible and by providing detailed instructions, via data terminals, for each process in the production.

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Digital Transit Exchanges AXE 10

Torbjörn Andersson and Olle Ljungfeldt

Telephone exchange system AXE 10 comprises a number of subsystem which can be combined to form exchanges of different types and sizes, from very large transit exchanges to small rural exchanges.
This article describes the use of system AXE 10 for transit exchanges at all levels in the network. The functions of the various subsystems are also described, including the subsystem for operator handling of calls, which features operators' positions equipped with data display units and keyboards. All ticket writing has been replaced by direct input in data stores, which gives faster and more efficient call handling with less effort.

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681.327

In many countries the telephone networks are being converted to digital operation. Pulse code modulated transmission systems, digital switching stages and the integration of digital transmission and switching give technical and economic advantages. The four-wire transmission gives better transmission conditions and increased possibilities of combining exchanges. Local and transit exchanges can be combined and the number of network levels can thus be reduced. National transit exchanges can be equipped with facilities for traffic with mobile units[1].

The article first deals with some characteristics of the AXE 10 system which are of particular interest when the system is used for a transit exchange in a digital network.

System characteristics

High capacity

The size of the group selector stage can be increased in steps of 512 digital multiple positions to a maximum of 65 536. It is not sensitive to uneven loading and gives full accessibility between inputs and outputs. With an average traffic of 0.8 erlangs per multiple position the congestion is not more than 10^{-6} and thus negligible. This makes it possible to use free disposition of junction lines without regard to the amount of traffic they carry. A group selector stage of maximum size can handle a total traffic of about 25 000 erlangs.

The digital group selector operates rapidly, which, together with fast signalling systems, gives short through-connection times and reduces the post-dialling-delay.

The number of calls handled per busy hour can amount to between 600,000 and 800,000. The exact number depends on the proportions of simple and complex calls.

Fig. 1
A transit exchange in Kolding, Denmark, for 8000 junction lines

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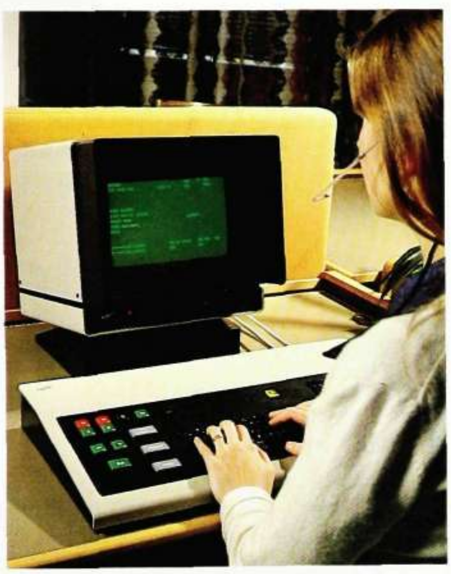


Fig. 3
The telephone operator uses her keyboard to enter order data on a form shown on the display unit

Flexible traffic routing

The central processor has a large capacity for number and route analysis. The number of area codes, routes and lines per route are unlimited, and so is the number of secondary routes in each direction. Any line can also be selected individually, for example for testing and measurements.

An operator can easily alter the traffic routing by means of a command that changes the routing plan, fig. 2. Such tasks form part of the network management and simplify traffic control in the case of overload or other disturbances in the network.

Stored program controlled network synchronization

A prerequisite for digital networks is that the exchanges and PCM systems work in synchronism. The synchronization of AXE 10 can be carried out in different ways and is stored program controlled, so that the synchronization method best suited to the surrounding network can be chosen.

Standby equipment gives high reliability

High reliability is achieved by such means as duplicating the processors and the group selector and effectively limiting the spreading of any software faults. The quality of service is checked continuously by automatic monitoring of each connection.

Compact structure

Large exchanges require a floor area of only 15 m^2 per 1,000 circuits. This figure applies if approximately half the junction lines are digital. It does not include the space needed for the power supply equipment and control room.

Easy to adapt to future requirements

The memory capacity of the processors is sufficient to meet large future demands. The store of a central processor can be extended to 4 M words for programs and 8 M words for data.

New function blocks can be introduced and existing ones changed, normally without having to make changes in the other parts of the system. This is possible because the division into function blocks has been strictly observed, with standardized signal interfaces between the blocks, and because the addressing of the program and data areas in the blocks is done via a special reference store.

The data area allocations in an exchange can be altered by making changes in the reference store. Hence the operating staff can carry out extensions during operation by changing the data area allocations with the aid of commands.

High signalling capacity with CCITT no. 7

CCITT signalling system no. 7 is used for common channel signalling. Its high transmission speed, 64 kbit/s, enables very large quantities of information to be transmitted over the signalling channel per unit of time. This can be exploited in future for new facilities and for wider use of older facilities, for example call forwarding, outside the local exchange area. The large signalling capacity can also be valuable in integrated networks, in which the equipment is to be used jointly for telephony, data transmission, text transmission etc.

Operator handling with the aid of display units and keyboards

The writing of tickets for ordered calls

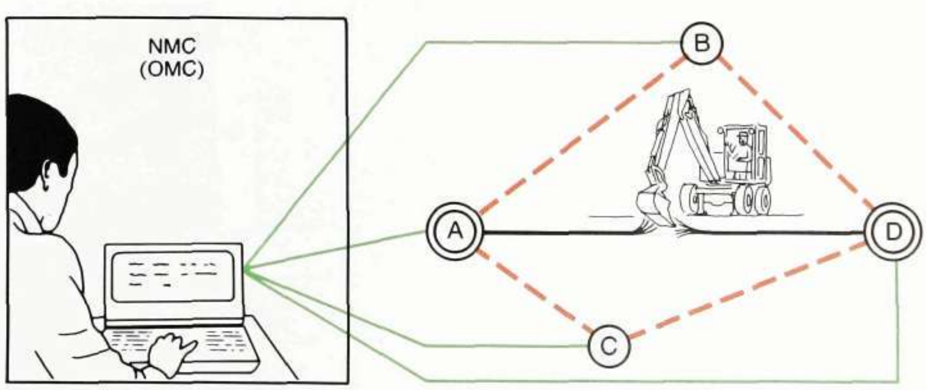


Fig. 2
An example of a network management action in an AXE 10 network, aimed at reducing the effect of an important route having been put out of operation

Ordinary route
Secondary route
Link from NMC (OMC) to AXE 10

Fig. 4
The subsystems that are used in different types of telephone exchanges

Hardware
Regional software
Central software

SYSTEM CORE

TSS Trunk and signalling subsystem, consisting of function blocks associated with the connected signalling systems

GSS Digital group selector subsystem, consisting of a number of time and space switch modules and clock modules for synchronization

TCS Traffic control subsystem, which contains programs and data for traffic routing, number analysis and supervision of connection and disconnection

OMS Operation and maintenance subsystem, comprising aids for the administration and supervision of AXE 10 exchanges

ADDITIONAL SUBSYSTEMS FOR DIFFERENT APPLICATIONS

CHS Charging subsystem, containing function blocks for pulse metering, toll-ticketing and accounting between adminsistrations

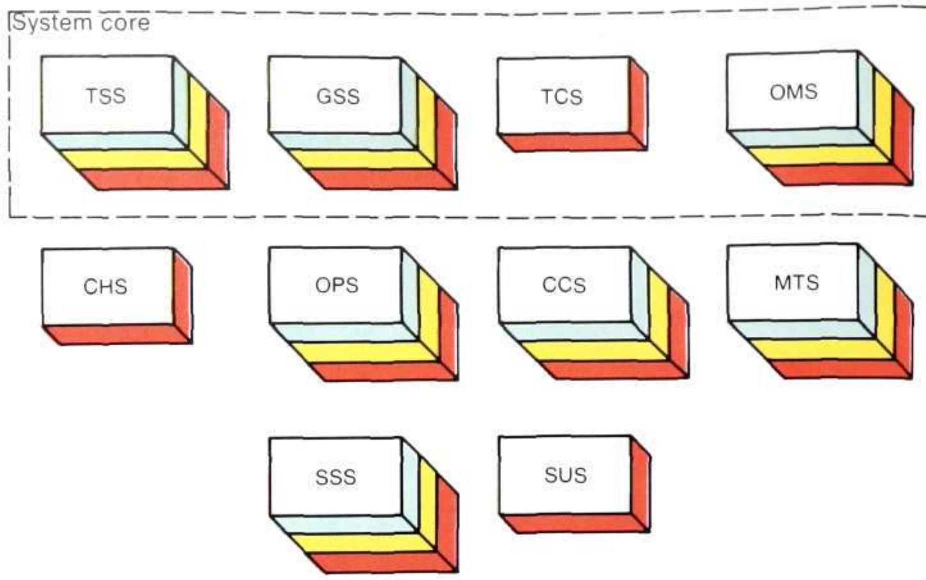
OPS Operator position subsystem for manual handling of calls

CCS Common channel signalling subsystem, for example for signalling in accordance with CCITT signalling system no. 7

MTS Mobile telephone subsystem, interfacing with base radio stations for traffic with mobile subscribers[1]

SSS Subscriber switching subsystem, which is divided into groups of 2048 suscribers, with an extension module of 128 subscribers

SUS Subscriber services subsystem, comprising function blocks that vary depending on the requirements for facilities over and above the ordinary telephone traffic between subscribers



has been replaced by direct input of order data from a keyboard with a display unit at the operator's position, fig. 3. The operator fills in a form, which is displayed on the screen, with the information for each ordered call. The system processes these data in order to establish the desired connection. The handling procedure is simple and the handling time short. The method offers the possibility of new operator services. The operators' positions can also be remotely connected, which gives considerable flexibility as regards the location of the operators' room.

Efficient aids for operation and maintenance

Automatic supervision, built-in aids for testing and fault localization and the possibility of remote control of operation and maintenance functions help to make the work more efficient and reduce the work load.

Commands and printouts are formulated in the man-machine language, MML, recommended by CCITT. Its structure is simple, and it is easy to handle and simplifies the work.

Division into subsystems

An AXE 10 exchange consists of a number of subsystems. Certain subsystems are necessary for all applications, whereas the individual requirements decide which of the optional subsystems are to be included in an exchange. The interfaces between the subsystems are well defined, which means that the subsystems can be further developed independently of each other[2].

Each subsystem comprises a number of function blocks, which can consist of just software or software and the controlled hardware. In the latter case the software is divided between the central processor and a number of regional processors.

Fig. 4 shows all subsystems that are used in any type of telephone exchange.

The subsystems used in transit exchanges are described below.

Control system

The control system consists of a central processor and a number of regional processors which are placed together with the equipment that is to be controlled, fig. 5. A brief description of the control system is given below. A more detailed description will be given later in a separate article.

Central processor

The central processor, CP, hardware is duplicated for reasons of reliability. The duplication makes it possible to detect faults and locate the faulty printed

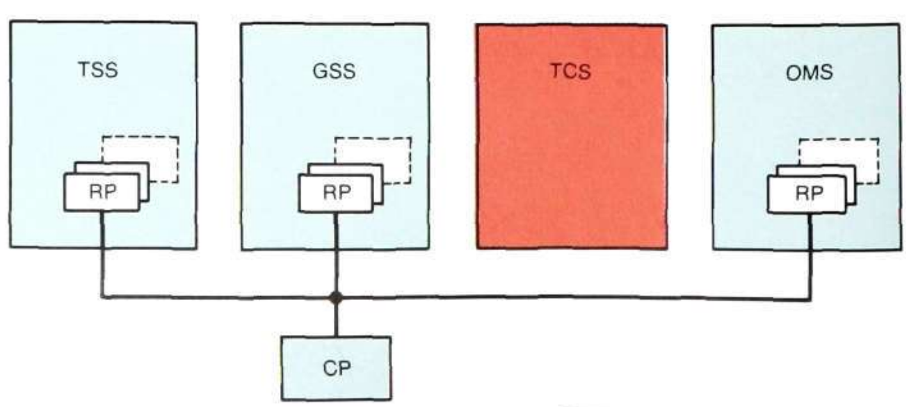


Fig 5.
Central and distributed control

CP Central processor with duplicated central processing unit, data store, program store, reference store and the associated software

RP Regional processors placed together with the controlled equipment

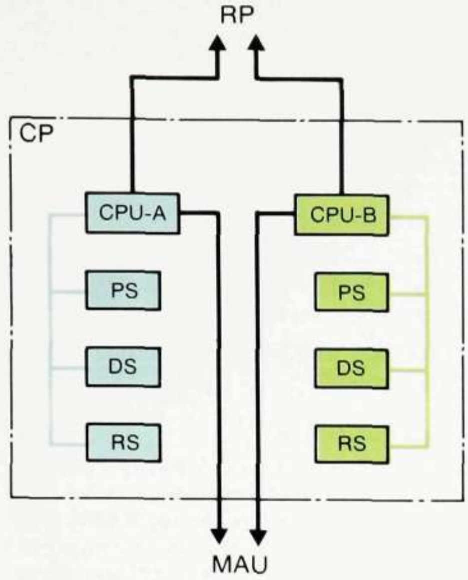


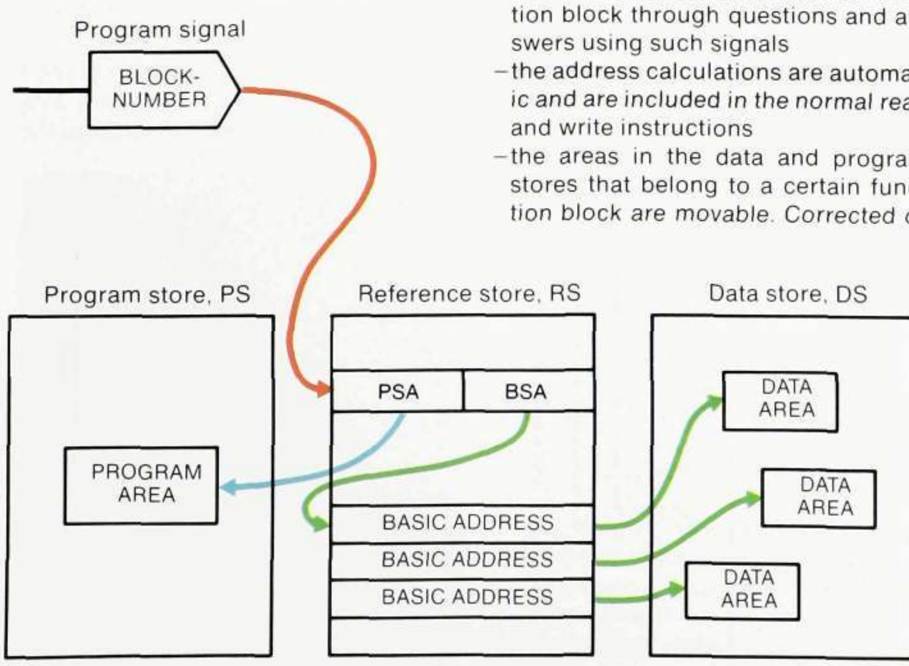
Fig. 6
The functional units in the central processor

CPU	Central processing unit
PS	Program store
DS	Data store
RS	Reference store
MAU	Maintenance unit

Fig. 7
The method off addressing in AXE 10 using the reference store

PSA	Program start address
BSA	Basic start address

Each program signal from one function block to another contains the block number of the addressed block. This number gives the start address of the program area in PS allocated to this block and the required basic addresses in RS. Each basic address indicates the data area in DS that contains the relevant type of data. This addressing method permits automatic reallocationn of the programs and data areas for the different function blocks



board assembly very quickly. One processor part works in the executive mode, handling the traffic through the exchange, and the other works in parallel in the standby mode. A fault in the executive part never has time to interfere with the traffic since the other part is always ready to take control, and this is done without any break in the operation. The fault localization is carried out automatically.

The duplication also simplifies the introduction of new function blocks or the modification of existing ones, since changes can be carried out in one part at a time.

A processor consists of central units, CPU, data stores, DS, program stores, PS, and reference stores, RS, fig. 6. The reference stores contain addresses to the program areas in each function block and the data areas in each store. This addressing principle, which has been described in detail in a previous article[3], gives easy handling and great software reliability, fig. 7, since

- the programs in a function block can only address the data areas in that block. This protects the other store areas and prevents faulty addressing. All interworking with other function blocks is carried out by means of program signals. A function block can therefore only get access to information in the data area of another function block through questions and answers using such signals
- the address calculations are automatic and are included in the normal read and write instructions
- the areas in the data and program stores that belong to a certain function block are movable. Corrected or modified function blocks can therefore always be accommodated without special correction areas being needed. Extensions can be given the necessary data areas through reallocation of the data store by means of commands.

The central and regional processors are micro-programmed. This makes for very powerful machine instructions without complicating the hardware. The central processor stores are also self-administering and have a pre-planning function that calculates store addresses in good time before they are to be used. This increases the processor speed and gives it a high data processing capacity.

Complicated tasks that occur relatively infrequently, for example digit analysis, routing, tariff analysis and fault localization, are handled by the central processor.

Regional processors

Simple tasks of a repetitive nature that occur frequently, such as signal sensing, decoding of digit information, measuring time and operating relays, are allocated to the regional processors. They also handle the control of input and output devices. A regional processor consists of a central processing unit, CPU, a data store, DS, and a program store, PS.

Two regional processors normally control a number of equipment modules, EM, which form a magazine group. An EM contains a number of telephone devices of the same type.

Maintenance

The maintenance unit, MAU, supervises the control system and is programmed to carry out automatically the necessary actions when faults occur so that the traffic handling in the exchange can proceed uninterrupted. The following tasks must be handled:

- fault detection. The processors are monitored and faults in printed board assemblies and other disturbances are detected and recorded automatically
- fault localization. The effects of a fault are limited by the faulty unit immediately being blocked. Diagnosis programs are then used to locate the faulty printed board assembly

- checking that the fault-clearing actions carried out by the staff, e.g. change of printed board assembly, have had the desired effect.

The supervisory function utilizes the fact that all central equipment is duplicated, that stores and buses also include parity bits, that there are different types of store protection and time supervision, that special routine tests are carried out by both the central and the regional processors and that abnormal data processing gives rise to an alarm.

When a fault is detected the faulty processor part is blocked while the other continues with the traffic handling. The faulty unit in the blocked part is then located and diagnosed. Diagnosis programs then pinpoint the faulty printed board assembly.

Input and output

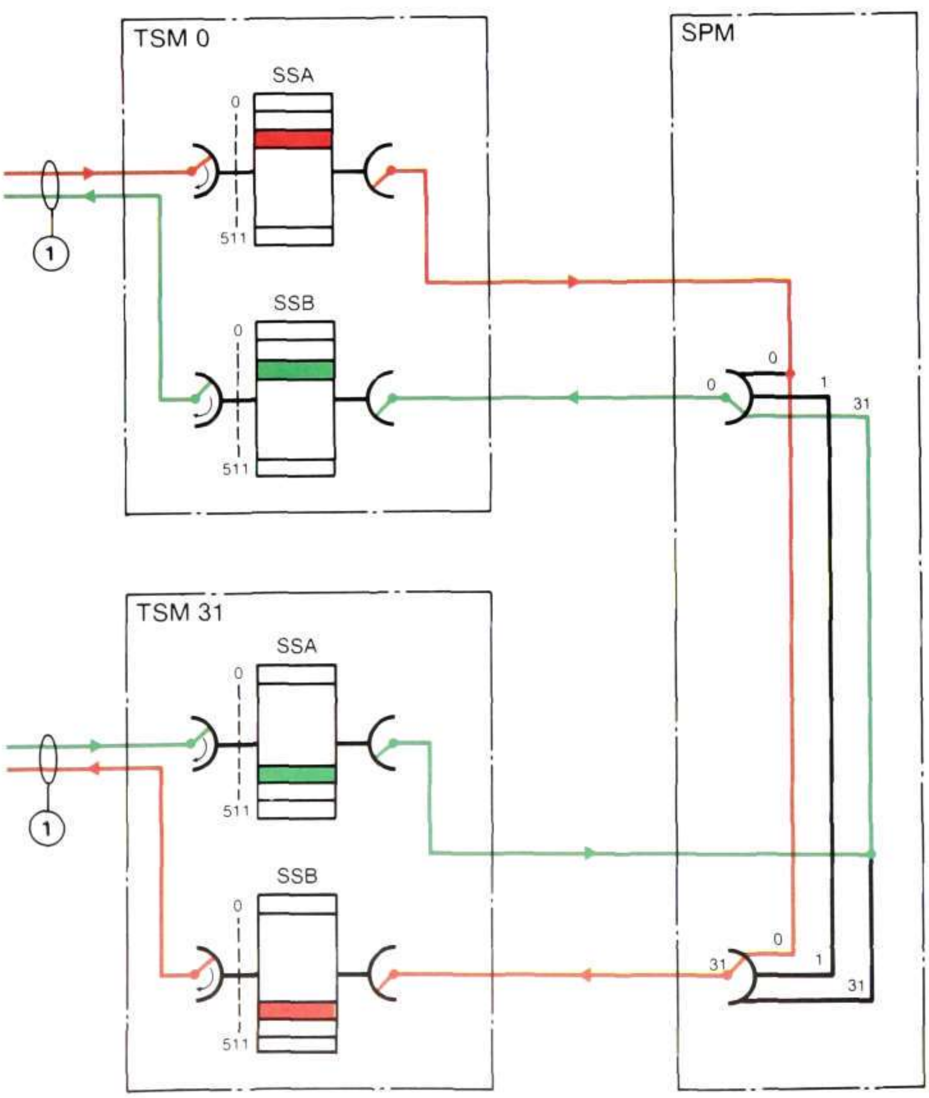
The following types of input and output devices can be connected:
- data display units with keyboards and printers or typewriters for the input of commands and output of operating messages
- cassette tape recorders and magnetic tape units for feeding in large amounts of programs and data, and for feeding out charging data and other information for further processing.

The input and output devices can be remotely connected via point-to-point or switched data links. Output can be made simultaneously to several devices in different places.

The operation staff have a total of about 500 commands at their disposal for various actions in the exchange. All input commands are checked both as regards the operator's authorization and the use of that type of command over the input device in question.

Fig. 8
The digital group selector

Red line: Speech data for the incoming traffic direction
Green line: Speech data for the outgoing traffic direction
(1) Incoming and outgoing speech directions for a total of 16 first-order PCM systems
TSM Time switch module
SPM Space switch module
SSA Sample store for the incoming speech direction
SSB Sample store for the outgoing speech direction



Digital group selector for 65,000 multiple positions

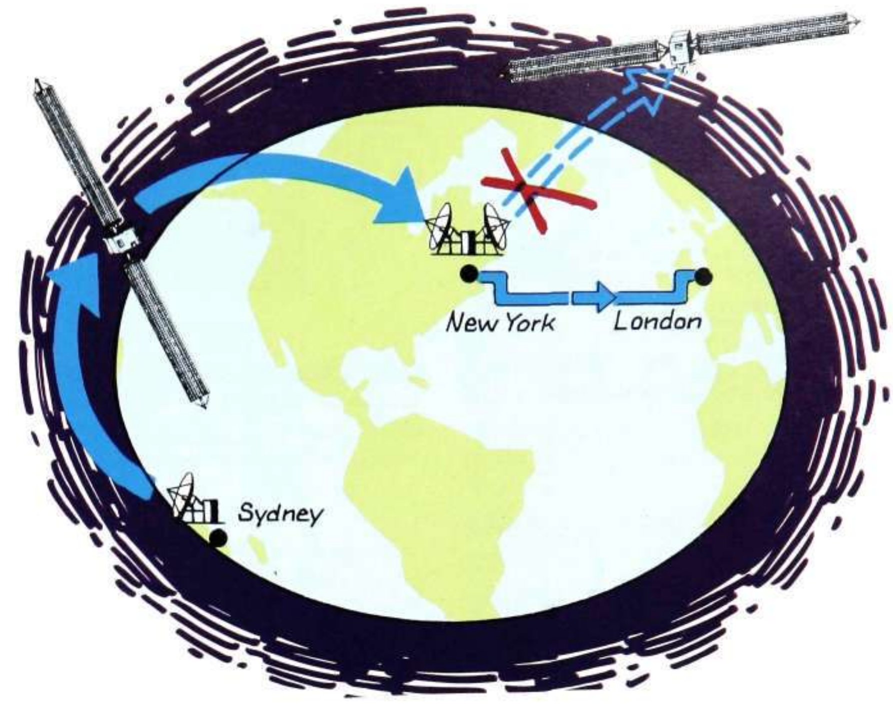
The digital group selector in system AXE 10 and its use have been described in previous articles[4,5]. A summary of the structure and main features of the selector is given here.

PCM systems as well as analog lines can be connected to the group selector. The latter are analog/digital converted in the signalling subsystem TSS.

The group selector has a time-space-time (TST) structure and is built up of time switch modules, TSM, and space switch modules, SPM, figs. 8 and 9. TSM contains stores for the PCM samples in the incoming speech direction, SSA, and the outgoing direction, SSB. The space switch module consists of cross point matrices for parallel transmission of 8-bit samples between SSA and SSB.

Two PCM channels that are to be connected together via the selector usually belong to different PCM systems in separate TSM and use different time slots in their respective systems. The incoming

Fig. 10
AXE 10 prevents two satellite links from being connected in series in the same circuit



sample in each speech direction is stored in SSA, read from SSA to SSB, at a time that suits SPM, and is finally transferred from SSB to the time slot in the outgoing PCM channel.

Each time switch module has 16×32=512 multiple positions for the connection of 16 first-order PCM systems. 480 multiple positions are used for speech transmission and 32 for signalling and synchronization. When analog lines are connected, all 512 multiple positions can be used for speech transmission. One time switch module often gives suffficient capacity for the group selector in small primary centres.

Group selectors with more than 512 multiple positions are equipped with a space switch module, SPM. 32 TSM can be connected to an SPM, which can thus serve 512×32=384 multiple positions. A TSM can be connected to several SPM, with a maximum of four. Connecting each TSM to four SPM requiers a total of 16 SPM and gives a space switch matrix with 128 inputs and 128 outputs. The maximum size of the group selector will then be 512×128=65,536 multiple positions.

The selector equipement is duplicated. All calls are set up along identical paths in two selector planes, and the final choice of plane is made in the outgoing junction line equipment, after a check that both speech directions have been through-connected. This method enables any call to be automatically switched over from a faulty to a faultless plane.

The group selector synchronization can be arranged in different ways[2,4,5]. The synchronization is ensured by three identical clock modules, which in their turn are synchronized with highly stable external reference clocks or with clock signals from another exchange over PCM lines. The clock modules work in parallel, and the time control is regulated by regional and central software.

Fig. 9
The digital group selector

Traffic control

The traffic control subsystem, TCS, in AXE 10 is realized entirely in software. TCS controls and coordinates all activities in the exchange for the setting up, monitoring and disconnection of calls. The B-number is transmitted to TCS for analysis, routing and choice of secondary route. The setting up over a free line in the chosen route is initiated from TCS, as is the digit and signal transmission for establishing the remainder of the switching path. TCS also monitors the connection and controls the disconnection and exchange of signals associated with this.

The charging information for a call, the B-number and perhaps also the A-number, are assembled in TCS and transmitted to the charging subsystem.

When a call is set up, the combination of incoming and outgoing route is also analyzed. The analysis result and incoming signalling information is used, for example, for connecting or disabling echo suppressors and to prevent prohibited connection of satellite routes, fig. 10.

TCS also controls the various cases of operator handling and operator-controlled setting up of conference calls.

The assembling in TCS of number analysis, routing and traffic control facilitates flexible traffic management. The data for these functions can be changed by

Fig. 12a
Functional diagram of comon channel signalling in accordance with CCITT system no. 7

(1) Data link, an optional time slot in a PCM system
(2) Signalling terminal, control and supervision of the signalling link
(3) Control of the signalling link network and routing of messages
(4) User parts, UP (CP functions in TSS)

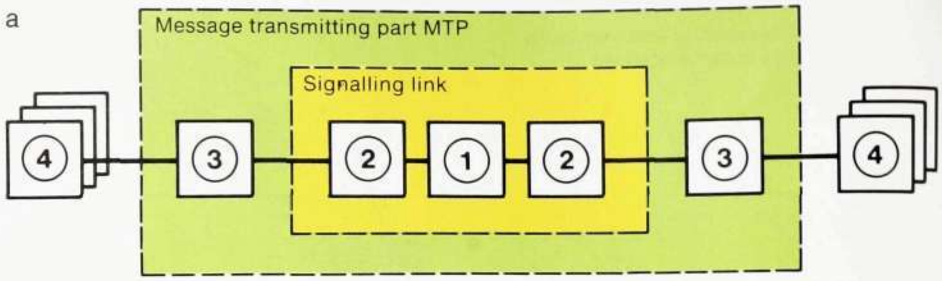
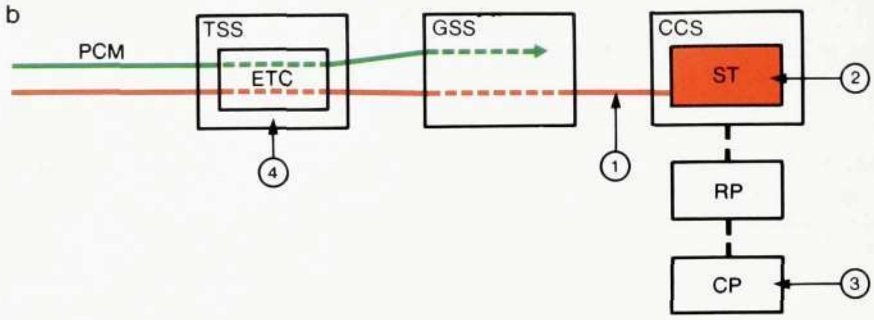


Fig. 12b
Hardware for common channel signalling in accordance with CCITT system no. 7 in AXE 10

Speech channels
Signalling channel
TSS Trunk and signalling subsystem
ETC Terminal circuit for first-order PCM systems
GSS Digital group selector
CCS Common channel signalling subsystem



means of commands. The administrative functions for this purpose and the functions for network manegement are described in the section Operation and maintenance.

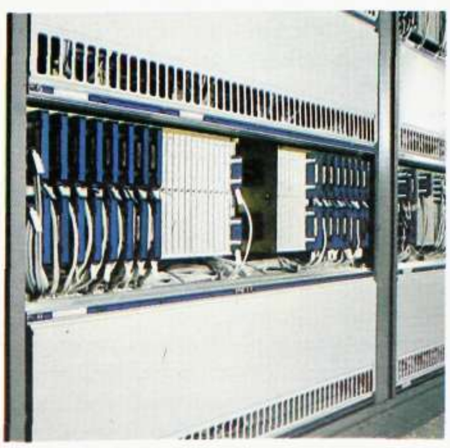
Signalling

AXE 10 is designed so that it can easily be adapted to any existing international or national signalling system. Such adaption is made to the signalling systems recommended by CCITT, e.g. R2, no. 5, no. 6 and no. 7, and to a large number of national signalling systems.

The traditional channel-associated signalling over junction lines is handled by subsystem TSS. The interface conditions that are used between TSS and the other subsystems utilize the signal concepts in signalling systems R2 and no. 7, with additions for charging and maintenace. All translation between telephone signals and the standardized internal signals takes place in TSS, and the other subsystems are therefore entirely unaffected by any adaptation to a new signalling system.

Two signalling systems are described below, namely R2, which is an example of channel-associated signalling, and no. 7, which is an example of common channel signalling.

Fig. 11
The trunk and signalling subsystem TSS



Channel-associated signalling

Signalling system R2 is intended for international and national traffic. In national networks R2 is often used in a modified form.

Line signalling over analog circuits is usually carried out using continuous out-band signalling. The two-way signalling channel provided by the common signalling time slot, T16, in the PCM system is used over digital circuits.

Register signalling is carried out using compelled MFC signalling. Six frequencies are used in each direction. The register signals are exchanged between code senders and code receivers.

Incoming, outgoing and two-way analog lines are connected via analog/digital converters to the 2.048 Mbit/s PCM interface of the group selector. Digital circuits are connected to the same interface via exchange terminal circuits, ETC.

Common channel signalling

Signalling system no. 7 is intended primarily for telephone traffic between digital SPC exchanges in national and international telecommunication networks. It can also be used for operation and maintenance signalling. The exchange of signals between two exchanges takes place over a signalling link which is common to several speech channels. The signalling system is optimized for a transmission speed of 64 kbit/s on digital channels, but it can also be used at lower speeds on analog channels.

Signalling system no. 7 can be used with associated signalling when a route has a sufficient number of speech channels to carry the cost of its own signalling link. However, this signalling system is usually used with non-associated signalling, especially when the routes are small. This means that several routes use common signalling links via central signal transfer points, STP.

Fig. 12a shows a functional diagram of signalling system no. 7, and fig. 12b shows the associated hardware.

Signalling system no. 7 consists of a message transfer part, MTP, which is the same in most applications, and an individual user part, UP. MTP defines the interfaces and procedures for the signalling between exchanges. UP defines the signals and thus corresponds to the signalling diagram. The MTP functions are provided by a special subsystem, CCS, whereas the UP functions belong to TSS.

In the case of associated signalling at least two channels in the PCM route are used for the common channel signalling. The route can consist of one or more PCM systems. The signalling links are used in accordance with the load sharing principle. If a fault occurs on one link, all signalling is transferred to the remaining link(s).

The signalling links are switched through the switching network to a microprocessor-controlled signal terminal, ST, which is connected to a regional processor, RP. The latter handles, for example, the sending and receiving of signals, synchronization and detection and correction of transmission errors.

Since the signalling links and the signalling terminals are connected via the group selector, they are easily replaced by standby links or terminals if a fault occurs. It is also easy to reallocate the signalling terminals.

The signalling messages contain a label that gives the channel identification, and the message is thus associated with the correct speech channel.

When a transit exchange functions as a signal transfer point it sends out the incoming signalling message on the correct outgoing signalling link.

Charging and inter-administration accounting

The charging subsystem, CHS, provides complete facilities for tariff analysis and the settling of accounts between telecommunications administrations. CHS consists of central software.

The correct tariff for the charging of a telephone call is determined either in the local exchange where the call is initiated or in a higher-ranking transit exchange.

The system allows 255 different tarriffs. In the case of tariffs that are dependent on distance, the B-number is analyzed when deciding on the tariff. The day of the week, time of the day and type of service used may also affect the tariff decision. The relationship between the tariffs and these factors can be changed by means of commands.

There are two possible charging methods, pulse metering or toll ticketing, fig. 13. In the latter case the A-number, B-number, date, time and call duration are recorded. The call data are stored on magnetic tape. It is also possible to combine the two methods, for example so

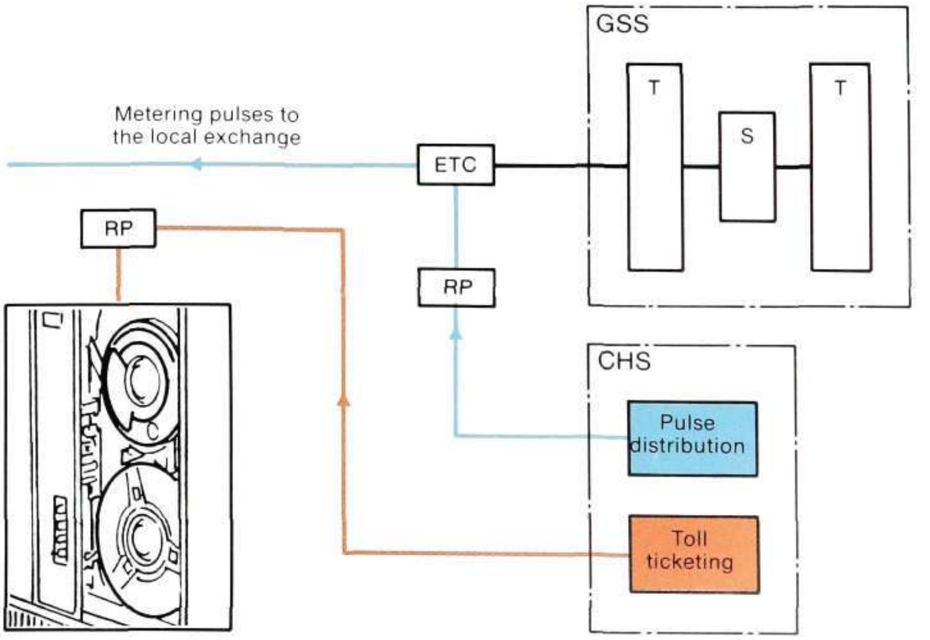


Fig. 13
The system provides pulse metering or toll ticketing

Box no. 1

OPERATOR FUNCTIONS

Call allocation. The calls are allocated to certain operators' positions with consideration given to the type of call, language group etc.

Call queue. If all operators' positions are engaged, the calls are put in queues for each type of origin, language, category or similar factor.

Direct completion. The call is set up while the subscriber waits.

Delayed completion. The call is set up as soon as possible or at a prearranged time.

Inquiry. This function is used, for example, when an operator must make an inquiry to another operator in order to be able to set up a call.

Transport. Used when a call has to be transferred from one operator to another during the setting-up process.

Conference call. A call with several participants, who are connected to centrally placed conference equipment.

Assistance operator funtions. An assistance operator can be connected in on international calls, for example if there are language problems.

Chief operator functions. The chief operator supervises the traffic intensity with the aid of queue indicators, ensures that a suitable number of positions are manned and redistributes the traffic to the positions if necessary.

Automatic toll-ticketing charging. The charging information is stored on magnetic tape or cassette tape.

Immediate pricing. The price information is given to the A-subscriber directly after the call.

that national calls are metered and toll-ticketing is used for international calls. If the metering method is used, a limited number of subscribers can have their calls specified on request.

The price information can be obtained as soon as a call is finished, which is of particular advantage to hotels.

The account-settling facility is always needed for international traffic and also for national traffic if the telecommunications of a country are operated by several administrations. The settling of accounts is based on the measurement of the total number of call minutes over each route concerned. Alternatively, in the case of national settling, and if the charging is handled by the transit exchanges, the number of charging pulses per route can be counted. The result is stored in the data store.

For safety's sake the charging and settling data in the data store are copied regularly in the form of output to a cassette tape recorder. The ordinary reading is carried out using a cassette tape recorder or another I/O device as desired.

Operator handling

Subscribers want rapid connection through the long distance network even when the calls are set up by operators. It is therefore essential that calls handled by operators can be set up quickly and efficiently. In order to achieve this it is necessary to abandon the earlier method of writing, sorting and distributing tickets, which is very time-consuming. There is also a need of new facilities, for example to be able to pay for calls by means of credit cards.

Subsystem OPS contains functions for operator handling, and the system has been designed to meet this and future demands. The operators are provided with data display units and keyboards, which can be connected to OPS either direct or remotely via data links.

Extensive ergonomic studies preceded the designing of the operators' positions. The environment has also been taken into consideration. Recommendations for layout, lighting and colour schemes have been prepared, fig. 14.

The operators' positions can be used for all types of traffic. The chief operator decides which type of traffic each operator is to handle. The right type of calls will automatically be routed to an operator's position when it is marked as attended.

When a call comes in, all available data on the call are shown on the operator's display, arranged on a form. The A-subscriber number is shown if it can be transmitted from the local exchange. The operator uses the keyboard to complete the form, mainly with the area code and B-subscriber number. OPS automatically processes these data and initiates the setting up of the call.

For calls that are ordered for a certain time, or which cannot be set up immediately because of a busy line or no answer, the information is stored in the system after entering the time for a new display. The data concerning completed calls are also stored. The operator can retrieve information concerning completed calls, for example in order to inform the A-subscriber about the price.

The handling process described here eliminates all ticket writing, and also a number of administrative routine tasks. The handling time for any type of traffic is short, because of the automatic processing in OPS. Tests have shown that the improvement is in the order of 20%. The advantages are even more pro-

Fig. 14
A recommended layout of operators' positions with data display units and keyboards

Box no. 2

OPERATION AND MAINTENANCE FUNCTIONS

Supervision

Blocking supervision, which gives an alarm if the number of blocked devices per route exceeds a present value.

Disturbance supervision, which indicates malfunctioning devices and routes, for example by monitoring signalling errors and time releases.

Seizure supervision, which checks that there has been at least one answered call on each junction line during a supervision period.

Seizure quality supervision, which indicates devices with faults that result in abnormally short seizure times, for example because of line faults.

Selector supervision, which checks that every call is correctly through-connected and disconnected. The clock distribution and the handling of addresses and speech samples in the selector are also supervised.

Load supervision, which monitors the load during busy periods and controls the number of calls being handled.

Route load supervision, which monitos the load on outgoing last-choice routes and a number of high-usage routes, and also the queue length on code receiver routes.

Testing and fault localization

Tracing of connection paths, to identify devices in the connection path. The device at which tracing starts can be selected.

Signalling and state recording, for analysis of signalling functions.

Device state indication, to indicate whether individual devices or groups are free, seized, blocked etc.

Test calls, for testing telephony devices and switching paths. The function permits operator monitoring and connection of measuring equipment for circuit testing. It is also possible to activate individual control points in the switching equipment, to decide in advance the switching path for test calls, to select devices and to inhibit the effect of time supervision.

Transmission measurements, to test the transmission quality of the junction circuits, can be carried out by connecting external equipment of type ATME 2 or ATME N2.

Code answer, which is needed for, among other things, transmission measurements and traffic route tests.

Statistics

Traffic recording on routes and number directions. The traffic in erlangs, number of calls, number of seized devices, number of blocked devices and call congestion can be recorded.

Charging recordings, for determining the distribution of calls on different tariffs.

Traffic observations, for assessing the quality of traffic handling as it is experienced by the subscribers.

nounced when many attempts at setting up a call have to be made.

The most important operator functions offered by the system are shown in box no. 1.

Operation and maintenance

In a transit exchange it is essential that the operation and maintenance functions are designed so that the work in question is simple and easy. National transit exchanges are often so situated in the network that they form a natural centre for the operation and maintenance activities for the transmission network and connected exchanges as well.

The software for operation and maintenance in an AXE 10 exchange is approximately of the same volume as the software for traffic handling. The operation and maintenance functions are assembled in subsystem OMS. The guidelines for the design of operation and maintenance facilities were as follows:
- the quality of service to be supervised by monitoring of all connections through the exchange
- the operating staff to be given only the information that is necesary for their work
- the day-to-day operation to be carried out by staff with experience of, for example, crossbar exchanges and who have had additional training in AXE 10
- the major part of the daily work to be carried out in the exchange control room. It is possible to centralize this work further, to operating centres. Even large exchanges can be left unstaffed.

The AXE 10 operation and maintenance subsystem contains functions in the following fields:
- supervision
- testing and fault localization
- statistics
- administration.

The following description of functions is limited to those of particular importance to transit exchanges. For further information regarding operation and maintenance functions reference should be made to a previous article in Ericsson Review[6] and box no. 2.

Supervision

Functions are included for supervising both hardware and software as well as the actual traffic. Data that are of interest to the supervision are continuously stored in the traffic handling subsystems. These data are checked regularly and an alarm is given in accordance with the service alarm principle when a predetermined quality level is no longer met.

Faulty units are automatically blocked for traffic. The traffic-carrying devices are also monitored to ensure that each

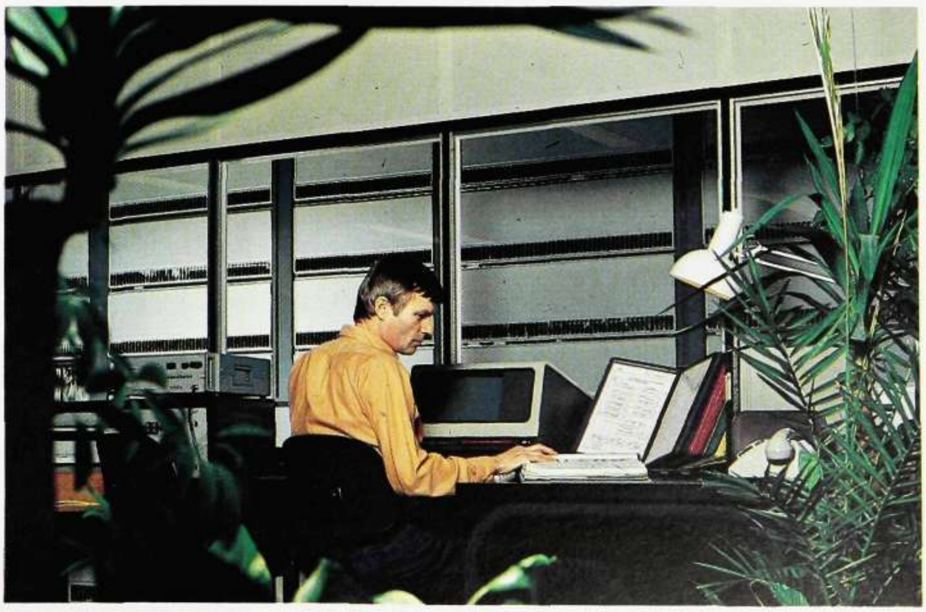
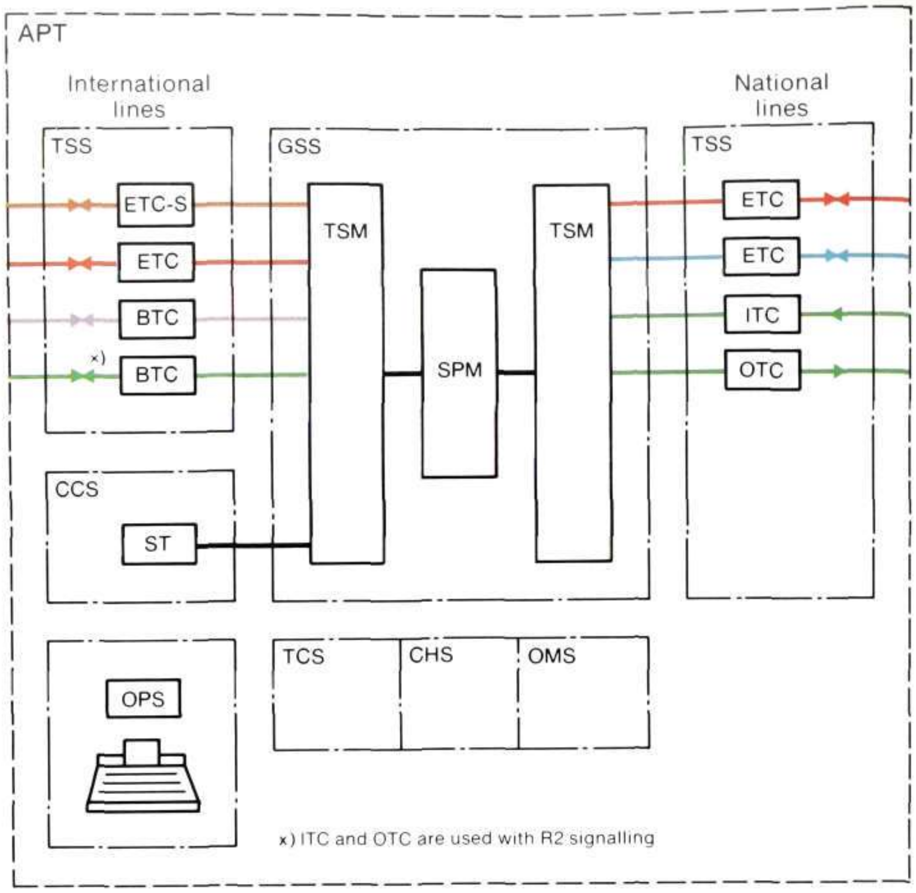


Fig. 15
The control room in the Kolding transit exchange, Denmark

Fig. 16a
AXE 10 as an international exchange

Satellite circuits
National and international PCM circuits with common channel signalling in accordance with signalling system no. 7
National PCM circuits with channel-associated signalling, e.g. in accordance with signalling system R2
International analog lines with common channel signalling in accordance with signalling system no. 6
National and international analog circuits with channel-associated signalling in accordance with signalling systems R2 and 5 respectively
Circuits to base radio stations for traffic to mobile units

TSS	Trunk and signalling subsystem
ETC-S	Exchange terminal circuit for satellite circuits
ETC	Exchange terminal circuit for PCM system
ITC	Incoming trunk circuit for analog traffic
OTC	Outgoing trunk circuit for analog traffic
BTC	Bothway trunk circuit for analog traffic
GSS	Group switching subsystem (digital group selector)
TSM	Time switch module
SPM	Space switch module
TCS	Traffic control subsystem
OMS	Operation and maintenance subsystem
CHS	Charging subsystem
OPS	Operator position subsystem
CCS	Common channel signalling subsystem
ST	Signalling terminal



is seized in the course of the supervision period.

Digital transmission systems that are connected to AXE 10 are supervised in accordance with CCITT recommendations. The incoming bit stream is monitored for bit errors and loss of frame and multiframe alignment. Supervision of the signalling channel is particularly important for routes that use signalling system no. 7. The monitoring comprises, among other things, the bit error on the signalling channel, the load on the send buffer and the accessibility for the signalling traffic to different destinations when STP are used. If a fault occurs, the traffic is immediately switched over to the standby channel.

Alarms from carrier equipment are also acted upon. For example, if a pilot alarm is received, the corresponding traffic-carrying devices are automatically blocked.

Testing and fault localization

A number of test and diagnosis programs are provided for testing when alarms and faults occur. The programs are initiated either automatically or by means of a command.

The maintenance of the lines in the network becomes increasingly important the higher their level in the network hierarchy. The lines are then longer and the transmission equipment more expensive. Large transit exchanges should therefore be equipped with automatic transmission measuring equipment, ATME, for supervision of the transmission quality. The maintenance of junction lines is most suitably concentrated to special service positions, from which all lines and relay sets can be reached for measurements and tests. The positions must be equipped with input and output devices, since all actions require commands for their control, and all results are obtained as printouts.

For international exchanges it is of course particularly important that the maintenance of the exchange and lines can be carried out in accordance with international recommendations. The operation and maintenance functions of system AXE 10 enable service positions to be set up for the supervision and maintenance of international circuits and lines in accordance with the CCITT recommendations for international maintenance centres, IMC.

Statistics

The planning and follow-up of exchange and network extensions require traffic statistics for routes and number directions. AXE 10 contains traffic recording and statistical functions that are activated by means of commands. The results are either output locally in processed form on a printer, or processed or unprocessed on magnetic tape. The results can also be fed out to a remote device connected via a data link.

Administration

The administration of an exchange in-

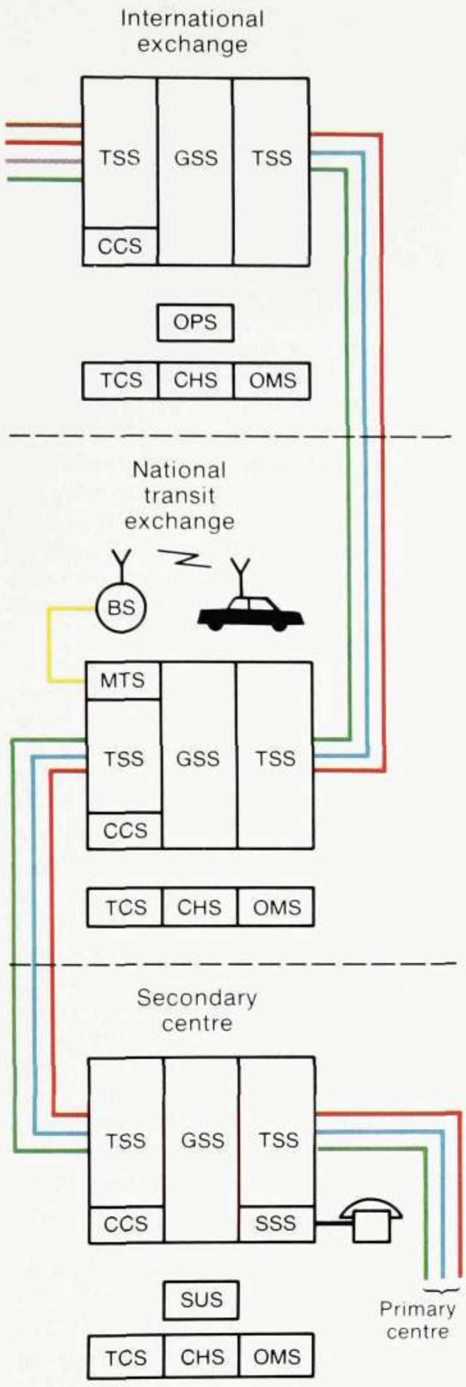


Fig. 16b
Routes between AXE 10 working as an international exchange and AXE 10 transit exchanges at various levels in the network. The colour codes are the same as in fig. 16a

cludes changing the semi-permanent data that describe:
- the build-up of the exchange
- routes and line allocation
- analysis conditions
- traffic routing plans
- charging conditions.

Some hundred commands are provided for these functions.

One aim when designing the administrative functions was to simplify the duties of the staff and minimize the effect of any mistakes.

Network management is a function of major importance in transit exchanges. It is used when there is an imbalance between the traffic load and the traffic capacity in the network. The operator is made aware of abnormal traffic situations, for example by means of an alarm from the route load supervision. He can then request information regarding the traffic load, congestion and blockings on the routes concerned. After analysis the operator carries out one or more remedial measures, such as
- activating on alternative routing plan
- cancelling an alternative routing
- blocking incoming junction line equipment
- blocking the traffic to certain destinations
- blocking the traffic from subscribers without priority
- routing to a route for announcing machine messages.

Transit exchanges at different levels in the network

The following tables show how AXE 10 is used as a transit exchange at different levels in the network and the functions that are associated with the various levels. Figs. 16a and b show which subsystems are required at the different levels.

International transit exchanges
- Operator handling
- Charging by means of toll ticketing
- International accounting based on the actual number of call minutes
- Analog international circuits with signalling systems R2, no. 5 and no. 6.
- Echo suppressors for satellite communication
- Analog carrier circuits and digital PCM circuits with R2 signalling to national transit exchanges
- Transmission measurements on international and national circuits
- Maintenance centres for international circuits

National transit exchanges
- Charging by means of toll ticketing for traffic from local exchanges with A-number identification
- Pulse metering of all other traffic, in which case the tariff can be determined at the transit exchange
- Mainly PCM circuits to subordinate exchanges, either with channel-associated R2 signalling or with common channel signalling in accordance with signalling system no. 7
- Traffic to mobile subscribers, who can be reached via base radio stations connected to subsystem MTS
- Transmission measurements on national circuits

Secndary and primary centres
- Charging by means of toll ticketing for traffic from local exchanges with A-number identification
- Pulse metering of all other traffic, in which case the tariff can be determined at the transit exchange
- Mainly PCM circuits to subordinate exchanges, either with channel-associated R2 signalling or with common channel signalling in accordance with signalling system no. 7
- Traffic to mobile subscribers, who can be reached via base radio stations connected to subsystem MTS
- Transmission measurements on national circuits
- Subscriber stages placed centrally as well as remotely in the network to replace small terminal exchanges.

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Time Division Multiplex for Telex and Data Transmission

Arturo Gatta and Giorgio Squartini

The Italian company FATME, a member of the Ericsson Group, have developed a time division multiplex system for telegraphy (telex) and asynchronous data transmission on telephone channels in accordance with CCITT Recommendation R.101, alternatives A and B.
The system, which is designated ZATF 46 CD, permits multiplexing of, for example, 46 channels for 50 bauds to a common bit stream having a bit rate of 2400 bit/s.
The system has been designed in collaboration with LM Ericsson, and the operation and maintenance functions are adapted to LM Ericsson's telex exchange system AXB 20. In this article the general features of the system and the electrical and mechanical construction of the equipement are described.

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The continuous and rapid growth of telex and data traffic creates a demand for greater traffic capacity and new transmission facilities in the network. The capacity can be increased by means of time division multiplexing (TDM), a technique which, compared with voice-frequency telegraphy, permits more telegraph and data channels on the same telephone circuit.

To meet these demands FATME have developed a time division multiplex system, ZATF 46 CD. This system permits the transmission of 46 telex channels at 50 bauds over a single telephone channel in the form of a combined bit stream with a bit rate of 2400 bit/s. The equipment is programmable and allows mixing of different standard speeds up to 300 bauds, different character codes and signalling systems in the same transmission system.

One of the main features of the system is its low distortion; each transmitted character is regenerated in its ideal form, and thus also characteres which are received very distorted are retransmitted practically undistorted.

The multiplexing is based on the bit interleaving principle, which introduces minimum signal transfer delay through the system.

The equipment is built up of functional units. They consist of printed board assemblies with modern and reliable components. The printed board assemblies are plugged into narrow racks of the FATME N2 type, which are 2600 mm high, 120 mm wide and 225 mm deep.

Applications

The TDM system can be used for telex, telegraph and data networks and gives better utilization of the telephone channels than conventional VF telegraph systems. The system is suitable for both analog and digital networks, being connected to the line via a data modem and a data circuit terminating equipment (DCE) respectively. Fig. 1 shows some applications.

System ZATF 46 CD includes a data modem for 2400 bit/s which meets the requirements of CCITT Recommendation V.26, and thus no external equipment is necessary for connection to the analog telephone network. The system can therefore be connected direct to a

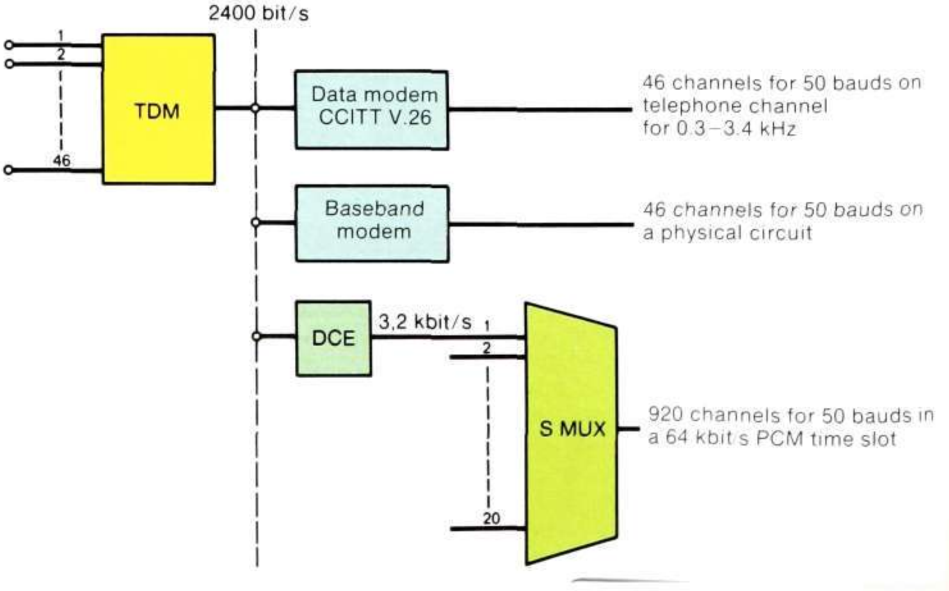

Fig.1
Connection of ZATF 46 CD to the telecommunication network

TDM Time division multiplex equipment
DCE Data circuit terminating equipment
S MUX Multiplexor towards the synchronous data network

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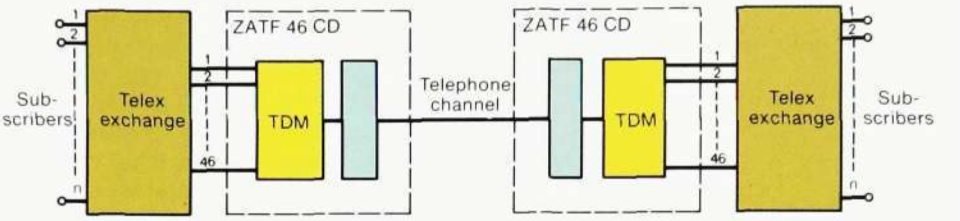


Fig. 2
ZATF 46 CD used for circuits between two telex exchanges other than AXB 20

TDM Time division multiplex equipment

normal 4-wire telephone channel, which can be a carrier channel or a physical circuit for the frequency band 0.3–3.4 kHz.

If required, a 2400 bit/s baseband modem can be used instead of the internal data modem, fig. 1, for transmission over physical circuits.

Two or four ZATF 46 CD systems can also share a telephone channel equipped with a modem for 4,800 bit/s and 9,600 bit/s respectivley.

*The TDM equipment can also be con*nected to a higher order multiplex, for instance by using a multiplex, S MUX, in accordance with CCITT Recommendation X.50, fig. 1. A DCE must then also be used. The encoding format is 6+2 bits and the bit rate of the data signals is 3.2 kbit/s in the baseband. S MUX allows 20 data channels at 3.2 kbit/s to be multiplexed to a standard 64 kbit/s digital channel for PCM. The total capacity is then 920 channels for 50 bauds.

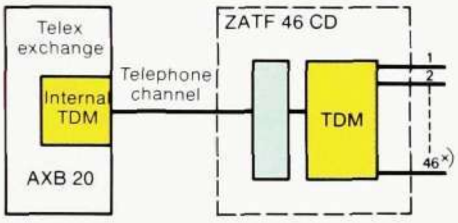


Fig. 4
ZATF 46 CD used to connect another telex exchange or remote subscribers to LM Ericsson's telex exchange AXB 20

TDM Time division multiplex equipment

*) One of the 46 channels is used for maintenance.

System operation

System ZATF 46 CD is primarily intended for use in telex networks, figs. 2 and 3. It is very suitable both for connections between telex exchanges and for remote connection of groups of subscribers to an exchange. Fig. 4 shows how the system is connected to the LM Ericsson telex exchange AXB 20.

AXB 20 is a stored program controlled exchange for telex and asynchronous data traffic. It has been designed for use *as a combined local and transit ex*change for both national and international traffic. It is particularly suitable for the connection of remote subscribers via concentrators or multiplexors such as ZATF 46 CD, since it contains a built-in multiplexor and modem. This means that no channel interface units are needed on the exchange side[2,3].

ZATF 46 CD contains functions for the operation and maintenance of unattended system terminals. One of the 46 channels in the system is then used as a maintenance channel for the necessary *signalling.*

Lines to teleprinters can be connected in three ways:
- double current in full duplex, 4-wire circuits on two wires with an earth return circuit
- single current in half duplex on 2-wire circuits
- V.21 subscriber modems in full duplex on 2-wire circuits.

The telegraph signals coming from each subscriber or from the telex exchanges have a standardized speed and charac*ter structure, since 7.5 unit elements* (20 ms) and the international telegraph alphabet no. 2 are used.

A central logic device in the TDM scans the channel inputs in turn, and after signal generation combines the signals for all the 46 channels into a single bit stream. The resultant signal, with a bit rate of 2.4 kbit/s, is then taken to the internal modem, which converts it to a VF signal for transmission over the line.

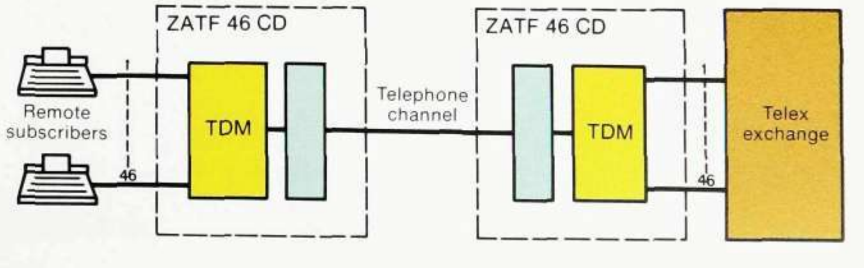


Fig. 3
ZATF 46 CD used to connect remote suscribers to a telex exchange other than AXB 20

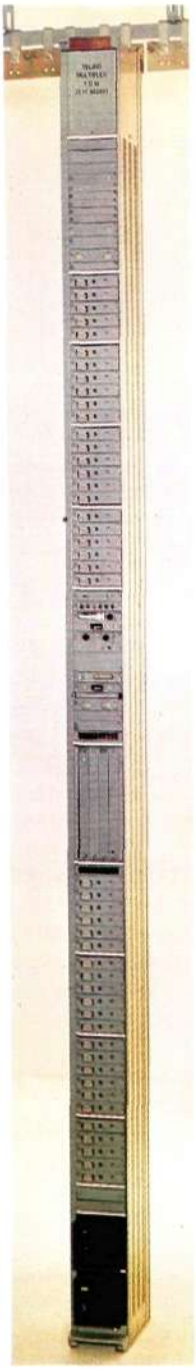


Fig. 5
ZATF 46 CD for double current working

In a similar way the VF signal coming from the line is converted in the receiver to a digital signal. This signal is demultiplexed by the TDM equipment, which separates the data for each channel, restores the telegraph signals and transmits them to the telex subscribers or the telex exchange.

System flexibility

System ZATF 46 CD meets CCITT Recommendation R.101, alternatives A and B, for different combinations of asynchronous channels having different data transmission rates, different code structures and different alternatives for signalling and fault supervision. See the technical data at the end of the article. The choice of alternatives in the wide range available is made by means of strappings for each individual channel in a common strapping field.

Since alternatives A and B have different synchronizing procedures and work with different formats, adaption to one of these two alternatives must be made by changing programs in the central control unit. No units have to be changed, only a few programmable memories (PROM) and a few straps.

Data transmission rates and character structures

When the FATME TDM system is operating according to alternative A it allows the multiplexing of two telegraph speeds, 50 and 75 bauds, both with 7.5 elements. When it is operating according to alternative B it can handle simultaneously the complete range of standard speeds from 50 up to 300 bauds and all codes with 7.5, 9, 10 or 11 elements per character.

Telex signalling alternatives

The system is so flexible that it can handle all types of signalling used for telex. Each low speed channel can thus be strapped for any of the CCITT signalling types: A, B with keyboard selection, B with dial selection, C or D.

Alarms

The equipment continuously monitors the local functions and the quality of the received signal, and it also receives alarms from the far end terminal. Alarms are given for the following faults:

- loss of synchronism
- loss of carrier, which is detected by CCITT circuit 109 in the modem
- deterioration of the signal quality, which is detected by CCITT circuit 110 in the modem
- faults in the central logic equipment, which are detected by an internal test loop and parity checking in connection with memory operations
- programming errors, which can lead to two channels using the same time slots
- faults in the far end terminal
- power failures.

Alarms are given for the individual connected circuits in the case of

- too high distortion of the incoming signal
- line breaks.

Mechanical construction

The ZATF 46 CD equipment is mounted in the FATME N2 rack, which is 2600 mm high, 120 mm wide and 225 mm deep. Five such slim racks can be installed side by side and then form a 600 mm wide rack group.

The steel rack side plates are joined to a bottom plate and some further plates, which are mounted at different heights depending on the functional division of the rack. The bottom plate has adjusting screws for levelling the rack.

The two steel rack sides are provided with slots in modular steps of 5.08 mm for plastic guides that ensure correct insertion of the plug-in units. The units consist of printed boards of fibreglass reinforced epoxy laminate equipped with components and gold-plated contacts for the external connections. The boards can have double-sided printed wiring with through-plated holes and two different widths are used: single and double N2 boards. The single-width boards are inserted horizontally, taking up the whole width of the rack. The double-width ones, whose larger surface is particularly useful for complex digital functions, are inserted vertically. A mechanical locking device prevents the printed board assemblies from being removed accidentally.

Connection panel

Rack interface unit

Data modem

Channel interface units

Service unit

Central logic unit

Channel interface units

Electronic power supply

Telegraph power supply

Fig. 8
ZATF 46 CD for single current working

The front of each unit is fitted with a plastic protective cover with access points for U-links, test plugs etc.

The space at the left-hand side of the rack, behind the unit connectors, is used for the rack cabling.

At the top of the rack the external cabling is connected to the connection panel, which is accessible from the front. This allows the rack to be taken out of operation for fault clearing and also makes it easy to replace.

Fig. 5 shows the rack layout for system ZATF 46 CD with double current working. The TDM central logic, fig. 6, and the service unit, fig. 7, divide the channel interface units into two groups. The data modem is placed at the top of the rack and the power supply packs at the bottom.

Fig. 8 shows the rack layout for single current operation. Due to the higher power dissipation in the equipment when this operating mode is used, particularly for short subscriber lines, two racks are used, each contaning the interface units for 23 channels.

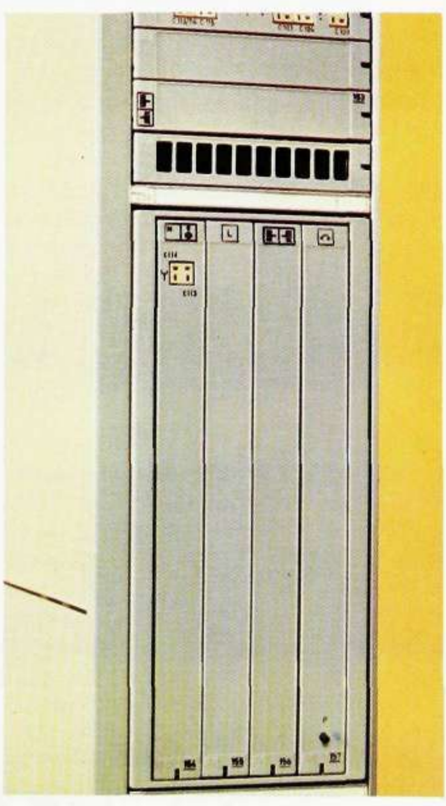
Circuit description

A brief description of the various circuits in the transmission equipment is given below.

Channel interface units
Five main types of channel interface units have been developed to meet the requirements of different types of line signalling:

Double current and high voltage
This unite, fig. 9, is designed mainly for matching towards conventional telex exchanges, for which a ±20 mA telegraph signal current is normally required. The voltage of the regenerated signals can be adjusted up to ±60 V.

Double current and high voltage with fault localization facilities
This unit has the same electrical characteristics as the first one but is designed mainly for interworking with subscriber apparatus and conventional electromechanical exchanges. It has built-in fault localization facilities, for example open line alarm. The unit also contains digital loop connection facilities, which are particularly useful for testing remote



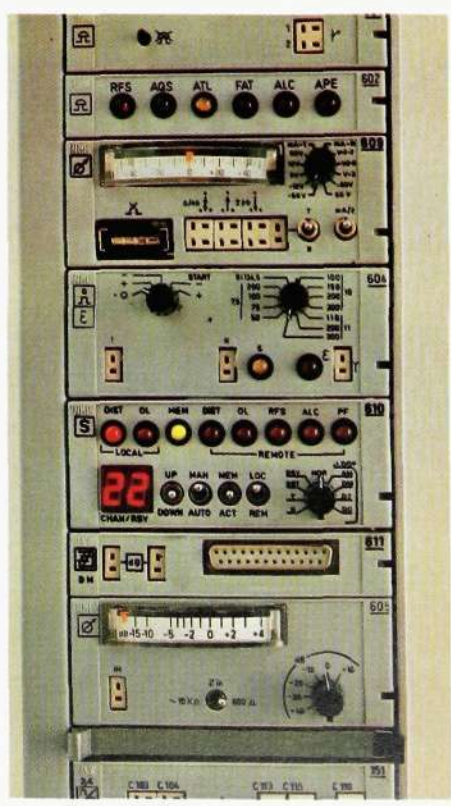
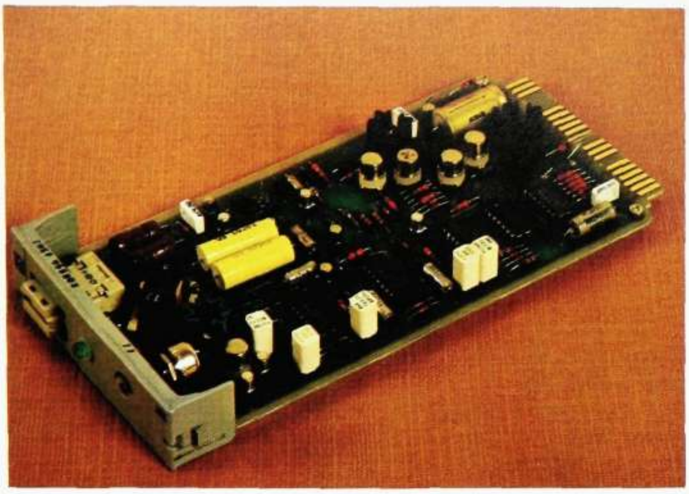


Fig. 6, left
Central logic unit

Fig. 7, right
Service unit



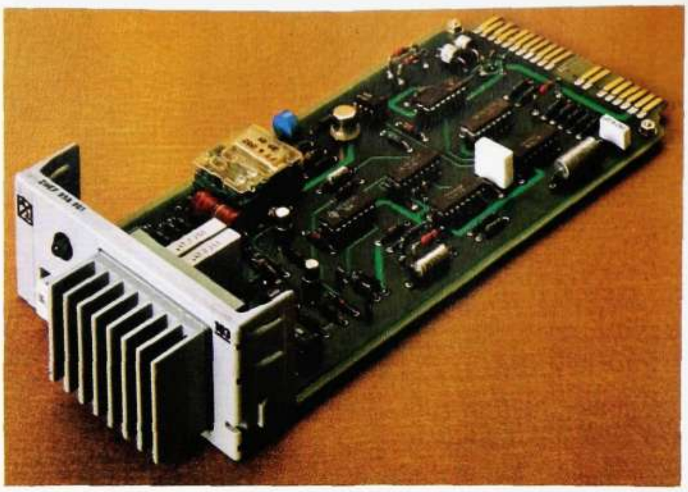


Fig. 9, left
Channel interface unit for double current and high voltage

Fig. 10, right
Channel interface unit for single current

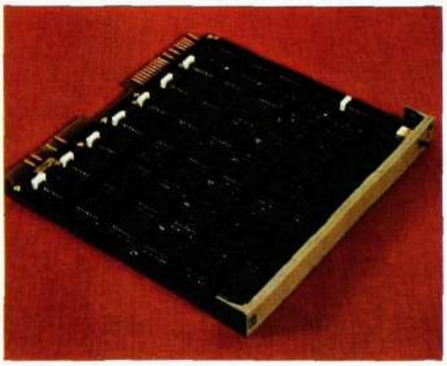


Fig. 12
Strapping field

subscriber equipment. The unit is equipped with efficient lightning protection.

Double current and low voltage
This unit is designed for matching to new electronic telex exchanges having an interface in accordance with CCITT Rec. V.28. In this case the voltage is ± 12 V and the line current not more than 12 mA.

Single current
This unit, fig. 10, is designed for a nominal current of 40 mA and ± 60 V voltage and has efficient lightning protection.

VF signalling in accordance with Recommendation V.21
This unit is designed for V.F. signalling using frequency shift modulation.

Central logic equipment
The central logic unit consists of a central processing unit, a store, a multiplexing unit, a demultiplexing unit and a strapping field.

The channel interface units are connected to the central unit via buses. Fig. 13 shows a simplified block diagram of the system. In this diagram three buses are shown: the address bus and the send and receive data buses. Exchange of data with a channel interface unit takes place when this particular unit is addressed.

The strapping field, fig. 12, permits individual strapping of each channel as regards speed and code structure.

The information in the strapping field can be transferred to the central unit store by pressing a reprogramming button. It is then possible to remove the strapping board for changes without disturbing the operation of the equipment. This gives the system complete flexibility and the possibility of reprogramming on site.

The action to be taken in the case of a multiplexor fault can also be arranged by means of straps. The following three alternatives are available:
- switching over to steady start polarity
- switching over to steady stop polarity
- switching over to steady start polarity after loop connection of the channel towards the local end for 5 seconds.

All timing information is derived from a central crystal-controlled clock. This timing gives scanning of every channel input at the centre of each unit element, counted from the beginning of the start element, and forming of a common single bit stream.

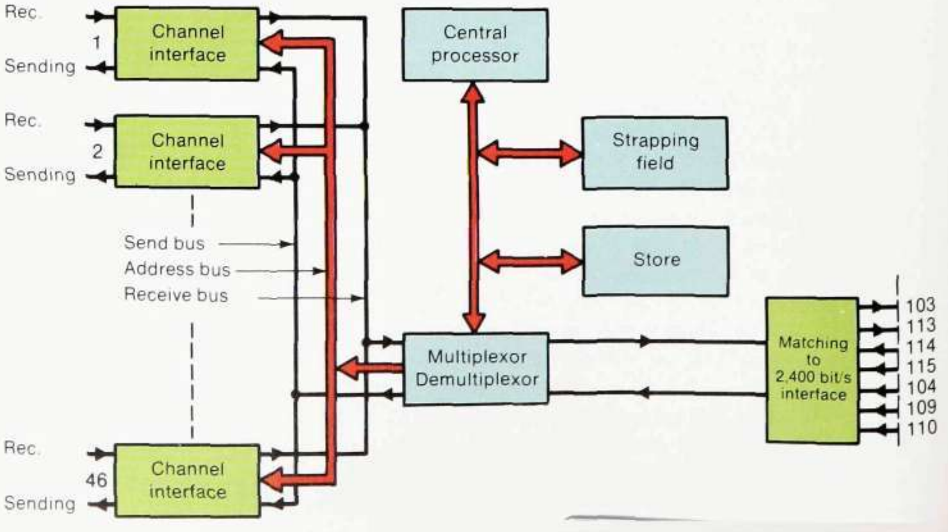
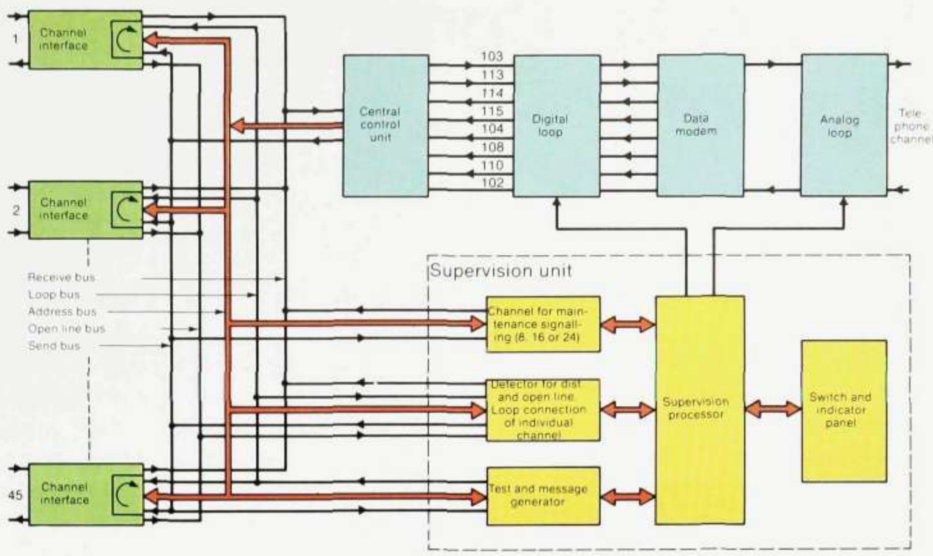


Fig. 11
Simplified block diagram of ZATF 46 CD

Fig. 13
Simplified block diagram of ZATF 46 CD with a supervision unit



Technical data

Type of system	Code and speed dependent time division multiplex in accordance with CCITT Recommendation R.101	
System capacity		
–Alternative A	Modulation rate, bauds	Number of channels
	50	46
	75	22
–Alternative B	Modulation rate, bauds	Number of channels
	50	46
	75	30
	150 or 134.5	22
	100 or 110	15
	200	10
	300	7
Speed tolerance	Max. +2% for 50 and 75-baud signals. Max. +1.8% for all other permitted speeds	
Highest acceptable distortion of the unit pulse to the receiver	46.6%	
Maximum start-stop distortion at the channel output	3%	
Types of channel interface units	–Double current, high voltage –Double current, low voltage –Single current –V.21 signalling	
Channel interleaving	On a bit basis	
Bit rate after multiplexing	2,400 bit/s	
Internal data modem		
Modulation method	Differential 4-phase, code A or code B	
Line connection	4-wire	
Nominal impedance, line side	600 ohms	
Send level limits	–0.5 and –46 dBm	
Receive level limits	–3 and –43 dBm	
Power supply		
Mains voltage	220 V	
Limits	+10 and –15%	
Frequency	45 and 65 Hz	
Battery voltage	48 or 60 V	
Limits	+20 and –15%	
Rack		
Height	2,600 mm	
Width	120 mm	
Depth	225 mm	

A bit interleaving multiplexing technique is used in order to achieve minimum transfer delay. Two different code structures can be used as recommended in CCITT Recommendation R.101.

The 2400 bit/s bit stream is converted from TTL levels to the electrical characteristics specified in CCITT Recommendation V.28. This is the standard interface between the multiplex equipment and the external or internal data modem.

Supervision equipment
The supervision unit, which contains a microprocessor, is a powerful device for monitoring and fault tracing. It is particularly useful when one ZAFT 46 CD terminal is unattended.

One of the 46 channels in the circuit is used as a maintenance channel, fig. 12. This allows the supervision unit to check the operation of the system. The quality of the incoming telegraph signals can be monitored and open line conditions detected. If there is an alarm at the far end terminal, for example if the distortion exceeds a preset value or there is an open line, the supervision unit sends a message to the attended multiplex. The message includes the number of the affected channel.

The near-end supervision unit receives the alarm message and displays it on an indicator. It also records the number of resynchronizations and on request transmits this information to the remote terminal.

Subscriber equipment can be tested from the supervision unit, which then transmits a special distorted test message. Similarly it can also check a distorted message received from the subscriber.

The same type of exchange of messages is used when a remote multiplex is operating in conjunction with AXB 20[3,4].

Data modem
The modem equipment operates at a data rate of 2,400 bit/s, synchronously over 4-wire telephone lines. The modem interfaces are in accordance with CCITT Recommendations V.24, V.26 and V.28.

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Computer Controlled Interlocking System

Hans S. Andersson and Gunnar Hagelin

LM Ericsson, in collaboration with the Swedish State Railways, have developed a computer controlled interlocking system for railway yards. The computer control means a considerable modernization of equipment compared with electromechanical technology. This modern interlocking system is already in operation in Sweden in the Gothenburg and Malmö areas.
The authors describe the system and how its fail-safe function has been achieved. This is followed by a description of a planning system for installations, and the article concludes with a brief account of the installations already in operation.

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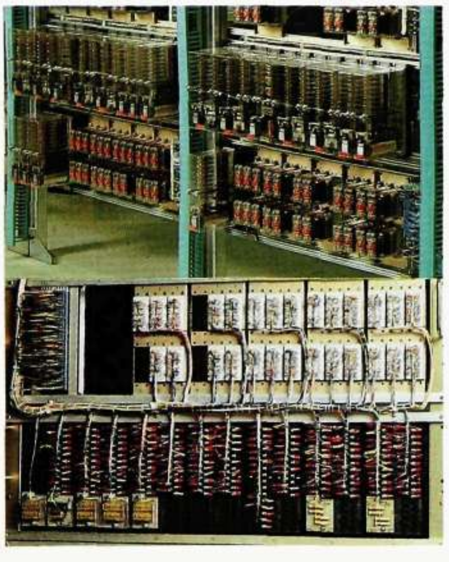

Fig. 1
The degree of safety obtained with robust relays, large insulation distances between the circuit elements, guided contacts and simple circuit structure corresponds to what is obtained with large information and system redundancy in a computer controlled system

Interlocking systems are used in railway signalling systems in order to ensure the safety of train movements. Before any train is moved a train route is prepared, which is then protected by the interlocking system against
- other trains in the train route, by checking that the track is clear
- other frontal train movements, by checking that there is an overlap area also beyond the end of the train route and that signals in the opposite direction show stop
- other flanking train movements, by checking that conflicting train movements are prevented by trap points and signals at stop
- changes in the point positions, by checking that all points in the actual train route, the overlap area and the flank protection area are locked in the correct position.

The protection is supplemented by a regulation that instructs the driver to keep within the applicable speed limit and to stop the train at the end of the train route. Equipment is also available which supervises the speed of the train and brakes it automatically if the driver does not comply with the regulations, as has been described in previous articles in Ericsson Review[1,2].

The checking that all conditions for authorizing a train movement have been met is carried out wholly automatically in modern signal safety systems. Conventional systems use safety relays, the contacts of which are connected together to form current paths that correspond to the different conditions. In LM Ericsson's new system, the interlocking conditions are checked by a computer, figs. 1 and 2.

System principle

Stored program control has been chosen for the interlocking function because the increasing demands for more complex interlocking conditions have made it very difficult to design systems using relay technology that can easily be modified and extended. The use of

Fig. 2
The LM Ericsson computer UAC 1610 P for stored program control of the signal box for the Malmö railway yard area, in south Sweden

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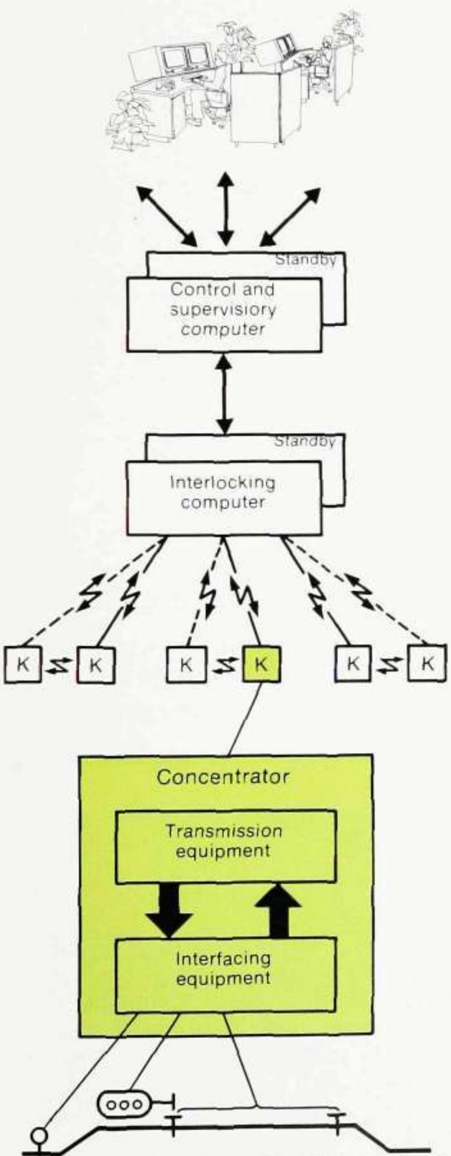

Fig. 3
The main parts of the interlocking system

computer control for the interlocking function makes the matching to the remainder of the signalling equipment easier. The overall cost is lower, not only for the equipment itself but also for the planning and installation.

The trackside devices, such as track circuits, points, signals etc., are connected in groups to concentrators, which are then connected, via transmission links, to the interlocking computers. Messages are transmitted in both directions in serial form, and each message is supplemented with redundant information in order to ensure fail-safe function.

The system comprises (see fig. 3):
- control and supervisory subsystem
- interlocking subsystem
- transmission network between the interlocking subsystem and the trackside concentrators
- subsystem for interfacing between the concentrators transmission terminals and the trackside devices.

The first two subsystems are computer controlled and the computers are duplicated to ensure availability. The transmission network is supplemented with alternative routes.

A documentation system, which uses a separate computer has also been developed for the planning of installations.

Control and supervision subsystem

In the new interlocking system colour displays replace the old type of indication panels, where lamps were used to indicate train positions, signal conditions, point positions etc. Each operator now has a work position with two display units and a keyboard which is used to give all commands, figs. 4 and 5. One display gives an overall picture of the supervised track area, and the other gives detailed information for a selected part of the track.

Different types of alarms are also shown on the display units, and the operator can enter commands via the keyboard to display alphanumerical information concerning a particular alarm.

The system also permits automatic commands. Such commands are programmed in advance and are released when certain conditions are met. The operator can also compile automatic functions himself, for example for frequently recurring shunting movements.

Commands to the interlocking system, for example the setting up of a train route, are always reviewed before the interlocking system starts to arrange safeguards, block devices, change points etc. This is done to prevent the system

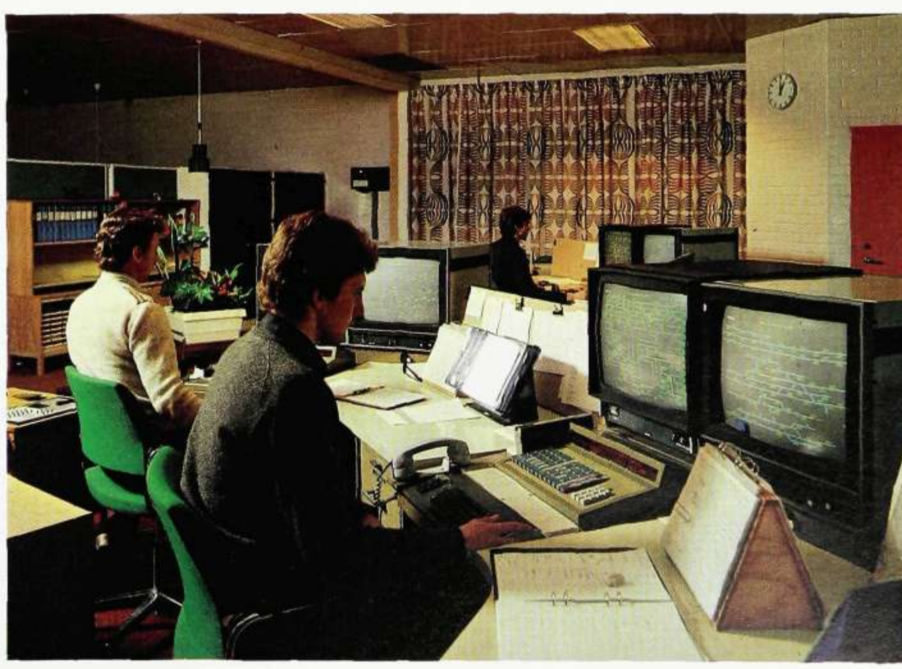

Fig. 4
The control office for the Gothenburg railway yard area, western Sweden

Fig. 6
The processing stages during an operating cycle

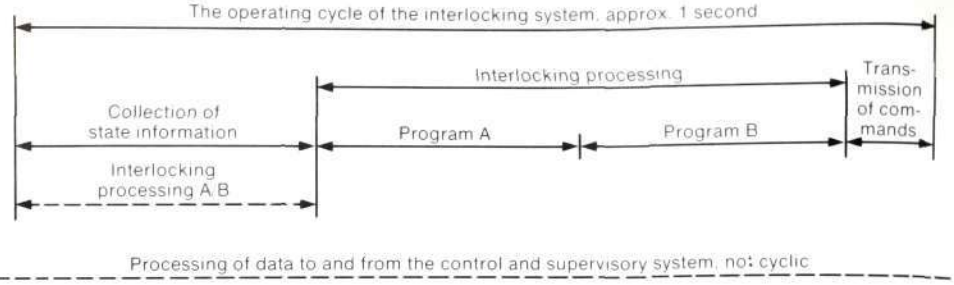

Fig. 5
Keyboard for the input of commands

from being loaded with unnecessary blockings. A command that is not accepted in the review is put in a command queue, and is then reviewed repeatedly until the conditions are met or the command is cancelled manually.

Interlocking subsystem

The interlocking subsystem acts as a safety filter and prevents dangerous commands from the control system from being executed. The stored program control in the interlocking system uses an algorithm for this filter function, so that

- correct commands from the control system are safely transmitted to points, signals and level crossing equipment
- devices that are to be included in a train route are blocked against use in other routes
- blocked devices are relased when the train is clear of the route.

The processing in the interlocking computer is cyclic. The cycle time is approximately one second. During each cycle, fig. 6,

- all information concerning the state of the various devices is collected
- any commands from the control and supervision system are processed
- the interlocking data are processed in two separate program sequences
- commands to the devices are compiled and transmitted
- information concerning the yard status is transmitted to the control and supervision system.

Commands from the control and supervision system are transmitted in a background program and not as a part of the fixed cycle.

The data processing is duplicated for safety reasons. Two different program sequences each process the yard device data in accordance with the algorithm. The processing results in two commands per device, and check bits are added to both in order to ensure safe transmission. Finally the command message from one program sequence and the check part from the other are combined and sent via the concentrator to the interfacing equipment for the trackside device.

Interlocking conditions according to the geographical method

The interlocking conditions have been given a stringent mathematical descrip-

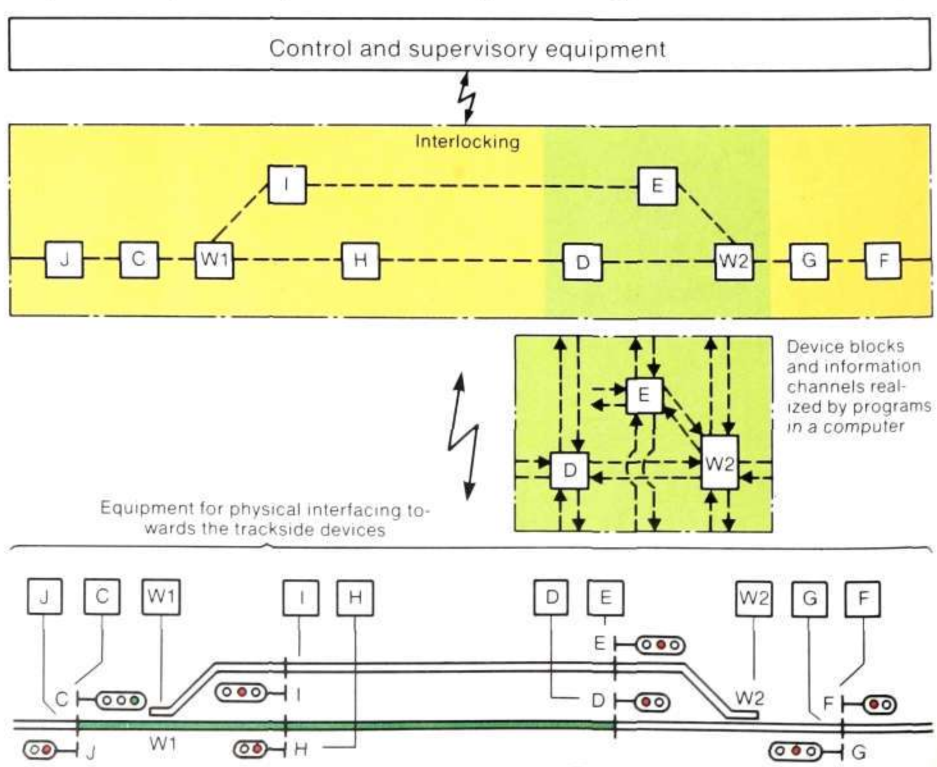

Fig. 7
The basic principle of the geographical method

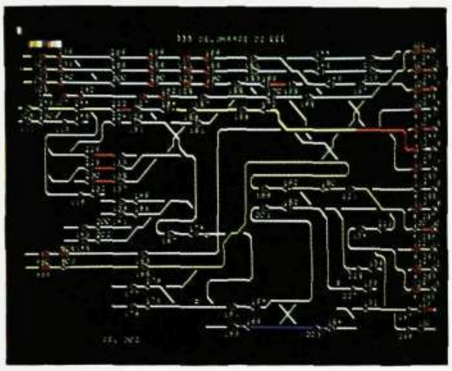

Fig. 8
A set train route is marked with a green line on the display screen and a shunting route is marked with yellow or blue alternatively

tion. The conditions are described in accordance with the geographical method, which means that they are related to the various trackside devices: points, signals, derailers etc.[1] For each device the conditions for every possible state and every possible change of state are set. Fig. 7 shows the geographical method in principle. Each device has an associated block with interfaces towards

- the control system
- the trackside device
- the blocks for the "geographical neighbours".

The interfaces towards the neighbours are the same for all devices, whereas the interfaces towards the control system and towards the trackside device are the same for each type of device.

When a train route is set up, figs. 7 and 8, the block for signal C receives an order from the control system to seek the necessary protection for the train route, so that command to show green light can be sent to the signal. At the same time the other blocks in the train route are ordered to assume states that form the conditions for establishing the route. For example, signal D is ordered to form the end point of the train route, which in its turn means that signal D must seek the necessary protection for the overlap area beyond the signal. Messages are then exchanged between the blocks in accordance with the program, and the blocks successively change state until the states of the whole chain of blocks in the train route agree with the interlocking conditions. The changes of state of the blocks also mean that the points in the train route and the flank protection are set and locked in the correct position etc. When all this has been completed, all conditions for the train route have been fulfilled and the block for signal C can send a command to set the signal to "clear".

The messages that are exchanged between blocks which are geographical neighbours can be divided into the following categories, namely messages that

- state the type of train route that is to be established, and which command the locking of the route
- indicate the type of flank protection and the length of the overlap area required for the train route
- inform that flank protection and overlap protection are achieved
- indicate clear track along the train route, in the overlap area and in the flank protection areas
- state the maximum speed for the train route
- control the level crossing devices
- release the devices in the train route when the train has passed.

Types of blocks

For each block there is a description of how the block must react to an incoming message, and which messages the block is to send to its neighbours, its own device and the control system.

The system contains the following eight types of blocks:

- signal blocks for signals
- advance signal blocks for independent advance signals
- point blocks for points and stop blocks
- crosssing blocks for track crossings
- road blocks for level crossing devices
- boundary blocks for the boundary towards areas without interlocking
- line blocks forming boundaries against lines between stations and against other signal box areas
- obstacle blocks, which add dependence on extra track circuits.

Processing of blocks

The conditions for each type of block are described by a number of equations in algebra that is similar to Boolean algebra, fig. 9. However, each variable can normally take up more than two values.

When processing a block, for example signal block D, the computer program uses the equations that apply for signalling blocks on the data of signal D, fig.

```
IF (K.EQ.4.AND.(P1.EQ.2.OR.P1.EQ.3).AND.RØ.EQ.1.AND.
*(PK.NE.Ø.OR.R6.EQ.1.AND.(U2.NE.8.OR.
*I2Ø5.EQ.Ø.AND.T2.EQ.Ø)))R6=1.
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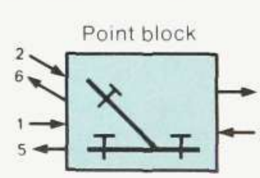
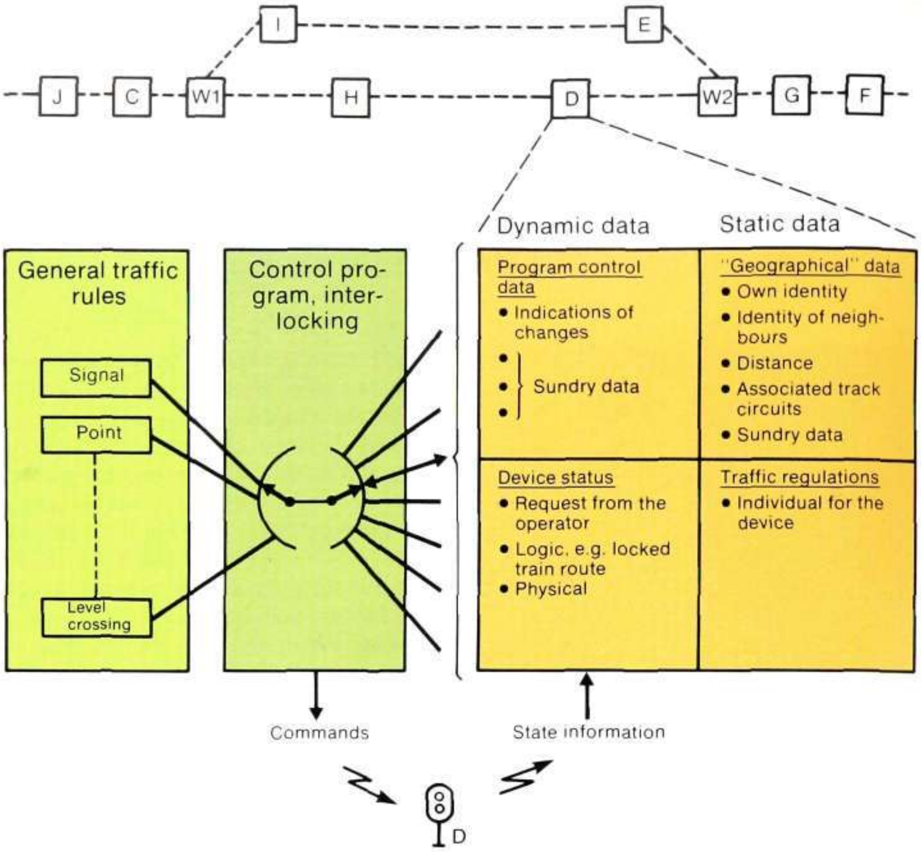


Fig. 9
An equation that describes a sub-condition for a device

Fig. 10
The basic principle of the processing of the data concerning an object block



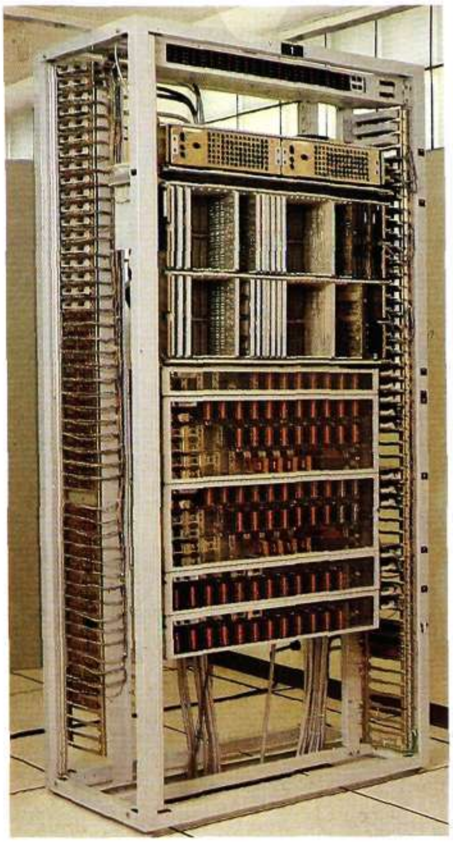


Fig. 11
Transmission terminal and interfacing relay units in a concentrator

10. The processing, including the exchange of messages with neighbouring blocks, continues until the equations have been satisfied and have resulted in

- a change of state for the block in question
- a change of state for the geographical neighbours
- the necessary commands to the device associated with the block
- information to the control system.

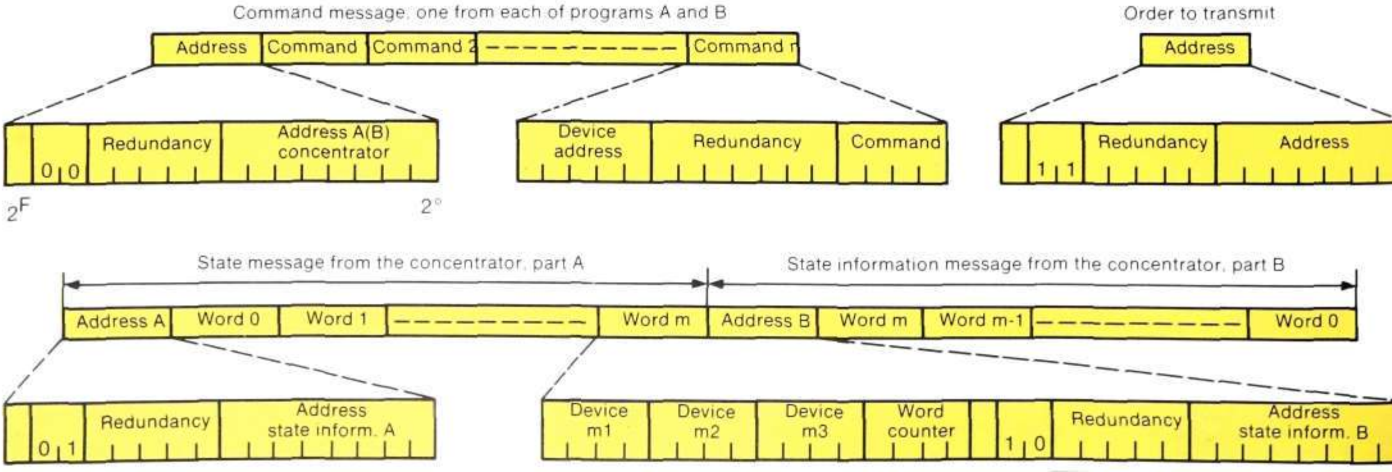
Transmission network

Concentrators are placed in the track area near groups of devices. Each concentrator contains interfacing equipment for the various devices and a transmission terminal, fig. 11. The system is dimensioned so that each terminal can serve 24 track circuits and 31 other devices. The system can address 64 terminals. However, the cycle time, one second, limits the number of devices that can be served to less than the total addressing capacity. Two important parameters in this connection are the interdependence of the devices and the number of simultaneous train movements in the track area served.

The exchange of messages between the interlocking computer and the concentrators is serial in half duplex form over two-wire circuits. The transmission rate is 4,800 bit/s. Two concentrators can be connected to each two-wire circuit. The transmission terminals can be reached from the computer via two alternative routes.

The exchange of messages must meet the fail-safe requirement. Each message therefore contains a number of check bits in addition to the actual information, which ensure that distorted messages cannot be misinterpreted and cause danger. Fig. 12 shows the struc-

Fig. 12
The format of telegrams between the interlocking computer and the concentrators



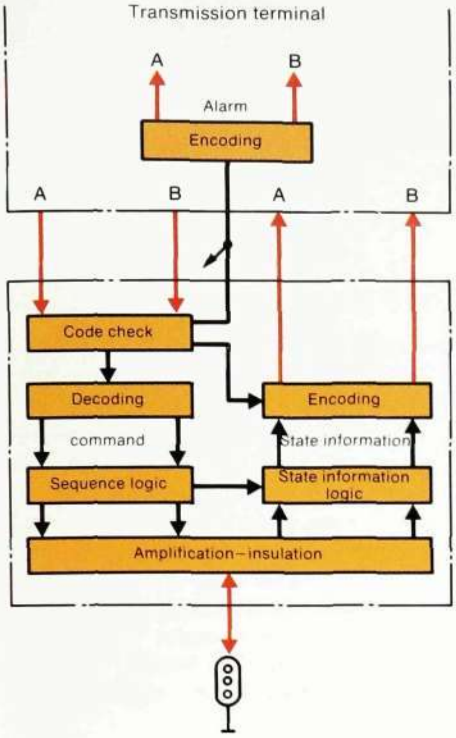


Fig. 13
Block diagram of the interfacing circuits for a trackside device

ture of the messages to and from the interlocking computer.

Trackside interfacing equipment

The equipment for interfacing towards the trackside devices is realized in conventional relay technology. It also includes relays for the decoding and checking of orders from the interlocking system. In addition it contains equipment for encoding the information about device states that has to be sent back to the interlocking system, fig. 13.

For example, for a point the following information is exchanged between the interlocking system and the interfacing equipment:

Commands
- release the locking of the point
- lock the point
- set the point to the reverse position
- set the point to the normal position
- release the point for local operation
- resume control of the point.

State information
- switching is taking place, or the position is not under control for some other reason
- the point is locked in the reverse position
- the point is locked in the normal position
- the point is released for local operation.

Fail-safe function

The use of computers in equipment with fail-safe function requires a system design that can never set the controlled devices in dangerous positions, even if faults occur in the hardware or the software. Thus the data processing that leads to such commands as "clear" for signals is always carried out in two separate program sequences, and the results must be compared outside the computer before the command can be executed, fig. 14.

The two program sequences have been designed by two separate programming teams and have both undergone careful examination and testing. The program sequences with the assocciated data are stored in different places in the computer memory, so that any hardware faults will also be discovered.

One prerequisite for the system is that the data to be processed are not too old. The stored information in the computer concerning the state of the different devices etc. is therefore updated every program cycle. Furthermore the data are labelled with the time, so that their age can be checked.

The mathematical description of the safety conditions, which forms the basis for the whole system, has been examined in detail by signal and traffic experts and has also been tested in a simulator. There is only one version of the description, but it is stored in the memory area of each of the two progam sequences, and will therefore be used in two different ways.

Individual data, which describe the various devices and their neighbours in each installation, also occur in only one version, but are also stored in both program areas.

The system contains further functions to ensure fail-safe operation. This problem has been discussed fairly comprehensively in a previous article[2].

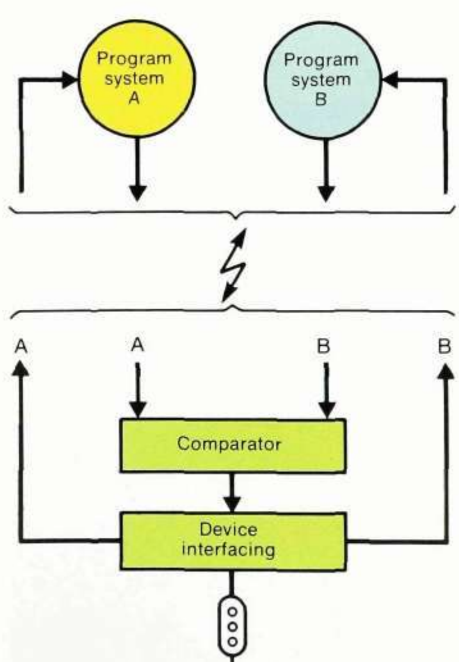


Fig. 14
Duplicated processing of commands to ensure fail-safe function

Fig. 15
The control office for Malmö railway yard area

Project planning system

A project planning system is used to prepare installation documents and the individual data for the control computers. An off line computer is used for the project planning system. The input data for this system are specified on standardized forms by the customer's project planners. The input data consist mainly of information concerning the structure of the track network and the individual characteristics of the yard devices.

The system provides
- data files for the control computers
- information for the installation of concentrators, cabinets, cables etc.
- materiel lists.

The project planning system is also used to plan extensions, handle version numbering etc. The data concerning each installation are stored in a data base.

Installations

Interlocking systems of the type described above are in operation in Gothenburg and Malmö yard areas.

Trial operation started in a small part of the Gothenburg yard area in May 1978. The results were satisfactory, and after minor modifications to the program system the installation was extended in November 1979 to include the central parts of the yard area.

The Gothenburg yard area is extensive and includes a large number of passenger stations as well as goods, harbour and industrial yards. Before the installtion of the new system the five passenger stations had individual signal boxes. These were worn and the operation was very personnel-demanding. The goods yards, and the tracks between them, lacked adequate safety arrangements, which meant that a large staff was required for the traffic handling and that the traffic capacity was low.

With the new system the traffic control and the safety interlocking have been centralized to one place, fig. 4. The trackside devices are successively being connected into the system. At present over 600 devices are under control, including 115 points, 216 signals and 203 track circuits. The central equipment communicates with the devices via 15 concentrators. When fully extended the installation will comprise about 1,200 devices.

The Malmö installation will comprise three passenger stations, two of which were completed in February 1981 and which contain about 330 trackside devices, including 40 points, 145 signals and 110 track circuits. The devices are connected to the central equipment via nine concentrators.

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A Rectifier for Large Plants

Leif Hansson and Renzo Santi

LM Ericsson are now introducing a new thyristor rectifier, BMT 343, for 48 V and 400 A. It forms part of a new power supply system, BZD 412, for large telecommunication plants. The authors describe how the rectifier functions in that system, its electrical and mechanical design, its control arrangements, its protection and alarm circuits and its installation, operation and maintenance features.

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LM Ericsson's previous power supply system, BZD 101, was replaced for small plants by system BZD 112 in 1978. The product range is now also being updated for large plants by the introduction of system BZD 412. An important part of this new system is the thyristor rectifier, BMT 343, for 48 V and 400 A.

BMT 343, fig. 1, is intended primarily for feeding large electronic exchange systems for telephony, telex or data, such as the LM Ericsson systems AXE 10, AXB 20 and AXB 30.

The new rectifier

- meets the demands that are made on power supply units for electronic equipment as regards ability to withstand transients on the a.c. side and low transient and interference levels on the d.c. side
- is equipped with protective devices, which prevent damage or operational disturbances in the equipment which it supplies
- is suitable for connection to low quality mains, e.g. mains with large variations in voltage and frequency, or with frequent interruptions, or from low power high-impedance mains, e.g. local standby power plants
- contains few units, which makes for simple installation, testing and putting into operation
- has high reliability, is easy to handle and requires little maintenance. It can be remotely controlled as regards switching on and off, changing the voltage for battery charging etc. Alarms are automatically forwarded to central equipment. These features make the rectifier very suitable for unmanned exchanges
- is designed to ensure high personnel safety. Live parts have been made so inaccessible that accidental contact is impossible
- is dimensioned for natural cooling.

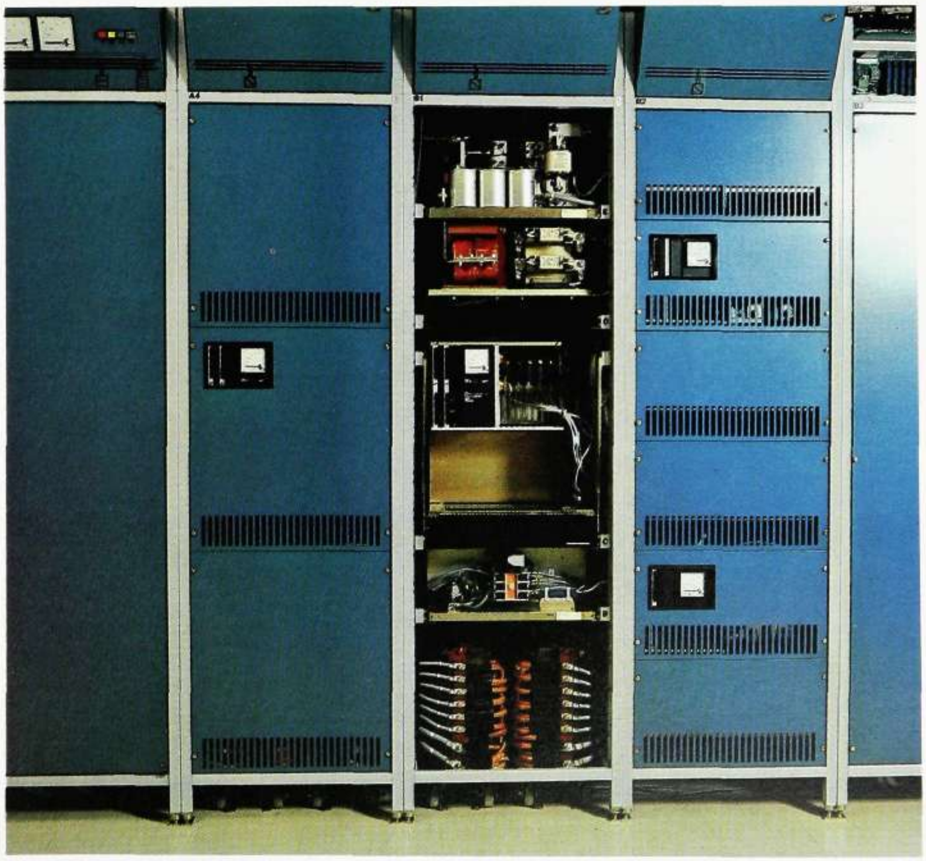

Fig. 1
Power supply system BZD 412.
The picture shows, from the left, distribution rack BMG 651, a rectifier BMT 343 with front cover, a rectifier without the front cover and two 400 A converters, BMR 273. Each rack has the dimensions 600×600×2200 mm


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Function in the system

The rectifier, BMT 343, can be used in different power supply systems containing batteries, fig. 2. During operation the battery is float-charged in the conventional way. The rectifier voltage is kept so high that the self-discharge of the battery is compensated.

After a heavy battery discharge, for example after a mains failure, the rectifier output voltage is raised to the recharging level. When the battery is fully recharged, the voltage is decreased to the float level. The state of the battery is monitored continuously by automatic charging equipment, previously described in Ericsson Review[2].

Several rectifiers can be connected in parallel and the current load is then shared equally between them. Step-connection equipment can also be used, which connects and disconnects rectifiers according to the load. This step-connection equipment is only provided where the current consumption varies considerably.

Special Master Voltage Control (MVC) equipment is used in very large systems if the power supply is sectioned. MVC is connected to the rectifier group in each section and provides them with correction signals, so that the different parts of the powered telecommunications plant receive exactly the same voltage from each rectifier group. The rectifier design also allows for control from a centralized microcomputer supervision system.

Technical description

The rectifier consists of the following units:
- d.c. controlled contactor for connection to the a.c. mains
- two transformers for transforming down to a twelve-phase secondary voltage
- thyristors with control circuits for the rectifying function
- interphase transformers for connecting together the neutral points in the star windings of the secondary sides
- a filter for smoothing the d.c. voltage.

The rectifier also contains devices for operation and alarm, mounted on the front, and circuits for receiving and executing remote control commands. There are also internal protective devices which disconnect the rectifier in the case of overvoltage and then automatically start it up again. In addition the rectifier contains phase failure protection and electronic fuse alarms.

Rectifier circuit

The three primary windings are star-connected in one transformer and delta-connected in the other, fig. 3. The secondary windings of each transformer are connected as two three-phase stars with 180° phase shift between them. In this way each transformer gives six phases with 60° shift relative to each other. The different connections of the respective primary windings to the mains mean that the two six-phase stars have a phase shift of 30° and thus the overall result is a twelve-phase star with 30° between the phases.

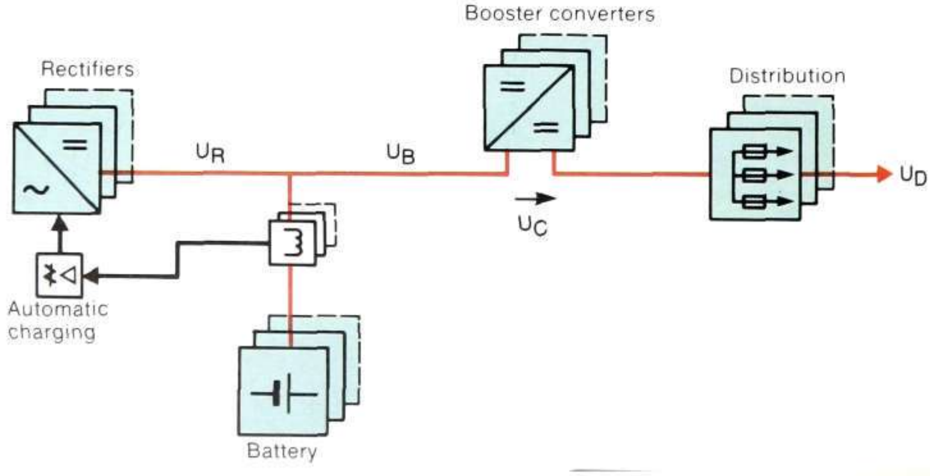


Fig. 2
Power supply system BZD 412 with thyristor rectifiers BMT 343 and high-frequency booster converters.
The block diagram shows the position of the various units in the system

On the secondary side the neutral points of the two stars in each transformer are connected to an interphase transformer. The centre points of the two interphase transformers are then connected to a third interphase transformer, the centre point of which constitutes the negative pole of the rectifier.

The interphase transformers maintain the voltage differences that occur between the neutral points of the stars and constrain the current to divide equally between the two halves of the windings. This means that each three-phase star will contribute a quarter of the total current. There is no d.c. magnetization of the interphase transformers since the currents in their two winding halves are equal and oppositely directed.

The rectifier consists of twelve thyristors, one for each phase. Each thyristor normally conducts for a third of the mains cycle, i.e. the conducting angle is 120°. This means that four thyristors, one in each three-phase star, conduct simultaneously. The peak current through each thyristor is thus a quarter of the output current.

The output voltage from the inter-connected thyristors is a d.c. voltage with a ripple frequency that is twelve times the mains frequency, namely 600 Hz. This high ripple frequency means that the smoothing filter that follows can be made with small mechanical dimensions. The filter is a T-type low pass filter with chokes in the series branches and two electrolytic capacitor banks with fuses in the shunt branch, an LCL filter. The a.c. voltage component is attenuated in two steps in the filter, first by the choke nearest the interphase transformer and the capacitor banks, then by the second choke and the battery. The chokes limit the ripple current, and the capacitor and battery shunt the current, so that the resultant noise voltage at the output across the battery is very low.

A fuse which also functions as an isolator is included in the rectifier output. When the rectifier is to be connected to the battery, the filter capacitors must be charged before the fuse is inserted. This charging is carried out automatically by a special circuit. An LED indicates when the charging is completed. Slow charging is necessary, otherwise the large capacitor banks would experience a current surge that could shorten their life. Furthermore the filter capacitor fuses would not withstand a rapid charging.

On the d.c. side the rectifier satisfies the radio interference requirements of CISPR Recommendation No. 43. On the mains side, radio interference suppression filters are not standard but can be included in the rectifier as optional extras.

Control circuits

Voltage-control of the rectifier is effected by changing the trigger phase angle of the thyristors so as to keep the output voltage constant. When the output current exceeds the rated value, the

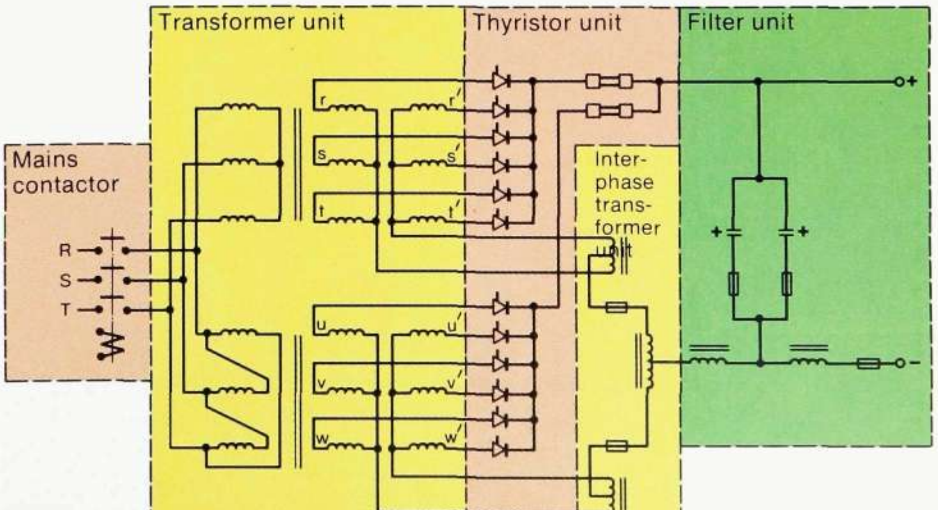


Fig. 3
The rectifier circuit.
Three-phase mains voltage is fed to the two transformers via the mains contactor. The thyristors in the thyristor unit rectify and control the voltage, which is then smoothed in the filter unit. The thyristors receive trigger pulses at the correct instants so that the output voltage is kept constant

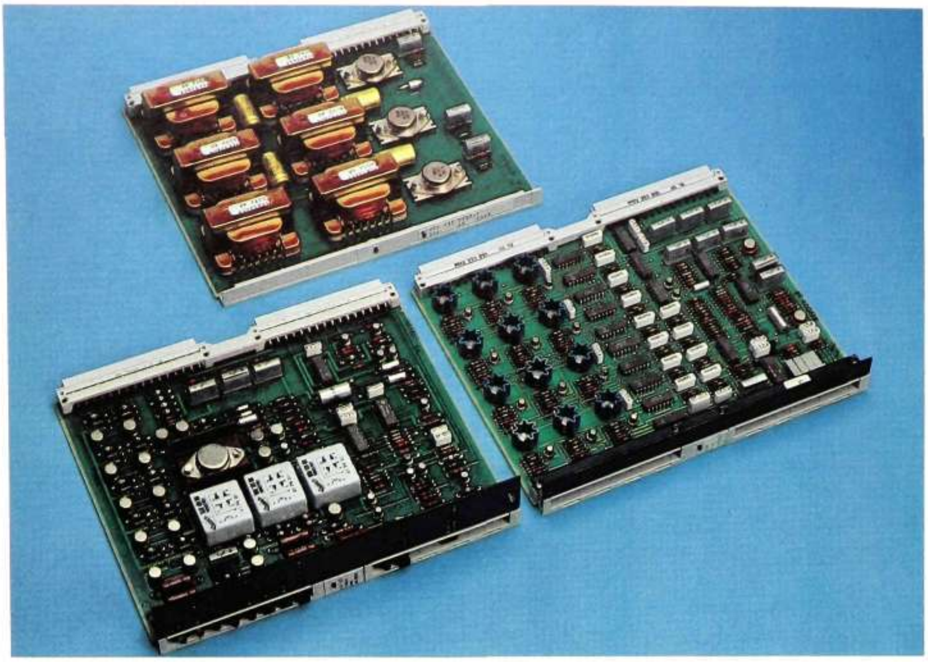
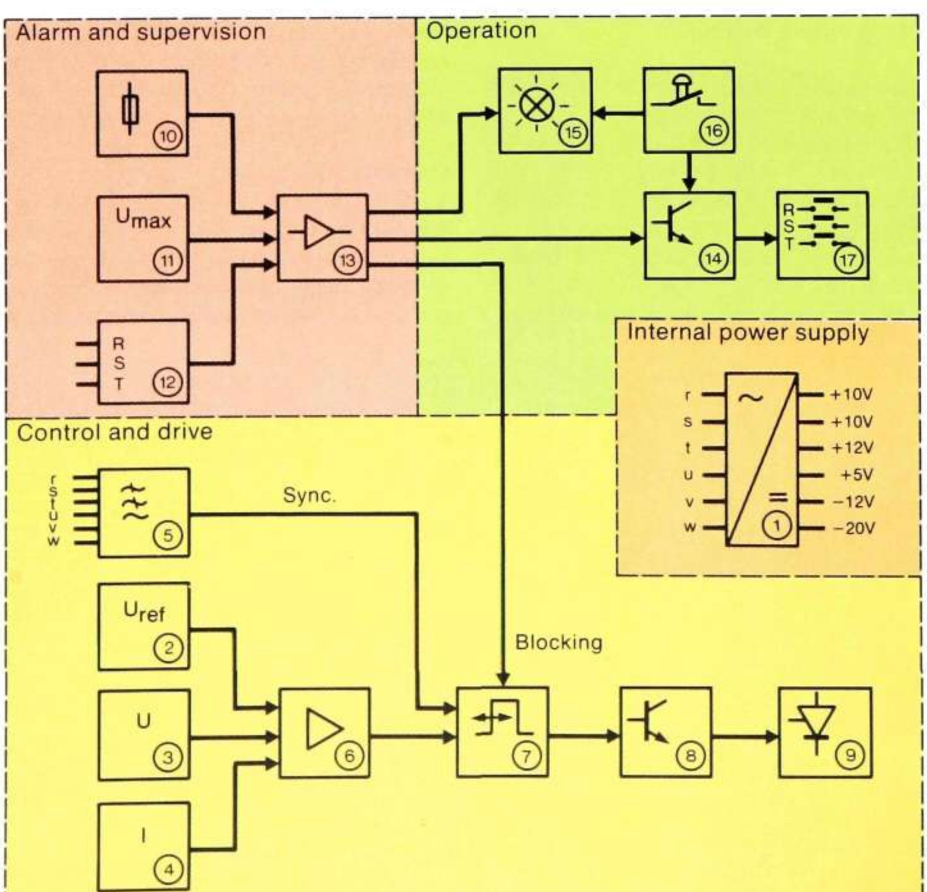


Fig. 5
The printed board assemblies with the control circuits. At the top the printed board assembly for the internal power supply, below those for all control circuits

Fig. 4, below
Block diagram of the control circuitry, which is divided into four blocks. The control and drive circuits provide the thyristors with trigger pulses phased so that the output voltage and current are kept constant. The alarm and supervision circuitry consists of drive circuits for the mains contactor and push-button switches for external control of the rectifier.
The internal power supply provides the feeding voltages for the control circuitry

1 Internal power supply
2 Reference voltage
3 Voltage sensing
4 Current sensing
5 Integrator
6 Comparator
7 Pulse generation
8 Thyristor drive
9 Thyristors
10 Fuse sensing
11 Overvoltage sensing
12 Phase sensing
13 Supervision and alarm
14 Contactor drive
15 Indication
16 Operation
17 Mains contactor



constant voltage control is changed into constant current control in order to avoid overloading the rectifier, fig. 4.

The control circuits, with their alarm and supervision circuits, are mounted on two printed boards, fig. 5. A third printed board holds transformers for synchronizing, trigger pulse feeding and circuits for the internal power supply.

The interal power supply is stabilized by voltage regulators. The reference voltage consists of the voltage across a zener diode with compensated temperature dependence. A resistive voltage divider is used to sense the voltage and a shunt to sense the current. The difference between the actual and desired d.c. voltage values is fed to the control amplifier.

The output signal from the control amplifier, together with the synchronization voltages, are fed to comparators, which give twelve trigger pulses per period with a phase shift of 30°. The phase position of the control pulses relative that of the a.c. voltage is affected by the output signal from the control amplifier, so that constant voltage or constant current control is obtained. There is an amplifier stage for each trigger pulse to ensure large control pulses with a rectangular shape and steep flank, which is necessary for triggering large thyristors. The control current is constant and independent of the thyristor characteristics.

The current control circuits in all rectifiers that are connected in parallel are connected via special amplifiers, one in each rectifier, in such a way that they share the total direct current equally.

When the rectifier is started, the current and voltage are increased slowly (walk-in start). This method avoids voltage transients towards the load and current shocks towards the battery.

The rectifier output voltage can be adjusted to between 44 and 61 V using potentiometers. The upper limit for the rectifier output current is normally 400 A. With manually controlled rapid charging of the battery, this current can be limited to other values below 400 A by means of another potentiometer.

The main features of the control system are:
- correct function even with large mains waveform distortion
- even current sharing by the 12 thyristors in the rectifier
- the regulation level is not sensitive to variations in temperature
- even load sharing between rectifiers that work in parallel.

Protection and alarm circuits

The rectifier is protected against excess current by the current limiting of the control system and by the fuse on the output, which will blow for the current surge that occurs with a short circuit.

Fig. 7
A complete rectifier.
The units are installed and the cabling is done from the front

Further short-circuit protection is provided by two cartridge fuses, which protect the transformers and current measuring shunts against short circuits in the thyristor unit.

The rectifier has a selective overvoltage protection combined with automatic restart, fig. 6. If the output voltage exceeds a predetermined level, the thyristor trigger pulses will be momentarily blocked, thereby cutting off the power output from the rectifier. The rectifier is then restarted in the walk-in mode. If the overvoltage recurs and at the same time the current from the rectifier exceeds a certain value, the rectifier will be completely switched off via the mains contactor and an alarm given. Current sensing is carried out in order to achieve selectivity. The rectifier that causes the overvoltage will be delivering all of the current to the load. This means that the rectifiers which have overvoltage on their output but do not deliver current have not caused the overvoltage. These rectifiers therefore do not have to be disconnected.

Automatic restart effectively prevents spurious shut-downs due to voltage transients of external origin, for example caused by a fuse blowing.

If an interruption occurs in one phase, the rectifier would work as a single-phase rectifier with a risk of overloading the thyristors. Moreover the noise voltage at the rectifier output would increase. This is prevented by a phase failure protection, which blocks the thyristor trigger pulses and gives an alarm if there is an interruption in any of the phases. Restart is carried out automatically when the fault has been cleared.

All fuses in the rectifier are supervised by an electronic circuit, which disconnects the mains contactor and gives an alarm for a blown fuse.

Operation
The rectifier can be operated directly or remotely.

Direct operation is by means of pushbotton switches placed on the front of the rectifier. With direct operation it is possible to
- connect and disconnect the rectifier
- increase the output voltage for battery charging
- reset alarms
- test the overvoltage protection.

Remote operation is carried out over a cable plugged into the rectifier. WIth remote operation it is possible to
- increase the rectifier output voltage for battery charging
- control the rectifier output voltage so that it follows an external voltage (MVC)
- block the thyristor trigger pulses and thus obtain momentary disconnection
- operate the rectifier mains contactor, for example with control from a step connection device.

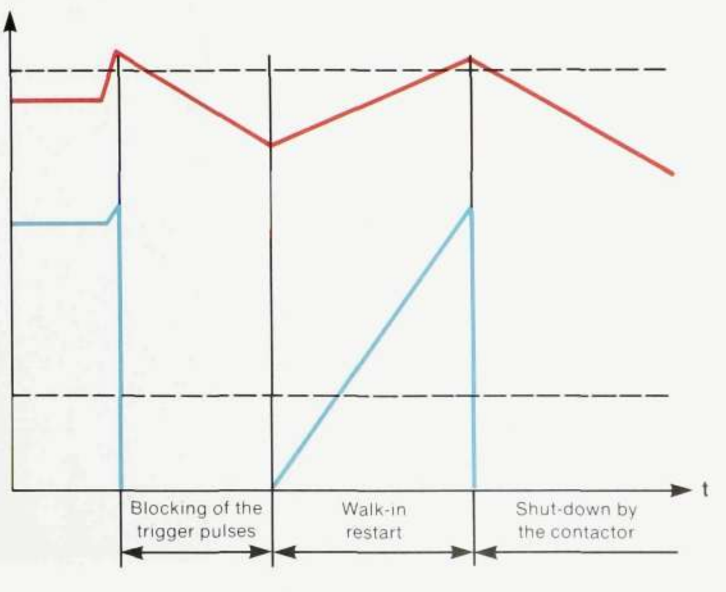


Fig. 6
The operation of the overvoltage protection.
If the rectifier output voltage becomes too high, the rectifier is first blocked momentarily, then restarted. If the overvoltage recurs, and at the same time the current exceeds a certain preset value, the rectifier is completely disconnected. However, no disconnection takes place if the rectifier operates normally after the restart. Thus transients cannot cause disconnection

Fig. 8
The transformers are equipped with wheels, which simplifies their handling during installation. The front cross-member of the rack is removed when the transformers are installed. Clear labelling ensures correct connection to the secondary side. The fixed cables on the primary side are connected direct to the mains contactor

Mechanical construction

The rectifier is mounted in a rack, BAF 201, with dimensions 600×600×2200 mm, fig. 7. It is covered with three front plates. The six units in the rectifier rack are mounted in the following order (from the bottom): transformers, mains contactor, thyristor unit, interphase transformers and filter unit. The rack sides are equipped with guide rails, so that the units, with the exception of the transformers, can be slid in and out of the rack. The units are cooled in accordance with the parallel cooling principle, which means that there are several air inlets in the front panels.

The transformers are placed direct on the floor, fig. 8. They are mounted on wheels, which simplifies installation and reduces acoustic noise (hum) during operation. Fixed cables on the primary side of each transformer are connected to the mains contactor. The secondary side has a terminal strip with screws to fix cable lugs.

The thyristor unit contains four heat sinks on which the twelve thyristors are mounted, fig. 9. At the front of the unit a cassette is mounted which holds the three printed board assemblies for the control electronics, an ammeter and all secondary circuitry for the plug in connection of the other units.

The interphase transformer unit contains the three transformers and two fuses. The filter unit contains the two chokes, the electrolytic capacitors, the 500 A output fuse and the capacitor charging circuit.

Installation, operation and maintenance

Simple and quick installation was one of the main aims when designing the rectifier. It is delivered from the factory in fully tested, easy-to-handle units. The rectifier is connected to the system busbars by means of bar contacts, fig. 10.

The installation only requires ordinary hand tools, and the installation testing is reduced to a visual inspection to detect any transport damage, followed by a functional test.

The rectifier works wholly automatically and all operational changes take place without any manual intervention.

Fig. 9, left
The thyristor unit, the control circuitry and cable connections to the other units can easily be pulled out from the rack. The components are then accessible for measurements and service

Fig. 10, right
This side view of the rectifier shows the vertical positive and negative busbars. These bars are connected to the horizontal system busbars at the top of the rack by means of bar contacts

Technical data

Input data		
Mains voltage, 3-phase, standard	V	380, 220
Permissible voltage variation	%	−15 to +10
Do. with 2 % regulation accuracy	%	−20 to +20
Permissible frequency variation	Hz	47 to 63
Permissible mains distortion	%	30
Primary current with nominal input voltage and maximum output current	A	41
Power factor with nominal input voltage and 75 % output current	cos φ	0.88
Effficiency with nominal input voltage and 60–100 % output current	%	≥92
Radio interference on the mains side (relative 1 μV) measured in accordance with CISPR Recommendation No. 43, using additional radio interference suppression filters		
0.15–0.50 MHz	dB	<66
0..50–30 MHz	dB	<60
Output data		
In parallel operation with a battery of	Ah	1600
System voltage	V	48
Output current	A	400
Static regulation over the whole permissible variation range for mains voltage, mains frequency and output current	mV	100
Dynamic regulation with step changes of the output current from 50 % to 75 % and back to 50 %		
response time	ms	35
voltage deviation	V	1
Noise voltage		
psophometric	mV	<1
peak value	mV	<6
Radio interference on the d.c. side (relative 1 μV) measured in accordance with CISPR Recommendation No. 43		
0.15–0.50 MHz	dB	<80
0.50–30 MHz	dB	<74
Adjustable levels		
Voltage		
normal float level	V	44 to 53
charging level	V	55 to 56
rapid charging	V	44 to 61
Current limiting	A	0 to 400
General data		
Ambient temperature		
operation	°C	0 to +45
non-destructive	°C	−10 to +55
Reliability, MTBF	years	17
Acoustic noise level measured at a distance of 1 m	dBA	<60
Dimensions		
width	mm	600
depth	mm	600
height	mm	2200
Weight	kg	680

The valuse given above are normal values and are subject to alteration.

In order to reduce the risk to personnel working on the rectifier, all parts at mains voltage have been shielded. The rectifier can easily be taken out of operation for work on the units without the staff having to come close to any live parts.

Reliability

Rectifiers for telecommunications plants must have high reliability. This has been achieved in the design of BMT 343 by

- choosing only components of high quality and subjecting them to extensive testing before acceptance
- applying dimensioning rules with wide safety margins,

when engineering the system, by

- always ensuring that standby rectifiers are available
- designing each rectifier as an independent unit, i.e. ensuring that its function does not depend on a central control unit and that selective disconnection can take place autonomously.

The MTBF (Mean Time Between Failures) is calculated to be 17 years. The life of the rectifier is estimated to be 40 years under normal operating conditions.

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Central Expert Support for Maintenance and Installation

Lars Estberger

LM Ericsson's stored program controlled telephone exchanges are equipped with a fault diagnosis system which gives detailed information on how to clear any faults that may occur in the exchange hardware. The fault clearing is usually simple and a matter of routine. However, expert assistance may be necessary for rare faults of a complicated nature. Such assistance is normally organized centrally within the country, but during an introductory stage it may be desirable to be able to consult an external group of specialists. In this article a description is given of the expert support provided by LM Ericsson in Stockholm, Sweden, in the form of guidance for complicated fault tracing. The expert support can also include regular inspections of telephone exchanges to determine the condition of the equipment and to locate any faults. Assistance can also be provided for processor installation and extensions.

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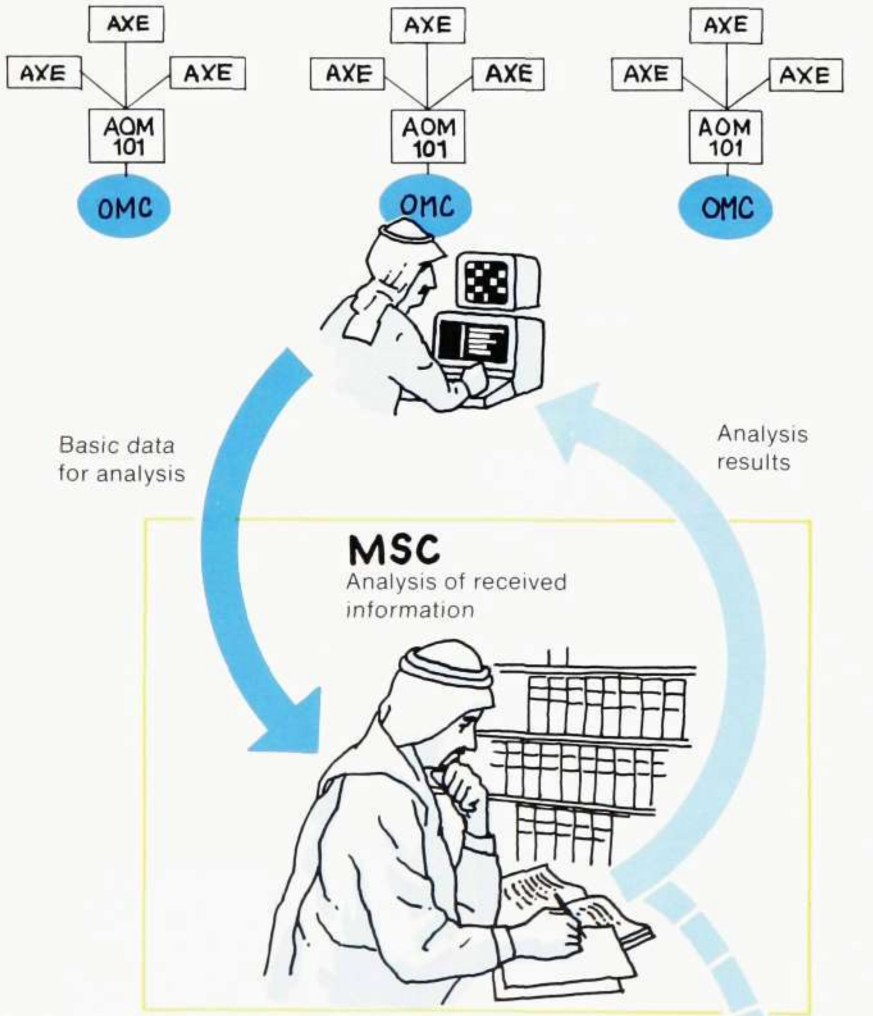

Fig. 1
An expert located at the MSC (Maintenance Support Centre). The illustration indicates the working philosophy. As necessary, the expert goes to the OMC or the exchange to give the appropriate assistance. Fig. 9 shows alternative means of communication.

AOM 101 Operation and maintenance system for the network
OMC Operation and maintenance centre
MSC Local maintenance support centre
MIPSC Central maintenance support from LM Ericsson in Stockholm, Sweden

LM Ericsson's telephone exchange systems have long been well-known for the small amount of effort needed to maintain the equipment. High reliability and comprehensive supervision equipment with good coverage permit controlled corrective maintenance[1]. The introduction of stored program control (SPC) has led to further improvement of the maintenance functions. LM Ericsson's SPC exchanges have a very extensive maintenance system, with automatic analysis and reporting of equipment behaviour. The maintenance functions in system AXE 10 and the centralization of the maintenance functions in a telephone network have been described previously[2,3].

This centralization has reduced the maintenance work further. For example, a normal telephone network with AXE 10 exchanges requires only about 0.05 hours per subscriber line and year for the maintenance of the exchange equipment. At the same time the maintenance work has changed, and this necessitates some changes in the way the work is organized. Experience has shown that it is suitable to use a hierarchic organization which distributes the tasks to different personnel groups with different training.

SPC technology simplifies the ordinary maintenance work

The increasing demands for reliability, flexibility and services have led to increasingly advanced technology being applied in the exchange equipment.

Before the introduction of SPC the exchange control functions were incorporated in the mechanical construction or in electrical circuitry. With the aid of the corresponding diagrams an experienced technician could follow all individual stages in the operation of the telephone system and this enabled him to carry out his job without knowing the system in all its details. Traditionally all technical maintenance work in telephone exchanges has therefore been carried out by "all-round" technicians with an ability to improvise, and thus only the minimum of external assistance has been required.

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In SPC exchanges the control functions are primarily realized in software. The powerful processors run extensive diagnostic programs. Normally only a limited number of faults occur in such exchanges, and the majority of these are automatically identified and reported to the maintenance staff. This has simplified the maintenance work considerably, and it is comparatively easy to train maintenance staff for these routine tasks. At same time, the possibility to improvise the maintenance work has largely disappeared, and hence it is suitable to divide the tasks among personnel groups with different training.

Team of experts within the country

The main part of the maintenance work in a network with AXE 10 exchanges can be centralized to one or more operation and maintenance centres, OMC. The OMC staff can localize most faults. However, if a complicated fault should occur, it may be necessary for this staff to have access to experts with a thorough knowledge of both the hardware and the software. Seldom occurring faults, for instance in the fixed exchange cabling, could be very difficult to localize. The expert assistance should therefore be concentrated to a common support centre for an administrative area such as an entire country. Such a maintenance support centre (MSC) is equipped with all necessary documentation and the special instruments and test equipment required for complex fault localization.

Having a centralized team of experts makes it easier for the specialists to keep their system knowledge up to date, since it gives them the opportunity of more regular fault localization. This is very important, since there are otherwise few opportunities for practical training in complex fault localization, either during the installation or the operation of SPC exchanges. During the short installation time the functions of the equipment are tested mainly by means of special automatic test programs and this results in there being few opportunities for normal fault tracing. Moreover the equipment is delivered from the factory so thoroughly tested that the processors usually work perfectly from the beginning and no fault tracing is necessary.

Fig. 2
LM Ericsson have established a Maintenance, Installation and Production Support Centre, MIPSC, in Stockholm. The picture shows an AXE 10 exchange in MIPSC. It is employed for detailed analysis of complex problems

Central expert support from LM Ericsson in Stockholm

Scope and organization

A previous article has described several systems which have been developed to aid the work on LM Ericsson's telephone exchange systems[4]. These systems have now been supplemented by the Maintenance, Installation and Product Support Centre, MIPSC, which LM Ericsson have established in Stockholm, Sweden. The centre, which is also used for normal production, was set up in connection with the introduction of SPC technology. MIPSC consists of five separate units, which are responsible for

1. AXE and AXB exchanges
2. ARE exchanges and subsystems, such as toll ticketing, operator and I/O systems
3. AKE exchanges
4. PABX systems with SPC
5. Test equipment for SPC exchanges.

The units, figs. 2, 3, 6, 7, 8, 11 and 12, are organized to provide assistance in maintenance and installation work at short notice. The organization is flexible enough to ensure that the appropriate

```
PW       MIPSC6-02/1    R3A*0915   TW-4    TIME 791214 1017
ALARM A2/APT
SEIZURE QUALITY SUPERVISION
DEV             STATE  BLS
BJ-128          BLOC   ABL
END
```

The exchange gives an *alarm, type A2*, and indicates a *quality fault for BJ number 128*.

Repair

```
PW       MIPSC6-02/1    R3A*0915   TW-4    TIME 791214 1018
SEQAR:DEV=BJ-128!
EXECUTED
```

The printed board has been exchanged and *the alarm is acknowledged*.

```
PW       MIPSC6-02/1    R3A*0915   TW-4    TIME 791214 1018
ALARM CEASING A2/APT
SEIZURE QUALITY SUPERVISION
DEV             STATE  BLS
BJ-128          BUSY
END
```

The exchange confirms that the *alarm condition has ceased* and *BJ has been put into operation*.

Fig. 4
When a fault occurs, the AXE 10 exchange normally indicates the faulty unit. The quality supervision gives an alarm and carries out blocking if the number of unsuccessful connection attempts via a device exceeds a preset percentage

```
PW       MIPSC6-02/1    R3A*0915   TW-4    TIME 791214 1053
ALARM A2/APZ

RP FAULT

RP   FCODE  INF1    INF2    INF3
 68  H'4    H'4     H'54    H'23
 68  H'11   H'0     H'0     H'0

MAG       CARD        WEIGHT
P-RP- 68                1
RP- 68    EMBU          2
RP- 68    OBU           5
RP- 68    IBU           5

RP- 68    PSH           3
RP- 68    DSH           3
RP- 68    MIG           3
RP- 68    MPSU          2
RP- 68    PS-4& 5      10

END
```

The exchange gives an *A2 alarm* and indicates that *RP (Regional Processor) number 68* has a check sum fault on *program page 4*. (The fault code is explained in the exchange manual.) *PROM boards 4 and 5* are listed as having a high probability of being faulty.

Repair

```
EX-A     MIPSC6-02/1    R3A*0915   TW-4    TIME 791214 1056
DIRPI:RP=68!
RP CHECK PASSED
END
```

The printed board assemblies have been changed and a *test of RP no. 68* is ordered. The response confirms that RP is working properly.

```
EX-A     MIPSC6-02/1    R3A*0915   TW-4    TIME 791214 1056
BLRPE:RP=68!
BLRPE:RP=68!
;
EXECUTED
```

Deblocking of RP is ordered. This command has been classified as an important one and is therefore repeated by the processor. After acceptance the order is executed.

```
PW       MIPSC6-02/1    R3A*0915   TW-4    TIME 791214 1057
ALARM CEASING A2/APZ

RP FAULT

RP   FCODE  INF1    INF2    INF3
 68  H'4    H'4     H'54    H'23

END
```

The exchange informs that the *alarm condition for RP no. 68 has ceased*.

Fig. 5
If there are possible alternative fault causes, the fault diagnosis system in the AXE 10 exchange will list all printed board assemblies involved, together with the fault probability for each one

type of assistance can be given on every occasion. This assistance can vary form telephone consultation to active aid on site.

Since the technicians in OMC or the exchanges will normally contact their national MSC for assistance with complex fault clearing, the MIPSC staff in Stockholm will be approached only if the MSC staff need assistance. Contact with MIPSC can therefore be considered as an extra safeguard in the case of rare and especially complicated faults.

Access to such expert assistance can be particularly important during an introductory stage, before the maintenace staff have acquired sufficient experience.

The services offered by MIPSC for AXE 10 exchanges are indicated in the following. Firstly, the normal procedure for clearing faults in an AXE 10 exchange is described together with some examples of how the OMC or exchange staff carry out such work.

Typical fault clearance in AXE 10

The maintenance functions in AXE 10 (see the previous article on this subject[2]) cover the various subsystems in the exchange. When a fault occurs, the fault report received is normally so specific about the nature of the fault that the repair work is more routine. In most cases the faulty printed board assembly is indicated directly, fig. 4, and can be replaced by a spare one from the spares store.

Sometimes the caracteristics of the fault are such that there could be more than one possible cause. In such cases a fault printout is obtained that lists the possible faulty printed board assemblies together with the fault probability for each one, fig. 5. The repair work starts by replacing the printed board assembly with the highest fault probability. If the fault remains the next printed board assembly is replaced and so on.

In certain cases the alarm printout information may be insufficient to directly identify the fault, and fault tracing with the aid of built-in test functions must be carried out. The procedure is described in the operation and maintenance man-

Fig. 3
The MIPSC unit dealing with the telex exchange systems, AXB 20

Fig.6
Work on toll ticketing equipment in the MIPSC unit dealing with the ARE systems

ual for the exchange. The fault localization is usually carried out from OMC, as has been described in a previous article[3].

The maintenance functions cover faults in the switching network, and associated devices, faults in memories and power supply equipment and faults in maintenance circuits and switch-over functions. The hardware in the AXE 10 control system is supervised by comparing the output of the duplicated, synchronous working processors. If a comparison fault is detected, a test program is automatically started to identify the faulty processor side. This side is automatically blocked and then the faulty unit is pinpointed and an alarm is given.

Som incidental faults are not reported to the maintenance staff until the same fault has occurred several times. This avoids unnecessary investigation of circuits where the faulty state no longer exists. However, the maintenance staff can at any time request a printout of the stored information concerning such incidental faults.

Fig. 7
Measurements on the processor part of control system ANA 30 in the MIPSC unit dealing with the ARE system

The powerful automatic recovery capabilities of AXE 10 mean that MIPSC need seldom be called upon

The automatic blocking of faulty devices limits the effects of faults and consequently the traffic handling ability is not noticeably impaired by a small number of individual faults. Furthermore, faults in the common sections of the exchange do not normally affect the traffic. This is because such sections are at least duplicated, and the faulty unit is automatically blocked until the repair has been carried out.

Even if an incidental fault in, for example, a processor does not immediately result in a positive identification, the fault diagnosis proceedure continues in a predetermined way. The executive side of the duplicated processor continues the traffic handling and the standby side is stopped. If the fault occurs again within ten minutes, a changeover is carried out and the standby side now takes over the traffic handling and the executive side is stopped. The net result is that automatic blocking of a faulty processor side is achieved.

Whenever there is a processing failure, not involving hardware faults, the system recovers automatically with the aid of a minor restart. In most cases the effects of a software fault are thus eliminated as result of the central processor being cleared of all work in progress. Connections that have already been established are not affected, but the limited number of calls that are in the register stage are disconnected, and the subscribers in question receive a new dialling tone.

If a further processing failure occurs within ten minutes of a minor restart, a major restart is initiated. All variable data are reset and all established connections are released. If this action does not rectify the situation, degeneration of programs or data has probably occurred. Another processing failure within ten minutes therefore automatically initiates reloading of both programs and data from a magnetic tape unit.

Whenever a restart occurs the exchange records details of the sequence of events, and a printout of this information is obtained automatically. Fault localization with the aid of this information requires a thorough knowledge of the system. MSC normally provides the required assistance, but help can also be obtained from MIPSC in Stockholm. The printout gives very detailed information so that the necessary corrective measures can be carried out at an early stage.

Commmunication with MIPSC as and when required

A request for assistance is normally sent to MIPSC via telex, fig. 9. The disturbances should be described in sufficient detail to enable the system expert to analyze the situation. The MIPSC staff can also simulate the fault situation in a model exchange. The result of the analysis and a recommendation for suitable action are then sent back via telex.

In certain cases a technician may need guidance for fault localization in a telephone exchange. It is then possible to telephone MIPSC, where a system expert is available to give advice.

If assistance is required outside normal working hours, the MIPSC staff can be reached via an alarm centre equipped with telex and telephones. Whenever a request for help is received at the alarm centre, the staff on duty will notify an

Fig. 8
Processors of type APZ 130 and APZ 150 in the MIPSC unit dealing with the AKE system

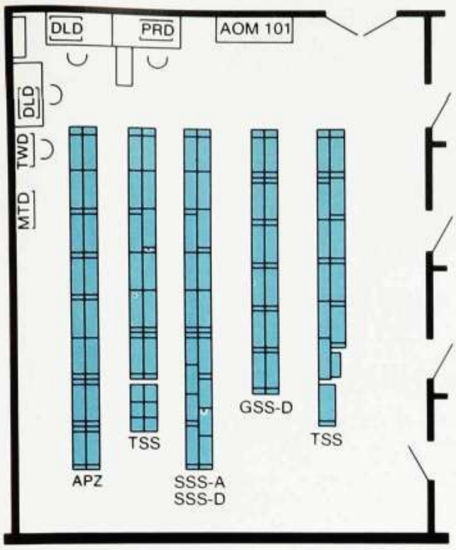

Fig. 10
The AXE 10 model exchange in MIPSC contains sufficient hardware to permit simulation of several exchange variants

APZ	Control subsystem with duplicated synchronous-working central processors
TSS	Trunk and signalling subsystem, adaptable to different markets
SSS-A	Analog subscriber stage
SSS-D	Digital subscriber stage
GSS-D	Digital group selector
AOM 101	Operation and maintenance subsystem
DLD	Digital display unit
PRD	Line printer
TWD	Typewriter
MTD	Magnetic tape unit

MIPSC system expert, who will then make the required contact as quickly as possible.

Certain fault situations require analysis of long printouts. It is extremely important that every single figure is exact when this information is transmitted to MIPSC. Experience has shown that telex is not suitable for this purpose. MIPSC is therefore equipped with telefax, which gives rapid and reliable transmission of written data over a normal telephone circuit. After detailed analysis of the printout the MIPSC staff can recommend suitable action to the exchange staff.

It is possible to send a system expert to an exchange at short notice if it proves impossible to give sufficient assistance from a distance. However, the need of such visits is expected to be very small.

Model exchange for simulating different variants of AXE 10

MIPSC contains a model exchange of type AXE 10, fig. 2. The model exchange contains a fully equipped, duplicated central processor and sufficient switching equipment to simulate several exchange variants, fig. 10. The store capacity is so large that the exchange configuration can be changed by reloading programs. This makes it possible to carry out detailed analysis of complicated faults, which are reported by the installation and maintenance staff in the field.

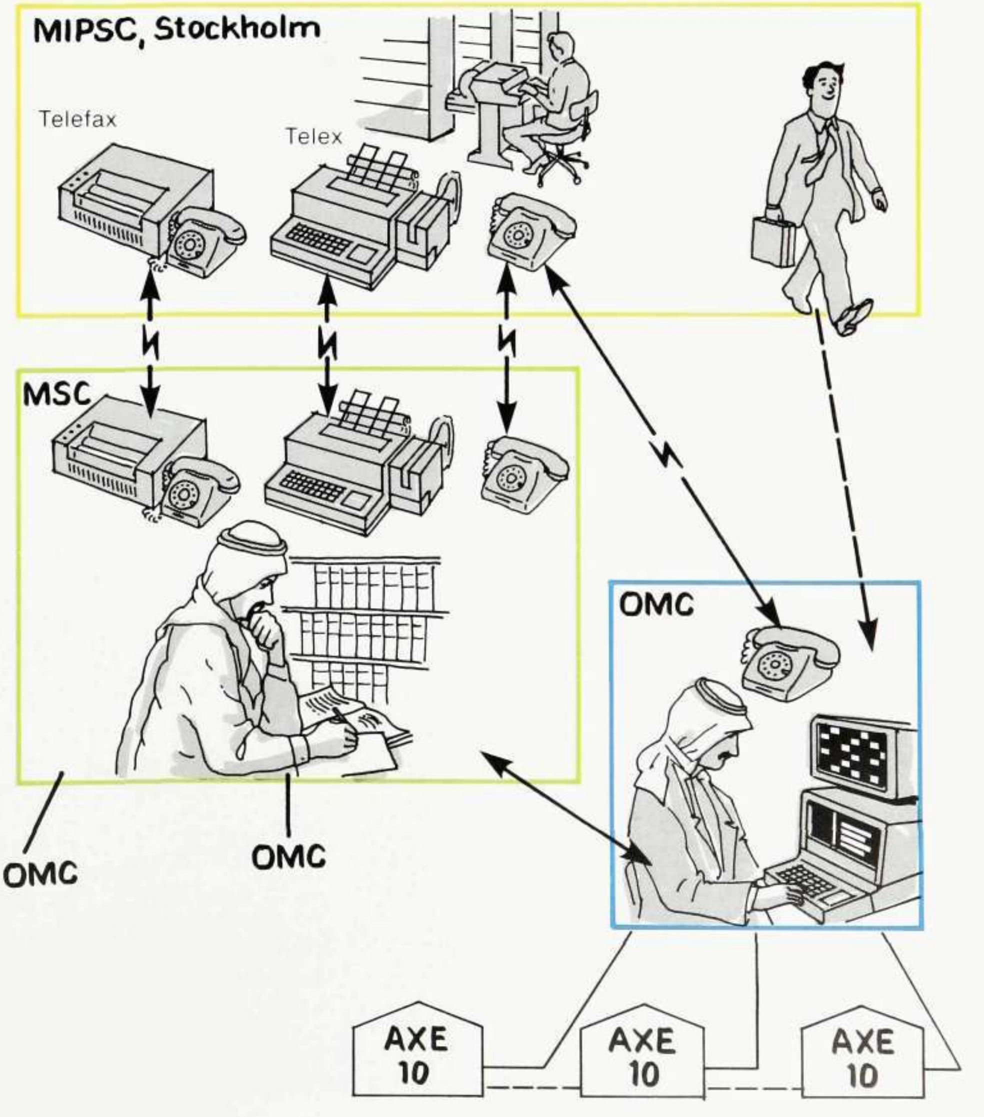

Fig. 9
Communication with MIPSC can take place via telephone, telex, telefax or personal visits

Fig. 11
PABX type ASB 900 installed in the MIPSC unit dealing with stored program controlled PABXs

Special test equipment makes it possible to load the exchange with concentrated traffic, so that problems which only appear in such circumstances can be investigated. The load is then considerably greater than any load that can occur in a telephone exchange. This simulation facility is particularly useful for testing system revisions before they are introduced in exchanges that are already in operation.

Testing of programs and data before installation

Programs and data for an SPC exchange are normally compiled independently of each other and are then tested separately in automatic test equipment. However, it is possible that certain faults remain in newly designed software in spite of such tests. Further testing can be carried out by loading the programs and the exchange data in the MIPSC model exchange, and then checking that the programs are correct. This procedure means that any remaining faults are detected at a sufficiently early stage to permit correction before the software is needed for testing of the exchange on site.

Testing of hardware and software before complicated extensions

Additional hardware has to be installed when an SPC exchange is to be extended and this means that new data, and sometimes new programs, must also be introduced. The various stages in an extension have been described in a previous article[2]. In the case of a complicated extension, or when the staff who are to carry out the extension have limited experience, it may be advantageous to first simulate the extension in the model exchange. The methods used are the same as in the actual extension work, and the staff thus receive on-the-job training. At the same time the software is checked and any faults are cor-

Fig. 12
Calibration of stored program controlled traffic generators in the MIPSC unit dealing with test equipment

rected before the actual extension is carried out. The MIPSC staff can also provide assistance on site if necessary.

Help with processor installation

The MIPSC staff are prepared to help with the starting up of the control system for a new exchange if the local staff lack the necessary experience. The starting-up process takes very little time, since the control system is thoroughly tested at all levels before delivery. The extensive test programs included in the control system are then used to test the telephone system, thereby taking advantage of all the fault detecting facilities provided by the control system[5].

A similar service can be provided when changing program packages in an exchange which is in operation. Such assistance may be considered an extra safeguard, but it may be of value if the exchange staff have not sufficient experience.

Service contract

MIPSC can be used in different ways. A suitable way would be for a telecommunications administration to enter into a service contract, which could comprise all or some of the following services:

- consultation via telephone or telex
- telephone assistance in tracing complicated faults
- regular service visits 1–4 times per year
- visit by an expert if a particularly complicated fault should occur.

Such a contract also promotes the building up of an efficient maintenance organization by providing the administration's staff with continuous information concerning general practices and improvements in maintenance methods. In the long run it will therefore enable the telecommunications administrations to become completely self-sufficient in respect of the installation and maintenance of AXE 10 exchanges.

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ERICARE

Anders Lennström and Curt Sundmalm

LM Ericsson Telematerial AB have developed a telephone system, ERICARE, which provides old-age pensioners and handicapped people who live alone with the means of calling for help in various situations. The system registers alarms from the subscribers, automatically sets up telephone connections to an alarm centre and transmits alarm and identity messages. The system also permits speech communication with the person who has requested help, without the caller having to lift the handset. A message is given via a loudspeaker, and the speech of the person in distress is transmitted by microphones in the flat or house. Alarms can be originated in different ways, for example from small, portable radio signal transmitters. Transmitters and receivers for this type of alarm have been developed by SRA Communications AB, a subsidiary company of LM Ericsson. In this article the equipment in the subscriber's home and at the alarm centre are described, followed by a description of the course of an alarm call and, finally, technical information.

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Many old-age pensioners and handicapped people have to live alone, without access to nearby aid. ERICARE has been developed for this steadily increasing category of people. Technical aids can never replace personal care, but they can help to make life safer for the elderly and the handicapped people who have to live alone. ERICARE enables the lonely person to send an alarm in an emergency and then speak to somebody who can arrange help.

The basic equipment in the suscriber's home is easy to install. It can be put in and tested by non-specialists and is easy to move. The system can have a few or several hundred pensioners and handicapped people connected to one and the same alarm centre. Public institutions, such as old people's homes, nursing homes, health centres and fire stations, can be used as alarm centres.

The main function of the system is to sence an alarm from a subscriber's home, automatically set up a telephone connection to the alarm centre and transmit alarm and identity information. When an alarm has been received, the staff on duty at the alarm centre can speak to the person via a units placed in the subscriber's home which contains a microphone and a loudspeaker.

Home equipment

The basic equipment in the subscriber's home consists of a telephone base unit and a box with electronic equipment. The base unit contains a microphone, a loudspeaker and an amplifier for loudspeaking calls. A large alarm button is mounted on a panel on the base unit. Extra alarm buttons can be wall-mounted to give added opportunities for initiating alarms. Extra units with microphone and loudspeaker can be installed in other rooms in the subscriber's home in order to make speech communication possible in all rooms.

A portable alarm button with a radio signal transmitter has several advantages over fixed buttons. In the case of an accident—a fall in the bathroom—a touch on the portable button will give an immediate alarm. There is no need to crawl

Fig. 1
Loudspeaking calls provide information and aid the decisionmaking, and thus reduce the number of emergency visits to the old-age pensioners and handicapped people.
The person on duty at the alarm centre learns what has happened, can advise and reassure the pensioner and arrange help when necessary.
It is not possible to set up a loudspeaking call from the alarm centre for listening-in on the pensioner. It is only when an alarm has been sent that the loudspeaking two-way speech circuit is opened

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over to a wall button, which would often be impossible, for example if the person had a fractured thigh. The portable alarm button is available as a bracelet or as a medallion on a band round the neck.

The range of the radio signal transmitter is sufficient to penetrate reinforced walls and reach the receiver even in a large house, and it is the best and safest method for a pensioner etc. to send an active alarm.

A person cannot set off an active alarm if he or she is unconscious or cannot reach the alarm button. For this reason supplementary equipment for passive alarm is often also installed. This type of alarm is released when a normal activity is not repeated within a certain time. ERICARE has an electronic clock which measures the time, for example from the last time the toilet was used. After, for example, 12 hours a passive alarm is sent to the alarm centre.

Alarm centre equipment

In the telephone exchange a group number for three or more lines is reserved for the alarm centre and used only for alarm calls. The person on duty can switch between incoming alarms and deal with them according to urgency. A separate telephone line at the alarm centre is used for outgoing calls. The staff on duty can use this line to call an ambulance, a doctor, a caretaker etc., or make ordinary calls to the pensioners.

The central equipment is mounted in a wall rack and consists of the standard printed board assemblies used in telephone attendance system AVE 100.

The control equipment at the alarm centre consists of a telephone base with two units. The lower one has buttons for connecting up 3–6 alarm lines. The upper unit has six control buttons and a digit indicator. One of the buttons is used to change the speech direction in the home equipment. The button is depressed for speech and released for listening. In the home equipment there is corresponding switching between microphone and loudspeaker.

The telephone set at the alarm centre can be a standard set, e.g. DIALOG or DIAVOX. However, it is more convenient if the switching of speech direction can be done with a key in the handset instead of a panel button. If the telephone set has a carbon microphone, changing it to a dynamic microphone with amplifier will give better sound quality in the loudspeaker in the home equipment.

Theoretically, 10,000 alarm sources can be identified with a four-digit indicator. A recorder can be connected to the central equipment to record the time and identity of incoming alarms.

The alarm centre does not have to be manned. It can be equipped with an ERICALL radio transmitter which, when an alarm comes in, automatically pages the person in charge, who is thereby called to the alarm centre.

Fig. 2
The telephone base unit has a large red button for alarms. A second button gives easy, single-handed calling of an optional telephone number, usually to a close relative.
The button at the far left cancels an initiated alarm call

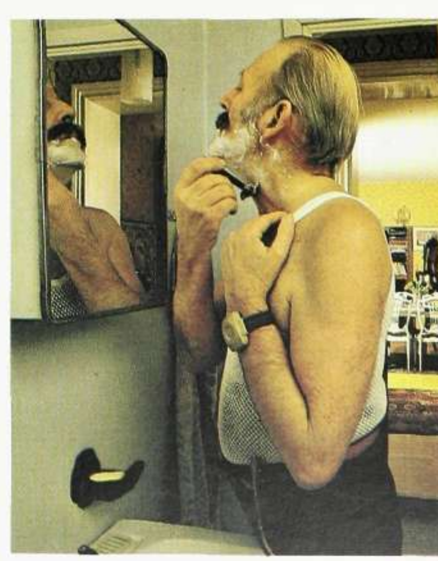


Fig. 3
The portable alarm button gives a wireless alarm signal to a radio receiver built into the telephone base unit. The receiver then automatically initiates a call to the alarm centre.
The portable alarm button is worn as a bracelet or as a medallion on a band round the neck.
The radio signal transmitter is equipped with automatic battery checking. When a change of battery is due, a special signal is sent to the receiver in connection with an alarm or test signal. The green diode lamp in the telephone base unit starts to flash. Moreover the digit indicator in the alarm centre displays the letter C, which indicates that the battery should be changed

Alarm procedure

When an alarm is initiated the telephone exchange is called automatically, and the alarm centre number is transmitted. For about 10 seconds the pensioner will hear, via the loudspeaker, the signals and tones that are sent out during the calling process. During this time the call can be cancelled by depressing the button marked Reset.

If the alarm centre lines are engaged, or if the exchange is congested or connects up to a wrong number, this call attempt is abandoned and the call is automatically repeated until the alarm centre is reached. If the alarm centre does not answer within about 90 seconds the call is disconnected and a new call is again automatically repeated until the alarm centre answers. The person in duty there answers the call by lifting the handset and depressing the line button whose call lamp is flashing. A tone code is sent to the home equipment and releases tone transmission of alarm type and identity number.

The alarm code and identity are displayed on the digit indicator used by the person on duty. He can request new transmission of the information, by depressing the button New code, if it is not shown or is shown distorted.

The person on duty can carry out a conversation with the pensioner by means of the key on the handset or the button Speech control. If he finds it difficult to hear or to make himself heard, he can connect in extra amplification in both speech directions by depressing the button Sound amplification.

The digit indicator shows the letter A for an active alarm and B for a passive alarm. The letter C is shown for alarms or alarm tests from the portable alarm button if the battery needs changing.

The person on duty carries out the appropriate action on the basis of the information received during the call. The call is then disconnected by depressing the button Reset and replacing the handset.

Technical description

CMOS circuits have been used to obtain high reliability, low power consumption and small volume. Standard circuits have been used for supplementary functions, such as tone encoding and decoding and also number sending. The electronic circuits in ERICARE, fig. 4, are used for the following functions:

In the subscriber's home:
- registering an alarm situation
- automatically calling when an alarm is given
- sending predetermined telephone numbers
- receiving control signals from the alarm centre
- sending an identity number
- loudspeaking communication, simplex.

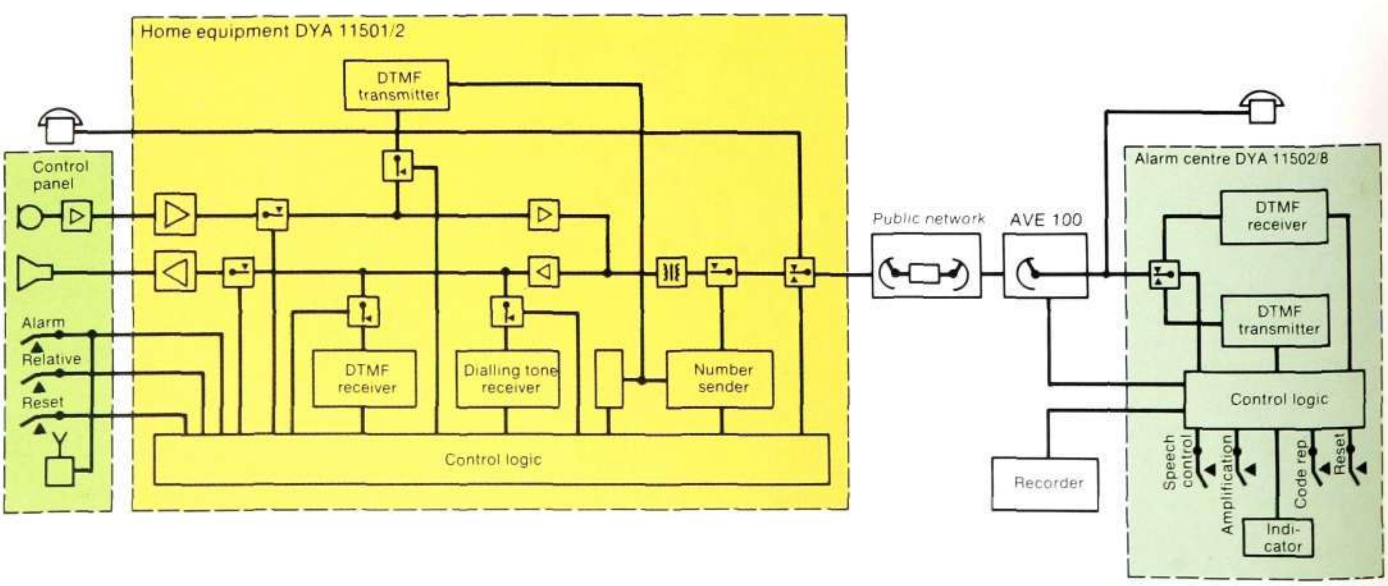


Fig.4
The block diagram for ERICARE

Fig. 7
Four figures show the identity of the person sending the alarm. The letters A–F give the type of alarm

Fig. 5, left
The digit indicator in the telephone base unit at the alarm centre shows the identity of the pensioner and whether the alarm is active or passive. The person on duty has a file with notes on the person, his or her name, telephone number, doctor, medicine requirements, nearest neighbour, caretaker, relative etc.
An important facility in this system for caring for people is that the person on duty can easily switch over from one alarm line to antoher, and thus for example park a "conversation alarm" in order to attend to a real alarm

Fig. 6, right
A recorder can be connected to the alarm centre to record the time of each incoming alarm and the identity of the caller

In the alarm centre:
- receiving and registering the identity number of the home equipment
- sending control signals to the home equipment.

Active alarms are initiated from fixed alarm buttons or radio signal transmitters. The receiver, ERICALL CONTACTOR, for the wireless alarm is placed in the telephone base unit in the home equipment. The receiver and radio signal transmitter have both been developed by SRA Communications AB. The transmitter contains a special circuit for signal encoding.

A special signal is sent in connection with alarms or alarm tests when the battery needs changing. This signal is forwarded to the alarm centre where it gives the alarm code C on the digit indicator. Thus the transmitter itself indicates when it is time to change the battery, and it is not necessary to check the battery manually.

Alarms can also be initiated by special time supervision equipment; passive alarms.

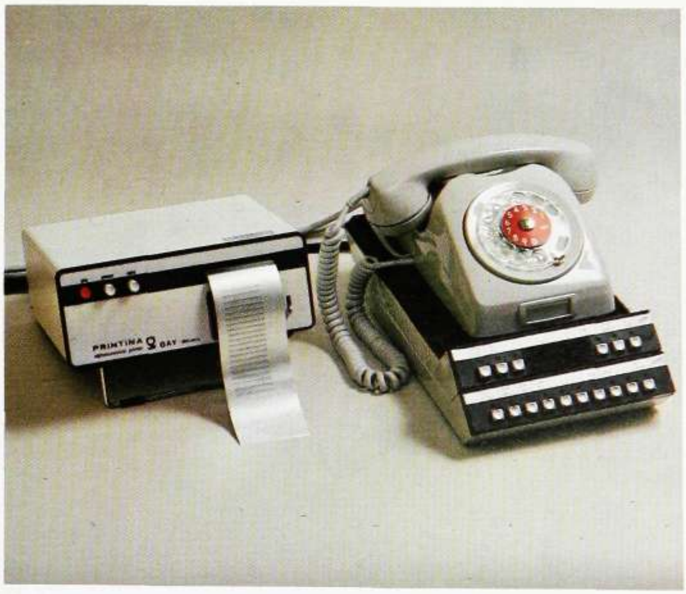
The type of alarm is registered in the home equipment, and is transmitted and indicated by a letter on the digit indicator at the alarm centre:

A. active alarm, initiated from an alarm button or a portable transmitter
B. Passive alarm
C. Active alarm, initiated from a transmitter with a low battery voltage
D. Alarms from other objects, fire alarm
E. or burglar alarm
F. Fault alarm, caused by a break in an external alarm loop.

When an alarm is registered, a relay disconnects the telephone line from the telephone set in the subscriber's home and connects the line to the amplifier circuits in the home equipment. A loop call is made to the exchange and the dialling tone is detected by a tone receiver. If the tone is accepted, the number sender starts sending the alarm centre number. The number is obtained from a progammable memory with a capacity of 8×32 bits. The memory also contains the telephone number of a relative and the identity number of the equipment within the system.

Supervision is carried out during and after the number sending, and a new call is made if the home equipment receives the busy tone or the call is not answered within a reasonable time, fig. 8. The supervision function is blocked during calls to the relative.

The transmission of control signals to the home equipment, and of alarm type and identity number to the alarm centre, is carried out using DTMF signalling over the established telephone circuit. A filter and detection circuits, each in a standard package, are used for the



Technical data

Home equipment		
Mains voltage	V a.c.	220
Maximum power consumption		
– idle	W	5
– during an alarm	W	10
Maximum output power for the loudspeaker	W	1.5
Microphone sensitivity	dB rel. 1 V/Pa	–45
Maximum line level		
– with speech transmission	dBm	0
– with signalling	dBm	–10
Maximum line attenuation, home equipment		
– alarm centre	dB	30
Line matching	ohm/nF	600/15
Return loss	dB	>9
Impulsing	pulses/second	10
Temperature limits	°C	0 and +55
Air humidity limits	%	40 and 90
Alarm centre		
Voltage	V d.c.	24
Power consumption		
– idle	W	2.5
– during an alarm	W	20
Signal level during transmission	dBm	–10
Line matching		
– minimum during recieving	kohms	10
– during transmission	ohm/nF	600/15
Return loss	dB	>9
Temperature limits	°C	0 and +55
Air humidity limits	%	40 and 90
Radio signal transmitter		
Frequency	MHz	26.855
Output power	mW	>1
Digital code	bits	12
Weight with battery and bracelet, approx.	g	40
Battery life, approx.	years	3
corresponding to alarms, approx.	times	1,400
in the button is kept depressed	sec./alarm	10

DTMF signalling. The filter is of the switched capacitor type.

When the call is answered at the alarm centre an acknowledgement signal is sent to the home equipment, which then initiates the sending of identity number and alarm type. This information is registered in the alarm centre and is displayed on the digit indicator. Signals can then be sent from the alarm centre for controlling the speech direction, for increasing the amplification in the home equipment in both speech directions and for requesting repetition of the identity number.

Time supervision of the speech control is arranged in order to prevent the signalling being blocked if the sound level in the subscriber's home is too high as can be the case if, for example, a radio or TV set placed near the microphone is switched on. When the speech direction is set for listening, the sound from the radio or TV will go out on the telephone line at a level of nearly 0 dBm. If the line attenuation is high, the received DTMF signal will be about 30 dB below the level of the disturbing signal. This can prevent the two-tone signal from being received.

The time supervision automatically changes the speech direction and connects in the loudspeaker in the home equipment if the home equipment does not receive any speech control signal for about 20 seconds. The person on duty at the alarm centre hears when the speech direction is switched over, and can then take the opportunity of informing the pensioner that the alarm has been received and what action is being taken etc.

When the call is completed, a disconnection signal is sent from the alarm centre to the home equipment. The disconnection is also supervised. If there is no signalling for about 5 minutes, the home equipment is automatically disconnected.

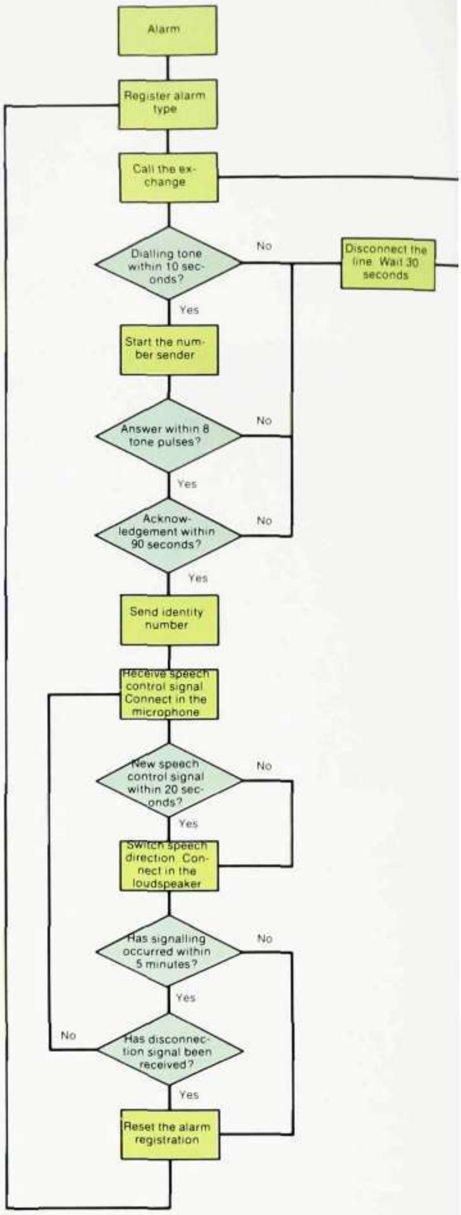


Fig. 8
Sequence diagram for ERICARE

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MOBILE TELEPHONY IN THE NORDIC COUNTRIES
CONTACT RL400—A NEW RADIO RELAY EQUIPMENT
PCM SIGNALLING EQUIPMENT IN THE BYB CONSTRUCTION PRACTICE
MANUFACTURE OF HYBRID CIRCUITS

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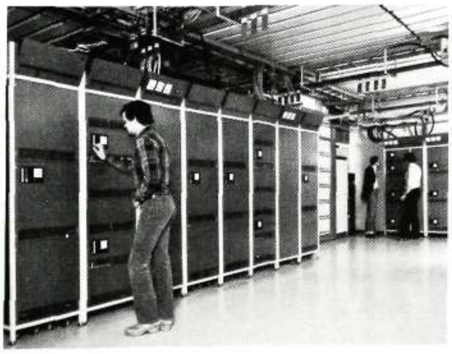

COVER
Prototype plant BZD 412, 1600 A, undergoing type testing in the Power Supply Department laboratory. In the background a plant of the BZD 112 type.

Digital local exchanges AXE 10

Kjell Persson and Siwert Sundström

The AXE 10 system has been described in several earlier articles in Ericsson Review. Recently a general survey of the system[1] and a description of its use as a transit exchange[5] have been published.
The present article deals with the use of AXE 10 for local exchanges, with special emphasis on the digital subscriber stage.

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Since the introduction of AXE 10 on the market the system has been successively supplemented with new and variant subsystems. A four-wire digital group selector was offered at an early stage as an alternative to the two-wire analog group selector. In networks based increasingly on digital circuits, great advantages can be realized by using a digital group selector[3]. The changeover to the digital group selector therefore took place very quickly and sales of exchanges with digital group selectors are now predominant.

As an alternative to the analog subscriber stage a digital subscriber stage is now also available. The digital subscriber stage can be placed in the exchange, as a remote unit or as a replacement for minor exchanges. A remote unit can be converted to an autonomous exchange with limited alteration of the installed hardware.

Fig. 1
The interior of an AXE 10 exchange

For local networks AXE 10 can be used exclusively as a local exchange, but also as a tandem or a combined local and tandem exchange. The tandems have largely the same set of functions as the local exchanges but have no subscriber switching or charging subsystems.

The fact that the same system can be used for all applications has advantages, for example for operation and maintenance, such as uniform documentation, uniform operational routines, joint training, possibility of centralized operation, etc. This is also valid for telex exchanges, AXB 20, and data networks, AXB 30, which are members of the same system family.

The modular structure of AXE 10—with its building blocks: system, subsystems, function blocks and function units—guarantees a possibility of further development and good characteristics during the system's entire life span.

System characteristics

A summary will now be given of the functions of the subsystems that are characteristic of an AXE 10 local exchange.

Digital group selector

The digital group selector[2,3] is loss-free and has several other advantages. Since it has four-wire through-connection the transition to two-wire is made further down in the local network. Four-wire transmission advantages permit combined exchanges and favour extended exploitation of high-usage routes.

The analysis and traffic routing functions of the system are very flexible and meet all requirements as regards number of routes, sizes of routes, etc. The routes can be extended as the need arises and the circuits in a route can be positioned freely in the multiple. The constructional elements are the same regardless of the size of the group selector, and extensions are easily made in steps of 512 multiple positions.

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SIWERT SUNDSTRÖM
ELLEMTEL

Subscriber stage

AXE 10 can be equipped with both analog and digital subscriber stages. Exchanges which have been built with analog subscriber stages from the outset can be extended with digital subscriber stages.

Remote placing of digital subscriber stages implies that the digital interface is moved closer to the subscriber. This permits savings in the primary network, at the same time as the overall transmission characteristics can be improved.

Remote placing in a container is in some cases advantageous for quick and reliable installation, fig. 2.

Traffic equalization over a 2048-line group

The digital subscriber stage is designed to provide traffic equalization over an entire 2048-line group. This makes it insensitive to asymmetrical loading, so that no consideration need be paid to placing of high-traffic subscribers in the multiple. Only the number of speech channels to the group selector needs to be decided according to the traffic for the 2048-line group.

Internal traffic in the event of link failure

The connection with a remote unit normally consists of at least two digital line systems. For reliability reasons these should be divided between two cables run on different routes. In the event of a total link failure affecting the remote digital subscriber stage, its function is automatically changed so as to permit internal traffic between the unit's subscribers (stand alone function). The function also allows connection of calls to alarm numbers–fire brigade, police, ambulance, etc.–via standby paths in the subscriber multiple.

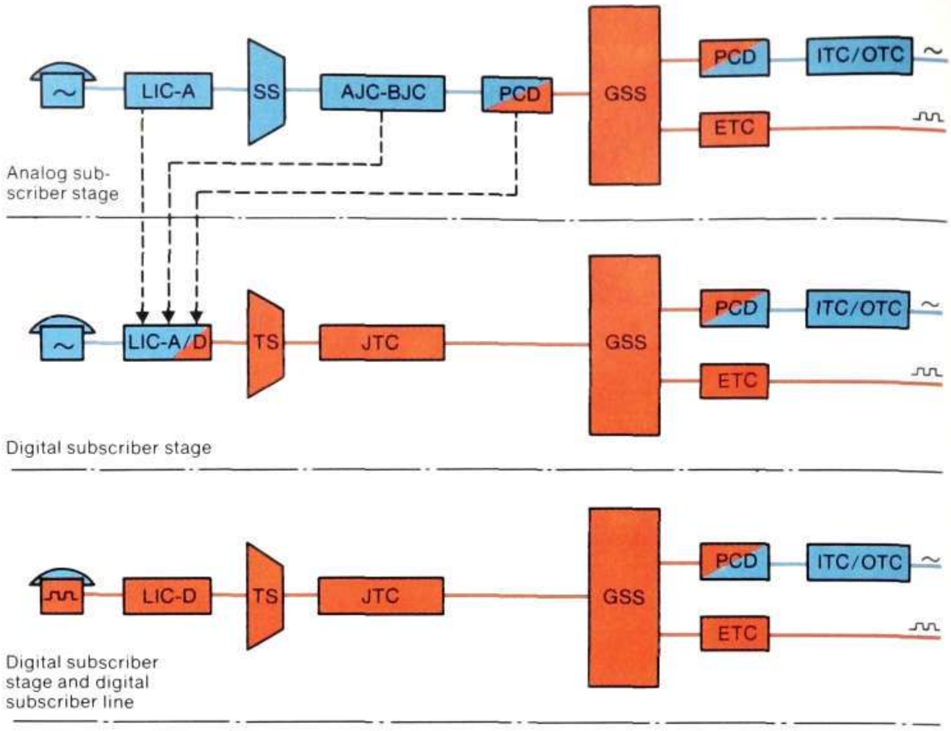
Number group function

AXE 10 allows a number group function facility for the entire exchange area including remote digital subscriber stages. The number group function simplifies the procedure in conjunction with subscriber movements. If there are subscriber lines connected to the multiple, no work in the main distribution

Fig. 2
Digital subscriber stage placed in a container for remote location

Fig. 3
Comparisons between the function of the analog and the digital subscriber stages

(blue line)	Analog functions
(red line)	Digital functions
LIC-A	Analog line circuit
LIC-A/D	Analog/digital line circuit
LIC-D	Digital line circuit
SS	Analog subscriber stage
TS	Time Switch in digital subscriber stage
AJC/BJS	Cord circuit for A- and B-subscriber functions
PCD	Analog/digital converter for 32 channels
JTC	Link to group selector
GSS	Digital group selector
ITC/OTC	Incoming and outgoing analog trunk circuits
ETC	Terminal for first order PCM system



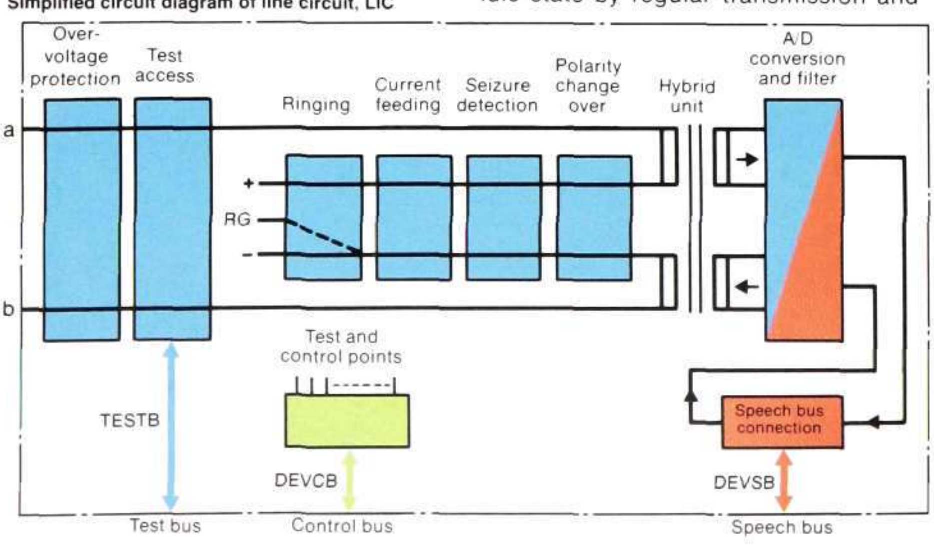
frame is necessary. The number group function also means that a free multiple position can immediately be used for a new subscriber number. The number reserve thus consists mostly of storage space instead of multiple positions.

Digital subscriber lines

The digital subscriber stage in AXE 10 is so designed that it also permits the connection of digital subscriber lines. Laboratory experiments are being made with the special line circuits and terminal equipments needed for this purpose. The experiments are based on the work at present being done by the CCITT. The intention is to allow for connection of digital as well as analog subscriber lines to the digital subscriber stage.

Digital subscriber lines permit the connection of more qualified subscriber terminals which allow transmission of text, pictures, data or alarm. Digital subscriber lines can also be supervised in the idle state by regular transmission and checking of predetermined bit patterns. For this part of the subscriber line network, maintenance characteristics are in this way attained which are comparable to those for digital trunk circuits.

Fig. 4
Simplified circuit diagram of line circuit, LIC



Operation and maintenance

AXE 10 covers all applications in the telephone network, such as local exchanges, combined exchanges, tandem, transit and mobile telephone exchanges. Coordinated operation and maintenance is thus possible for the entire network. This may cover training, documentation, spare parts and software management and, with centralized operation, also the current operation and maintenance work.

Centralization of operation and maintenance can be effected with system AOM 101[4], which offers efficient supervision of equipments in the network from several specialized work centres. It allows connection of different exchange systems, e.g. AXE 10, ARF, ARM, ARE and ARK. Maintenance outlets of transmission equipments, power plants, etc., may be connected to AOM 101 as well.

The man-machine functions in AXE 10 are designed in accordance with CCITT recommendations.

Functions

The digital Group Switching Subsystem, GSS, the Common Channel Signalling Subsystem, CCS, The Operator Position Subsystem, OPS, and the Mobile Telephone Subsystem, MTS, have been described in earlier articles[1,2,3,5]. The digital subscriber stage and the functions in the switching and

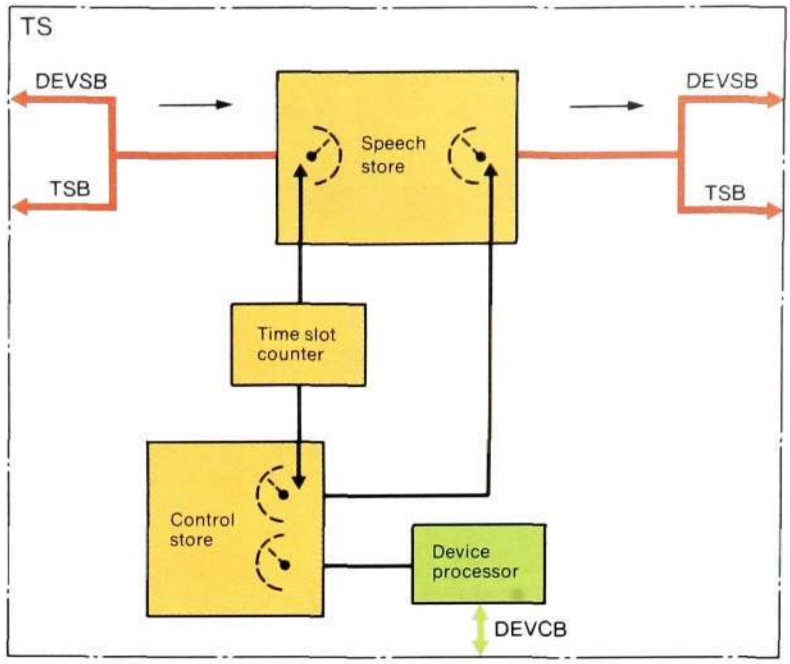


Fig. 5
Simplified diagram of time switch, TS

	Speech data
	External control data
	Internal control data
DEVSB	Device Speech Bus to which line circuits, LIC, Key tone receivers, KRD, and links, JTC, to the group selector are connected
TSB	Time Switch Bus used for equalization of traffic between the 128-line groups
DEVCB	Device Control Bus connecting the device processor of the time switch to the regional processors, EMRP

A connection from a LIC to a link to the group selector in the same 128-line group runs from LIC–DEVSB–Speech store–DEVSB–JTC, and the reverse in the other speech direction.

When there is no free link to the group selector in the originating 128-line group the connection is passed via TSB to JTC in another 128-line group as follows: LIC–DEVSB–speech store–TSB–speech store–DEVSB–JTC, and the reverse in the other speech direction.

Incoming speech samples from DEVSB to TSB are written successively into the speech store under control of the time slot counter. On read-out to DEVSB and TSB the time slot counter identifies the relevant position in the control store where the address of the relevant position in the speech store is stored.

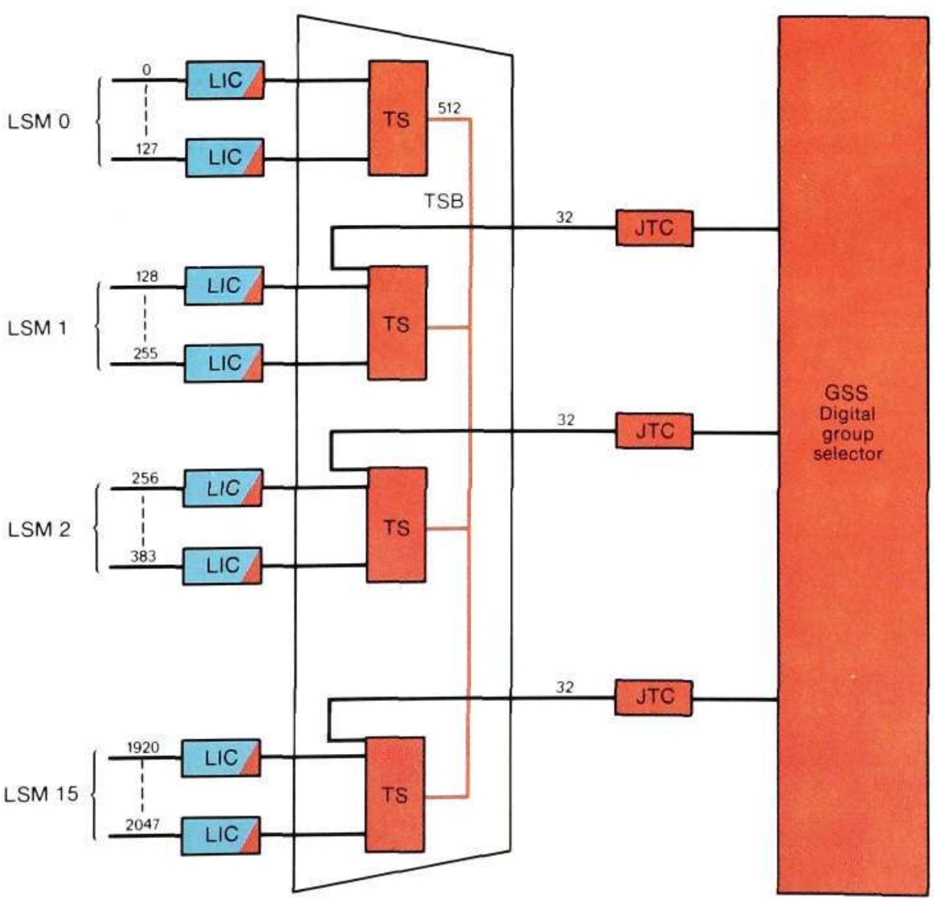
On the set-up of every connection, data are changed in the control store by the device processor, which is controlled by the central processor.

Fig. 6
The way in which traffic equalization takes place per 2048-line group in the digital subscriber stage of AXE 10

TSB	Time switch bus with 512 time slots
JTC	Link to the group selector for 32 speech channels
TS	Time switch with one speech sample store per 768 positions
LIC	Line circuit
LSM	Line switch module for 128 lines

Each line switch module LSM can, via the time switch, TS, either be connected to the group selector GSS over its own PCM system link JTC with 32 speech channels or utilize one of the 512 time slots in the time switch bus TSB for access to a free speech channel in JTC in another line module.

As all line circuits have access to all speech channels to the group selector, the selector has full availability and is thus insensitive to asymmetrical loading.



control systems that are unique to local exchanges are described in the following part. Furthermore the control system will be described in more detail in a later article.

DIGITAL SUBSCRIBER STAGE

The digital subscriber stage shall have the same functions as an analog subscriber stage: current feed, ringing and digit reception in addition to the concentration function, fig. 3.

In the digital subscriber stage the concentration takes place in a digital switch, TS. The analog/digital conversion is done before access to the switch. Thus all "cord circuit functions" must be performed in the line circuit as they require DC-connection with the analog subscriber line. This solution permits use to be made of developments in component technique and at the same time constitutes a natural step towards the introduction of digital subscriber lines.

Functions of the subscriber stage

The digital subscriber stage has a line circuit for each connected subscriber line. In the line circuit the speech is converted between analog and digital form. Fig. 4 shows the various parts of the line circuit and their functions.

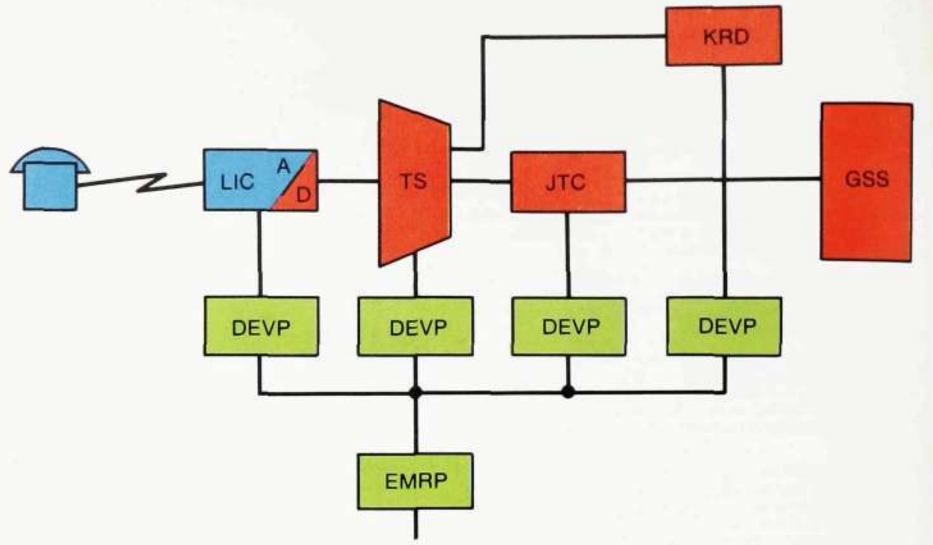
Modern components in advanced technique have been used in the line circuit. As intense development of semiconductor circuits for transmission purposes is under way, great attention has been paid to defining the line circuit interfaces so as to have flexibility for future changes to even more sophisticated circuits.

A subscriber stage for 2048 subscribers consists of 16 line modules, LSM, for 128 subscribers each. The time switch for each line module has a speech store with 768 positions, of which 128 are used for the subscriber lines, 512 for connection to a bus linking together all line modules, 32 for connection of a PCM link, eight for tone receivers, and four for test purposes. The principle of the switch is shown in fig. 5.

The traffic from a line module can pass via its own speech channels to the group selector or use one of the 512 speech time slots in the time switch bus and thus reach a free speech channel to the group selector in one of the other 15 line modules, fig. 6. This means that all

Fig. 7
Control structure for the line module LSM

(blue)	Analog part
(red)	Digital part
(green)	Control part
LIC	Line circuit
TS	Time Switch
JTC	Link to group selector
KRD	Key tone receiver
GSS	Digital group selector
DEVP	Device processor
EMRP	Regional processor



line modules need not have their own speech channels to the group selector. The group of altogether 16 line modules can be equipped with the number of speech channels required by the total traffic.

Control

The control functions in the subscriber stage are highly decentralized. The line circuit boards, time switch board, key tone receiver board and the board for speech channels to the group selector are all provided with microprocessors, DEVP, with permanently stored programs, fig. 7. These microprocessors in a line module for 128 subscribers are in turn controlled by a regional processor, EMRP, also of microprocessor type. The same high level language, PLEX, is used for its programming as for the central processor software.

Structure of the line module

Each line module, LSM, fig. 8, contains 128 line circuits, time switch, key tone receiver, printed circuit board assembly for speech channels to the group selector, and equipment for testing of subscriber lines and line circuits. Each line module also contains a regional processor, EMRP. The various units in the line module are interconnected over three bus systems, one for speech, DEVSB, one for control, DEVCB, and one for tests, TESTB.

Connection

The digital subscriber stage can be connected direct to the group selector or as a remote unit. In the former case the regional processor, EMRP, of the subscriber stage is connected via a bus converter, RPBC, to the regional processor bus, RPB, of the central processor, fig. 9, top. At the bottom of the same figure is shown the connection of a remote subscriber stage to the parent exchange. The connection is made over the number of 2.048 Mbit/s PCM systems necessary for the traffic.

Control of the remote and of the exchange-located stage is effected on the same principles. The central and regional parts of the switching programs are therefore independent of the placing of the subscriber stage.

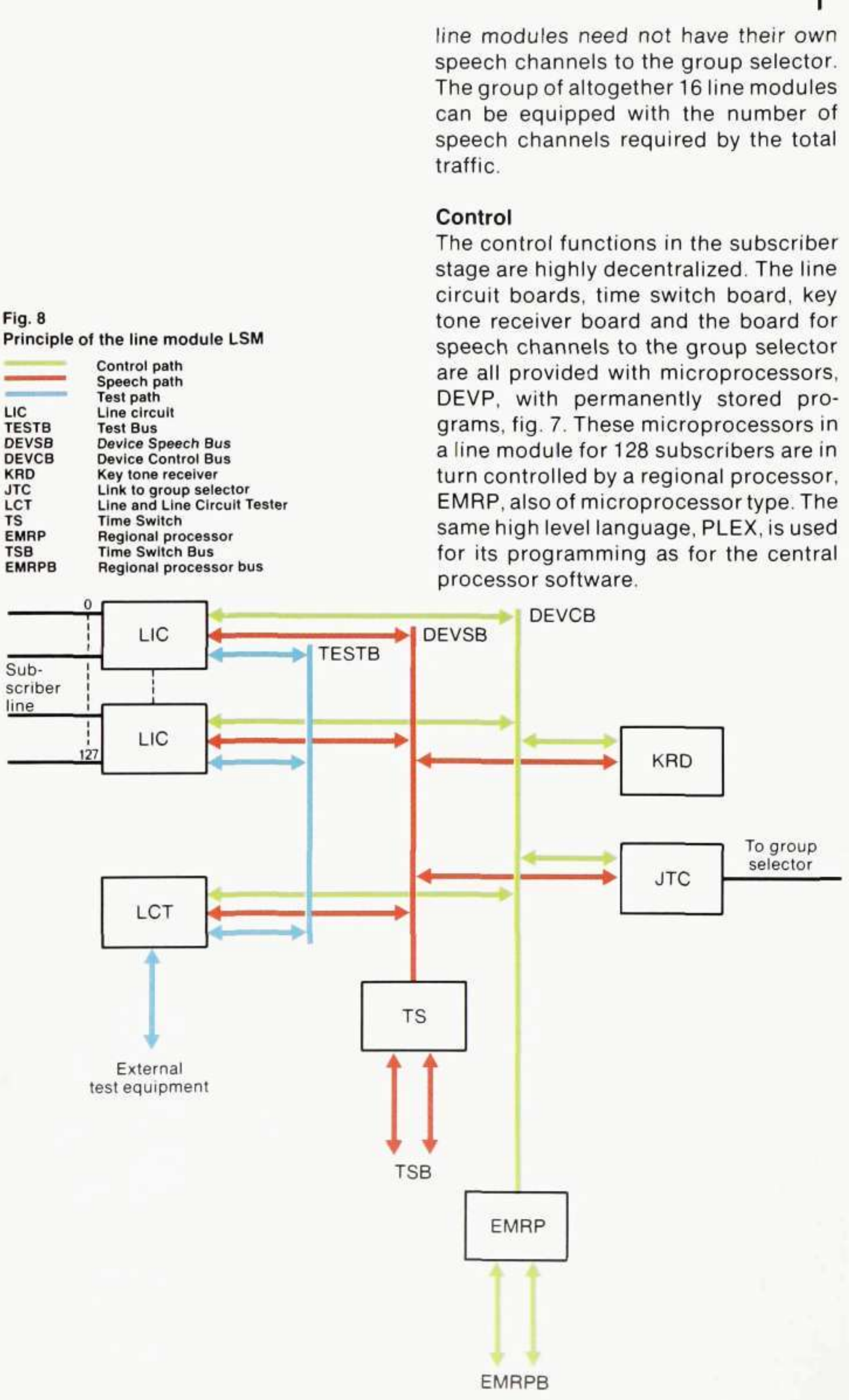
Time slot 16 in two of the PCM systems is used for signalling to and from the regional processors in the remote subscriber stage. Signal terminals, ST-C and ST-R, at each end of the signalling links reshape the signal messages to the stipulated signal format. In respect of procedures and reliability arrangements a signalling system is used which is based on signalling system no. 7 recommended by CCITT.

Synchronization

In the digital network, group selector and digital line systems work in synchronism. The digital subscriber stage must work in synchronism as well. It re-

Fig. 8
Principle of the line module LSM

(green)	Control path
(red)	Speech path
(blue)	Test path
LIC	Line circuit
TESTB	Test Bus
DEVSB	Device Speech Bus
DEVCB	Device Control Bus
KRD	Key tone receiver
JTC	Link to group selector
LCT	Line and Line Circuit Tester
TS	Time Switch
EMRP	Regional processor
TSB	Time Switch Bus
EMRPB	Regional processor bus



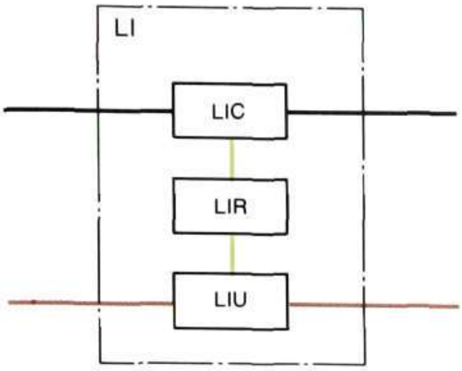


Fig. 10
Function block LI for connection of subscriber lines

(dark line)	Speech path
(green line)	Signal paths within the function block
(brown line)	Signal paths to other function blocks
LIC	Line circuit
LIR	Subscriber line interface, regional software
LIU	Subscriber line interface, central software

Fig. 9, down
Block diagram of AXE 10 local exchange with exchange-located and remote digital subscriber stage

Common equipment for exchange-located and remote digital subscriber stage

LIC	Line circuit
KRD	Key tone receiver
TS	Time switch
EMRP	Regional processor

Specific equipment for remote digital subscriber stage

ETC, ETB	Exchange terminals, near and far end
ST-C, ST-R	Signal terminals

Specific equipment for exchange-located digital subscriber stage

JTC	Link to group selector
RPBC	Bus converter

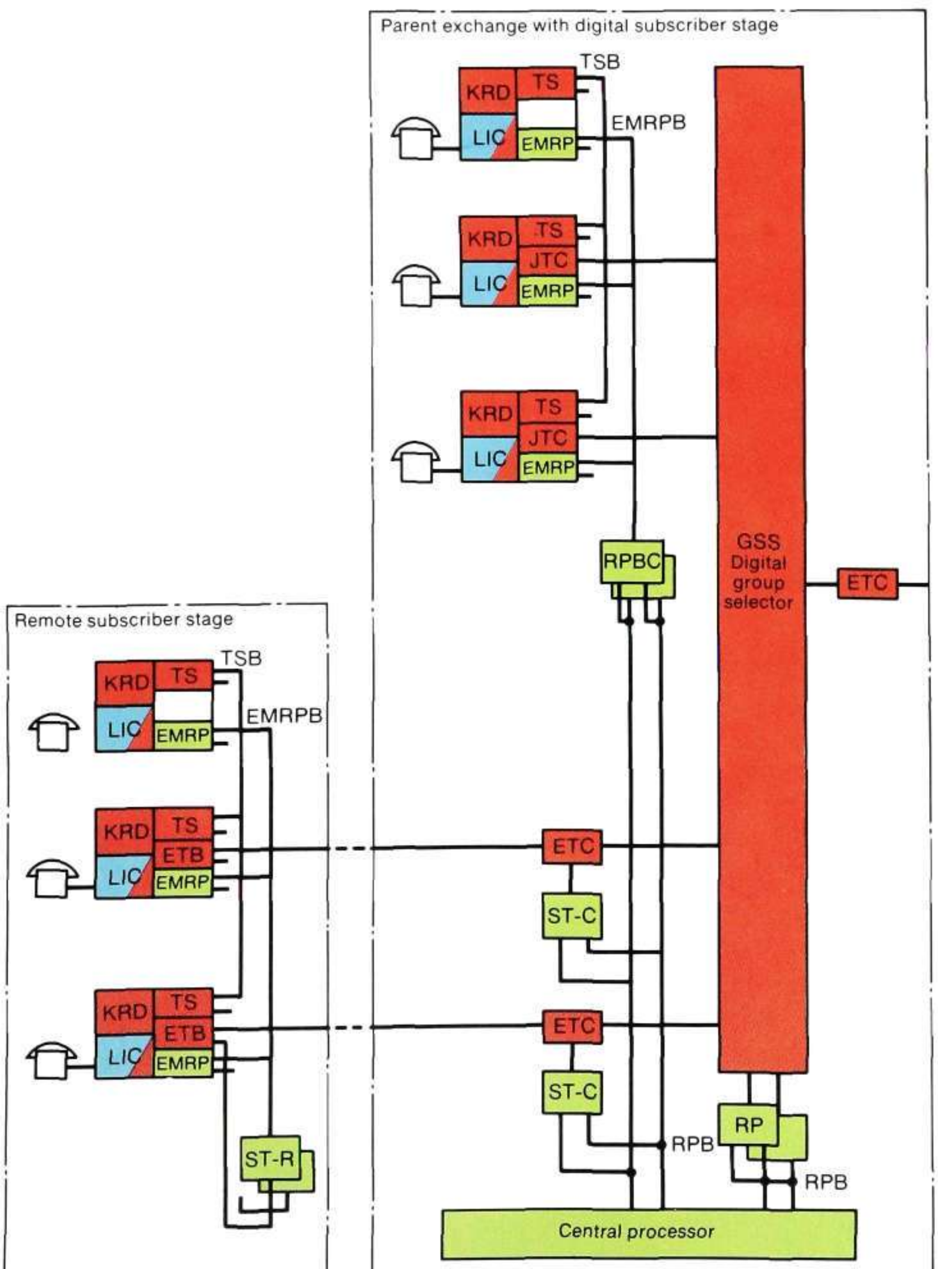
ceives its synchronizing information from the digital group selector. All 128-line groups have an oscillator for synchronization. Two of these groups receive synchronizing information from the group selector and control the other groups over the time switch bus.

Function block structure

The function blocks in the digital subscriber stage are shown in Technical Box 3 at the end of the article. Fig. 10 shows the function block for connection of subscriber lines, LI. It comprises both hardware and central and regional software.

The hardware consists of line circuit boards with a microprocessor for control. The permanently stored programs in this processor exchange software signals with the regional software in EMRP.

Interworking between function blocks normally takes place only in the central processor by the exchange of program signals. Regional interworking occurs, however, in the exceptional case when internal traffic is connected direct in a remote subscriber stage because of link failure.



Components

Modern component technique has been introduced for the functions in the line circuit. Standard LSI circuits are used for

- stores in processors and time switches
- microprocessors
- single channel codec and filter.

custom design circuits are used for

- terminals for digital line systems
- bus connection circuits.

With their built-in control functions the line modules are well suited for automatic testing. They are completely tested in the factory and require a very short installation time.

The digital subscriber stage occupies about half as much space as the analog.

SUBSCRIBER FACILITIES

AXE 10 offers a wide range of optional subscriber facilities, as appears from Technical Box 2 at the next side. Most facilities are limited to the home exchange, but means exist for introduction of overall network facilites also. Digital subscriber lines will make additional facilities possible.

OPERATION AND MAINTENANCE

The operation and maintenance functions are described in a previous article in Ericsson Review[5]. This presentation will be limited to the additions and alterations in the operation and maintenance configuration necessitated by the digital subscriber stage. The main dif-

Technical Box 1

CAPACITY

Subscribers per line module, max.	128
Line modules per subscriber stage, max.	16
Speech channels per link or digital line section to the group selector	32 (31)
Links or digital line sections to the group selector per subscriber stage	16
Traffic in erlangs per subscriber when installed to full capacity, max.	0.21

Technical Box 2

SUBSCRIBER FACILITIES

The subscribers in AXE 10 can be allotted a number of special facilities, the procedures for the use of which are as recommended by CEPT and CCITT.

Subscriber facilities within an exhange:
- Pushbutton dialling
- Abbreviated dialling
- Hot line
- Registered call
- Do not disturb
- Call waiting
- Enquiry
- Conference call
- Subscriber-controlled restriction of calls on certain routes
- Automatic alarm-call service

Facilities with overall network function:
- Tracing of malicious calls
- Registered call
- Call transfer
- Priority

ference is that the normal "cord circuit functions" have been placed in the line circuit. This has the following consequences:
- connection to a subscriber line for tests is done in the line circuit
- the increased number of functions per line circuit calls for regular function tests
- extraneous voltage on a subscriber line does not affect equipment common to several subscribers. No special indication of extraneous voltage is therefore needed in conjunction with the setting up of a call.

Each line circuit has a test relay for splitting of the line and connection of test equipment to the line side and the exchange side. One line and circuit test equipment exists per line module of 128 subscriber lines. With this equipment a simple subscriber line test can be made in conjunction with clearing or as part of a routine on lines that are used sporadically. Line circuit tests can be made, furthermore, on suspicion of fault, e.g. on line lock-out or absence of answer. The line circuit test covers all analog functions in the line circuit. PCM codec and hybrid units are also tested on a routine basis by transmission of test patterns over the speech path. The line and circuit test equipment can also be used for controlling test connections over a given line circuit. Portable I/O devices for maintenance work on site are connected to the EMRP-bus.

Measurement on subscriber lines must be possible also for remote units and can be done with the line and circuit test equipment. For more extensive measurements separate measuring equipment is used which is controlled from the parent exchange.

Common equipment in the 128-line group, time switches, clock circuits and speech buses are supervised by means of parity checks and similar methods.

Traffic measurements can be made in each direction for every remote unit and every 2048-line group in the exchange.

SIGNALLING

Signalling from subscriber to exchange is done on analog circuits in the conventional way by loop signalling or key tone signalling. Small PABXs can be connected over subscriber lines with the same simple signalling. Large PABXs can be connected over lines with more complex signalling. The lines can in such cases be connected directly to the group selector and the signalling can then include also in-dialling to the PABX.

The new facilities that will be possible with digital subscriber lines require more advanced signalling between exchange and subscriber terminal. Provision has been made in the digital sub-

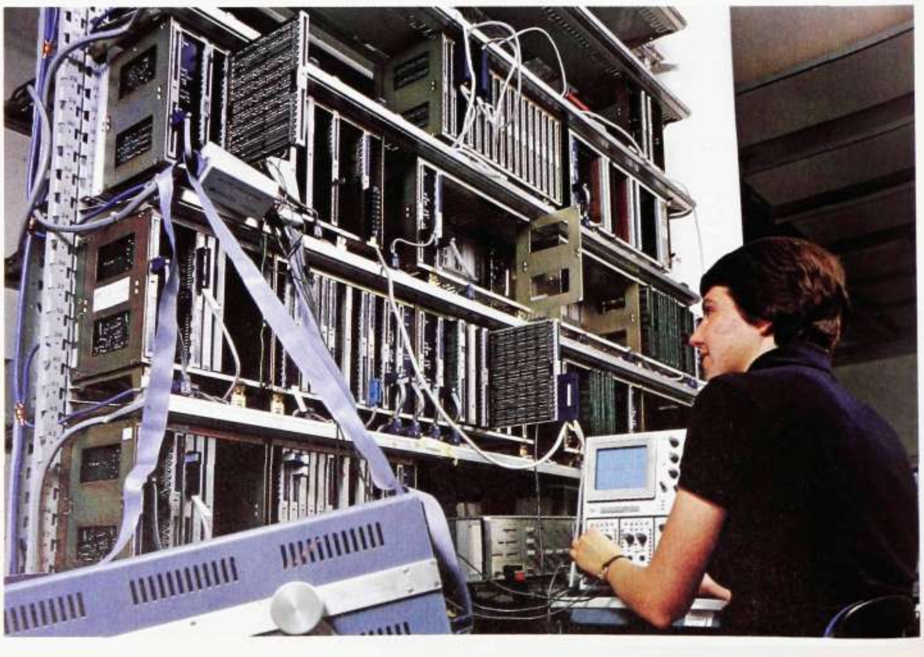


Fig. 11
Laboratory testing of the digital subscriber stage

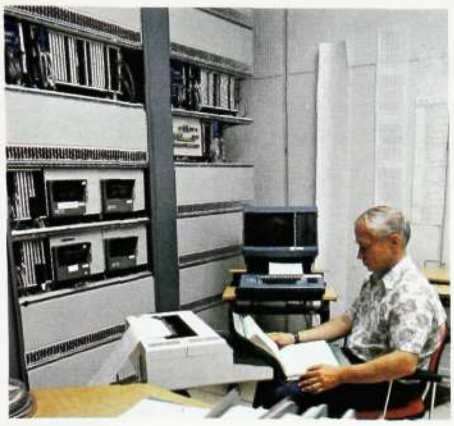


Fig. 12
Functional testing of the digital subscriber stage

scriber stage of AXE 10 for this extended signalling facility. The signalling relations which now exist as far as the line circuit board in the subscriber stage can, with digital subscriber lines, be extended right out to the subscriber terminal.

Signalling between local AXE 10 exchanges and other exchanges in the network has been dealt with in the referred articles[1,5]. Adaptation is successively taking place to different national signalling systems. In the digital part of the network CCITT system no. 7 is standard, but function blocks for channel associated signalling are also available.

CHARGING
In AXE 10 charging can be done both by toll ticketing and pulse metering. Combinations of the two methods are also possible.

The charging system allows complete national charging as well as charging of international calls in local exchanges, which can thus become charging points. This has the advantage that metering pulses need not be transmitted between exchanges. Alternatively charging can be done in a superior exchange by toll ticketing or transmission of metering pulses. Instead of transmitting the individual metering pulses an alternative is, when the signalling scheme so permits, to transmit special tariff messages to the local exchange.

The charging information is conveyed to the I/O devices of the system. Normally it is stored on cassette or magnetic tape for later processing, but it may also be conveyed to a typewriter or via a data channel to charging centres.

LOCAL NETWORKS
Digital networks can be very efficiently utilized[3]. This applies also to the parts of the subscriber network where the digitalization is brought nearer the subscribers through remote digital subscriber stages.

As AXE 10 also permits combined exchanges and offers good routing facilities, the network structure can be simply improved in step with the introduction of digital equipment. The transmission conditions are then also improved, signalling through the network is quicker and the total call set-up times are reduced.

Metropolitan networks
Metropolitan networks may comprise several local AXE 10 exchanges of different sizes. To achieve an efficient network structure the exchanges can have both exchange-located and remote digital subscriber stages. The exchanges

Fig. 13
Laboratory testing of circuit board assembly with microprocessor

Technical Box 3

FUNCTION BLOCKS IN DIGITAL SUBSCRIBER STAGE

The following function blocks are always included in the digital subscriber stage:

LI Subscriber line functions
- call detection
- reception of digits
- current feed
- translation, multiple position–directory number
- blocking
- connection of lines for PBX number
- special subscriber functions

CJ Combined cord function
- reception of digits from LI and KR
- initiation of time slot seizure on PCM link
- time-outs
- initiation of seizure of TCS and digit transmission to TCS
- clearing

RT Terminal functions for remote subscriber stage
- selection of PCM link
- selection of time slot on PCM link
- maintenance of PCM link

TS Time switch functions
- selection of time slot on time switch bus
- setting up of connection
- check of through-connection
- supervision of connection
- clearing

CD Clock signal distribution functions
- clock regulation
- synchronization

PX PBX number functions
- selection of PBX route
- selection of circuit in PBX route
- administration of PBX route data

KR Key tone reception

The subscriber stage can also be equipped, if necessary, with the following function blocks:

SE One or more standardized or market-adapted function blocks for special subscriber line signalling, e.g. for public call boxes, subscribers' private meters and special PBX functions

ATL Function block for remote subscriber stage which, on total link failure, permits internal traffic within the stage and calls to alarm numbers.

are linked together over direct routes or via tandem exchanges. Local and tandem exchanges can advantageously be combined and tandem exchanges can also be used for national transit traffic.

In the peripheral areas of large cities both autonomous exchanges and remote subscriber stages can be placed. On growth of the network the remote units can be built out into autonomous exchanges which, after further growth, can have their own remote subscriber stages.

Networks for medium-sized and small towns

In medium-sized towns a network of a few exchanges without tandems is usually sufficient. If the traffic warrants only small direct routes between the exchanges, these can have the form of high usage routes and the overflow traffic can be passed via one of the other local exchanges. One of the local exchanges can also be used for national transit traffic.

Summary

The AXE 10 system comprises all the functions and building blocks necessary to modernize and extend exchanges in the analog telephone networks by adding digital equipment. It permits both successive introduction of digital technique and more extensive conversion of entire zones. Since the digital subscriber stage occupies little space and can also be located as a remote unit, the introduction of AXE 10 permits buildings in central city areas to be released for other purposes. The remote units can be optimally placed in the subscriber line network.

The AXE 10 system was developed for the digitalization of telephone networks that is now in progress and is so designed that it can be further developed to cater for successively changing requirements.

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Power Supply Equipment for Large Telecommunication Plants

Kjell Rundqvist, Per-Uno Sandström and Roland Wald

In 1978 LM Ericsson introduced a new generation of power supply equipment, the BZD 112 type, consisting of units for 100 A rated current, and intended for the medium-size range of telephone exchanges.
This article presents the BZD 412 power supply system with units for 400 A rated current for large exchanges. The systems have many features in common, the same mechanical packaging structure is used and the same booster converter principle working with a high frequency (20 kHz). In this article the BZD 412 system, the booster converters, the distribution system and the packaging structure are described in detail while the rectifier, which was dealt with in a previous article[1], is mentioned briefly.

UDC 621.39:620.9

New electronic and stored program controlled (SPC) telecommunication systems were introduced in the late 1960s and gained wide acceptance during the 1970s. Electronic technology made new and exacting demands on power supply equipment and this led to new system solutions in this field. Another factor which prompted development was the availability of new powerful components and the facilities offered by new power conversion techniques. To meet these new requirements LM Ericsson developed a number of power supply systems with booster converters. These have been described in previous articles in this journal[2,3].

Variation in distribution voltage – a serious problem

Uninterrupted power supply to telecommunication equipment is usually provided by rectifiers powered from the mains and connected in parallel with lead-acid batteries. The voltage from the rectifiers is chosen to keep the batteries fully charged while the rectifiers are supplying current to the exchange. If the mains voltage should fail, the batteries take over without any interruption.

During a mains failure, when the batteries are under load, their voltage decreases. For example in the case of 23 battery cells there is a rapid reduction from 51 to 46 V and then a slower fall to about 40 V during the discharging period. To recharge the batteries rapidly after a mains failure, the voltage must be increased to around 54 V. Unless further precautions are taken, the telecommunication equipment will have to be designed to function satisfactorily over a range of 54 – 40 V.

Increasing the voltage from the batteries during the discharge phase creates far more favourable conditions for the telecommunication equipment. There are several methods of achieving this, one of which is to overdimension the batteries; this is common in small exchanges. LM Ericsson has solved the problem by means of the booster converter system with a battery-powered d.c./d.c. converter in series with the battery. This regulates its own output volt-

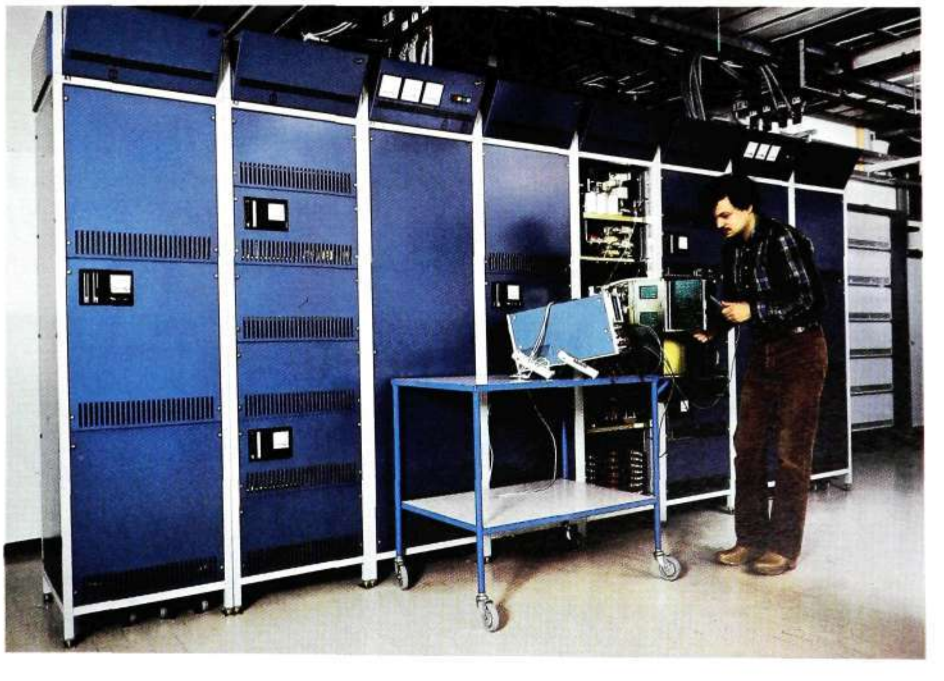
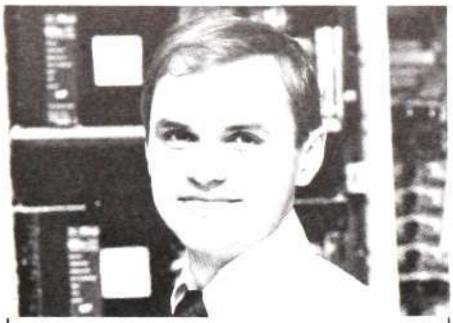


Fig. 1
Type testing the power supply plant BZD 412 in the laboratory



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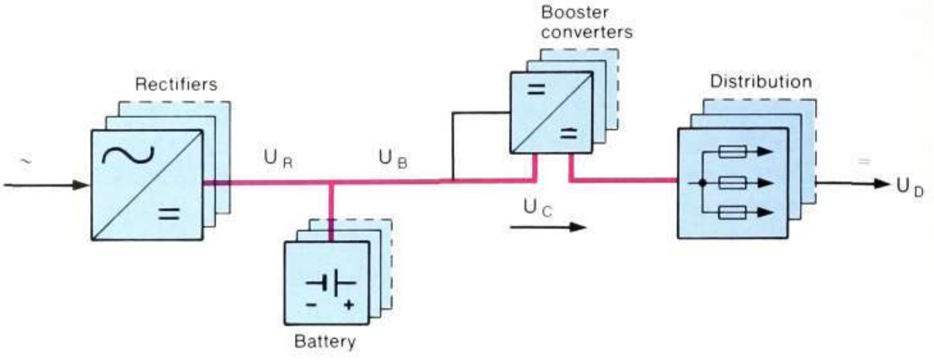


Fig. 2
The power supply system BZD 412 with high frequency booster converters

age so that the sum of the battery voltage and the converter voltage is constant during the discharge stage.

System Description

The function of BZD 412 can be best described by studying figs. 2 and 3. Fig. 2 is a simplified block diagram and fig. 3 shows the voltage variation through a cycle of normal operation–mains failure–recharging–normal operation.

During normal operation the battery voltage is kept at a specified level, 51 V ± 0.5%, by the rectifiers which are powered from the mains. This voltage, corresponding to 2.22 V per cell, float-charges the batteries, that is they receive a small maintenance current which compensates for self-discharge.

In this situation the booster converters function as active filters and provide an additional 0.5 V d.c. bringing the system's output voltage U_D to about 51.5 V. When a mains failure occurs, the battery takes over the task of supplying power and the voltage across it sinks. However, the booster converters' output voltage successively increases so that the total sum of the battery voltage and the booster converter voltage will be constant.

When the mains voltage is restored, the rectifiers automatically take over the supply of power while at the same time they start to recharge the battery. The booster converters successively reduce their output voltage and revert to a purely filtering function when a normal voltage level has been reached. Operational battery charging now starts to bring the battery quickly back to a fully-charged state. On an order from the automatic control, the rectifiers increase their output voltage to the operational charging level which is typically 2.35 V per cell and a total of 54 V. When the process has been completed, the order is discontinued and the rectifiers return to the normal level.

System characteristics

Some distinctive features are:

- The system delivers a constant distribution voltage both during normal operating conditions and when there is a mains failure, when the battery voltage drops. Thus the telecommunication equipment and the batteries can be designed in a rational way and safe operational conditions obtained.
- Transient voltage ratings and periodic noise voltages are limited to very low values. This is achieved by a special transient-limiting distribution

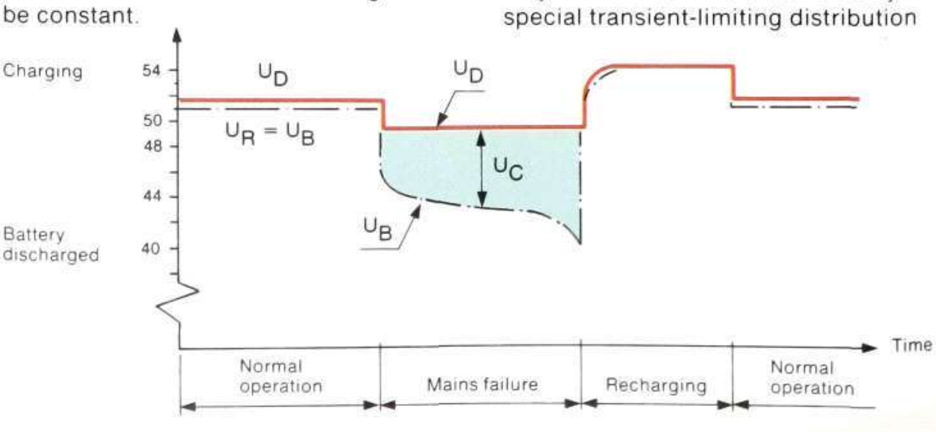


Fig. 3
The booster converter system for 48 V with 23 battery cells. The cycle of events for a mains failure and subsequent recharging

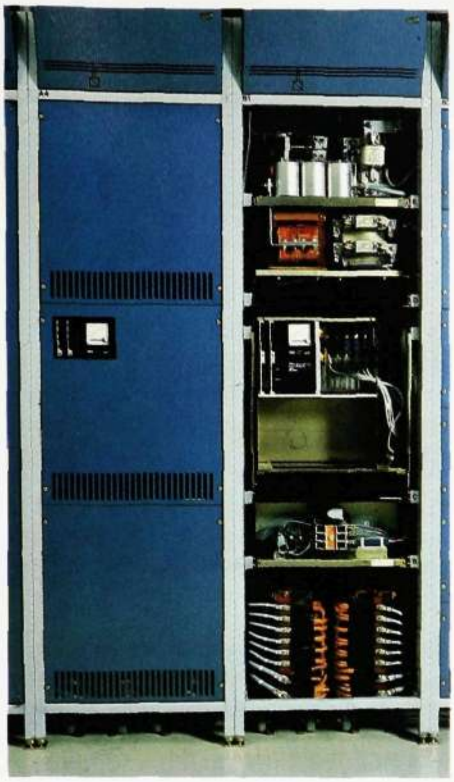


Fig. 4
Two thyristor rectifiers BMT 343, one with front panels and one without

for the BZD 412 system and by letting the booster converter function as an active filter[4].

- The booster converters work at a high frequency, 20 kHz, which gives advantages in the form of small dimensions, silent operation and fast regulation.
- The system is completely automatic and suitable for unattended exchanges. In particular, a new automatic battery charging principle incorporating digital logic[3] is used. The system can also be upgraded with microcomputer control and digital communication with a supervision centre monitoring several exchanges.
- The new packaging structure is compact and installation, operation and maintenance are simple. The design provides a high degree of staff safety.
- BZD 412 is extremely flexible, easy to extend and to use.
- The system design gives a high degree of reliability.

Thyristor rectifier

The rectifier BMT 343 for 400 A and 48 V has been described in detail in a previous article in Ericsson Review[1]. The rectifier is three-phase connected and has two transformers and a thyristor unit, twelve-phase coupled on the secondary side. The output voltage and the output current are regulated by means of phase angle control. The voltage from the thyristor unit is filtered with an LCL filter. The rectifier has the following characteristics:

- it can be used in all types of power supply systems
- it is designed for use with bad mains, that is mains with major voltage and frequency variations, frequent mains failures or weak mains with high impedance such as local standby generating sets
- it has protective and control equipment suitable for completely automatic operation in unattended exchanges
- it can be connected in parallel with an unlimited number of rectifiers, electronically controlled so as to divide the load equally
- it has all live parts protected from inadvertent contact.

Booster converter

The BMR 273 booster converter is a d.c. converter supplied with 48 V battery and with an output rating of 0-8 V and 400 A.

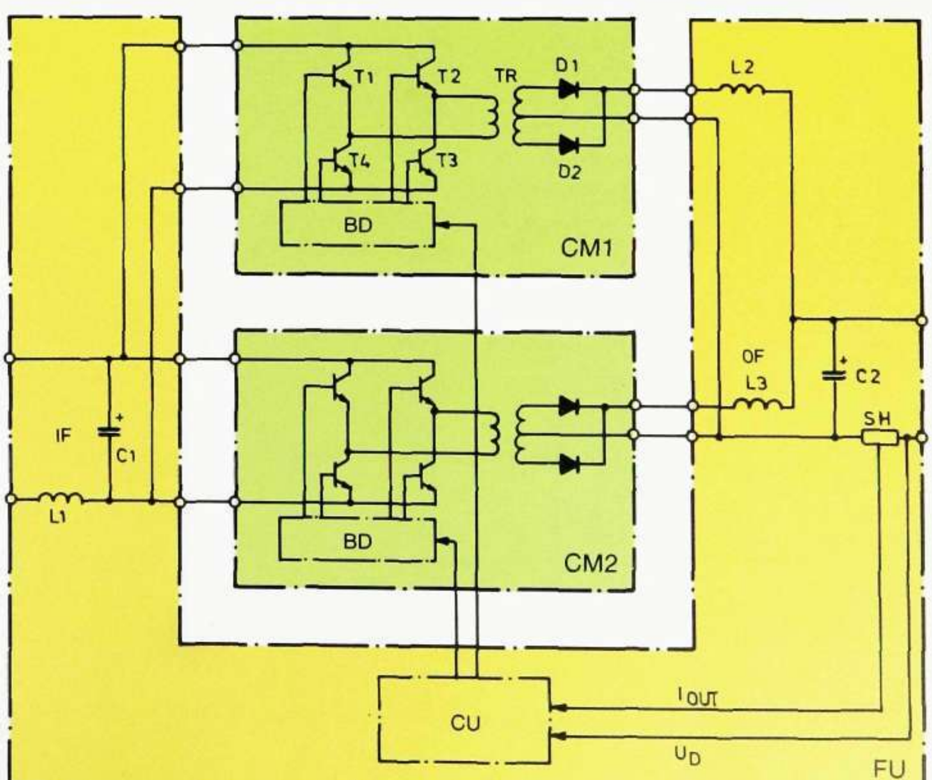


Fig. 5
Simplified circuit diagram for BMR 273

CM1	Converter module 1
CM2	Converter module 2
FU	Filter unit
T1-T4	Transistor units 1–4
TR	Transformer
D1-D2	Rectifier bridge
BD	Base drive circuits
CU	Control unit

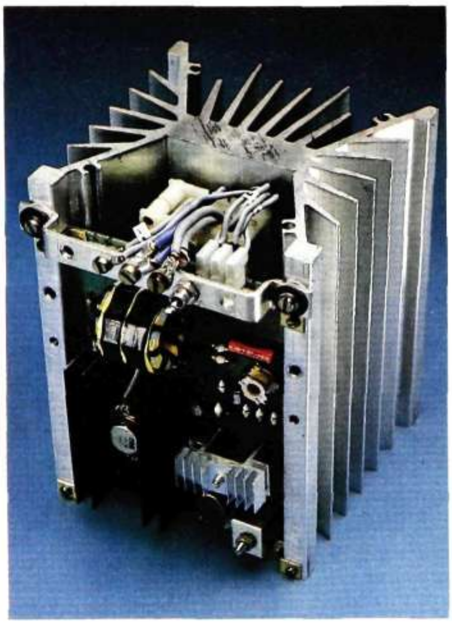
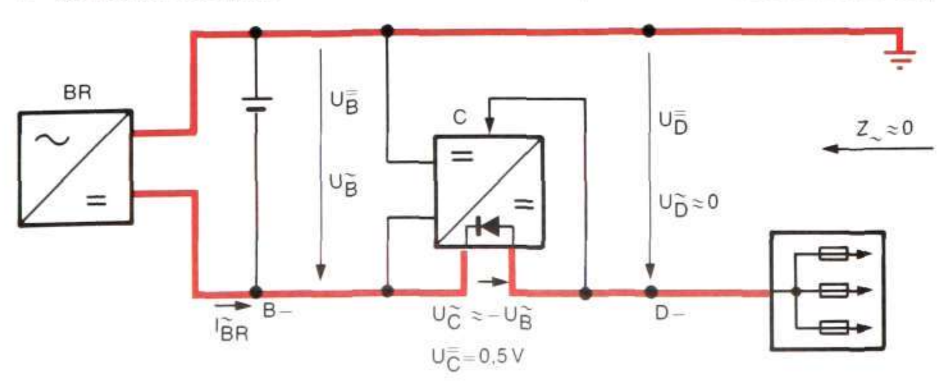


Fig. 6
The transistor unit containing power transistors, base drive circuit and heat sink

Fig. 7
LM Ericsson's standard converter system

BR Rectifier which delivers current to the exchange and also charges the batteries
C Booster converter which supplements the battery, for instance during a mains failure, and also functions as an active filter
$I_{BR}^{\sim}$ Alternating current from the rectifiers which generates noise voltage across the battery
$U_B^{\sim}$ Noise voltage across the battery
$U_B^{=}$ Battery d.c. voltage
$U_C^{\sim}$ Alternating voltage which the converter generates to counteract $U_B^{\sim}$
$U_D^{\sim}$ Noise voltage which reaches the distribution ($U_D^{\sim} << U_B^{\sim}$)
Z~ The impedance of the system



It adds its output voltage to the battery voltage and regulates the system output to the desired level, for instance when battery discharge occurs due to a mains failure. Because of good control characteristics the converter also functions as an active filter, suppressing low-frequency ripple voltages in the 0–600 Hz frequency range.

The converter circuit

Fig. 5 shows a simplified circuit diagram of the converter.

Two identical synchronously working converter modules, CM1 and CM2, are powered via an input filter L1 and C1. Each of the modules contains an inverter bridge equipped with transistors T1-T4 and associated drive circuits, BD, a ferrite transformer, TR, and a rectifier bridge D1 and D2 with Schottky diodes. The inverter bridge supplies the transformer with rectangular, width-modulated pulses of a frequency of 20 kHz. After step-down and rectifying, rectangular d.c. pulses of variable pulse-width are obtained at each converter unit output. From the two converter modules the voltage pulses are supplied to the converter output filter, L2, L3 and C2, which suppresses the a.c. component.

The inverter bridge in each converter unit is built up of high-speed, surge-current-resistant power transistors. Each transistor switch consists of two transistors connected in parallel. A special method of connecting the transistors in parallel has been developed in which the load currents are equally balanced with extreme precision both during the conducting time and during the switching sequence.

The base drive circuits, BD, convert the control pulses from the control unit, CU, into carefully formed drive pulses in order to ensure good functional characteristics during all possible operational situations.

The transistors, their heat sinks and the base drive circuit are mounted in a compact unit, fig. 6. Each inverter bridge contains four such units.

The control pulses are automatically regulated so that symmetry is obtained both for the internal a.c. in each converter module and for the load between the two modules.

The converter output circuit is rated for a continuous load of 150% of the nominal output current.

Control

All the operational control and supervision functions are built into the control unit. This means that each converter is an independently functioning unit but can react to external signals.

The control unit sends pulse-width modulated control signals with a repetition frequency of 20 kHz to the two converter modules. The control circuits regulate the pulse width so that the resulting distribution voltage (battery voltage + converter voltage) is kept constant within the load range 0–400 A. A minor drop in the control characteristic of about 150 mV guarantees equal load distribution between a number of units working in parallel. The desired control level is set by means of a potentiometer on the front of one of the control boards.

If there is a tendency for the load current to exceed the nominal value, the converter switches over to the constant current control mode. The output current is sensed by means of a shunt in the output circuit.

Active filtering of the ripple voltage

When rectifying mains voltage, a superimposed a.c. component is obtained, whose frequencies are integral multiples of the mains frequency. The amplitude of this ripple voltage can amount to several hundred mV, depending on the load, the impedance in the battery circuit, and on asymmetry in the three-phase supply network. The converter control system is so fast that ripple voltage in the frequency range 0–600 Hz is suppressed to levels in the 1 mV range.

Fig. 7 explains the filtering function in the converter system during normal operating conditions. Effective filtering requires the converter output voltage to be always at least 0.5 V. The converter generates an a.c. component $U_{\widetilde{C}}$ superimposed on the d.c. component $U_{\overline{\overline{C}}}$ and in phase opposition to the ripple voltage $U_{\widetilde{B}}$ across the battery. The resulting ripple voltage across the load $U_{\widetilde{D}}$ is limited in this way to a low value of the order of 1 mV. The converter filter function permits the system's output impedance $Z\sim$ for frequencies within the 0–600 Hz band to be kept very low, some tenths of a milliohm.

The filtering function makes it necessary for the converter always to be in active operation and to provide an output voltage of at least 0.5 V. For this purpose the control unit has a special regulator which interworks with the main converter regulator. Switching between these regulators takes place smoothly without overshoot.

If required, the filtering function can easily be disconnected, turning the converter into the passive operation mode in which the pulse width is brought down to zero when the distribution voltage exceeds the preset control level. The converter secondary circuit then introduces a voltage drop of about 1 V. Selection of the operational mode is made by a wire strap on one of the control unit boards.

Remote sensing, special functions

Sensing the distribution voltage normally takes place internally in the converter. However, sensing can be made at any desired point in the distribution by connecting this point to the converter by an extra wire. In this case the converter will be compensated for the voltage drop in the distribution conductor and hold the voltage constant at the sensing point.

As an alternative the converter control system can be connected to the system for master voltage control or for master-slave control.

The loss of any of these external signals causes the converter to revert immediately to normal constant-voltage control.

Protective circuits

The converter has the following protective functions built into the control unit:

- current limiting to the rated current, which prevents thermal overloading during operation
- high-speed overcurrent protection, which blocks the converter when major surge currents occur, for instance when there is a short-circuit in the distribution. Restart takes place automatically
- undervoltage monitor, which blocks the converter when the battery is discharged to a very low level. At the same time an alarm is given. The blocking is automatically cancelled when the voltage returns to the normal level
- selective overvoltage monitor, which blocks a converter that generates too high a voltage. Afterwards the monitor initiates a restart. If overvoltages occur repeatedly, the converter is disconnected and an alarm is given. The monitor must then be reset manually
- limitation of the converter output voltage so that excessive voltage is avoided during filter operation or master-slave operation
- slow start-up, which is initiated when a restart takes place after blocking. This gives a smooth regulation back to the correct level so as to prevent voltage overshoot

Fig. 8
Units forming part of BMR 273.
Two converter units and one filter unit. The control unit is located on three printed boards

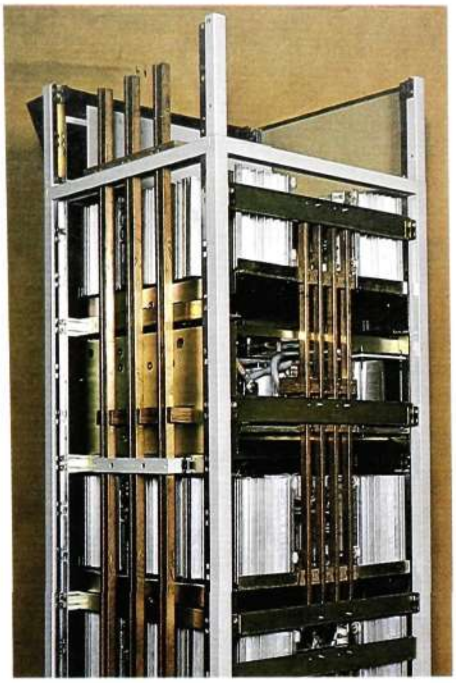


Fig. 9
The converter rack viewed from the rear and from the side.
The four vertical copper bars in the rack rear plane form the internal circuitry between the units. The equipment is connected to the main busbars via the bars shown to the left in the illustration

- encapsulated fuses to protect against internal short circuits
- electronic fuse alarm.

Parallel operation
An unlimited number of converters can operate in parallel and share the load both in active and passive operation.

Design
The complete converter consists of two identical converter modules and a common filter unit, which contains the converter input and output fuses and the control unit, fig. 8.

The control unit consists of three printed board assemblies plugged into a board magazine. The push buttons and the indicating diodes are placed on the front of one of the boards. An ammeter is mounted on a separate front panel.

All signal connections are made via plugs and jacks to the front of the units. Power is supplied to the units via fork contacts from the busbar system in the rack's rear plane. Connection to the system is made to the busbars in the rack via a switch on the right-hand side of the filter unit, fig. 9.

Each rack holds two converters.

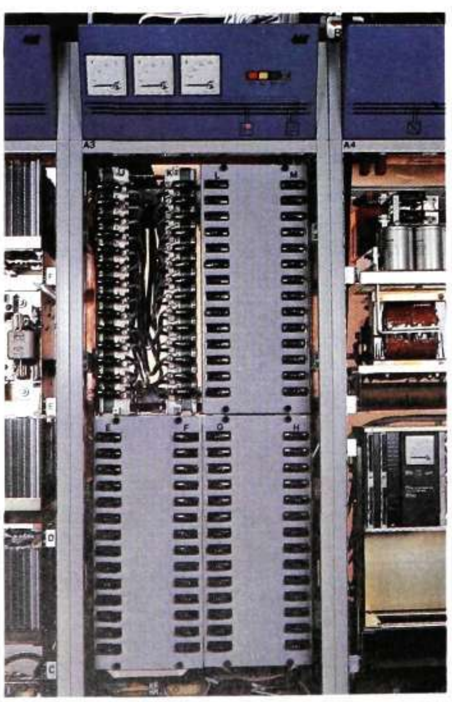


Fig. 10
Transient-limiting distribution.
Fuses ranging from 6.3 A to 35 A.
The plastic protection prevents accidental contact with live parts when changing fuses

Distribution

The distribution in BZD 412 can either be transient-limiting or low-ohmic.

The transient-limiting method of distribution[5] has been developed to supply electronic telecommunication equipment. Supply is effected over individual cables directly from the distribution rack to the units in question. One typical feature of the system is that the resistance in each of the distribution branches is at least 10 times greater than the total internal resistance of the power supply. It is possible to connect a resistor in series with each fuse to modify the conductor resistance for different distribution distances. This method of distribution effectively limits troublesome voltage transients when there is a short circuit in the distribution network.

The low-ohmic distribution method is used in electro-mechanical telephone exchanges where brief transients do not affect the operation. Here supply is carried out from the distribution rack fuses to the telephone exchange over heavy cables, which are then split up into smaller cables and run to the equipment. Thus each distribution branch will have a relatively low resistance compared with the internal resistance in the power supply.

Automatic battery charging
Optimum function and life of lead-acid batteries are achieved by always keeping them fully charged. An automatic charging system BMP 130 is included to provide high-speed, total recharging after every discharge.

The equipment supervises the state of the battery and sends pulses to the rectifiers to start and stop the charging process. During charging the rectifiers increase the voltage across the battery to 54 V (2.35 V/cell).

The battery charging state is supervised by measuring the change in the charging current over a period of time. This new principle has a number of advantages. It is independent of the type and size of the battery, and it avoids problems related to the dependence of the charging current on temperature and the age of the battery.

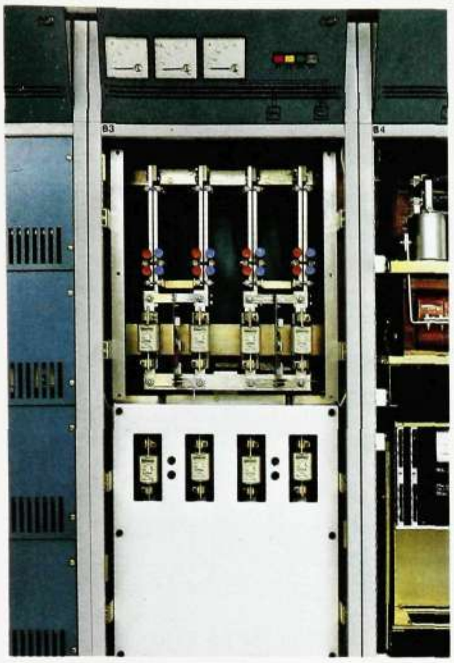


Fig. 11
Low-ohmic distribution
Cartridge fuses for a maximum of 400 A

The distribution rack

The distribution rack contains the distribution fuses, the battery fuses and, sometimes, equipment for automatic battery charging. The fuse units are suspended between the vertical power busbars in the left and right-hand rack uprights.

The battery fuse unit contains three fuses for a maximum of 630 A each, fig. 13. The battery cables are connected to the battery fuse unit with clamps or cable lugs. A maximum of eight 150 mm^2 cables can be connected per pole and battery fuse.

The rack for transient-limiting distribution can have 112 or 168 fuses, each for a maximum of 35 A. Outgoing cables are connected with a solderless terminal with a maximum of two 10 mm^2 cables per pole, fig. 10. In order to make cabling in the distribution rack easier, a cable holder has been mounted in the rear corner of the rack.

The rack for low-ohmic distribution has 28 fuses each for a maximum of 35 A and four fuses each for a maximum of 400 A or, as an alternative, eight fuses for a maximum of 400 A. The outgoing distribution cables are attached by clamps onto copper bars, one for negative and one for positive for each fuse. There is room for a maximum of six 150 mm^2 cables per pole and fuse, fig. 11.

The alarm wires from the fuse units are connected by plug-in cables to the signal and alarm unit. Visual alarm indicators are provided, one for each distribution fuse and one common to each battery fuse unit. A plastic protector is located in front of the fuses to prevent live parts being touched when fuses are changed. For this reason distribution fuses may be replaced by staff without special authorization to work on high voltage plants.

Mechanical packaging structure

The same packaging structure has been used for the BZD 412 system as for BZD 112[2]. The systems can thus be combined in one and the same installation.

The objectives which have been considered when designing both BZD 112 and BZD 412 are:
- great flexibility
- simple handling during installation, operation and maintenance
- a high degree of staff safety
- rational utilization of the space available
- esthetically pleasing appearance.

Rack design

The rack is 600×600×2200 mm with 30 mm square steel tube sections in the corners. The corner uprights are linked together with U-sections and aluminium joints. There are attachment bars on the uprights with 100 mm vertical spacing on which guide rails or units can be mounted at the desired height for the equipment. The front of the racks consists of equipment panels or doors. The side and rear surfaces are covered with

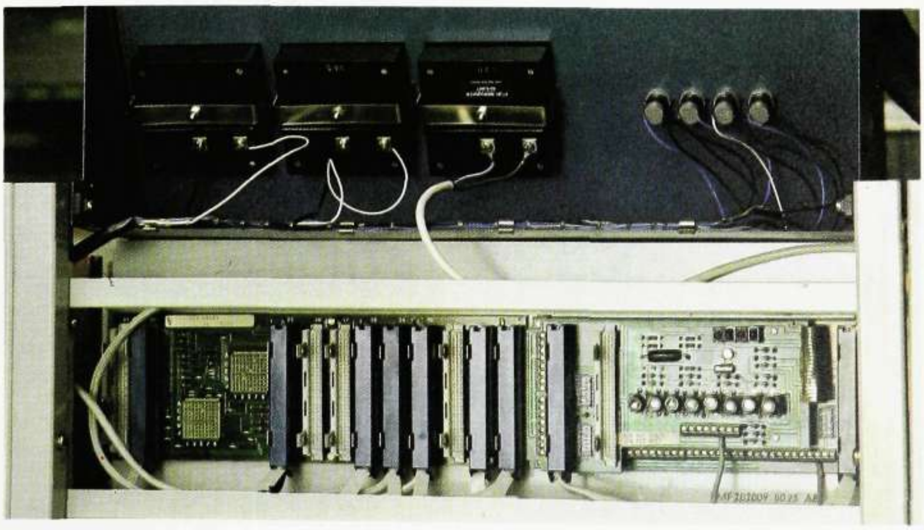


Fig. 12
Jack strip for connection of the plant alarm and operational signals

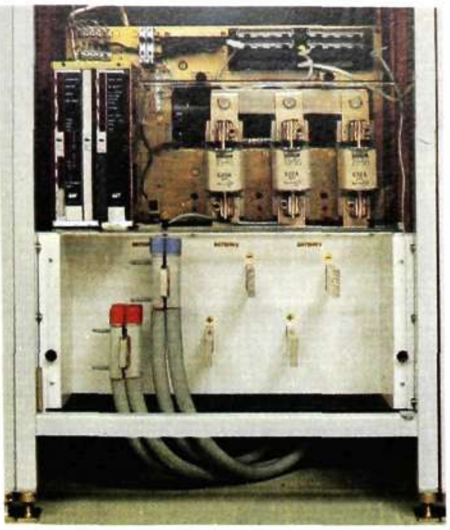


Fig. 13
Battery fuse unit with automatic charging control equipment of the BMP 130 type for a maximum of 630 A fuses

aluminium plates which are secured by screws.

Test instrumentation, alarm lamps for the system and the equipment survey diagram are placed in a metal hood on the top of the rack. The hood is sloped towards the observer making it easier to read the instruments. Behind the hood there is a box containing the signal cables in which the signal and alarm equipment is mounted; alarm and operational signals can easily be connected here, fig. 12.

The rack equipment is linked to vertical power bus bars in the rack end plates. These are connected at the top of the rack to horizontal bars which join all the racks in the plant. The racks are provided with adjustable baseplates to make it easier to set them up on uneven flooring. The rack frames are lacquered in light grey and the other plate surfaces have a blue hammer-finished lacquer.

Equipment design
Each piece of equipment is built up of one or several units either 470 or 500 mm wide, 570 mm deep and the height is in multiples of 100 mm. An example is shown in fig. 8. The units consist of side plates and between these, either a perforated plate or a framework for mounting the components. The instruments, indication lamps and push buttons for the normal operation of the units are visible through windows in the front panel; the latter has a perforated lower edge.

The units are convection cooled. Cold air enters through the bottom of the rack and through the perforations in the front panel.

The units are slid in on guide rails in the rack and connected to the vertical power buses in the rack via a switch or directly with cables. The signal wires from the units to the plant and between the units are connected with plugged cables. Installation can be carried out using simple hand tools by staff without any special training, fig. 15.

Design of a power supply plant

The design and packaging structure of the units results in power supply equipment offering very great flexibility. It can easily be upgraded and adapted to various types of telecommunication plant, fig. 14.

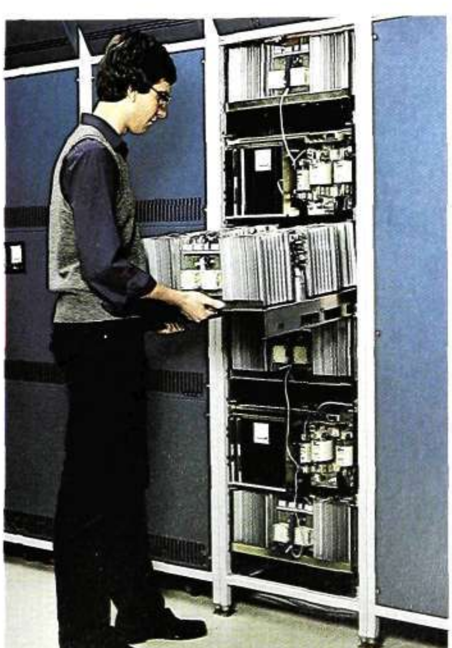
A power supply plant consists of racks 600x600x2200 mm in size, containing either:
- one rectifier for 400 A

Fig. 14
The illustration shows two plant modules, each for 800 A, consisting of two rectifiers between which the converters and distribution have been placed to limit the current in the top bars

Technical data for BMR 273

Input data		
Voltage, permissible variations	V	38 to 56
Maximum current at $U_{IN}=40$ V and $I_{OUT}=400$ A	A	115
Efficiency with 50% of rated power	%	80
Output data		
Current	A	400
Maximum voltage with $U_{IN}=41$ V and $I_{OUT}=400$ A	V	8
Static regulation accuracy	%	±0.5
Dynamic regulation		
– response time for step changes in load with 100 A	ms	<1
Noise voltage over the load		
– psophometric	mV	<0.5
– peak value at 40 kHz	mV	<100
Operational data for the converter system		
Regulation level for distribution voltage		
– normal value	V	49
– setting interval	V	45 to 54
System efficiency, active operation	%	95
Voltage drop across the output with passive operation and $I_{OUT}=400$ A	V	1.05
For the noise voltage in active filter application the ratio between the levels for the converter out of, and in operation is		
– at 100 Hz		>40
– at 300 Hz		>10
Power consumption with active filtering		
– $I_{OUT}=400$ A, $U_{OUT}=0.43$ V	W	925
– $I_{OUT}=100$ A, $U_{OUT}=0.48$ V	W	200

Fig. 15
The equipment consists of factory-assembled units which are slid into the rack on guide rails



– two converters for 400 A
– distribution equipment in the transient-limiting mode for a maximum of 800 A
– distribution equipment in the low-ohmic mode for a maximum of 1200 A.

The plant has been designed so that a minimum of current will flow in the connection bars between the various racks. Extensions to the distribution equipment and battery take place in step with the upgrading of the rectifier and converter equipment.

The equipment and rack design permit considerable freedom of layout. The plant can be assembled in stand-alone rows, double-sided rows or against a wall and additions can be made both to the right and left of the row. This makes for considerable ease in planning new or extending existing plant, and available premises can be utilized rationally.

Reliability

The power supply equipment for a telephone exchange must be extremely reliable. This has been achieved by the following precautions:

When designing the equipment
– only high-quality components have been selected and these have been subjected to extensive tests before being approved
– design rules have been applied which afford wide safety margins.

When planning the system
– there is a stand-by for every piece of equipment and for each important function (redundancy)
– each piece of equipment has been constructed as an independent unit
– there are no central units which can affect the function of the whole plant.

The repair frequency has been calculated to be of the magnitude of 0.05 per equipment unit and year.

The estimated mean time between system failures (MTBSF) is 3000 years or more, assuming a normal equipment redundancy of 20% or at least one extra unit. A system failure has been assumed to occur when the number of faulty units exceeds the number of redundant units. This normally means only a degradation of the plant function and not an interruption in operation. The life of the equipment has been estimated to be 40 years. The probability of a system failure during this period will be less than 1%.

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Mobile Telephony in the Nordic Countries

Thomas Haug

The collaboration between the Nordic Telecommunications Administrations originally concerned only matters that related to the handling of the traffic between the countries. Since then the collaboration has successively been extended to other fields and has also included technical development projects. Such a project is the Administrations' joint development of a Nordic mobile telephone system. This article describes the Nordic collaboration in this field and gives the background to some of the problems and their solutions. Technical descriptions of the system have been published earlier[5, 6]. For details of the system, reference should be made to these articles and to the publications of the Nordic Mobile Telephone Group[1-4].

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During the latter half of the 1960s the number of subscribers in the Nordic mobile telephone systems increased rapidly, and the Administrations realized that new systems would soon be needed. The matter was discussed at the Nordic Telecommunications Conference in 1969, and it was decided that it would be most advantageous to have compatible systems in Denmark, Finland, Norway and Sweden. The situation was in many respects similar in these four countries, and the road traffic across the borders was increasing steadily, which made the prospect of joint mobile telephony increasingly attractive. A working group was therefore appointed with the task of investigating the prerequisites for compatible systems in the Nordic countries.

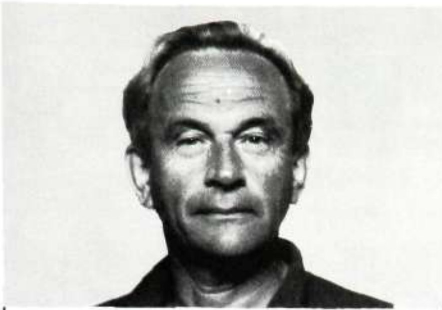
The working group, which took the name Nordic Mobile Telephone Group, NMT, first prepared outline specifications for a manual system, almost of an interim type, which was later built in Denmark, Norway and Sweden. This was followed by the considerably more extensive work on specifications and other necessary data for an automatic system.

Frequency and permit problems

Two problems which were of fundamental importance for the usefulness of the system were the choice of frequencies and the question of permits for mobile subscribers who are outside their own country.

First a frequency band had to be found that was suitable for mobile communication, that was available in all four countries and also had sufficient capacity for the amount of traffic that could be expected during the life of the system. It was not easy to find a frequency band that met all these requirements, partly because the countries have different frequency allocations for military purposes. There was no possibility at all of coordinating any frequencies below 425 MHz. The bands 453–457.5 and 463–

Fig. 1
The base station for mobile telephony at Nacka, outside Stockholm, Sweden. As far as possible, existing radio and TV masts and buildings are used for the base stations. In this case the mobile telephone antennas are placed in the left-hand mast, at a height of approximately 200 m. The other base station equipment is placed in the building immediately to the right of the mast



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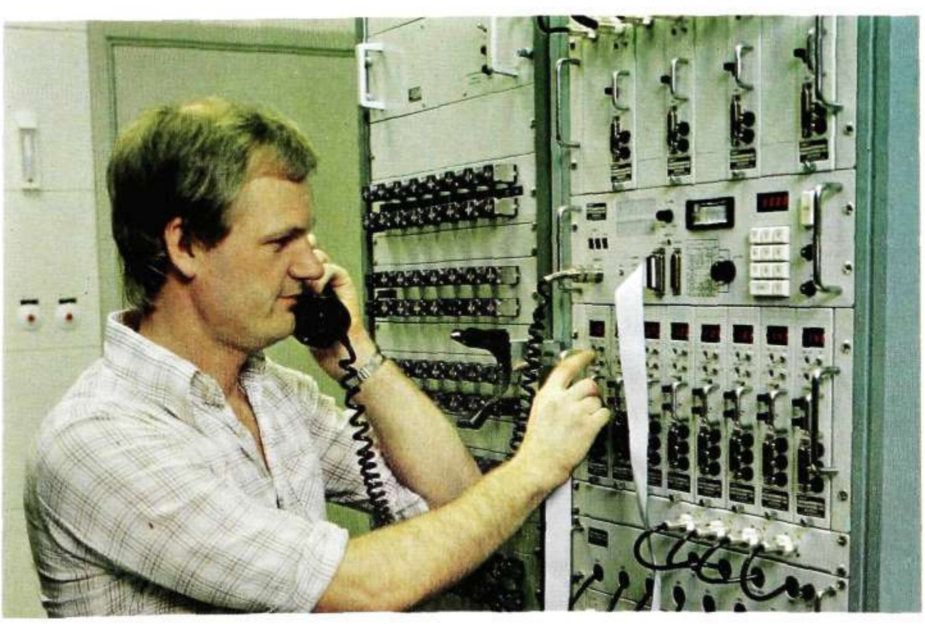
467.5 MHz were suitable for most of the countries. As far as Sweden was concerned, the problem was that an agreement with the defence establishment prevented these bands from being used for civilian purposes in wartime and during periods of military preparedness. In view of the large investments in military equipment for these frequency bands it was difficult to obtain any changes in the agreement quickly. It was only after long negotiations that the problem could be solved satisfactorily. The Swedish Administration was then able to inform the other countries that it could agree to the new system using the above-mentioned frequency bands, which with a channel spacing of 25 kHz gave 180 duplex channels. By this time the problem had become acute, since the manual system was almost ready to be put into operation. This system was to use some of the channels in the agreed bands. The automatic system would later successively take over these channels, and the manual system could then be closed down.

The second problem was that existing regulations had to be changed so that mobile subscribers could also use the equipment during journeys in the neighbouring countries. The usefulness of compatible systems to the subscribers depends on their being able to use the systems in the other countries without any bureaucratic procedures and also being allowed to use radio circuits across the border, at least in the border regions. The older systems did not permit such joint traffic, and exhaustive discussions were necessary before all countries could agree to give blanket permission. In one case the law had to be changed.

Fig. 2
The base station equipment at Nacka. To the left is the line rack and to the right the base station, a version for eight channels

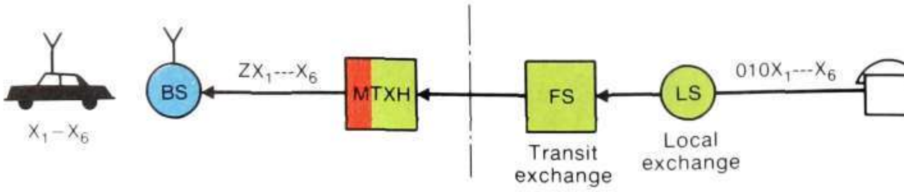


Technical principles

The main part of the work of the NMT group has been to specify the automatic system and verify that the ideas were feasible. The group started the work on the automatic system by laying down some preliminary basic operational requirements. One of the main principles was that the system should, as far as possible, function as an extension of the fixed network. Consequently the behaviour of the system, as experienced by both mobile and ordinary subscribers, has to be as similar as possible to that of the fixed network. This requirement had to apply for all parts of the system in both traffic directions, for the handling of the mobile exchanges, for calls from the fixed network, for the services offered and for the security functions. It was also desirable that the system should offer the same traffic facilities as the fixed network. Thus it had to be possible for any A-subscriber to establish contact with a mobile station without any special operations, as long as the mobile station was within the range of the system, even if it was away from its home area. It was also clear that for economical and practical reasons it was impossible to make any appreciable changes in the fixed networks, which must therefore be accepted as they were.

The above-mentioned requirements meant that the system had to be equipped with facilities over and above those now provided in the fixed networks. The chosen design means that a stored program controlled exchange, MTX (Mobile Telephone eXchange) which provides the majority of the new functions, is placed at the interface to the fixed network. MTX is identical in all countries with the exception of variations in the interface towards the fixed network. For routing and transmission reasons MTX is connected to a transit exchange in the telephone network, and

Fig. 3
A mobile station which is reached from its home MTX (MTXH). The access code 010 applies for Sweden



will itself in some respects function as such an exchange. MTX must also contain many of the functions which in the fixed network are placed in the local exchanges, such as rating, charging and other subscriber functions. The set requirement are considerably more demanding than those set for previous mobile telephone systems, and this naturally affected the solutions found for the various problems.

As a result of the requirement that the system should be compatible with the existing telephone network without changes it was necessary to find new ways of solving the numbering problems. Since the digit capacity of the local registers in the fixed networks was limited to seven digits (eight in Sweden) in addition to the trunk code, and since it was not possible to use an access number that was shorter than the trunk code followed by two digits, in general only five digits were available to indicate a mobile subscriber on the radio route. This capacity was obviously too small, particularly if it was to be spread over four countries. Sufficient number capacity was obtained by equipping MTX with the possibility of inserting a country code, Z, before the subscriber number in the case of calls to mobile stations. This means that a call to a mobile subscriber will always first be routed to his home MTX (MTXH). In order to enable the callers to reach mobile subscribers who are out of reach of their MTXH, the latter must add further digit information. This means that on the basis of its knowledge of the mobile subscriber's whereabouts, the MTXH sets up a call to the MTX concerned, regardless of in which country that MTX is situated. The information concerning the identity of the sought subscriber, including the country code Z, is then transmitted using MFC signalling end-to-end. Since the MTX concerned receives the information over a speech channel that has already been established, it can distinguish this case from the cases where it must insert its own Z, figs. 3 and 4.

However, the call connection method described here means that calls to a mobile subscriber away from his home area would use a longer path than that for which the caller is charged. The principle of always charging the A-subscriber had to be adhered to. Hence the use of the long distance circuits would not bring the Administrations any additional income. The proposed connection method would thus introduce a new rating principle, but the Administrations accepted it unanimously since its advantages were considered to outweigh the disadvantages.

The possibility of switching a call from one base radio station to another while the call is in progress[5,6] helps to give good speech quality. The advantages of this facility become even more apparent when the range of the base radio stations is reduced and a small cell system is introduced. In a few years this will be done in the region comprising Copenhagen and Malmö, where the traffic is expected to increase most rapidly.

Trial system

At an early stage the NMT group realized that the proposed functions would require processor control of both the base radio stations and the mobile stations. This fact was not considered a problem in view of the rapid development in the microprocessor field. However, the demands made on the signal transmission over the radio route could cause problems, and practical tests were required to verify the ideas.

A small joint trial system was designed by a subgroup within NMT and was built

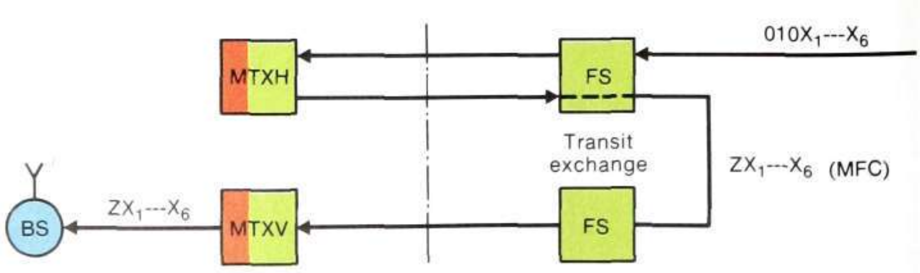


Fig. 4
A mobile station which is reached from an MTX (MTXV) other than the MTXH

in Stockholm, in the laboratory of the Swedish Telecommunications Administration. It had been calculated that a 1200 baud binary signalling system would meet the requirements regarding transmission capacity and flexibility. However, many questions remained unanswered, for example which modulation method would be best suited to the transmission medium in view of the fact that reliable signalling was required everywhere where the field strength was sufficient for acceptable speech quality. A number of subjective listening tests were first carried out in order to determine what could be regarded as satisfactory speech quality and to relate this to a certain input signal, with and without fading, to the mobile station. It was then decided what signalling error rate could be accepted with the lowest acceptable speech quality, and thus objective, measurable quantities were obtained for use in the trial system.

Fig. 5
Equipment for combining a maximum of ten channels to a common output or antenna. The picture shows one unit for ten channels and one for nine.

The transmission reliability is affected by many factors, especially on radio routes, for example:
- intermodulation
- interference from adjacent channels
- interference from the same channel from a distant base station
- fading.

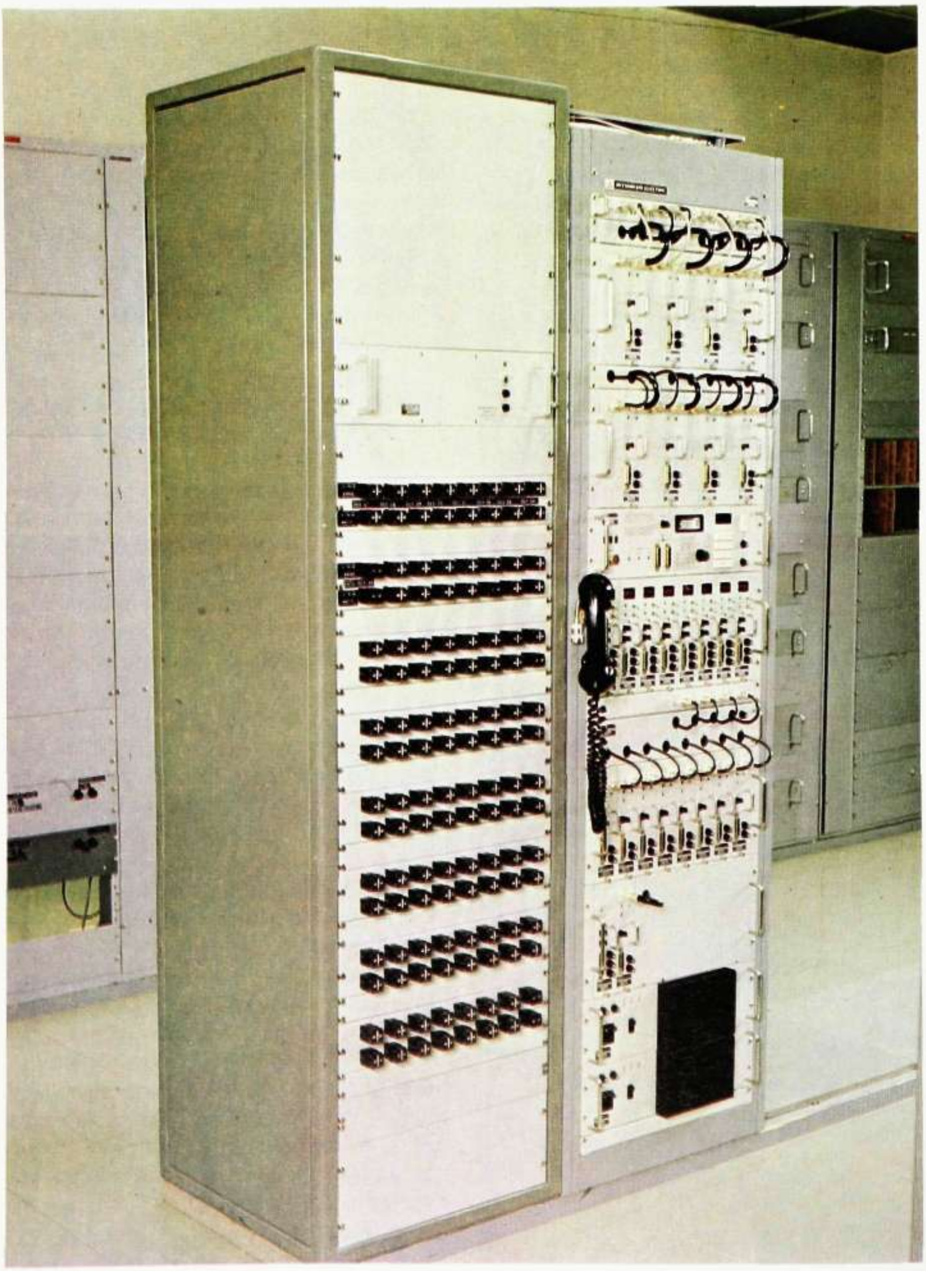
The effects of fading have been studied thoroughly in the trial system. There are basically two reasons for fading in mobile communication on land. The first is obstacles, such as buildings, hills etc., which cause sharp or diffuse shadows. A moving mobile station experiences these as fading which with normal driving speeds lasts for several seconds (slow fading). The second reason is that in a terrain that permits multipath propagation, i.e. where reflected waves can interfere with each other or with direct waves, there will be variations in the received field strength, which in a moving mobile station give fading with a shorter period. 10–20 ms is a common value for the 450 MHz band at a speed of 50 km/h.

These two types of fading often occur simultaneously. Furthermore, the field strength will of course vary with the distance to the base station. The resultant variation of the field strength with time is therefore a complicated function, and it was not possible to calculate theoretically how it would affect the signal transmission. Extensive tests must therefore be carried out.

Laboratory tests were first carried out, with fading recorded on tape, and it was found that certain modifications had to be made. The signalling system could then be tested in the trial system, which consisted of an exchange and three base stations set up in two traffic areas. The laboratory tests had proved that the signalling system would work, but a large number of tests, with subsequent statistical analysis of the various signalling sequences that could occur, were required in order to ensure optimum function. As had been expected, the analysis showed that certain sequences had a lower degree of reliability than calculated, and these sequences were modified. For example, pre-seizure dialling from cars was made compulsory, since it increased the setting-up reliability. The work on the trial system also gave valuable information for improving the system in many other respects.

It has been decided to keep the trial system in operation for some time yet in order to make it easier for the manufacturers to test equipment. A summary has been compiled of the tests that have been carried out using the trial system[7].

Fig. 6
A base radio station with the line rack to the left



Traffic simulation

The mobile telephone system contains many new ideas which have not been tested in systems in service. It was possible to check the suitability of the signalling system in the trial system and to carry out the necessary modifications. However, the behaviour of the system with a heavy traffic load could not be tested in the trial system, since the latter only included a few mobile units. The system contains several functions which could cause traffic effects that had not previously been studied in any detail. As the subscribers are mobile, the number of subscribers in any area varies. Moreover the subscribers are often within reach of more than one base station, particularly in the city regions. The transmission quality on the radio route also varies largely with time, which results in changeovers during calls. The criteria on which the mobile station decides which base station to use are of great importance, among other things for the switching functions in MTX.

In order to get a clear understanding of the effect of traffic on the function of the system, A/S Norsk Regnesentral, Oslo, Norway, was contracted to carry out extensive traffic simulation. The input data for the simulations included the result of statistical analyses of the fading tests in the trial system. Some of the questions for which answers were sought were:

- How are the mobile stations distributed among the base stations when the overlap areas are allowed to vary in size?
- How many changeovers will the system carry out during each call with different criteria for the changeover?
- How is the traffic distributed among the different base stations?
- How large will the amount of updating traffic be?

It is not possible to describe the simulation work in every detail here. The main result was that the system in accordance with the chosen model seems to work satisfactorily. The slow fading is the most important factor for deciding the number of changeovers between base stations and the number of reconnections and disconnections. It was found that a considerable reduction in the number of changeovers and reconnections can be obtained with moderate changes in the placing and power of the base stations. The simulation program, which is the joint property of the Administrations, will subsequently be used to solve specific problems concerning the placing of base stations in and around the capitals.

Other problems

In order to obtain conformity throughout the Nordic countries the group has also discussed several non-technical problems. One example is the question of who is to own the mobile stations. In the fixed network it is usually the national or local Telephone Administration who owns the telephone sets. In view of the fact that the mobile stations have a more complicated interface towards the system than a telephone set, it may seem obvious that the Administrations should also own the mobile stations. This is the case in the present Swedish local automatic mobile telephone system in Stockholm, Gothenburg and Malmö, MTB. However, the group found that a system with the mobile stations owned by the Administrations would have more disadvantages than advantages. Above all, large investments would be necessary, both for purchasing mobile stations and for building up a service network. Another important factor was that in a system where the Administrations own the mobile stations it would not be feasible to supply all makes of mobile stations. It would be necessary to limit the range severely, and the desired amount of competition between manufacturers could not be obtained.

The main advantage of all mobile equipment being owned and supplied by the Administrations would be that a certain level of maintenance quality could be ensured. However, this would require some form of regular inspection, which was not considered desirable for administrative reasons.

The group therefore proposed that the purchase and maintenance of the mobile equipment should be a matter between the manufacturer and the subscriber. The Administrations accepted the proposal. This means that the Administrations have no control over the mobile stations beyond the type testing, which therefore becomes very important. One prerequisite for the inter-country traffic facility is that the mobile station interfaces towards the land-

Fig. 7
Different makes of mobile station equipment

based equipment is identical everywhere and for all makes. This interface is rather complicated, and it is essential that the type testing is carried out meticulously and under exactly identical conditions for each test, regardless of place or time. If this uniformity can be achieved, it should normally be sufficient to carry out detailed type testing of a mobile station in only one country. The acceptance in the other countries where the manufacturer desires to market his equipment will then usually be only a formality.

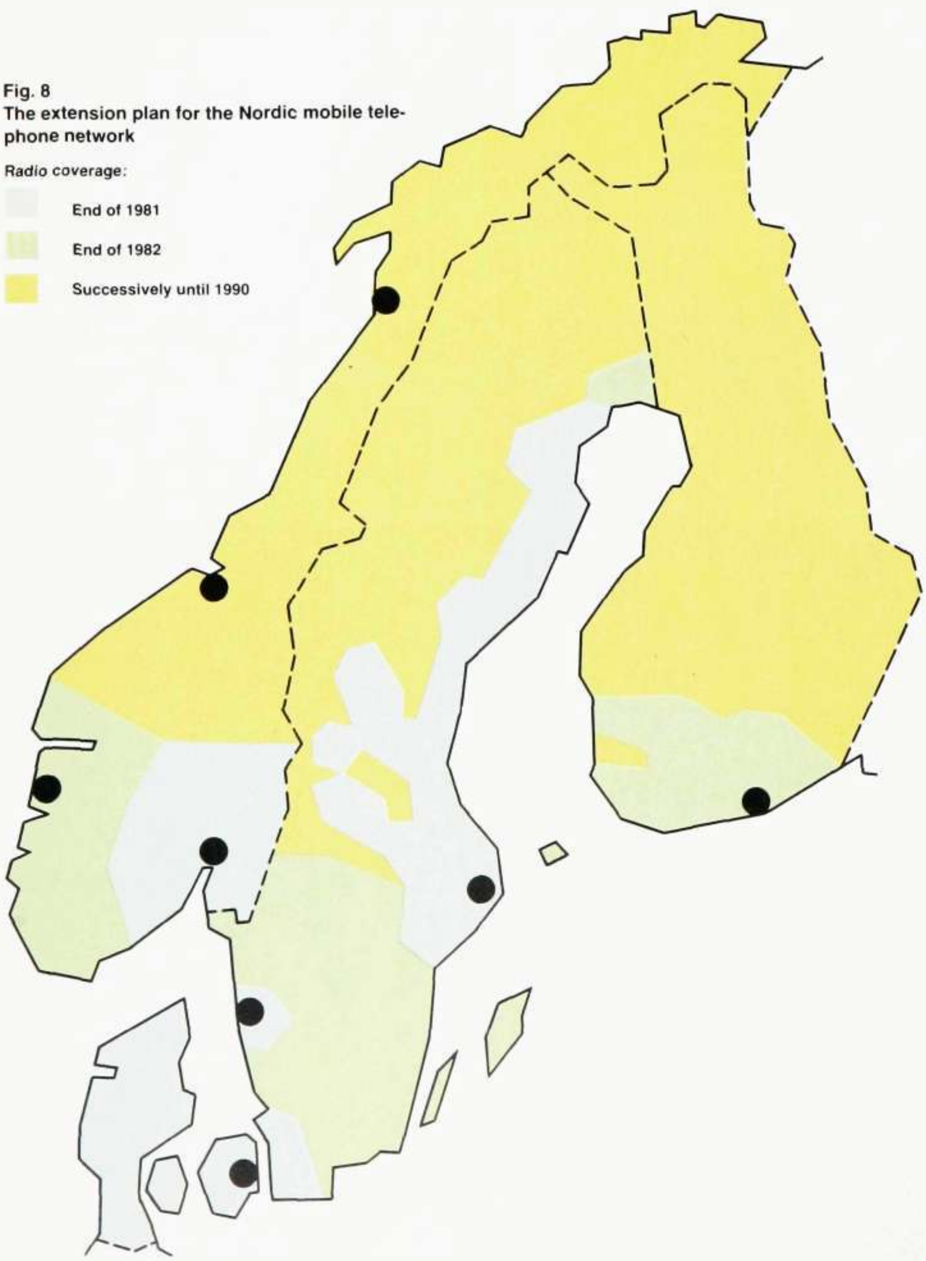


Fig. 8
The extension plan for the Nordic mobile telephone network

Radio coverage:

End of 1981

End of 1982

Successively until 1990

The group devoted a considerable amount of time and labour to specifying the testing method and equipment in order to ensure the desired uniformity of tests. Certain functional tests must be repeated many times under different, carefully specified conditions, after which statistical evaluation is carried out. This requires a system simulator, which simulates the land-based system and which quickly carries out the required number of measurements. The simulator was specified jointly by the Administrations, and each Administration has purchased one. The uniformity of the evaluations is now assured as far as possible.

Another aim of the NMT group was to standardize, to some extent, the man-machine interface towards the mobile stations, without preventing the manufacturers from following different paths towards what they considered the optimum design for the equipment. Fig. 7 shows some types of mobile stations.

The Administrations must of course own the mobile telephone exchanges and the base radio stations and be responsible for their performance. It was decided that they should be purchased in the normal way by the appropriate department in the different Administrations. Thus the role of the group could in this respect be limited to preparing certain common specifications. However, the conditions concerning the construction and operation of the system are so similar in the four countries that it was quite natural for the group to coordinate the activities of the Administrations also as regards the invitation to tender, evaluation, delivery and follow-up.

As regards mobile telephone exchanges, NMT appointed two subgroups which were responsible for the technical specification and evaluation of tenders, and for the commercial evaluation. The basic data for the tenders were issued simultaneously by all Administrations and couched in identical terms. This laid the foundation for a uniform assessment, which greatly simplified the subsequent work. The result of the common assessment was that LM Ericsson's tender for a modified AXE 10 exchange was placed first. The four Administrations then contracted for a total of six mobile exchanges, to be delivered in accordance with a time plan prepared jointly by the Administrations. The good collaboration between the Administrations, which had started during the tendering stage, has continued during the follow-up period.

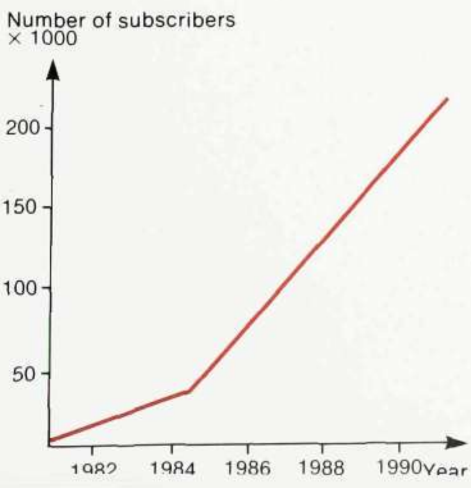
Coordination was also needed for the base radio stations, and a joint technical specification was therefore prepared by an expert group. For several reasons the Administrations desired to distribute the orders among three manufacturers. Extensive, coordinated follow-up work is now also being carried out for the base stations.

Another field that needed coordination was tariffs. The fact must be accepted that the tariffs differ in the Nordic countries. The tariff levels in the wire networks vary and the countries have different tariff policies. However, a similar tariff structure seemed feasible, so that the same principles were applied when charging for the various services. Tariff experts from the Nordic countries prepared a proposal for such uniform principles. This proposal formed the basis for the tariff regulations.

Summary

The mobile telephone system has now been or is being installed in the Nordic countries and was in part put into service in the summer of 1981. It will successively be extended in accordance with the plan shown in fig. 8. The corresponding subscriber prognosis is shown in fig. 9.

Fig. 9
Prognosis for the number of subscribers in the Nordic mobile telephone systems



The system is in many respects a compromise between conflicting demands. The requirements that were originally formulated by the NMT group have been met in general, if not in every detail. However, the great interest which the work of the group has aroused abroad concerns not only the design and characteristics of the system, but also the fact that the project has been carried out in collaboration between Telecommunications Administrations. This collaboration has been considerably more far-reaching than is usual outside the Nordic countries. The excellent result is largely dependent on the fact that the NMT group, like many other Nordic working groups, has not been troubled by the confrontations that so often occur in international working groups. Naturally there have been several vigorous discussions concerning difficult problems where the members have been of different opinions. Nevertheless the group has always been able to keep the discussions on the technical plane. The dividing lines have more often lain between representatives of different technical branches than the representatives of different Administrations. Unlike political problems, technical problems can generally be analyzed and solved with the aid of common sense and a will to compromise. When the Nordic mobile telephone system is now taken into service, the NMT group hopes that the system will meet the technical, traffic and economical demands made on it by the Administrations and the subscribers.

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CONTACT RL400—a New Radio Relay Equipment

Einar Lundblad

SRA Communications AB, a Swedish subsidiary of LM Ericsson, has developed a radio relay equipment, CONTACT RL400, for telecommunication between mobile military units. The equipment works in the UHF band, providing 24 telephone channels when analog transmission is used and 120 channels with digital transmission. The equipment is microprocessor controlled, which makes it easy to handle and provides efficient supervision.
The article describes the equipment, its supervisory system, which also provides protection against jamming, and how this protection can be developed further.

UDC 621.396.93

Modern warfare requires a high degree of mobility and good telecommunications for coordinating activities. Most defence forces are provided with equipment that enables them to quickly establish and rearrange telephone networks between military staffs. Frequency multiplexing is used in order to obtain sufficient capacity over the connections, and the original transmission medium consisted of cable. However, as the staff have to move often and quickly in order to adapt to the tactical situation, the cable connections have gradually been supplemented with or replaced by radio relay links.

Radio relay equipment which operates in the UHF band has therefore been used in military telephone networks for some decades. However, the use of radio means that the transmitters can be detected, monitored and located. The changeover to digital time multiplexing, with equipment for bulk encryption, has now made monitoring useless.

The possibility of locating transmitters increases the risk of attacks or jamming. One countermeasure is to use the various radio circuits only for short periods. This necessitates light, mobile communication units which can be used to set up new connections quickly to replace others. The increasing number of equipments and the complexity of the combined networks mean that flexibility and easy operation are two prerequisites for such communication units.

These operation prerequisites and the requirement for protection against jamming have all been considered when designing CONTACT RL400, fig. 1. The design and construction have been chosen so that the protection against jamming can easily be improved further.

The equipment is designed for transmitting signals from both the older, frequency multiplex systems and the new, encrypted, digital time multiplex systems in order to facilitate a gradual changeover from the older to the newer systems.

Fig. 1
Radio relay equipment CONTACT RL400

EINAR LUNDBLAD
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Operation

CONTACT RL400 is controlled and supervised by a microprocessor. Commands and information are fed into the processor via buttons on the front panel. The information from the processor is shown on a display screen on the front panel, fig. 2.

There are two types of buttons, function and digit buttons. In order to prevent accidental change of operation of the equipment it is normally necessary to depress a function button while the associated information is being fed in.

Channel setting is carried out by depressing the button marked RADIO CH. The channel number is selected by depressing button A or B and three digits. Each channel number corresponds to one transmit frequency and an associated receive frequency. Buttons A and B determine which frequency is to be used for transmitting and receiving respectively. If one station selects channel A 183, the opposite station must select B 183. The use of set frequency pairs simplifies network planning and the operation of the equipment.

However, there is a risk that by means of signal search the enemy radio intelligence will succeed in discovering the relation between the receive and transmit frequencies for different channels. When the transmit frequency of one station has been detected it will then be possible to jam the receive frequency of the same station. This can be avoided by selecting independent frequencies for the receiver and the transmitter. The button TX FREQ or RX FREQ is then depressed while the desired frequency is fed in in the form of four digits, corresponding to the frequency in MHz, with one decimal. The processor then checks that the frequencies are covered by the equipment and that the combination is permissible.

When the frequencies have been selected and accepted, the processor controls the frequency synthesis in the equipment, connects in the required filters and displays the selected frequencies on the display panel, together with the channel number if a channel has been selected.

The button OP MODE is used to set the equipment to the type of multiplex equipment to be used and to the desired output power. When the button is depressed, the alternatives for a first choice are displayed, namely TDM or FDM, with information regarding which digit buttons correspond to the different alternatives. When the desired alternative has been selected, the alternatives for selecting multiplex capacity and output power are successively displayed. In this way the operator is guided towards all necessary choices.

When the above-mentioned choices have been made, the corresponding information has been stored in a memory that is independent of the power supply, and the equipment is ready for operation.

The equipment can also be programmed via a multi-pole connector, OPERATING MODE, on the front of the unit, to which an external control equipment or a programmed plug can be connected. The programmed plug is particularly suitable if the equipment is to be used in a network where the settings are not changed very often. In the case of a fault the programmed plug can be moved to the replacement unit and quickly give this the same programming. When the programmed plug is connected to the equipment the function buttons are usually inoperative.

Supervisory system

The equipment has a built-in automatic supervisory system, which enables any faults to be located quickly. During operation all internal test points are scanned and the results are compared with limit values. If any test point value falls outside the limit, this is indicated by a short audio signal, and the test point number is displayed. The operator can get the value in question displayed by depressing the button TEST. The operator can also accept the test point alarm by depressing TEST and B, whereby automatic alarms from this test point are cut out. This may be appropriate if the test value only differs from the limit marginally and the equipment is otherwise working satisfactorily.

The individual test point results can also

Fig. 2
The keyboard and display panel on the front of radio relay equipment CONTACT RL400

be checked, for example during a check-up or maintenance, either by addressing the desired test point, by depressing TEST and keying the test point number, or by depressing TEST and A, which gives the first test point value. Depressing A again will give the following test point, and so on. The test point number is shown when A is depressed and the test point value when A has been released.

A transmission fault causes a test point alarm but also an intermittent audio alarm, a visual alarm signal on the front panel and a contact closure for external alarm. The audio alarm and the external alarm can be disconnected by depressing TEST. A return to normal alarm function takes place automatically when the fault that caused the alarm has been cleared.

Simple local testing of the equipment can be carried out by means of two different loop connections. These are set up with the LOOP button. With the high frequency loop the transmitter is coupled back to the receiver for a complete functional check of the equipment, including any multiplex equipment. Any functional faults can then be further located with the aid of the low frequency loop alowing functional testing of the low frequency parts of the equipment including the multiplex and interconnecting cables.

External meters can be connected via a two-wire cable for monitoring the received HF signal at the antenna mast when adjusting the antenna direction. The strength of the received signal is displayed also on the front panel in the form of a normal test point value, and on an indicator with four light emitting diodes. With digital transmission the diodes show the result of the continuous bit error monitoring of the transmission.

The display panel is normally extinguished 30 seconds after a command has been received. It can be lit again or switched off earlier by means of the button LIGHT. The button marked LED is used to test all light emitting diodes in the display panel.

Electrical design

CONTACT RL420 is the first version in a series of equipments with the common designation CONTACT RL400. RL420 has four 50 MHz bands in the frequency range 610–960 MHz. The four 50 MHz bands can either be combined to form one 200 MHz band or they can be placed separately within the range. The frequency coverage can be altered by changing the duplex filter unit. The new unit provides the processor with information regarding its frequency coverage.

Both analog (FDM) and digital (TDM)

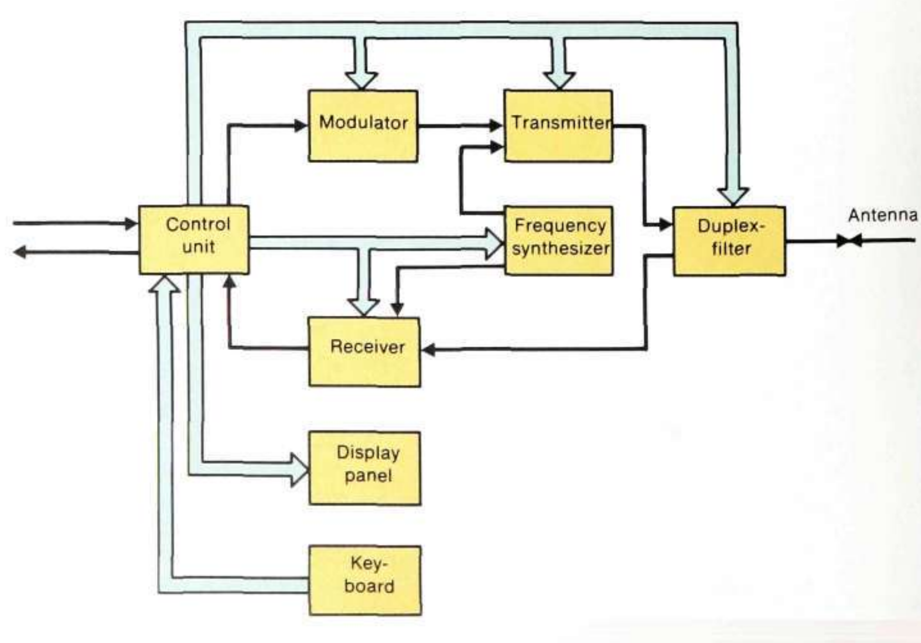


Fig. 3
Block diagram of CONTACT RL420

multiplex systems can be transmitted using CONTACT RL420. With analog transmission the equipment can transmit the basebands of systems with between 4 and 24 channels. The equipment can also be modified to suit FDM systems with a larger number of channels. With FDM operation the physical channel, 0.3–2.5 kHz, is used as the service channel.

In digital operation (TDM), any of the data speeds 256, 512, 1024 and 2048 kbit/s can be chosen for the transmission. This corresponds to 7–60 or 15–120 delta modulated telephone channels depending on which data speed is used per channel in the multiplex system.

The digital multiplex signal is interleaved with signals from a built-in digital service channel and internal data channels. The internal data channels are used for exchanging certain control information between link equipments in a circuit and for bit error monitoring of the transmission.

Fig. 3 shows a simplified block diagram of the equipment. The transmitter and receiver are connected via a duplex filter to a common antenna connector. The duplex filter consists of four 50 MHz filters with fixed tuning. A suitable combination of filters is chosen by the control unit, which also checks that the transmit and receive frequency are not chosen from within the same band.

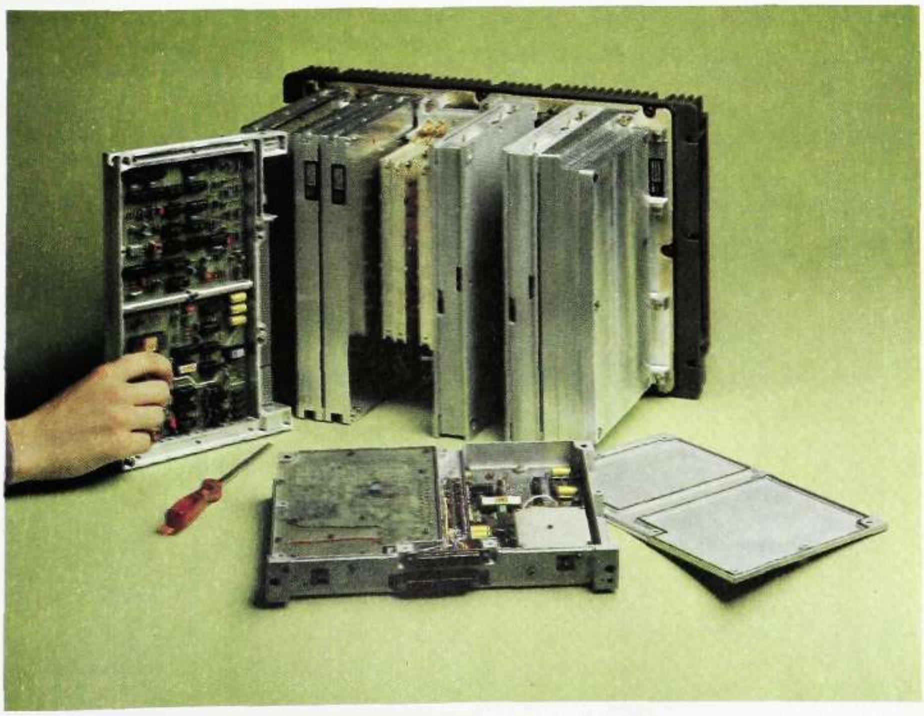
The receiver in the equipment functions as a normal double superheterodyne with the intermediate frequencies 160 and 10.7 MHz. The control unit selects band pass filters for both intermediate frequencies to give optimum filtering.

On the send side the information signal passes through filters that are chosen for the actual transmission mode, after which it modulates the oscillator frequency 500 MHz. The modulated signal is then mixed with the signal from the transmitter frequency synthesizer, and the difference frequency is filtered out and amplified to the final power level in a wide-band amplifier. Its output power is controlled by the control unit and an internal regulating system. A directional coupling function also supervises that there is adequate load on the output and automatically disconnects the power if too great a part of the output power is reflected back to the transmitter. Information regarding such a disconnection is forwarded to the control unit, which then automatically tests whether the fault remains, by means of short-term reconnection of the output power.

In addition to the control and test functions the control unit handles all the signal processing that is necessary to adapt the information signal to the connected multiplex equipment. The control unit also handles the interleaving and separation of the service channel and internal data channels from the information signal.

The equipment is powered from 220 V mains voltage or 24 V d.c. voltage, with automatic switching to d.c. operation in the case of a mains failure.

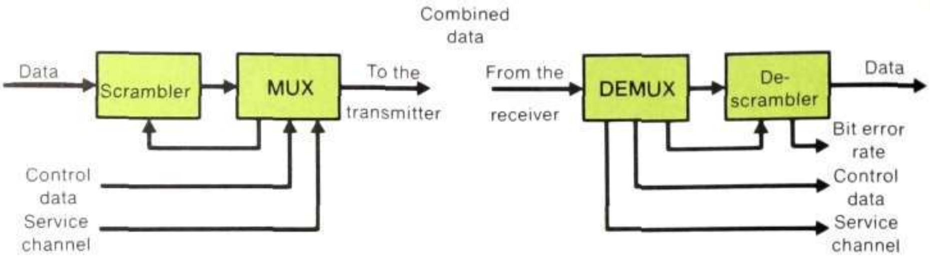
Fig. 4
Radio relay equipment CONTACT RL420 with the cover removed



Mechanical construction

CONTACT RL400 is a robust equipment designed for use in rough conditions in the field. The equipment withstands stringent mechanical testing, which includes six fall tests of 1 metre, corre-

Fig. 5
Block diagram of the scrambler and internal multiplex for the service channel and internal control channels



sponding to a shock of approximately 500 *g*, and a bump test of 24,000 blows of 50 *g*.

The equipment, which is waterproof, consists of a front panel, a rear panel, an intermediate cover and a number of subunits. All parts are designed to be able to withstand handling as spare units under field conditions, fig. 4.

All connections to the equipment are made via connectors on the front panel. In addition to the connectors, key board and display panel, the front panel contains cooling flanges for the transmitter. All subunits are of plug-in type and are fixed to the back of the front panel with captive screws. The rear panel holds the power supply unit and is also equipped with cooling flanges.

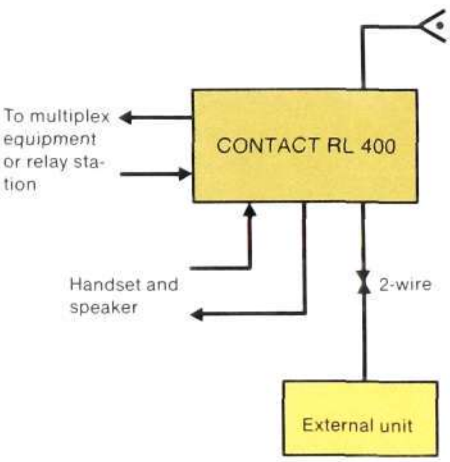


Fig. 7
Facilities for connection to the digital service channel system

Technology

CONTACT RL400 has been designed using the most modern technology available. For example, microstrip circuits are used in the UHF amplifiers, PIN diode attenuators and PIN diode switches in the power regulating system, strip line technology in the duplex filters and SAW (Surface Acoustic Wave) filters in the intermediate frequency amplifiers. The control functions are handled by a microprocessor, and the signal processing is carried out in a number of specially developed LSI circuits. The power supply unit has individual pulse width regulated converters for mains and battery operation respectively, with direct rectification of the mains voltage.

Special functions

A built-in data scrambler makes it possible to transmit any type of data signal using CONTACT RL400, without suffering reduction of the range if the distribution of ones and zeros is unbalanced. Such unbalanced distribution can often occur during unencrypted transmission of data and usually results in displacement of the transmitted HF spectrum relative the carrier. Such displacement can be avoided and the selectivity of the receiver can be optimized for the data speed in question if a balanced distribution of zeros and ones is ensured.

The data scrambler function has been combined with the transmission of the digital service channel and the internal control data channels. For this purpose the equipment is provided with circuits for multiplexing and demultiplexing, fig. 5. The control channels are used to exchange data between the receiver and transmitter, as a backward channel and for continuous supervision of the bit error rate during normal traffic.

The control processor is also used to regulate the output power of the transmitter. This contributes considerably to making enemy monitoring more difficult. The equipment operates at the lowest output power that gives a good connection and with automatic adjustment for any changes in the propagation attenuation, fig. 6. If interference occurs, the power will also be adjusted so that, if possible, the connection is maintained at the same quality. If the interference is caused by an enemy jammer it does not matter if the power is increased, since the connection has already been detected. However, the difficulty in determining whether the interference is intentional or not means that the lowest possible output power should still be aimed at.

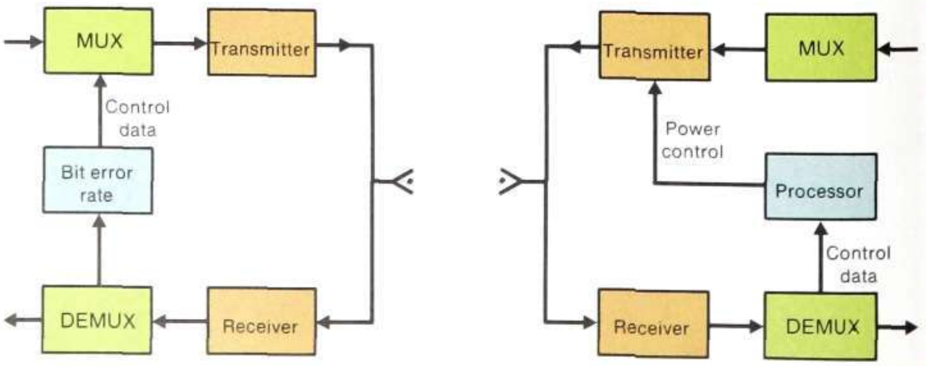


Fig. 6
Block diagram of the power regulating system

Technical data for CONTACT RL420

Frequency range	610–960 MHz
RF bandwidth	4×50 MHz
Channel spacing	100 kHz
Number of RF channels	2000
Duplex spacing	Fixed or variable
Modulation method	FM
Output power	10–15 W, 0.5–1 W or 0.05–15 W
Noise factor	8 dB
FDM transmission	4, 12, 24 telephone channels
TDM transmission	256, 512, 1024, 2048 kbit/s
Service channel	0.3–2.5 kHz analog with FDM 16 kbit/s digital with TDM
Power supply	185–275 V 45–65 Hz 21–32 V battery
Dimensions	310×345×440 mm
Weight	35 kg

Service channel subsystem

CONTACT RL400 contains a built-in service channel subsystem for fast and efficient communication, fig. 7. The system is of the omnibus type, i.e. everybody hears everybody else. With digital operation the service channel is also digital and can be encrypted using external equipment. The handset is normally connected to the connector marked HANDSET. The connector marked MULTIPLEX EQUIPMENT can be used for four-wire connection of a service channel from the multiplex equipment or a relay station. Two-wire connection is also possible, via the AUXILIARY EQUIPMENT connector, for encrypting equipment and for an extended service channel circuit, for example to a quarters tent. These connections can be used in parallel. The speech control key on the handset must be used, since the service channel is of the omnibus type and the transmission is digital. When an operator has depressed his key, the speech facility is blocked for the other operators. However, calling over the service channel can be carried out even if the channel is engaged, by depressing the button EOW CALL. A calling signal is then transmitted which makes it possible to attract attention even during a call.

When radio operators are trying to set up a connection over difficult radio paths the transmission quality of the service channel can be improved by disconnecting the multiplex signal internally in the equipment. The whole radio channel is then used to transmit the service channel information until the signal strength has been improved, e.g. by adjusting the antenna direction, and the multiplex signal can be connected again. In this case the service channel transmission will be analog, and any external digital service channels will be disconnected. The receive side of the equipment is always automatically switched over to analog reception when no digital signal can be detected.

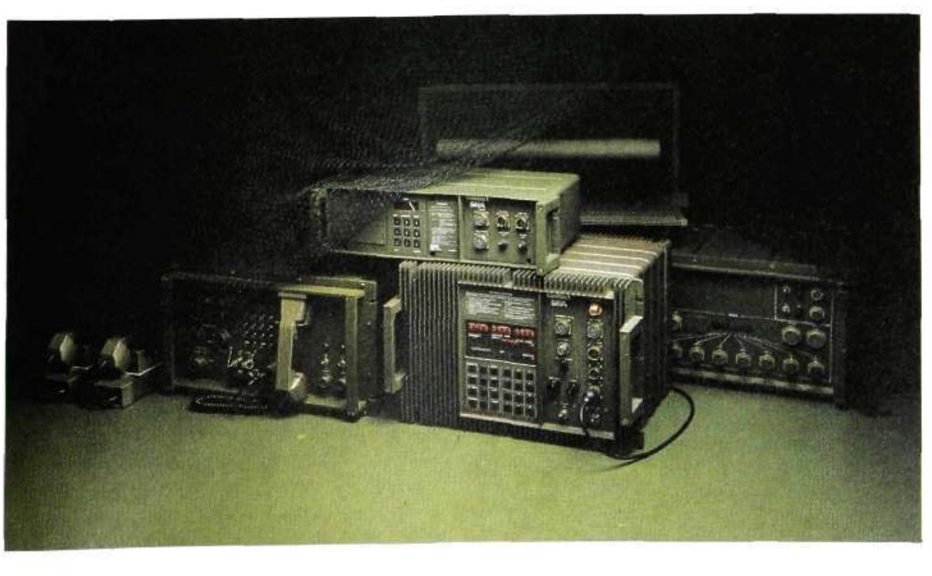
Development possibilities

Almost all functions in CONTACT RL400 are controlled by the built-in microprocessor. This means that functions and handling procedures can easily be changed by changing program stores. External control systems can be connected to the interface in the OPERATING MODE connector for communication with the processor. Among the possible new functions are: automatic connection of a standby station, automatic change of channel and centralized control and supervision at complex communication nodes.

The system design has also been chosen with a view to facilitating further development of the protection against interference. Thus all circuits are wideband in order to avoid manually or electrically controlled tuning. The division into 50 MHz bands makes it possible to use an even wider spectrum for the transmission. Such band spreading can, for example, be carried out by combining the present frequency shift modulation with encrypted phase shift modulation. The regulation system that is a prerequisite for using such a band spreading method for transmission in complex networks has already been introduced.

In the basic version the power regulating system is used to avoid excessive coverage, which considerably reduces the risk of detection and locating. The risk would be even further reduced if band spreading was used.

Fig. 8
Radio relay equipment CONTACT RL420 with field telephones, bulk encryption equipment, digital multiplexors and digital node switches are some of the units that are now available for building up digital encrypted telephone networks



PCM Signalling Equipment in the BYB Construction Practice

Lars-Erik Larsson

When developing new generations of PCM equipment, LM Ericsson is designing them for the same construction practice, BYB, that is used in the digital telephone exchanges AXE 10. This mechanical integration will become increasingly important as digital technology is introduced into the telephone networks. Mechanical compatibility simplifies redeployment of equipment in connection with rearrangements in the network.
In this article the signalling facilities and signalling requirements on PCM circuits are discussed. The signal conversion equipments that are available for different applications are described, with a detailed description of one of the signalling equipments, ZAK 03-03, which is used for matching between an analog exchange and timeslot T16 in a 30-channel PCM system.

UDC 621.376:
621.395.38

Frame no.	Bit no. in T16: 1	2	3	4	5	6	7	8
0	0	0	0	0	1	X	1	1
1	1a	1b	1c	1d	16a	16b	16c	16d
2	2a	2b	2c	2d	17a	17b	17c	17d
·	ı	ı	ı	ı	ı	ı	ı	ı
·	ı	ı	ı	ı	ı	ı	ı	ı
·	ı	ı	ı	ı	ı	ı	ı	ı
15	15a	15b	15c	15d	30a	30b	30c	30d

Fig. 1
The allocation of T16 with channel-associated signalling. In bit 6, frame 0, loss of multiframe alignment is transmitted to the other terminal. × = 0: no errors; × = 1: multiframe alignment error.

Fig. 2
CCITT signalling diagram R2, digital variant

Signal or state	Signalling code: Forward a_f	b_f	Backward a_b	b_b
Idle	1	0	1	0
Seizure	0	0	1	0
Seizure acknowledge	0	0	1	1
Answer	0	0	0	1
Clear back	0	0	1	1
Clear forward	1	0	0	1
			or	
			1	1
Return to idle	1	0	1	0
Blocking	1	0	1	1

Signalling capacity of a 30-channel PCM system

A first-order PCM system in accordance with CCITT Recommendation G.732 is intended for transmission of 30 simultaneous calls. It contains 32 timeslots of eight bits each. Timeslot T0 is used for frame synchronization and T16 for signalling. Since T16 only contains eight bits, it must undergo further time division if channel-associated signalling is used. A multiframe is formed for this purpose.

In a multiframe, T16 is used once for multiframe synchronization (frame 0) and in the other fifteen frames for the signalling for two speech channels at a time, fig. 1. Thus four signalling bits, a-d, are allocated to each speech channel with a time spacing of $16 \times 125 = 2000$ µs. The transmission speed per signalling channel is 500 bit/s.

Between digital exchanges, common channel signalling can also be used, for example CCITT signalling system no. 7. In this system no multiframe is formed but the information is transmitted in packages, which are individually synchronized. Channel-associated signalling is usually the best method when at least one PCM terminal has to cooperate with an analog exchange.

CCITT Recommendation Q.421 for signalling system R2 proposes a signalling diagram, figs. 2 and 16, for use with channel-associated signalling in which only bits a and b are used.

When a PCM system is used as a link between a digital and an analog exchange special attention must be given to the signalling diagram. Procedures must be specified for all signalling states, even those that are not part of the normal signalling sequence, otherwise blocking or self-oscillation can easily occur. It is also important to standardize in order to avoid expensive reprogramming.

Standardization of the signalling diagram also reduces the number of program blocks per exchange needed for signalling, which simplifies the operation and maintenance of digital exchanges.

Signalling requirements

When PCM systems terminate in analog exchanges, signal converters are needed to convert the d.c. signals from the exchange to digital signals in T16.

As analog techniques have evolved, the exchanges themselves and the signalling over the junction lines between them have been successively improved. This means that several d.c. signalling diagrams may be in use even for the same type of exchange. New variants of signal converters must therefore often be developed for slightly different d.c. signalling diagrams.

Interworking needs between different generations of analog exchanges have forced a choice between alternative solutions. In some cases it was economical to use the signalling of the older exchange also for the new exchange. In other cases the older exchange was modified so that the facilities of the new signalling diagram were made available to all subscribers. The PCM signal converters must, of course, be adapted to

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Telefonaktiebolaget LM Ericsson

the signalling diagram used for interworking between the analog exchanges.

Another reason for the large number of signal converter variants is that, for economical reasons, the interface towards the PCM equipment can not be the same in all telephone networks, fig. 3. In the figure, the signalling equipment for a circuit has been divided into its functional parts. The group selector signalling is matched to the d.c. signalling of the junction in its relay sets, FUR and FIR. The d.c. signals are modified to E&M signals in the units FUP and FIP, and the adaptation to the 64 kbit/s bit stream in T16 is done in the E&M block.

If neither the cost of previously installed equipment nor development costs have to be considered, the most economical solution, from the point of view of the hardware would be to carry out all signal handling up to the group selector in the signalling equipment of the PCM system. In reality this integration is rarely economically feasible. However, LM Ericsson's production program includes variants for any degree of integration. The alternative that is preferred by most customers is to combine equipment for E&M signalling with FUP and FIP respectively. This gives a PCM system that is directly matched to the exchanges which means that already installed junction relay sets can be retained.

The PCM signalling equipment must therefore be adapted to a number of different d.c. signalling systems. LM Ericsson has achieved this flexibility by dividing the signalling equipment into a d.c. matching part, one of which is required for each channel, and a control part that is common to 30 channels. The same d.c. unit can then be used for all systems having the same d.c. signalling diagram. The adaptation to the line signalling diagram is done by programming the control unit.

Signalling diagram over PCM

If the PCM system is to be used only between analog exchanges, the only requirement for the signalling diagram is that it must be able to transmit d.c. signals between the PCM terminals. The gating network needed to implement the signalling diagram towards T16 is then often very simple, particularly if the ability of the PCM system to transmit up to four binary signalling channels per speech channel is utilized.

In those cases where the two PCM terminals are to work with different exchange types, or when the d.c. signalling diagram is complicated, some form of signal processing is required. This means that the gate network between the test and operate points and the signalling diagram towards T16 often becomes disproportionately large.

Considerable signal conversion is needed for adaptation between, for example
- one analog and one digital exchange
- two different d.c. signalling systems, i.e. if the PCM system has to convert the d.c. signals between two different types of analog exchanges
- a d.c. signalling system in a local exchange and an existing E&M signalling system, e.g. in a transit exchange
- d.c. signalling diagrams where the decadic information is transmitted between the registers in encoded form, e.g. LM Ericsson's d.c. code and pulsed code used in some crossbar exchanges.

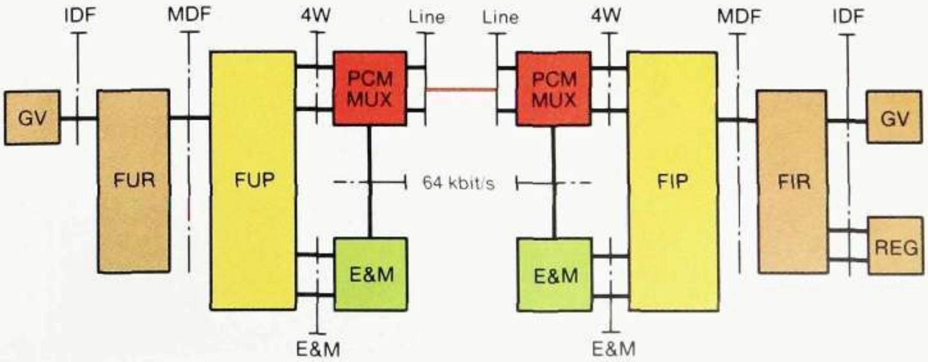


Fig. 3
The different interfaces to which the PCM signalling equipment can be adapted:

IDF	Interface between the group selector and FUR or FIR
MDF	The traditional interface between the exchange and the analog junction line
4W	Four-wire interface for the speech path of the PCM equipment
E&M	E&M interface between E&M signalling equipment and the signal converter FUP or FIP
64 kbit/s	The 64 kbit/s interface of the PCM system
Line	Interface towards the 2 Mbit/s line system

In the first two cases the need of a standardized PCM signalling diagram is obvious. The digital version of the CCITT signalling diagram R2 is well suited to such standardization. However, there are a number of signals in the analog local networks which are not included in the CCITT diagram, and complete standardization is therefore not possible.

In the third case the E&M signalling diagram already in use towards the transit exchange must be applied, and in the last case the difficulties of designing a channel-associated network can be overwhelming.

PCM signalling equipment must therefore be easy to adapt to different PCM signalling diagrams. LM Ericsson's signalling control unit, which is common to 30 channels, is then doubly useful. It is used not only to control the test and operate points of the channel boards, as has already been mentioned, but also to implement the signalling diagram towards the digital side. The programming facility makes it easy to implement custom designs.

Alternative signalling equipments

The position of the signalling equipment in the PCM hierarchy is shown in fig. 4. Fig. 5 shows where in the telephone network the various signalling equipments can be used. The signalling equipments that have been developed are listed below, with their applications:

- ZAK 01 is used when the exchange is equipped with junction line relay sets for E&M signalling
- ZAS 01-07 is used for subscriber line signalling, for example in rural areas with few subscribers, or in urban networks for connecting subscribers to foreign local exchanges
- ZAK 02 is used for signal conversion towards LM Ericsson's exchange system ARF 101, i.e. register signalling with d.c. code
- ZAK 03 is used for matching to LM Ericsson's exchange system ARF 102, which has a standardized line signalling system with direct current in a loop and register signalling with compelled MFC signalling. ZAK 03 is available in several versions, e.g. for decadic impulsing as used in Strowger exchanges
- ZAK 04 is used for matching to exchanges with signalling in accordance with Siemens' EMD system
- ZAK 05 is used for matching to LM Ericsson's 500-selector exchanges, AGF, with translation registers for MFC.

Among these types ZAK 03-3 has been chosen for a more detailed description of its development, system design and signalling diagram.

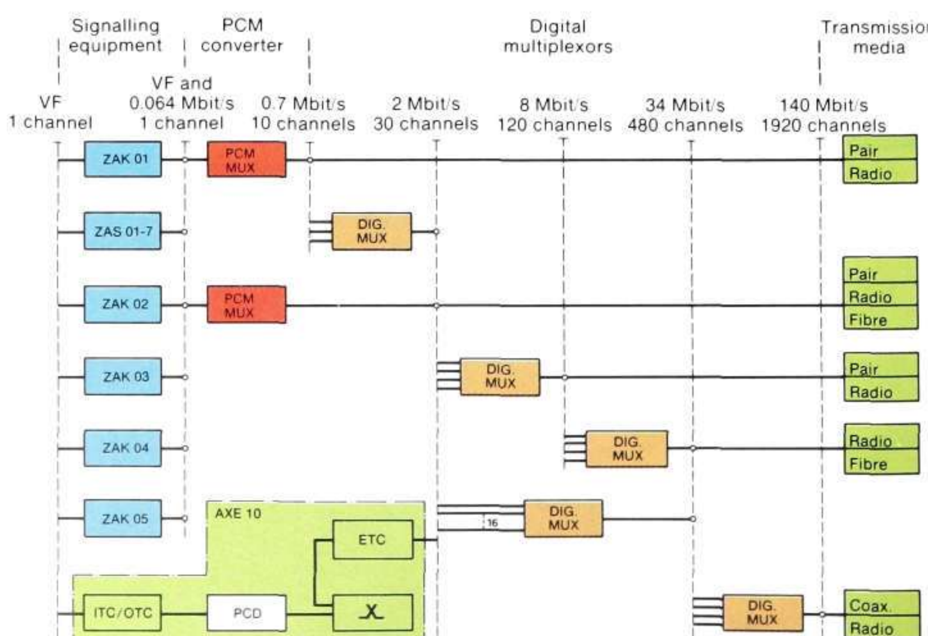


Fig. 4
The position of the signalling equipment in the PCM hierarchy. The figure shows the interconnection of the various systems and their association to AXE 10

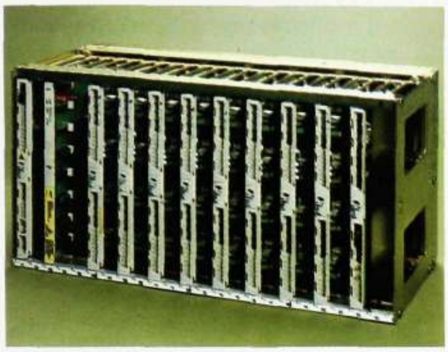


Fig. 6
Magazine for signalling equipment ZAK 03-3

Signalling equipment ZAK 03-3

ZAK 03-3, fig. 6, is the most recently modernized PCM signalling equipment. The design objectives were that
- the sensing and polarity inversion of the d.c. signals should be transistorized
- few straps were to be used, to simplify commissioning
- coding of the signals should be carried out using a microprocessor
- the requirements for extension over physical circuits could be modified
- construction practice BYB was to be used.

Sensing and polarity inversion using transistors

The advantages of using transistors instead of relays for the sensing and polarity inversion of the d.c. signals are quieter and faster operation and less maintenance. Moreover, the polarity inversion transistors are controlled via an

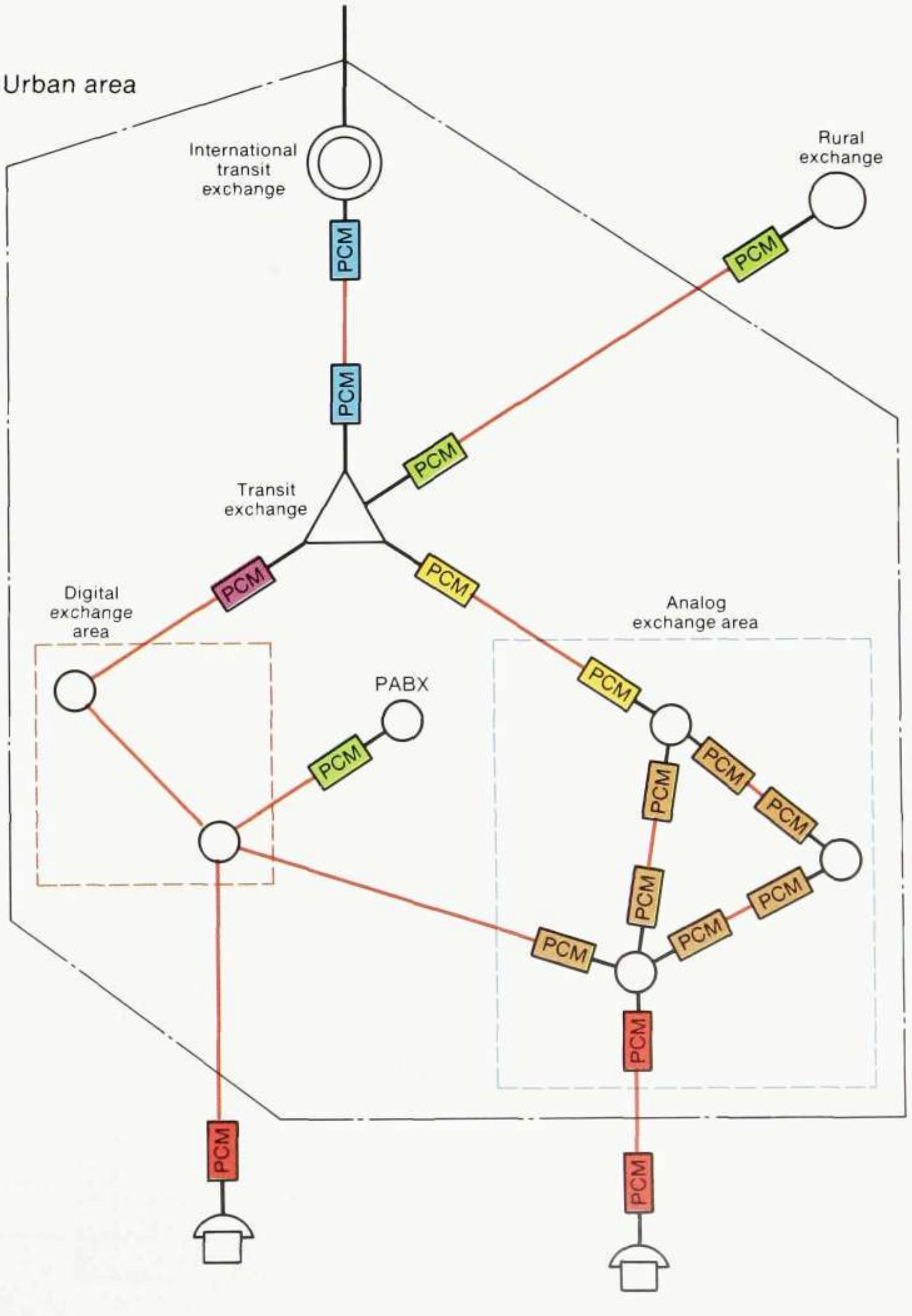


Fig. 5
A telephone region with different types of signalling

- ZAK 01
- ZAK 01 alt. 03
- ZAK 02–05
- ZAS 01–7
- ZAK 01 alt. 02–05
- ZAK 01 alt. 03–05
- Digital line

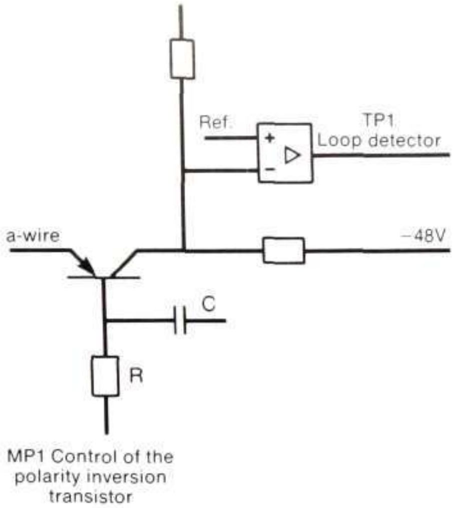


Fig. 7
The basic principle to obtain quiet polarity inversion together with fast loop detection. The figure shows only one of the polarity inversion transistors, for the a-wire

TP Test point
MP Operate point

RC network, which makes the polarity inversions less steep. Charging pulses can then be transmitted without interfering with calls in progress, fig. 7, while at the same time loop detection is so fast that decadic impulsing is possible.

Coding using a microprocessor

In the signalling equipment coding is carried out between the received signalling information, a_b and b_b, and the operate points for d.c. conditions towards the exchange, and also between the test points for d.c. conditions from the exchange and the transmitted signalling code, a_f and b_f. In principle the coding can be performed in three different ways, fig. 8.

If no demands are made on the digital signalling code except that the analog signals are to be transmitted, the method using channel-associated logic is usually preferable, fig. 8a. However, if an advanced digital signalling diagram such as CCITT R2 is required, this method is less attractive, because it gives a large array of gates per channel.

The alternative using clock-controlled logic, fig. 8b, is a method relying on redesigning hardware. When modifications or new designs are required the unit with the clock-controlled logic must be entirely redesigned.

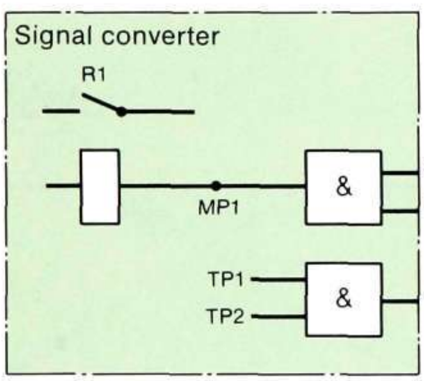


Fig. 8a
Symbolic diagram of a channel-associated gate network for decoding received signals, a_b and b_b, *and coding the transmitted signal*, a_f

MP Operate point

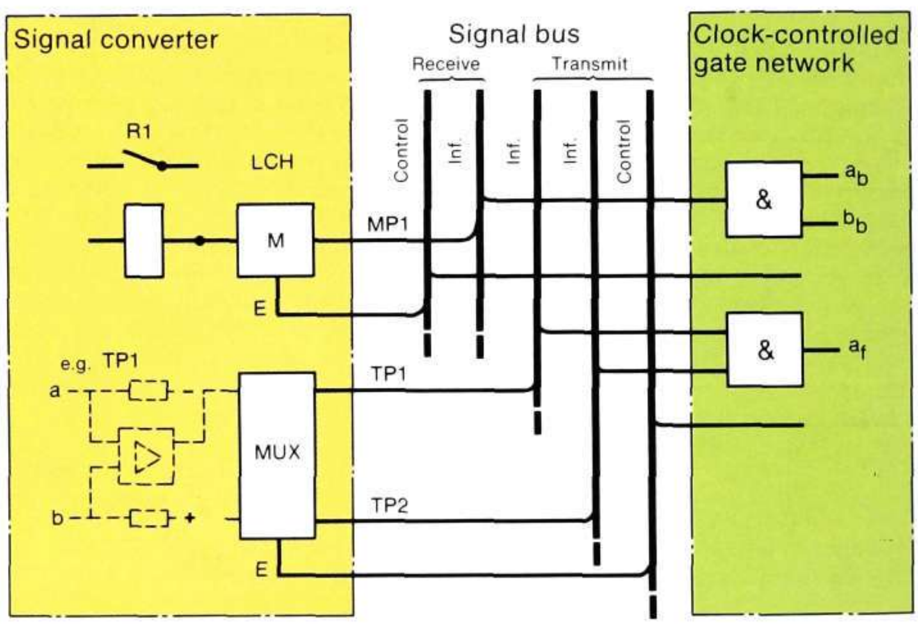


Fig. 8b
Clock-controlled gate network for the same function as shown in Fig. 8a

MUX Data selector, multiplexor, in the send direction
LCH *Data selector with memory*, **M**, *in the receive* direction (latch)

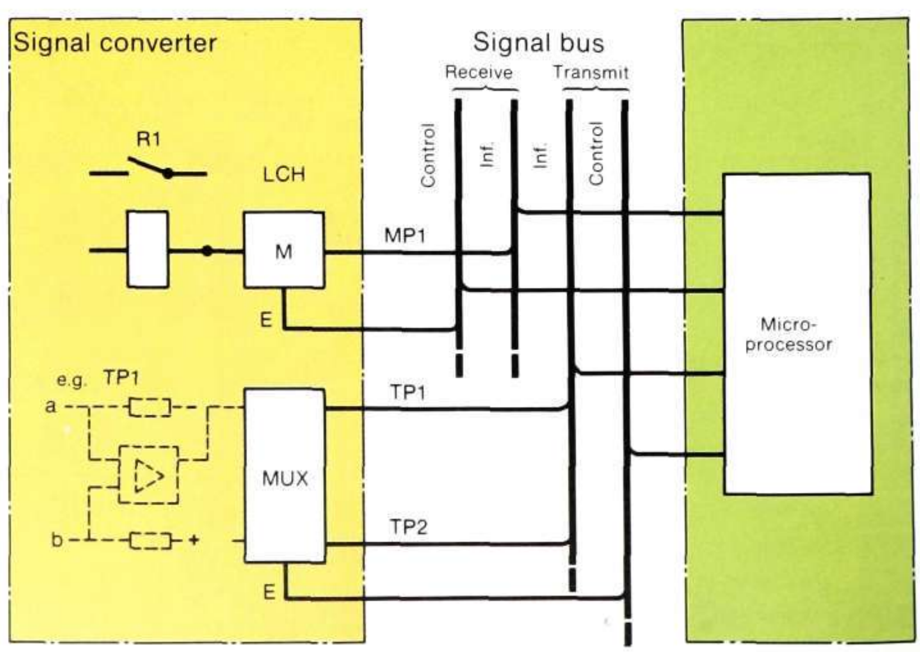
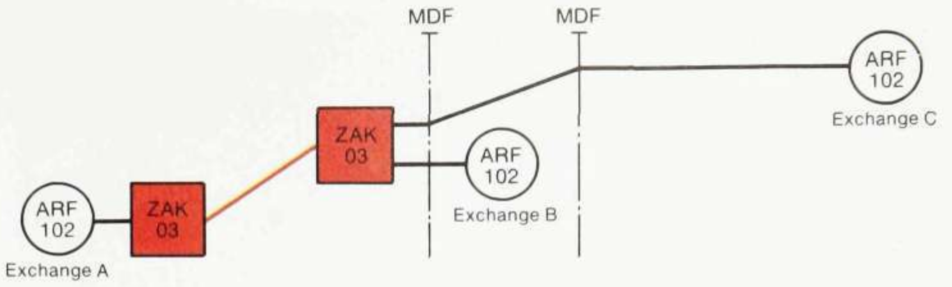


Fig. 8c
The gate network in fig. 8b replaced by *microprocessor control*

Fig. 9
Through-connection of PCM channels from exchange A through B to exchange C

Mux + line system
Physical line < 1300 ohms



With microprocessor control, fig. 8c, such a change in hardware is replaced by a change in program. This alternative therefore gives greater flexibility and more reliable function. Optimization of the logic functions is easier to carry out in programs than in hardware. The progress in the semiconductor industry has brought down the cost of alternative 8c to such a level that it is now quite reasonable in view of its advantages. This alternative has therefore been chosen for ZAK 03-3. However, the microprocessors available on the market were all too slow to serve 30 PCM channels, and hence a special PROM-controlled processor has been developed.

Modified requirement for extension over physical circuits

In an earlier version (ZAK 03-1) in the M5 construction practice[4], the PCM channels could be through-connected over physical circuits, fig. 9. This ability has been reduced in ZAK 03-3. It is only rarely used, and transistorized sensing circuits and polarity inverters that are immune to interference have proved to be very expensive. The disturbances that normally occur in a telephone network consist of longitudinal and transversal interferences caused by differences in potential, lightning or nearby power lines. However, a study has been started to investigate whether cable networks in large cities are sufficiently free from interferences that the equipment can be used up to the resistance limit of about 1000 ohms.

Construction practice BYB

The BYB construction practice, which has been chosen for this generation of PCM signalling equipments, has previously been described in several articles[1,2,3].

The use of this construction practice for transmission equipment also provides mechanical compatibility between the digital exchange and transmission equipment. This will be an advantage for the rearrangement of transmission equipment that will become necessary during the evolution of the digital network. In many cases the trunk circuit equipments, OTC and ITC, in system AXE 10 can also be used as signal converters for PCM systems.

SYSTEM STRUCTURE

Signalling equipment ZAK 03-3 consists of five different units, figs. 6 and 10.

The signal converters FUP and FIP each contains equipment for four PCM channels. FUP is used for the outgoing and FIP for the incoming traffic direction.

The control unit, the 64 kbit/s interface unit and the d.c./d.c. converter are common to all 30 channels.

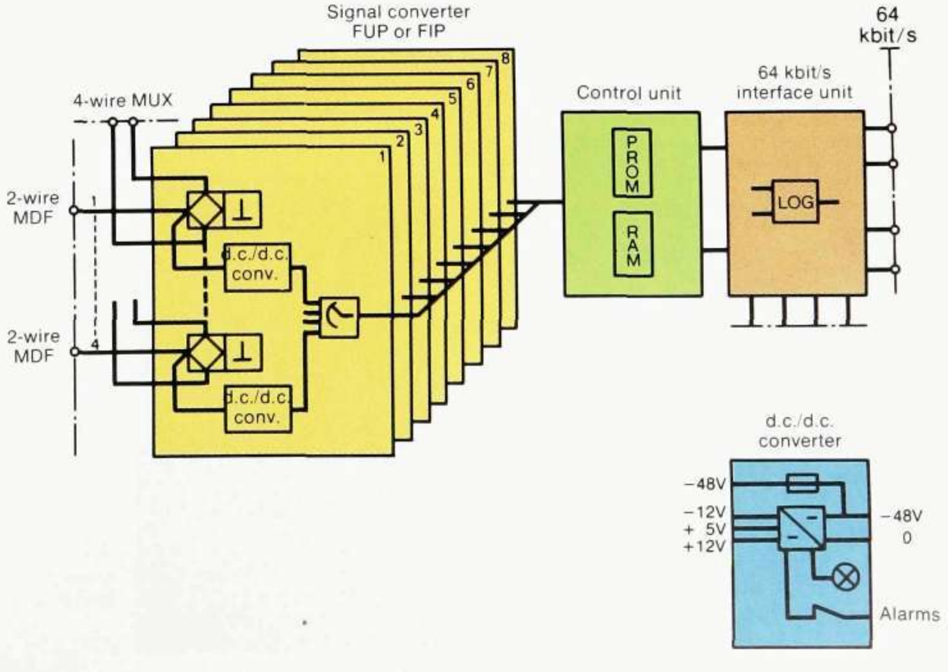
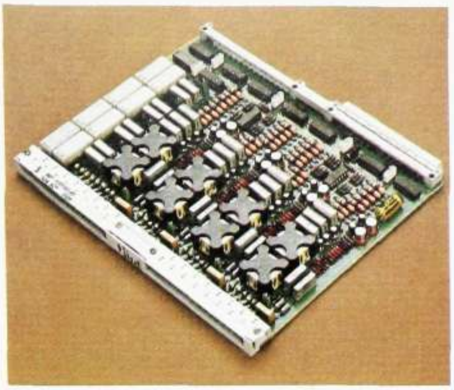
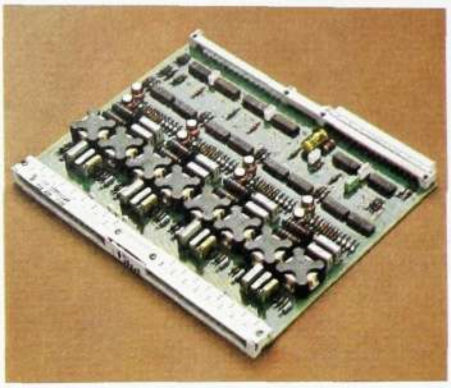


Fig. 10
Block diagram of signalling equipment ZAK 03-3





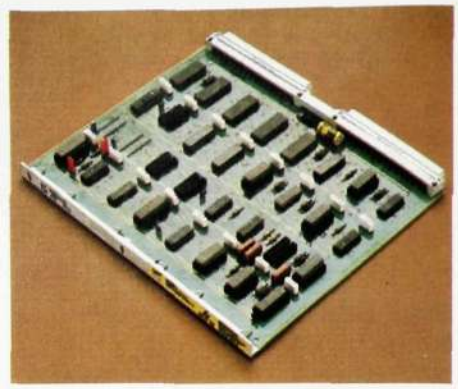


Fig. 11
Signal converter FUP

Fig. 12
Signal converter FIP

Fig. 13
Control unit

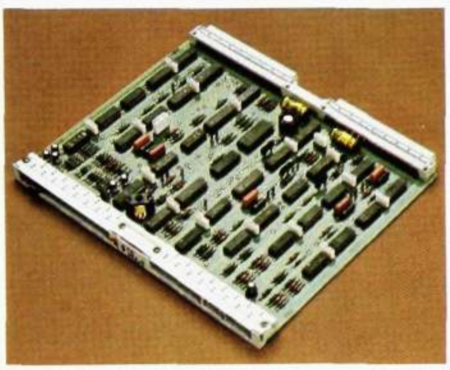
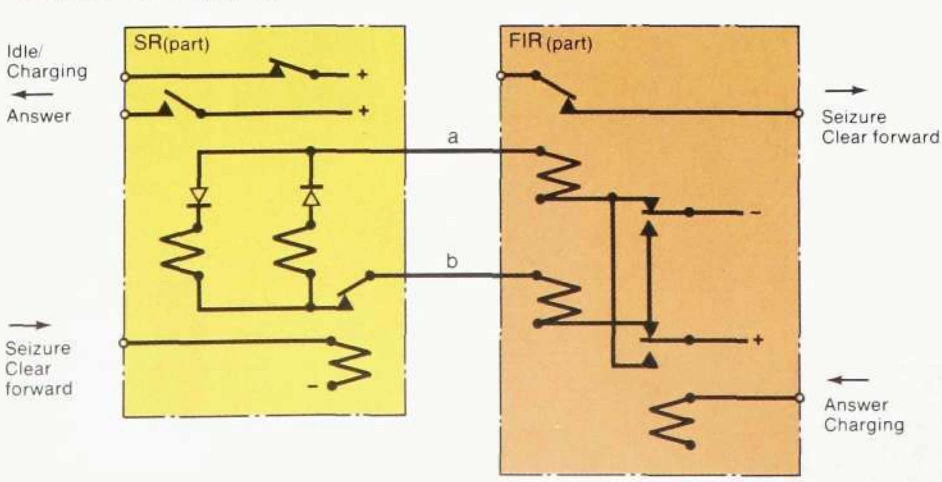


Fig. 14
64 kbit/s interface unit

Fig. 15
The interworking between two analog exchanges where the sending of a charging pulse, a polarity inversion, momentarily gives a false clear forward because of the high inductance of the relays in SR.



FUP and FIP, figs. 10, 11 and 12, contain a hybrid circuit which provides the transition to the four-wire speech path. The fourwire speech path is connected to the PCM multiplex magazine. The hybrid circuit is also used to separate the speech and signalling paths. The signalling path contains the transistorized converters for conversion between analog d.c. signals and TTL levels.

The transmission between the signal converters and the control unit is done over a common bus that is divided into send, receive and control paths, see fig. 8c.

In addition to the bus leads shown in fig. 8c there is still another information path, over which the control unit is informed whether an FUP or an FIP board is inserted, so that the correct signal converter program can be activated.

The PROM circuits in the control unit, fig. 13, contain the programs for setting the operate points and coding the test point information to the signalling diagram. They also contain timing programs, which are needed for example when the d.c. signalling of analog exchanges is not full duplex. Fig. 15 shows a typical case where timing is necessary. The control unit can also be programmed for pulse correction, double current detection of polarity inversions, generation and detection of timed signalling elements etc. However, all these facilities are seldom needed in one design.

The PCM multiframe structure is generated in the 64 kbit/s interface unit, fig. 14.

The send direction contains a 16-counter which is stepped once for each frame. The multiframe synchronization word is transmitted when the counter is in the position for frame 0. In the other frame positions the signalling code for the relevant channel pair is transmitted.

The receive direction also contains a 16-counter which is stepped in synchronism with the counter in the transmitting terminal. When the former is in position 0, a check is made that the synchronization word has been received, otherwise a resynchronization routine is initiated. If the system is in synchronism the received signalling code is connected through to the control unit during each of the subsequent frames.

SIGNALLING DIAGRAM

A signalling diagram for ZAK 03-3, with signalling between two analog local exchanges of type ARF 102, is shown in fig. 16. The time axis points downwards in the diagram. The signalling sequences are specified by the state numbers. All states having the same number are identical, i.e. the signalling sequence can continue with any of the signals that start with the same state (same colour).

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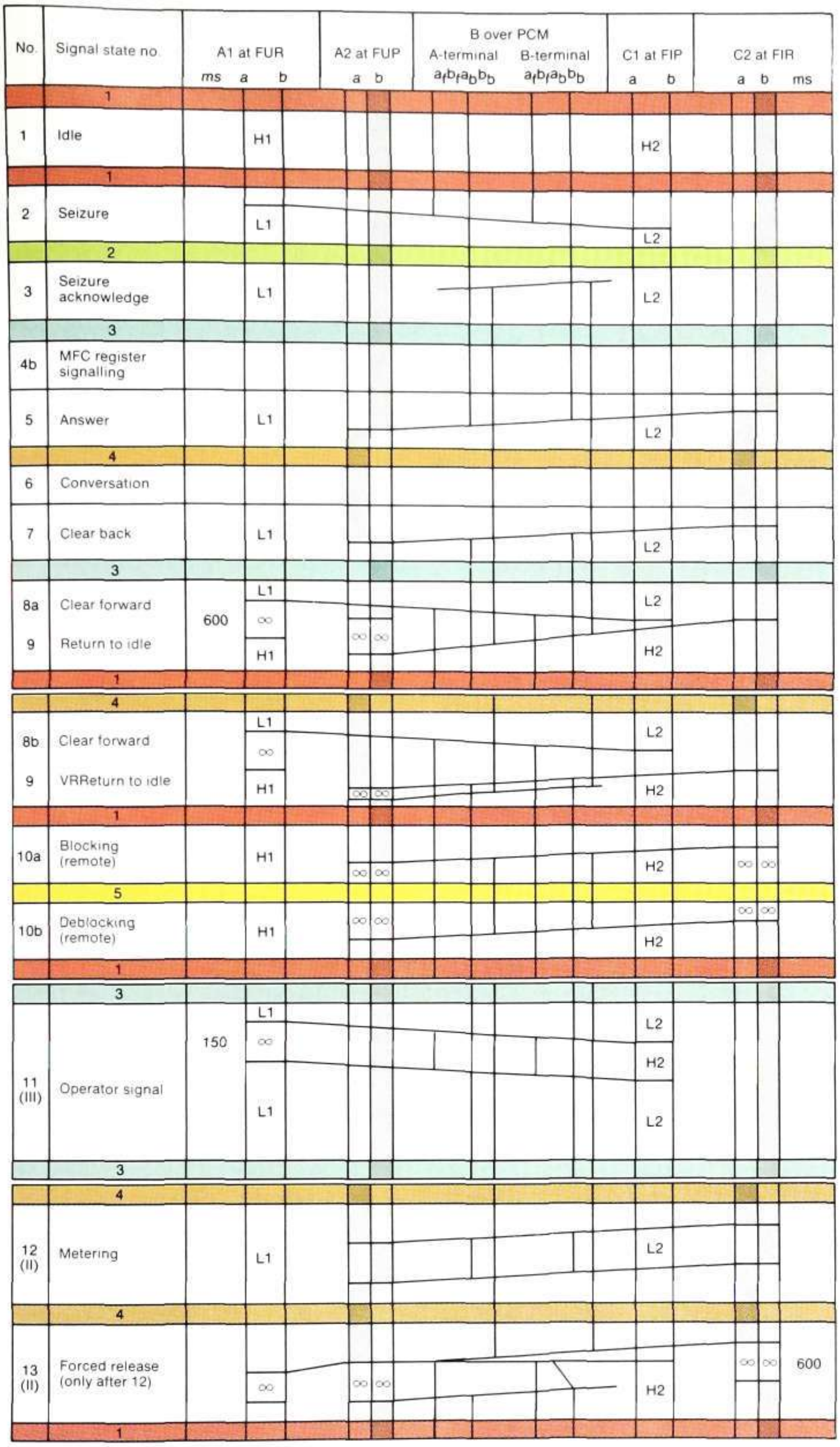

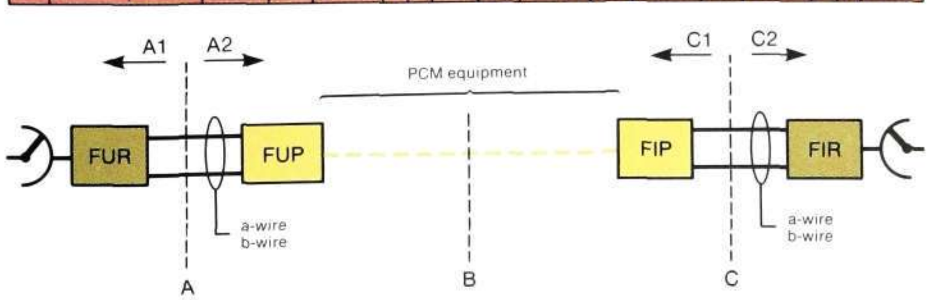

Fig. 16
Signalling diagram for ZAK 03-3 used between two ARF 102 exchanges

"B over PCM"
(line) = 1
(no line) = 0

a b

H High-ohmic loop
L Low-ohmic loop
+polarity on the a-wire
−polarity on the b-wire
−polarity on the a-wire
+polarity on the b-wire
∞ ∞ break or +polarity

Technical data

Transmission characteristics

Frequency range, speech path	300–3400 Hz
Nominal impedance, IN/OUT	600/600 ohms, bal.
Return loss on the two-wire side measured against 600 ohms	
300–600 Hz	15 dB
600–3400 Hz	20 dB
Loop attenuation when the line side is terminated in a nominal compromise balance	
300 Hz	27 dB
1000 Hz	40 dB
3400 Hz	34 dB
Balance attenuation towards earth	
300–3400 Hz	50 dB
Attenuation 2-wire–4-wire, nominally	5 dB
Attenuation distortion	
300–600 Hz	+0.6 to −0.2 dB
600–3400 Hz	±0.2 dB
Group delay distortion	
500–600 Hz	200 μs
600–3400 Hz	100 μs

Signalling characteristics, outgoing signalling unit FUP

Internal resistance between the a- and b-wires	2×800 ohms
Blocking signal, a-wire to earth	800 ohms
Blocking signal, b-wire to earth	800 ohms
Low-resistance detector, operate limit	10 mA

Signalling characteristics, incoming signalling unit FIP

Resistance between the a- and b-wire	
in the high-resistance state	>100 kohms
in the low-resistance state	<1300 ohms
Polarity detector sensitivity	
in the high-resistance state	<0.3 mA
in the low-resistance state	>1 mA

General data

Feeding voltage	−48 V
limits	−10 to +15%
Power consumption, equipped magazine	
with 8 FUP and all channels idle	40 W
with 1 erlang per circuit	60 W
with 8 FIP and all channels idle	25 W
with 1 erlang per circuit	25 W
Dimensions of the magazine	
height	244 mm
width	488 mm
depth	220 mm
Weight fully equipped	10.8 kg

Manufacture of Hybrid Circuits

Bengt J. Becker, Johan Berg and Christer Olsson

This article deals with the manufacture of thick film hybrid circuits at RIFA. The authors discuss the requirements on premises for such production and describe the production organization. More detailed descriptions are then given of the series production of resistor networks, chip & wire circuits and circuits with soldered components, and also of production techniques and quality controls. Finally the manufacture of high reliability circuits is described.

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RIFA started manufacturing hybrid circuits in 1971, when a unit was set up near Stockholm. This factory employed about ten people, and the production consisted of hybrid circuits of the chip & wire type.

The hybrid circuit production increased rapidly during the second half of the 1970s. In 1978 the unit moved to RIFA's new, modern and functional premises just outside Stockholm, where it has an area of approximately 5000 m^2 at its disposal.

By the end of 1980 about 300 people were employed in the manufacture of hybrid circuits. By now the production range comprises over 200 documented items in different techniques and encapsulations. The production volumes have risen dramatically. For example, the number of transmission circuits manufactured each week for the standard telephone set DIAVOX 100 is over 10 000.

The processes, manufacturing methods and quality control are all designed to satisfy the stringent quality and life requirements that are applicable for components used in the telecommunication field.

The basic technique used, thick film, surface soldering and chip & wire, have been chosen and further developed by RIFA to ensure good production economy and high reliability. A summary description follows, which explains how these techniques are used in the production of modern high quality electronic components.

Factory premises

The manufacture of hybrids requires a supply of electricity, ventilation air, compressed air, pure water, a number of solvents and gases, such as hydrogen and nitrogen, and also spot evacuation and vacuum. The rapid development of production techniques and processes means that such supply arrangements must be extremely flexible. A supply floor has therefore been placed above the factory floor. From the supply floor connection can be made to any point in the factory, fig. 1.

The manufacture of microcomponents is extremely sensitive to contamination. The cost of maintaining satisfactory purity constitutes a large part of the

Fig. 1
The supply floor above the factory floor

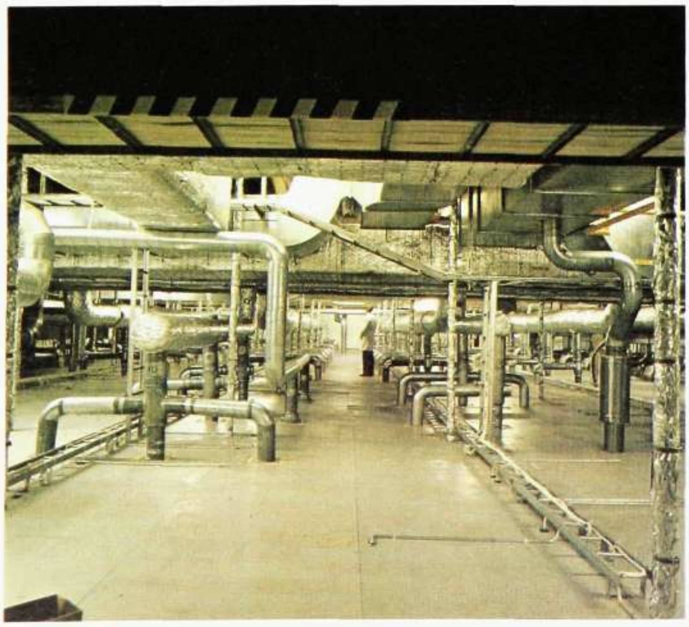

Fig. 2
The circuits are stored in cassettes between processes in the various manufacturing stages



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CHRISTER OLSSON
AB RIFA

Fig. 3
The department for assembly of chip & wire circuits. The subdued lighting is specially adjusted for microscopy

investment and production costs. A high degree of basic cleanliness is obtained by making the premises easy to clean. All employees and visitors must wear protective clothing. Smoking is only permitted in rest rooms and certain, enclosed offices. The circuits are kept in cassettes during and between the various manufacturing stages, fig. 2. Process stages that have different cleanliness requirements are carried out in different rooms. The soldering of leads, encapsulation, marking and cleaning are completely separate from more sensitive processes, such as printing, bonding and mounting of soldered components.

The purity of the air is checked regularly. The air must not contain more than 10 000 particles larger than 5 μm per cubic foot. Outdoor air in a city usually contains between 100 000 and 1 000 000 such particles per cubic foot. The temperature is regulated to 22 ±1°C. The relative humidity is not allowed to fall below 40%.

Particular care has been taken over the decoration and lighting of the factory. For example, the general lighting in the bonding department is adapted to microscopy. The brightness is carefully adjusted and the fluorescent tubes are equipped with special anti-dazzle grids, fig. 3.

Organization

In order to increase the work motivation, and thus reduce process times, running-in periods for new products, cassation etc., it was decided to delegate the responsibility for different types of products by dividing the factory into different production units for

- printing and trimming
- assembly and encapsulation of resistor networks
- assembly and encapsulation of chip & wire circuits
- assembly and encapsulation of circuits with surface soldered components
- final testing.

Production methods, planning, quality control and machine maintenance are separate functions directly under the production manager. The tasks of the individual employees are divided among the various production units in accordance with the matrix principle.

Series production of thick film circuits

The unit for large scale manufacture of thick film circuits produces high-quality circuits primarily for telecommunication, but also for other demanding industrial applications. The manufacture comprises three types of products:

- resistor networks
- chip & wire circuits
- circuits with surface soldered components.

Resistor networks
The resistor networks consist of ceramic substrates on which conductor patterns and resistors have been screen

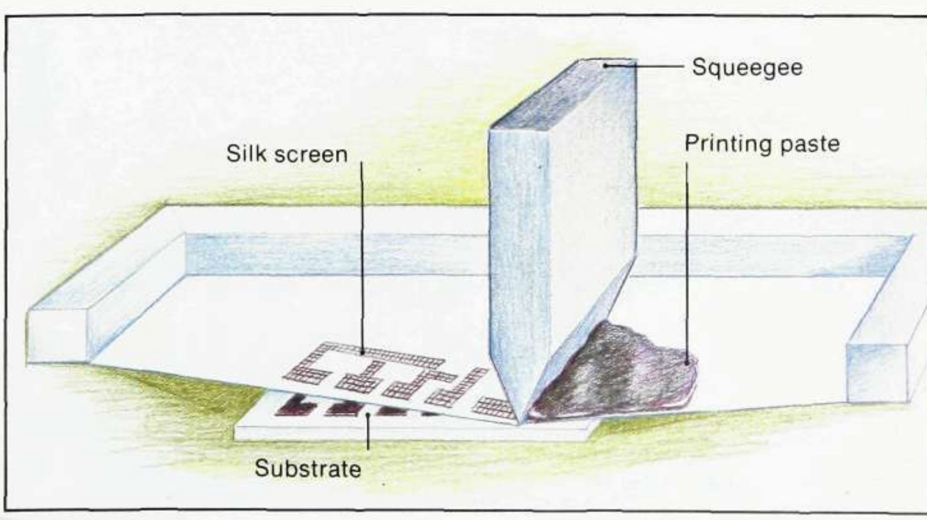
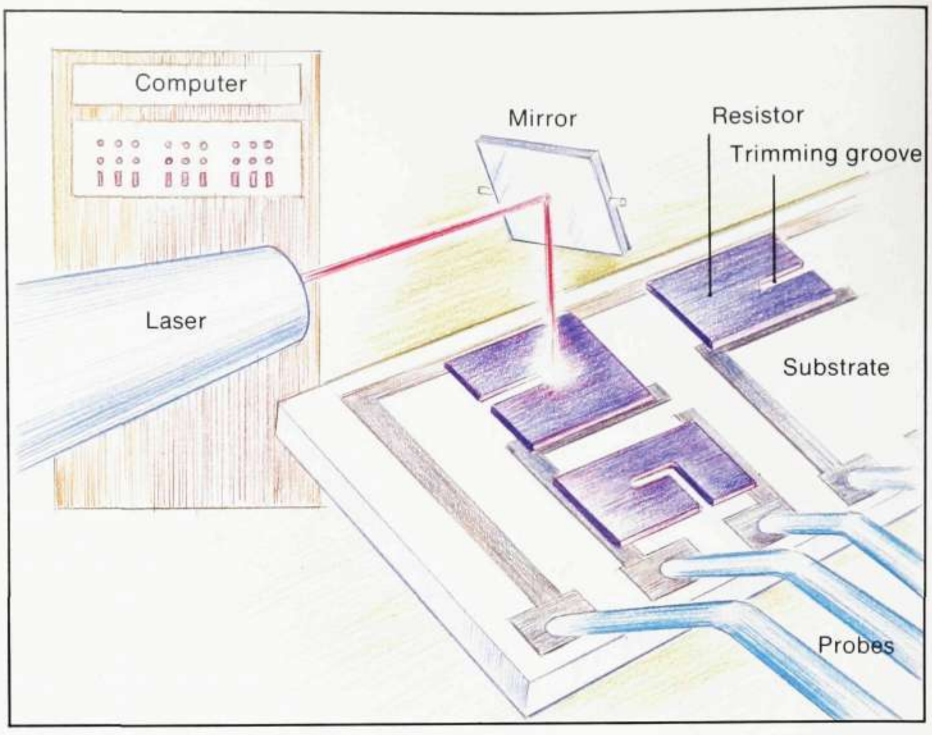


Fig. 4
Screen printing of thick film

Fig. 5
Laser trimming of thick film resistors



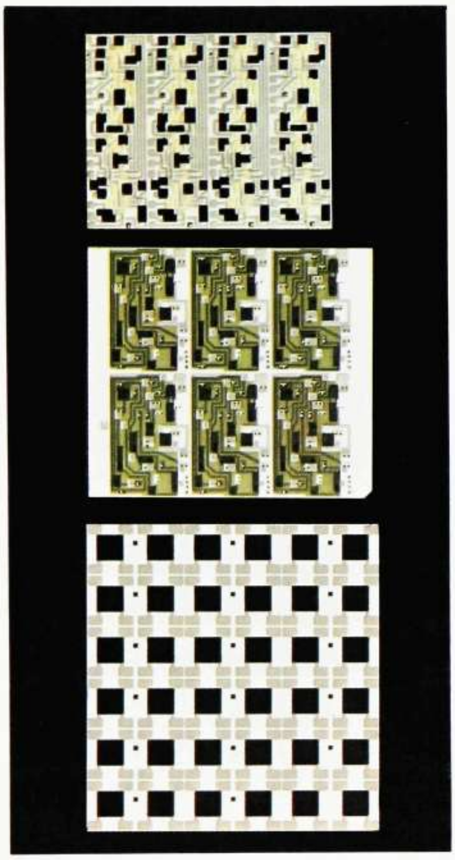


Fig. 6
Ceramic substrates and printing pastes undergo incoming goods inspection before the printing. Conductive patterns, resistors and protective glass are screen printed in 5–10 layers with drying and sintering in between. Each layer is 10-15 μm thick. The resistors are laser trimmed to a limit of 0.5 %. The picture shows printed and trimmed "snapstrates" of a chip & wire circuit, a circuit with soldered components and a resistance network

printed, figs. 4 and 11. The printing pastes used are a mixture of, for example, a conducting material in powdered form, glass powder and an organic binding agent. A palladium-silver paste is normally used for the conductors and different metal oxide pastes, e.g. ruthenium oxide, for the resistors. The conductor and resistor patterns are then made electrically and mechanically stable by sintering at 850°C.

Since the screen printing gives a well defined printing thickness, the resistance of each resistor made of a certain paste will be determined solely by its length and width. The width of the resistor can be reduced by laser trimming, which increases its resistance to the desired value, fig. 5.

A lead frame is mounted on the ceramic substrate, and is connected to the resistor contact surfaces by means of dipping in a solder bath, fig. 9. The leads are then cut to the correct length and the resistor network is ready for final electrical testing. This is done in processor-controlled test stations with automatic handling of the circuits.

Chip & wire circuits
When manufacturing chip & wire circuits an additional gold layer is screen printed which overlaps the palladium-silver layer. The gold layer is used to fix semiconductor chips on the substrate by means of eutectic soldering. At the eutectic temperature 380°C gold and silicon form an alloy which gives good contact between the chip and the con-

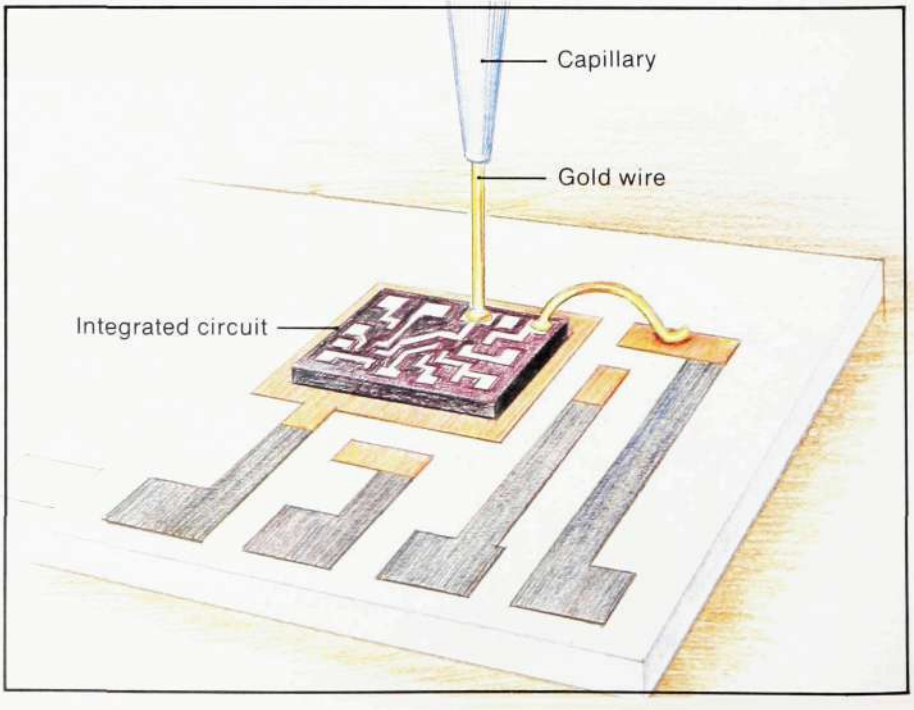


Fig. 7
The gold wire connects the chip to the conductive pattern on the substrate

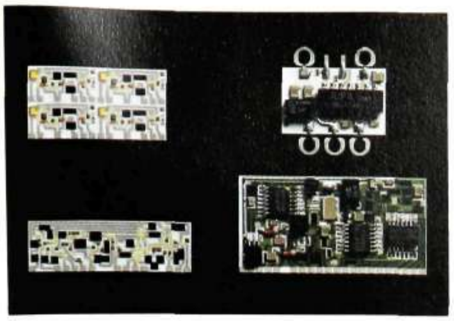


Fig. 8
The components are mounted after the substrates have been snapped. The chip & wire circuit to the left has semiconductors soldered on and then connected via gold wires to the gold conductors on the substrate. The circuits with soldered components, to the right, are first screen printed with solder paste, after which the components are soldered in an IR furnace

Fig. 9
The next stage in the manufacturing process is the lead assembly. The picture shows a chip & wire circuit, a circuit with soldered components and a strip with resistor networks, where the leads are soldered on by means of dipping in a solder bath

ductive pattern on the substrate. During the subsequent bonding the chip and gold pattern are connected by means of a 25 μm thick gold wire, figs. 7 and 14.

This process results in a chip & wire circuit, i.e. a circuit that consists of printed conductors, printed resistors, printed capacitors and semiconductor chips as diodes, transistors and other monolithic circuits.

The chip & wire technique is very space-saving. Many circuit types manufactured in this way are less than 3 mm thick, with an area of less than 4 cm^2.

After the assembly and soldering of leads the circuits are encapsulated for mechanical and environmental protection. The chip & wire circuits are moulded in silicone and epoxy resin. The final testing is then carried out.

Circuit with soldered components

In these circuits encapsulated semiconductor chips are connected direct to the conductive pattern on the substrate by means of surface soldering. Semiconductor chips are available as standard 3-module DIP. Other common encapsulations are TO 92, TO 220 and SOT-23. Other components, such as ceramic capacitors and tantalium capacitors, are also available for soldering.

Surface soldering of circuit components starts with screen printing of solder paste on certain parts of the conductive pattern on the substrate. The components are then positioned on the circuits, with the pins in the solder paste. The circuits are fed through an IR oven, where the solder paste melts and the components are soldered to the substrate. After this the solder joints are inspected, the leads are assembled, and the circuit is encapsulated and tested.

Circuits with soldered components are mechanically insensitive. They can be repaired by changing a faulty component. This is particularly advantageous when manufacturing large and complicated circuits.

Production techniques

RIFA's series manufacture of hybrid circuits is characterized by sophisticated production techniques and a high degree of automatization. Among the sophisticated process techniques may be mentioned laser trimming of thick film resistors to an absolute tolerance of 0.5% and a relative tolerance of 0.1%, and through-plating of holes on the ceramic substrate. (Computer-controlled machines, test systems and multi-operation machines are some examples of the high degree of automatization).

Large production series and strict standardization of dimensions and components have also enabled many operations to be automatized, such as the mounting of soldered components, bonding, the mounting of leads and the final testing. Several projects for further automatization of the production are in progress. The main advantages of automatization are, apart from the lower direct cost, a higher yield and a better quality.

Fig. 10
After encapsulation and cutting of the leads to the correct length the circuits are ready for the final testing. The figure shows various types of encapsulated circuits

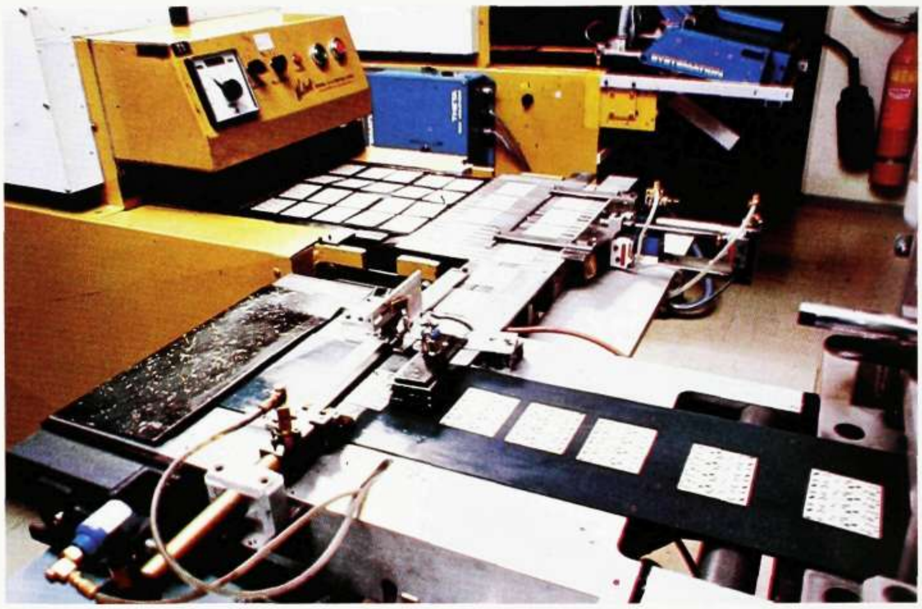


Fig. 11
Printing of substrates for speech circuits

Fig. 12
Final testing of speech circuits

Quality control

RIFA's extensive control activities ensure that the hybrid circuits are of a high and uniform quality. The control activities comprise

- incoming goods inspection
- production control
- final testing
- periodic quality tests.

All material is subjected to incoming goods inspection before being put in store. Quality tests are carried out at regular intervals in order to check the quality of purchased components. The life of the components is then tested under different load conditions and in varying environments.

The production control activities consist of operator, process and acceptance control. The operator is made quality conscious and his interest in checking his own work is stimulated by means of intensive instruction activities and a quality bonus in the wages system. In addition quality inspectors take random samples during the production processes. Many types of circuits undergo a processor-controlled test as soon as all components have been fitted. At this early stage it is easy to analyze and correct any faults. Acceptance tests are included at critical points in the process to ensure a satisfactory quality level. The information from the acceptance tests is fed back into production and provides data for corrections.

Fig. 13, left
Manufacture of high reliability circuits

Fig. 14
Processor-controlled bonding machine

Fig. 15, left
Seam welding machine

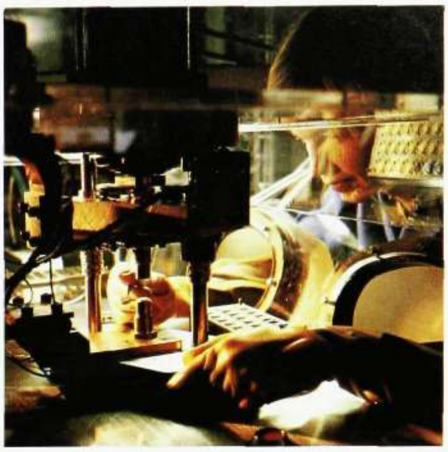


Fig. 16
The package welding takes place in a glove box containing pure nitrogen

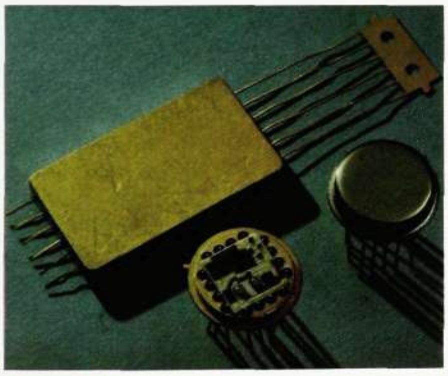


Fig. 17
Hermetically encapsulated circuits

All circuits undergo a final test, which for all series produced circuits is carried out in processor-controlled test stations. These can provide direct print-outs of fault specifications for each individual circuit and a statistical fault distribution for a whole batch. Many types of circuits are tested both at room temperature and at a higher temperature.

After the final testing, fig. 12, the quality control department, which operates as an independant unit, carries out a screening of the circuits. A statistically chosen sample is tested with regard to the electrical and mechanical characteristics. Some circuits are also selected for more comprehensive quality control.

Manufacture of high reliability circuits in small series

The factory also contains a unit for the manufacture of high reliability circuits, fig. 13. This unit is housed in a separate department, supplied with hydrogen, nitrogen, oxygen, vacuum chambers, compressed air, return air, cooling water and deionized water. The ventilation system provides the premises with filtered air with constant humidity. "Laminar flow" hoods are used for the process stages that require extreme cleanliness (class 100). The machinery includes two processor-controlled bonding machines and a seam welding machine for hermetic encapsulation, figs. 14 and 15.

The tasks of the unit can be summarized as:

- manufacture of small series of high reliability circuits and circuits with a high degree of complexity, for example for military and medical equipment
- development of new processes and technical preparation of new products using new techniques.

Fig. 18, left
The printing of fine line patterns takes place in extremely pure air under laminar flow hoods

Fig. 19
The whole batch is inspected after most process steps

Box

Production flow for high reliability circuits

1 *Thick film substrates*
1.1 Screen printing of thick film patterns with conductor widths down to 0.15 mm in several layers (fine line and multi-layer printing), fig. 4
1.2 Sintering of the pastes at 850°C
1.3 Laser trimming of resistors
2 *Hybrid circuits*
2.1 Glueing of semiconductor chips and ceramics capacitors on thick film substrates with silver polymers
2.2 Bonding of semiconductors and substrate using gold wire (d=25 μm), fig. 7
2.3 Glueing of thick film substrates with components in the package base
2.4 Gold wire bonding to the package leads
2.5 Electrical testing and pre-cap inspection of the whole batch
2.6 Changing any faulty components (repair)
2.7 Sealing
2.8 Electrical test and leakage test
3 *Screening*
3.1 High-temperature baking (e.g. 125°C, 24 h)
3.2 Centrifugal test (e.g. 20 000 *g*)
3.3 Temperature cycling test (e.g. −65/+150°C, 10 cycles)
3.4 Electrical test
3.5 Electrical burn-in (e.g. pulsed load at 125°C during 168 h)
3.6 Electrical test
3.7 Helium leakage test
3.8 Bubble leakage test

One characteristic of high reliability circuits is that they are usually hermetically encapsulated, mostly in metal or ceramics. The package protects the hybrid from the environment and also gives good mechanical protection, fig. 17.

Hermetic sealing of packages is carried out by welding or soldering. It is performed in a glove box containing pure nitrogen, fig. 16. The quality of the hermetic sealing is tested by means of a helium spectograph. The humidity of the nitrogen in the glove box is monitored continuously. Before sealing the circuits are baked in an oven.

The high reliability circuits manufactured are more complex and are manufactured by means of more complicated processes than the mass-produced circuits. A typical production flow for a high reliability circuit is shown in the box to the left.

The whole of each batch is inspected after practically every process step, fig. 19, in order to obtain the required quality. Acceptance tests of samples are carried out after items 1.3, 2.2, 2.6 and 3.8. A screening procedure is carried out to remove weak circuits.

A high degree of work motivation is required of the staff if the high quality is to be maintained. For this reason project groups of about five persons have been formed. Each group manufactures similar circuits. Each operator is responsible for and carries out all process steps for a batch of circuits. The operator knows the calculated time and yield for each process step, and can thus judge the amount of work required to complete the product.

The wide knowledge of the staff in the fields of printing (fine line, multi-layer), connection of semiconductors and encapsulation (both hermetic and plastic moulding) has been a prerequisite for the manufacture of prototypes and pilot versions of sophisticated hybrid circuits, for example for telecommunications.

The interest and wide technical skills of the staff in the manufacturing unit have contributed to the development of prototypes and the pre-series manufacture of several new and important circuits, for example for new exchange equipment. The circuits have then been prepared for series production in close collaboration with the production preparation unit and quality control unit of the hybrid factory.

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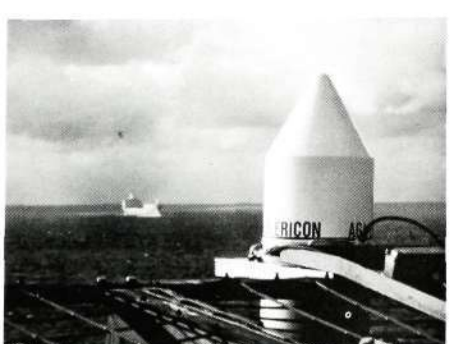


COVER
The radar beacon AGA-ERICON installed on the caisson lighthouse Trubaduren at the entrance to the harbour of Gothenburg on the west coast of Sweden

ERICSSON

Björn Svedberg
Head of
the Ericsson Group

Ericsson Towards the 1990s

For more than a century the activities of the Ericsson Group have been devoted almost exclusively to the telecommunications field – development, manufacture and marketing. Although the emphasis has been placed on public equipment for telecommunications administrations, and particularly on telephone exchanges, the Group holds a prominent position in the whole field of telecommunications.

Within the Group, which has large resources as regards technology, production, marketing and management, a number of changes have been carried out, during the last two years. A certain degree of restructuring and augmentation of these resources has enabled the Ericsson Group to offer a wider product range and has resulted in a more market-oriented structure.

From the point of view of the Ericsson Group the telecommunications market can be divided into three main sectors:

Telecommunications Administrations:	Telecommunications administrations and public companies etc. which provide public networks for telephony, data and telex.
Private enterprises and administrations:	Companies, public and private administrations and organizations requiring internal telecommunications ("the private sector").
Defence:	Defence administrations, naval and air force administrations.

The Ericsson Group offers a very wide product range for all three market sectors, supplemented by a number of additional facilities, such as servicing, training, installation etc.

Telecommunications Administrations

The division for public telecommunications, which forms part of the parent company, develops and markets all types of public telecommunication exchanges for telephony, data and telex, analog and digital transmission equipment, manual telephone systems and power equipment. The division is thus very well equipped for implementing complete telecommunication networks, which is becoming an increasingly common method of marketing and purchasing. The Ericsson Company has recently successfully completed such turnkey contracts in Saudi Arabia and Oman.

Private enterprises and administrations

Telecommunications and data processing are becoming more closely integrated, and the requirements of computer systems as regards communication and network functions have both increased and become more technically demanding. The Ericsson Group has therefore made use of its extensive communication know-how to enlarge its product range within the private sector by introducing systems for administrative data processing, office management and organization. The Group is now also established as a manufacturer of complete systems for information handling, i.e. the transfer, processing, storing and presentation of speech, data, text and visual displays. This has been achieved through the purchase of *Datasaab* by the parent company and by the Group's own earlier development work in the field. A new company, *Ericsson Information Systems AB,*

The Ericsson Head Office in Stockholm, Sweden was formed from the Datasaab group, supplemented by the divisions for information systems and subscriber equipment, which were transferred from the parent company. Ericsson Information Systems is described in a subsequent article in this issue of Ericsson Review.

The product range available to the private sector has been further supplemented by the inclusion of *Autotank AB* in the Group, and by the parent company becoming part owner of *AB ID-Kort*. Autotank AB develops and markets petrol station terminals which enable customers to purchase petrol by means of credit cards or banknotes even if the station is unattended. This technology will have a number of other applications in the retail trade. AB ID-Kort manufactures different types of bank, credit and identity cards, and is thus a logical addition to the Group.

Defence

Several units within the Group are engaged in the design, manufacture and sale of defence equipment. The marketing side has been reinforced, and this has enabled the Group to offer complete strategic and tactical telecommunication networks with associated operating centres. The networks include products from the parent company's divisions for defence electronics and for public telecommunications as well as from *SRA Communications AB* and Ericsson Information Systems. Some well-known Ericsson defence products are interactive computer systems for air traffic control, radar, IR and laser systems for air, marine and ground use and equipment for satellite communication.

Network installation and other services

In addition to the activities that can be considered to be aimed at a certain market sector, the Group has extended its range of more general services. The Group is well established in the field of planning and installation of public networks, including the supply of network material. The range of services offered here has been supplemented to give the Group greater scope for installing entire networks, and to extend these activities to include private, military and industrial networks. Thus the Group provides equipment for railway signalling, for the mining industry, and for the oil industry in the form of telecommunications and telemetry for pipelines.

Planning, installation, operation and maintenance and the training of customer staff are all services of great importance to all the branches of the Group. To these can now be added services in the field of data processing. A new company, *Ericsson Programatic AB*, has been formed, and another company, *AU-System Network AB*, has joined the Group to provide resources in the software field. The consultative and project work, as well as development work on application software carried out by these companies, constitutes an important addition, particularly within the private sector.

Technology

The Ericsson group uses advanced technology, which requires extensive research and development work. R & D are carried out in all units, although only three cases of particular interest will be mentioned here.

In the optical field the Group has carried out research and development work for over a decade, and optical fibre cables and the associated transmission equipment are now being marketed. This technology is already well established in public city networks, and is expected to be an important alternative to both traditional cable and other transmission media in all types of networks within a few years.

Rapid advances are taking place in component development in both the telecommunication and data processing fields. Custom design circuits are of particular interest. Such circuits are developed for specific applications in particular products, and as resources for such production are available within the Group, alternative supplies are ensured and the need for external manufacture is reduced. *AB Rifa* and a special development unit, *LSI Design Center*, handle these activities.

The world-wide success of the AXE 10 system is partly due to the revolutionary principles applied in the design and handling of its software. In the software field special projects are now in progress which are aimed at providing more efficient programming aids and software that is simpler to handle.

The investments made by the Group in this field, as well as the increase in service resources provided by the software companies, are essential for attaining the overall goal, since the cost of the software represents an increasingly large part of the overall system cost and the number of programmers available tends to be limited.

Strengthening of the Group internationally

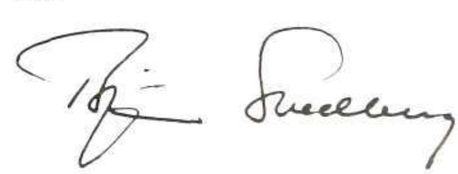
This brief, general description of the Group and its aims would not be complete without reference to the international aspect. In 1980 a new company, *Anaconda-Ericsson Inc.*, was formed in the USA jointly by Ericsson and the American enterprise Atlantic Richfield Corporation. The main production of Anaconda-Ericsson now consists of cable and wire manufactured in a number of factories in the USA and Latin America. The Anaconda-Ericsson Telecommunications Division, which already markets PABXs, transmission systems and bank terminal systems, constitutes a valuable addition to the Ericsson Group, forming a basis for the activities of Ericsson Information Systems in the USA. The private sector in the USA constitutes about 50% of the world's private market, and establishing the Ericsson Group in the USA is an extremely important move, intended to reach a large potential market as well as adding to the development resources.

The changes that have been described here will quickly penetrate other foreign markets, and the initial effect will be a strenthening of the marketing side.

Ericsson

The Ericsson Group has entered the 1980s as a stronger enterprise, with a wider product range and with an organization for more efficient marketing. The changes that have already been carried out and others that are still to be made are important and necessary measures in order to maintain the position of the Group as one of the leading enterprises in the field of telecommunications. The Group with its changed identity faces a new epoch.

This new Ericsson Group is symbolized by a new visual Ericsson identity, the new logo.



Ericsson Information Systems – A New Company

Lars Ramqvist and Martin Thorén

The Ericsson Group is in a dynamic stage of development. A milestone in the development of the Group will be passed on January 1st, 1982. A new subsidiary company, Ericsson Information Systems AB, will then be formed. It will consist of the main part of Datasaab AB and the divisions for Subscriber Equipments and Information Systems from LM Ericsson. In this article the authors describe the development that has led to the formation of the new company and give a summary of the company, its aims, strategy and products.

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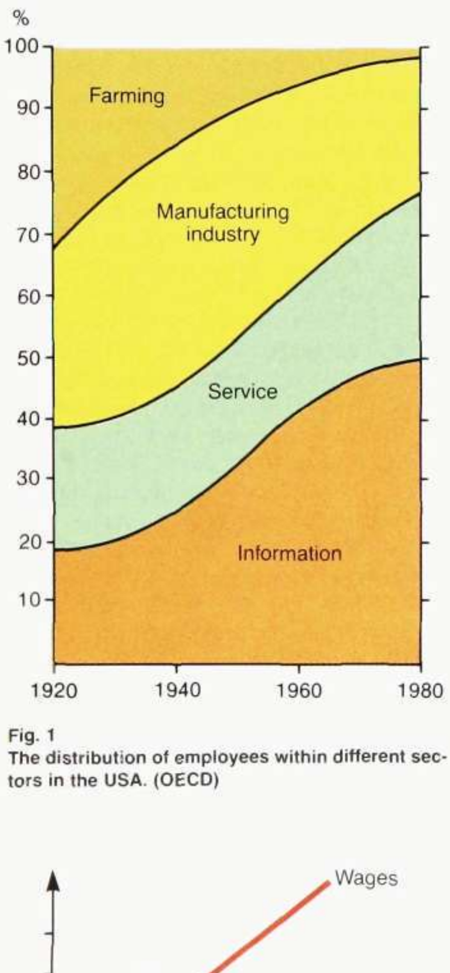

Fig. 1
The distribution of employees within different sectors in the USA. (OECD)

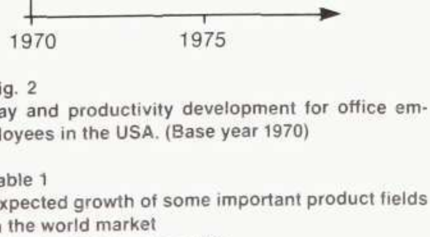

Fig. 2
Pay and productivity development for office employees in the USA. (Base year 1970)

The decision to set up Ericsson Information Systems on January 1st, 1982 was the result of the desire to expand the activities of the Ericsson Group beyond the field of telephony. Expansion should take place within a sufficiently large and growing sector of the market. One such sector comprises information systems for private and public activities, i.e. large industries, banks, insurance companies and public companies. This market is called the private sector in this article.

Markets and trends

The decision to expand into the field of information systems for the private sector was based on analyses of market, industrial and technical trends. As can be seen from table 1, the market for small computers, terminals and work stations for offices is growing rapidly, in certain cases at more than 20% per year at a fixed money value. Moreover, the communications part of this market is growing faster than public telecommunications. Software is another interesting field with rapid growth.

Thus the world market for these products is very large and also expanding quickly. This development is affected by two trends in present-day society.

- An increasingly large part of the work force is engaged in the information sector, whereas the part employed in direct production is decreasing, fig. 1.
- The wages for work in the information field have increased rapidly during recent years, and at the same time the increase in productivity has been considerably slower than in the industrial sector, fig. 2. However, the amount invested in each employee for the purpose of increasing the productivity is several times higher in industry than in, for example, offices.

These trends imply that investments aimed at increasing productivity are now also expected within the growing information sector. In order to be able to optimize such investments it is necessary that purchased equipment can be connected to an integrated system which offers means of communication and also facilities for using the units in the system for several different purposes.

The world market for products aimed at the private sector is expected to amount to 38 billion US dollars in 1985. The USA alone is responsible for half of this market, fig. 3. Furthermore the US market is in the lead as regards technology and is often first with new products. The USA will therefore constitute a key market for Ericsson Information Systems. Know-how will be obtained and products developed in collaboration with the American subsidiary Anaconda-Ericsson Inc.

35% of private sector products are sold in Western Europe, which will naturally play an important role as the home market for Ericsson Information Systems.

The rapid growth that has been recorded during the last few years, and which is also forecast for the near future within the distributed data processing, communication and data storage fields, means that new sales outlets can be created within LM Ericsson's particular field and can form the basis for future expansion. This applies particularly to the private sector.

Table 1
Expected growth of some important product fields in the world market
(Prices for 1980, in million US$)

Product field	1980	1985	Annual growth
Small computers	7 000	18 000	20%
Word processing equipment	1 800	7 400	32%
Work stations	1 400	4 800	28%
Other terminals	540	1 000	13%
Communications	10 600	15 400	9%
Consultancy/software	8 600	21 800	20%
Main frame computers	15 000	18 000	4%

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Division for Information Systems

The first stage of the venture into information systems for the private sector was initiated in the middle of 1980 with the setting up of a new division within the parent company, the division for Information Systems. The aim of the division was to be able to provide complete systems for data/text/video, which are based on LM Ericsson's extensive know-how in modern telecommunication and computer technology.

The activities of the division cover three fields, namely data transmission with modems and other network equipment, private data networks for packet switching, and office automation comprising work stations with word processing, document handling, telex communication etc.

Since its inception the division has carried out development projects to meat specific commercial requirements. During the first year of operation customer orders were already being received for both ERIPAX data networks and ERITEX office automation equipment. Modems, which were previously marketed by the parent company, have also been a well established product for a long time.

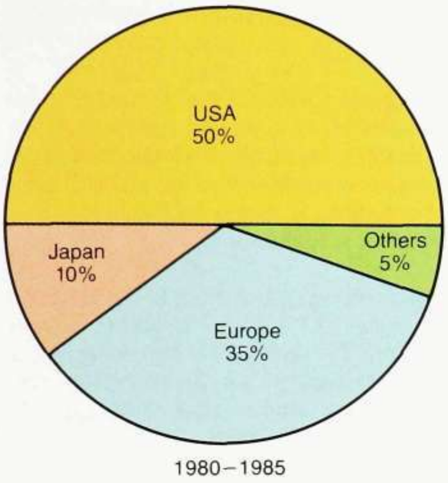
Software is important

It is often said that there is an international software crisis. Development and maintenance of software is often a burden to customers who have purchased office automation and information systems, and it forms an increasingly large part of the total cost of data processing, fig. 4. The Ericsson group has therefore decided to offer the customers complete software packages, as well as consultative and service facilities in both EDP and technical fields, such as data communication. The Ericsson group has extensive know-how in the software field based on experience from its own large computer centre, and also from development work on the computer-controlled telephone exchange system AXE 10.

It was decided that collaboration with independent software companies was desirable in order to gain further experience in this field. At the end of 1980 LM Ericsson therefore purchased a third of the shares in AU-System Network AB, and on January 1st, 1981 a new company, Ericsson Programatic AB, was formed in collaboration with Programator. The ownership details are illustrated in fig. 5.

AU-System Network AB is a consultant company which has concentrated its activities within the fields of data communication and distributed data processing. The company is primarily marketing software products and systems in the Nordic countries, but it can also undertake contracts outside Scandinavia, e.g. as a subcontractor to LM Ericsson.

Programator is one of the foremost Swedish companies for qualified and complete consultative services in the EDP field. The company offers an all-embracing service, from the preliminary studies to the follow-up and maintenance, and sells software for, for example, minicomputers, distributed processing systems, display terminals, data base systems and real time systems.



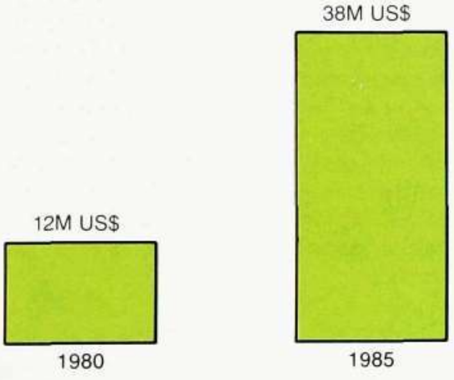


Fig. 3
The whole world market for the type of private sector products marketed by LM Ericsson

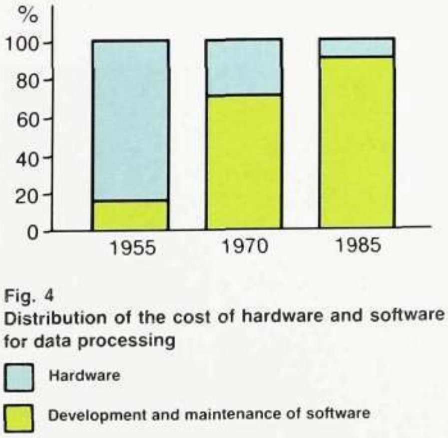


Fig. 4
Distribution of the cost of hardware and software for data processing

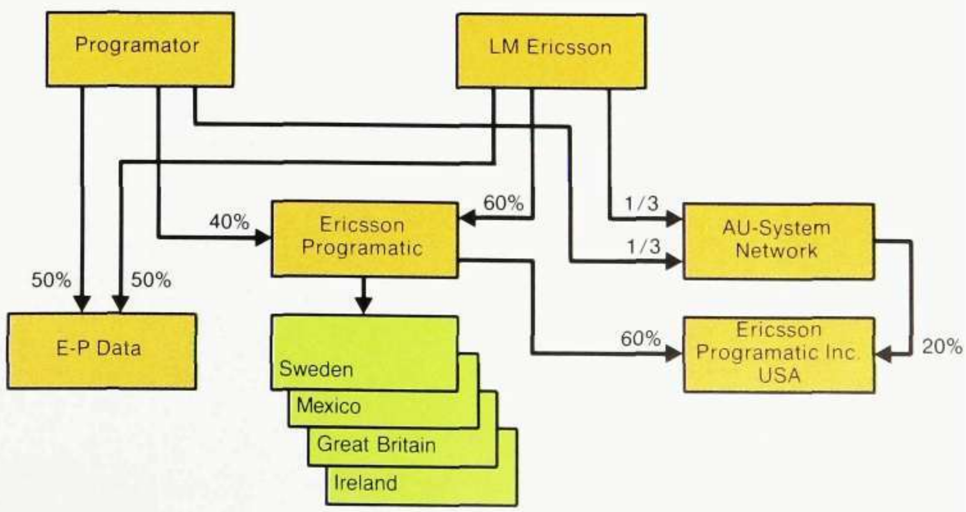


Fig. 5
The ownership of the software companies that are affiliated to LM Ericsson

In markets outside Sweden the new company, Ericsson Programatic, will offer consultant services similar to those provided by Programator and AU-System Network AB in Sweden operating as a company called E-P Data, which is owned jointly and equally by LM Ericsson and Programator. An American subsidiary, Ericsson Programatic Inc., has also been formed, primarily for the purpose of marketing the services of AU-System Network in the very important US market, particularly in banks.

This investment in software companies has several purposes. There is of course the purely commercial interest, since the companies operate independently and have to prove profitable in a rapidly expanding international market. However, it is also a means of increasing contact with the market with a view to obtaining better information regarding the demand for hardware and software as well as application trends. There are certain possibilities of collaboration with the software companies in tenders and purchasing. In such situations these companies can contribute system studies and other consultative services in the initial stages, while LM Ericsson provides the products and systems. The companies can also be considered as a programming source, necessary when the current scarcity of programmers is considered.

Purchasing of companies

At an early stage the management of LM Ericsson realized that it would be necessary to purchase companies in order to achieve the substantial growth of the private sector activities planned for the Group. In view of the integration of the telecommunication and computer fields that was taking place, the interest was concentrated on Datasaab, the largest Swedish manufacturer of terminals and computers.

It was soon obvious that Datasaab's experience of minicomputer systems and terminals was an excellent complement to LM Ericsson's know-how in the fields of telecommunication, computer technology and complex integrated systems.

Extensive negotiations led to LM Ericsson acquiring 90.5% of the Datasaab shares on April 1st, 1981. The remaining 9.5% were obtained by the Swedish Telecommunications Administration through its subsidiary Teleinvest.

At the same time a survey was carried out to investigate the possibility of coordinating the activities of Datasaab and LM Ericsson in the private sector, both as regards marketing and production. Since the requirements of the private sector are somewhat different from those of telephone administrations, which are LM Ericsson's traditional customers, it was soon clear that a private sector subsidiary ought to be formed.

On June 4th, 1981, it was therefore announced that two of LM Ericsson's divisions, the divisions for Information Systems and Subscriber Equipments, were to be combined with the Datasaab divisions

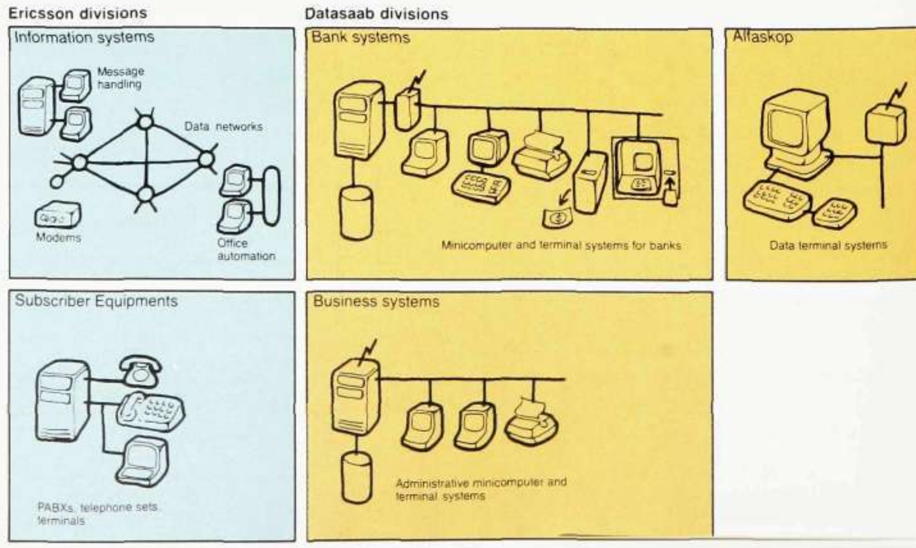


Fig. 6
The Ericsson and Datasaab divisions forming Ericsson Information Systems

for Business Systems, Bank Systems and Alfaskop, fig. 6. Legally the activities in question were to be based on Datasaab and were to be operated as a subsidiary of LM Ericsson.

It was also decided that the remaining division within Datasaab, Interactive Data Systems, should be transferred to SRA Communications AB, another subsidiary of LM Ericsson. The division in question produces air traffic control systems, simulators and defence electronics, which all fall outside the planned scope of the new company, but which are well in line with the activities of SRA.

Ericsson Information Systems

The new subsidiary, Ericsson Information Systems AB, will be fully operative from January 1st, 1982. Teleinvest is also a minority shareholder in this company, with 9.5% of the shares. LM Ericsson holds the remaining 90.5%.

The aim of Ericsson Information Systems is that the company shall establish itself during the 1980s as an important supplier of complete systems and system products in the field of internal communication, distributed data processing and data storage. The main strategy of the new company is to provide high quality products based on the present activities of Datasaab and LM Ericsson's divisions for Subscriber Equipments and Information Systems, and to increase its profitability and competitiveness by marketing a modular and flexible integrated system. This also provides further opportunities for the marketing of service facilities.

The company's products will successively be developed into components in such an integrated information system, which it must be possible to structure in different ways to meet different customer requirements. The customers must be able to purchase individual system components and extend the system when necessary, starting with an arbitrary unit. Advanced operation and maintenance functions will also form an important part of the integrated system.

Ericsson Information Systems will have a functional business structure reflecting the aim of being able to offer integrated systems, primarily based on communication systems, business systems and terminals, fig. 7.

It is also an aim to use engineering techniques common to the whole of the production range in order to attain the desired compatability between the system components and to reap the benefits of large-scale manufacture. From the functional point of view the software companies mentioned above, which operate as separate commercial units, are considered as interfaces to the market. However, the main part of the marketing and sales will take place through the distributing companies, which will consist of the subsidiaries of Ericsson Information Systems and some other subsidiaries and associated companies of the Ericsson Group.

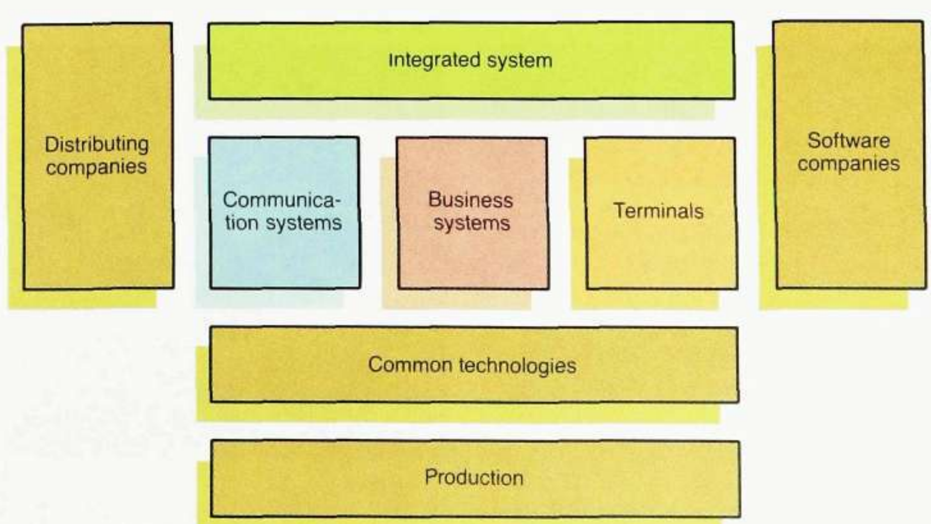


Fig. 7
The functional structure of Ericsson Information Systems

Fig. 8
MD 110, a new stored program controlled PABX for voice and data. The system has a modular structure and can be extended to 10 000 extensions

Fig. 9
Series 16, a minicomputer system for offices, developed by Datasaab

Fig. 12
The terminal system ALFASKOP System 41

Fig. 10
The Datasaab bank system

Fig. 13
The digital special telephone set for MD 110

Fig. 11
ERITEX 10, a typewriter terminal with word processing and teletex communication

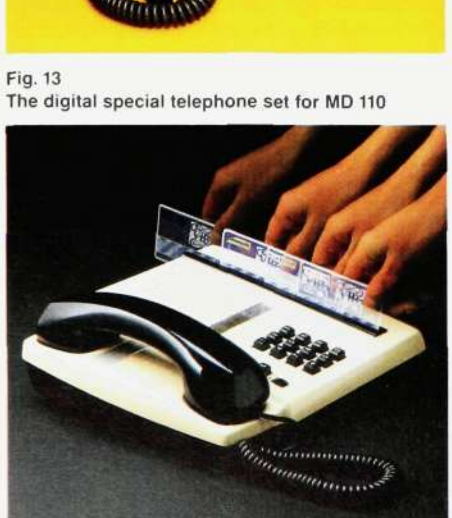


Fig. 14
Authorization terminal for credit cards

Products

Certain of the products of Ericsson Information Systems have already been described in Ericsson Review, and others will successively be presented in subsequent issues. A brief list is given here:

Communication systems
- MD 110, a digital, stored program controlled PABX with facilities for simultaneous data transmission, fig. 8.
- ASB 20, 100 and 900, stored program controlled PABXs[1-4], DIAVOX 406 and 824, stored program controlled office communication systems[8]
- ERIPAX, a data network for packet switching
- ERIBUS, a local data network for transmission at Mbit/s rates
- ERIMAIL, a system for computer controlled telex and teletex
- Modems, from 50 bit/s to 64 kbit/s

Business systems
- Series 16, an administrative minicomputer system for work positions with display units, fig. 9
- System LXT for distributed data processing in offices
- Bank systems with cashier terminals, note dispensers, cash dispensers etc. and a version of system LXT, fig. 10
- Terminal systems for the retail trade

Terminals
- ERITEX, an office support system with word processing, document handling, information retrieval and teletex communication
- ERITEX 10, a typewriter terminal for word processing and teletex communication, fig. 11
- ALFASKOP System 37, an editing terminal for input of data to large computers
- ALFASKOP System 41, a terminal with local data processing and storage, fig. 12
- DIAVOX, standard telephone set [5, 6] and special set[7, 8]
- Special digital telephone set for MD 110, fig. 13
- Authorization terminal for credit cards, fig. 14

Integrated information systems

The products listed on the opposite page are used to build up an integrated information system. Facilities and functions for administrative data processing, support systems for offices etc. can be combined according to the customers' requirements with the aid of communication systems for voice and data, terminals and modular hardware and software for information processing, fig. 15. Fig. 16 gives a more detailed description of these functions and facilities. Some of these functions and the corresponding products are the responsibility of the subsidiaries LM Ericsson Telemateriel AB (LMS), SRA Communications AB and Autotank AB. LMS is responsible for time recording, alarms, supervision and other functions associated with buildings. SRA is responsible for mobile radio, paging etc. and Autotank for petrol station credit and payment equipment.

A hypothetical example of such an integrated system, containing several of the system components described above, is

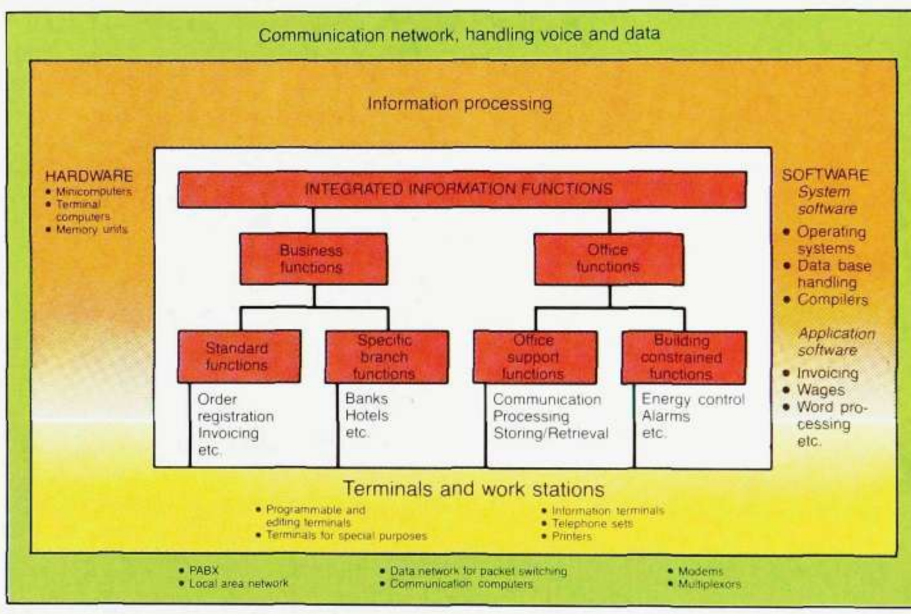


Fig. 15
The structure of an integrated information system

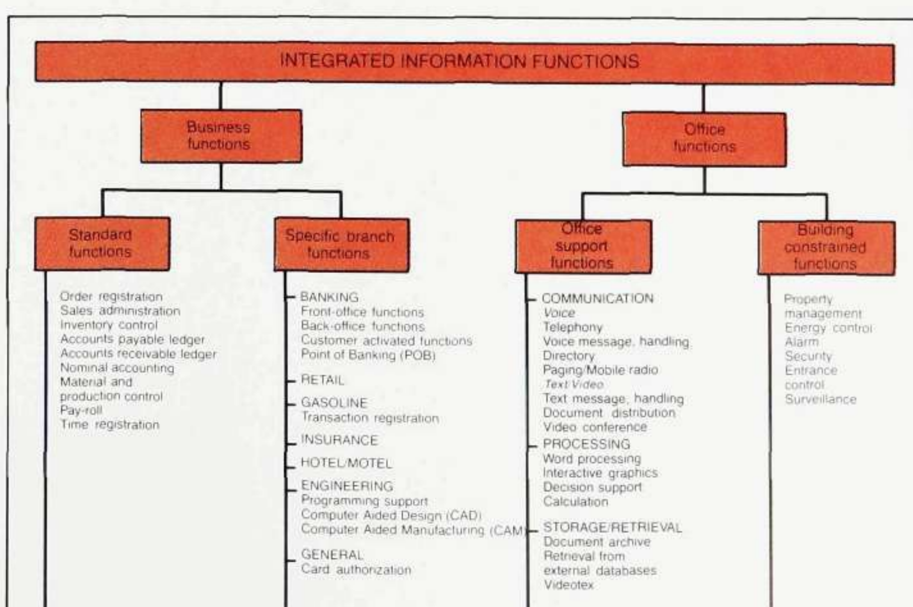


Fig. 16
A functional analysis of an integrated information system

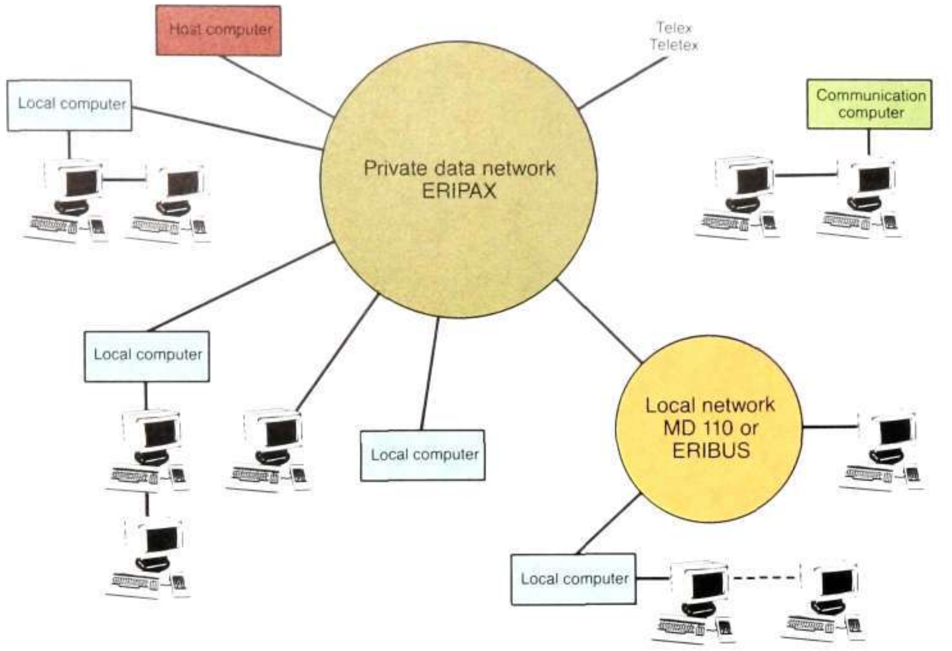


Fig. 17
A hypothetical example of an integrated information system

shown in fig. 17. The private ERIPAX network is used for global communications. The local communications are handled by MD 110, or by ERIBUS if integrated voice communication is not required. ALFASKOP systems, connected via a concentrator unit, are used for communication with the main computer. Local computers of type Series 16 are used for extensive local processing, and terminals are connected via terminal buses, or via ERIBUS if a very high communication capacity is required. Terminals can be accessed via a special communication computer if the required amount of local processing is not too large. Computers and terminals can also be connected direct to ERIPAX via standardized interfaces.

Ericsson Information Systems will develop the integrated information system in accordance with the principles which LM Ericsson has so successfully applied for the complex AXE 10 system, i.e. software and hardware modularity with standardized interfaces, extensions in steps and advanced operation and maintenance functions.

The great step LM Ericsson now takes in the field of information systems with the formation of Ericsson Information Systems AB necessitates collaboration from the other units in the Ericsson Group. This applies particularly with regard to companies that operate within the private sector, namely LM Ericsson Telemateriel AB, SRA Communications AB, Autotank AB and certain other of LM Ericsson's subsidiaries and associated companies, both within Sweden and abroad.

Taken as a whole, the Ericsson Group has the resources and the know-how, and thus the prerequisites for establishing itself successfully as an important international manufacturer and supplier in the rapidly expanding information system market.

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AXE 10 in Sweden

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The digital telephone exchange system AXE 10 has been developed jointly by the Swedish Telecommunications Administration and LM Ericsson. The main part of the development was carried out by the jointly owned ELLEMTEL Development Company. The system replaces both 500-line selector exchanges and crossbar exchanges, and it is now the standard system of the Swedish Telecommunications Administration.
A changeover to digital equipment in the transmission network is also taking place in parallel with the installation of AXE 10. The AXE 10 equipment is manufactured for the Telecommunications Administration by its industrial division Teli and by LM Ericsson.
In this article the author describes briefly the decisions and activities that led to the development and introduction of AXE 10 in Sweden and also the introduction process.

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The forming of ELLEMTEL

Collaboration between the Swedish Telecommunications Administration and LM Ericsson regarding development work has existed for a long time in different forms. For example, in 1956 joint development work started on electronic exchange systems. However, the two parties wished to try different solutions, and two systems were therefore developed. LM Ericsson's AKE 12 was put in operation in the Stockholm suburb of Tumba in 1968, and the Administration's A 210 was put in trial operation in another suburb, Storängen, in 1970.

The experience gained from the Tumba and Storängen exchanges showed that the computer-controlled switching systems had great advantages, but that it was unprofitable to run two projects in parallel. It was also clear that digital exchange systems would have to be considered in the near future. It was therefore decided to start closer collaboration on joint projects. In April 1970 an agreement was made to set up a jointly owned development company with the main task of developing electronic equipment for telecommunication. This also meant a broadening of the long-standing development cooperation. The company was designated ELLEMTEL Development Company[1].

Development of AXE

The development of AXE started in the autumn of 1970 within ELLEMTEL with a system survey, which was to form the basis for the choice of a new local exchange system. Naturally the experience gained from A 210, AKE and ARE was utilized. AKE and ARE are LM Ericsson's stored program controlled telephone exchange systems with code switches and crossbar switches respectively.

The first report, in July 1971, recommended a reed switch system with central and regional processors. The system was designed so that both the group selector

Fig. 1
The first Swedish stored program controlled telephone exchange, AKE 12, was put in operation in 1968 at Tumba, a suburb of Stockholm

Fig. 2
Rack and shelves in the BYB construction practice. Magazines are placed on the shelves

and the subscriber stage could be exchanged for digital variants. The technology available at the time justified an initial version with reed switches. However, the system was to be optimized for digital operation.

One of the characteristics of the AXE design is that the control functions are divided up between regional and central processors and the software and hardware is divided into modular units. This division simplifies operation and maintenance, and also the introduction of new functions. It also enables the system to be adapted and developed further as new components and ciruits become available.

As soon as the development work had been initiated, both the Telecommunications Administration and LM Ericsson started preparing requirement specifications for different types of exchanges, beginning with large local exchanges. The basic characteristics and function prerequisites were formulated in 1971 and were used to evaluate the system designs developed by ELLEMTEL.

The new exchange system also required a new construction practice adapted for automatic production, easy installation and simple maintenance. The development of such a general construction practice for electronic equipment, designated BYB 101, was started in 1971 at ELLEMTEL.

A high-level computer language, PLEX, was developed in order to simplify the programming of the system. This language is specially adapted for telephone exchange functions, and later became one of the foundation stones for CHILL, the language recommended by CCITT in 1980. The central processor, APZ 210, which was developed for AXE, was of course optimized for PLEX.

In 1972 the Telecommunications Administration specified model stations for 3000, 8000 and 25 000 subscribers. These models were used to evaluate the cost, capacity and space requirements of the AXE system. The Administration also provided the exchange and network in Södertälje, 35 km west of Stockholm, for a field trial.

The equipment at Södertälje, for 3000 subscribers, was taken into service in March 1977 and has performed according to expectations. However, it differs in many respects from the AXE 10 system which during recent years has been widely installed in the Swedish network, since the Administration decided in January 1977 that new local tandem and transit exchanges were to be equipped with digital group selectors. It has also been decided to introduce digital subscriber stages and digital concentrators.

Fig. 3
The control room in the AXE 10 exchange at Södertälje, completed in 1977

Fig. 4
A magazine in the BYB construction practice, with a circuit board assembly for a digital switch extracted

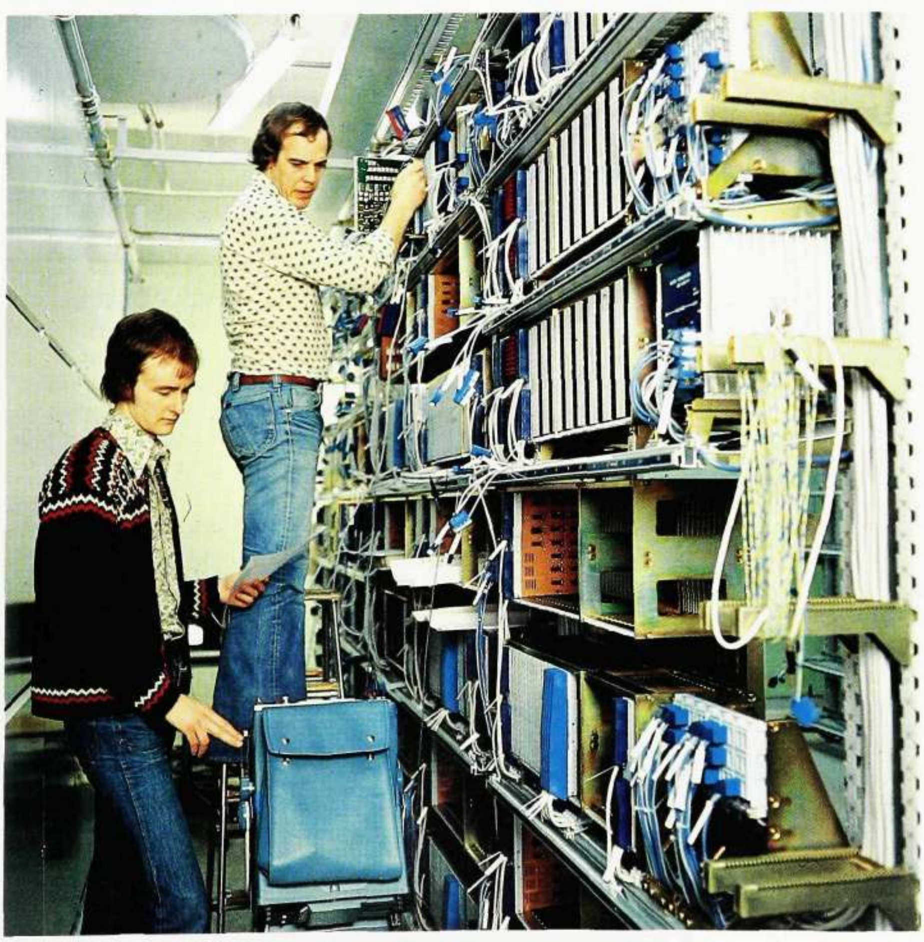
Strategy for modernizing the Swedish telephone network

In 1980, when AXE 10 was first introduced in the Swedish telephone network, the network contained installed equipment for nearly six million subscribers. Three million of these lines were connected to the crossbar system A 204, 2.5 million to the 500-line selector system AGF and 0.4 million to rural exchanges with crossbar selectors.

Sweden has 80 telephone sets per 100 inhabitants, which is the second highest density in the world. The density of subscribers' main stations is the highest in the world. In spite of this, the annual growth is about 110 000 subscribers. This figure is expected to fall to about 75 000 during the second half of the 1980s. 60% of the growth is in exchanges with less than 8000 subscribers and 15% in exchanges with less than 200 subscribers.

The traffic volume is approximately 0.07 erlangs per subscriber and the number of call metering pulses exceeds 3000 per exchange line and year. However, the earnings trend during the remainder of the 1980s is such that the traffic volume per household cannot be expected to increase materially.

Fig 5.
The Södertälje exchange during the installation



In the business sector and the public sector the situation is different, since telecommunication plays an essential role in the efforts to increase efficiency and productivity. This also requires new facilities, which can easily be provided with modern digital switching systems of the AXE 10 type. Since the oldest equipment in the Swedish telephone network is to be found in the cities, where the number of business subscribers is largest, it is natural that the replacement of old equipment by AXE 10 is carried out in these areas first.

It is the objective of the Swedish Telecommunications Administration to be able to offer its customers the same telecommunication facilities regardless of geographical position. Customer-tailored solutions will therefore be used in regions where the telephone network will not be digitalized in the near future, in order to meet the business requirements for advanced telecommunication facilities also in these areas. Such customer-tailoring may consist of special terminals, auxiliary equipment in exchanges and special transmission equipment. The need for such special measures is expected to be greatest during the next five years, after which it will successively decrease as the digitalized part of the network increases.

The strategy chosen means that the requirements of business subscribers can be met, and at the same time the Administration can limit the digitalization to what is justified by the need for growth and modernization. Thus the introduction of AXE 10 is concentrated to limited geographical areas. Detailed replacement programs have been prepared for electromechanical exchanges, which are dismantled, renovated and used again for extension of the parts of the network where such equipment is acceptable. Analog transmission equipment will also be re-used in a similar way. Thus very little analog exchange and transmission equipment will be purchased after 1985.

The possibility of modernizing the local network is particularly interesting. The use of concentrators enables the network to be

Fig. 6
The AXE exchanges in Sweden by 1988

Stockholm	**16**	**exchanges**
Gothenburg	**15**	**"**
Malmö	**3**	**"**

Fig. 7
The Sävedalen exchange in Gothenburg was taken into service in 1980

restructured and simplified, and centrally situated premises can be freed for other purposes. The transmission network will also be simplified and easier to maintain. There will be greater possibilities of offering digital transmission right up to the subscriber terminal.

New, digital PABXs are being installed in parallel with the introduction of AXE 10. The majority of such PABXs are installed in the cities and are digitally connected to the AXE 10 group selector stage. This means that in a few years a large part of Sweden's business telecommunications will be digital from PABX to PABX.

Modernizing with AXE 10

Since the oldest 500-line selector exchanges in Sweden are almost 60 years old, one aim of the modernization program had to be to replace all such exchanges. According to the present plans this work will be completed by the end of the century. By the year 2020 it is probable that all crossbar exchanges will also have been replaced. However, it is likely that for various reasons, e.g. simpler maintenance, the modernization will be speeded up and more than 150 000 lines will be replaced each year. If growth is also taken into account this means that the Administration will install at least 250 000 lines of AXE 10 per year for the next 40 years. In order to show an acceptable financial result this must be done at a cost per line that is less, or no more than the present cost for crossbar and 500-line selector equipment.

In Sweden the AXE 10 system will be used for all types of exchanges, i.e. small terminal exchanges, local exchanges, local transit exchanges, national transit exchanges and complex international exchanges. The terminal exchanges consist of concentrators, which in rural applications must be able to handle internal traffic and alarm traffic even if the connection to the main exchange is broken. The concentrators can be extended from 128 to 2000 lines. The maximum capacity for a unit with a central processor is 65 000 subscribers at 0.07 erlangs, but with normal growth such a unit is already economically viable for an exchange with 1000–2000 subscribers initially. All exchanges have digital group selectors, to which PCM line systems can be connected. The digital concentrators and PABXs are also connected via such line systems.

The rural areas of Sweden are very sparsely populated, and the concentrators used in these areas must therefore be exceptionally reliable. The maintenance costs will otherwise be far too high. It will also take time to train staff for this type of operation, and therefore the concentrators cannot be introduced on a large scale until after 1985.

Since the AXE 10 system will be introduced in digital "islands" in the network it will be necessary to use signal converters for interworking with analog equipment. CCITT signalling system no. 7 will be used for the traffic between AXE 10 exchanges from 1984.

A parallel, digital network will be stablished in the long-distance network so that all AXE 10 exchanges can be connected together via digital lines.

The introduction of AXE 10 means that the point of changeover to four-wire working is moved. Previously this has usually been at the input to the transit exchange, but now the changeover can take place in the extension circuit in a digital PABX, in the subscriber circuit in a digital concentrator, on the output of an analog subscriber switching stage or on the output of an analog terminal exchange.

Conversions in Eskilstuna and Gothenburg

The planned conversions in Eskilstuna, a town 100 km west of Stockholm, and Gothenburg, the second largest city in Sweden, are good examples of the possibilities offered by AXE 10 and digital technology.

Today Eskilstuna has one 500-line selector exchange for 34 000 subscribers and a 25-year old cable network which must gradually be replaced, partly because manholes are too small.

Two conversion alternatives have been studied. The first alternative means that the existing exchange would be replaced by an AXE 10 exchange of the same size and that the conduit routes would be rebuilt and improved. During the next 30 years the primary network would also be replaced and concentrators would be introduced.

The second alternative means that a central AXE 10 exchange for 8000 numbers would be built and that 26 digital concentrators for a total of 28 000 numbers would be connected to the exchange. In the primary network 82 km of 25-year old cable would be replaced by 36 km of modern cable for PCM.

The advantages of alternative no. 2 are that it would cost less for the rebuilding and extension of premises, and that a centrally situated building could be used for the Administration's sales activities. The cost of cable vaults, culverts, ducts and manholes would also be considerably lower, and the cost of maintenance and gas protection in the cable network would be reduced. The greatest disadvantage of this alternative is the difficulty of finding suitable premises for the digital concentrators. The cost of the initial stage would also be slightly higher for the second alternative, but the costs over 15 years would be 20 – 40% lower. The secondary modernization effects and the long-term gain justify the conversion of Eskilstuna in accordance with alternative no. 2. Since the conversion means a radical change of the telephone network throughout the town it is necessary to allow adequate time for the work. The conversion is therefore planned for completion in 1985.

In Gothenburg three of a total of 23 exchanges have already been replaced. At the same time the trunk network between the exchanges is rapidly being converted to PCM transmission. Optical fibres will be used for routes with a large amount of traffic.

When planning the Gothenburg network it was discovered that no suitable premises were available for the replacement of one of the city's oldest and most central exchanges, Drottningtorget. One solution would be to divide the 25 000 numbers of this exchange between 10 – 20 digital concentrators, which would then be connected to two adjacent AXE 10 exchanges, Kålltorp and Kaserntorget. At the same time the cable network and conduit routes would be restored in the same way as in Eskilstuna and with corresponding profits. The introduction of digital concentrators will be later in Gothenburg than in Eskilstuna, but before that a large number of digital

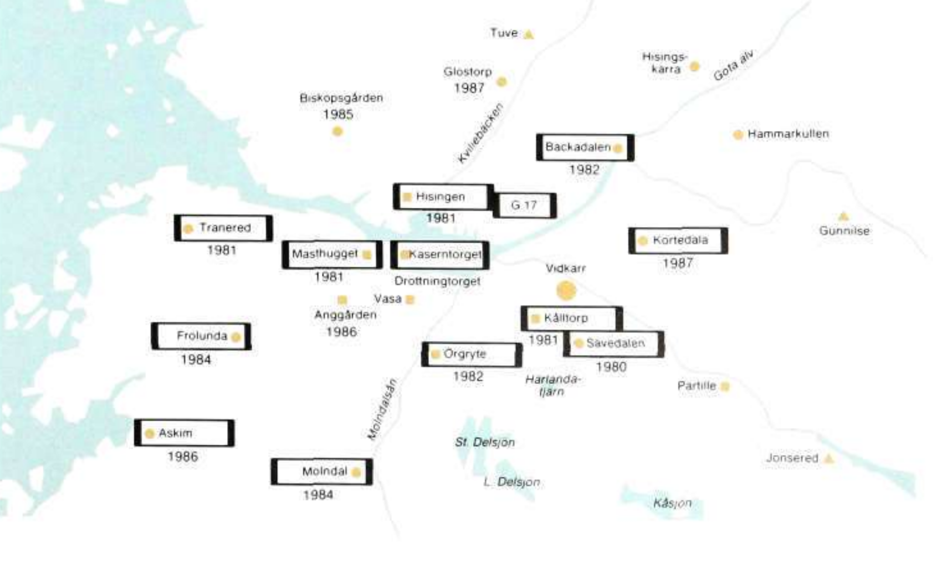
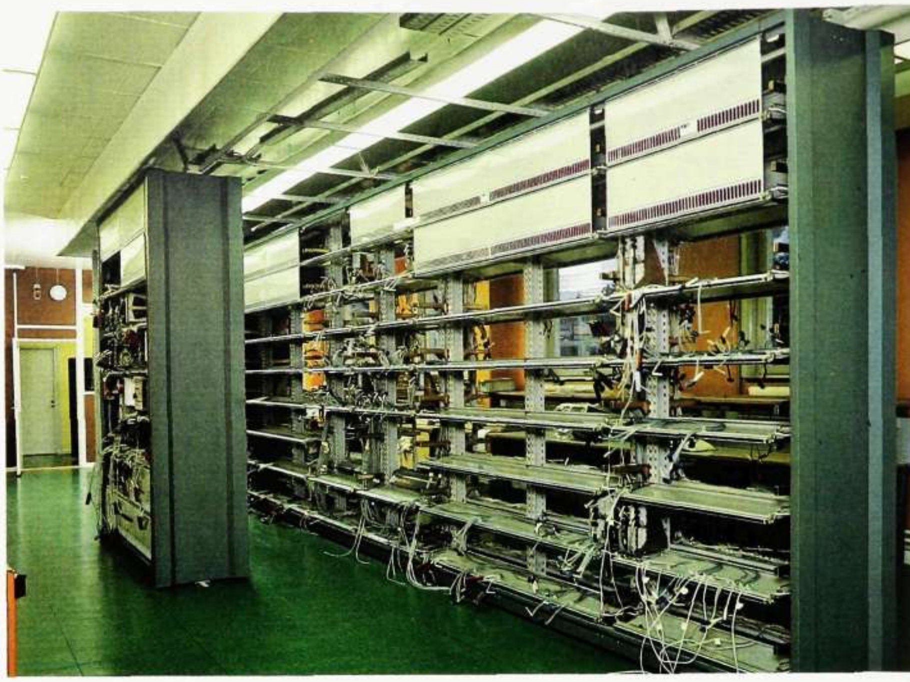


Fig. 8
Computer-controlled exchanges in the Gothenburg area, with the year they were or are to be put into operation. Framed names indicate AXE exchanges

- City exchange
- Suburban exchange
- Automatic rural exchange
- AKE 13, AXB 20 and 30

Fig. 9
An AXE exchange being assembled in the Teli factory at Nynäshamn



PABXs will have been taken into service in the Gothenburg area, for example a separate PABX network for Volvo.

Planning, adaptive design, operation and maintenance

In 1977 it was decided to replace 20 exchanges for 380 000 subscribers between the middle of 1980 and the middle of 1982. Of these LM Ericsson is to supply 11 exchanges for 240 000 subscribers and Teli, the Administration's Industrial Division, is to supply eight exchanges for 140 000 subscribers. The scedule for the subsequent two-ear period comprises approximately 400 000 lines, with a comparatively larger proportion for Teli. In addition an international transit exchange, which will also handle satellite traffic, has been ordered from LM Ericsson for the Hammarby exchange in Stockholm.

The size of the orders and the stringent time schedule meant that the Administration's central resources for project planning and dimensioning were not sufficient. These tasks had to be delegated to the local telecommunication centres, which necessitated an extensive training program. Each conversion object was so large that it had to be coordinated by a project group led by the local telecommunication centre, with the central technical units as consultants.

The above-mentioned decentralization of the project planning and dimensioning activities had been planned, but not at such an early stage. It meant that at first there was a lack of instructions, which put the knowledge and resources of the telecommunication centres to the test. However, on the whole the conversion projects are running according to plan and the centres have managed the tasks very well.

The selection of the first twenty exchanges to be converted to AXE 10 was made partly on the basis that the need for adaptive design should be minimized. A system study showed that 21 program blocks had to be designed for the Swedish market. LM Ericsson designed nine of these, the Administration ten and ELLEMTEL two.

During the years 1977–79 the Telecommunications Administration built up the required design resources, which were dimensioned for the adaptive design work to come and in order to be able to administer the blocks designed by the Administration.

LM Ericsson and the Telecommunications Administration have agreed that the production of programs for all AXE 10 exchanges in Sweden should be carried out by the Administration. All exchanges will have the same software in order to keep the amount of work required for both the production and the maintenance of programs within reasonable limits. In practice this means that two program packages are maintained simultaneously. One of these is used for new installations and the other is in operation in previously installed exchanges. In order to achieve the goal of the same software in all exchanges, the software in the previously installed exchanges is successively being replaced by the latest version. In most cases a third program package is also being developed.

Each AXE 10 has its own, unique exchange data. In the case of an exchange with complex traffic cases it may be necessary to compile about 10 000 parameters for input. Instructions and training material had to be prepared very quickly in order to be able to carry out this work for the first 20 exchanges, with their stringent time schedules. The most laborious part of the work, the collection of data, was immediately delegated to the telecommunication centres.

Fig. 10
Computer-aided designing of printed board assemblies at ELLEMTEL

The use of AXE 10 was originally limited to Stockholm and Gothenburg, but was quickly extended to another six of the 20 telecommunication areas in Sweden. Extensive course and training packages have been prepared, so that the whole of the operating organization can become acquainted with the AXE 10 system. Courses for the training of technicians and repairmen for AXE 10 were first started in the middle of 1979. The training exchange, installed in the Administration's Traning Centre by Teli in 1979, has been very useful. The courses have been supplemented by practical training since the summer of 1980, when the first AXE 10 exchanges were put in operation.

At the beginning of 1978, when the Administration ordered the first AXE 10 exchanges, priority was given to the work on conversion methods, choice of products for adaptive design, project planning instructions and dimensioning standards. However, during 1980 and 1981 the resources for system design, requirement specifications for new facilities and adaption to local conditions have been increased considerably.

Another aim when introducing AXE 10 was to reduce the operation and maintenance staff in the exchanges. It is expected that for the first seven exchanges, with a total of 150 000 lines, the staff in the station and MDF areas can be reduced from 56 to 36 people. This reduction is of course made possible by the very low fault rate of AXE 10 and by the automatic aids for traffic administration and fault clearing that form part of the system. The stringent standardization of both hardware and software is another contributory factor.

Successful introduction of a new telephone exchange system like AXE 10 also requires thorough training of the personnel in the field. The need for training has been so great within the Administration that during the first years the introduction of AXE 10 had to be limited to certain telecommunication areas. The operating staff have a very heavy work load just now, since new types of PABXs, telephone sets, teleprinters and data services, and also the new facilities teletex and telefax are being introduced simultaneously with AXE 10.

AXE 10 is designed so that it can be connected to operation and maintenance centres, from which the field activities can be administered. However, if such centres are to be efficient they must serve a number of exchanges within the area. This means that in the near future such centres can only be of use in Stockholm and Gothenburg, and centres for these areas are now being installed. Operation and maintenance centres are also planned for the rest of the country, but they must also be able to handle PBXs and older exchange systems.

Experience shows that a large number of faults and disturbances must be expected

Fig. 11
The Telecommunications Training Centre at Kalmar, in south-east Sweden

during the hectic period when a new exchange system is being introduced. Exchanges in the start up phase are particularly prone to disturbances. Both LM Ericsson and Teli have therefore set up support groups, which can intervene in difficult and abnormal situations. Since such situations can also occur after the manufacturer has handed over responsibility to the Administration, for example during program change-overs, staff from the Administration will take part in these central operational support activities. These activities will be combined with fault clearing, introduction of corrections and development of special operation and maintenance functions.

Changeover to manufacture of AXE 10 at Teli

Teli, the Industrial Division of the Swedish Telecommunications Administration, has factories situated in several places throughout Sweden. Its main products are exchanges, PABXs and telephone sets. Practically all the crossbar equipment in the Administration's network was supplied by Teli. The decision to introduce AXE 10 meant that the demand for electromechanical equipment would decrease very rapidly. Teli had to change over its production from crossbar technology to digital technology, and the manufacture of telephone sets from DIALOG to DIAVOX 100.

Fig. 12
The AXE 10 exchange at Ulriksdal, Stockholm, delivered by Teli in 1980

In 1975 extensive rationalization was carried out within Teli in order to create the prerequisites for the manufacture of new products. The manufacture of AXE 10 is now one of the largest production branches at Teli. The new technology means new production equipment and methods.

The series production of AXE 10 within Teli was prepared by a project group, formed in March 1976 and containing representatives from Teli's technical staff and the AXE factory at Nynäshamn. The group was responsible for the whole planning of a five-year manufacturing and delivery program. The group had to decide whether details and components should be bought or manufactured, and make decisions regarding product and production documentation, space requirements and the use of premises, production equipment, investment frameworks, personnel and training planning, project and product calculations, delegation of responsibility and time schedules.

The project also included the planning and installation of AXE 10 systems. The aim was to deliver exchanges that were ready to be put into operation.

In 1978 and 1979 Teli delivered a number of small exchanges, for example a system test exchange to the main office and a training exchange to the Telecommunications Training Centre. Teli's part of the AXE 10 deliveries will increase gradually with the successive increase in production capacity.

The first public exchange delivered by Teli was installed at Ulriksdal in the Stockholm telecommunication area. This exchange was the real pilot project for Teli. It comprises 10 000 lines and replaces a 500-line selector exchange. After the operational testing the exchange was handed over in June 1980. Subscribers and lines from the old exchange were changed over in July and August, after which the old equipment was dismantled and used for extensions in the Stockholm area.

The installation of AXE 10 exchanges is quite different from that of crossbar exchanges. The strict standardization of the connectors and cables for AXE 10 means

Fig. 13
The training exchange at the Telecommunications Training Centre, Kalmar

that a large amount of the cabling can be prefabricated. Each such exchange is also assembled and undergoes complete functional testing at the factory, and thus the amount of final testing required on site is very small. The software and exchange data have been thoroughly tested before delivery. The magazines are delivered on site fully equipped and tested. This method is particularly valuable as regards processors and group selectors.

The new production and testing methods required extensive investment in production and testing equipment. New production premises were also needed to provide an environment that met the stringent requirements of the new technology.

The work on the AXE 10 system has also necessitated additional training of the factory and installation personnel. Some of this training has been carried out internally within Teli, and the remainder has consisted of courses arranged at the Administration's Training Centre.

Conclusion

Few products have such a long life as telephone exchanges. The decision to develop AXE 10 was taken in 1971–72, the first orders were placed in 1977, the first exchanges were put in operation in 1980 and the last of the old exchanges will not have been replaced until the year 2020. A system with such a long life cycle has to be flexible, so that new functional requirements can be met and new technology introduced. With its modular structure, its combination of central and distributed control, and its facilities for modifying the software, AXE 10 provides the necessary flexibility. This ensures that the Swedish Telecommunications Administration, by introducing the system in its network, is able to maintain its position as one of the world's leading telecommunications administrations.

The material in this article has been obtained from previous articles and internal reports written by the Technical Director *Torsten Larsson*, engineer-in-chief *Evert Jarnbrink*, division heads *Anders Sundblad* and *Stig Johansson*, section head *Lars Rydin* and the head of Teli's AXE factory, *Sten Zälle*, and other people within the Administration.

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LSI Design Center

Klas-Håkan Eklund and Göran Norrman

LSI Design Center is a central unit in the Ericsson Group for designing custom LSI circuits in MOS technology. The unit is located at RIFA, where a process laboratory has been set up for the manufacture of circuit prototypes and pilot series.
Design groups have also been formed within some of the design departments in the Group's divisions and subsidiaries. With support from the LSI Design Center these groups will be able to design their own circuits and have them manufactured, for example by RIFA.
In this article the authors describe the background, aims, organization and resources of the Center.

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Fig. 1
A projection pattern aligner.
A picture of the mask is projected on the silicon wafer, which has been coated with a photoresist. This method avoids the damage to the wafer that could occur with a pattern alignment method, where the wafer and mask are in contact with each other. The projection method increases the yield for a large LSI circuit by about 20%.

In order that LM Ericsson shall be able to maintain its leading position in the field of telecommunications it must be able to renew the product range by combining new system principles with new technology.

Since the 1950s electronics have gradually replaced electromechanical technology in telephone exchange systems. The change was particularly marked during the 1970s, when the development of integrated circuits was very rapid. Digital technology and increasingly advanced circuits are used not only for switching, control and supervision but also for the transmission of speech.

Since the transistor was invented in 1948 semiconductor technology has been the driving force in the tremendous development in the electronics field. The LSI circuits of today consitute complete subsystems, e.g. microcomputers and digital filters. At present the design and manufacture of such circuits mainly takes place outside Sweden. LM Ericsson is therefore in danger of becoming dependent on foreign companies for the supply of components and know-how as regards new techniques.

Future telecommunications systems will contain a greater proportion of LSI and VLSI circuits. Designing such circuits requires extensive knowledge of telecommunication systems. It is of vital importance to LM Ericsson to safeguard the unique system know-how that has been built up within the company, and the building up of its own design resources for VLSI circuits is a natural consequence.

Organization

RIFA, which is a subsidiary of LM Ericsson, designs and manufactores integrated circuits in bipolar technique. This technique has previously been predominant and is still the obvious choice when fast operation or the ability to withstand high voltages is essential.

During recent years the development has led to transistors that require very little space, $5 \times 10\ \mu m$. However, in order to fully utilize the possibility of manufacturing circuits with tens of thousands of transistors, the power dissipation of each transistor must be very low. In this respect MOS technique is superior to bipolar technique. LM Ericsson has therefore decided to increase its resources in the MOS field in order to be able to design and manufacture its own advanced LSI circuits, primarily custom design circuits.

The activities are organized as follows:
– an LSI laboratory has been set up for

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following up new techniques and for manufacturing prototypes and small series. Work on new techniques requires modern equipment, qualified staff and good contacts with the technical development abroad
- a central unit for designing advanced circuits has been formed. This unit also has the overall responsibility within the Ericsson Group for design methods, aids, training and contact with suppliers
- local groups for designing integrated circuits have been formed within design departments in the divisions and subsidiaries in the Ericsson Group. The main part of the circuit design work will be carried out close to system projects, but with method training and computer program support from the central unit.

The USA is predominant as regards technical development in the semiconductor field, although Japan and certain Western European countries contribute considerably. However, the American companies are superior when it comes to realizing new techniques in products and adapting their product engineering and marketing.

LM Ericsson has increased its contacts with development centres on the West Coast of the USA. The main purposes are to obtain
- knowledge and possibly also manufacturing licences for the LSI activities
- early and reliable information regarding development trends, new techniques and new methods in the LSI field.

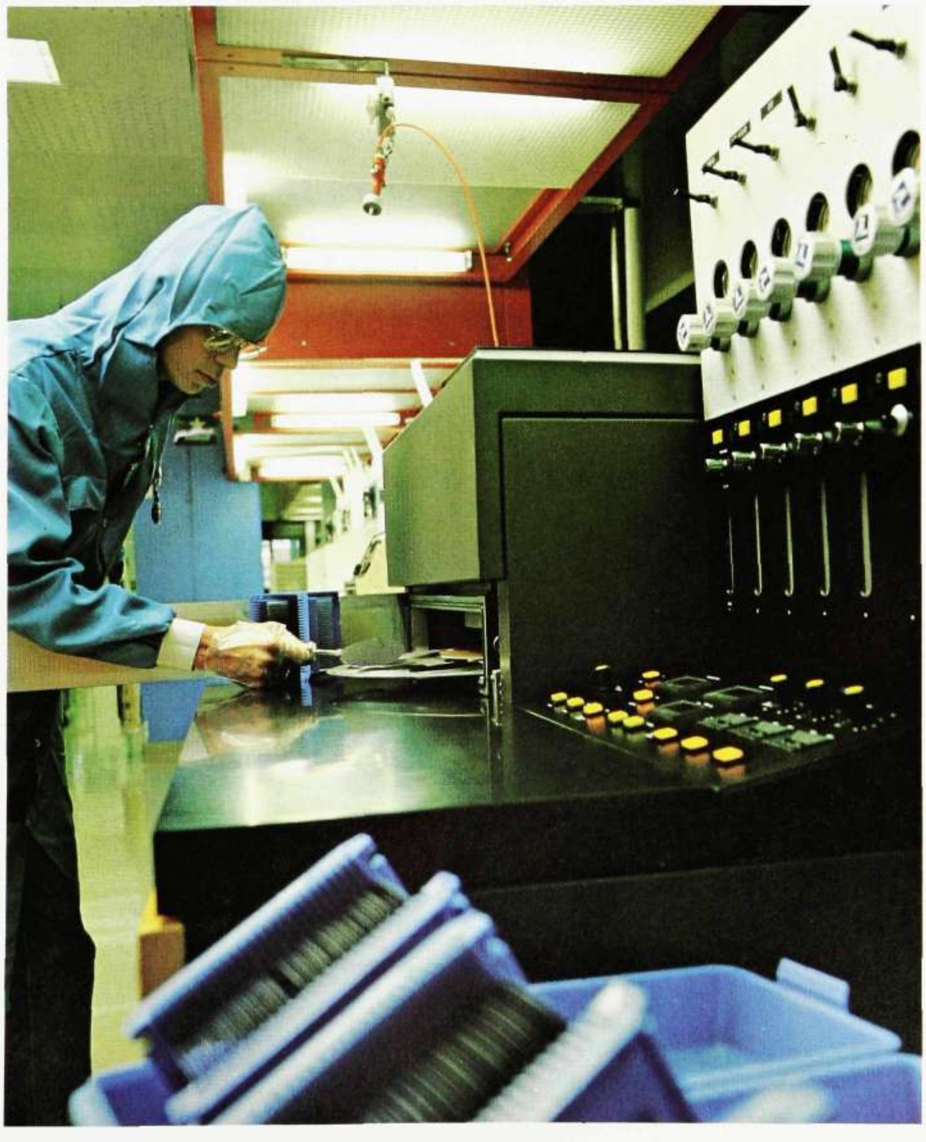


Fig. 2
Plasma etching equipment.
Conventional etching of patterns, for example in an oxide layer, is done by immersing the wafers in a chemical bath. In such cases the etching procedure is isotropic, i.e. the etching is carried out to the same extent in all directions under the photoresist. By etching in plasma it is possible to make the etching process mainly anisotropic and directional, which is necessary in order to achieve the desired tolerances, which are of the order of μm.

LSI laboratory

The main aim of the LSI laboratory is to build up a MOS process for the manufacture of prototypes and pilot series. LSI Design Center must be able to design circuits for this process and quickly obtain prototypes and experimental results. The closeness to the process provides a more dynamic environment for the designers, and they can fully utilize all the possibilities offered by the process in their designs.

Some other important aims are to
- develop new processes
- follow up components and processes
- follow up development trends.

The current tasks include collaboration with the LSI Design Center in
- specifying the electrical and geometrical design rules to be set for the circuit designers
- designing mathematical models of the available basic components. These models will then be used for circuit simulation
- cooperating with the circuit designers in the evaluation and debugging of prototype circuits. Test programs for this purpose will be designed by the process engineers and circuit designers
- manufacturing prototype circuits and ensuring that the electrical parameters of the circuits comply with the design rules
- optimizing the design and processing during the manufacture of the pilot series in order to obtain a suitable yield
- administering the manufacture of masks and assembly of circuits carried out by other companies.

	n-MOS, Si gate local oxidation
Minimum conductor width	3.5–4 μm
Gate oxide thickness	700 Å
Channel length	2.5 μm
Fully ion-implanted	Yes
Number of mask stages	8–10
Delay	1.6
with fan out	3
Packing density, approx.	150 gates/mm²

Table 1
Characteristic data for the n-MOS process

Choice of process

The laboratory has chosen to start with an n-MOS process. The design rules permit a smallest conductor width of 4 μm. Table 1 shows the characteristic data for the process. The packing density is approximately 150 gates per mm^2. An LSI circuit of normal size, 5×5 mm^2, can have a total of about 4000 gates. The gate delay is approximately 1.5 ns.

The chosen process exploits present technology to the full, although a few semiconductor companies have used conductor widths down to 2–3 μm. LM Ericsson have also acquired equipment which can be used with conductor widths down to 3 μm.

Status

The building up and manning of the laboratory is a gradual process which was started in January 1981. Hitherto ten people, mostly engineers, have been employed.

The equipment was installed and put into operation in the spring of 1981. A standard circuit, a 4 kbit static memory, has been produced in order to check the possibility of maintaining electrical parameter values and obtaining a satisfactory yield. The first circuits were manufactured in the summer of 1981, and the process was fully evaluated and established in the autumn.

New processes

Today n-MOS is the most common and cheapest process for such LSI circuits as memories and microprocessors.

CMOS has long been considered an exclusive and expensive technique. It gives better performance and is therefore used for curcuits where very low power consumption is a requirement, e.g. clock circuits.

However, the interest in CMOS is growing noticeably. It is reflected in large investments in advanced CMOS technique by the large semiconductor companies. The reasons for such investments are the possibilities offered by CMOS of combining analog and digital functions, and the extremely low power consumption, which becomes increasingly important with increase in the number of functions that have to be integrated on one and the same chip.

CMOS technique is used for such circuits as operational amplifiers, which have a performance similar to that of bipolar circuits.

In the telecommunications field there is a great need for circuits where analog and digital functions can be mixed. At the same time the power consumption per gate must be low, since the CMOS technique permits the manufacture of array circuits with 2000

Fig. 3
Diffusion line.
The wafers are fed into the oven automatically. The process is controlled by a microprocessor, to the left in the figure, which also regulates the temperature and gas flow in the oven to give a reproducible growth of oxide

gates. Such a circuit can replace a large number of standard MSI circuits in TTL technique.

The demand for CMOS circuits for telecommunication purposes is expected to increase sharply, and a process line for such circuits will therefore be installed in the laboratory in the spring of 1982. The process will use conductor widths of between 2 and 3 μm.

Design activities

LSI Design Center designs primarily custom circuits intended for LM Ericsson systems which are made in such small numbers that the semiconductor manufacturers will not undertake the design work, or which have such important system characteristics that they should not be revealed by contracting out the design.

When manufacturing semiconductor circuits, silicon wafers are treated in several process stages. In many of these stages the areas on the wafer that are to be treated are defined by a mask. An MOS process requires a total of between 7 and 16 masks, depending on its complexity. The work of designing a semiconductor circuit includes defining the appearance of all such masks.

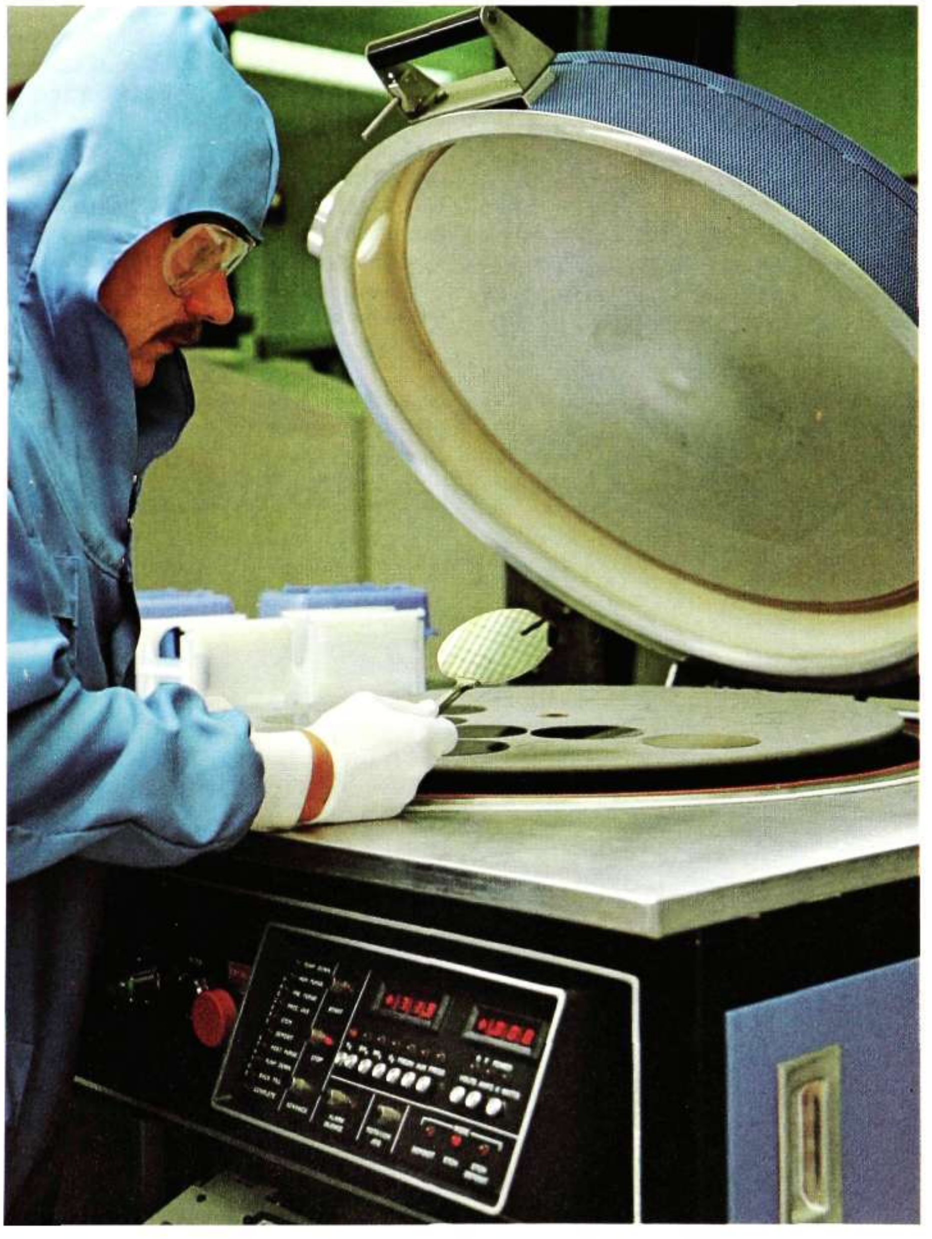
Full custom design

The basic way of designing circuits is to design all transistors, resistors and capacitors in the circuit from scratch. Each component must then be defined in about 10 mask layers. The design work therefore becomes very complex when the number of transistors is large. The design work is also time-consuming and the risk of mistakes is considerable. Computer aids are used to reduce the risks by checking that all design rules are observed and that the layout really gives the desired function. This method is called full custom design and is so costly that it can only be used for circuits which are to be manufactured in large numbers.

Design work requires access to design rules and process parameters for each process. The manufacture of prototypes is expensive and time-consuming, and it has therefore largely been replaced by simulation. The input data required for the simulation program are the geometry of the design and the doping profiles, oxide thicknesses etc. of the semiconductor process. With the aid of this program it is possible to calculate the function of the circuit in detail. Simulation is used for the parts of the circuits which are most difficult to assess. A small part of the circuits, e.g. a few transistors, is simulated in each run.

Designing in accordance with this method requires several years of training, and full custom circuits will for the time being be designed only at the LSI Design Center. At present the available resources permit the designing of two to three fairly difficult circuits each year. Both n-MOS and CMOS techniques are used.

Fig. 4
A plasma nitride reactor.
The last layer, on top of the aluminium conductor pattern, consists of a silicon nitride layer, which protects the circuit better than an oxide layer which has been deposited in the conventional way at a low temperature (vapox, silox). This increased protection is very important for circuits which are to be encapsulated in plastic



Cell library

A simplified design method consists of using a cell library. A library contains about 125 cells, which have been designed in advance, and information regarding all masks is stored in a computer-controlled graphic design system. A cell can correspond to the function of a standard curcuit. There are simple cells for gates and more complex ones for shift registers, counter blocks etc. When designing a circuit, the circuit diagram is divided into function blocks which correspond to the cells available in the library. The next stage consists of positioning the cells and arranging the connectors between them. Programs for automatic positioning and connection of cells are available on the market. The cell method is considerably faster than full custom design. Moreover it does not require the detailed technical knowledge needed for the latter. The disadvantage of the cell library method is that the wafer surface is not utilized so well.

Both full custom and cell library design require that all masks are prepared and all process stages carried out individually for each type of circuit.

Within the Ericsson Group the cell library method is used mainly by SRA Communications AB. Hitherto the supply of good cell libraries has been inadequate. One reason is the high cost of the design and documentation work. In addition the cells become obsolete when better processes are developed.

A cell library provides the system designer with the possibility of designing direct on the silicon. The LSI Design Center will therefore investigate the possibility of introducting a satisfactory cell library at LM Ericsson.

The array method

The simplest and cheapest design method is to use prefabricated circuits that contain a number of transistors but no connections. The transistors are usually placed in groups of two or three. The groups are arranged in rows and columns, an array.

A drawing showing the physical position of all transistors in the circuit accompanies the array. The design work consists of connecting the transistors in accordance with the circuit diagram. In order to obtain an individual circuit it is thus only necessary to design the mask that defines how the top metal layer must be etched to give the desired connections. All process stages except the etching of the last metal layer can be carried out in advance, and thus a prototype can be manufactured very quickly. However, this method does not utilize the wafer surface as well as the cell library method.

A large number of semiconductor companies offer prefabricated arrays for different speeds. The gate delay is less than 1 ns for an ECL array and between 2 and 4 ns for a TTL array. An array with 1000 gates consumes 2–3 W. Today the largest array circuits, with up to 5000 gates, are made in

Fig. 5
Decoding a layout.
A manually designed circuit section is decoded by means of a computer-controlled graphic aid, Calma. The screen shows what is being decoded on the drawing board. All cells in a circuit are decoded and combined in the Calma system so that a complete layout is obtained. The information is then stored for subsequent manufacture of masks or drawings

CMOS. present-day technology gives delays of 5–15 ns, but a reduction to 3–5 ns can be obtained with processes that give a conductor width of 3 μm.

A CMOS array with 600 gates has been designed by the LSI Design Center. It differs from other array circuits in that it also contains a number of linear circuits, such as operational amplifiers and comparators.

System designers who have to learn circuit design could most suitably start with array circuits. The designer needs computer aids (CAD) for logic simulation, for automatic test program generation and for automatic connection, in order to be able to work efficiently. LM Ericsson's resources in the CAD field, together with its considerable process know-how, enable the company to design its own CMOS array family in the size range above 2000 gates.

CAD

There are several computer aids for the design of semiconductor circuits.

Logic simulators are used to verify that the designed logic diagram meets the functional requirements. They can also be used to check the ability of test programs to detect all possible types of faults. Programs for the generation of test programs are also available.

A circuit simulator is used to study in detail the function of a small group of transistors.

Layouts can often be prepared manually, but computer-controlled aids are usually employed in order to simplify the drawing work. Programs for automatic positioning and connection of cells are also available.

Control programs are available for verifying that all design rules have been observed.

Computer aids for the design work are extremely important. The input of data and the interpretation of the results must be done in a way that seems natural to the designer. Large resources are rquired for the purchasing of aids and adaption or development of programs.

Training

The staff to be trained in LSI design are assigned to the LSI Design Center and given the task of designing a full custom circuit. Three people can be trained simultaneously. They must first have taken a one-month course in the function of MOS transistors. This course is given by a consultant company which specialises in training staff for semiconductor companies.

Training in the use of array and cell library techniques are primarily provided by specialists from design departments within the Ericsson Group. The LSI Design Center provides assistance for units having no specialists of their own.

Effects on systems

The use of custom design circuits can reduce the number of printed board assemblies required for systems, since the circuits need very little space. Furthermore the system speed can be increased because of shorter connections. Less power is required to operate the equipment, and fewer external connections are needed. Greater reliability can therefore be expected.

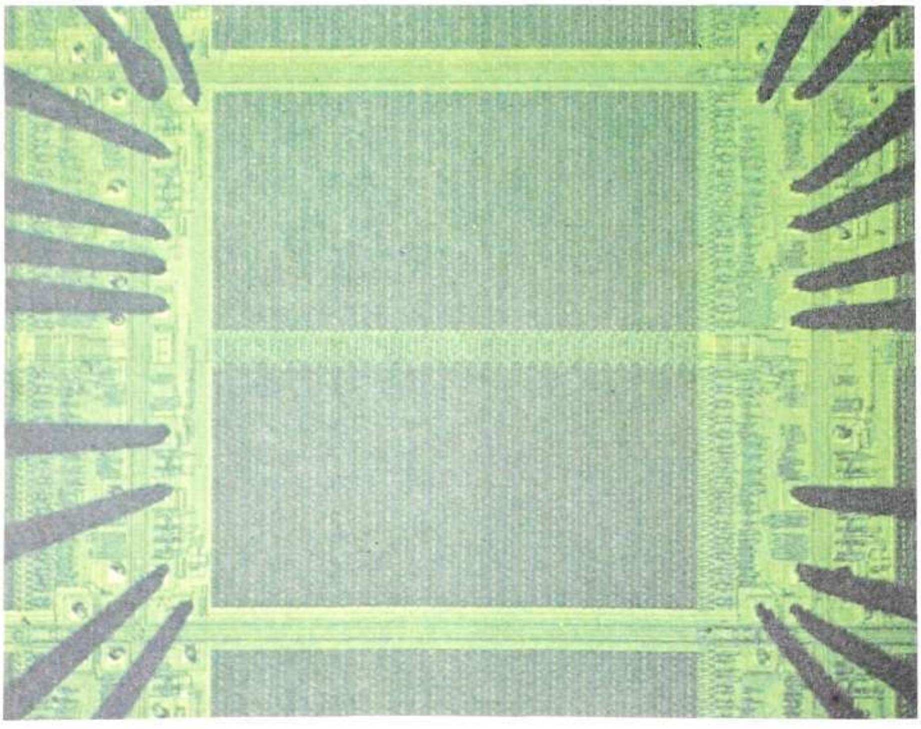
Rules have been formulated, which take test requirements into consideration. By including these rules in the specification it is possible to improve the testing properties and to reduce the test times for circuits and printed board assemblies, which is of value, for example in debugging.

Fig. 6
Detailed testing of a circuit.
A probe station is used for making measurements in a circuit. The probes are controlled by means of micro manipulators and can be positioned to an accuracy of 1 μm. Normal laboratory instruments are connected to the probes

The processes which LM Ericsson now uses and plans to use for the manufacture of circuits are identical to processes used by at least one other semiconductor company. This prevents the Group being dependent on a single supplier.

The expected development in MOS technique will make it possible to produce, soon after the mid-1980s, dynamic memories with a capacity of a million bits. This corresponds to two million transistors per circuit. In order to be able to use this technique for logic circuits it will be necessary to develop well structured design methods. Such custom design circuits will be of importance for our systems of the future.

Fig. 7
Test of a chip on a 4" wafer.
Faulty chips are coloured and rejected. Acceptable chips are passed on to the encapsulation stage. The figure shows the testing of a 4k static n-MOS memory manufactured in the MOS laboratory. The size of the chip is 3.3×4.1 mm.



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ASB 900 in the Finnish Railway Network

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Finnish State Railways, VR

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The Finnish State Railways has its own telephone network, which has successively been modernized with LM Ericsson's crossbar exchanges. In a further modernization stage the exchange in Helsinki has been replaced by a code switch exchange, AKD 792, with a transit stage AKM 302, and certain network centres are now being equipped with the stored-program controlled PABX ASB 900. A total of 14 such PABXs have been ordered, and six of these have already been put into operation. This modernization stage will be completed in 1982.
In this article the author describes the development of the telephone network of the Finnish State Railways, how the network is used and also the motive and procedure for the modernization with the introduction of the ASB 900.

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The total length of track in the network of the Finnish State Railways, VR (Valtion Rautatiet), is approximately 6000 km, fig. 1. In connection with the railway network there is a well developed telephony network, which is owned entirely by VR.

Table 1 (next page) shows the telecommunication requirements of the different branches of the railway activites, and also that the telephone is the telecommunication facility which is most frequently used.

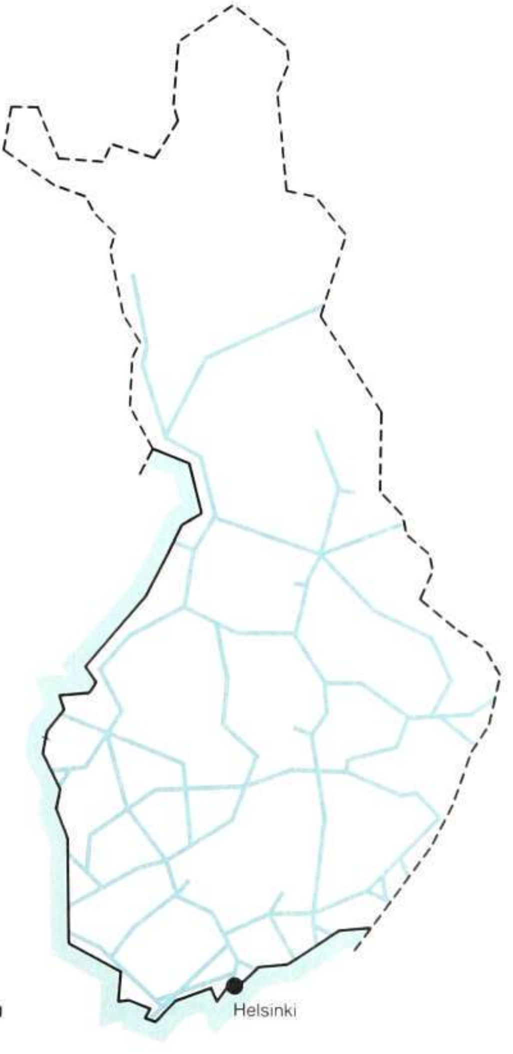


Fig. 1
The railway network of the Finnish State Railways

The rail traffic is supervised using point-to-point connections, which are separated from the rest of the network. The greater part of the telephone network is automatized.

The automatic telephone network of VR and its development

The first automatic exchange was purchased for Helsinki, in the 1920s. All telephones for the Railway Board were connected to this exchange. All other telephone traffic in the VR network was handled by operators until the end of the 1940s, when selector systems were introduced on several railway lines. In the selector systems several telephone sets are connected in parallel to pairs of wires which run between the stations. The station staff and linemen can then call each other automatically via equipment in the stations. The selector network, which is very economical as regards lines, reached its maximum size at the end of the 1960s, when about 1700 selector extensions were in use.

By the beginning of the 1950s five automatic exchanges had been installed in the VR network. The three newest were LM Ericsson 500-line selector exchanges of type AGD. The traffic between the exchanges was handled by operators. This traffic grew and loaded the manual handling resources to an increasing extent. To improve the situation it was decided to automatize both local and transit traffic throughout the railway telephone network.

In order to be able to implement the decision it was necessary to increase the capacity of the routes to the level required for automatization. Limited investment resources meant that the modernization of the telephone network had to be spread over a long period.

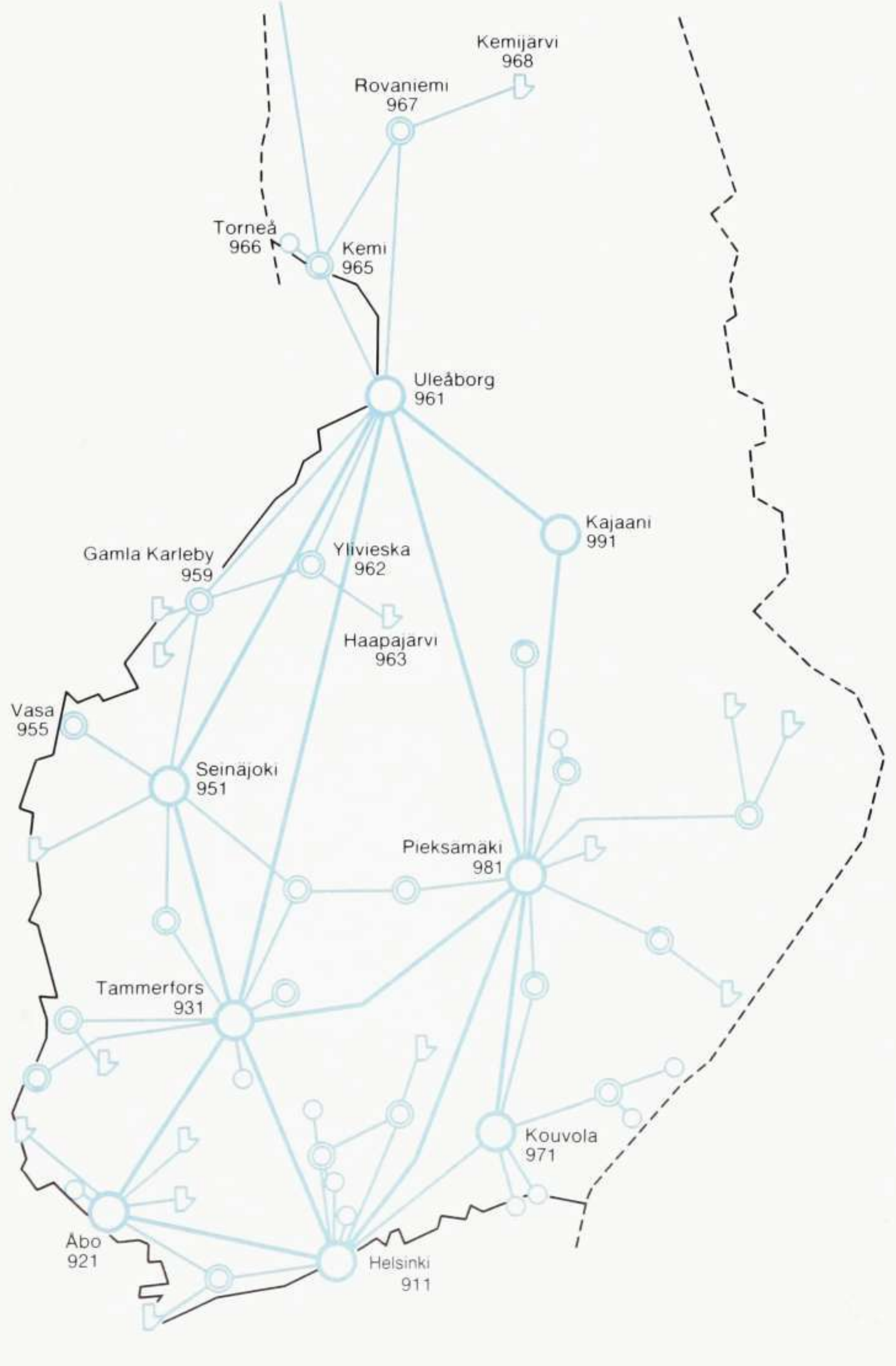
It was decided to remove the worst bottlenecks in the network by temporary through-dialling equipment on lines between already installed automatic exchanges. Large manual exchanges were also connected to this through-dialling system.

Table 1

The need of telecommunications for different branches of the railway activities	Traffic supervision	Passenger traffic	Goods traffic	Material purchasing	Maintenance	Administration
Telephone	X	X	X	X	X	X
Teleprinter	X		X	X		X
Radio	X				X	
Remote control	X					
Data terminals		X	X	X	X	X
Signs, loudspeakers		X				

Fig. 2
The telephone network of the Finnish State Railways at the beginning of the 1970s

Transit exchange
Group centre
Terminal exchange
Manual exchange
Trunk line
Junction line



Thus the operators in these exchanges could dial direct to the extensions in the automatic exchanges, without going via the operator at the automatic exchange.

At the beginning of the 1960s the main stage of the automatization of the VR network was started, and by the beginning of the 1970s the telephone network included about 40 automatic exchanges. The temporary through-dialling system had by then been replaced by a permanent system, which was better suited to the telephone requirements of the railways.

At this stage the automatic part of the telephone network had reached the extent shown in fig. 2. Its main features were that
- crossbar exchanges were used throughout, with a few exceptions. The number of extensions and the position of the exchange in the network decided the choice between LM Ericsson's ARD 321, ARD 326, ARD 331 and ARM 301.
- all transit traffic had to go via the VR network. Only local calls were allowed on the lines between the VR exchanges and the public network.
- call connections between the A and B extensions were set up automatically without A having to know the route. Several alternative routes were arranged for the telephone traffic in order to improve the capacity and the reliability of the network. The choice of route for the connection path was free.
- because of the oblong shape of the telephone network a call could pass through as many as six transit exchanges. A high signalling speed and good transmission quality were therefore necessary. MFC signalling was used in the trunk network, with four-wire through-connection in the exchanges.
  - locally the exchanges operated as PABXs.

The present telephone network of VR

The telephone network of the Finnish State Railways now contains about 8000 automatic telephones and 1000 selector extensions. The network contains 50 automatic exchanges. In addition 11 manual exchanges with a total of 200 LB extensions are connected to the network in the semi-automatic mode.

The telephone network is also used for data traffic. If it is difficult or impractical to arrange a point-to-point data channel, the data terminal is equipped in accordance with CCITT Recommendation V.26 bis. A data circuit can then be connected up with the aid of a telephone set. Using the telephone network in this way has made further demands on the transmission quality.

During the years the VR telephone extensions have to a great extent been moved from function points along the railway lines to braching stations and regional administrative centres. This is partly because on certain railway lines the railway signalling system has been supplemented by remote control (CTC). The selector traffic has also decreased on such routes.

On certain railway lines it was necessary to increase the capacity of the network when CTC was introduced. It was then possible, at a fairly low marginal cost, to obtain more channels for the telephone traffic. There were no difficulties in connecting the railway line telephones to the nearest exchange. In certain cases it has then been possible to discard the selector telephones. The exchanges are placed at a distance of 40–50 kilometres along these railway lines.

The cost of maintaining the selector telephone batteries is high. For this reason it is desirable to reduce the number of selector telephones. However, in certain, quite common cases the selector system offers the only possibility of automatic selection. It is therefore desirable to retain the possibility of connecting selector lines to the exchanges.

Maintenance of railway lines with high traffic must be carried out without disturbing the traffic. This means that the work has to be divided up into carefully specified periods. In order to be able to use the periods efficiently the work teams must be in radio contact with the traffic staff. It must also be possible to establish contact via radio and the telephone network. A radio communication system that operates in accordance with this principle, so-called maintenance radio, has been developed for VR. The system operates with selection in both directions between radio and the telephone network. Connection between two radio telephones is either established direct or connected via the telephone network, depending on the distance.

Guidelines for the modernization of the VR telephone network

The operational activities of the railways cover a large geographical area. The long distances mean that the activities require good telephone circuits and rapid connection. This in its turn means that the railway requires a whole network to itself.

The automatization of the network has made the telephone service considerably more efficient. Further improvement can be achieved with the current modernization phase, the aims of which are to

- introduce push-button dialling in a part of the telephone network
- introduce abbreviated dialling, primarily for international calls. Abbreviated dialling gives faster calling and can, in combination with trunk traffic restriction, limit superfluous calls and thus reduce the telephone charges
- make the signalling between exchanges faster through the introduction of MFC signalling in parts of the network other than the trunk network

Fig. 3
The building and mast of a radio relay link station in Ruukki

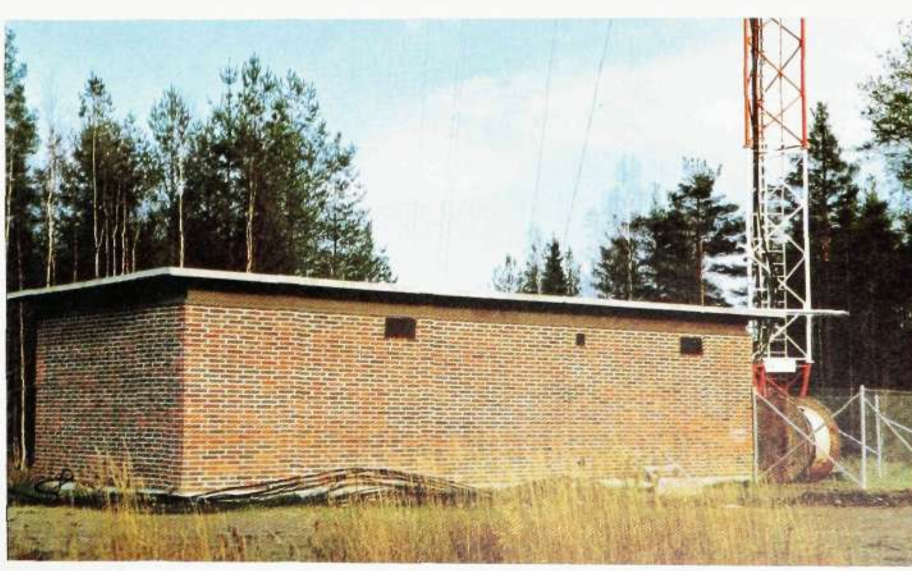
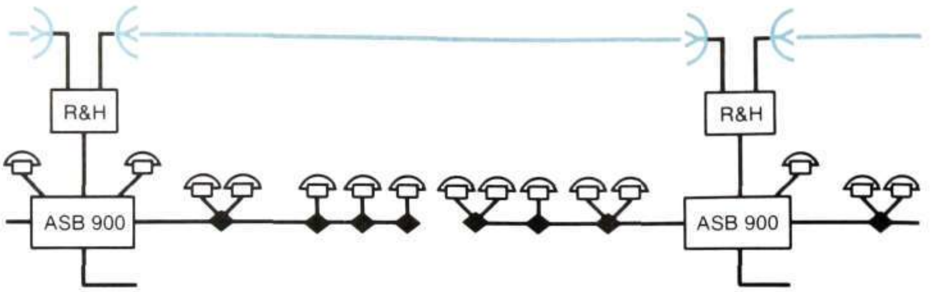


Fig. 4
Connection of the radio relay link and cable to the ASB 900 exchanges on the route Seinäjoki–Uleåborg

R&H Intermediate station and branching point of the radio relay link
Cable branching point



- introduce other exchange functions which make telephony more efficient. Many of the desired functions are standard features of the more recent types of PABXs.

Another aim within VR is to rationalize the operation and maintenance of the telephone network itself. For example, it should be possible to change extension numbers without having to make alterations in the main distribution field. The possibilities offered by stored program control as regards centralized supervision of the network and fault localization are gradually being utilized.

Modernization stage 1981–82

The telephone network that was completed at the beginning of the 1970s contained exchanges with electromechanical components. These exchanges made it expensive and difficult to achieve the aims described in the previous section. However, many of these aims can be achieved, at an acceptable cost, with the aid of stored program control.

The two largest exchange projects in the current modernization stage are Helsinki and Hyvinge. The exchange in Helsinki, which was of type ARD 331/ARM 301, has this year been replaced by a code switch exchange AKD 792/AKM 302, which includes a stored program controlled number translator. The number translator is primarily used to register and process extension data during the setting-up stage.

In Hyvinge a 500-line selector exchange of type AGD will be replaced by an exhange of type ASB 900. ASB 900 exchanges have also been ordered for the 340 km long line Seinäjoki-Uleåborg, which is now being electrified. On this line the whole telecommunication system, including the selector lines, will be replaced by ten ASB 900 exchanges. The former open wire line is being replaced by a radio relay link and a cable, to which the new exchanges will be connected, fig. 4.

A total of 14 ASB 900 exchanges have been ordered. By May 1981 six had already been taken into service very successfully. The whole stage will be carried out by degrees during the years 1981–82. Fig. 6 shows how the ASB 900 exchanges will be connected to the electromechanical VR transit system.

Features of ASB 900

From the point of view of the extensions the main facilities offered by the new ASB 900 exchanges in the VR network are:

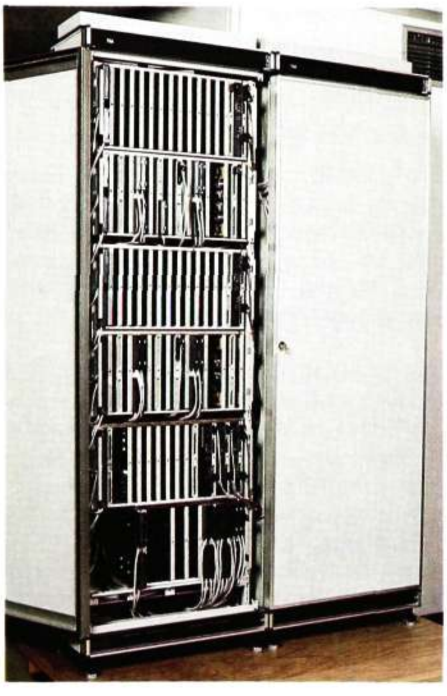


Fig. 5
An ASB 900 exchange

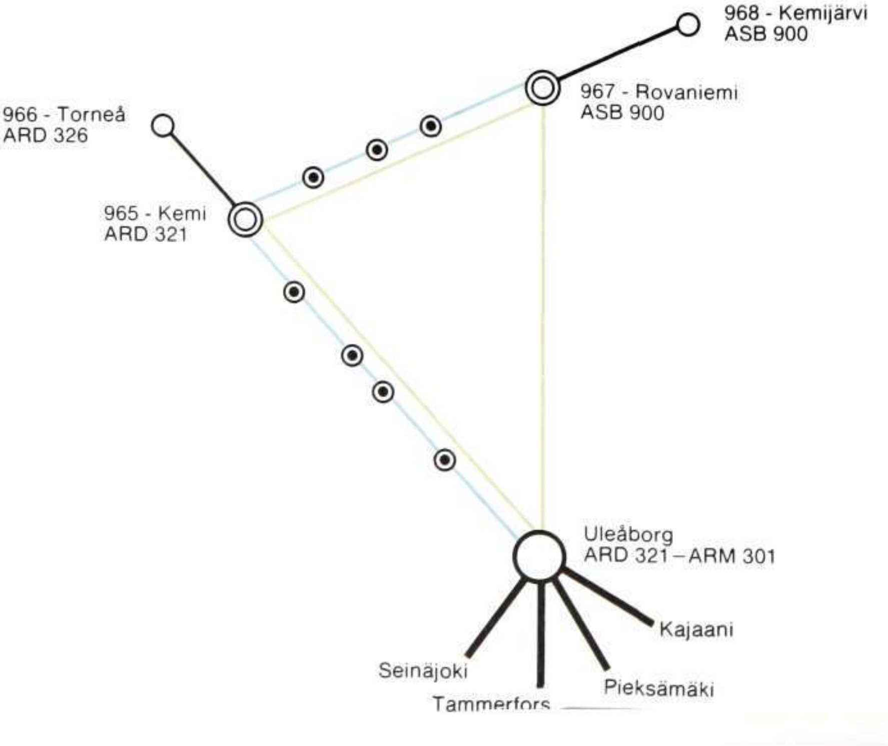


Fig. 6
The method of connecting the ASB 900 exchanges to the VR transit system containing crossbar switches

Selector lines
Long-distance route

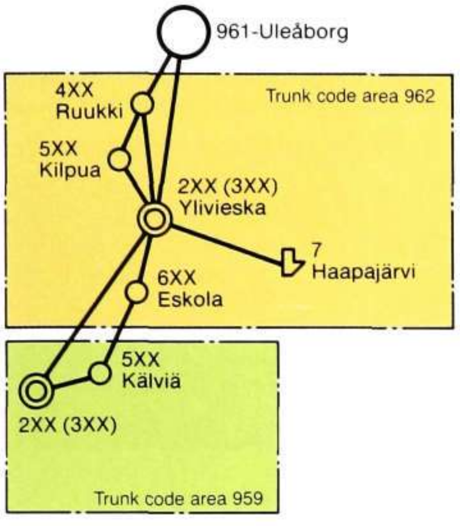


Fig. 7
An example of the numbering system for different trunk code areas

- facilities for tone frequency key sending, using push-button telephones, or decadic impulsing, using dial sets. Both types of sets can be connected to one and the same exchange
- five extension categories, from fully open extensions to those that are only allowed calls to other extensions in the exchange
- abbreviated dialling
- enquiry and transfer
- add-on conference
- diversion to a common answering position in the case of no answer
- direct in-dialling from the public network
- paging
- group calls
- follow-me
- automatic call back.

From the point of view of the telephone operator the functions of the new exchange type are versatile and help to speed up the handling of calls. This also applies for calls which, when necessary, are connected over the railway long-distance network by operators.

Night service is available for calls both from the public network and over the VR junction lines.

The ASB 900 exchanges in the VR network are equipped for MFC signalling in order to speed up connection over junction lines. Other signalling systems are also possible. A new signalling system can be introduced in the transit system by entering the corresponding program blocks in the exchange memories.

The local extensions in the new ASB 900 exchanges are numbered in groups, fig. 7. The first figure specifies the exchange to which the extension belongs. A group of exchanges has a common area code, which is used for calls from other groups. Good accessibility between the exchanges in a group is obtained by utilizing the facilities for alternative routing provided in ASB 900.

The junction lines are supervised, so that a line which is found to be faulty when a call attempt is made is automatically blocked to traffic and an alarm is given.

The exchanges can be tested and their extension data can be changed from terminals with typewriter keyboards. Such terminals are installed both in the exchange rooms and in remote operation and maintenance centres. Circuits for remote control of the ASB 900 exchanges are connected over the telephone network.

The importance of ASB 900 to VR

The introduction of the ASB 900 exchanges in the VR telephone network constitutes a new, decisive stage. The new exchanges offer the extensions better services and facilities than previous exchanges. However, the maintenance characteristics are of greater importance. The stored program control offers new possibilities as regards maintenance. The staff can easily learn both the actual exchange technology and the maintenance principles. The modular structure of the hardware and, above all, the software in ASB 900 has contributed to the very successful changeover to stored program controlled operation by the Finnish State Railways.

AGA-ERICON – a Marine Radar Beacon

Bo Morwing

AGA-ERICON is a new type of radar beacon, developed by the Defence and Space Systems Division of LM Ericsson, in close collaboration with the Swedish Administration of Shipping and Navigation. When the beacon intercepts pulses from an X or S-band radar it gives a coded response at the frequency of the searching radar. New types of microwave semiconductors, together with extensive system studies, have made it possible to develop a product that meets most of the demands which can be made on a modern radar beacon. AGA-ERICON is now in series production and the marketing outside Sweden is handled by AGA Navigation Aids.

In this article the author describes the demands made on radar beacons, the design and structure of AGA-ERICON and different applications. Operational experience has been obtained from the first AGA-ERICON, which was installed in October 1980, and it is most satisfactory.

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The development towards ever increasing tonnage in modern shipping has accentuated the need for advanced navigational aids to improve safety at sea. More than 3000 ship collisions and groundings occur each year in North European waters. Approximately the same number of accidents occur along the coasts of the USA and are estimated to cost shipping lines more than 3 billion US$ per year. Supertankers loaded with oil or other chemicals represent large sums and also constitute potential threats to marine ecology, fig. 1. Amoco Cadiz, Torrey Canyon and Argo Merchant are just a few names associated with environmental catastrophes.

Conventional navigation aids, such as lighthouses, buoys and navigation markers are today not sufficient to ensure safety. The largest ships require information at a distance of over 10 nautical miles in order to be able to manoeuvre out of dangerous situations.

New systems for reducing the risk of accidents at sea are being developed or planned. Among other things radar beacons, also called racons, have attracted an increasing amount of interest during the last decade, and the number of installations is expected to grow rapidly. In parallel with further development of conventional racon types, systems are being studied which would present the racon response on the ship's radar indicator without the normal radar picture being displayed. Strong land echoes and sea clutter can mask the response from present-day racons.

Racons

Radar is an invaluable navigation aid for shipping. In difficult weather with reduced visibility the radar is often the only instrument that enables ships to move in busy waters. The range of a large ship's radar is usually over 20 nautical miles, which means that action can be taken at such an early stage that dangerous situations can be avoided.

However, radar has certain limitations. The echoes from small buoys and navigation markers are often masked by noise or sea

Fig. 1
Supertankers which are very difficult to manoeuvre transport oil products and minerals in shipping lanes along coasts where a wreckage could cause an environmental catastrophe. In unfavourable weather conditions efficient aids are needed to ensure safe navigation

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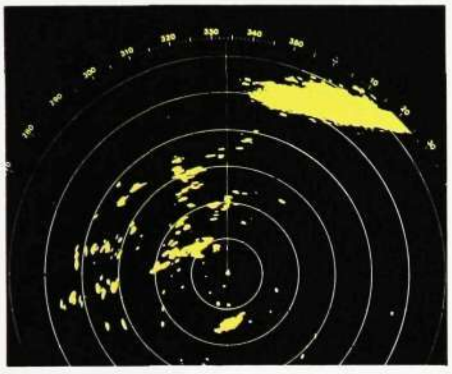


Fig. 2
In many situations it can be difficult to distinguish and identify specific targets on the radar display. The echo from a navigation buoy can easily be confused with an echo from a small ship

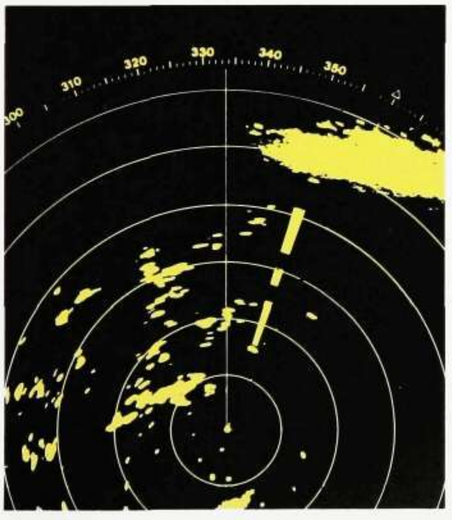
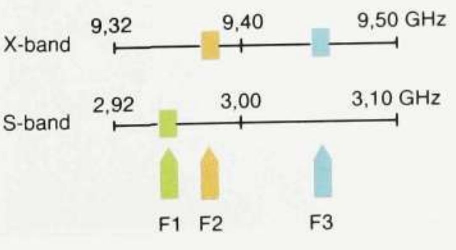


Fig. 3
If the buoy is equipped with a racon its position and identity can be determined unambiguously

Fig. 4
The frequency bands allocated to civil marine radar



clutter, and in complicated passages the display can be difficult to interpret, fig. 2. Ever since radar was introduced there has therefore been a need for equipment which can improve the possibility of detecting specific targets and also make identification easier. Passive reflectors, which give a larger target area, were available quite early on and they are still widely used. However reflectors only give a stronger echo and do not make identification any easier.

In order to meet both demands some type of active equipment was required which could respond at the frequency used by the searching radar, the response being coded or modulated, fig. 3. Many different solutions were suggested and tested. This type of equipment was designated radar beacon or racon.

Radar frequencies

The main difficulty proved to be returning a response at the frequency of the searching radar. Different ship radars operate at different frequencies in the frequency bands allocated to shipping, fig. 4.

The receive bandwidth of the radar is in the order of 10 MHz or approximately 5–10% of the allocated frequency band. Some type of tunable oscillator is required in the racon if it is to be able to serve all ships within its range.

Slow sweep racon

The first racon in practical use was the slow sweep racon, fig. 5. An oscillator connected to the common transmit receive antenna is swept slowly over the frequency band in question. When the racon receives radar pulses from a ship it responds momentarily with an extended pulse at the frequency that is generated by the oscillator at that moment. Since the oscillator continuously varies its frequency over the whole of the radar band, all ships will at some time have their radar frequency matched by the racon, and the racon response will then be shown on the indicator, superposed on the normal radar display. The sweep rate of the oscillator and the bandwidth of the radar receiver are the factors that determine how often and for how long the racon response will be displayed.

The whole frequency band is usually swept in about 2 minutes, or at a rate of 1.5 MHz/s, which means that the racon response is displayed every second minute, for 5 to 10 seconds. The low updating rate and the short display time necessitates incessant radar observation. In spite of this weakness most present-day racons are of the slow sweep type.

Fast sweep racon

In a fast sweep racon the oscillator frequency is swept over the frequency band at a high speed and frequency matching between the racon and a ship's radar will occur several times during the radar sweep, fig. 6.

Each time the racon oscillator sweeps over the radar receive band a dot-shaped indication is obtained on the indicator. Since the racon frequency is not swept synchronously with the transmitted radar pulses, and since the racon response is received for up to 25 sweeps during an illumination period, the overall effect of the response

Fig. 5
The principle of the slow sweep racon

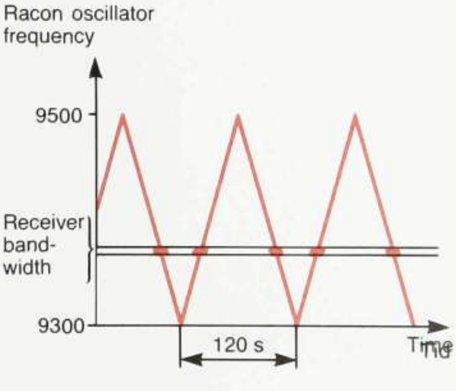
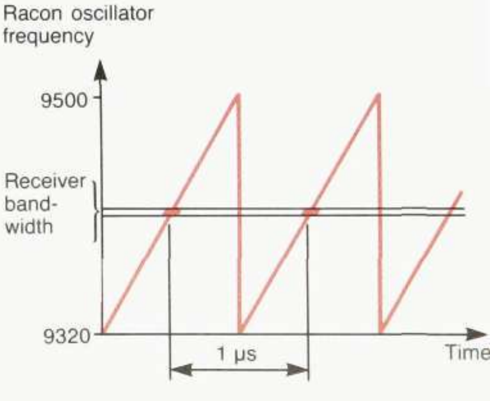


Fig. 6
The principle of the fast sweep racon



dots is seen as a diffuse line on the indicator.

Thus the fast sweep racon offers a practically continuous display of the racon response at the cost of a weak response signal in the radar receiver. The low received power means that the racon response is often masked by noise, rain or sea clutter. There is no easy way of encoding the response of the fast sweep racon. Today there are only a few fast sweep racons in operation.

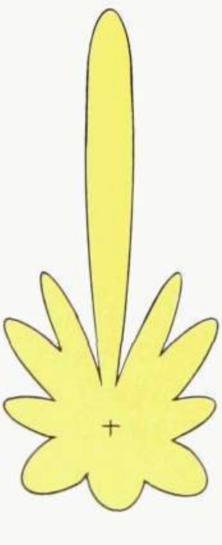
Frequency agile racons
Recent technical development has made it possible to design a new type of racon which meets most of the demands made on a modern radar beacon. When the new type, called frequency agile racon, receives a radar pulse it responds at the same frequency with a high degree of frequency accuracy and with little delay. The length of the response signal can be varied, and it can easily be coded in Morse or some other system. Since the racon always responds at the frequency of the searching radar, the whole of the transmitted power is available for the response. This reduces the sensitivity to different types of clutter. The waiting time between responses is short and the racon response can be displayed during each antenna rotation.

AGA-ERICON is the first racon of this type and it has attracted much interest on the international market. Development of similar racons has started in other countries.

Side lobe interference
Large radar antennas are required in order to obtain good angular resolution and bearing accuracy. Large ships usually have 9–12 foot antennas with lobe widths of less than one degree, whereas small boats have 3-foot antennas or less, with lobe widths of 2–3 degrees. Fig. 7 shows a typical antenna diagram with small lobes, so-called side lobes, in other directions than the required one.

The smaller the antenna, the worse the ratio between main lobe and side lobes. At short distances the power transmitted in side lobes can be sufficient to activate a racon. The ship's indicator will then present racon responses in many false directions, and at close range the side lobe interference can completely blanket the normal radar picture. Built-in suppression of side lobe responses was therefore a prerequisite in the development of AGA-ERICON.

S-band racon
International recommendations and certain national regulations specify that large ships must have two radar systems. During recent years the S-band radar has become increasingly popular, and large new ships are equipped with both X and S-band radar as standard. It seems natural to complement the better resolution at close ranges offered by the X-band radar with the superior weather properties of the S-band radar, fig. 8. In certain cases two S-band radars are used.



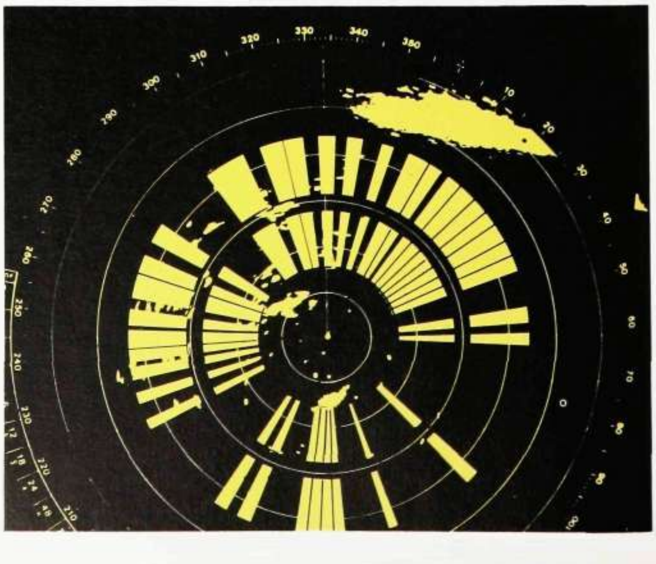


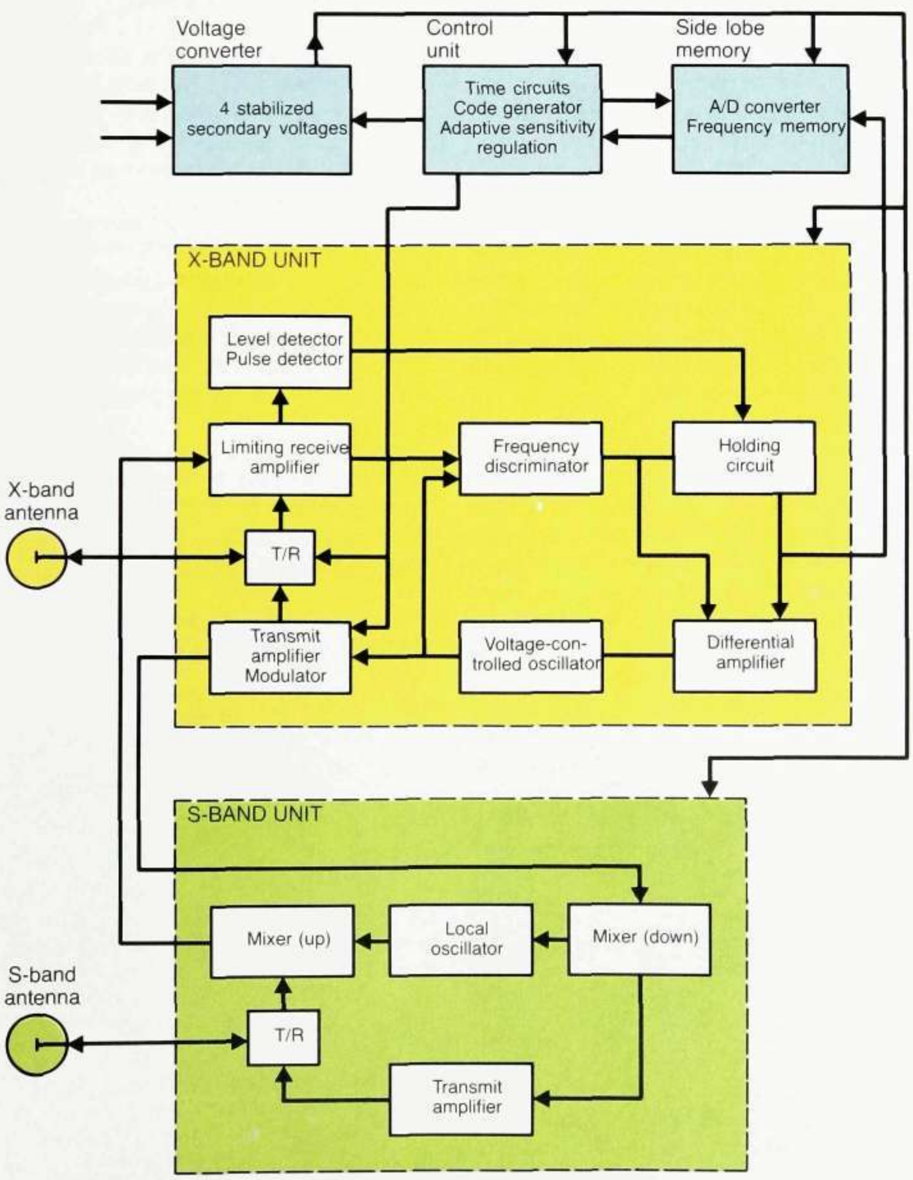
Fig. 7
The drawing to the left shows a typical antenna diagram, and the picture to the right shows the effect of side lobe activated racon response on the ship's radar display

Fig. 8
A passenger ferry with radar antennas for the X and S bands. The S-band antenna is at the top

In many situations the radar is the only instrument that enables the ship to navigate. A radar fault can mean that further movement is made impossible or extremely dangerous. From the point of view of safety it is therefore extremely important that future racon systems can serve all ships, regardless of the type of radar carried or in operation. Today there are only a few S-band racons in operation.

Thus another prerequisite for the development of AGA-ERICON was that it should be able to serve both X and S-band radars.

Fig. 9
Functional block diagram for AGA-ERICON



Functional description

The block diagram in fig. 9 gives a general picture of the signal flow between the various function blocks in AGA-ERICON.

The X-band unit contains the receive circuits for sensing the level and frequency of the received radar pulses, and also the functions for generating the response signal at the frequency of the received radar pulse.

The S-band unit converts received S-band pulses to the X band for signal analysis and frequency regeneration. The response signal is then converted back to the S-band, amplified and sent out via the omnidirectional S-band antenna.

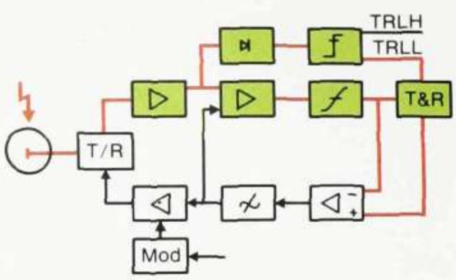
The control unit contains programmable circuits for different operational modes and for the generation of the response code, and also control circuits for adaptive regulation of receiver sensitivity.

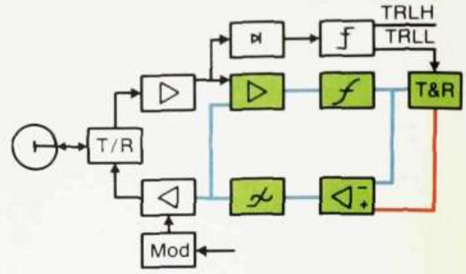
The side lobe memory is used to prevent the racon from responding to radar pulses transmitted in the side lobes of the ship's antenna. Each ship in the vicinity of the racon is given a "frequency identity" which is stored in a special frequency memory. The power level and frequency of the received pulses and their status in the memory then decide whether the racon will respond or not.

The d.c./d.c. converter converts a primary voltage of between 9 and 35 V to four stabilized secondary voltages.

Fig. 10
Receiving, left.
On the receive side the information concerning the frequency of the radar pulse is stored for 50 ns after detection

Fig. 11
Frequency regeneration, right.
During the frequency regeneration the racon oscillator frequency is adjusted in a closed loop to match the frequency of the received radar pulse. The building-up time is approximately 0.3 μs





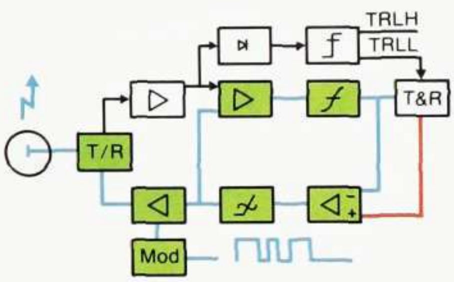


Fig. 12
Transmitting.
0.4 μs after the radar pulse has been detected, the racon can respond with an extended coded pulse at the frequency of the received radar pulse

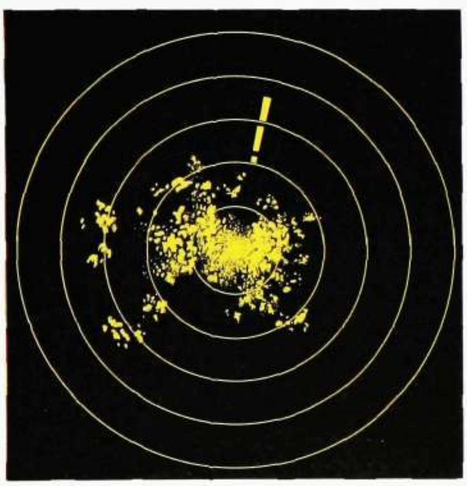


Fig. 13
Encoding.
15 out of 16 time slots can be encoded, by means of switches, to provide any radar pulse response. The code shown in the figure is the Morse character W

Receiving

The racon receives radar pulses, via omnidirectional antennas, from ships in the vicinity. The pulses are amplified in a limiting amplifier chain, fig. 10, and then fed to a frequency discriminator. The discriminator gives an analog voltage which is proportional to the frequency of the received radar pulse. At the beginning of the amplifier chain a part of the radar pulse power is diverted and detected, and the level is sensed in two threshold circuits. The lower threshold, TRLL, determines the racon activating level, whereas the upper threshold, TRLH, controls the side lobe suppression of the racon. The difference in threshold levels corresponds approximately to the ratio between the main and side lobe level from normal ship radar antennas. The output value of the frequency discriminator is stored in a hold circuit for a certain time, 0.05 μs, after the detection of a radar pulse. The stored voltage value is a measure of the frequency of the received radar pulse.

Frequency regeneration

During the time that the frequency value is stored, the first part of the amplifier chain is switched off and a voltage-controlled oscillator is started, fig. 11. A part of the output power from the oscillator is fed to the frequency discriminator via the last amplifiers in the receive chain. The analog output voltage of the discriminator corresponds to the momentary oscillator frequency. The discriminator output signal is compared with the stored frequency value in a differential amplifier. The resultant output signal adjusts the frequency of the voltage-controlled oscillator until the difference signal at the input to the differential amplifier becomes zero. The oscillator frequency then matches the frequency of the received radar pulse. The frequency regeneration takes approximately 0.3 μs and this time does not depend on the frequency of previously received pulses.

Transmitting

The oscillator output signal is fed via transmit amplifiers, fig. 12, to the omnidirectional antenna, and approximately 0.4 μs after a radar pulse has been received the racon can respond with an extended pulse at the received frequency and at an increased power level. The delay of 0.4 μs gives a distance error of 60 m, which is negligible in most cases. The response pulse, which has a maximum duration of 25 μs, is shown on the ship's indicator as a radial line with a length of two nautical miles.

The receiver is shut off for 75 μs after a pulse has been sent, in order to prevent self-triggering. Thus the racon can determine the frequency of and respond to received radar pulses at the rate of 10 000 pulses per second.

Encoding

The response from AGA-ERICON can be encoded, fig. 13, to give one Morse character or a combination of several characters. The pulse length of 25 μs is divided into 16 time slots, which can be programmed individually.

The programming is carried out in the racon control unit. The figure shows the radar display of an AGA-ERICON response coded to a Morse "W".

The basic version of AGA-ERICON uses adaptive regulation of the receiver sen-

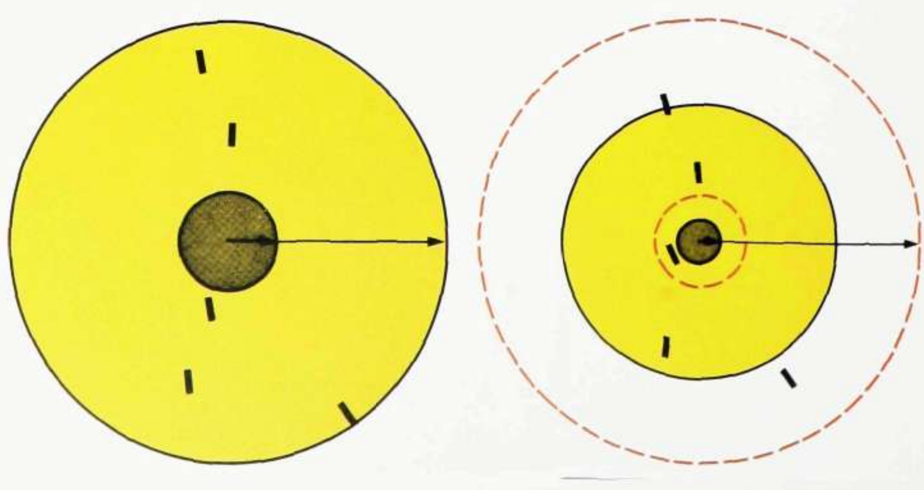


Fig. 14
The normal coverage of the basic version of AGA-ERICON extends to the radar horizon (left). During the time a ship passes close by, the sensitivity of the racon receiver is reduced in order to avoid side lobe activation. This means a temporary reduction of the range (right)

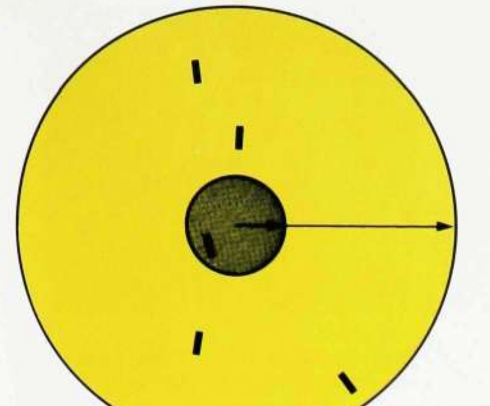


Fig. 15
An AGA-ERICON with a side lobe memory suppresses side lobe responses to nearby ships and at the same time provides coverage to the radar horizon

sitivity in order to avoid triggering by side lobes. Nearby ships give high levels in the racon receiver. When a ship has come so close to the racon that its pulses exceed the upper threshold, TRLH, there is a risk of side lobe triggering, fig. 14. The output signal from the threshold circuit is integrated and drives a voltage-controlled attenuator in the receiver input circuits. The attenuation is increased until no pulses above the upper threshold are detected. The reduction of the receiver sensitivity means that the coverage of the racon is reduced temporarily. The range is reduced to approximately 20 times the distance to the nearest ship. When the nearby ship has passed, the sensitivity is restored to normal level after a certain period of time.

AGA-ERICON can be equipped with a special side lobe memory if the operational requirements demand maximum range even when ships are passing close by. Ships in the range of the racon are given an identity which is based on the frequency of the received pulses. The analog frequency value at the discriminator output is A/D converted to 8 bits and if the received pulse exceeds the upper threshold TRLH the digital frequency value is stored in a special frequency memory. When pulses are received that exceed only the lower threshold, TRLL, the memory is read. If the frequency is found in the memory the response is blocked. The frequency memory is erased and updated twice every minute.

Operation

AGA-ERICON can be programmed for different operational modes, which meet different operational requirements. The racon is passive for at least nine seconds during each 30-second interval in order to ensure that the racon response shall not hide other echoes of interest. The passive period can be increased to 24 seconds in steps of 3 seconds. During the active period the racon responds, with suppression of side lobe responses. The adaptive sensitivity regulation means that distant ships can temporarily lose contact with the racon when a ship passes close by. The racon can therefore be programmed for a "non-restrictive operational mode" during 3 or 6 seconds every minute. This ensures a basic availability for all ships in the normal coverage area of the racon, but nearby ships can then suffer side lobe interference, fig. 16.

Availability

One of the most essential characteristics of a racon is its availability, i.e. how often it can be seen and for what length of time. The way AGA-ERICON operates, establishing the frequency of the received radar pulse and responding at the same frequency, means that a racon response can be given for each antenna rotation. Since each received radar pulse is treated individually, AGA-ERICON can deal simultaneously with what is in practice an unlimited number of ships.

The range is determined by how high the racon and radar antenna are mounted, and the output power of the radar. Fig. 17 shows the range of AGA-ERICON as a function of the height at which it is installed, for four different types of ship radar.

Voltage supply

Many isolated lighthouses and most light buoys are today powered by batteries or chargeable accumulators with a limited capacity. The cost of changing batteries or accumulators is high, which means that the electrical apparatus installed in such units must have low power consumption.

All versions of AGA-ERICON require a primary input voltage in the range 9–35 volts. The mean power consumption is dependent on type, programming and traffic intensity. Fig. 18 shows the calculated mean power consumption for the different versions as a function of the number of ships within range of the racon. The calculations are based on a racon programmed to respond for 15 seconds during each 30-second interval.

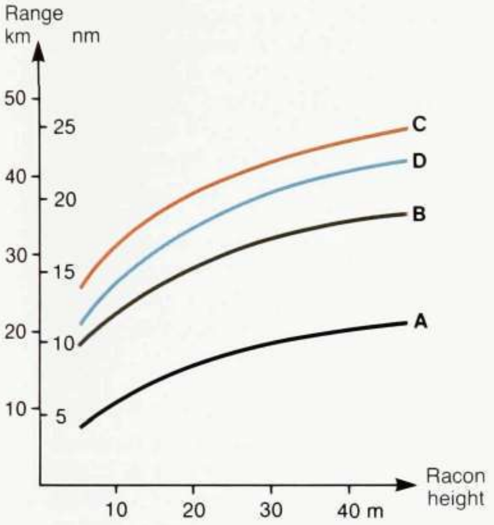


Fig. 17
Calculated ranges as a function of the height at which the racon is mounted

	Pulse power (kW)	Antenna height (m)
A: Small X-band radar	3	5
B: Medium X-band radar	25	20
C: Large X-band radar	50	40
D: Large S-band radar	60	40

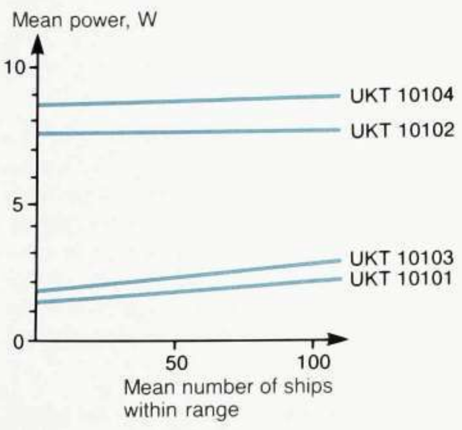


Fig. 18
Calculated mean power consumption for the different versions of AGA-ERICON as a function of the number of ships within range

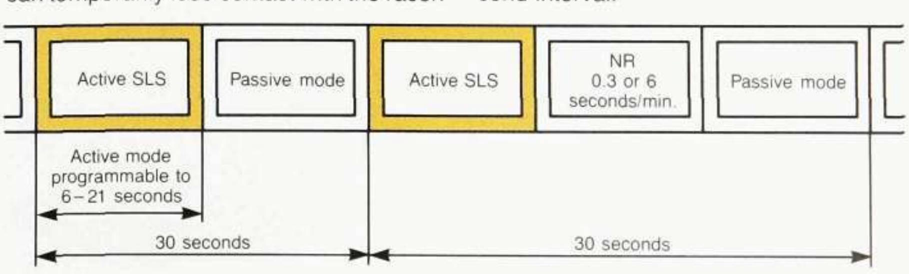


Fig. 16
The 60-second operating cycle of the racon can be programmed for different operational modes with varying intervals

SLS Side lobe suppression
NR Non-restrictive

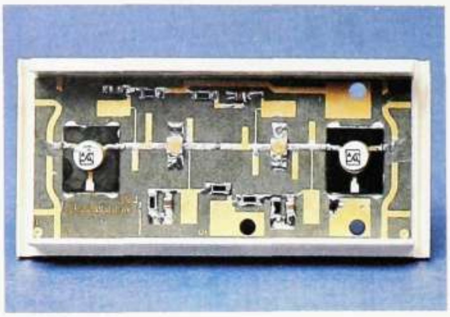


Fig. 19
AGA-ERICON equipped with the S-band subunit and side lobe memory

Fig. 20
Small-signal amplifier with two GaAs-FET transistors

Fig. 21
An X-band cassette with integrated microwave modules

AGA-ERICON – construction and technology

AGA-ERICON has a modular structure. Five subunits can be combined to give four different versions:

UKT 10101 X-band racon with adaptive sensitivity regulation
UKT 10102 X+S-band racon with adaptive sensitivity regulation
UKT 10103 X-band racon with side lobe memory
UKT 10104 X+S-band racon with side lobe memory

A basic version can quite easily be equipped with additional facilities on site at any time. Subunits can be replaced or added without any readjustments of the other subunits being necessary.

The subunits are mounted in magazine and are connected together by means of cabling at the rear. Semi-rigid coaxial cables are used for RF connections to the antenna system and between the microwave cassettes. The magazine is mounted underneath a sturdy flange made of anodized aluminium, with feed-through connectors for the power supply cable and coaxial cables to the antenna system. The magazine is protected by a strong container made of anodized aluminium. It is screwed on to the flange and the joint is sealed, fig. 19.

The flange also contains a dessication capsule with colour indication. The antennas are mounted on top of the flange and are covered by a radome made of structured cellular plastic.

Technology

The quality standards applied for the development and manufacture of AGA-ERICON are those used by the division for military electronic equipment. A main customer requirement for this type of equipment is high reliability, since it often has to be installed in isolated and inaccessible places, where replacements and repairs would be costly. The MTBF for the most extensive version is calculated to be 25 000 hours.

The electronic functions in the microwave units are built on printed circuit boards made of a teflon-based substrate, using so-called microstrip technique. One circuit, the frequency discriminator, is built up on a ceramic substrate.

In the X-band unit all amplifiers and the oscillator are built up of GaAs-FET transistors, a type of semiconductor components that has only recently come on the market. This type of transistor provides a considerably improved basis for advanced signal processing at the high microwave frequencies at a reasonable cost, figs. 20 and 21.

Bipolar transistors are used for the amplifiers in the S-band unit. The local oscillator in this unit has a dielectric resonator, which gives high frequency stability and small dimensions. The side lobe memory, the control unit and the voltage converter are built up on the standard boards of the BYB construction practice, with through-plated holes and protective lacquer on both the foil and component sides. The digital microcircuits are with few exceptions ceramically encapsulated.

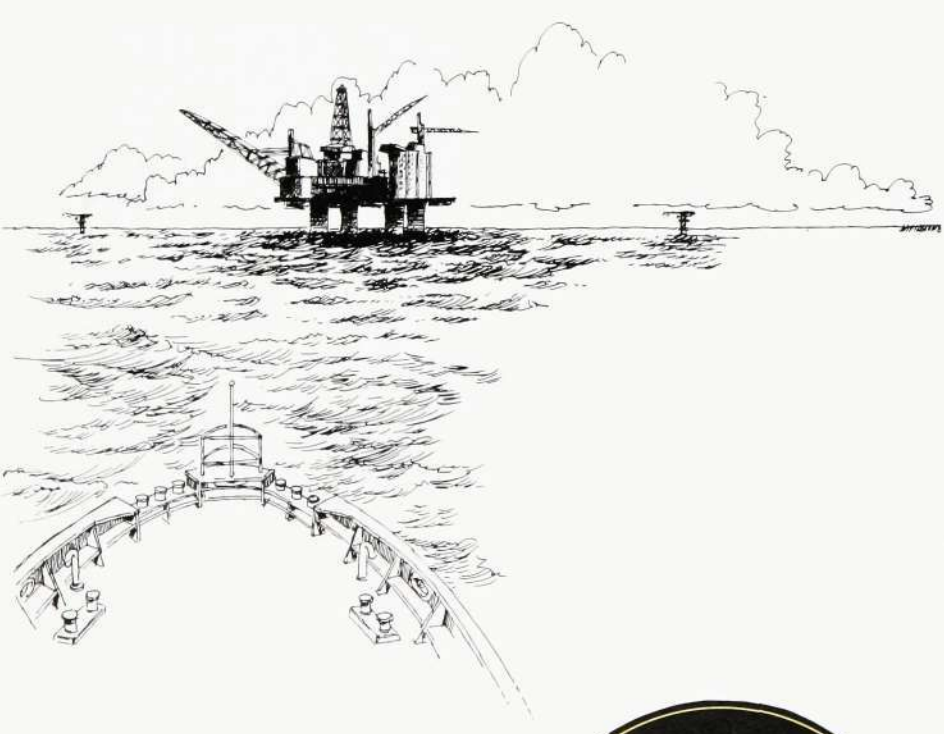


Fig. 22
When navigating by radar in areas where oil is being extracted it is often difficult to orientate oneself and identify specific targets. Ships at anchor and fixed platforms give similar echoes on the radar indicator. The relative positions of different installations can change from one visit to the next. Racons with different response codes installed on stationary platforms give easily identifiable reference points and reduce the risk of disastrous navigational errors. In the case of a gas leak or other dangerous situations on a platform a racon with a specific response code can warn approaching ships

Technical data

		X-band	S-band
Frequency range	GHz	9.32-9.50	2.92-3.10
Frequency accuracy	MHz	<2	<2
Output power	W	1	0.5
Response delay	μs	0.4	0.45
Receiver sensitivity	dBm	−40	−33
Maximum response rate	pulses/s	10 000	10 000
Antenna data			
Polarisation		Horisontal	Horisontal and vertical
Gain	dBi	4	0
Direction		Omni-directional	Omni-directional
Vertical lobe angle degrees		>18	>20
Power supply			
Input voltage	V DC	9-35	9-35

The power connection is equipped with internal lightning protection and is filtered against RF interference

Power consumption			
UKT 10101, UKT 10102	W	1−3 depending on programming and traffic intensity	
UKT 10103, UKT 10104	W	7−9 depending on programming and traffic intensity	
Dimensions		X-band	X+S-band
Diameter	mm	440	440
Height	mm	655	895
Weight	kg	20	23

Applications

During recent years the use of racons as navigational aids has attracted an increasing amount of interest, and many new applications have also been suggested. The development of new types, among them AGA-ERICON, which offer greater availability in difficult weather conditions, with less risk of interference, is expected to bring a further increase in the interest shown.

In narrow passages, on bridges or on large lighthouses in harbour entrances the AGA-ERICON is able to provide information from short distances, less than 100 metres, right out to the radar horizon, without obscuring the radar pictures of nearby ships with side lobe responses.

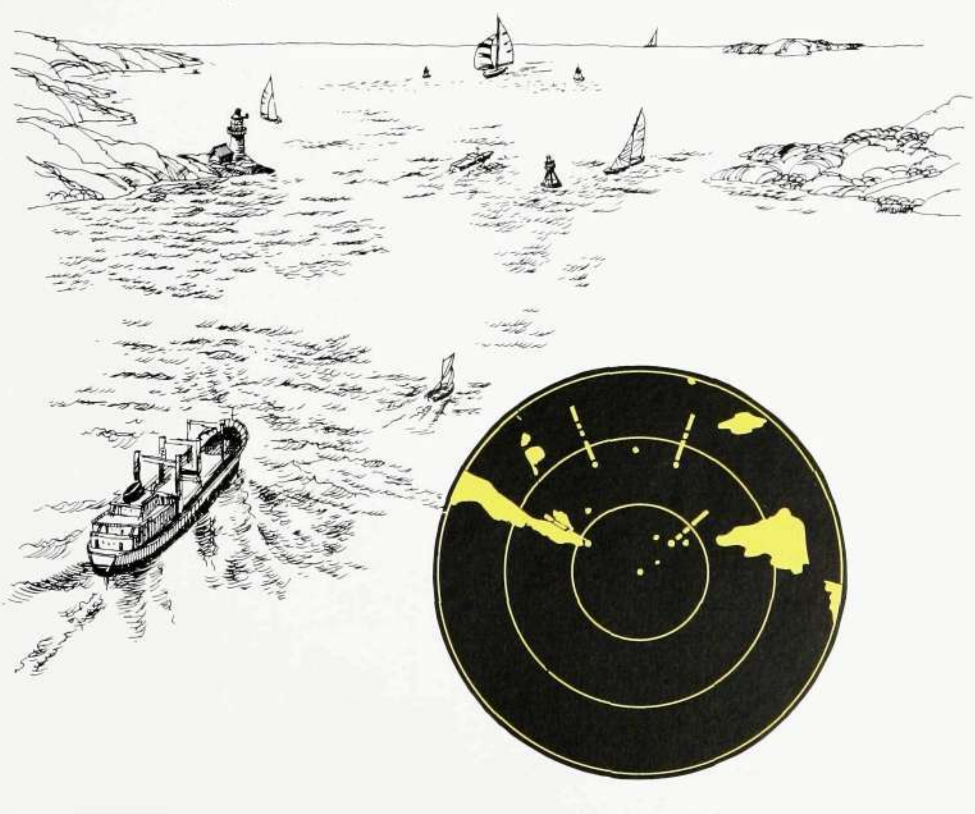
Newly discovered navigation obstructions, such as drifting sandbanks and shipwrecks, can be marked with buoys equipped with racons. Since AGA-ERICON has a high response frequency and responds on both frequency bands it is most likely that the radar observer notices the unexpected danger, regardless of which system he happens to be using.

Operational experience

In October 1980 a prototype of AGA-ERICON was installed on Trubaduren, a caisson lighthouse at the entrance to the harbour of Gothenburg, on the west coast of Sweden (the cover picture). It replaced an older, slow sweep X-band racon and a fast sweep S-band racon. It is programmed to respond for 30 seconds per minute and is equipped with a side lobe memory.

At the time of writing this article the AGA-ERICON prototype has functioned faultlessly for 10 months, to the great satisfaction of the ships' officers who have made use of it. An enquiry on the ferries running between Gothenburg and Fredrikshavn (Denmark) has shown that the racon response is usually visible at a distance of 18 nautical miles, sometimes at up to 22 nautical miles, and in spite of the ships passing close to Trubaduren no problems with side lobe interference have been reported. The displayed racon response was considered to be clear, and the general impression was that the availability was good or very good.

Fig. 23
Very precise navigation is required in narrow passages and complicated waters. The multitude of echoes from rocks, skerries and small boats makes the radar display difficult to interpret, but the position and identity of navigation marks equipped with racons are quite unambiguous



A Cooling System for Electronic Telephone Exchanges

Ragnar Almquist

LM Ericsson have developed a system for cooling electronic telephone exchanges. It differs from conventional systems in that water is used instead of air to remove the dissipated heat from the exchange premises. In particular this makes it possible to store the coolant and so ensure operation during a mains failure.
The author deals with the general requirements which must be satisfied when cooling electronic telephone exchanges and describes the function of the system and its units. The article shows how these requirements are met. Finally the advantages of the system are listed.

UDC 621.395.34:
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697.97

Electronic telephone exchanges take up far less space than electromechanical systems. Power consumption is not reduced proportionally and the amount of heat radiated per unit area will be higher, which means that the cooling system is of increased importance for the functioning of the telephony system. If cooling is interrupted, the temperature in the exchange room rises. If the temperature exceeds the permitted value, there is a risk of disturbances in operation and should the temperature continue to increase, components may be damaged.

A cooling system for electronic telephone exchanges should meet the following requirements:

High reliability
High reliability is sought in electronic systems. To ensure this, it is important that the reliability of surrounding equipment, such as the power supply system and the cooling system, should be on a par with the telephony system.

Coolant reserve
The cooling system should function even when the switching equipment is powered from the exchange battery because of a mains failure.

Simple extension
It can be difficult to forecast the rate at which a telephone exchange will be extended and what its final capacity will be. It may not be expedient to install a cooling system for the planned final capacity right from the initial stage. The cooling system should therefore be modular so that it can be extended at the same rate as the exchange.

Minimum of maintenance
It is possible to concentrate the operation and maintenance activity for SPC exchanges to a small number of centres and leave the exchanges unmanned. Maintenance of the cooling system, which should not require special training, should therefore be restricted to limited service at regular intervals.

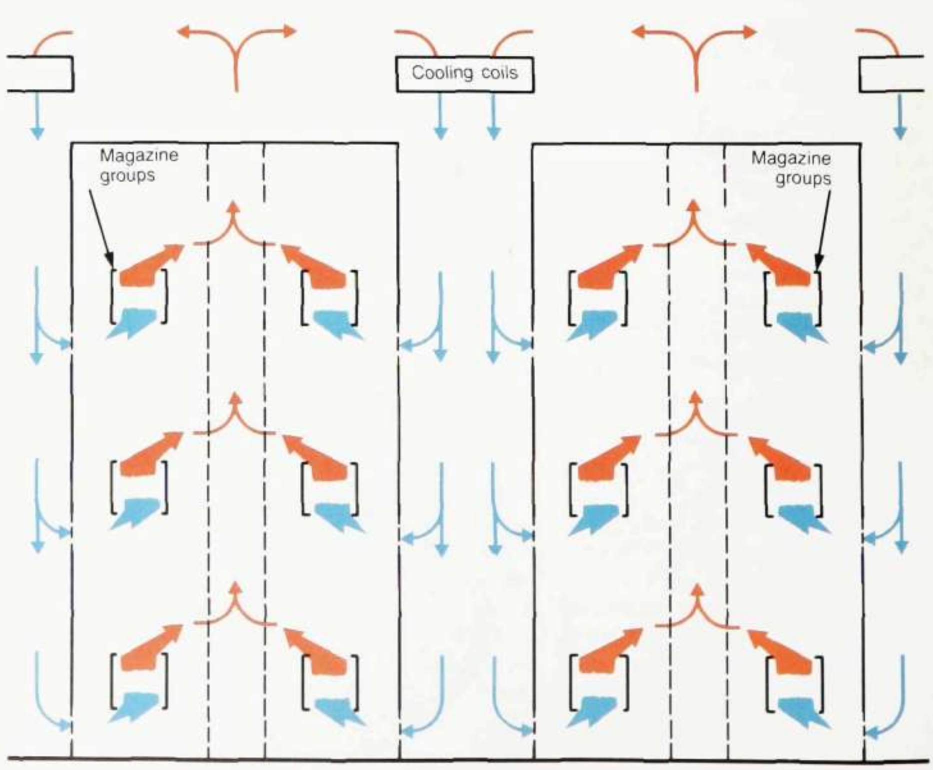

Fig. 1
All cooling of the electronic equipment takes place by means of self-convection (without fans for forced air circulation). This method gives effective cooling and a quiet and draught-free environment.

Red arrows: Warm air
Blue arrows: Cold air

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Fig. 2
The cooling coils in the exchange room are located above the aisles between the equipment suites. All central cooling equipment is placed separately, possibly out-of-doors

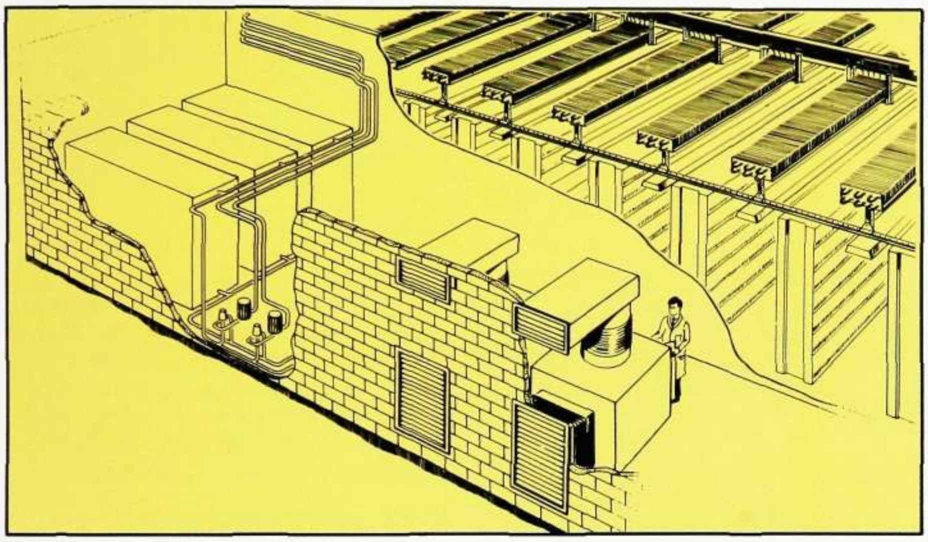
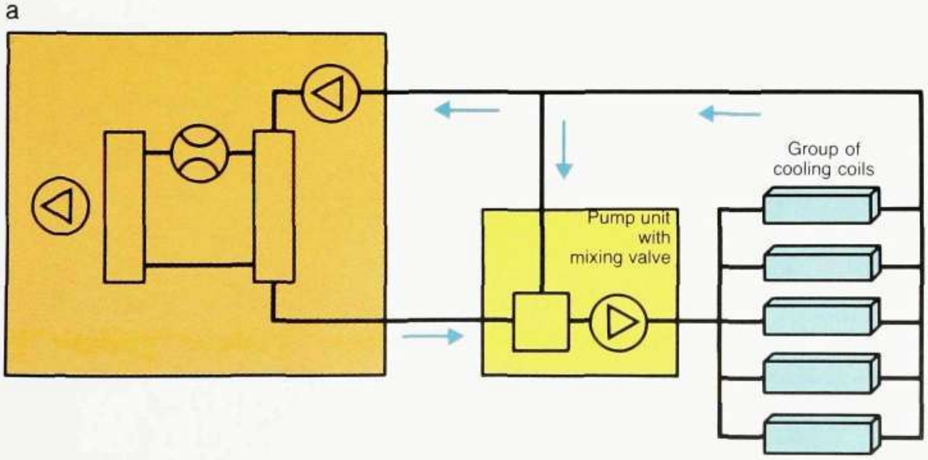


Fig. 3, below
The principles of the water cooling system
a. Functional block diagram
b. Reliability block diagram
When there is a failure in any part of the system, the cooling process stops. Reliability calculations show that the failure frequency, that is, the number of failures per year of such duration that there will be a risk of operational disturbances in the switching system, amount to 0.6; this means that a failure can be expected about once every two years. When the mains voltage is unreliable and without an emergency power supply, the failure frequency increases to 2–3 failures per year

a



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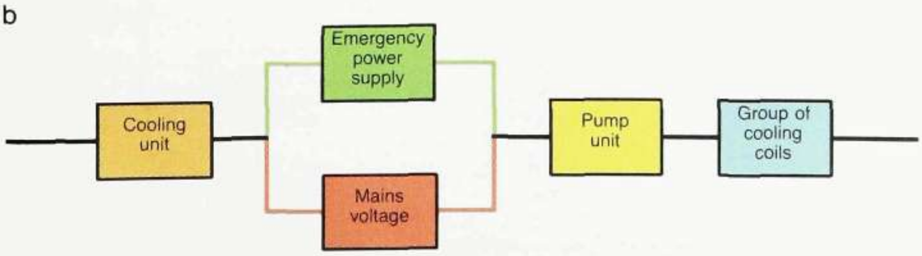


Simple installation

Electronic telephone exchanges do not take long to install. So a cooling system should be simple and easy to set up. Existing buildings should require no or only minor modifications, and the amount of space required should be small.

Functional description

LM Ericsson's electronic telephone systems have components mounted on printed board assemblies and these are grouped in magazines. The heat which the components dissipate must be removed. The packaging structure is designed for parallel cooling. This means that air enters each magazine from the front, takes up the heat while passing through it and rises by convection through a duct at the back, fig. 1.

Before being recycled through the magazines the heated air must be cooled. To do this the air is passed through cooling coils located above the aisles between the rack suites, fig. 2.

As the density of the air alters when there is a change in temperature, natural convection occurs and no fans are required to keep the air moving.

Water, circulated in a closed system, is used to remove excess heat from the exchange room. The principle for a simple water cooling system can be seen in fig. 3a. The system has three functional blocks: the cooling unit, the pump with a mixing valve, and the cooling coils. Water passes through the cooling coils which function as heat exchangers between the air and the water.

In the cooling unit the temperature of the water is reduced to about 8°C. The cold water is mixed with water returning from the exchange room and is pumped to the cooling coils. The ratio between cold water and returning water is regulated by the mixing valve controlled by the temperature monitor in the exchange room. In this way the temperature can be kept at a constant level, for instance 25°C.

This system design corresponds to the usual solution with conventional air conditioning systems. As each part of the system is important for the cooling function, only a limited degree of reliability is obtained. This is shown in the reliability block diagram, fig. 3b.

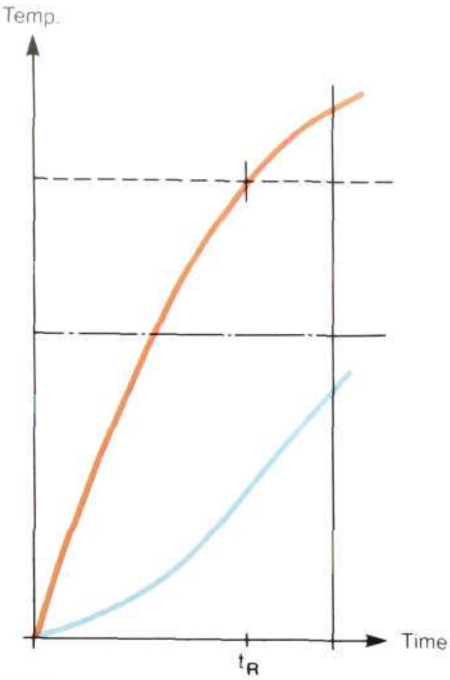


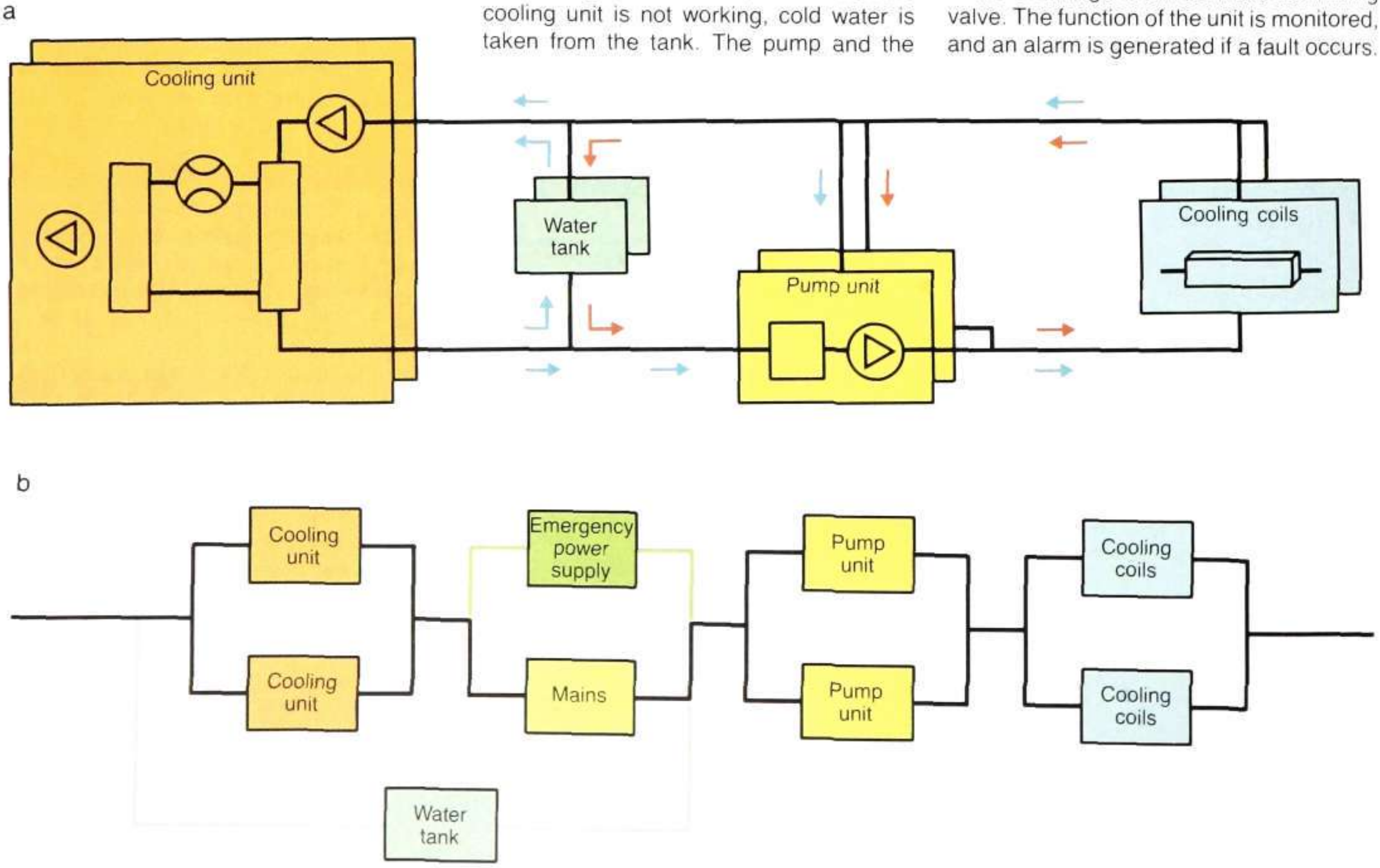
Fig. 5
Example of temperature characteristics with and without a coolant reserve. The example refers to exchange premises that are fully utilized. In this example the battery and coolant back-up have been calculated for the same reserve period

Temperature limit for non-destruct
Temperature limit for secure function
Temp. characteristics without coolant reserv
Temp. characterstics with coolant reserv

Fig. 4
Cooling system with redundant equipment
a. Functional block diagram
b. Reliability block diagram
A complete system with coolant reserve has a calculated failure frequency of 0.0007 failures per year. When the mains voltage is unreliable and without a back-up power supply the failure frequency increases to 0.02 failures per year

Water circulation during normal operation
Water circulation when there is a mains failure

a



Redundancy gives high reliability
Reliability is considerably increased by having several cooling units, by designing the system so that cooling requirements are met even if one of the cooling units should be out of operation, and by dividing the cooling coils into at least two circuits; in other words by introducing redundancy, fig. 4a. The cooling coils are distributed between the circuits so that the system can hold the temperature below the maximum permitted value even if one circuit is out of operation.

In redundant systems the reliability of the a.c. current supply is critical, fig. 4b. If cooling is to be retained during a mains failure, either a reserve power supply (preferably with redundancy) or some form of coolant reserve will be required.

Water tank as coolant reserve
To permit the system to function when there is a mains failure it has been supplied with a cold water tank, fig. 4a. During normal operation some of the water from the cooling unit will circulate through the tank keeping the temperature of the water to about 8°C. During a mains failure, that is when the cooling unit is not working, cold water is taken from the tank. The pump and the mixing-valve-control circuits are powered from the exchange battery. The coolant reserve in the tank corresponds to the power reserve in the exchange battery. The increase in temperature with and without a coolant reserve is shown in fig. 5. The reliability block diagram for a complete cooling system is shown in fig. 4b. This system guarantees extremely high reliability and is recommended for large telephone exchanges.

The units

The cooling unit
The cooling unit contains a compressor, an evaporator and a condensor, fig. 6. It is powered from the mains. After a mains failure, the unit starts automatically when the voltage has stabilized. Pressure, water flow and temperature are monitored, and an alarm is generated if a fault occurs.

Pump with mixing valve
The pump and the mixing valve form one unit. The pump motor operates on a.c. from an inverter which is powered from the exchange battery. The temperature monitor in the exchange room controls the mixing valve. The function of the unit is monitored, and an alarm is generated if a fault occurs.

Fig. 6
Cooling unit consisting of a compressor, an evaporator and a condensor as well as control and supervision equipment

Water tank
The water tank, made of stainless steel, is available in a standard size and designed for easy installation. The required tank volume is obtained by connecting a number of tanks in parallel.

Water distribution network
The water is distributed through flexible plastic tubes of a new design. The material selected prevents oxygen diffusion and thereby also corrosion and the formation of algae in the system.

The water is pumped to the distribution tubes and from these, through the flexible plastic tubes via individual gate valves to the cooling coils, fig. 7. Each pump unit, together with the distribution tubes, gate valves and cooling coils, forms a separate cooling circuit. Each circuit can be equipped with automatic cut-off valves which turn off the water supply if a leak should occur.

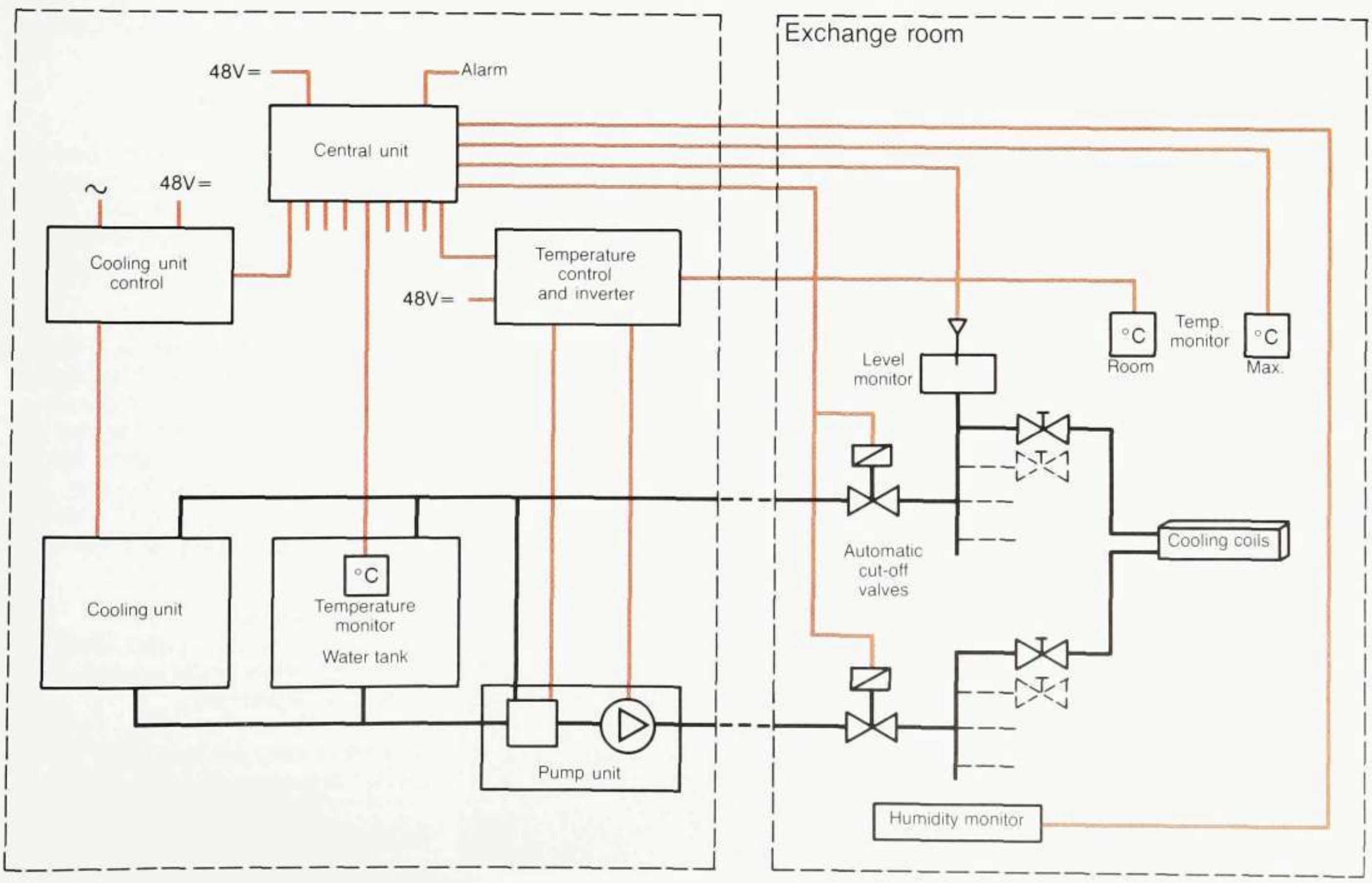
Control and monitoring
The cooling system is continually monitored, fig. 7. The printed board assembly containing the control and monitor function is powered from the exchange battery.

The internal monitoring system for each cooling and pump unit is connected to a central device containing the alarms and control equipment for the whole system. This device can connect stand-by units if a failure should occur. A failure in the control device cannot affect the function of the system. From the control device, alarm signals can be sent to alarm displays in the control room and passed on, via the exchange equipment, to a centrally-located operation and maintenance centre.

System design

Minimal risk of water leakage
Despite the great advantages water has as a coolant, there has been little enthusiasm for its use in telecommunications because of the leakage risk. When developing the LM Ericsson cooling system great care has been taken to minimize this risk. Before being taken into operation the system is tested with an overpressure many times greater than the pressure used in opera-

Fig. 7
Control and supervision.
The LM Ericsson cooling system continually monitors all important functions



tion. The chance of a leak occuring is very slight because of the low pressure, normally about 0.3 kg/cm^2, and the minimal temperature variations. The probability of a fracture in a tube or cooling coil can be disregarded. The parts of the system requiring most attention are the junction points.

The design incorporates the following safety features:
- the number of junction points has been reduced to a minimum
- only tried and tested junction technology has been used
- the cooling coils and junction points are located between the rack suites and not over the switching equipment
- a moisture-sensitive strip has been placed along the water tubes in the exchange room. Moisture alters the resistance between two conductors enclosed in the strip, and this causes an alarm. The LM Ericsson cooling system can also be supplemented with equipment which automatically turns off the water supply to a faulty coolant circuit.

Fig. 8
The cooling coils are mounted above the aisles between the equipment suites

Fresh-air unit controls the humidity
Fresh-air ventilation is needed in the exchange room to provide a good working environment. This is supplied by means of a separate unit. The unit adjusts the temperature of the incoming air to 25°C and the relative humidity is kept at 50%. Overpressure in the exchange room prevents dust and heat leaking in.

Small differences in temperature prevent condensation
All parts of the system where the water temperature is lower than 15°C are insulated. The temperature in the exchange room is kept at 25°C and the relative humidity at 50%. This means that there is no condensation risk, since the temperature in uninsulated parts of the system exceeds the dew point by a considerable margin.

Easy to extend because of the modular design
When additions are made to the switching equipment and the cooling requirement exceeds the capacity of the system, it can easily be extended. New cooling units and tanks are connected in parallel to those already installed.

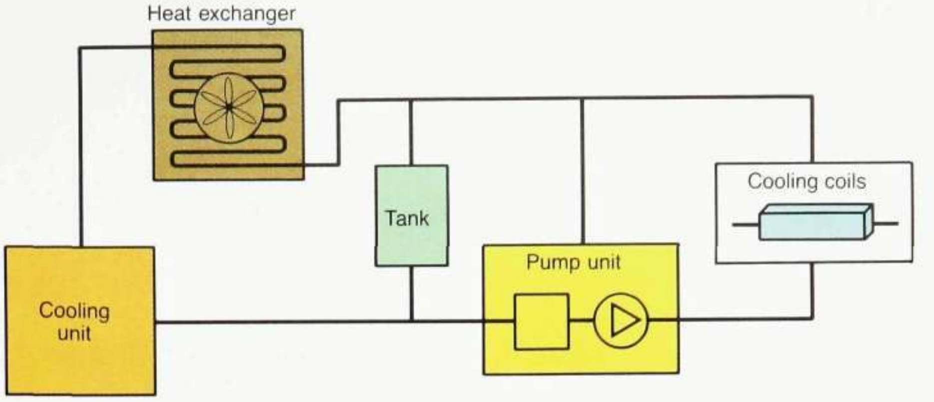
New pump units and cooling coils form new circuits. For small extensions it is sufficient to connect new cooling coils into existing circuits. All such work can be carried out while the system is in operation without interfering with the cooling function. The system can be extended from a few units to a very large, theoretically unlimited number.

Simple installation
When developing the system emphasis has been placed on simple installation and small space requirements.

The cooling coils are located in frames mounted on the exchange structure, fig. 8.

The flexible plastic tubes for water circulation inside the exchange room are placed in

Fig. 9
In temperate climates, one or several cooling units can be replaced by a heat exchanger between the outdoor air and the water. The only moving part in the heat exchanger is a fan. The system is extremely reliable and cheap to run



standard cable chutes. Only 50 cm free ceiling height is required above the exchange equipment, and the ceiling design is of no importance.

The cooling unit, the water tanks and pump units should be located in a separate cooling equipment room. The water flows between this room and the exchange room in flexible plastic tubes placed in normal cable ducts.

All the units in the equipment room are designed to be located out-of-doors, under a screen roof or in a separate container.

All units have been tested in the factory, so the installation test is confined to a test pressurization of the system and some functional checks.

System variants

System variant for temperate climates

In localities where the average daily temperature during 10 months of the year is less than 20°C, one or some of the cooling units can be replaced by a heat exchanger in which the water is cooled by the outdoor air, fig. 9. This method saves energy. The cooling unit will be in continual use only during the warmest days of the year and for the rest of the time will be connected intermittently to keep the tank water temperature low.

Simplified system for small plants

A simplified variant has been developed for small plants. The cooling unit, pump unit and water tank have been combined to form a single unit. The cooling circuits are unchanged. Instead of cooling the water in the cooling unit, the coolant loop has been placed in the tank, fig. 10. The water temperature in the tank is reduced to almost 0°C. The circulation of the cold water through the mixing valve, pump and cooling coils takes place as described previously.

Heat recycling

By the use of simple additional equipment the heat dissipated from the telephone exchange can be recycled and used to heat adjacent premises. In this way heating costs for the building can be considerably reduced. For example in a Scandinavian-type climate the amount of the heat dissipated from a 10,000 line electronic exchange can be used to heat about 600 m^2 of office space.

The LM Ericsson cooling system compared with air conditioning systems

Greater reliability

To secure acceptable reliability values with a conventional air conditioning (A/C) system, the system should be duplicated and, in the event of a mains failure, it must be supplied from the reserve power unit, for which there should be redundancy. Fig. 11 shows a conventional A/C system and its reliability block diagram. As has previously been mentioned in connection with fig. 4, the LM Ericsson cooling system offers considerably greater reliability even without an emergency power plant.

Better environment both for staff and equipment

Water has a higher heat-absorption capacity than air. To achieve the same cooling

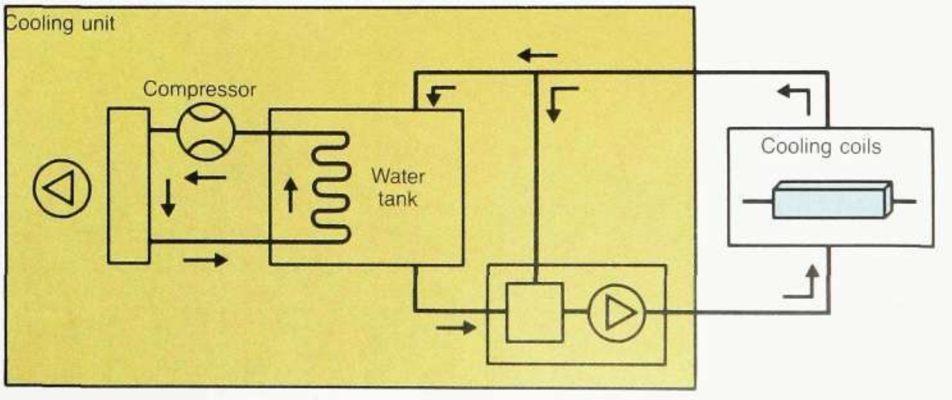


Fig. 10
For small exchanges the cooling unit, pump unit and water tank are combined into a single unit. It is designed for housing in a container together with the exchange

capacity with an A/C system, forced air circulation must be used. Staff then find the premises draughty and noisy. Dust in the room whirls around more easily when the air velocity is high.

Saves space, makes planning and installation easier

The LM Ericsson cooling system takes up little space and is easy to plan and install. In conventional A/C systems the whole volume of air must often be transported long distances via bulky air ducts in order to be cooled and returned. These ducts, which are often suspended from the ceiling, can be several square meters in size, and this implies constraints on ceiling height and construction. When planning duct extensions, consideration has to be given to other equipment, cable chutes, etc., to secure an optimal layout.

Easier to extend

The LM Ericsson system can be extended at the same rate as the telephony exchange. On the other hand A/C systems are often sized for the expected final capacity.

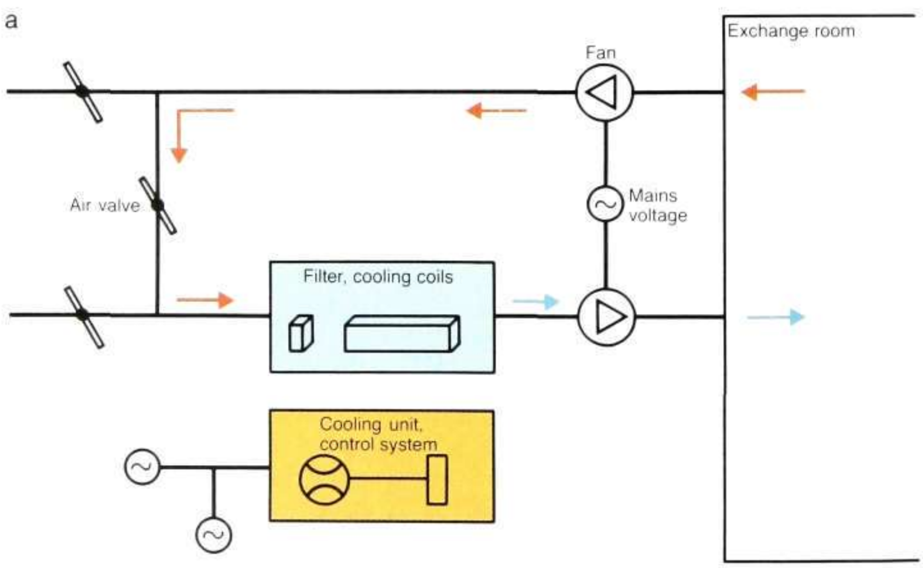
More effective cooling

The function of the LM Ericsson system automatically ensures that the cooling will be most effective where most heat is radiated. To avoid heat pockets in an A/C system, careful planning of the air flow for heat removal is required in relation to the equipment location.

Lower energy consumption

It has been calculated that, for the same cooling effect, the LM Ericsson system offers energy savings of between 10 and 20% compared to a conventional system,

a



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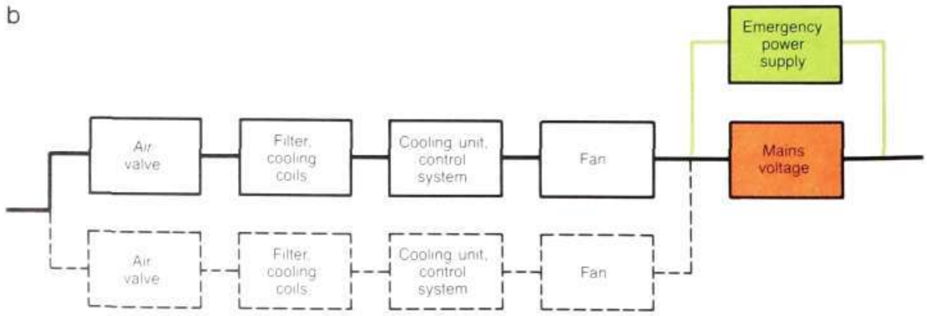

Fig. 11
Conventional cooling system.
a. Functional block diagram
b. Reliability block diagram. The dashed blocks show the duplicated system
c. Table of the number of failures per year
Reliability calculations show a failure frequency as in the table. The number of failures only refers to system failures in the cooling system of such a duration that there is a risk of operational disturbances in the exchange equipment

Warm air current
Cold air current

Table c
Number of failures per year

	Reliable mains voltage		Unreliable mains voltage	
	with emergency power	without emergency power	with emergency power	without emergency power
Single system	1,2	1,7	1,4	16
Duplicated system	0,006	0,24	0,08	15

depending on how the latter is designed. The system variant for temperate climates offer a corresponding saving of about 80%.

Lower maintenance costs
A system which blows air into a building, with stringent requirements imposed on dust content, must contain a large number of filters which often have to be cleaned or exchanged. The LM Ericsson system has only one small filter in the fresh air unit. Maintenance is limited to periodic functional checks.

Fire does not spread along a water pipe system
If a fire occurs, it can easily spread along air ducts unless special precautions are taken such as automatic closure of some air routes.

Cooling systems of the future

The trend in telecommunications technology is towards a reduction in size of electronic telephone exchanges. However, the power requirement will not be reduced to the same extent. Thermal density will increase further and with it a demand for effective and reliable cooling systems.

The use of water as a coolant will probably increase in pace with the increased power concentration in the switching equipment. In the future, direct cooling of the magazines for the printed board assemblies may be necessary to remove the dissipated power.

Summary

The system which LM Ericsson has developed for cooling electronic telephone exchanges meets stringent requirements imposed on reliability and creates a good working environment for the telephone equipment and the staff on the premises. Outstanding features for the system are:
- the ability to store coolant and retain the cooling function even during a mains failure
- cooling of the electronic equipment by self convection, that is without the use of fans
- the modular construction which permits simple extension of the system when the switching equipment has to be extended
- low power consumption due to the relatively high heat absorption capacity of water, which gives improved system efficiency compared with conventional systems
- the system has considerable flexibility and so can be used in numerous different applications, such as heat recycling.

Higher-Order Digital Multiplexors

Hans-Henrik Hamacher and Stig Karlsson

LM Ericsson has previously introduced second and third-order digital multiplexors, for 4×2 Mbit/s to 8 Mbit/s and 4×8 Mbit/s to 34 Mbit/s respectively. Now the fourth-order multiplexors, for 4×34 Mbit/s to 140 Mbit/s, and multiplexors that work directly between the 2 and 34 Mbit/s interfaces, i.e. for 16×2 Mbit/s to 34 Mbit/s, are being introduced. The general multiplexing principles have already been described in connection with the presentation of the first two types of equipment[1]. In this article the description is limited to the features that distinguish the two new multiplexors.

UDC 621.395.43

Digital telephone exchanges and digital transmission links are being used in the telephone network to an ever increasing extent. At first this meant that digital islands were formed in the analog network. Within these islands first-order PCM systems for 30 telephone channels constituted the predominant transmission system. The transmission medium consisted of pair cables, and the speed was 2 Mbit/s. This transmission capacity was not sufficient for large routes, and higher-order PCM systems were developed, 8 Mbit/s for 120 telephone channels, 34 Mbit/s for 480 channels and 140 Mbit/s for 1920 channels. These systems use different transmission media, such as special pair cables, radio relay links, coaxial cables or optical fibres. There was also a need for higher-order digital long-distance systems that could connect together the digital islands, partly in order to be able to utilize the digital facilities to the full.

The exact transmission speeds, which are usually abbreviated to 2, 8, 34 and 140 Mbit/s, are actually 2048, 8448, 34368 and 139264 kbit/s.

Fig. 1 shows the positions of the different multiplexors in the system hierachy. The second and third-order multiplexors, ZAK 30/120 and ZAK 120/480, have previously been described, together with the general principles of digital multiplexing[1]. The equipments now being introduced are the fourth-order multiplexor, ZAK 480/1920, fig. 2, and the 2/34 Mbit/s multiplexor, ZAK 30/480, fig. 3.

All multiplexors meet the applicable requirements of CCITT Recommendations G.703, G.742 and G.751. They can work in an asynchronous environment if the bit rates of the tributaries are within the recommended limits. Justification is carried out by means of buffering of a small number of bits from each tributary, and also by positive pulse justification. The direct multiplexing between 2 Mbit/s and 34 Mbit/s that is carried out in ZAK 30/480 has no exact equivalent in the CCITT recommendations, but both interfaces are in accordance with Recommendation G.703. Moreover, the frame length and frame alignment word are chosen in accordance with G.751, which means that in most cases normal test instruments can be used for installation and fault clearing.

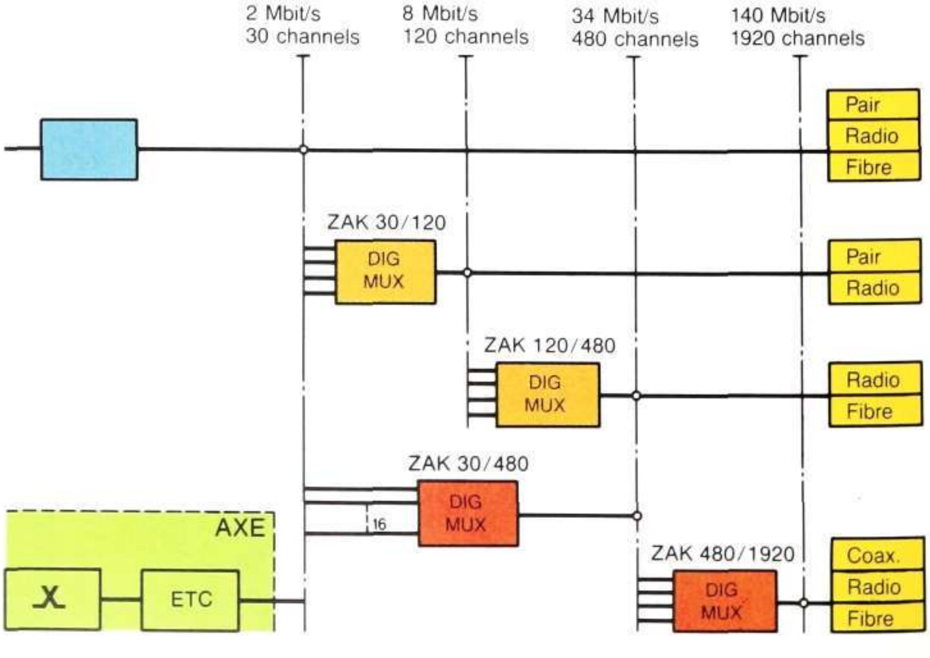

Fig. 1
Higher-order multiplexors in the digital network

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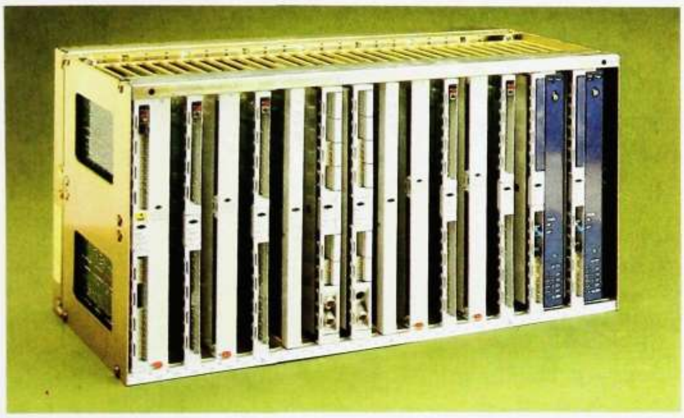


Fig. 2
ZAK 480/1920. The wide ventilation slots between the printed board assemblies give good cooling

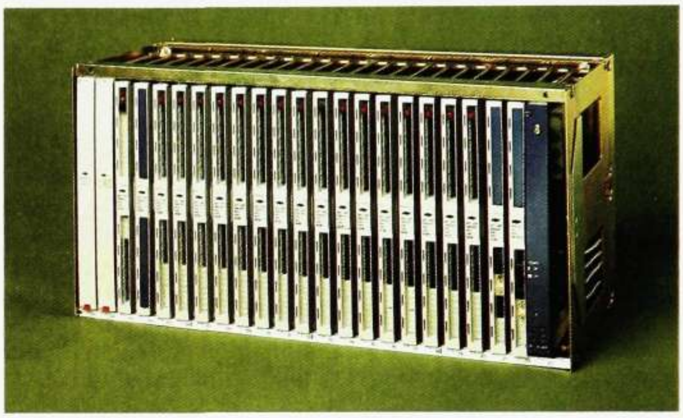
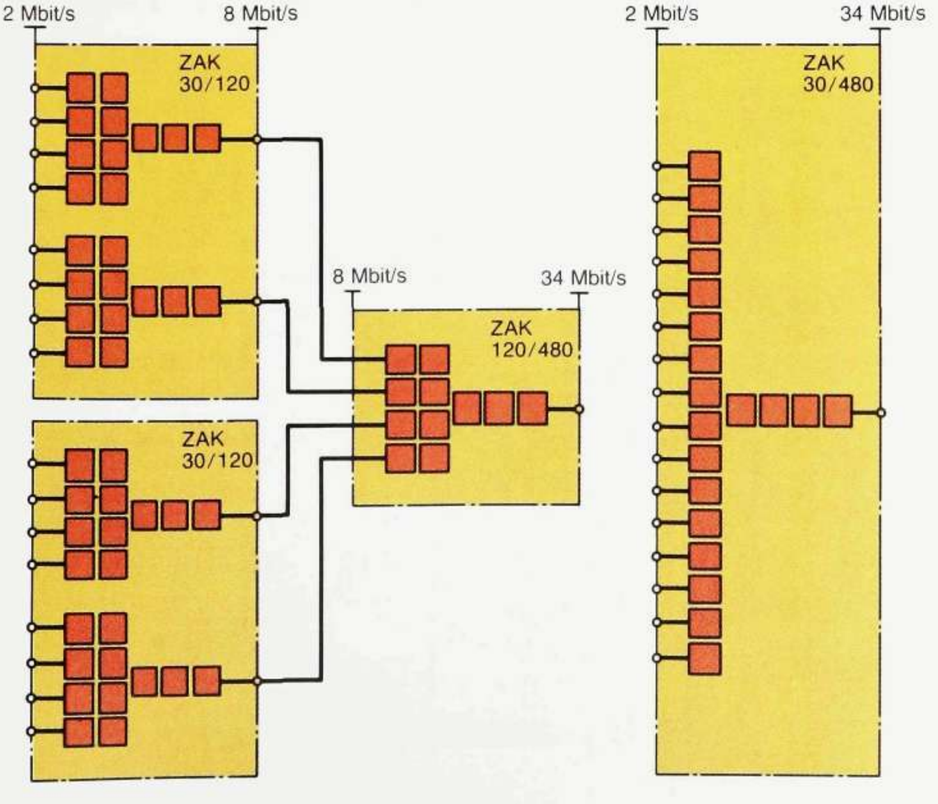


Fig. 3
ZAK 30/480 fully equipped for 16 tributary bit flows of 2 Mbit/s

Fig. 4
A comparison of the amount of equipment needed for direct multiplexing from 2 to 34 Mbit/s using ZAK 30/480 (to the right), and multiplexing in two stages using ZAK 30/120 and ZAK 120/480 (to the left). Each small square represents a printed board assembly (unit) and each block with a broken outline represents a magazine (shelf)



Construction and alarms

The new multiplexors ZAK 30/480 and ZAK 480/1920 are each mounted in a BYB magazine with a width of 12 building modules (488 mm). They can be installed in M5/BYB bays[2], BYB row construction practice[3] or BYB cabinets.

It has been possible to use normal wire-wrapping methods for connections and standard structures for magazines and printed board assemblies even for the highest transmission speeds. This means that the new multiplexors are as easy to handle as other BYB equipment. All external connections are made on the fronts of the magazines, by means of plug-in cables. Each multiplexor is equipped with its own d.c./d.c. converter, which works with any battery voltage between −30 and −72 V without restrapping.

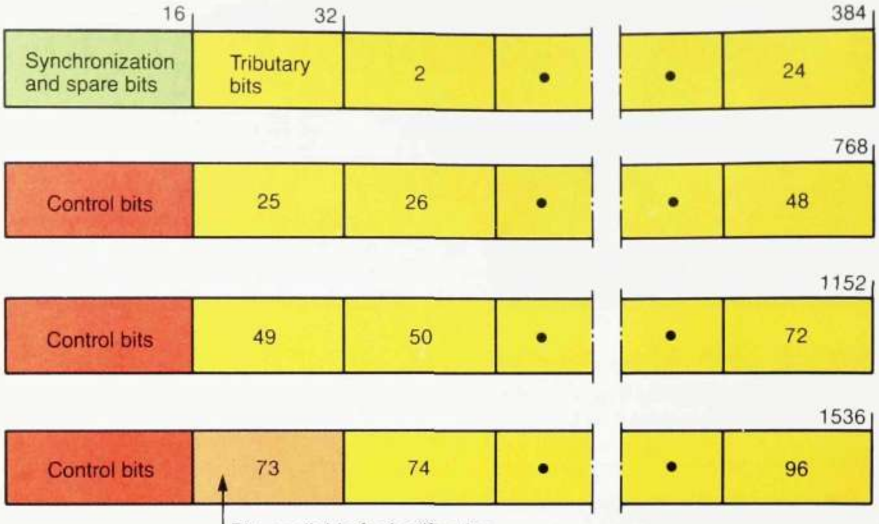
All alarms are in accordance with CCITT recommendations. The principles for the transmission and concentration of alarms are the same as for other BYB transmission equipment[4]. This means that the system can be connected to automatic supervision equipment, for example ZAN 01.

ZAK 30/480

The comparison in fig. 4 shows that direct multiplexing between the 2 Mbit/s and 34 Mbit/s interfaces, with no facilities for through-connection at the 8 Mbit/s level, reduces the required amount of equipment from two and a half shelves to one magazine, and the number of units or printed board assemblies from 55 to 20. This reduction certainly justifies the use of the ZAK 30/480 variant from the points of view of space, power and economy.

Fig. 6
The frame structure for ZAK 30/480

Frame alignment word	1111010000
Alarm to the far end	bit 11
For national use	bit 12
Spare bits	bits 13–16
Frame length	1536 bits
Maximum justification rate per tributary	22 375 bit/s



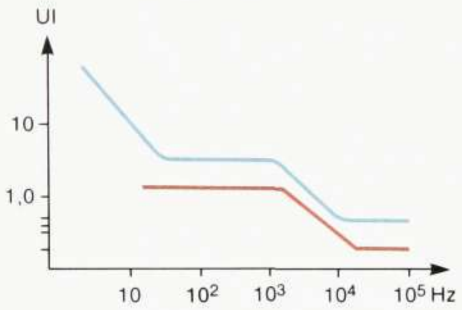


Fig. 7
The limit for acceptable jitter as a function of frequency. The CCITT requirement (red curve) is added for comparison purposes

Fig. 5
Block diagram of ZAK 30/480. The printed board assemblies are outlined in broken lines

In ZAK 30/480 a total of 16 tributary bit flows at 2 Mbit/s, each corresponding to 30 telephone channels, are multiplexed to form a joint 34 Mbit/s bit flow, corresponding to 480 telephone channels. Fig. 5 shows a block diagram of the equipment.

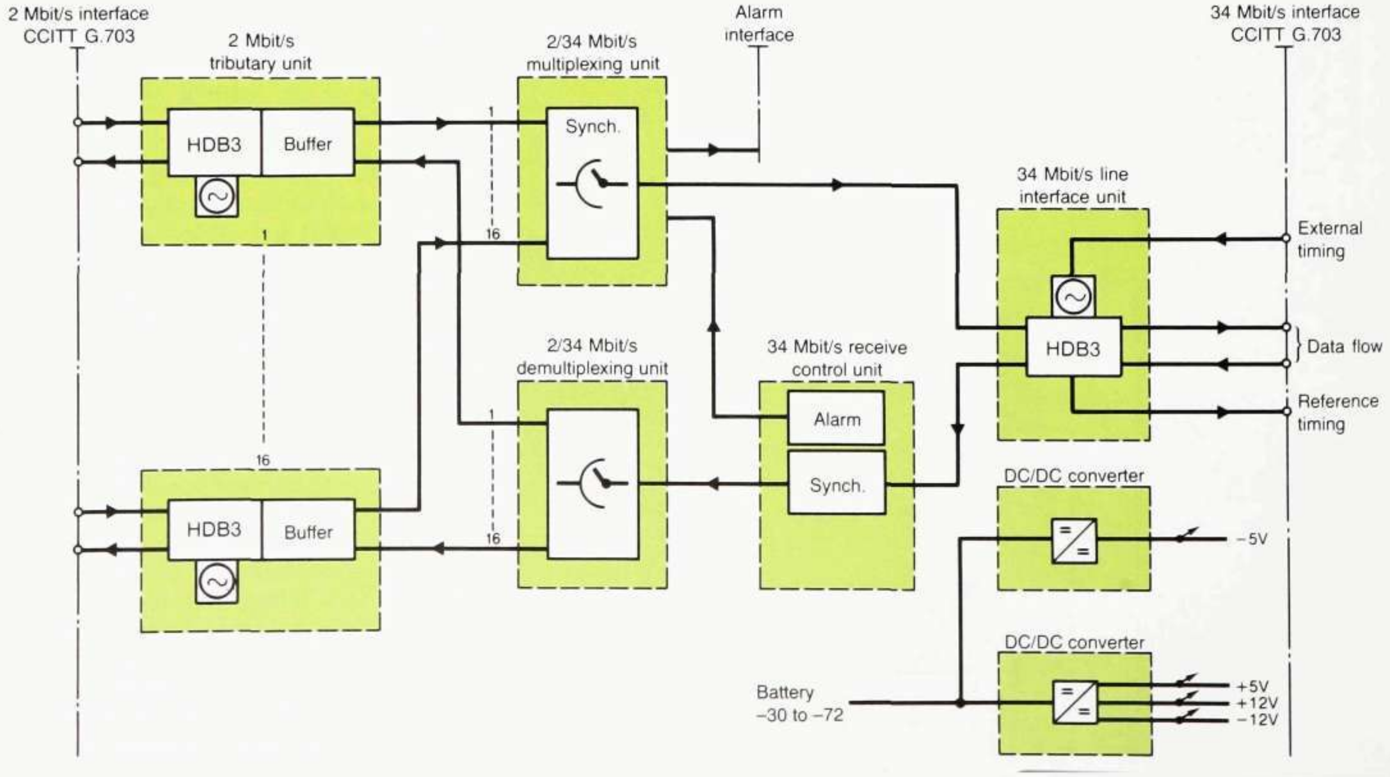
The frame structure has been chosen so that a high pulse insertion capacity is obtained, fig. 6. This makes it possible to keep the buffers for the tributaries small and the equipment can be made very compact. At *the same time the signals have less jitter* than they would if two second and third-order standard multiplexors were used, connected in tandem. The limit for acceptable jitter in the tributaries is therefore higher than the limit recommended by CCITT, fig. 7. This means that connections can be built up with an unlimited number of through-connections for 2 Mbit/s.

TTL technology is used throughout, with low-power Shottky circuits for the tributary units and with Shottky circuits for the high-speed units. The 34 Mbit/s interface unit which has previously been developed for ZAK 120/480 is also used in both ZAK 30/480 and ZAK 480/1920.

ZAK 480/1920

The digital multiplexor ZAK 480/1920 combines four 34 Mbit/s tributaries to one 140 Mbit/s bit flow. Its function is illustrated in the block diagram in fig. 8.

The incoming tributary signals are received in the interface units. The signal elements are converted from the HDB3 line code to binary code and are stored in the buffer stores. These stores are then read out one after another by the common logic circuits, at a slightly higher speed than that required by the transmission capacity. Breaks in the reading are made under control of the pulse justification logic and thus the buffer stores are never emptied. In the common circuits check bits are added for frame alignment, alarm and pulse justification,



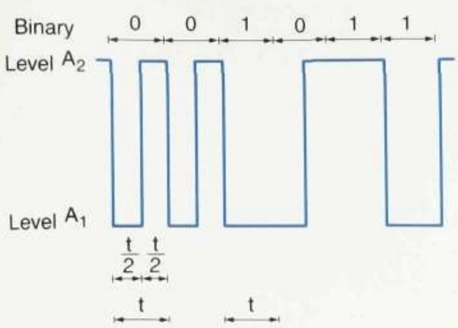


Fig. 9
The CMI code for 140 Mbit/s transmission recommended by CCITT

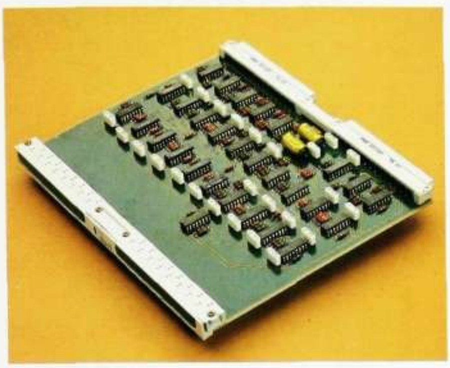


Fig. 10
A control unit for ZAK 480/1920 equipped with ECL components. Multi-layer printed boards have been used in order to obtain impedance-matched connections between the components

and the resultant signal is fed to the CMI unit, where code conversion and level adaption to the line code is carried out. The CMI encoding for 140 Mbit/s transmission recommended by CCITT is illustrated in fig. 9.

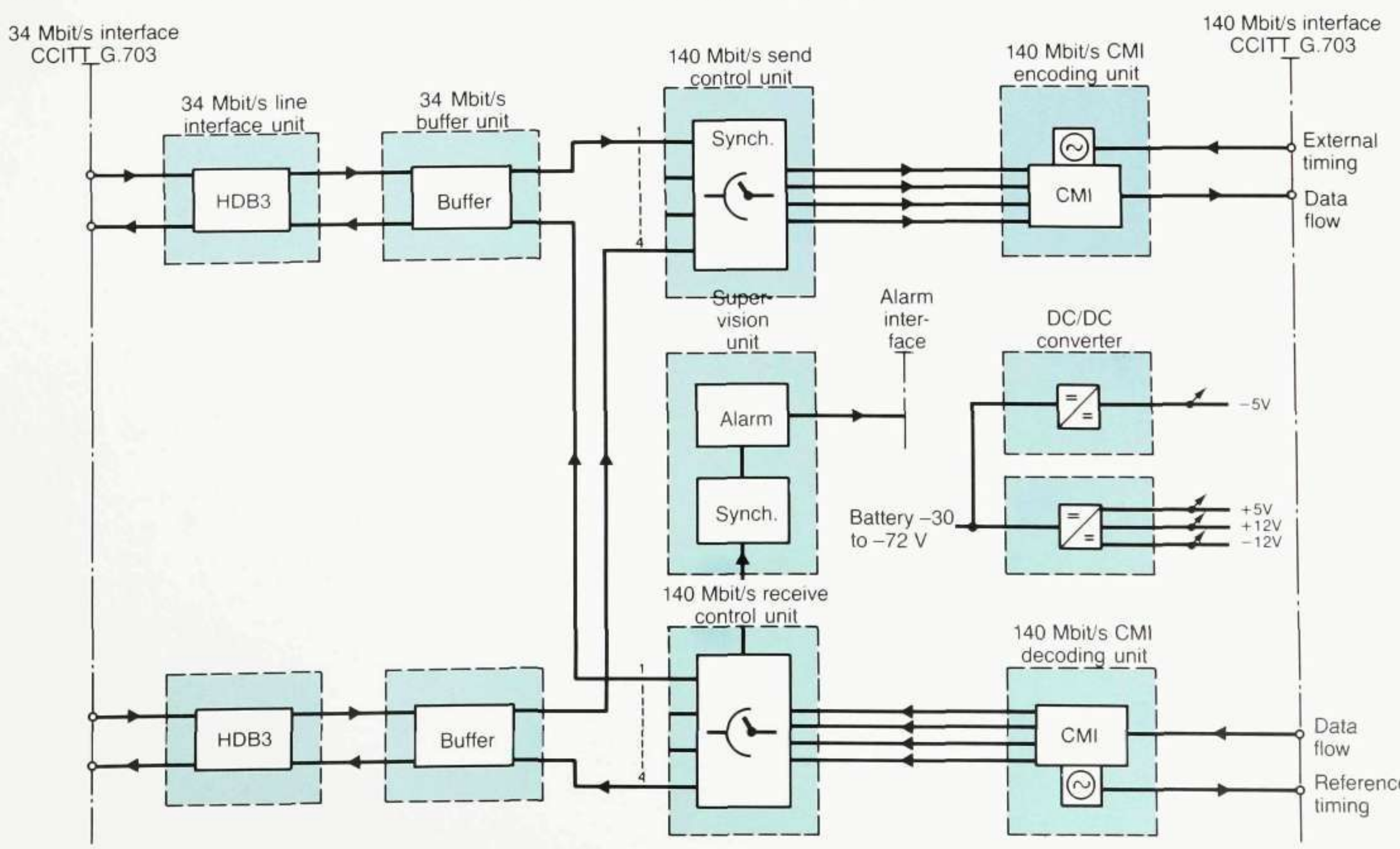
The receiver works in a corresponding way. The incoming signal elements are converted from the line code to binary code, after which frame alignment and analysis of alarm and pulse justification information is carried out. The inserted extra bits are removed and the reconstructed interleaved signal is divided up and stored in the buffer stores for the different tributaries. The read-out rate from these stores is slowly regulated so that they always contain the same amount. This regulation method means that the high-frequency jitter is minimized in the signal that is passed on. The conversion to line code for each tributary takes place in the 34 Mbit/s interface units.

Emitter-coupled logic circuits, ECL, are used in order to obtain sufficint reliability for the high bit rates. The ECL circuits are fast and have excellent transmission characteristics at high speeds. However, one problem is that they require high power. The power density and chip temperature can be reduced by reducing the number of gates and flip-flops on each chip, but this means an undesirable increase in the number of chips. A detailed study of possible structures gave a solution that is optimized from the point ov view of reliability. Fig. 10 shows a printed board assembly equipped mainly with ECL circuits.

The highest transmission speed within the magazine is 34 Mbit/s for the tributaries. The corresponding connections between the printed board assemblies consist of balanced wire pairs.

The control information is processed in TTL circuits, which contain low-power Shottky elements. These circuits have a high function capacity and low power requirement per chip, but they cannot operate at speeds above 10 Mbit/s. The time difference that occurs is bridged by delaying the tributaries in a number of buffer flip-flops, so that decisions from the slower decision circuits can catch up. In this way the best features of the two circuit families have been combined and the number of power-demanding ECL circuits has been limited.

Fig. 8
Block diagram for ZAK 480/1920. The printed board assemblies are outlined in broken lines



Technical data

		ZAK 30/480	ZAK 480/1920
Nominal bit rate	kbit/s	34 368	139 264
Limits	$\times 10^{-6}$	±20	±15
Bit rate for tributaries	kbit/s	2 048	34 368
Number of tributaries max.		16	4
Multiplexing method		Cyclic bit interleaving with positive pulse justification	
Frame structure		See fig. 6	CCITT G.751
Frame alignment loss and recovery		CCITT G.751	
Jitter		G.703, G.742, G.751	
Electrical interfaces		CCITT G.703	
Signalling channel	bit	12	14
	type	E&M	E&M
	bits		15 and 16
	type		TTL
External timing	kHz	8 592	34 816
Level	dBu	0	ECL
Limits	dB	+1, −3	
Alarm		CCITT G.751 supplemented for bit error supervision ($>10^{-3}$)	
Power supply from battery	W	90	120
Battery voltage	V	−30 to −72	
Mains rectifier	Hz	45 to 65	
(optionally)	V AC	110, 127 or 220	
Limits	%	+10 to −10	
Magazine dimensions Height × width × depth	mm	244 × 488 × 220	
Weight approx.	kg	14	13

Summary

The introduction of ZAK 480/1920 completes the range of higher-order digital multiplexors up to 140 Mbit/s. ZAK 30/480 is a valuable addition in those cases where multiplexing direct from 2 to 34 Mbit/s is possible. Fig. 11 shows an example of a M5/BYB bay fully equipped for digital multiplexing of 64 2 Mbit/s tributaries to one 140 Mbit/s flow, using the two multiplexors described here.

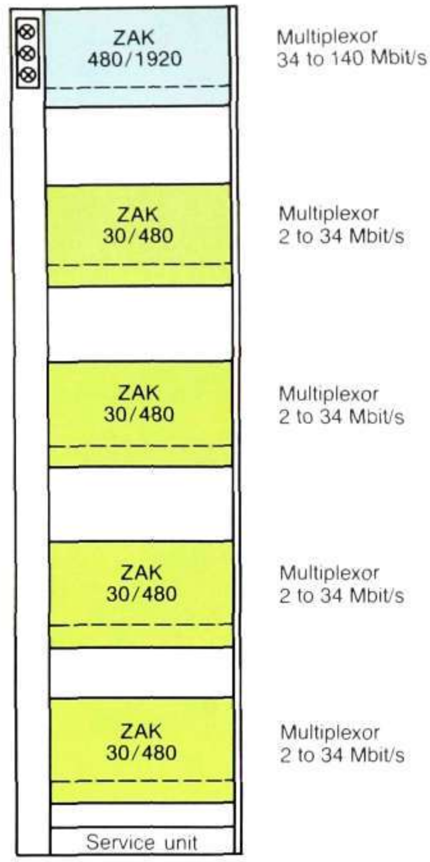


Fig. 11
Bay equipped with four multiplexors ZAK 30/480 and one ZAK 480/1920 for the multiplexing of 64 tributaries at 2 Mbit/s to form one 140 Mbit/s bit flow

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