ERICSSON REVIEW

2 1985

ERICSSON REVIEW

Number 2 · 1985 · Volume 62

Responsible publisher *Gösta Lindberg*
Editor *Gösta Neovius*
Editorial staff *Martti Viitaniemi*
Address S-126 25 Stockholm, Sweden
Subscription one year $ 16
Published in Swedish, English, French and Spanish with four issues per year

Contents

Cover
MINI-LINK installed on the water tower at Kalmar, South-East Sweden. The bridge in the background leads to the island of Öland.
Photo: Urban Gustafsson, The Swedish Telecommunications Administration's Radio Division

MINI-LINK in the Swedish Network

Johnny Norremark, Bernt Skyttermark and Roland Wallgren

Since 1980 the Swedish Telecommunications Administration has used Ericsson's digital radio MINI-LINK 10 for the transmission of 30 telephone channels (2 Mbit/s) over distances of up to 20–25 km. Since 1983 MINI-LINK 15 has also been used for the transmission or 30 or 120 telephone channels (2 and 8 Mbit/s respectively) over distances of up to approximately 30 km.

The authors describe the background, fields of application, installation methods and costs of MINI-LINK. They also describe operational and maintenance experience and discuss the possibilities MINI-LINK offers in strategic planning.

UDC 621.396.6.004
microwave links
installation
maintenance engineering

At present more than 200 microwave radio terminals are installed in Sweden each year. The majority consist of radio equipment with electronics combined into one mast-mounted unit and antenna. This simplifies and reduces the cost of installation work and also leads to less stringent requirements being imposed on masts.

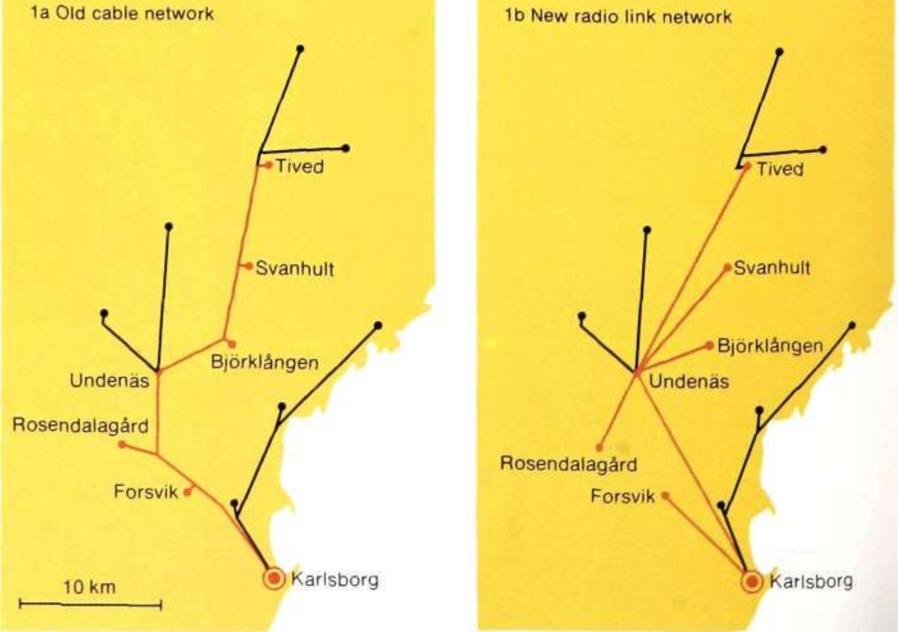
Unlike conventional microwave links this new type is not used in the long-distance network but as an alternative to cables in the junction network, where distances and number of circuits are such that economy is obtained after only a few kilometres.

Ericsson Radio Systems manufactures such radio link systems, designated MINI-LINK 10, MINI-LINK 13, MINI-LINK 15[1] and MINI-LINK 18. They operate in the frequency bands 10.5, 13, 15 and 18 GHz respectively. Two of the types, MINI-LINK 10 and MINI-LINK 15, are used by the Swedish Telecommunications Administration, which now has a total of over 600 terminals in operation.

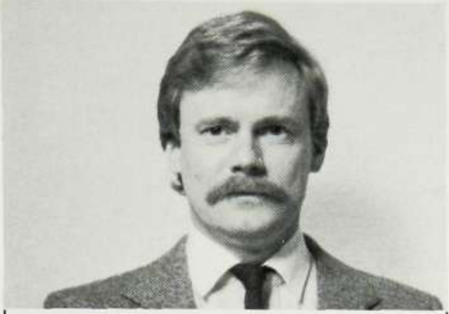
The Swedish Telecommunications Administration first investigated MINI-LINK in 1979, when MINI-LINK 10 was tested and evaluated. A number of systems were purchased and installed in southern Sweden, the Karlsborg area, where the junction cable was deteriorating and thunderstorms caused major problems.

This early project includes some fundamental important features: choice of masts, branching problems and choice of (1 + 1) or (1 + 0) system, i.e. with or without standby. The cable to be replaced, see fig. 1a, was approximately 30 km long with branches approximately every 5 km. Routes with branches are usually not ideal projects for microwave links. Each branching requires an intermediate repeater station with three radio relay link terminals, two in the direction of the route and a third for the branch. As a result a large number of radio relay terminals may be required and the project becomes unprofitable.

The Karlsborg project shows how this problem can be overcome. Since the distances to all telephone exchanges were relatively short, a common point



Figs. 1a and b
Changing the network structure from tree- to star-shaped made it profitable to use MINI-LINK



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was sought that had a line of sight to all exchanges. (All microwave links require a line of sight between the transmitter and the receiver.) With a 60 m mast on a hill approximately 1 km from the Undenäs primary centre all exchanges except Tived could be reached in a single hop. It was therefore possible to reduce the number of radio terminals from the original 22 to 14. Fig. 1b shows the final system configuration.

The following conclusions can be drawn:

- It is economical to replace an old cable network which contains branching points (tree-shaped network) with a star-shaped radio link network if a point can be found from which most exchanges can be reached in a single hop.
- In order to minimize the total cost of masts, a high mast should be used at the common point, so that lower masts can be used at the other exchanges.
- 2 Mbit/s radio relay links (and also 8 Mbit/s links) are usually built as (1 + 0) systems, i.e. without standby. This is in conformity with the normal practice for cable systems, which in most cases do not have standby paths for routes of this size.

When the number of circuits required is between 30 and 60, such as between Karlsborg and Undenäs, one 8 Mbit/s or two 2 Mbit/s systems can be installed. The two alternatives are equal as regards costs. From the point of view of security, however, the second alternative is preferable, since it means that a breakdown in a link will only affect half the circuits. With the circuits from an exchange divided between two links, a failure of one link will not result in a total operational breakdown at the exchange, only greater congestion. It could be said that this alternative provides a free standby path.

This also applies to the interval 120–240 circuits, where the cost of one 34 Mbit/s radio link is of the same order of magnitude as the cost of two 8 Mbit/s links.

The Karlsborg system, which was put into operation in 1981, was soon followed by several others. Conversion of the telephone exchanges to digital operation has led to a rapid growth in the demand for digital transmission, but the quality of existing cables is often too low for PCM transmission. In such cases MINI-LINK provides an alternative to the installation of new cables.

The growth of digital operation and the fact that network planners receive training in radio relay link technology has meant that MINI-LINK is being used to an increasing extent. Another contributory

Fig. 2
MINI-LINK 15

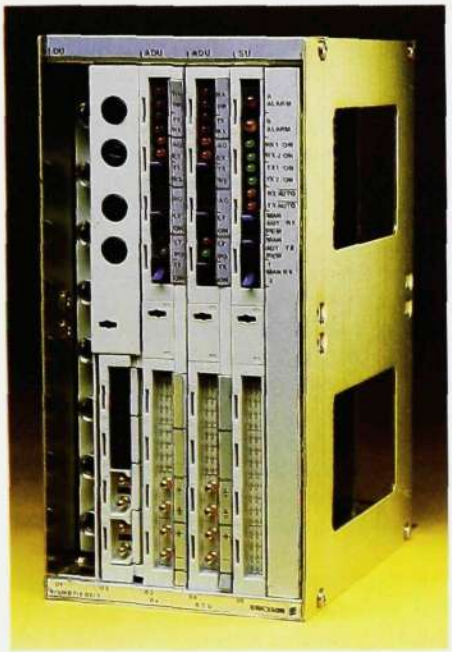

Fig. 3
Radio Terminating Unit (RTU)

factor is to be found in the organization of the Swedish Telecommunications Administration. All radio activities have been assembled in one division with six regional radio offices, each constituting a financial unit. This has vitalized the organization, with a large flow of information going from the radio offices out to the telephone regions. Furthermore some rapid installations have demonstrated the possibilities offered by microwave radios. The telephone regions have seen the advantages of these new links and have started to use them more extensively.

MINI-LINK

The basic idea behind MINI-LINK is to obtain a low overall project cost by minimizing the cost of equipment, installation and maintenance. New technology, such as directly modulated transmitters and miniaturized components, has reduced the cost of the radio terminal. The combining of electronics and antenna has simplified installation, fig. 2. There is no need for a separate building to house the electronic equipment, a large mast with a strong foundation, pressurized waveguides or large separate antennas. Installation of MINI-LINK normally takes only a few days, whereas installation of the conventional type of equipment could take weeks.

MINI-LINK can be used separately or together with a Radio Terminating Unit, which is installed in the telephone exchange. This makes it possible to supervise alarms and control signals to and from the link at ground level, fig. 3.

Other auxiliary equipment for MINI-LINK includes a radom to protect the parabolic antenna from snow, a multi-cable for connecting MINI-LINK to multiplexer or Radio Terminating Unit, an installation kit for installing the equipment in masts or buildings, overvoltage protectors and adapters for connecting a larger antenna.

Applications in existing networks

The most common use of MINI-LINK is as an alternative to cable for circuits between two telephone exchanges in the

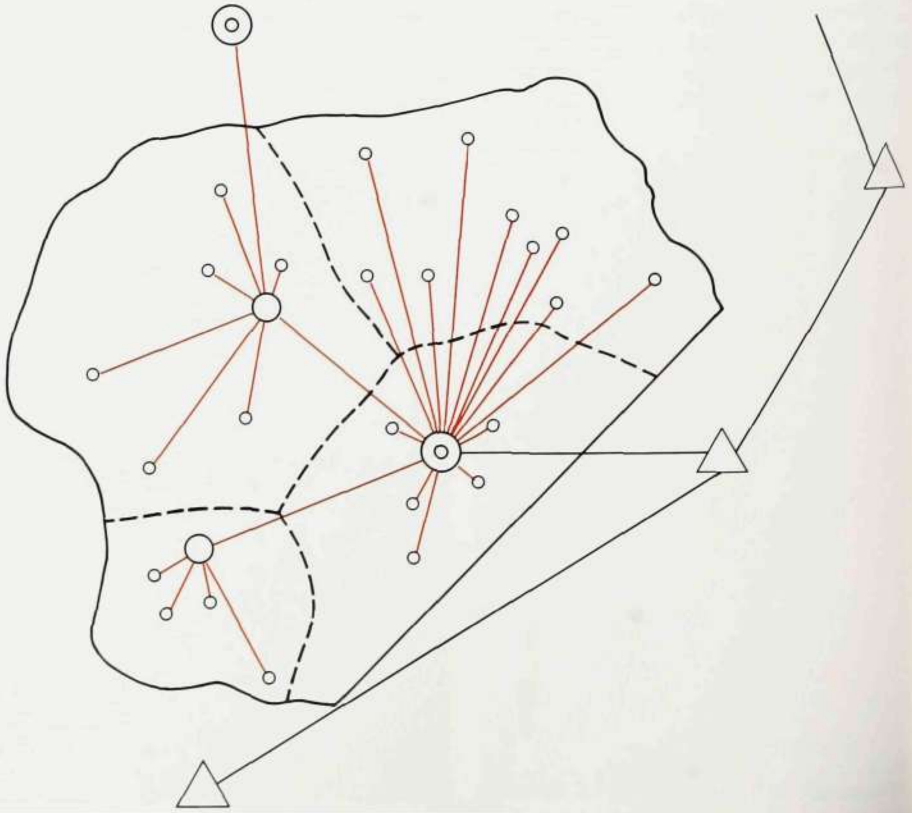

Fig. 4
MINI-LINK used in the junction network. The red lines indicate the routes where the transmission distance and capacity are suitable for MINI-LINK

◎ Zone centre

○ Group centre

∘ Terminal centre

△ Secondary centre

junction network, fig. 4. Other applications are for communication with islands, fig. 5, communication between AXE 10 and the base radio station for mobile telephone traffic, communication between remote subscriber stages and AXE 10 or digital PABXs, data circuits, branches from large link routes and temporary circuits for events, trade fairs etc. MINI-LINK is now being used in the junction network, where conventional radio relay links would never have been economical:

- for new circuits
- for extensions
- to replace old or damaged cable
- to take the traffic load when a cable is converted to PCM
- as a standby path between exchanges
- in cases of staff or equipment shortage during PCM conversion of cables.

Some of these applications are described in greater detail below.

Connection between two exchanges
A large number of the MINI-LINK systems now in service in the Swedish telecommunications network are used for circuits in the conventional analog network. The most common use is for expansion, or to replace old cable between a zone centre and a group centre, or between a group centre and a terminal exchange.

Since such circuits are pure point-to-point circuits with analog connection at the speech channel level at both ends, either analog or digital transmission (FDM or PCM) can be used for the multiplexed signal. As the costs of a digital and analog radio link are equal, while an analog multiplexer is considerably more expensive than a digital, digital transmission has been chosen in every case even though the surrounding network has been analog. Another advantage of digital radio links is that when the ex-

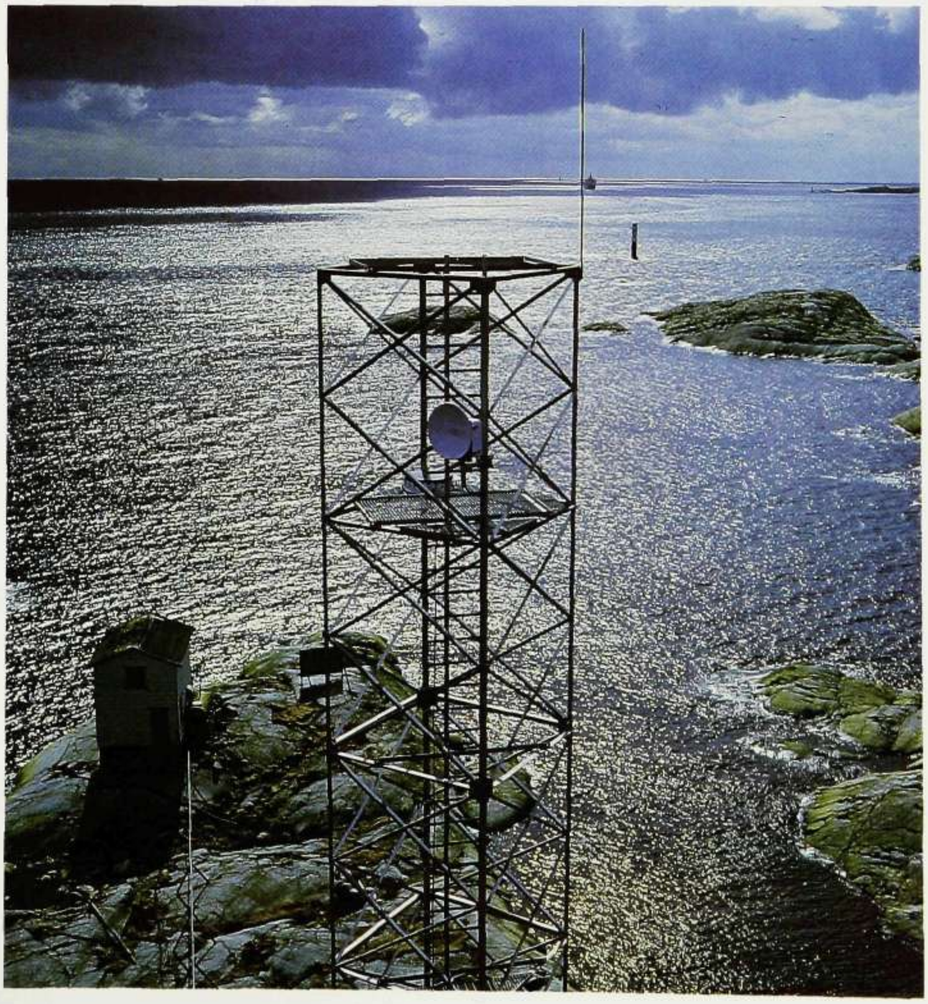

Fig. 5
Telecommunications for islands

changes are eventually converted to digital operation there will be no need to change the radio equipment. Digital MINI-LINK can thus also be used in the integrated services digital network (ISDN) of the future.

Most MINI-LINK installations in the junction network are comparatively uncomplicated: MINI-LINK is mounted outdoors on a mast or building, and the multiplexing equipment is installed in the exchange. However, the equipment is flexible and can be adapted to suit the individual requirements of each project. The use of MINI-LINK in more complex projects is illustrated here by a description of an installation that includes a long transmission distance, long connection cables and radio equipment installed indoors, fig. 6.

The system includes a 30 km route between the Kalmar AXE 10 exchange and the Borgholm exchange on the large island of Öland off the Kalmar coast. Because of the comparatively long transmission distance a MINI-LINK system with two 1.2 metre antennas is used. The radio equipment works without standby (1 + 0) and in spite of the fact that a large part of the route is across water there have been no variations in the input signal due to water reflections.

The terminal site at Kalmar is an old water tower, which today is the terminating point for a number of different radio routes. The strategic position of the water tower meant that it was envisaged as a future junction for several microwave routes, and that was why the Administration invested in a connection cable with larger capacity than was necessary at the time. As a result it has later been possible to connect a total of five systems via this cable at a very low cost.

In order to reduce the amount of maintenance required, no batteries are installed at the terminal site. Instead the radio link equipment is powered from the exchange power supply via the connection cable.

A Radio Terminating Unit (RTU) has been installed in the AXE 10 exchange in order to simplify service, maintenance and fault tracing. For the same reason the radio equipment has been installed indoors and connected to the antenna via a short waveguide.

At the other terminal, Borgholm, the equipment is similar with the exception of the connection cable. There the distance between the exchange and the terminal site is about 700 m, and a line system has therefore been installed,

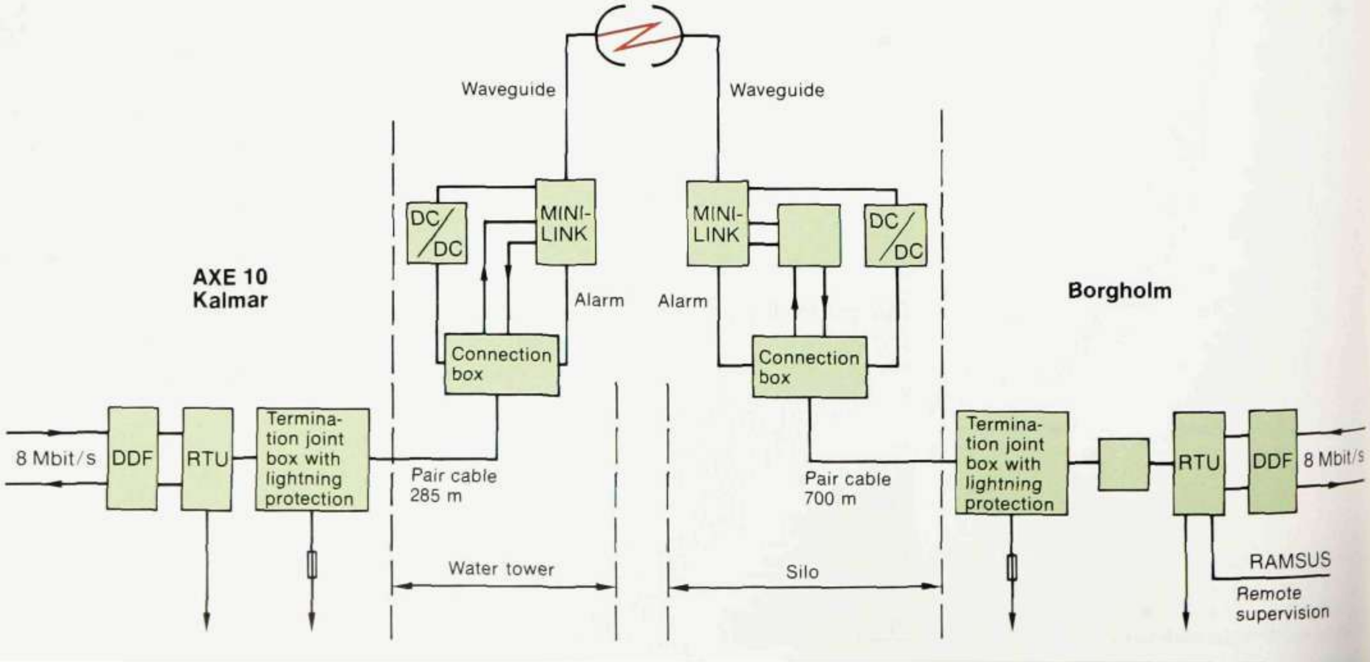

Fig. 6
The 8 Mbit/s PCM route Kalmar-Borgholm. The MINI-LINK equipment is installed indoors with terminal repeaters in the connection cables to one of the radio terminals, in order to compensate for the long cable distance between the multiplexer and the radio unit

consisting of two 8 Mbit/s line terminating equipments (LTE). This gives a maximum line attenuation of 45 dB, corresponding to approximately 1 200 m of 0.7 mm junction cable with plastic insulation (CHEME).

The Kalmar installation demonstrates the economy of strategic planning. As has already been mentioned, five terminals have by now been installed in the water tower. If the cost of each installation had been calculated as each project was carried out, most of them would have proved to be uneconimical. By anticipating future requirements it was instead possible to divide the initial cost between several projects, which has made all the projects profitable. The Telecommunication Area has thereby not only satisfied the traffic requirements at the lowest possible cost but also prepared the ground for a future quick conversion to digital operation, at a low cost.

Connection between a digital PABX and a remote extension stage

The demand for this type of connection has increased rapidly, and quick delivery is an important requirement. No customer in the private market is prepared to invest in a new PABX if the delivery time is long due to shortage of digital transmission lines. Unfortunately the installation of PCM on cable between a PABX and a remote extension stage is often time-consuming, since there are usually no direct circuits available. The nearest cable route normally goes via one or more exchanges, which makes it longer than if it could be run straight across country. Another problem with this type of connection is that the demand for it is more or less unpredictable and therefore cannot be incorporated in the normal digitalization plans.

The possibility of quickly establishing digital circuits via MINI-LINK has therefore proved to be useful. The provision of circuits between a central hospital and surrounding smaller units is an example of this type of application.

Connections between a PABX and remote extension stages are also common between social insurance offices, branch offices of banks and insurance companies, and different units in large industrial enterprises.

Connection between a telephone exchange and base radio stations

A relatively large amount of labour is required to connect base radio stations for mobile telephony into the telecommunication network when cable connections are used, since, for radio coverage reasons, such stations are normally located at high and inaccessible places. Another factor that further complicates the connection of the base radio station is the changing network configuration resulting from the introduction of small cell systems. In such cases radio relay links are superior thanks to the short installation time and their great flexibility.

Applications in future networks

The applications mentioned above represent the majority of the MINI-LINK installations now in operation. However, even wider use is envisaged in the digital network now under construction.

Connections between an AXE 10 parent exchange and remote subscriber stages

Remote subscriber stages (RSS) will be introduced in the Swedish telecommunications network in 1986. Their size can vary from 28 up to 2 048 subscribers, which means that the requirement for connections between the AXE 10 parent exchange and an RSS varies between 1 and 16 PCM systems. The economical limit for using MINI-LINK between an RSS and an AXE 10, fig. 7, is a maximum

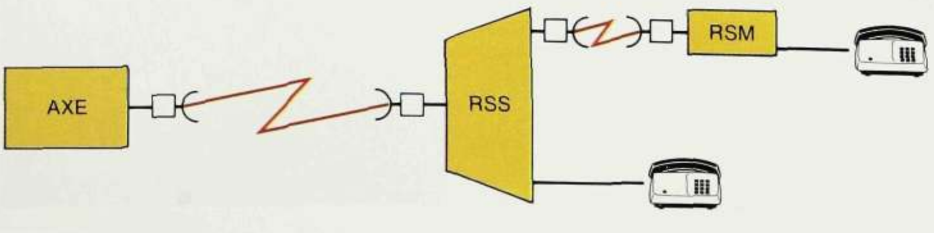

Fig. 7
Radio links can be installed between AXE 10 and remote subscriber stages when there is no cable route available, or in parallel with existing cable in order to increase security

Fig. 8
Installation kit for MINI-LINK

of eight PCM systems, corresponding to between 1 000 and 2 000 numbers in RSS. Such an RSS can be connected to the AXE 10 parent exchange via two parallel MINI-LINK systems (8 Mbit/s PCM systems), an arrangement which strikes a good balance between economy and security. A fault in one MINI-LINK system results in a higher level of congestion, but subscriber traffic will still flow. Emergency calls are automatically switched over to the operating link. The size of RSSs used in sparsely populated areas will be 128 to 256 subscribers, connected to an AXE 10 parent exchange via one or two PCM systems. Remote subscriber multiplexers (RSM)[2] can then be connected to an RSS and used to replace the smallest rural exchanges.

RSSs are installed primarily in places where cables are accessible. However, the more stringent requirements imposed on cables when converting to PCM transmission mean that not all old cables can be used. MINI-LINK is expected to be used for those RSSs that cannot be placed near a cable route of satisfactory quality. Radio links can also be used together with cable in order to increase security. The requirements for operational reliability over circuits between an AXE 10 parent exchange and an RSS can be met by using cable transmission for some PCM systems and MINI-LINK for the rest. This provides greater security than two cables in the same route, which can be damaged simultaneously by, for example, excavation or lightning.

Fig. 9
A passive reflector used for a MINI-LINK

Connections to subscriber multiplexers

Extension of small rural exchanges, such as the Administration's Standard 41, will be carried out using PMA (PCM multiplexer for subscribers). This means that a multiplexer will be placed in the exchange and connected to the superior exchange via a digital line system. A 2 Mbit/s system is used for the route to the superior exchange, which means that MINI-LINK can be used when the quality of the cable is unsatisfactory for PCM. This method for extending an exchange is justifiable when the exchange has reached maximum capacity or when no equipment is available for extension (Standard 41 equipment is no longer in production).

When the superior exchange is eventually converted to digital operation, the PMA equipment can be converted into an RSM simply by changing a few printed board assemblies. MINI-LINK can then either be retained or be removed for use elsewhere, so the total cost of extending an exchange by means of PMA and MINI-LINK is moderate.

The difference between a PMA and an RSM is that the RSM can be connected direct to the superior exchange at the 2 Mbit/s level, i.e. without any digital/analog conversion. The multiplexer can be connected to the exchange either directly or via an RSS, fig. 7.

RSMs are expected to be widely used in the conversion of rural exchanges to digital operation. Small rural exchanges with up to 60 subscribers will normally be replaced by RSMs.

Installation

If possible, radio links should always be planned to terminate at the telephone exchange, so that the radio equipment can be installed in existing buildings. However, since a line of sight is required between the transmitter and the receiver, the terminal must sometimes be placed higher than the exchange roof. In such cases the radio link equipment is

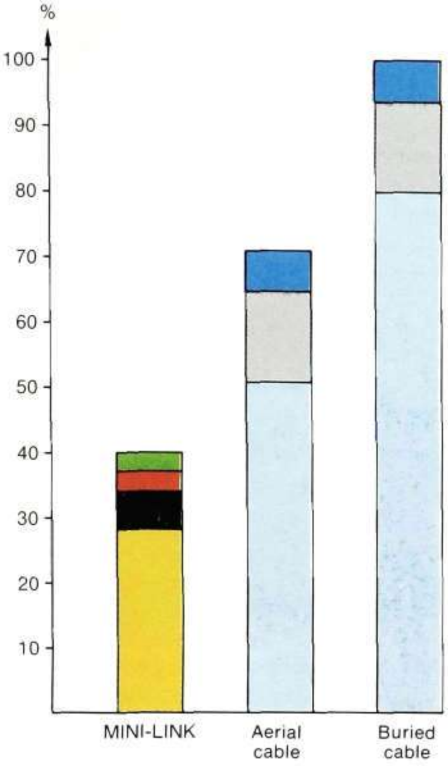

Fig. 10
Comparison of the cost of 4 x 2 Mbit/s PCM transmission over buried and aerial cable and over MINI-LINK, all over a distance of 22 km

🟩 **2/8 Mbit/s MUX**
🟥 **Connection cables**
⬛ **Mast**
🟨 **MINI-LINK**

🟦 **Line Terminal Equipment (LTE)**
⬜ **Regenerators**
▢ **Cable**

usually placed on an adjacent high building or a mast erected near the exchange.

Masts can be either guyed or self-supporting. The latter type is normally used in built-up areas, where there is no room for guy wires.

The low weight and wind load of MINI-LINK mean that simple masts can be used. However, at the project planning stage, possible future extension should be taken into account: i.e. whether more radio equipment will have to be mounted on the same mast at a later stage. Another factor to be considered is that large antennas and higher frequencies make greater demands on the stability of the mast.

A common type of mast for MINI-LINK is a 24 m high self-supporting mast with a prefabricated base. The cost of this type of mast forms a relatively modest part of the total project cost, fig. 10.

Since MINI-LINK is usually mounted on a mast or roof and must be connected to power, radio terminating and multiplexing equipment at ground level, a special cable has been designed for this purpose. It contains a number of wires for alarm and control functions, power leads and two coaxial cables, all in one sheath, which simplifies cable running. The power supply is 24 or 48 V for MINI-LINK 10 and 20–60 V for MINI-LINK 15. The PCM signal to and from the radio equipment is fed over the two coaxial cables, which can have a maximum length of approximately 500 m. If longer cables are necessary, a symmetrical cable pair with a terminal repeater must be used.

MINI-LINK 15 contains a 120 ohm balanced cable pair terminal, while connection of MINI-LINK 10 via a cable pair requires an extra transformer for conversion from 75 to 120 ohms. Connection via a cable pair has been made in several installations in the telecommunication network, as existing cables to masts or high buildings can then be used.

The radio equipment is installed using an installation kit. This kit makes it possible to mount MINI-LINK on a brace or leg in a lattice mast with a maximum tube diameter of 152 mm, fig. 8, or alternatively to mount the unit direct on a roof or wall.

When planning a radio link route it is not always possible to find exchange sites that give a clear line of sight between the antennas. A passive repeater can then be a solution. A passive repeater consists of either a flat reflector, which serves as a mirror for the radio waves, fig. 9, or of two parabolic antennas connected by a waveguide.

Project costs

When planning a new route there are usually a number of transmission alternatives from which to choose:
- aerial or buried cable pair
- PCM over aerial or buried cable
- cable in ducting
- radio relay link
- optical fibre.

However, optical fibre is usually not economical at the capacities concerned here, i.e. up to 120 telephone channels.

A general comparison of the costs of the different transmission alternatives is difficult to make because of the different prerequisites that apply to each individual project. However, in order to give an idea of the different orders of magnitude, the diagram of fig. 10 has been prepared, showing typical relative costs under certain given conditions. The following three alternatives are compared:
- PCM over buried junction cable with plastic insulation
- aerial junction cable installed on existig poles
- MINI-LINK 15.

In all three cases 120 telephone channels are transmitted using 4 x 2 Mbit/s over 22 km, terminating in a digital distribution frame, DDF. 10-cell housings, equipped with four generators, are used for the cable systems. No fault location equipment is included. The distance between repeaters is 2 km.

In the case of the radio equipment it has been assumed that one terminal is placed in a high building, in an existing mast or direct on the telephone exchange, whereas the other terminal requires installation of a 24 m self-supporting mast. This is of a simple construction without ladder, so the radio equipment is placed at ground level and connected to the antenna via a waveguide. Because of the long transmission distance, 22 km, the standard antenna at one terminal has been exchanged for a larger. The cost also includes two digital multiplexers for conversion to four 2 Mbit/s streams, i.e. the same as for the cable alternatives.

Under these conditions radio is the cheapest alternative, primarily because of the relatively long transmission distance. With shorter distances the cost difference decreases, to become zero somewhere between 5 and 10 km. At shorter distances than this the cable alternative is cheaper.

When comparing the cost of different transmission alternatives it should also be noted that the link goes straight across country, whereas the cable route often follows roads and thus becomes 1.3–1.4 times longer.

Technical operation and maintenance

Since, in many respects, a radio link is to be considered as an alternative to cable it is of interest to compare the reliability and repair times for PCM transmission via MINI-LINK and via cable.

Fig. 11
Two MINI-LINK antennas with radoms installed on the water tower at Kalmar. The antennas are connected to the radio equipment via short elliptical waveguides

Unfortunately no direct comparative studies of reliability have been made as yet, but for an approximate comparison it may be supposed that the fault rate is dependent on the number of components. The fault rate for cable systems varies with the length of the route (the number of regenerators), whereas the fault rate for MINI-LINK is independent of the route length up to approximately 30 km (one hop). For a route of approximately 10 km the number of components, and thus the fault rate, is approximately the same for MINI-LINK as for PCM over cable. For longer routes the cable systems will have a higher fault rate.

Other factors that also affect the reliability are the environment and the transmission medium. The environment is usually slightly better for radio systems than for cable systems, whose electronic equipment is often placed in buried containers. As a transmission medium a cable is more liable to faults than the medium used for radio links, i.e. the air.

Experience shows that MINI-LINK is reliable. The Administration's Southern Radio District has studied about 100 terminals. The study showed an MTBF of approximately ten years per terminal of MINI-LINK 10. Operational experience of MINI-LINK 15 is still limited, but the similarity of construction makes it likely that its reliability will be as good as that of MINI-LINK 10.

In addition to the reliability, which shows *how often* equipment is out of order (MTBF), the repair time, which shows *how long* the equipment is out of order (MTTR) is of interest. Breakdowns during normal working hours are usually repaired the same day. Special routines apply to breakdowns during other times, usually involving standby duty rosters.

Strategic planning of telecommunication networks and radio relay links

The world surrounding the Administration is becoming increasingly more complicated. One of the major causes is the technical development: most things can now be made faster, better and

Fig. 12
A temporary MINI-LINK installation using a telescopic mast

more efficiently. It is also possible to combine different technologies to a much greater extent.

The need for strategic planning as a preparatory measure against emergencies has become more pressing, and at the same time the possibilities of traditional long-term planning have been reduced because of the rapid pace of development and the multitude of possible combinations.

The number of MINI-LINK systems in the telecommunications network is now so large that this network component has also been included in the Administration's strategic planning. Radio links (RL) are not only an alternative to cables, but correctly used they can provide strategic advantages over cables, for example in the following types of application:

- Preparatory work in the basic network. It is possible to survey, plan and to a certain extent prepare for the installation of a number of interesting RL routes, so that the necessary equipment can quickly be erected when the need arises.
- RL equipment can be used in the parts of the basic network where the forecasts are most uncertain. If the prognosticated traffic falls off or does not materialize, the RL equipment can be dismantled and used elsewhere. On the other hand an RL route can quickly be installed in the case of unexpectedly rapid growth.
- RL means shorter installation time than cable, provided that the equipment is in stock. A prerequisite is that the required multiplexing and signalling equipment is also available, preferably in a mobile version.[3]
- RL can help to improve the strategic network configuration. With RL it is often possible to establish additional, short-distance digital inputs and outputs to the telecommunication area much more readily than would be possible with PCM over cable. An infra-network with RL can thereby relieve overloaded traffic routes.
- RL makes it possible to establish more suitable standby paths, since the circuits do not have to follow the existing cable network. RL can change the standby path strategy of the entire telecommunication area.
- RL provides good coverage, since a few, strategically situated stations in a telecommunication area can accept traffic from any direction when the need arises. The radio link antennas can be directed towards places of interest for business networks. A new link is then set up for each new direction, and the link station works as a concentrator.

Summary

MINI-LINK increases the flexibility of the telecommunication network and also its ability to withstand damage. It facilitates rapid growth in network capacity when the market suddenly requires new services or when the traffic grows faster than expected. In addition MINI-LINK offers greater possibilities of handling the traffic with a minimum of disturbance to the subscribers in the case of faults or emergencies.

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Reliability Testing and Demonstration of Radar PS-46/A

Göran Holmberg and Gösta Steen

The fighter version of the Swedish Air Force's aircraft Viggen, JA37, is equipped with a sophisticated pulse Doppler radar. This radar, designated PS-46/A, has been developed by Ericsson Radio Systems AB in Mölndal, Sweden. Among the many demands made on a modern fighter radar, high reliability is in the forefront. A reliability qualification test has therefore been carried out on a number of PS-46/A systems in service with Air Force units, in order to demonstrate the radar's reliability performance.

The authors describe the practical aspects of the testing, the tests results and the experience gained. They also describe the methods used at Ericsson during design, development and production to assure fulfilment of the contractual reliability requirements.

UDC 621.396.962.33.001.42
radar systems
reliability
testing
doppler effect

Ericsson has developed, manufactured and delivered airborne radar systems for three generations of aircraft for the Swedish Defence Establishment. During the 1950s radar units were supplied for the Lansen aircraft and in the 1960s approximately 500 radar systems for the Draken aircraft.

Then came aircraft 37, or Viggen, a multi-purpose aircraft which was planned at the end of the 1950s and which, with different types of equipment, was to be able to serve in several different roles. The attack version, AJ37, came first, quickly followed by the reconnaissance version, SH37, both equipped with radar systems developed and manufactured by Ericsson Radio Systems.

At the end of the 1960s the studies for the fighter version, JA37, started. The radar for JA37 was developed by Ericsson Radio Systems during the period 1970–1978. The development comprised three prototype generations for different stages of testing on the ground and in the air. The first series production system was delivered in the spring of 1978.

The radar for JA37 is designated PS-46/A. It is technically the most advanced radar system Ericsson Radio Systems has delivered hitherto. It is built up of almost 10 000 parts or components, with 3 200 microcircuits, 900 semiconductors, nearly 5 000 resistors and capacitors and a large number of waveguide components, hydraulic details and mechanical parts.

The usefulness of a modern fighter aircraft is greatly reduced if the radar should fail. Consequently, for strategic reasons and also to ensure low maintenance costs the radar must have high reliability and short repair time.

As military systems become more complex and technically advanced, specifications and contracts make more stringent demands on the reliability performance of the equipment.

Fig. 1
Radar PS-46/A installed in the nose cone of aircraft JA37

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In the specification for PS-46/A the MTBF (Mean Time Between Failures) is set to 100 hours for in-flight operation. In the series contract it is specified that, in order to demonstrate fulfilment of the reliability requirements, Ericsson Radio Systems must follow up and evaluate the results obtained from reliability predictions, fault records etc. and the results of a reliability qualification test.

Design and construction

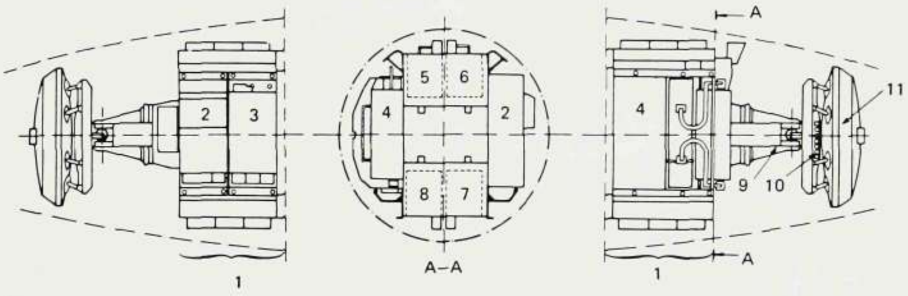
PS-46/A is a modern airborne pulse Doppler radar. A detailed description of the radar, its function and design has been published in a previous issue of Ericsson Review[1].

PS-46/A is secured in the nose of the aircraft by means of four bolts, fig. 2. The radar consists of ten replaceable units mounted in a rack, which in itself is a replaceable unit. The system also includes a power divider and two reference antennas placed elsewhere in the aircraft. All units are easy to replace in the field. Fig. 3 shows the designations and positions of the different units.

The electrical power, cooling air and hydraulic power for the radar are provided from the aircraft. Indirect cooling is used wherever possible. The two-axis antenna is operated by two hydraulic motors. The data and signal processors are digital with flat-pack circuits mounted on multi-layer printed circuit boards. This construction makes the units light and compact. The radar is equipped with a 50 kW transmitter with an air-cooled travelling wave tube. The total weight of PS-46/A is 298 kg.

Fig. 3
PS-46/A with the units mounted in their rack in the nose cone of the aircraft

1. Rack
2. Illuminator
3. Exciter
4. Power amplifier
5. Radar signal processor
6. Receiver
7. Power unit
8. Radar data processor
9. Pedestal unit
10. Microwave unit
11. Reflector



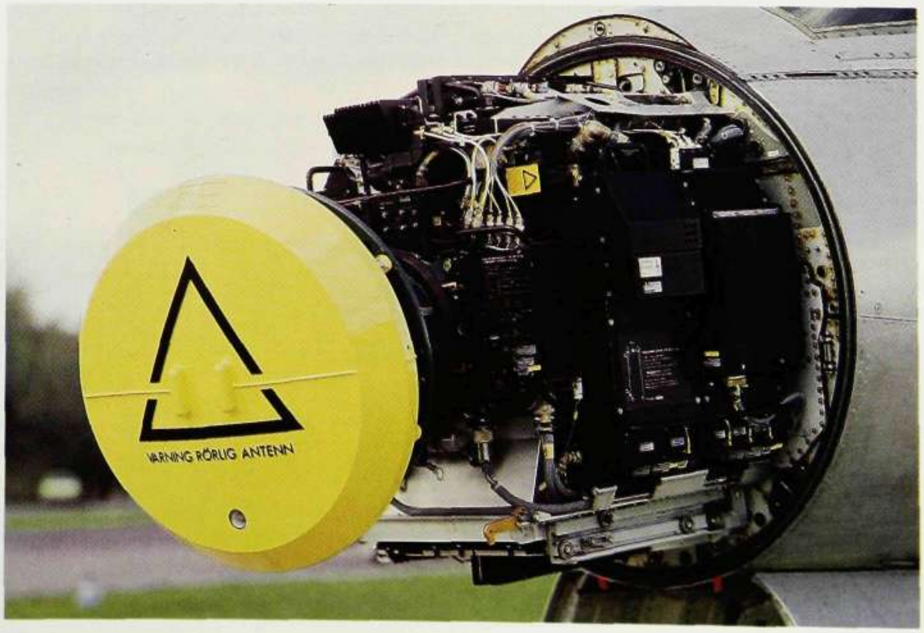


Fig. 2
Detail from fig. 1

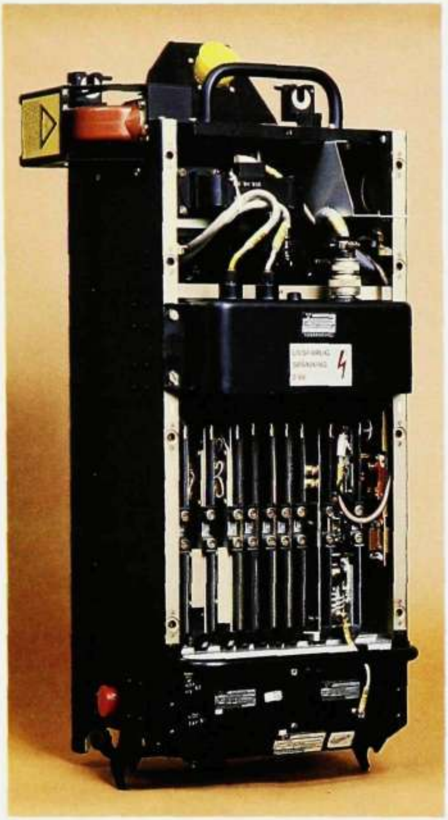
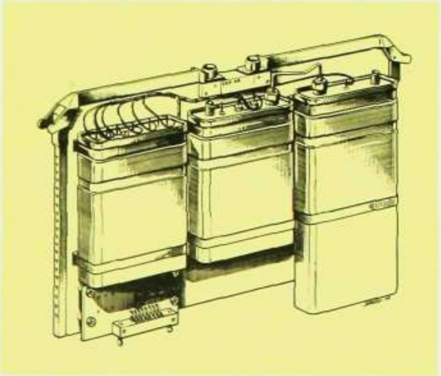
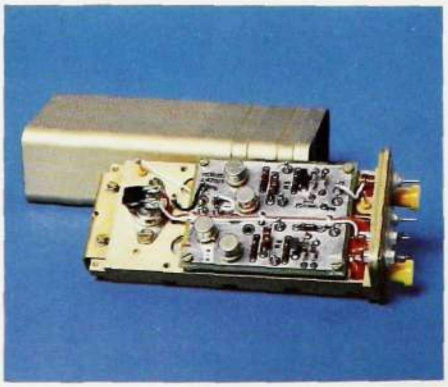


Fig. 4a
The illuminator with the cover removed. The klystron is placed at the top, with the high-voltage parts and electronic circuits on printed boards below

Fig. 4b
A module for microwave technology circuits. The microwave circuits are mounted in hermetically sealed cans mounted on a heat exchanger





Equipment intended for modern military aircraft is subject to rigorous demands as regards weight, volume and performane, and of course reliability performance. Fault localization and repair must be simple. As a result the design and construction requirements are very stringent, not least because of the tough environment.

Figs. 4a and b illustrate the robust design of the units and the easy maintenance.

A built-in supervision system, which does not affect the operation of the radar system, keeps the pilot informed continuously about the condition of the system. If a fault occurs, alarms are given via the head-down display or indicator lamps. Repair usually entails replacement of a unit. A built-in test system with automatic failure localization greatly facilitates maintenance in the field.

Reliability and maintainability activities at Ericsson Radio Systems

In order to be able to meet the high demands of both military and civil customers, Ericsson Radio Systems at Mölndal, Sweden, has gradually built up expertise in the field of reliability and maintainability. A system for failure data collection and failure analysis was introduced as early as the end of the 1950s, when the company moved to Mölndal. This system has been improved and further developed over the years and now covers type development, receiving inspection, manufacture and testing as well as the period after delivery.

Special efforts are made to collect data on delivered equipment and then to feed back the experience thus gained into new designs. This prevents faults from being repeated and utilizes the positive experience gained.

The results from failure data collection and analysis are also used to predict failure rate and MTBF for products being developed.

Computer-based models and systems are used for prediction and analysis of reliability performance, maintenance resources etc.

Individual reliability and maintainability programs are prepared for large projects. Such programs are adapted to and integrated with the other project activities and are controlled by a reliability and maintainability engineer specially appointed for each project.

Reliability and maintainability program for PS-46/A

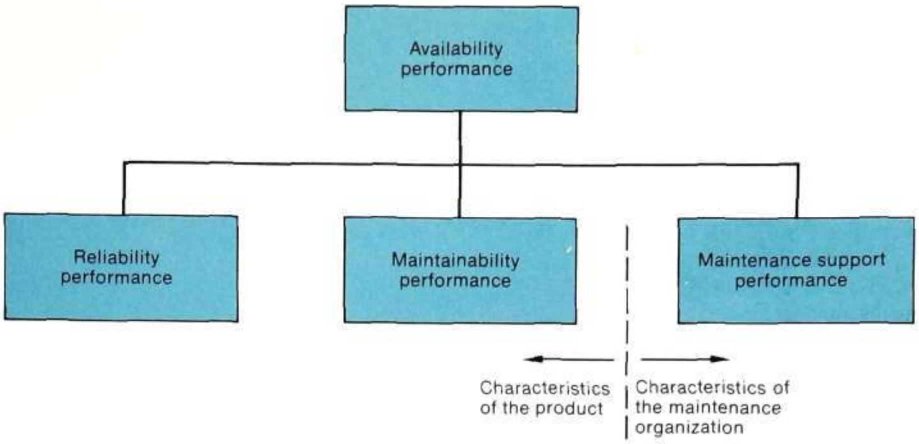
When the development of PS-46/A was started, guidelines were also laid down for the reliability and maintainability activities.

A special reliability and maintainability program was planned and carried out within the framework of the project in order to ensure that the specified MTBF would be met. The program comprised such activities as studies of similar projects, predictions and analyses, follow-up and evaluation of the results of development of prototypes, and at a later stage follow-up of series production and delivered equipment. Special measures were taken to increase the reliability of PS-46/A when the program results indicated that this was necessary.

Designs, constructions, component quality etc. have been chosen bearing in mind the reliability requirements. The manufacturing methods have also been adapted to suit these requirements. For example, before delivery each series produced equipment undergoes a burning-in test with the whole system in operation.

The specified MTBF, which is 100 hours for in-flight operation, refers to the con-

Fig. 5
Reliability and the associated concepts. Reliability is often given as the mean time between failures, MTBF, and is thus defined as the ability of a unit to carry out specified tasks without any failures that reduce its performance



stant failure rate period. Experience shows that for a flight radar of the type referred to, this period starts about 3 years after initial delivery and after a few hundred hours of operation for each individual radar system. These periods are approximate and can vary considerably from one type of equipment to another.

During the product development work the reliability was determined regularly by means of predictions and analyses.

Early predictions indicated that it would be difficult to meet the specified MTBF with the set prerequisites. Analyses showed that an economically suitable way of increasing the MTBF to the required level would be to raise the quality level originally chosen for microcircuits and certain semiconductors. The raising was decided on and introduced in the series.

Predictions made during later development stages indicated that there was a high probability that the specified reliability would be met. The latest prediction, made in 1979, gave an MTBF of 161 hours.

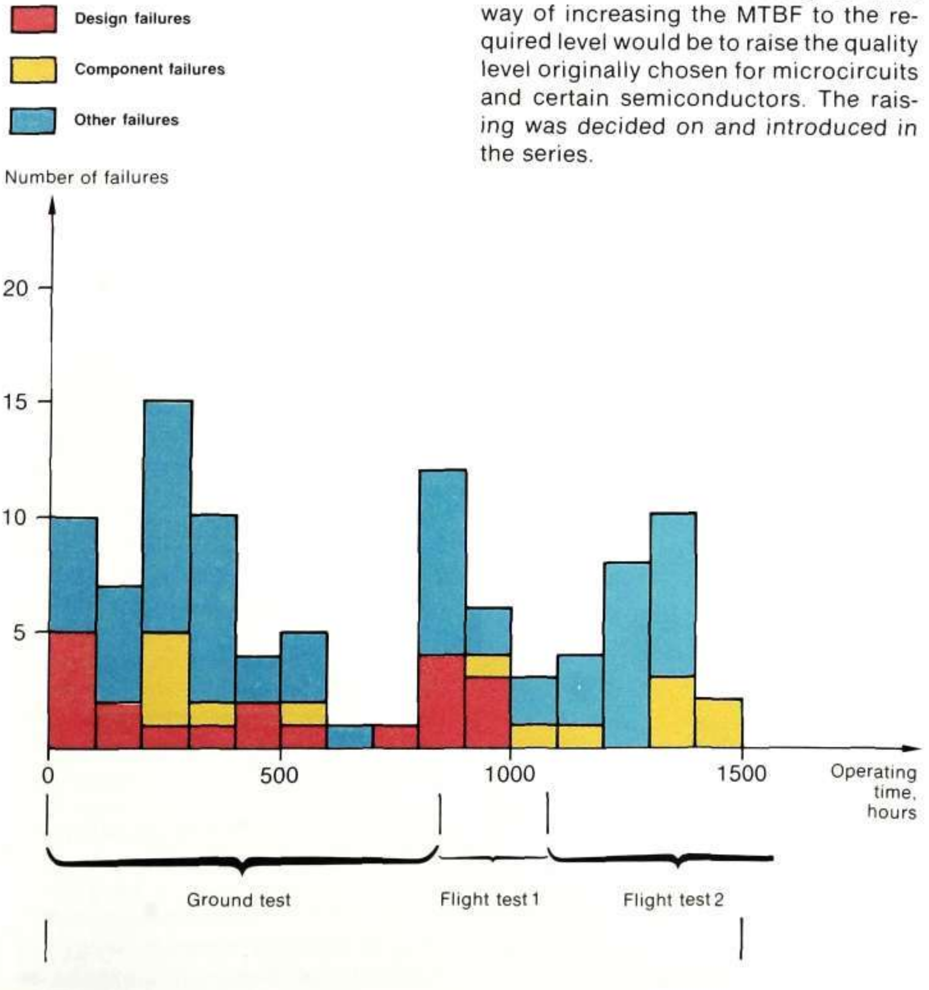
A series of prototypes were developed as a part of the development program. The first ones were used to test the function of the radar and its interworking with other systems in the aircraft. The later prototypes were more like series production units as regards construction, component choice and manufacturing methods, and they were useful for testing such features as reliability performance. The results of the tests were followed up and evaluated from many aspects, including the reporting and analysing of every failure and deviation detected.

Fig. 6 shows the failure spectrum for one of the later prototypes, and the figure shows how the design failures decrease with time.

Regular meetings have been held with, among others, the project manager, quality engineer, reliability engineer, senior design engineer and senior production engineer, where all failure reports from system tests, including burn-in, have been reviewed in order to ensure that adequate actions have been taken to prevent repetition of detected failures and weaknesses. Further analyses and measures have sometimes been decided upon, and the participants in the meetings have seen to it that decisions have been carried out with the effect intended.

Summaries of the failure reports from different stages indicated that the probability of reaching the specified MTBF was high. One prerequisite for this was of course that the work of correcting detected failures and weaknesses continued. Fig. 7 shows the situation for all delivered radar systems two years after

Fig. 6
Failure spectrum for one of the later prototypes. In this case the study has concentrated on the distribution of design and component failures with time. Note the decreasing trend in the overall failure picture, and the increase as the flight testing of the prototype started



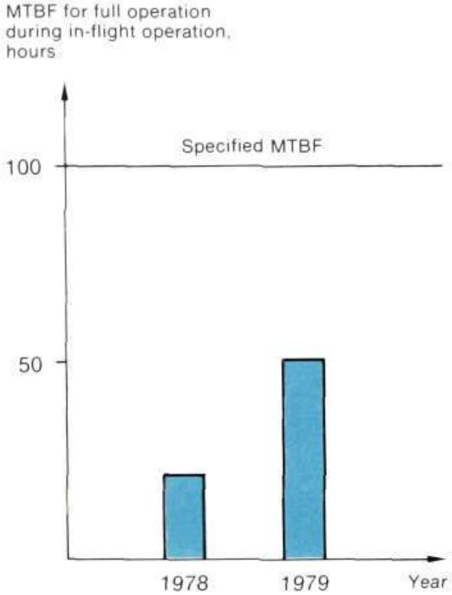


Fig. 7
The figure shows the measured MTBF at test start for all radar systems delivered during 1978 and 1979

the first delivery. It should be noted that the figure includes all early failures for each unit. If this fact is taken into consideration the development is more or less as expected.

Purpose and scope of the reliability qualification test

In accordance with the contract and at the request of the Defence Materiel Administration a reliability qualification test for PS-46/A was carried out. The test took place in connection with special priority flights at Norrköping by four JA37s. The purpose of these flights was to accumulate the maximum possible flight time over a limited period during the early part of the series and thereby facilitate early detection of wear-out and design weaknesses in the aircraft and its parts.

The purpose of the reliability qualification test was to measure the MTBF for four radar systems during normal operation, and on the basis of the results to assess whether or not PS-46/A met the specified requirements.

Participation in the special flights made it possible to carry out the measurements under controlled conditions and to obtain reliable results at a reasonable cost.

Five radar systems were used in the test: four installed in the four aircraft and the fifth used as a spare set for maintenance purposes.

The qualification test started on August 1, 1980. Originally the test was intended to finish in August 1982. A flight stoppage in 1981 extended the test time to September 10, 1983.

A preliminary test was carried out during a forced service test at SAAB, Linköping.

Test procedure

The qualification test was carried out in close collaboration between Ericsson Radio Systems at Möndal, the Materiel Administration of the Swedish Armed Forces (FMV), the Maintenance Department of the Swedish National Industries Corporation (FFV:U) and the Bråvalla Air Wing at Norrköping (F13).

F13 was responsible for the flights, the operational use and normal maintenance. FFV:U assisted in, for example, failure localization and analysis at operational level. Ericsson Radio Systems participated at operational level and also carried out failure analysis and repair of faulty units.

Follow-up meetings were held regularly with participants from Ericsson Radio Systems, FMV, FFV:U and F13. At these meetings practical matters concerning the test process were discussed, as well as events that had occurred, measures that had been taken and the various types of problems that had arisen. Failure classification was also carried out.

The qualification test was based on a test specification, which was prepared by Ericsson Radio Systems and accepted by FMV before the test started. The specification included rules and routines for the test, decision criteria, areas of responsibility, and rules for failure classification.

During the test period the radar systems were mounted in the four JA37s used for the priority flights. The operation and maintenance routines that applied to other equipment were also used for PS-46/A.

When a failure was detected and localized to a radar unit, this unit was immediately replaced. The replacements consisted primarily of units from the special replacement set. Units that had not been selected for the test were used only in special cases. The faulty units were sent to Ericsson Radio Systems for failure analysis and repair. The repair was always carried out down to such a level that the failure could be analyzed and classified with a satisfactory degree of certainty. Particular importance has been attached to the recording of any observations that could be useful in subsequent failure analysis and classification.

A maximum repair time of 20 working days was aimed at by Ericsson Radio Systems in order not to have to use spare units that had not been chosen for the test. The repairs were normally made within the set time.

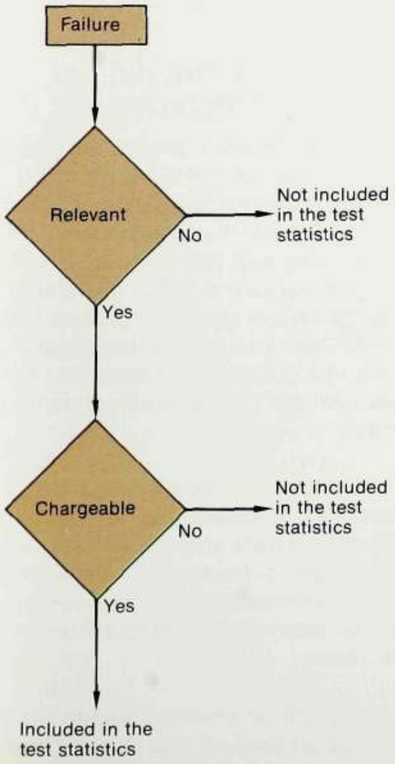
Fig. 8
Maintenance of the radar at Air Wing F13.
Photo: Rune Rydh

Fig. 9
Rules for failure classification

Verified failures are considered relevant unless caused by
- **accidents**
- **faulty handling**
- **environmental limits etc. being exceeded.**

Unverified failures and intermittent failures are also regarded as relevant.

Chargeable failures are: design, production and component failures and software errors that have not been cleared.
Secondary failures and failures caused by component life being exceeded or preventive maintenance not being carried out are non-chargeable failures.



All units used in the test, including those in the spare set, were marked with special labels for easy identification and to avoid mix-ups.

Before the start of the test, temperature indicators in the form of thermotape were placed at selected spots on the test objects. The indicators made it possible to check whether specified temperature limits had been exceeded and to record any occurrence of too high temperature within the units. The thermotapes were read off by Ericsson Radio Systems during checks and when faulty units were in for repair.

Tape recorders were used during the flights to record events that could affect the test results. The recordings were also used in the failure localization and analysis work. On certain occasions special recording apparatus, which registered all important signals in the radar during flight, was used to help locate failures.

Reporting and failure classification

Failures detected in the field were reported through the Air Force's normal system for failure data collection, DIDAS. Each failure was analyzed at Ericsson Radio Systems and then examined in order to determine its cause; for example design, manufacture, component or handling.

During the follow-up meetings the failures were classified as chargeable or non-chargeable to the test results. The fault classification was carried out in accordance with the rules given in the test specification, which in their turn are basically in accordance with the US standard MIL-STD-781C[2].

The failure classification comprised two stages. The failures were first classified as relevant or non-relevant. Non-relevant failures were, for example, those caused by external damage. The relevant failures were then divided into chargeable and non-chargeable failures.

The types of failures classified as chargeable were intermittent and unverified failures, and all design, manufacture and component failures. Software errors were also regarded as chargeable with the exception of those for which the necessary corrective measures were considered to have been taken, fig. 9.

Methods for calculating MTBF

The specified MTBF refers to the time the radar is in operation during flight.

Table 1
Accumulated operating and inoperative time during the test period. Aircraft no. 309 has a total of 683 flight hours. The corresponding times for aircraft nos. 310, 316 and 317 are 590, 687 and 585 hours respectively

Sub-period	Accumulated time, hours Real flight operating time	Ground time	Equivalent flight operating time
1	608	16 090	930
2	1 937	70 437	3 346
Total	2 545	86 527	4 276

Aircraft number	Sub-period 1		Sub-period 2		Whole test period	
	N	MTBF	N	MTBF	N	MTBF
309	5	70	2	388	7	161
310	1	351	3	208	4	244
316	0	–	6	168	6	192
317	0	–	7	135	7	147
Total	6	155	18	186	24	178

Table 2
The number of detected and verified chargeable failures, N, and the measured MTBF in hours for in-flight operation during the test period, broken down in terms of aircraft and periods

Unit	MTBF, operation during flight N	Measured	Predicted
Rack unit			2 538
Rack	–	–	–
Waveguide unit	2	2 138	–
Exciter	3	1 425	1 414
Power amplifier	7	611	703
Illuminator	2	2 138	1 681
Microwave unit	1	4 276	2 320
Pedestal unit	–	–	1 996
Reflector	–	–	55 556
Receiver	4	1 096	1 441
Radar signal processor	1	4 276	1 110
Radar data processor	3	1 425	2 410
Power unit	1	4 276	9 434
Power divider	–	–	200 000
Reference antenna	–	–	166 667
The whole PS-46/A	24	178	161

Table 3
The number of relevant and chargeable failures, N, and the measured and predicted MTBF for each type of replaceable unit in PS-46/A

Table 4
The failures classified as chargeable, divided up according to cause. There were no software errors among those considered as contributory. The reason for this was that the necessary measures to clear the failure were considered to have been taken for all software errors detected during the test. According to the failure classification rules, such failures should then not be considered as chargeable

Cause of failure	Number of failures
Design failures	2
Manufacturing failures	3
Component failures	12
Failures that could not be detected during checks by Ericsson Radio Systems	4
Failures of uncertain cause	3
Total	24

Failures also occur at other times, for example during test runs on the ground, when the aircraft is being transported on the ground with the radar switched off or when the aircraft is immobilised.

It is often difficult to determine the stage at which a failure has actually occurred. This problem was circumvented by including all failures that were detected during the test period and which were classified as chargeable in the statistics, and at the same time including the time the radar was on test runs or switched off during the test. The conversion to the equivalent flight operation time was made by adding 0.02 of the ground time to the actual flight operation time. The MTBF was calculated as follows:

$$\text{MTBF} = \frac{\text{Total equivalent flight operation time}}{\text{Total number of chargeable failures}}$$

MTBF was determined for the overall test time and also for the period before and after the flight stoppage, sub-periods 1 and 2. Sub-period 1 comprises the period August 1, 1980, to April 6, 1981, and sub-period 2 April 7, 1981, to September 10, 1983. The stoppage period has thus been included in sub-period 2.

Measured reliability

The total number of flight hours during the test period was 2545. The inoperative time and time for operation on the ground was 86 527 hours. The total equivalent flight operation time was 4 276 hours. Table 1 shows how the times are distributed between sub-periods 1 and 2.

During the test period 79 failure reports were received that concerned the test objects. Of these, 44 led to a unit being replaced. 24 failures were considered to be relevant and chargeable. Thus not all failure reports resulted in units being replaced. The reason for this is discussed later in the article.

The above-mentioned operating times and failure numbers give a measured MTBF for the whole test period of 178 hours. With a confidence interval of 90% the confidence limits are 126 and 259 hours, i.e. the probability that the real MTBF for flight is between 126 and 259 hours is very high.

Table 2 gives the measured MTBF for the different aircraft and periods.

Fig. 10 shows that the specified MTBF was reached during sub-period 1 and the predicted value during sub-period 2.

In table 3 the measured MTBF for operation during flight is given for the different units of PS-46/A. The MTBF value given in the specification is for a complete radar system. There are no similar values for sub-units. Nevertheless, in order to get an idea of the measured MTBF level for the individual units the predicted values are used as a reference. It should be noted that the predicted MTBF is 1.61 times higher than the specified MTBF. The table shows that most units meet the predicted values satisfactorily. However, the test time was rather short for a reliable assessment of the MTBF values for units. For example, a single failure in the power unit meant that the measured MTBF for this unit was only about half the predicted value.

All failures have been divided into categories according to their actual cause. Table 4 shows how the failures classified as chargeable are distributed between these categories.

Failure alarms that did not result in unit replacement

During the verification period the pilots reported 79 failures in the test objects. In 44 of these cases the failure was verified during a test on the ground, and the indicated unit was replaced. In the remaining 35 cases it was not possible to detect the failure during a ground test after the flight period. An investigation was carried out to try to establish the causes of the 35 unverified failure alarms.

The basic data for the investigation included tape recordings of each flight period, which were studied with respect to radar alarms. Information regarding function deterioration that did not give rise to an alarm was obtained from the pilots' notes.

The investigation showed that in most cases the unverified alarm had been

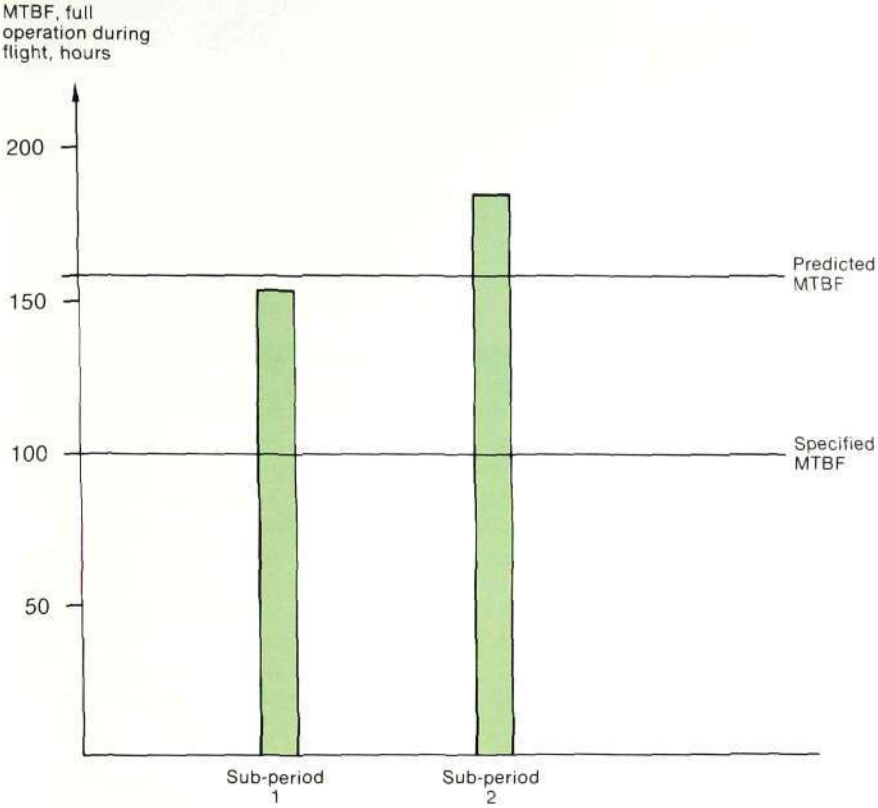


Fig. 10
The bar diagram shows the measured reliability for sub-periods 1 and 2. The specified and predicted MTBF values are shown for comparison purposes

caused by a faulty unit which had later been replaced because of that particular failure. It was therefore a case of "a fault building up", which at the early stages only caused sporadic alarms.

The fact that a unit that had been indicated as faulty was not replaced until the fault was fully developed simplified the failure classification work.

A small number of unverified complaints were caused by faults that were cleared by means of modifications made in the software for the radar data processor.

Only a few flights showed disturbances the cause of which could not be determined by the end of the test. However, there are reasons for assuming that these were also caused by developing faults.

Summary

The MTBF specified for radar PS-46/A is 100 hours for in-flight operation. The predicted MTBF is 161 hours.

The MTBF for operation during flight measured during the reliability qualification test was 178 hours. With a confidence inverval of 90% the real MTBF is between 126 and 259 hours.

The result obtained for the first part of the test period was 155 hours, and 186 hours for the second part.

The reliability qualification test shows that the specified MTBF is met with a high degree of probability.

The predicted MTBF was also reached during the test period.

The result must be considered wholly satisfactory and means that an accept decision has been reached.

FMV has declared itself very satisfied, not only with the good result but also with the positive and constructive atmosphere of the reliability qualification test. FMV has also pointed out that from the point of view of economy there are considerable advantages in carrying out a test of this type by following up the operation in the field rather than by carrying out supervised laboratory tests.

Finally Ericsson Radio System wishes to express its gratitude to all those who contributed to the excellent result, especially Jan Falk and Benny Olsson at F13, Sören Janeheden, Claes Wennerlund and Ingemar Selberg at FFV:U, and Lars-Erik Lindqvist, Gunnar Ericsson and Karl-Erik Klarby at FMV.

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MINI ELLIPSE

Nils-Olov Karlsson and Åke Sund

Ericsson Information Systems AB has developed a time recording system, MINI ELLIPSE, intended for small companies. It consists of autonomous terminals which replace the traditional time clocks. Magnetically encoded authorization cards are used instead of the traditional time cards. Existing Ericsson systems for time recording are intended for large companies and have terminals connected to a central computer for recording and evaluation.

The authors describe the advantages of the new system over earlier systems with clocking-in cards, the operation of the system and the combinations that are possible.

UDC 681.118.7
time recording equipment
computerized monitoring
office automation
personnel

Ericsson has manufactured and marketed time clocks for over 60 years. The company's mechanical time recorders are known throughout the world for their reliability. The system that has now been developed is just as simple and reliable, and also has several added advantages for both the employee and the employer. MINI ELLIPSE simplifies administration, particularly in small and medium-sized companies, and can be used to rationalize the calculation of wages. Not all companies have the same requirements, and two versions of the system have therefore been developed:

ELLIPSE 210	Records clocking-in and clocking-out times and presents a summarized attendance report for each employee
ELLIPSE 220	As 210, but it also allows different working hours to be defined, calculates balances for flexible working hours and overtime and gives deviation statements.

The terminals of the two versions differ only as regards the software. The programs are stored in replaceable modules, so that one version can be converted into the other if the need arises.

Each employee is issued with a personal authorization card of the convenient credit card size. The recording is very simple. The card is inserted into the card reader in the terminal. The magnetic strip on the back of the card identifies

Fig. 1
The MINI ELLIPSE terminal mounted on a wall

NILS-OLOV KARLSSON
ÅKE SUND
Ericsson Information Systems AB

the person making the registration. Simultaneously the terminal records the time. All calculations are made in the terminal.

In its simplest form a MINI ELLIPSE system consists of a terminal and a printer. A fully built-out system comprises five terminals and a common printer. Each terminal can handle registrations by up to 100 people.

The basic stipulation for the development of MINI ELLIPSE was that it should be as easy to use as its predecessor, the mechanical time clock, and also provide better information for both the employees and the company.

ELLIPSE 210

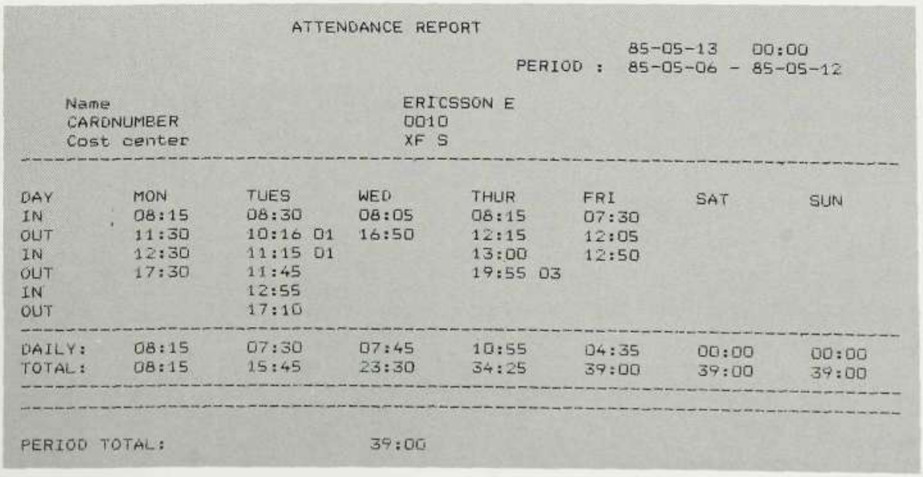
ELLIPSE 210 is the system version that works most like the mechanical time clock. At the end of each period the system automatically prints out, for each employee, a list of the time worked, fig. 2. The list contains all recordings during the period, shown in a manner similar to the recordings on the traditional time card. The time worked is summed both per day and for the whole period. At the end of the list there is room for up to twenty-five absence codes with explanatory comments. By each code there is also sufficient space to give the time absent.

The list can be printed, sorted on either card numbers or cost centres. If an employee registers at a time that deviates from the person's normal working hours, the attendance report will indicate this by means of an asterisk (*).

Employees can obtain their current balances by inserting their card in the card reader and depressing a key marked with a question mark. The information provided consists of the person's latest recording time, the hours worked during the current and previous day and the balance for the period in question.

ELLIPSE 220

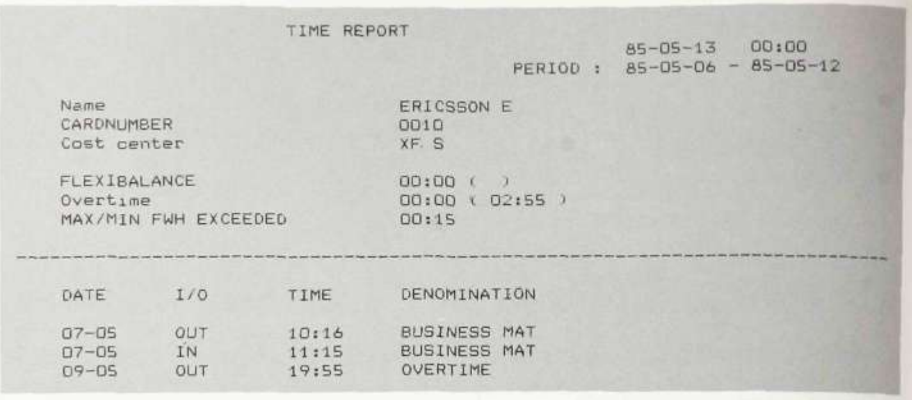
ELLIPSE 220 works with several working hour schedules and compares each person's recordings with the appropriate time schedule. Both fixed and flexible working hours can be specified. In the case of normal recordings the system is controlled entirely by the card, i.e. there is no need for manual input of information, and the registration is acknowledged by IN or OUT status, together with the current flex balance if the person has flexible working hours. If a recording deviates from the normal working hour schedule the employee is requested, via the display unit, to explain the deviation by entering a code. The codes, a maximum of 12, can be chosen individually for each system and



```
                          ATTENDANCE REPORT
                                                    85-05-13   00:00
                                          PERIOD :  85-05-06 - 85-05-12

    Name                         ERICSSON E
    CARDNUMBER                   0010
    Cost center                  XF S
--------------------------------------------------------------------------------

DAY        MON        TUES       WED        THUR       FRI        SAT        SUN
IN         08:15      08:30      08:05      08:15      07:30
OUT        11:30      10:16 01   16:50      12:15      12:05
IN         12:30      11:15 01              13:00      12:50
OUT        17:30      11:45                 19:55 03
IN                    12:55
OUT                   17:10
--------------------------------------------------------------------------------
DAILY:     08:15      07:30      07:45      10:55      04:35      00:00      00:00
TOTAL:     08:15      15:45      23:30      34:25      39:00      39:00      39:00
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------

PERIOD TOTAL:                    39:00
```

Fig. 2
An example of an attendance report

Fig. 3
An example of a time report



```
                         TIME REPORT
                                                     85-05-13    00:00
                                         PERIOD :  85-05-06 - 85-05-12

 Name                                ERICSSON E
 CARDNUMBER                          0010
 Cost center                         XF. S

 FLEXIBALANCE                        00:00 (   )
 Overtime                            00:00 ( 02:55 )
 MAX/MIN FWH EXCEEDED                00:15

-----------------------------------------------------------------------

 DATE        I/O        TIME         DENOMINATION

 07-05       OUT        10:16        BUSINESS MAT
 07-05       IN         11:15        BUSINESS MAT
 09-05       OUT        19:55        OVERTIME
```

associated with comments and calculation rules that specify whether the deviation is to be counted as worked time, overtime or time off. Overtime is calculated in accordance with the following three alternatives:

- After fulfilled normal working hours
- Outside the limits of flexible working hours
- Outside normal start/finish times.

If a person forgets to record, this is presented in an error report written out at midnight. Moreover, the next time the person records he/she is requested by means of the display unit to contact the operator.

As in ELLIPSE 210 the employees can at any time obtain personal information from the system, namely the flex balance, overtime balance, latest recording time together with any code given, and at what time work for the day will have been completed.

At the end of a period, a list of the time worked and a balance and deviation statement are written out for each employee. The list of the time worked is the same as in ELLIPSE 210 and includes all recordings.

The time report, fig. 3, contains information regarding flexible hour and overtime balances, and all deviations recorded during the period. The deviations are given in clear text, using the text the operator has attached to the recording code. The preceding recording time is printed together with the deviation text, which makes the statement clearer and also simplifies calculation of the amount of time absent.

Overtime recorded together with the overtime code is written in brackets together with the text and the recorded time.

Operator function

All information that is individual to the company, such as names, working hour schedules and calculation rules, is fed into the terminal by the appointed operator.

The operator has a special card, which together with a four-digit security code gives access to all registers and tables in the terminal. When entering information the operator is assisted by clear text shown on the display unit in the terminal.

Text is entered with the aid of the twelve special keys and a text plate, which is placed on the keyboard. The operator function is built up of several levels, the top level being the same in all system versions, see the fact panel.

Fig. 4
MINI ELLIPSE terminal with printer FACIT 4510

Operator menu for ELLIPSE 220

Level 1	Level 2
Correction	Card number
	Name
	Last code
	In/Out
	Lunch
	Recording missing a.m.
	Recording missing lunch
	Uncorrected error
	Latest recorded time
	Flex balance
	Overtime balance
	Daily total
Personal data	Card number
	Name
	Cost centre
	Revision status
	Category
List	Status report
	Time report
	Attendance report
	Personnel data
	Time schedules
	Day type description
	Calendar/holidays
	System parameters
Time parameters	Holidays
	Calendar
	Time schedules
	Day type description
	Date and time
System parameters	Function parameters
	Recording codes
	Lists and statements
	Languages
	Confirm list
	Restart
	New security code

The *correction* function enables the operator to correct incorrectly registered data, add information and update balances.

In the *personal data* records a card number is attached to each employee's name. A terminal can handle up to 100 card numbers. Each employee is also assigned to a personnel category. Persons belonging to the same category are assumed to always work to the same time schedule. The operator can define up to 10 personnel categories depending on the system version. Cost centres can also be included in the personal records.

The *list* function is used to order printouts of all stored information. It enables the operator to order end-of-period lists at any time during the period in question.

The function *time parameters* is used to define the time limits that are to apply, i.e. which working hour schedules are to be used and when. This function is also used to set the system clock.

The *system parameters* function is used to define how the system is to work, by specifying calculation rules, language, period length, number of cards etc.

Documentation

Changeover to new technology is often made more difficult by inadequate documentation. Great efforts have therefore been made to provide good documentation for MINI ELLIPSE. The basic aim has been that each terminal should be accompanied by documentation which quickly and easily provides both the operator and the other employees with comprehensible information regarding the functions of the system. The documentation includes:

- A *manual*, which step by step provides the operator with the necessary information on how the system is started up and how the day-to-day work is carried out
- A *quick reference booklet*, which is a summary of the manual and which is to be used by the operator once the system is in operation
- An *instruction folder*, which is distributed to all employees and which explains how the system works and how they are to use their authorization cards
- An *instruction board*, which is placed above the terminal. It supplements the instruction folder and shows how to record, request balance information etc.

System structure

In its simplest form the system consists of a terminal and a printer. In a fully built-out system, five terminals use a common printer. The different versions of the terminals can be combined to build a system that suits the individual requirements of a company, fig. 5.

One of the terminals is designated the main terminal. The other terminals and the printer are connected to the main terminal. Changeover between the main terminal and sub-terminals is carried out by the operator.

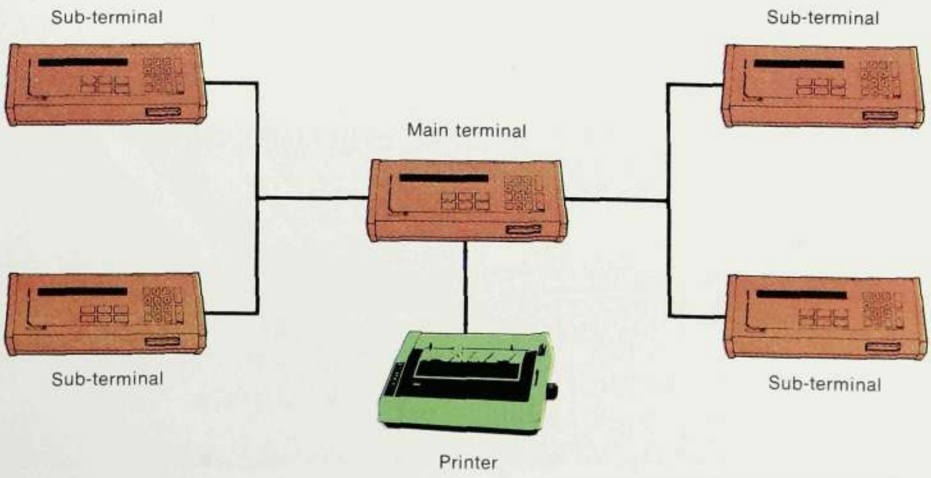


Fig. 5
Largest system configuration, with one main terminal, four sub-terminals and one printer

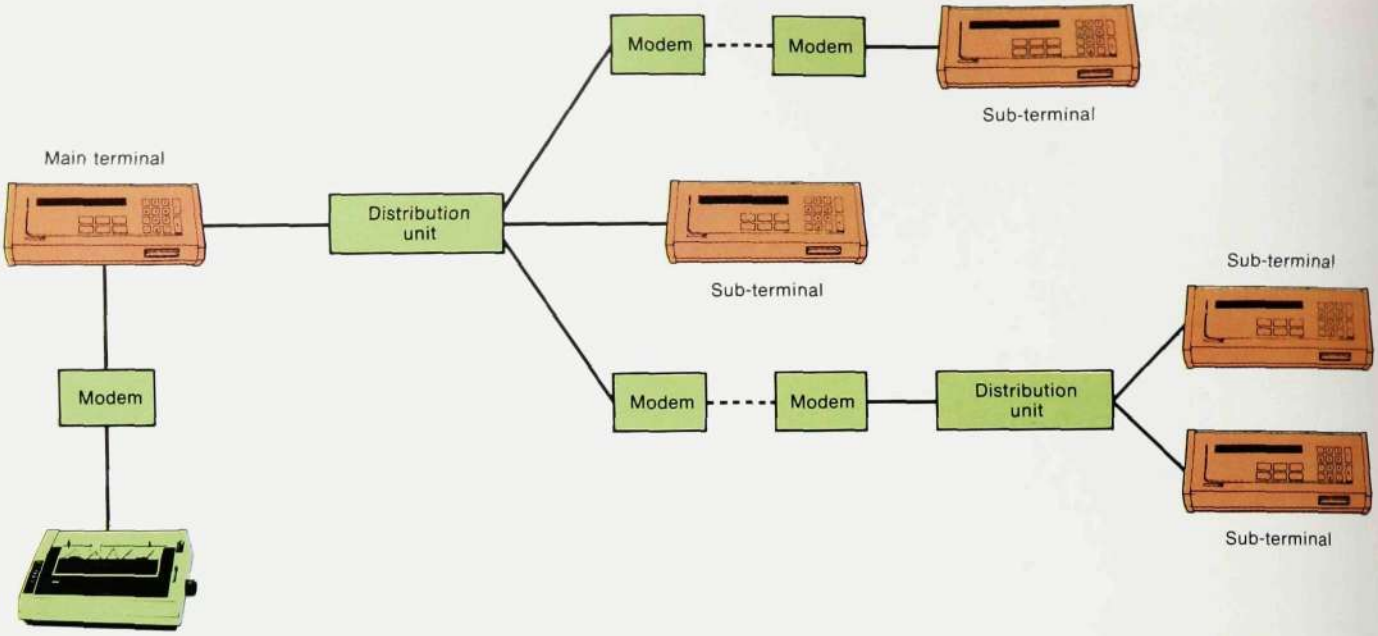
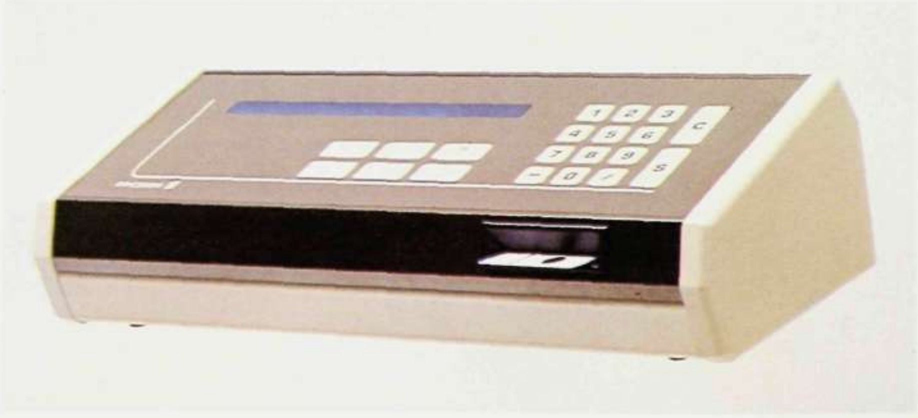


Fig. 6
Modems, and possibly also distribution units, must be used when the distance between the main terminal and the printer exceeds 50 m or when the distance between terminals exceeds 1 200 m

Fig. 7
Terminal for the MINI ELLIPSE system



The printer can be connected to the terminal via a short-haul modem if they are far apart. The terminals can also be connected to each other via modems. However, one or more distribution units must be used if more than two terminals have to be connected in this way, fig. 6.

Communication

The signal transmission between the terminals is in serial form and asynchronous, using ASCII code, via a V.11 interface (RS422). This interface is symmetrical to earth. Two signal wires are used in each direction, with a common conductor for signal earth. The sub-terminals are connected in parallel (multi-drop) and are asked by the main terminal in turn whether they have anything to send (polling). A terminal which has information to transmit responds immediately by connecting up to the common line and sending its message. The other terminals have a high-impedance coupling to the line (three state) and will not disturb the transmitting terminal. The longest permissible distance between the main terminal and the most distant sub-terminal is 1 200 m.

A V.10 interface is used when modems are connected directly to terminals. The V.10 and V.11 interfaces in the terminal have a common receiver circuit, so they cannot be used simultaneously. A distribution unit (593 650/3) must therefore be used if both terminals and modems have to be connected to a terminal. Another distribution unit can also be used at the other end of the modem line in order to be able to connect up more than one terminal. The distribution unit has interfaces V.11, V.24 and a 20 mA current loop in both directions.

The signal transmission to the printer takes place in serial mode, asynchronously and with ASCII code via a V.10 interface (RS423) in the terminal to the V.24 interface (RS232C) in the printer. Both these interfaces are unsymmetrical to earth. One signal wire is used in each direction, with a common earth conductor. This combination can only be used when the distance between the units is short. For longer distances modems must be used, and in most cases it is possible to use short-haul modems with current loop. The static signal READY is used to indicate that the printer is ready to receive data from the terminal.

Authorization card

The system works with magnetically encoded cards of the same size as credit cards. Both the size, CR 80, and the encoding are in accordance with the standard ISO 3554. Track 2 is used and the code must contain the following characters:

Start (B)	one character
Revision position (0–9)	one character
System number	four characters
Card number	four characters
Stop (F)	one character
Check sum (LRC)	one character

Technical data

Authorization card	CR 80
Magnetic encoding	ISO 3554 track 2
Card size	50×85.7×0.76 mm
Keyboard	Diaphragm
12 keys marked	0–9, /, -, S, C
12 special keys	6 for optional use
Display unit	Vacuum fluorescent
Number of characters	40
Number of matrix points	5×7
Character size	5.05×3.55 mm
Terminal interface	
Direct	V.11 (RS422)
For modem	V.10 (RS232C)
Code	ASCII
Data bits	7
Stop bit	1
Series transmission	Asynchronous
Speed	1 200 bauds
Printer interface	
Terminal side	V.10 (RS423)
Printer side	V.24 (RS232C)
Code	ASCII
Data bits	8
Stop bit	1
Series transmission	Asynchronous
Speed	1 200 bauds
Memories	
Program store	40 k×8 bits
Working store	2 k×8 bits
Register store EEPROM	<8 k×8 bits
Registration store RAM with battery backup	<32 k×8 bits
Power supply	
AC voltage	220 V
Limits	±10%
Power consumption per terminal	<10 W
Environmental requirements	
Ambient temperature	0–40°C
Relative humidity	20–80%
Terminal dimensions	416×168×105 mm
Colour scheme	
Case and keys	Beige
Panel	Brown

Between the card number and stop character there is space for four more characters, which are reserved for some other system, for example access control. The terminal ignores these characters for processing purposes, but they are included in the longitudinal redundancy check sum, LRC.

Authorization cards of standard type are provided with the terminal, but the customer is of course free to use an individual card design, for example identity cards with photographs.

Terminal design

The terminal for MINI ELLIPSE must be as user-friendly as possible. This was one of the main requirements during the development of the system. A vacuum fluorescent display unit was therefore chosen, which ensures good readability under different light conditions and varying reading angles. The terminal can be mounted on a wall or just placed on a table.

All terminal functions are programmed using the operator function. No straps or switching functions are required.

Texts for the display unit and printer are stored in the terminal in four languages. English is always included. Special PROM units are available for other languages, with up to three languages in each. The third index digit in the part number of the terminal indicates the language variant.

The electronic circuits in the terminal are built up on two printed circuit boards, a mother board and an extra board for memory extension and a real time clock. The memory board is connected to the bus system of the main processor, which consists of a 6803. A processor 8049 is used to generate characters for the display unit.

The mother board forms the basis for the whole range of terminals, which also includes terminals for connection to a time recording system with a central computer[1].

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1. Fabo, E. and Höglund, E.: *CTR – Computerized Time Recording*. *Ericsson Rev. 57* (1980):2, pp. 58–63.

Stored-Program-Controlled Field Telephone Exchange ABM 301

Ago Kristel and Hans Runske

Ericsson has developed a stored-program-controlled field telephone exchange with analog speech transmission, ABM 301, as part of a program for modernizing its equipment for temporary telephone networks, both military and civil. The exchange has a capacity of twelve extensions and three trunk lines. A maximum of three exchanges can be connected together to give a top capacity of 36 extensions and nine trunk lines. The use of stored program control has made possible the introduction of a large number of functions which could not be provided in previous field exchanges. These functions simplify telephoning and the operation of the exchange.
The authors discuss the need for this type of exchange and describe its function, design and construction.

UDC 621.395.2:681.3.065
electronic switching
telephone networks
private telephone exchanges

For a long time there has been a demand from both military and civil defence organizations for temporary telephone networks, and the demand appears to be growing. At the same time there is a need for improved traffic facilities in such networks. The subscribers must be able to connect up their own calls both internally in their own network and externally to other networks. It is also desirable that it should be possible to transmit data, telex and facsimile as well as normal telephone calls.

Field equipment, which is continually moved to new sites, often under very tough conditions, must be ready for operation quickly and without trouble. It must also be able to withstand arctic cold, tropical heat and high humidity, as well as vibrations and shocks during long and arduous transports.

Last but not least, the equipment must be easy to operate and maintain.

The new field telephone exchange, ABM 301, developed by Ericsson meets all these requirements.

Operation

ABM 301 is a stored-program-controlled (SPC) field telephone exchange with the programs stored in a programmable read only memory (PROM). The switch network is electronic with DMOS elements. The switch is congestion-free, and all extensions can therefore be in use simultaneously.

ABM 301 has a line capacity of three CB (common battery) trunk lines and twelve CB extensions. Four of the twelve extension lines can be switched over from CB to LB (local battery) operation and used as either extension or trunk lines. LB

Fig. 1
Automatic field telephone exchange ABM 301 for 12 extensions and three trunk lines

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Fig. 2
Up to three ABM 301 can be connected together to form a larger exchange

operation allows the connection of long and badly insulated lines, a type often found in temporary telephone networks. LB trunk lines can be used to connect up LB exchanges and thus build up a network of primary centres.

Decadic impulsing is used on both the internal and the external CB lines, and telephone sets with dials are therefore connected to the CB extension lines. The sets used with LB lines must have hand generators or electronic signal generators for calling the operator. A variant of ABM 301 having DTMF signalling over the three CB trunk lines will be available.

The capacity of the exchange can be increased by connecting together two or three exchanges. This increases the capacity to 24 or 36 extensions and six or nine trunk lines. A cable is provided at the rear of the exchange for this purpose.

Operator panel

The front of the exchange constitutes the operator panel. It contains a number of light emitting diodes and control keys used by the operator to process and supervise the traffic through the exchange. It also contains indicator lamps for the exchange microprocessor, power supply and signal generator.

All calls to the operator are indicated by acoustic and visual signals. At the same time a digit indicator shows the number of the line from which the call comes. The operator uses the push-button set on the panel to call the requested number. The called number is displayed on the digit indicator.

The operator panel of ABM 301 has only symbol and digit designations and is thus not tied to any language. It is equipped with illumination for operation at night.

External connections

The rear of the exchange contains a main switch and terminals for connecting up the supply voltage and earth. The exchange is fed from a d.c. voltage of between 0 and 70 V. It contains a d.c./d.c. converter which produces the necessary working voltages. The power consumption is normally 30 W during operation.

The lines are connected to two connection boxes, which in their turn are connected to the rear of the exchange via two line cables. The boxes and cables are equipped with bayonet connectors of the type that has long been used in Ericsson's field exchanges. The boxes are provided with overvoltage protectors to prevent high voltages, for example from lightning strokes, from damaging the equipment.

The rear plate of the exchange also contains two DIN connectors for a tape recorder. One connector is intended for the remote control of the tape recorder and the other for its signal input. If a call is to be recorded, the operator connects up the tape recorder to the extension concerned by means of a control key and the push-button set on the front of the unit. The recording does not start until the call has been connected through, and it stops when the receiver is replaced on the extension (or a clear-forward signal is sent from an LB set).

Fig. 3
The operator panel constitutes the front of the exchange

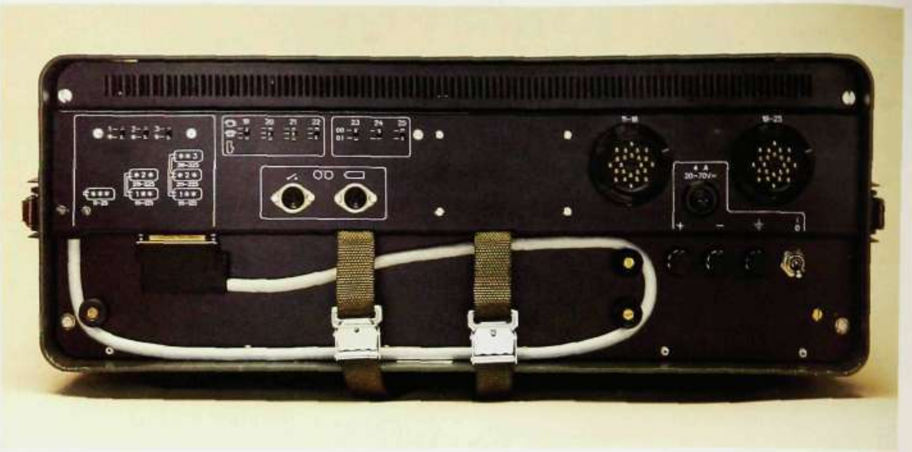

Fig. 5
The rear panel of the exchange has no text either, only symbols and figures

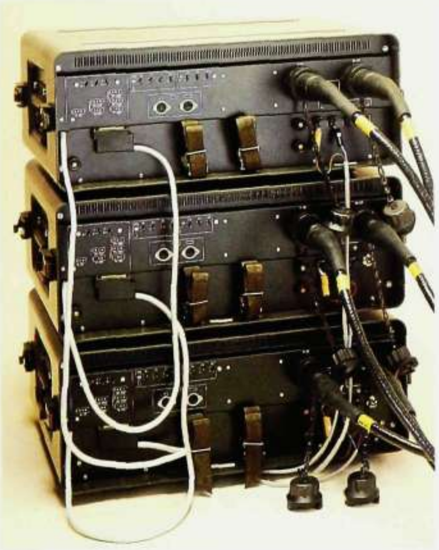

Fig. 4
All external connections and interconnections are made at the rear of the exchange

Exchange number series

The local number series in the exchange is 11–22 for the extensions and 23–25 for the trunk lines. When exchanges are connected together the number series is automatically changed to 111–125 in the first, 211–225 in the second and 311–325 in the third exchange. The order among the exchanges, i.e. which is to be the first, second and third, is set by means of three switches on the rear plate of the exchange. The first exchange is always the operator unit.

Three other switches give a choice of routing code, 00 or 01, for each trunk line. This renders it possible to make calls to two different networks, for example using 00 to the public network and 01 to another network.

Traffic facilities

Stored program control has made it possible to introduce a large number of new functions. The primary aim has been to simplify the work of the operator and the users when setting up calls, by providing the following facilities:

- incoming external calls via the operator
- outgoing external calls from CB extensions, either direct or via the operator
- outgoing external calls from LB extensions via the operator
- direct internal calls from CB extensions
- internal calls from LB extensions via the operator
- enquiry from CB extensions during external calls, either direct or via the operator
- transfer of external calls between CB extensions, either direct or via the operator
- blocking of outoing external calls from the extensions, so that calls have to be set up by the operator
- two automatic camp-on circuits for external calls to busy extensions
- two simultaneous conference calls, each with a maximum of seven participants
- external and internal lines can take part in conference calls
- queue device for calls to the operator
- night service with trunk lines connected to predetermined extensions
- choice of individual trunk line or another network
- external call returned to the operator if the extension does not answer
- connection of tape recorder to optional extension
- amplified call signal.

Mechanical construction

ABM 301 is built up of printed circuit boards type ROF 137 (192 x 220 mm) using construction practice BYB 101. This construction practice was chosen so that previously developed electronic equipment could be used for the CPU and the d.c./d.c. converters.

The line connectors and connection cables used in ABM 301 were originally developed for other field exchanges.

With plug-in units throughout, the exchange is very easy to service and maintain. Both the rear and front panels open, fig. 7.

The environmental requirements have been met through the use of well-tried technology and high-quality compo-

Fig. 6
Terminal block and cable

Fig. 7
The exchange with the rear plate opened

nents. A thermostat-controlled fan ensures operation even at extremely high ambient temperatures.

The outer case of the exchange is designed to withstand mechanical stress. It is made of aluminium alloy plate, with deep grooves that help to stiffen it. The lids are cast in aluminium alloy and are mounted on the case with snap-on locks.

The front panel consists of an anodized aluminium section. Two lamps for emergency illumination are mounted at the top of the panel.

System construction

Basically ABM 301 can be divided into a telephone unit and a control unit. The exchange of information between them takes place via a bus system. Fig. 8 shows a block diagram of the system.

The telephone unit includes a switching network, line circuits and operator circuits.

Switching network

ABM 301 is equipped with an electronic switching network built up of DMOS elements for unbalanced single-wire

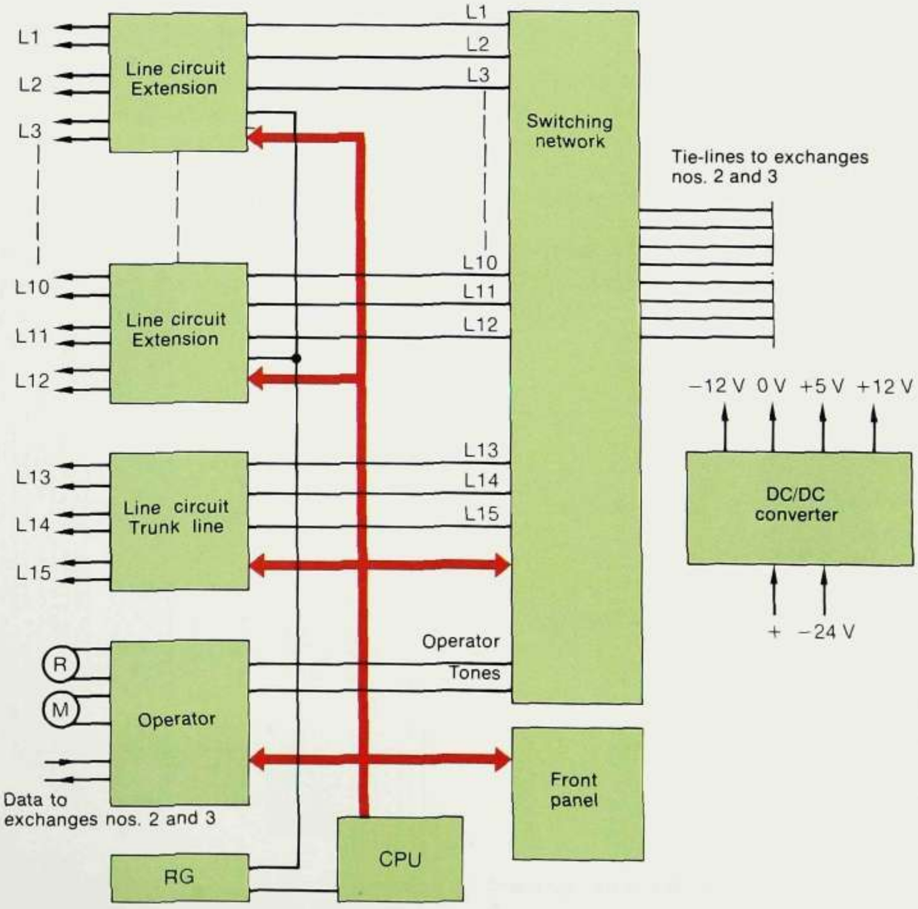

Fig. 8
Block diagram for the stored-program-controlled field exchange ABM 301

through-connection. Each switch element has two inputs and eight outputs. The inputs are connected to the line circuits, and by multiplying the outputs a switching network is formed that allows eight calls. This means that the switching network is free from congestion and permits all extensions to be connected up for calls at the same time.

Tie-lines are needed when two or three ABM 301 are connected together. The tie-lines are obtained by duplicating the switch elements, whereby the multiplied outputs provide eight links to the other exchanges, fig. 9.

Line circuits

The line circuit board contains three line circuits for extension lines. Two of the circuits are designed for connection to dial CB sets. The exchange accepts pulse ratios of between 33/67 and 50/50. The frequency can vary between 8 and 12 Hz. The power feeding is electronically controlled and the feeding voltage is 24 V, with +12 V on the A-wire and −12 V on the B-wire.

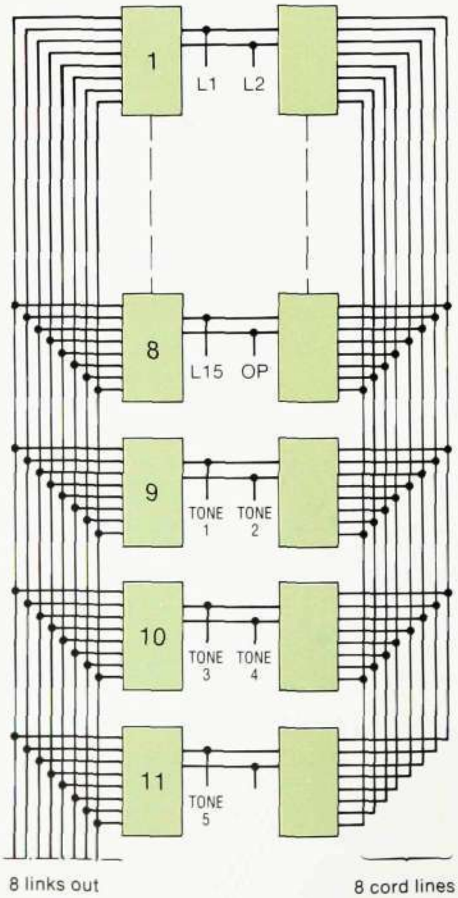

Fig. 9
The hardware structure of the switching network

The third circuit can be switched between CB and LC operation. It has a transformer output towards the switching network, and this output is matched to 600 ohms and equipped with a zener diode for noise suppression. Short-circuiting of a line does not damage the line circuit. The circuits are also equipped with protection against transients and voltage peaks from the lines. The line circuit board interworks with CPU via an address and data bus.

Operator circuits

The operator circuit board contains a power feeding circuit and a speech transformer for the operator, tone generators, control circuits for the ringing voltage generator and the processor, test point gates and circuits for interworking with other exchanges.

This board also interworks with CPU via the address and data bus and the associated control wires.

CPU

The central processing unit in ABM 301 is based on Ericsson's processor APN 16503, an 8-bit multi-purpose processor.

The software requires a 16 kbyte program store and a 4 kbyte data store. There is only space on the processor board for an 8 kbyte program store and a 4 kbyte data store, so that program store modules have had to be added. The program is stored in a PROM (which cannot be altered once it has been programmed), thereby avoiding the necessity of programming in the field.

Functional description

From the point of view of the software the environment consists of a number of test and control points, which must be scanned and operated respectively.

The test points can be divided into different groups. Some are scanned only during restart of the exchange and others only when needed. Some test points, however, are scanned regularly every five ms.

The control points operate:

- ringing signals towards the extensions
- the status of the trunk lines
- the status of the LB lines
- light emitting diodes
- the digit indicator.

The scanning programs scan all test points and decide whether detected information signals, for example concerning a change in line status, should be transmitted to application programs.

The software is divided into a number of functional modules. For example, the switching network module works mainly with the central battery and operator modules and, when exchanges are connected together, with the switching network modules in the other exchanges. It handles the allocation of cord lines and, when necessary, also tie-lines. The analog connections between extensions and to tone senders are also controlled by the switching network module.

The program handling in the exchange is based on the execution of application programs, ordered by the transmission of signals. All interworking between different processes takes place by means of signal transmission.

Signal transmission is arranged as follows. The sending program loads the required data into a working store and then calls the SEND routine. SEND transfers the contents of the working store to a free space in a job queue, after which control is restored to the sending program so that the program handling can continue. When the program has been completed, the next job in the queue is initiated.

In case of power failure all calls are disconnected, but the trunk lines are automatically connected through the exchange to predetermined extensions. When the power is restored, a jump is automatically made to a restart program.

The restart program contains a number of program modules that carry out the restart and then initiate cyclic processing of the job and time queues.

Summary

ABM 301 was introduced in the market in 1984 and has been the subject of several field trials by military units in Sweden as well as abroad. Operational experience has confirmed that the set requirements have been met satisfactorily, both as regards the mechanical construction and the handling of the exchange.

The development of ABM 301 completes Ericsson's range of manual and automatic field telephone exchanges. The range now comprises exchange sizes from 10 lines up to 160 lines.

ABM 301 has been in production for some time and is available for immediate delivery.

Technical data

Ambient temperature	−20°C to +55°C
Operating voltage	20 – 70V d.c.
Power consumption	30 W max.
Line resistance	1 200 ohms incl telephone set (CB lines)
Leakage resistance	> 15 kohms
Line impedance	600 ohms
Pulse ratio	
In from extension line	33/67 – 50/50
Out to trunk line, strappable	33/67, 40/60, 50/50
Pulse frequency	
In from extension line	8 – 12 Hz
Out to trunk line, strappable	10 or 16 Hz
Transmission loss	1 dB at 1000 Hz
Crosstalk attenuation	85 dB at 1000 Hz
Return loss	
Extension, CB or LB	≤ 20 dB
Trunk line, CB	≤ 18 dB
Trunk line, LB	≤ 20 dB
Balance return loss	
300 – 600 Hz	> 40 dB
600 – 3400 Hz	> 46 dB
Ringing generator	95 V, 25 Hz unloaded
MTBF	8000 hours
Dimensions	
Width	530 mm
Height	214 mm
Depth	520 mm
Weight	25 kg
Meets the environmental requirements of	DEF 133 table L3 MIL STD 810 C

RIFA's CMOS cell library

Göran Norrman and Eva Westberg

A system of aids for designing integrated circuits has been developed by Ericsson LSI Design Center. The Public Telecommunications Division is responsible for further development and administration of the system. RIFA AB markets the system in areas outside the scope of the Public Telecommunications Business Area. The system consists of prefabricated cells, a CAD (Computer-Aided Design) system and a set of design rules.

The authors describe the work that led to the decision to develop the design system, the facilities offered by the system and how RIFA's CMOS cell library is used.

UDC 621.3.049.774.214:681.3
circuit CAD
large scale integration
cellular arrays
CMOS integrated circuits

The powerful CAD tools and the sophisticated semiconductor technology now available open the way for system designers to design circuits direct in silicon. Instead of using standard components and mounting them on printed circuit boards it is now possible to compress whole systems or large parts of them into a single integrated circuit. The advantages are that the system becomes less expensive and it is more difficult for competitors to copy the design. Furthermore it is easy to include more functions, and the equipment becomes smaller, lighter and uses less power.

A reduction in the number of components, circuit boards and connectors also results in higher reliability.

Project managers have often hesitated to use semicustom-designed integrated

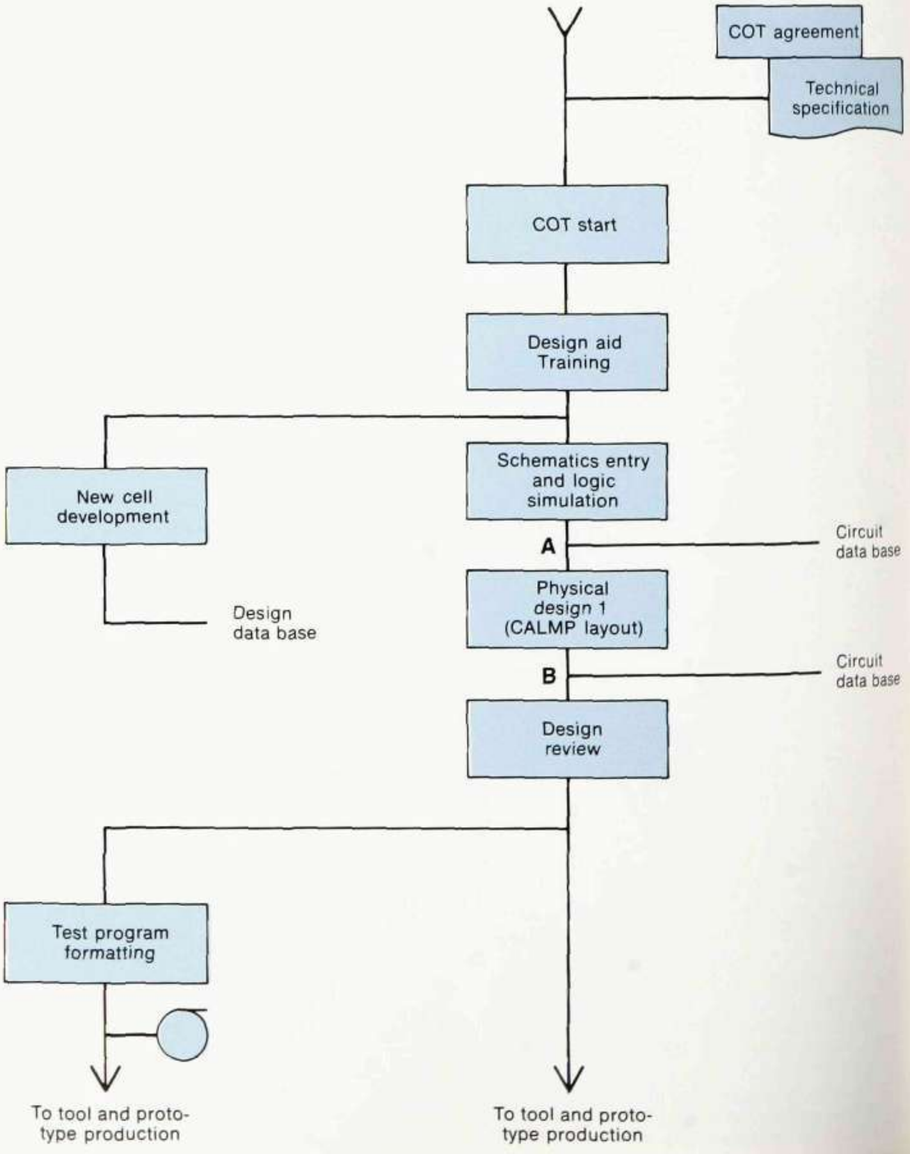

Fig. 1
A customer owned tooling (COT) project at RIFA entails design activities in accordance with this flow diagram.
A and B in the diagram are alternative interfaces between the customer and RIFA which include checking the basic data

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circuits. The development time has been long. Delays have affected the overall schedule for the whole project. The development work has not always had the desired result.

Today the situation is different. Excellent computer aids are now available for designing semicustom-designed circuits in both gate array and standard-cell technique[2-4]. A design is quickly transferred to silicon and the probability is high that the circuits will be correct when the first prototype is produced. The development in the semiconductor field has also meant that a high degree of complexity and good performance can now be obtained with both techniques at a relatively low cost.

Choice of technique

The market for both gate arrays and standard-cell ICs is expected to grow

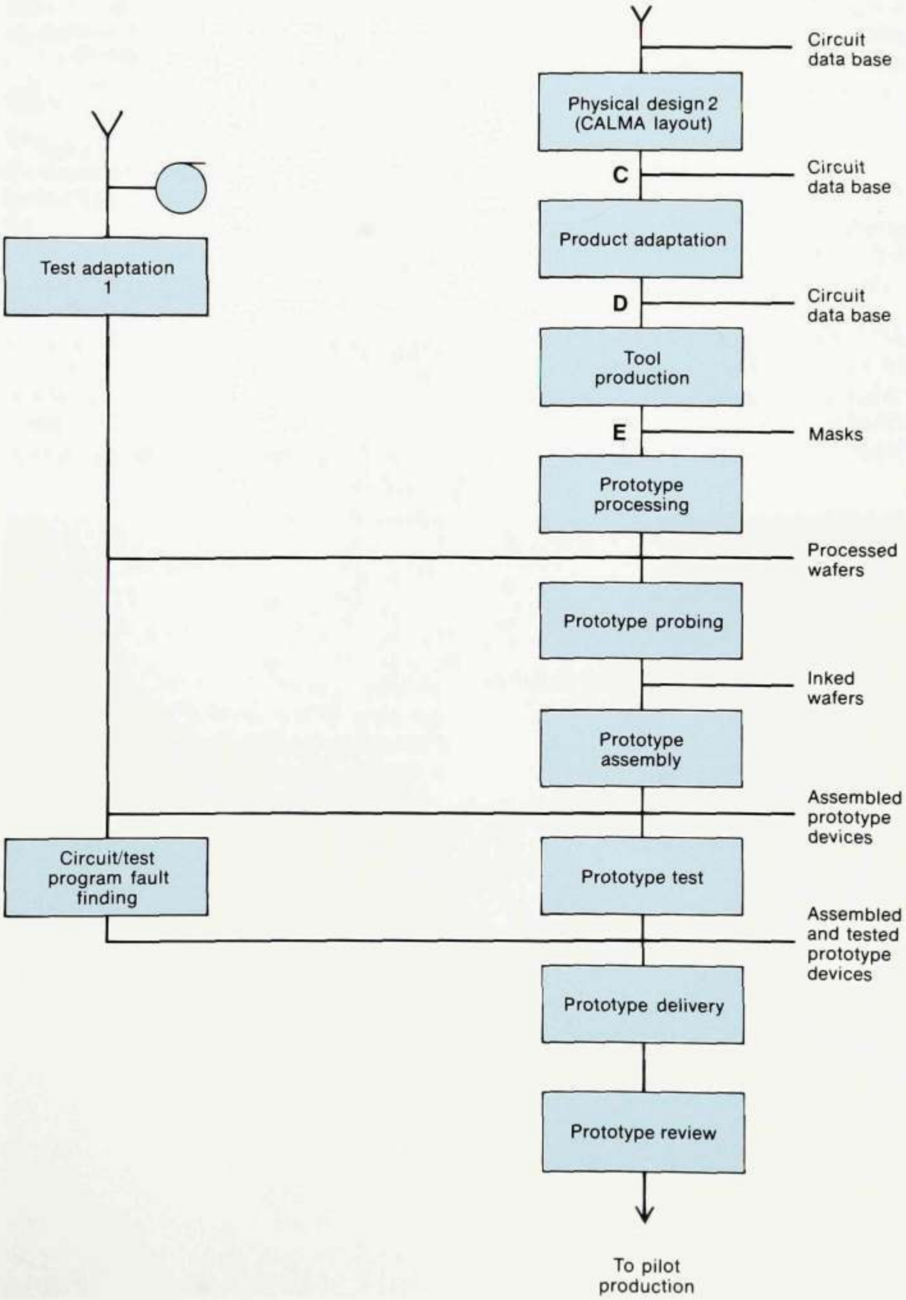


Fig. 2
COT activities for the manufacture of prototypes at RIFA. Basic data for testing is produced in parallel with the design work.
The wafer test checks that the process has been correct, that the circuits are logically correct and that the time requirements of the specification are met. Accepted chips are encapsulated and a final test and inspection are made.
C, D and E in the diagram are alternative interfaces between the customer and RIFA which include checking the basic data

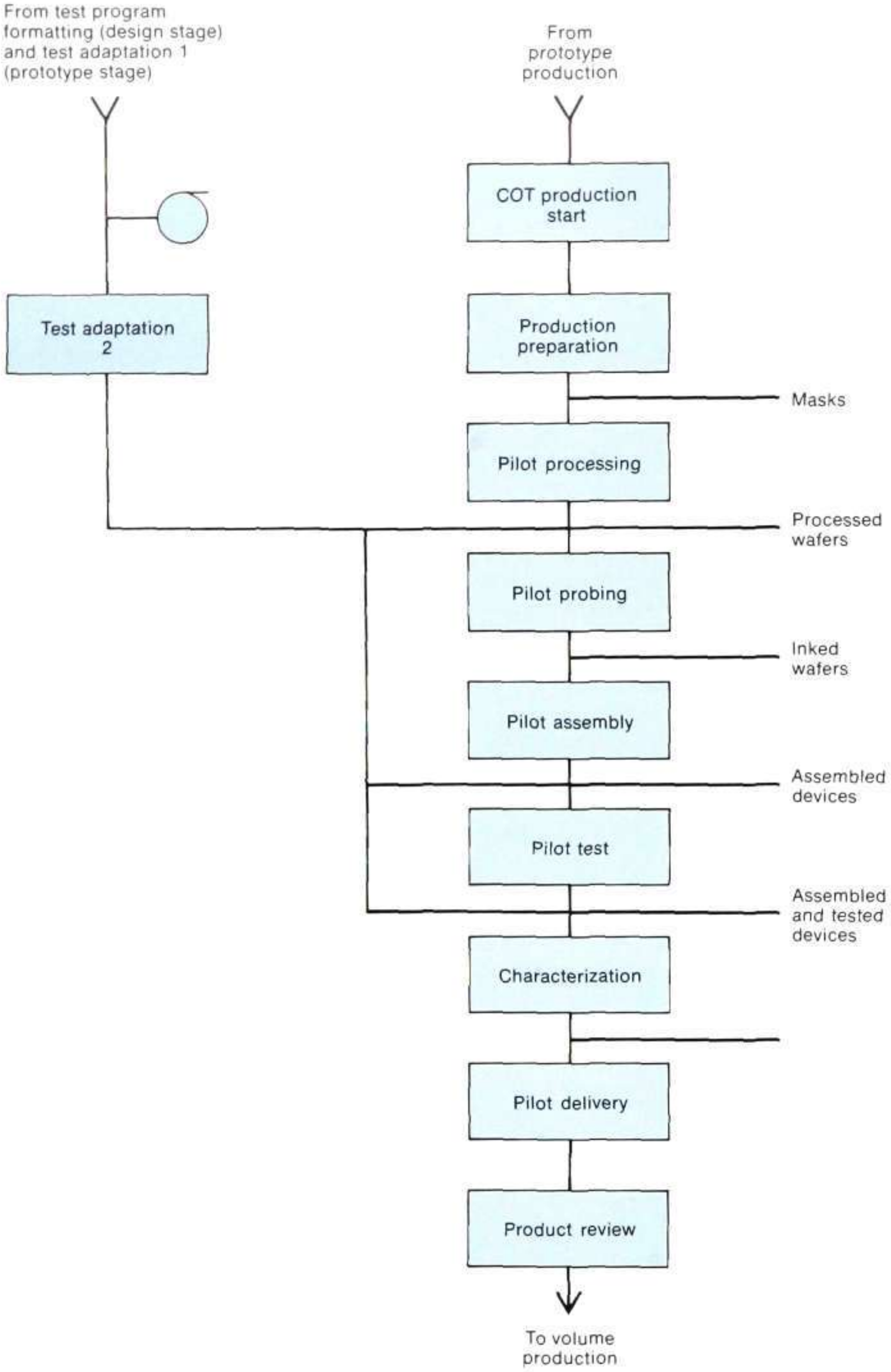


Fig. 3
A pilot production is run before series production starts

rapidly[5]. Some of the arguments for choosing these techniques are:

- Prototypes in gate array technique can be developed faster and at a lower cost than can be achieved using a cell library. However, as a result of the development of CAD tools the difference is no longer so great.
- Semiconductor manufacturers often initially provide gate arrays for their new processes; standard-cell libraries being created for more established processes.
- It is expensive to design new cells. However, conversion programs are now available which simplify the redesigning of cells when converting to a new process.
- The interest in standard-cell IC-design is growing since this technique offers greater flexibility, i.e. it is easier to adapt to suit different circuit designs.
- Standard-cell ICs often use a smaller chip area and therefore have a lower piece price.

The arguments for standard-cell design outweigh the arguments against, a conclusion which is supported by international opinion, expressed as early as November 1983 at the 3rd International Conference on Semicustom Circuits.

System properties

Ericsson has developed a design system, based primarily on a 2.5 μm CMOS process. This process is well established at RIFA and means that a minimum transistor is drawn with a gate length of 2.5 μm.

The process includes two low-resistance metallic connection layers. In addition both diffusion and polysilicon are used for wiring in the cells. These connections have a relatively high resistance. Polysilicon is also used for the connection of test structures, but since these are only connected when the circuit is tested, the extra time delay introduced by the resistance can be accepted.

The cell library, which now comprises approximately 90 cells, includes the most common SSI and MSI circuits and certain ROM and RAM structures. Software for automatic generation of ROM and RAM building blocks is now being developed.

The process characteristics gives the gates in a circuit an internal delay time of 1–2 ns. A 4 kbit RAM has a cycle time of 100 ns.

A CAD system is used to place the required cells and route all the connections and form the basis of the manufacturing process.

A chip with an area of 30 mm^2 and bond pads for 64 inputs and outputs also holds 2 500 gates or 10 000 transistors.

Customer owned tooling, COT, is the designation of the range of services RIFA offers its customers in order to enable them to design circuits on silicon for series manufacture at RIFA. Figs.

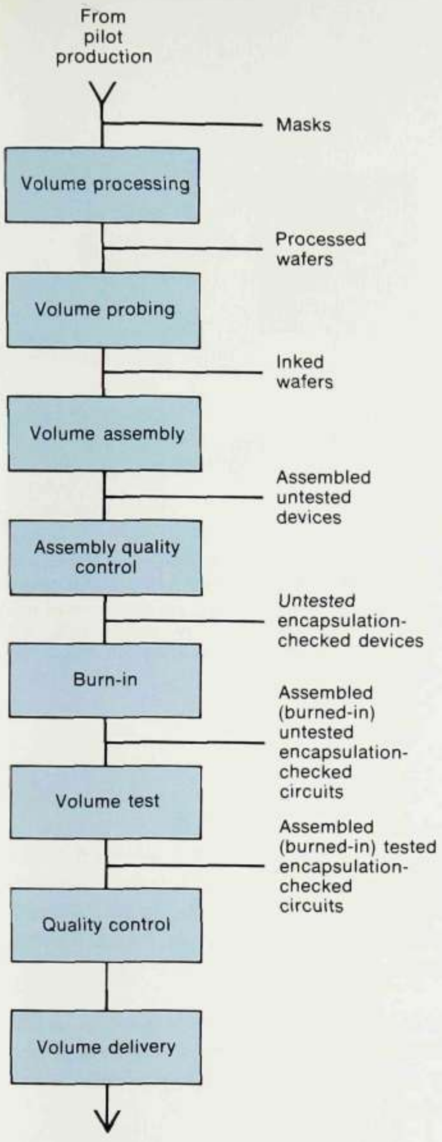


Fig. 4
Volume production.
The necessary basic data comprises masks, test fixtures and probe card, and also assembly and marking instructions for the assembly in the Far East, together with instructions for burning-in if this process is required

1–4 show the different activities in a COT project, from the design and prototype manufacture up to series production.

The purpose of the cell library system is to obtain a short, well-defined process time for the whole design procedure, from specification through evaluation to the final product documentation. New cells can of course be created with the sophisticated CAD tools now available, but such development introduces a measure of uncertainty in the design work since the cells have then not been verified in silicon.

Circuit design

The aim of designing a correct circuit (final product data) in a set time is achieved with RIFA's CMOS cell library by

- choosing cells from the library
- specifying how they are to be connected
- simulating the function logically and in the time domain
- using a computer to generate a test pattern
- letting a computer prepare the layout.

The advantages of this process are that

- the cells are available complete, tested and well-documented, which means that there is a high probability that a circuit construction will already be correct when the first prototype is manufactured
- the development time is short
- the designer does not require any knowledge of traditional LSI design.

The designer can work either in a customer room at RIFA or via a terminal connected up over the public telecommunication network to RIFA's development computer, fig. 5. It is also possible to install RIFA's cell library in the customer's own development system.

CAD system

Software for schematics entry, simulation and final placement and routing of cells is integrated into a CAD system.

CAD programs are run on a VAX 11/780 computer. The work stations are VT 100 terminals for alphanumeric information and TEKTRONIX 4107/4109 or RAM-TEK displays for colour graphics. The termi-

Fig. 5
A customer room equipped for the designing of circuits with the cell library system aids. The design work consists in choosing cells from the library and specifying how they are to be connected. The function is then simulated logically and in the time domain

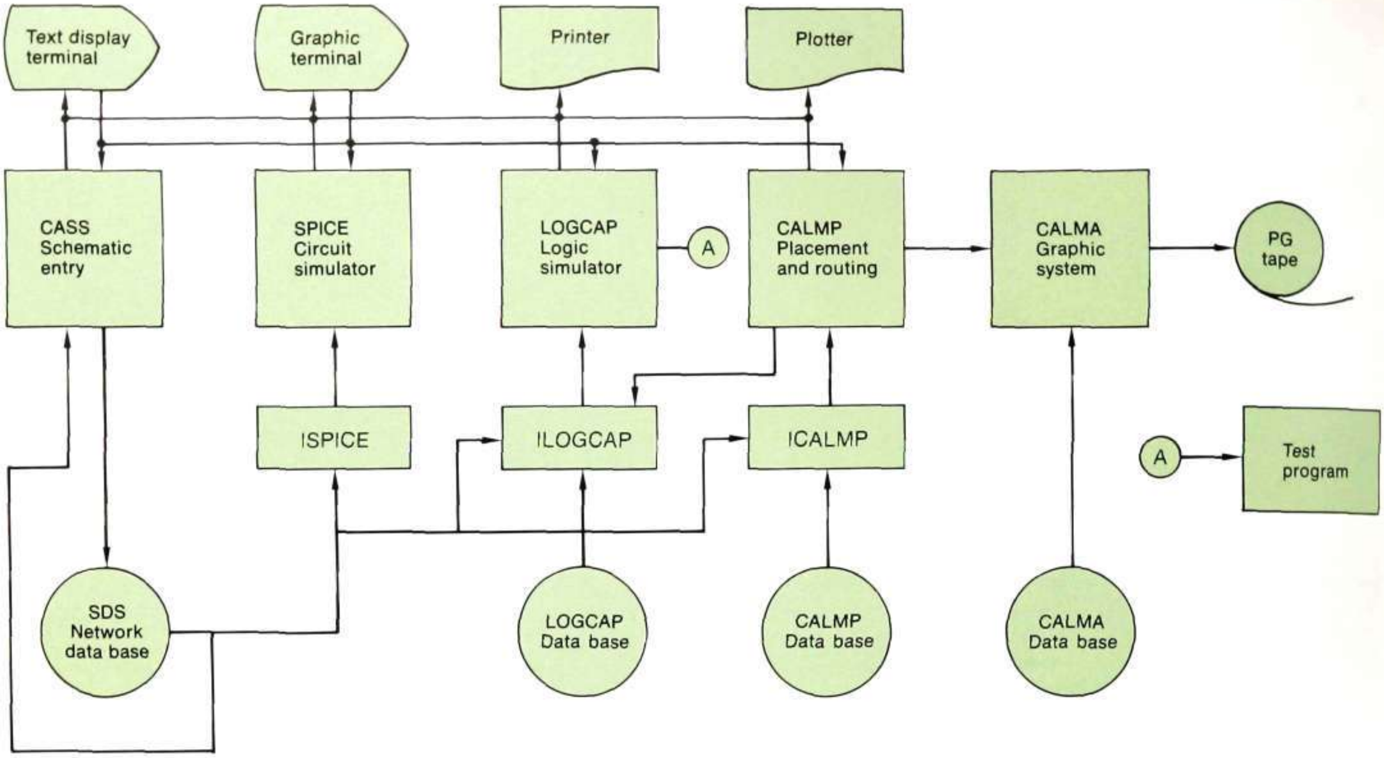


Fig. 6
The main programs in the CAD system.
The schematic is entered into the data base, and the network list is automatically extracted using SDS from Silvar Lisco.
The logic function is verified against the requirement specification with the aid of LOGCAP from Phoenix Data Systems.
The cells are positioned on the chip surface and connected by means of CALMP from Silvar Lisco.
Ericsson LSI Design Center[1] has developed programs that unite the different main programs into an integrated system

nal can be connected to the computer either direct or via a 1 200 baud modem.

The main programs in the system are
- schematics entry (SDS from Silvar Lisco)
- circuit simulator (SPICE)
- logic simulator (LOGCAP from Phoenix Data Systems)
- automatic placement and routing (CALMP from Silvar Lisco).

Ericsson has also developed a number of programs that unite the different main programs into an integrated system, fig. 6.

Procedure

Schematics entry

The designer builds up the circuit using library cells, which are fed into the CAD system from a colour graphics display. During the work the display shows a menu, with the cells that have been selected from the library on one side and editing commands on the other, fig. 7.

The graphic display is equipped with a digitizer and an electrically connected pen or "mouse". When the mouse is moved, a cursor (a cross) is moved on the screen. The cursor is placed over a cell designation or an editing command on the screen. When a key is pressed, the cell is selected or the command is executed. The cells are positioned and connected in accordance with a previously prepared logic diagram, which is gradually built up on the screen. A paper copy of the completed diagram can be printed for test or documentation purposes.

The schematics can be entered hierarchically, figs. 7–9. At the top level the circuit is represented by a few blocks and its inputs and outputs. The different blocks are given unique names.

At the next level the contents of each individual block are shown. The number of levels is limited only by practical aspects.

The schematic that has been entered is stored in a network data base with a hierarchic structure. Information for the subsequent verification and layout programs is automatically fetched from the data base.

Simulation

The designer must provide the simulator (LOGCAP) with run commands and input signals. All other information, such as network list and the individual delays of the cells, are automatically fetched from the data base. The delay times are adjusted with respect to the load capacitances on the outputs of the cells.

Simulations can be carried out for variations in process, temperature and voltage. The result is printed out or shown on the display.

The simulator permits fault simulation, which is a tool for compiling basic data for the testing of finished components. It is usually based on the input signal pattern used in the function simulation. The designer tries to make the input signal pattern complete so that as many faults as possible can be detected.

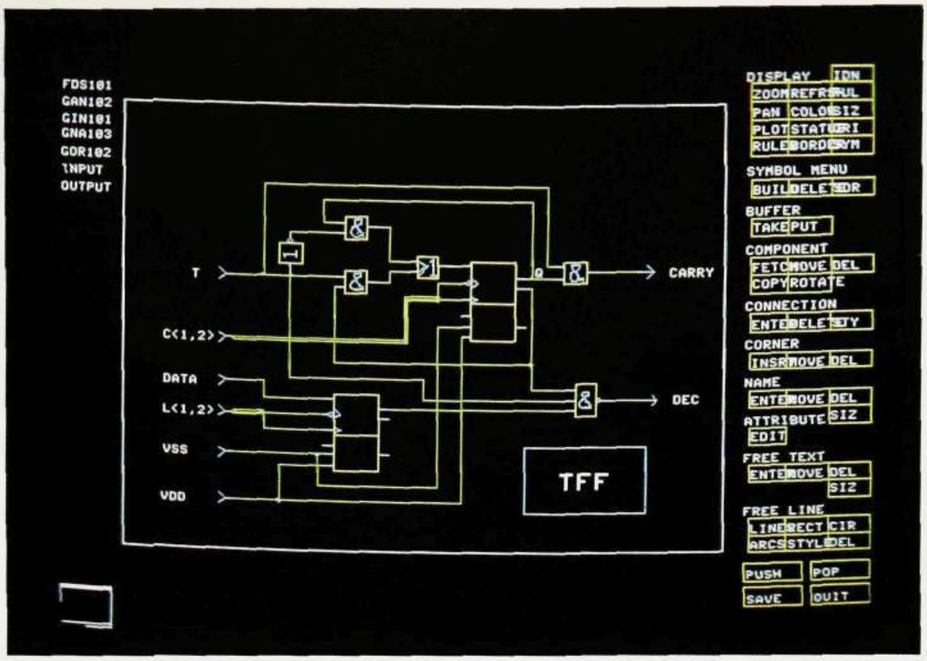


Fig. 7
The schematic can be entered at several hierarchic levels, which simplifies the design work. The figure shows a diagram at the lowest level, the cell level. A function, represented by one schematic, results in one symbol

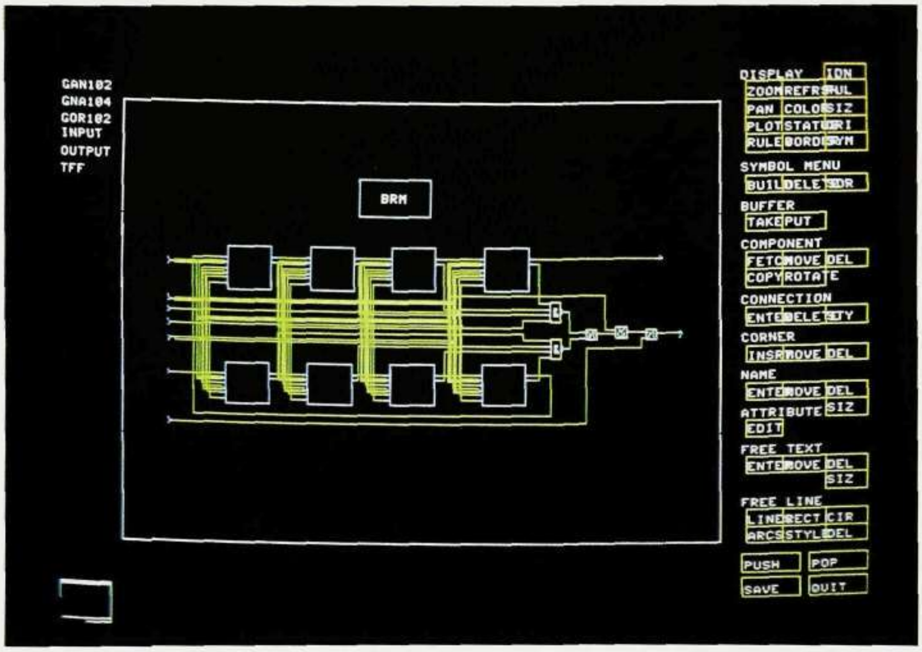


Fig. 8
At the next level, the block level, a diagram is created out of the symbols generated at the level of fig. 7

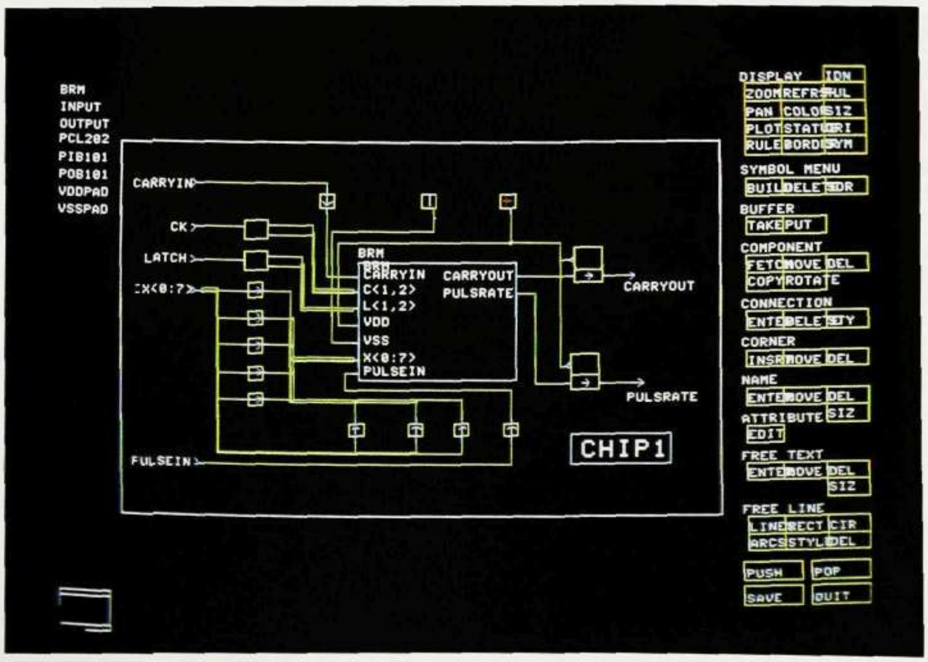


Fig. 9
The top level, the chip level, comprises only one or a few blocks, together with inputs and outputs, called pad cells

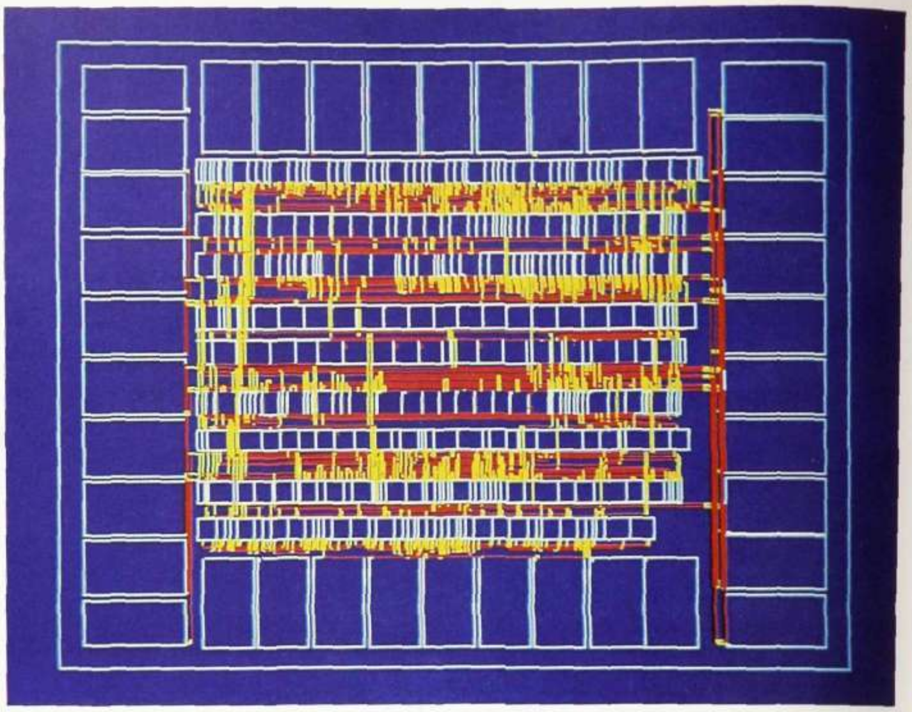


Fig. 10
Placemant and routing are made in such a way that the I/O cells with their bond pads are placed around the periphery, and other cells and connection channels are placed in the centre

Automatic placement and routing
When the simulation result is satisfactory it is time for the physical realization of the circuit. To place the cells and connect them you use the automatic layout program CALMP. The input data for the program is obtained from the network data base.

All standard cells have the same height but different width. The connection channels are given the height needed for the connections. The usual channel height is 0.1–0.2 mm.

The I/O cells with their bond pads are placed around the chip periphery, with the other cells in rows inside, fig. 10.

Line capacitances
When the layout is finished, the connection capacitance of each node can be calculated automatically and fed back to the logic simulator. An extra run can then be made to check that the time conditions are met. If this is not the case the layout must be modified. For example, cells in a part of the circuit where the timing is critical can be placed close to each other.

Cells

Each cell has a specification, with information regarding function, size, delay times, load dependency, power consumption etc. The specifications are the result of careful circuit simulations and form the basis of the designer's choice of cell. Some of the most common cells are listed in the fact panel on the left.

Standard cells
Most cells with digital function have a standard height of 0.1 mm, but the width can vary. They can be positioned automatically and connected in rows in the circuit.

Building block cells
The building block cells are digital or analog cells of non-standard height and width, which are also larger than the standard cells. ROM and RAM are building block cells.

I/O cells
The I/O cells (PAD cells) comprise the area for connecting the bond wire between the circuit and the package pin, protective circuits and transistor stages for input or output signals. They have a standard height of approximately 0.5 mm, but the height is dependent on the size of the feeding loop that must be run around the circuit. This, in its turn, is dependent on the number of outputs and their power requirements.

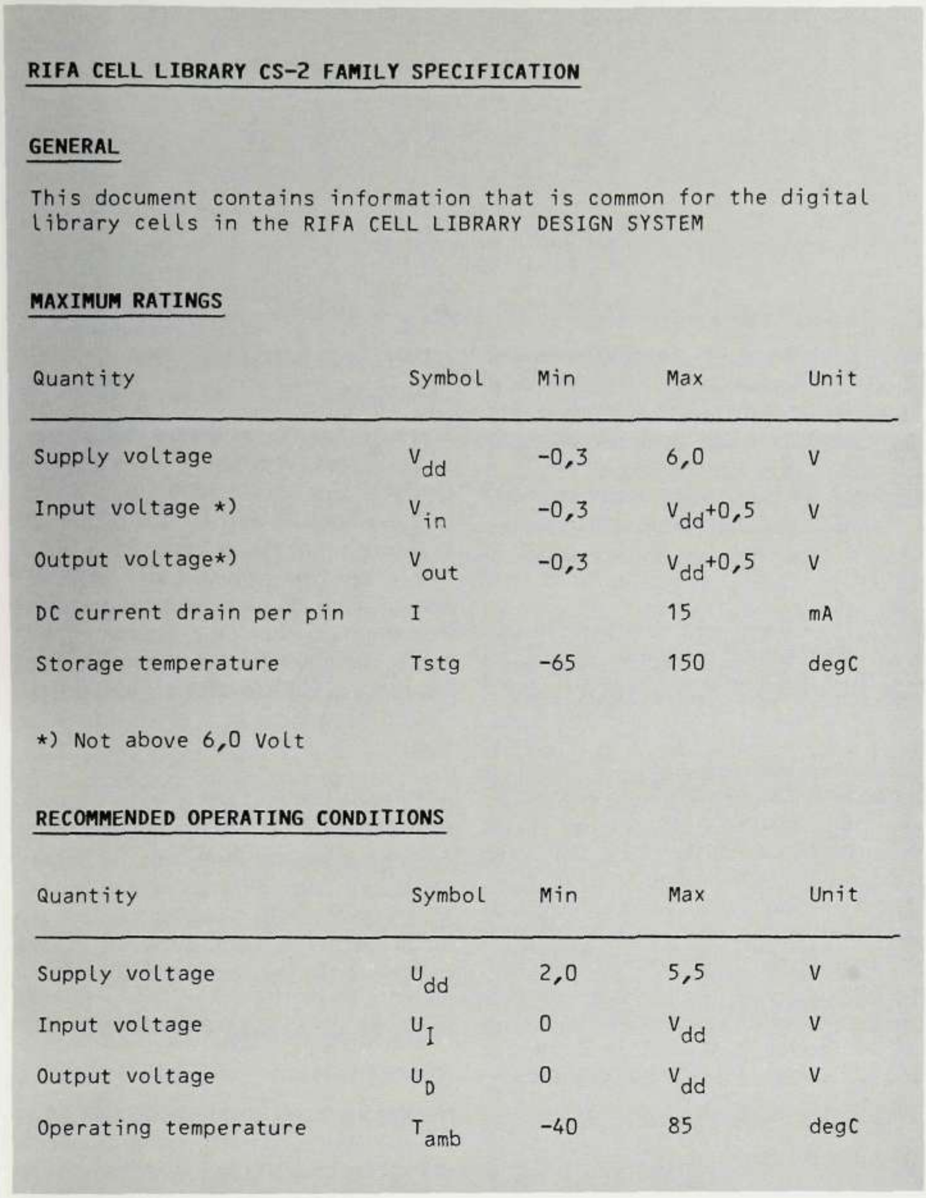
Circuit simulator

The CAD system includes the circuit simulator SPICE, which is normally used when designing new cells. The function of the cells, and particularly the delay, is tested for three cases: the best, typical and the worst. The cell designer has taken into consideration the variations in process, temperature and supply voltage that lead to the three cases. The data obtained from the simulation is given in the data sheet for the cell and is also fed into the library of the logic simulator.

In those cases where a circuit is to work with a voltage or ambient temperature outside the normal range, the circuit simulation must be repeated using the actual conditions. A network description in the SPICE format has been pro-

Cells in RIFA's library

Gates
Multiplexers
Latches
Flip-flops
Shift registers
Counters
Oscillators
Cell compiler for ROM
I/O cells with bond pads
Analog cells
Special cells, e.g. capacitors



RIFA CELL LIBRARY CS-2 FAMILY SPECIFICATION

GENERAL

This document contains information that is common for the digital library cells in the RIFA CELL LIBRARY DESIGN SYSTEM

MAXIMUM RATINGS

Quantity	Symbol	Min	Max	Unit
Supply voltage	V_{dd}	-0,3	6,0	V
Input voltage *)	V_{in}	-0,3	V_{dd}+0,5	V
Output voltage*)	V_{out}	-0,3	V_{dd}+0,5	V
DC current drain per pin	I		15	mA
Storage temperature	Tstg	-65	150	degC

*) Not above 6,0 Volt

RECOMMENDED OPERATING CONDITIONS

Quantity	Symbol	Min	Max	Unit
Supply voltage	U_{dd}	2,0	5,5	V
Input voltage	U_I	0	V_{dd}	V
Output voltage	U_D	0	V_{dd}	V
Operating temperature	T_{amb}	-40	85	degC

Fig. 11
A family specification for a cell library circuit

duced for each cell, which simplifies such simulation. The normal simulation is made for the following operating range:

– Voltage	4.4 to 5.6 V
– Temperature	−40 to +100°C

The permitted spread in the manufacturing process gives a factor of 3 between the largest and smallest delay. The fact panel on this page contains a specification for one of the cells in RIFA's cell library.

Testability

One basic rule for the designing of integrated circuits is that if a circuit cannot be tested it cannot be manufactured. This means that already at an early stage the designer must plan how the circuit is to be tested. The design should be such that the circuit is easy to test.

Reasons for testing

Circuits are tested direct on the wafer in order to detect faulty circuits before assembly. Measurements are combined with a functional check that the circuits are logically correct and that the time conditions of the specification are met. In addition a check is made that the analog electrical parameters also meet the specification. The process is repeated after encapsulation in order to sort out the circuits that are to go on to quality testing.

Circuits are also tested at a final quality control stage, where, in addition to the previous tests, the long-term reliability is tested under different environmental conditions, e.g. variations in temperature and humidity.

A characteristic feature of the different test programs is that the measurement tolerances applied are made successively less narrow. By using the narrowest limits during the tests on the wafer the probability is increased that the circuits will pass the tests after encapsulation, so that not too many circuits are encapsulated unnecessarily. However, the limits are still so narrow in the final test program that the original specification is met with a good margin.

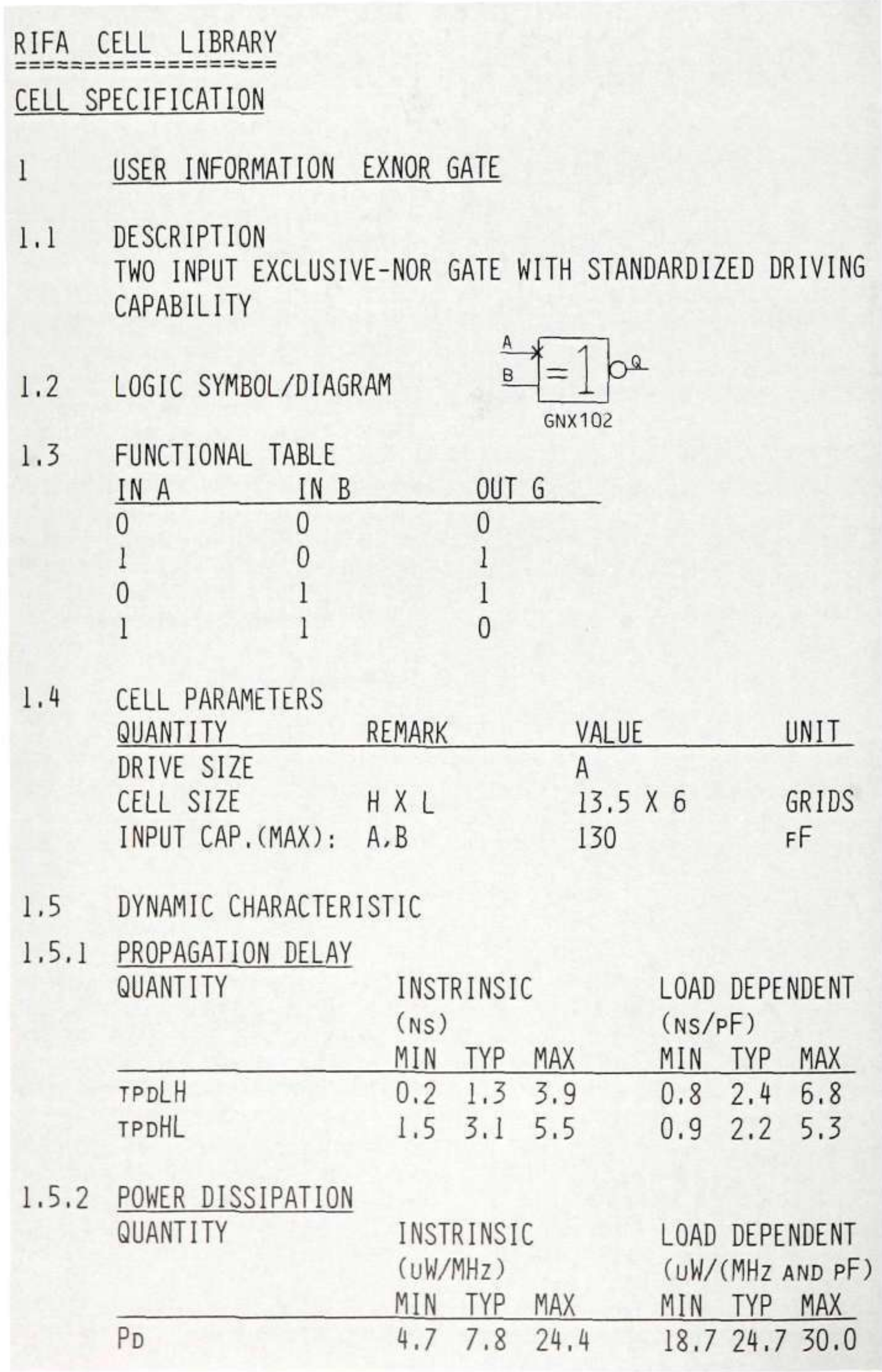
Built-in testability

Some cells have been given a special design in order to facilitate testing of cell library circuits. All output buffers are designed so that in the DC test mode they can, by means of command, simultaneously be set to the same logic state, high, low or tristate.

Another feature that simplifies testing is that all cells with a memory function, such as flip-flops and shift registers, can be connected together by means of a command to form a single, serial shift register. This makes it possible to use the scan-loop method for testing sequential circuits. With this method the whole circuit is reconnected to become a number of combinational networks separated by registers. Programs are available that can automatically generate test patterns for combinational networks with a high degree of fault coverage. This opens a possibility of automatic test program generation for a whole circuit.

The library includes a special input cell which can sense three different levels. This cell can be used to set a circuit to the functional mode, scan test mode or DC test mode. All these test aids are available to the designer. At the very least the designer must provide the basic data for the functional testing.

Fig. 12
A data sheet from RIFA's cell library



RIFA CELL LIBRARY

CELL SPECIFICATION

1 USER INFORMATION EXNOR GATE

1.1 DESCRIPTION
TWO INPUT EXCLUSIVE-NOR GATE WITH STANDARDIZED DRIVING CAPABILITY

1.2 LOGIC SYMBOL/DIAGRAM

1.3 FUNCTIONAL TABLE

IN A	IN B	OUT G
0	0	0
1	0	1
0	1	1
1	1	0

1.4 CELL PARAMETERS

QUANTITY	REMARK	VALUE	UNIT
DRIVE SIZE		A	
CELL SIZE	H X L	13.5 X 6	GRIDS
INPUT CAP.(MAX):	A,B	130	FF

1.5 DYNAMIC CHARACTERISTIC

1.5.1 PROPAGATION DELAY

QUANTITY	INSTRINSIC (NS)			LOAD DEPENDENT (NS/PF)		
	MIN	TYP	MAX	MIN	TYP	MAX
TPDLH	0.2	1.3	3.9	0.8	2.4	6.8
TPDHL	1.5	3.1	5.5	0.9	2.2	5.3

1.5.2 POWER DISSIPATION

QUANTITY	INSTRINSIC (UW/MHZ)			LOAD DEPENDENT (UW/(MHZ AND PF)		
	MIN	TYP	MAX	MIN	TYP	MAX
PD	4.7	7.8	24.4	18.7	24.7	30.0

Interface between the designer and RIFA

The work interface between the designer and RIFA is normally at the physical design stage, i.e. after functional design and verification and before placement and routing of the cells with the aid of the layout program CALMP. RIFA will also provide designer assistance during the work on the logic design and in those cases where the customer does not want to do the design work but orders it according to a given specification.

In CALMA the CALMP picture is transferred to the final silicon layout. A magnetic tape is generated with the pattern separated into different mask layers. This tape is then used to control the manufacture of the different masks needed in the production process[6].

Reduced printed circuit assemblies

Designing a cell library circuit is just as easy as designing a traditional circuit for mounting on a printed circuit board. In fact, it is even easier, since CAD tools are available for the IC design.

The cells do not contain anything new compared with what is already available as components. The new feature is the adaptation to the actual need. For example, a component package contains 4 NAND gates. With cell library technique only the required number of gates is included. Memories of RAM or ROM type can also be designed in the size required.

Most functions exist only in the form of circuit diagrams at higher levels. What is new about using the Computer-Aided Schematic System is that circuit drawings can now easily be modified. For the same reason they can be used in several designs. In this way the designers create source products for each other.

Design time

The design time varies greatly depending on the complexity and the performance of the desired circuit. The following general figures give an idea of the proportion of the design time required for each of the different stages:

– Schematics entry	1 week approx.
– Logic simulation and verification	at least 2 weeks
– Layout	1–3 days

The times given above do not include the time required to prepare a logic circuit diagram and a test pattern on the basis of a function specification. It may then be necessary to carry out simulation of the circuit, followed by modification of the diagram, repeatedly. The time needed for a complex circuit can be considerably longer than what is given above.

The present aim at RIFA is to be able to develop prototypes in approximately 12 weeks in normal cases. In the future this time will be reduced.

Training

Three courses have been developed jointly by Ericsson, RIFA and SIFU Elektronik (the Swedish Institute for Corporate Development):

- a two-day introduction to semicustom design in general and the aid system for cell library circuits in particular
- a two-day course giving an orientation in greater detail concerning the computers and terminals used in the CAD system
- a five-day course on how to handle the Computer Aided Schematic System and how to simulate logic functions. The course also gives a general insight into how cells and connections are placed on the chip surface physically.

SIFU Elektronik has also, on the initiative of ELLEMTEL AB, developed a four-day continuation course dealing with practical applications in which the LOGCAP simulator is used.

Constituent parts with intrinsic value

Each of the three constituent parts
- prefabricated cells
- CAD system
- set of design rules

have an intrinsic value.

For example, new cells can be created for a full custom design, but the two other constituent parts are used unchanged. It is also possible to make considerable changes in the CAD system alone.

Further development

A cell library is continually undergoing further development. Primarily new cells are added, but the CAD systems are also being refined. Better simulation facilities are needed when designing large VLSI circuits. For example, a multi-level simulator is to be introduced.

The method used for converting the cell library from one process to another will also be improved. The cell library can then quickly follow when the process technology is improved. A conversion of the cell library to 2μm CMOS is expected to be completed in 1986.

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Man-Machine Communication in AXE 10

Thomas Backström and Jan Lambert

Ericsson has developed a man-machine communication system, MMS, which increases the efficiency of the AXE 10 maintenance activities. Previously commands were fed in on a conventional terminal in accordance with operating instructions. With MMS the operator obtains a computerized aid which uses dialogue text on a display screen and menus for choosing the tasks to be performed. The data required for the task is requested via the screen, and after input, validation and activation the transmission of all necessary commands is automatically initiated.

The authors describe the reasons for developing MMS, the structure and scope of the system and its potentialities.

UDC 621.395.3:681.327.12
electronic switching system
maintenance engineering
man machine systems
computerized monitoring
telephone exchanges

The demands made on the quality and reliability of telecommunication facilities are high. Customers require rapid and reliable connection, good transmission quality and correct charging. The telephone administrations can meet these requirements only if the telephone network has good operation and maintenance characteristics.

AXE 10 has a sophisticated operation and maintenance system with a large number of functions. In an AXE 10 exchange most operation and maintenance activities are carried out by means of man-machine communication. The way in which this communication is arranged is therefore of fundamental importance to the quality of the services offered to the subscribers.

MMS increases the efficiency of the operation and maintenance activities in AXE 10. The operator does not need to feed in commands on a typewriter terminal in accordance with the operating instructions for the exchange, since MMS is a computerized aid that presents a menu from which he selects the next job, and then only has to feed in the necessary information on forms presented on a display unit.

Operation and maintenance of AXE 10

A large proportion of the AXE 10 operation and maintenance functions are automatized and integral to the system. The operator's job consists of *supervising the operation of the system, introducing changes and analyzing, locating and clearing faults.*

By operational activities are meant actions that adapt the exchange to the changing environment in the network. They include connection of new subscribers, traffic recording and connection of new junction lines.

Operational activities are thus normal every-day jobs, which do not concern faults or fault tracing in the exchange. Operational activities are normally initiated by a work order, which leads to the action that adapts the exchange to the new situation, fig. 2.

By maintenance is meant the direction and repair of faults. Maintenance ac-

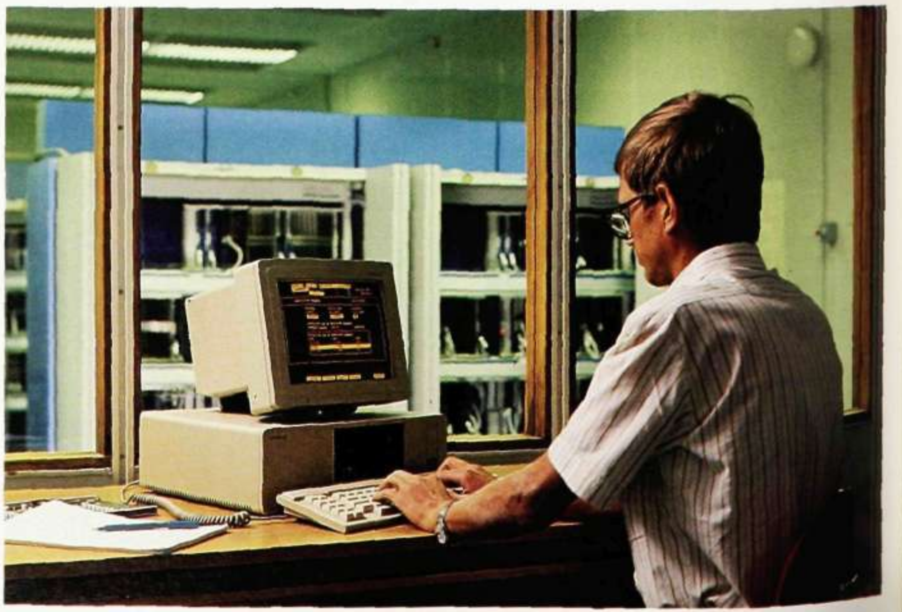

Fig. 1
The MMS work station gives access to an efficient tool for both local and centralized operation and maintenance activities

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tivities are initiated by abnormal conditions in the exchange, i.e. conditions that affect the quality of service. Such situations are detected by the system's internal supervisory functions, and the operator is informed by means of alarms. Faults can also be detected by subscribers. When an alarm or a fault complaint from a subscriber is received, the operator must take action to clear the fault, fig. 3.

The operating activities constitute approximately 55% and the maintenance activities approximately 45% of the total operation and maintenance activities. About 80% of the operation and maintenance work can usually be carried out by operators with limited knowledge of the AXE 10 system. Only 3% of the activities require experts with detailed knowledge of the hardware and software in AXE 10.

Traditionally, the operation and maintenance work is managed with the aid of a typewriter terminal and an operating manual. The manual contains instructions for the different tasks. The instructions are given in the form of flow charts with supplementary text, which describe, step by step, what the operator should do. Fig. 4 shows the flow chart for using the operating instructions. The manual includes approximately 400 operating instructions.

In addition, the manual contains descriptions of the commands and printouts that form the basis for the man-machine communication. Fig. 5 shows an AXE 10 command.

Man-machine communication

The experience gained from the operation and maintenance work shows that, in general, the communication between man and machine has been satisfactory. However, in certain respects there is room for rationalization, a fact which is also made clear in the comments and views put forward by administrations.

Each individual command initiates local changes in the system. Many commands also contain the same parameters.

When carrying out a job in accordance with the operating instructions, the operator may have to input the same pa-

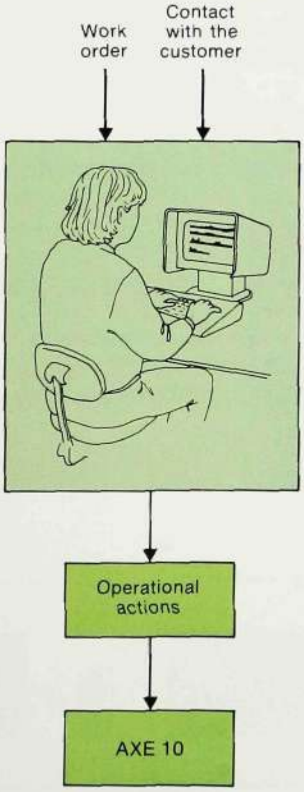


Fig. 2, right
Operation of AXE 10

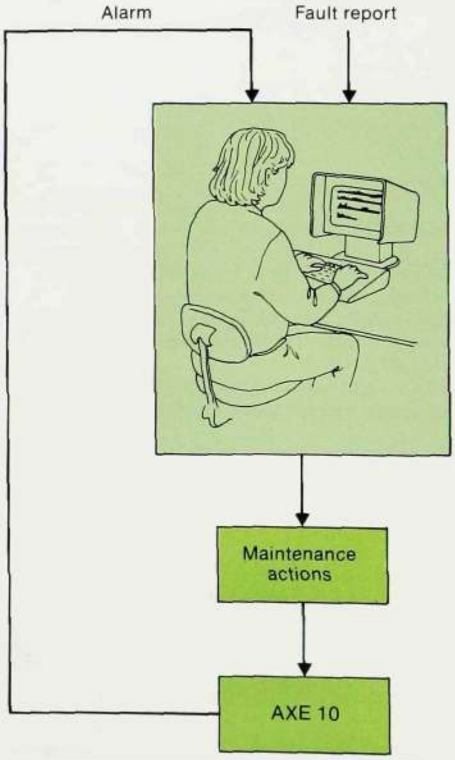


Fig. 3, far right
Maintenance of AXE 10

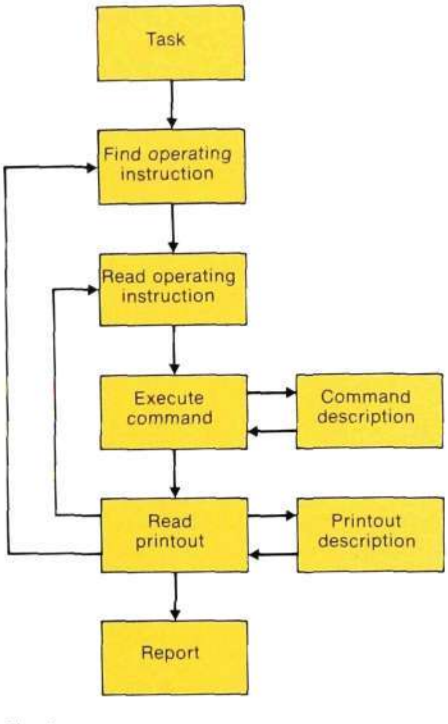


Fig. 4
The work flow during traditional operation and maintenance activities
The flow is not unique to AXE 10 but typical of complex processes in which instructions are used as aids for the operator

Fig. 5
Command

```
SULII:SNB=7190000, DEV=LI−10;
```

The command SULII is an abbreviation of Subscriber Line Initiate and is used to connect subscribers. In the command given above subscriber number 7190000 is connected to line circuit 10.
The basic structure of the AXE 10 command language is shown in the figure.

Between 500 and 700 commands are used, depending on the application.

rameters several times. In addition, the present language entails a lot of keying for most commands, fig. 5. Simplification of the input procedure can lead to great advantages to both operators and administrations.

The operating manual is extensive, mainly because a modern telephone exchange is a complex system. Another fact that contributes to the size of the manual is that such a handbook must be of a general nature so that it can be used by different categories of operators in administrations with widely divergent ways of working. A simplified manual, or even no paper manual at all, is a wish often expressed by administrations.

Experience gained from the operation and maintenance of AXE 10 exchanges shows unequivocally that the administrations want to adapt the operating procedures to their internal work methods. The requirements in this respect differ, and the only authority on the individual needs is the administration itself. It therefore seems a natural development to give the administrations facilities for designing their own operating procedures. Technically all such adaptation to organizations and individuals must be done as close to the user as possible, and one way of achieving this is to use intelligent display terminals.

Demands made on communication systems

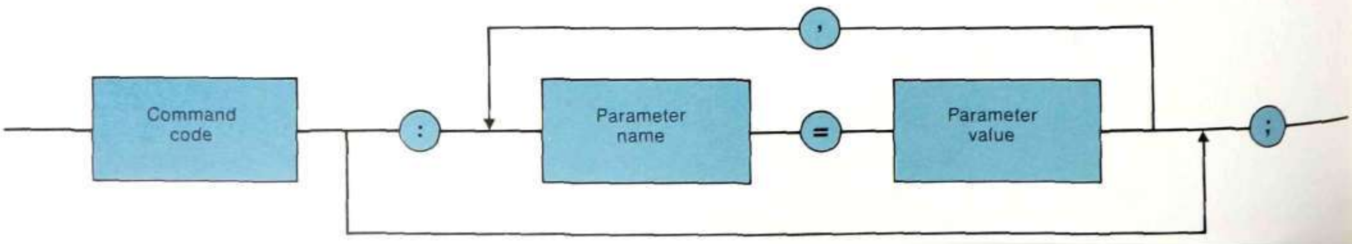
When a new system for man-machine communication is to be designed great things are expected from the new system. All requirements, wishes, views etc. must be considered. Fig. 6 shows typical results from field studies of the demands users make on computers and data processing systems. It is impossible for one design to satisfy all demands, especially as some of them are likely to be contradictory. A good computerized communication system must

- meet the demands of the process being controlled or supervised
- meet the operator's needs and requirements, i.e. be adaptable to the operator's actual work situation
- make the invisible visible, i.e. use the possibilities offered by the medium to present information in such a way as to facilitate the operator's work.

Transferred to AXE 10 and MMS this means:

Meet the demands of the process
Today, the communication with AXE 10 is handled with the aid of a language which contains commands and printouts. By means of this language the necessary messages can be exchanged between the operator and the processing system. The language, which is in accordance with CCITT recommendations, is long established and well tried. It was therefore the obvious choice for the communication between MMS and AXE 10.

Meet the operator's needs and requirements
There are two sides to this demand. One concerns administrations and the other concerns the individual operator. Administrations make different demands, intended to enable them to adapt operating procedures to suit their own type of organization. Since it is impossible to create a product that suits everybody, the alternative is to design a standard version of the operation and maintenance system, together with a design aid, so that the administrations that so desire can carry out their own adaptation. This is the method chosen for MMS.



- short reply times
- easily understandable dialogue
- interactive aids
- easy handling
- clear fault messages
- few system disturbances
- simple logging in and out
- system messages in clear text
- good text editor
- uniformity
- adaptable to the user level
- extensive programming and test aids
- clear choice of functions
- ability to cope with use errors
- flexible and compact enquiry facilities

Fig. 6
A typical result of field studies of the user demands on computers and data processing systems

On the part of the individual operator this requirement means that he is given a tool that is well suited to the work to be done. By tool is then meant both the dialogue design and the design of the tasks. Since there are several operator categories with varying knowledge of AXE 10 and the telecommunication network, the dialogue must also be adapted to the users' level of knowledge. This means that there can be several versions of a task, depending on what type of operators are to carry out the job. For example, the task *connection of a subscriber* will be different when it is carried out at a sales office compared with when it is done locally at an exchange, partly because the two jobs are so different.

Dialogue design also includes choosing the language for the dialogue. The user's native language should be used wherever possible.

Make the invisible visible

Compared with conventional communication media the computer has unique means of facilitating the operator's work because of its ability to present processed information.

In any form of communication it is necessary to know where you started, what has been done, where you are, where you are going and how to get there.

For an AXE 10 operator this means that all known facts that are relevant to a task are displayed on the screen, and that data only has to be input once, even if the same data is used several times during the job.

It must always be possible to obtain relevant auxiliary information. Such information can consist of data from previous tasks, various types of descriptions, valid syntax rules and value ranges, the purpose of auxiliary functions in the computer, etc. This type of information is often scattered and difficult to get hold of, and thereby invisible. It is made meaningful and visible by being assembled and related to the appropriate tasks.

MMS

Personal computers are now sufficiently powerful to provide the support needed to improve man-machine communication in AXE 10. Personal computers are therefore used for MMS. This makes it possible to adapt the system to suit not only different administrations and operators but also different AXE 10 applications. MMS can be used in AXE 10 exchanges already in operation as well as in future exchanges.

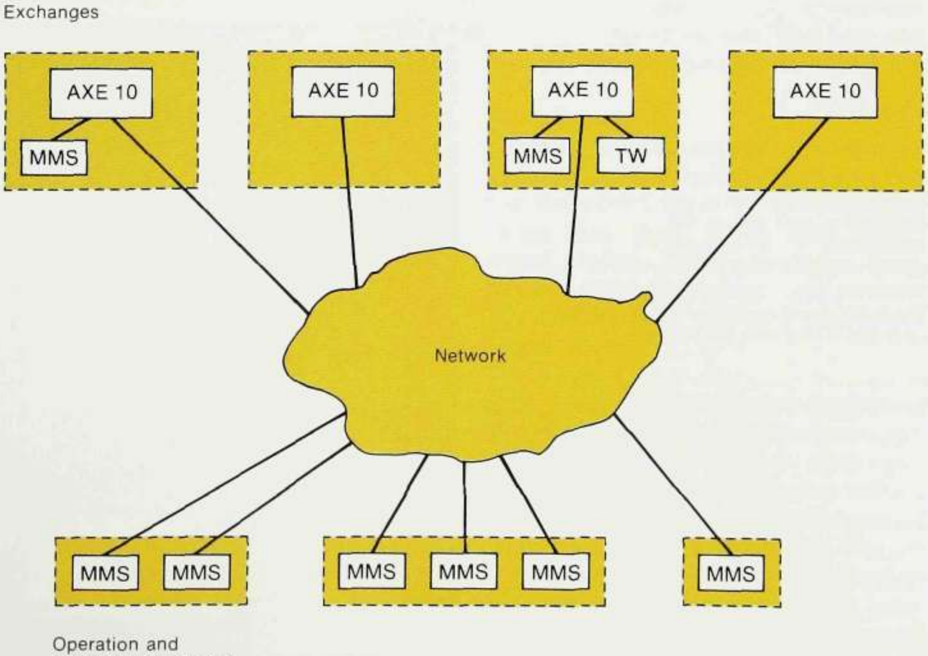


Fig. 7
MMS in the telephone network

The operation and maintenance activities are managed locally at exchanges or from an operation centre. MMS can be used in both cases, fig. 7. It is connected to the exchange or centre via either point-to-point or switched circuits.

SYSTEM STRUCTURE

MMS comprises two main parts: jobs and a support system.

A job comprises a program that controls the work, and a set of forms that are displayed on the screen. The support system contains functions for creating, storing, changing, testing and executing jobs, fig. 8.

From the point of view of AXE 10, MMS functions as a conventional terminal, which sends commands and receives printout data for presentation in accordance with the established AXE 10 method. The information presented to the operator is of course related to the operator's tasks but also adapted to suit the required level of knowledge.

The support system is written in PASCAL and assembler. The job programs are written in a high-level language specially designed for the purpose.

Jobs

The job concept is fundamental to MMS.

By job is meant a well defined task which is to be carried out by an operator towards AXE 10. A job can correspond to an operating instruction, part of an instruction, parts of several instructions or even several whole operating instructions.

Jobs are complete in the sense that all actions that need to be taken towards AXE 10 in order to carry out the task in question are built into the job. The operator feeds in telephone terms and quantities, and MMS handles the communication with AXE 10, the operation and maintenance system AOM 101 or other systems.

A job can be considered as an adaptation of AXE 10 tasks to the operator. In this adaptation, other factors are also taken into consideration, such as the operator's work situation, level of knowledge and authorization category.

Structure and scope

The use of computerized aids means that jobs can be designed so as to

- simplify tasks that occur frequently
- provide more support for less common or complex tasks
- provide more support for or simplify risky tasks, i.e. tasks that can cause traffic disturbances if they are performed incorrectly
- simplify extensive tasks.

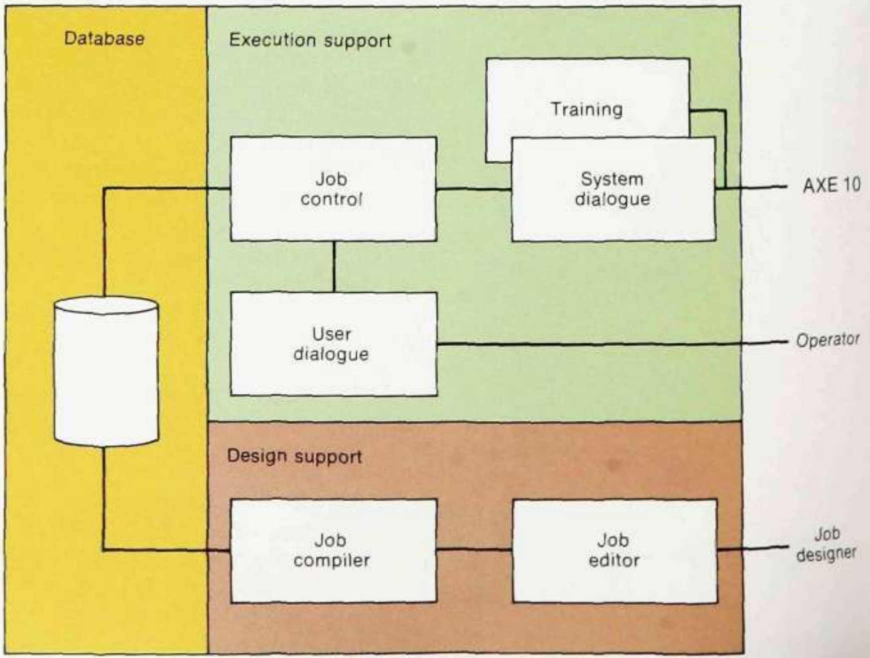


Fig. 8
Support system for MMS

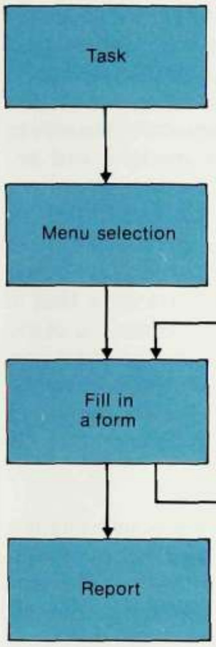


Fig. 9
The work flow when using MMS for the operation and maintenance activities

The structure of the jobs is in all essentials in accordance with the current operating manual, with a basic division into operating jobs and maintenance jobs. The subsequent organization of jobs is to a greater or lesser degree dependent on the administration concerned, operating jobs being more dependent than maintenance jobs.

On the basis of operational experience the jobs are arranged in groups within each area according to logical connections, how often they are used, in what order they are used, degree of importance, personnel categories, conventions, etc. Standard sets of jobs are then compiled for each area. If such standard sets do not meet the needs of the administrations they can easily be adapted to individual requirements, either by Ericsson or by the administration itself.

Job design

Designing a job means to adapt it to the operator and to define already existing tasks in AXE 10. The work of designing jobs out of existing tasks comprises three stages: specification of the job, description and analysis of the job content, and implementation. The two first stages are the most time-consuming.

Specification of the job includes setting the terms of reference for the job, such as objective, scope, relation to other jobs, work methods and organization.

The description and analysis of the job content must, on the basis of existing documents and specifications of the job, state the demands that should be made on the content and auxiliary functions during the implementation. Factors that are dependent on the operator, the organization and the systems are weighted and taken into consideration when designing a job.

Implementation of the job means that forms are designed, job programs written, and the completed job tested and properly documented.

Direct input of commands

There will always be a need for more direct communication with AXE 10 than what is offered by jobs. There are several reasons for this. For example, it is impossible to anticipate all situations that can occur in a telephone exchange, and thereby impossible to design jobs for such cases. Certain operator categories, mainly the system experts, need to be able to make exact diagnoses. The more exact questions they can put, the more precise will be the answers. It is thus necessary to be able to input direct commands to AXE 10.

However, MMS also facilitates direct input of commands. All command and printout descriptions are stored in MMS. There is no need to keep these descriptions stored on paper, and the general retrieve functions of the terminal quickly provide the desired information.

Support system

The support system has two basic functions: to provide an environment for the design of jobs and to execute jobs, fig. 8.

The support system software is to the greatest possible extent independent of computer make and operating system. The interface towards the computer hardware is well documented and has only a few dependencies.

The support system works as a new operating system. The user, whether a designer or an operator, works only with the support system and is not aware of the computer's own operating system.

MMS can be transferred for use in other personal computers simply by transferring the support system. The jobs can then be used unchanged.

Design support

Forms for a job are designed with the aid of a special form editor, which is part of the job editor, fig. 8. A form contains guide text, input fields with syntax check, output fields, auxiliary texts, graphic symbols, frames, and pictures of function keys. Fig. 11 shows some typical forms.

Jobs are controlled by job programs, which change forms on the screen, process the parameters fed in, send commands to AXE 10 and receive answer printouts. The job programs are created with the aid of the job editor. The job compiler then translates the programs into an intermediate code. The intermediate code is interpreted by the support system when executing the job.

The support system contains many specially designed functions that facilitate the designing of forms and job programs. For example, there are a large number of functions for the operation of the display and keyboard, including sophisticated editing and display functions. It is very easy to redesign forms, for example moving or translating texts, moving input fields, clarifying auxiliary texts and error texts. Such changes can be made without the job program being affected.

When designing such interactive products as jobs it is essential that the design testing cycle is short. For this reason the MMS support system includes not only the customary aids for interpreter execution of programs but also facilities for simulating the AXE 10 environment. This means that jobs can be tested without MMS having to be connected to AXE 10. This facility can also be used in the training of operators.

Execution

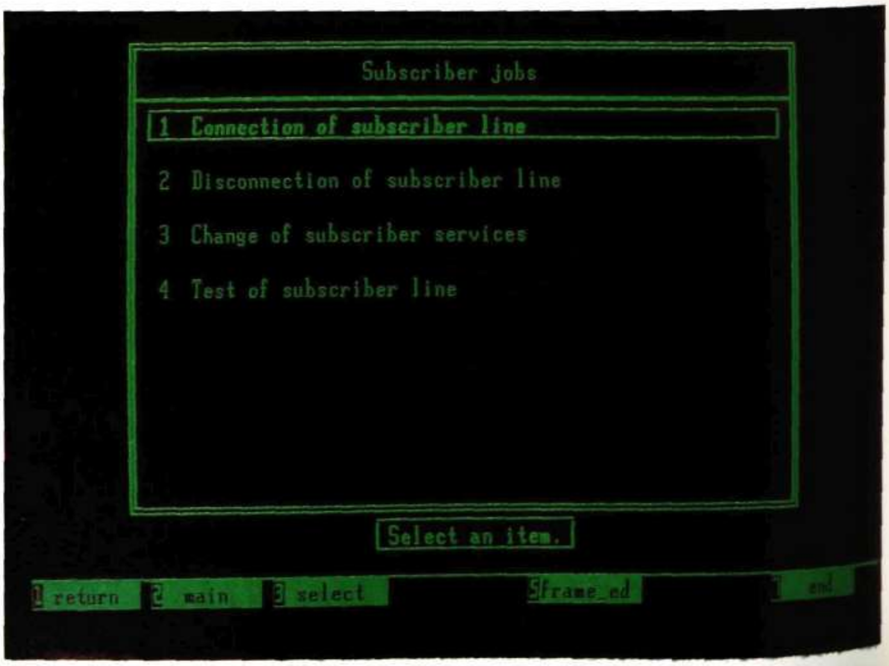
When the operator has chosen a job, the support system fetches it from the data base and presents the first form of this job on the display. When the operator has read the information in the form and entered data in the input fields he changes over to the next form by depressing a function key, fig. 9. MMS then automatically generates commands to AXE 10 with parameter values in accordance with the data the operator has entered in the input fields. A reference is made to the command description in the data base, which enables the system to identify the input parameters and ensures that syntactically correct commands will always be sent to AXE 10.

Printouts from AXE 10 are stored in the data base. If they contain data that is needed for the further processing of the job, MMS will analyze the printout and display the required information on the screen. All executed jobs are logged in MMS. The operator can scan this log for information.

The system dialogue, fig. 8, handles the communication to and from MMS. There are variants of the system dialogue, depending on where in the network the work station is situated. A local work station in an exchange is designed so that a typewriter protocol is simulated towards AXE 10. Other protocols are used for other places in the network.

Data base

The support system contains a data base which simplifies the designing and executing of jobs. The information stored in the data base includes
- menus
- forms
- job programs



Select an item.

Fig. 10
An MMS menu

- command and printout descriptions
- authorization data
- printouts
- text library
- job log.

There are several advantages in having the information stored centrally in a data base. For example, it means that the large amount of software that constitutes the job programs is not tied too closely to details in the AXE 10 software. Modifications in AXE 10 therefore usually only lead to changes in the data base, not in individual forms or job programs. All texts are stored in a special text bank in the data base. This means that language variants of MMS can be created by translating the texts in the text bank.

WORKING WITH MMS

Logging in and authorization check
The user gets access to a certain set of jobs by logging in at the MMS terminal, using identification, password and possibly also an identity card.

MMS has a very flexible authorization system. Each operator can be given individual authorization, which is confined to the jobs he has to handle. Modification and updating of authorization data are easy to carry out and can of course also be subject to authorization checking.

When the logging-in procedure has been completed, a menu is displayed to the operator. The menu contains only the jobs for which the operator has authorization.

Jobs
A job can be chosen either by means of a name command or by a series of selections from menus, fig. 10.

The chosen job (really a job program with forms) is fetched from the data base, and the first form of the job is shown on the screen.

The forms contain text consisting of requests and instructions, input fields where the operator must enter data, and output fields where answer printouts are shown. Fig. 11 shows some typical forms. There is no direct connection between the number of forms and the number of commands. A form can give rise to several commands, or several forms may be needed to specify one command.

A job includes support functions, which assist the operator explanatorily and helps him avoid making mistakes. Each form contains general information that explains the function of the job and the form. The operator can also supplement the forms with extra explanatory texts, special comments, etc. Each input field

Fig. 11
A job adapted to the customer's requirements. The figure shows the forms involved in the job "Connection of a subscriber line".
Figs. 11a and 11b show the first form before and after execution.
Figs. 11c, 11d and 11e show forms for specifying subscriber services. Fig. 11c also shows how auxiliary information for one of the services is presented.

Fig. 11f shows the final report of the job.

```
CONNECTION OF SUBSCRIBER LINE                 SNB SPECIFICATION

        Subscriber       Device type       Any service
        number           and number        (YES or NO)
                                           NO

        LIST OF CONNECTED SUBSCRIBERS
        SNB              DEV               SERVICES

        123454           LI-4567           YES
        988898           LI-1234           NO
        665577           LI-657            YES
        897755           LI-987            YES
        222222           LI-2222           YES
                            11
```

Fig. 11a

```
CONNECTION OF SUBSCRIBER LINE                    SNB SPECIFICATION

         Subscriber        Device type        Any service
         number            and number         (YES or NO)
         222222            LI-2222            YES

         LIST OF CONNECTED SUBSCRIBERS
         SNB               DEV                SERVICES

         444444            LI-4444            NO
         123454            LI-4567            YES
         988898            LI-1234            NO
         665577            LI-657             YES
         897755            LI-987             YES
                           10
```

Fig. 11b

has its own auxiliary function, which explains the type and structure of the parameter and gives examples. This auxiliary function is associated with the immediate syntax check on input data. The operator cannot proceed with the job until the syntax rule of an input field has been satisfied.

The operator has unrestricted editing facilities before the contents of a form are executed by means of a function key. In certain cases, but not generally, the operator also has the possibility of changing his mind after execution and restoring the exchange to the state it was in before the transaction. The operator can also park the job in order to complete it at a later time. It is even possible to interrupt the processing in the middle of a job.

Printouts from AXE 10 are stored in the data base. If information in the printout is needed subsequently during the processing it will be displayed to the operator. When the job has been completed, a final report is generated and displayed on the screen. The final report and all printouts can be fed out to a printer.

Fault messages from the AXE 10 system are always presented to the MMS operator in clear text. The message contains information concerning the type of fault, its source and the measures to be taken.

```
CONNECTION OF SUBSCRIBER LINE                    SERVICE SPECIFICATION

Subscriber number 222222          Device  LI-2222

Subscriber services               Current          New value
                                  value
Catch                             MCT-0            1
Prevent measuring                 LTE-0            1
Subscriber administration         TLI-0            1

0 = Not connected,  2 = Telephone box,  9 = BHE GD,  10 = Red list,  11 =
PABX,  12 = WT,  13 = CALC,  14 = BWT
```

Fig. 11c

CONNECTION OF SUBSCRIBER LINE SERVICE SPECIFICATION

Subscriber number 222222 Device LI-2222

Subscriber services	Current value	New value
Catch	MCT-0	1
Prevent measuring	LTE-0	1
Subscriber administration	TLI-0	14
Hot line	HLI-0	1
Alarm	ICS-0	3
Blocking	TBO-0	1
Private metering	PRM-0	1

Fig. 11d

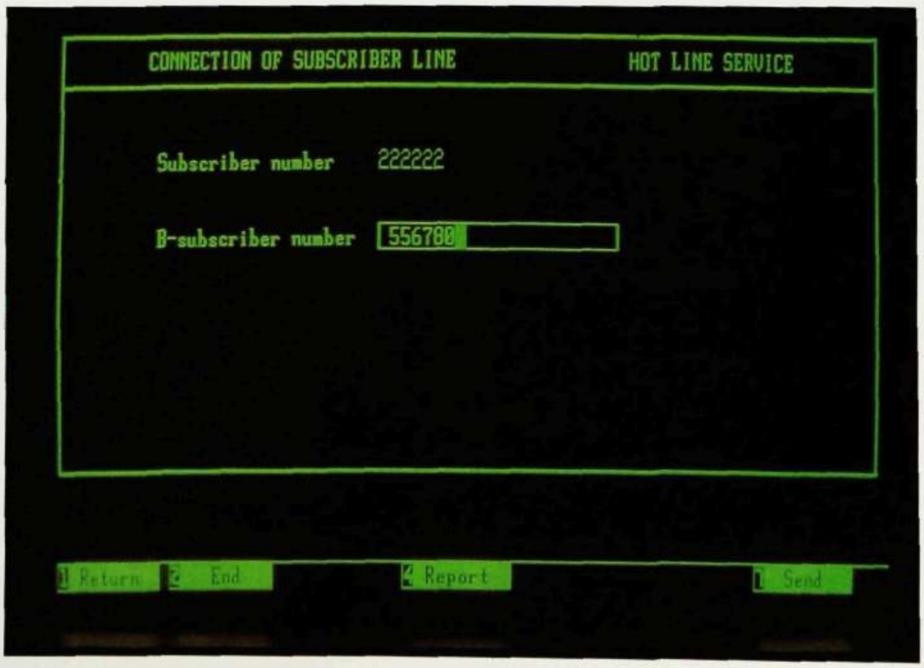
User influence

It is usually difficult to obtain the final user's views on a product at an early stage of the development. However, a dialogue with experienced operators was maintained throughout the development of MMS. A prototype of MMS was created on the basis of experience gained by operators. The prototype was used to design certain jobs, and in tests, both in the laboratory and in working exchanges. The experience obtained with the prototype was utilized for the final product. It resulted in changes in both work methods and the range of system functions. At the prototype stage experienced operators participated in the designing of jobs and in the operational testing of the system.

Summary

The technical development in the computer field, particularly of the personal computer, and the experience gained from the operation of AXE 10 exchanges has made it possible to develop a user-orientated and adaptable system for the communication between man and machine.

MMS gives more efficient handling of AXE 10 from the point of view of operation and maintenance. Instead of working with commands and operating instructions the operator using MMS works with a computerized aid where jobs are selected from menus, and the required information is fed in on forms displayed on a screen. This means many



CONNECTION OF SUBSCRIBER LINE HOT LINE SERVICE

Subscriber number 222222

B-subscriber number 556780

Fig. 11e

```
        CONNECTION OF SUBSCRIBER LINE                   REPORT

 Subscriber  Device type   Call meter   Subscriber
 number      and number    value        services

                                         HLI-1 B-no= 523445
                                         ICS-3
                                         TBO-1
222222       LI-2222       01234567      MCT-1
                                         LTE-1
                                         TLI-14
                                         HLI-1 B-no= 556780
                                         ICS-3
                                         TBO-1
                                         PRM-1
                                   8
```

Fig. 11f

advantages to administrations as well as to the individual operator:

User friendly

- Jobs can be designed to suit the work situation and the level of knowledge of the individual user.
- Auxiliary functions are available at different levels.
- The user's own language and designations can be used in the dialogue.
- The need for paper documentation is greatly reduced.
- Editing functions make it possible, for example, to change the data that has been input, add text and comments to the forms and change the design of forms.

Adaptable

- Jobs can be adapted to the organization and work methods of different administrations.
- Administrations can themselves design jobs.
- MMS can be used in both local and centralized operation and maintenance activities.
- There is a choice of computers.
- The system provides flexible authorization control.

Efficient

MMS

- simplifies the handling of operation and maintenance functions
- saves times
- gives immediate syntax check, which helps to reduce the number of communication errors.

With MMS the operating staff can concentrate on the central problems concerning operation and maintenance. MMS takes care of the routine work, such as syntactically correct communication with AXE 10, storing of printouts and interpretation of fault codes. This makes for efficient and reliable operation and maintenance activities.

During the development process the operating and maintenance activities have been analyzed and the central elements identified. These work elements will always be there. As AXE 10 is developed further the conditions for the execution of these elements will change and new facilities will become available. The flexibility built into MMS ensures adaptation to this changing AXE 10 environment.

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1. Söderberg, L: *Operation and Maintenance of Telephone Networks with AXE 10.* Ericsson Rev. *56* (1979):3, pp. 104–115.

Electronic Electricity Meter for Differentiated Tariffs

Hans Bång

RIFA AB has developed an all-electronic electricity meter with time-controlled setting of the rate. The meter is mainly intended for house-owners who can choose between electric heating and heating by other means, and who can distribute their power consumption to the times of the day, week or year when the electricity can be supplied at a lower cost because the overall consumption is low.

The author describes the problem that has led to the development of the meter, and also the function, design and use of the meter.

HANS BÅNG
RIFA AB

UDC 621.317.78:681.3.065
electricity meters*
programmed control
electricity supply industry
power system computer control

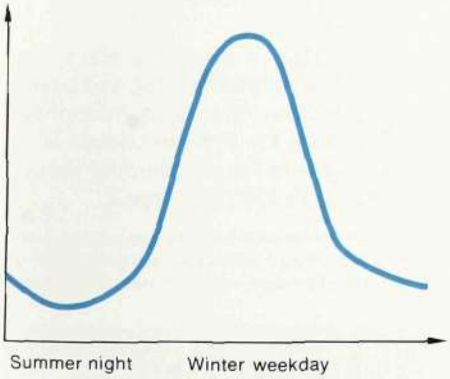

Fig. 1
The curve shows the annual variation in the marginal cost of electric energy

The power consumption in Sweden varies greatly during the year, the week and also the 24 hours of the day. During recent years the consumption during winter has grown rapidly as electricity is to an increasing extent being used for central heating, fig. 1.

Variations in consumption result in the well-known disadvantage that the power industry must dimension the power stations and distribution network for a consumption well above the average value. The production cost per kWh also varies considerably. During spring, summer and autumn, electric energy is mainly produced from water and nuclear power. During peak load periods – daytime in winter – oil and coal-fired power stations must be used. They have a very much higher production cost and also cause considerable environmental pollution.

One way of levelling out load peaks is to offer the customers differentiated tariffs that reflect the cost of producing electric energy.

The introduction of differentiated tariffs requires advanced measuring equipment on the customer's premises. Big consumers (high-voltage consumers, industries) are usually already provided with such equipment. The cost of the measuring equipment is not very important to this subscriber category.

House-owners is the largest group of customers for differentiated electricity tariffs. The electricity consumption of this group has grown substantially. Since the beginning of the 1970s the power consumption of the industrial sector has only increased by 10 %, whereas the corresponding figure for owner-occupied houses is 70 %.

In one single year (1982) about 90 000 single-family houses in Sweden changed over to electric central heating.

On the other hand, house-owners are the type of consumers that can use differentiated electricity tariffs to reduce their energy costs. They can regulate their consumption by distributing it to different parts of the day, week or year (night heating of tap water, combination boilers for electricity and solid fuel etc.).

One condition for affecting the consumption pattern of house-owners is that an electricity meter for differentiated tariffs is available. The meter must also be so cheap that the saving in energy costs remains attractive.

Fig. 2
Ericsson's all-electronic electricity meter, ZTE 351 01/1

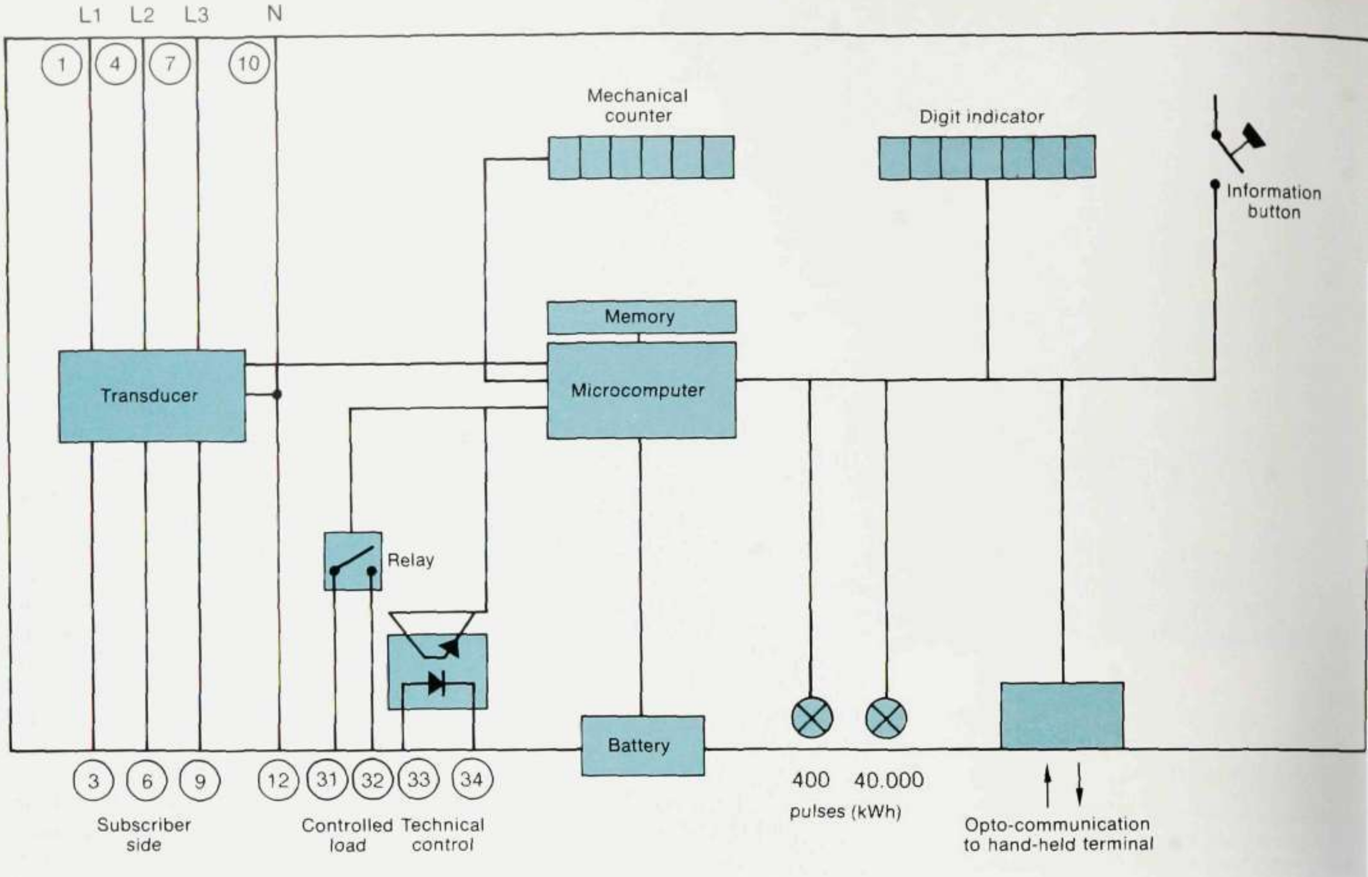

Fig. 3
Simplified block diagram of the all-electronic electricity meter. The encircled figures are the numbers of the terminals in the terminal block

Differentiated tariffs are profitable to both the producer and consumer of electricity. All-electronic meters make for simpler reading and are thus profitable to the electricity distributor.

Present electricity meters with induction meter and mechanical counters only permit simple time differentiation of the tariff. More complex tariffs and better reading methods require microprocessor-controlled information processing in the electricity meter.

The meter must also be equipped with an indicator which enables the consumer to plan actions and evaluate the results.

ZTE 351 01

The newly developed electricity meter, ZTE 351 01, differs from conventional meters in that it has a built-in tariff unit, which by means of stored program control can divide up the number of consumed kWh into four different time categories.

Transducer

The transducer is a normal electricity meter but it is fully electronic and based on the principle of analog multiplication. The data for the transducer is in accordance with the standard for induction meters SS 4060106 class 2.

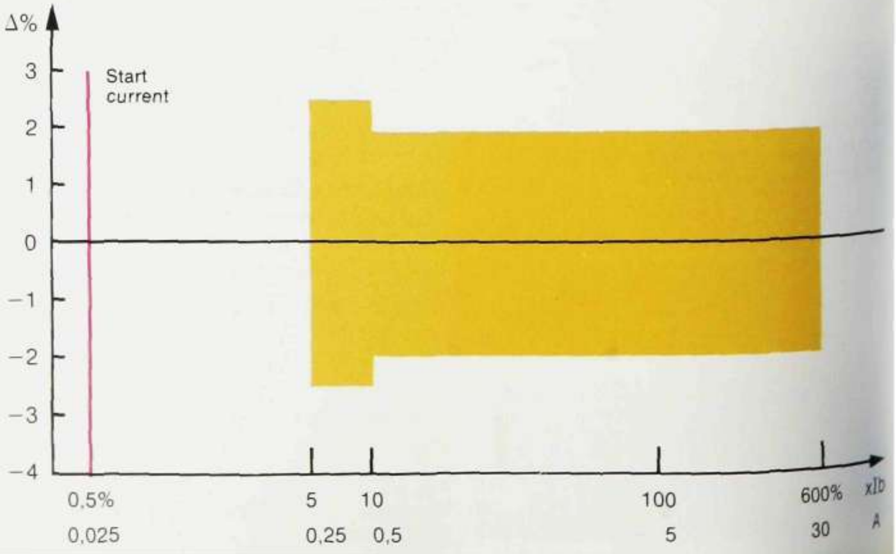

Fig. 4
The tolerance range of the all-electronic electricity meter for three-phase symmetrical load with cos φ = 1

Fig. 5
The meter-reading terminal is connected to a panel in the bottom right-hand corner of the meter. The coupling is by means of a magnet and a metal plate

Fig. 6
The customer can read off nine different registers by depressing the information button and thereby step the indicator from one register to the next

The demands made on the transducer are exacting. The electricity meter Ib=5(30)A, which is very common in the Swedish distribution network, must start at 25 mA/phase, and the maximum continuous current is 30 A/phase, fig. 4.

Tariff unit
The tariff unit controls and supervises all functions in the electricity meter and must

- sense the power from the transducer
- determine which rate applies
- set the indicator
- control communication for reading the meter.

Optical communication
Optical communication is used for all programming of the tariff unit and for reading the electricity meter. Infrared light, IR, is used, and the signals are transmitted through the plastic cover on the meter to the reading terminal, fig. 5.

Technical control
Another input is provided for technical control. It can be used by the electricity supplier, for example to obtain load management.

Digit indicator
The digit indicator contains seven-segment light emitting diode displays for seven figures, a control digit to the left and six information digits. Normally only the control digit is lit, showing the rate applicable at the moment.

When the subscriber depresses the information button the information digits will also light up, and with repeated pressing it is possible to check the state of nine registers, fig. 6.

1–4	show the amount of energy consumed at the rate in question since the meter was last read
5, 6	show the maximum amount of power the consumer has used during a programmable period of time (1–6 hours)
7	shows when the meter was last read, in the form of YEAR, MONTH, DAY, e.g. 840126
8	tests the indicator function. All figures should be eights if all segments work properly
9	shows the day and time as DAY, HOUR, MINUTE, e.g. 261114.

Mechanical counter
The mechanical counter in the meter accumulates the number of consumed kWh since the meter was manufactured. It cannot be reset to zero and can, with its six digits, indicate 999 999 kWh. With a normal consumption of 25 000 kWh/year it will take the counter approximately 40 years to step round to zero again.

Relay
A relay in the meter is used to control external load objects, for example water heater and accumulating heating systems. The relay is normally programmed to operate during periods 2 and 4, which is during nights troughout the year and during holidays.

Battery
A battery is necessary to ensure that the clock works even during a power loss. A lithium battery was chosen for the purpose. It is a primary battery with a voltage of approximately 3.4 V.

The battery capacity is sufficient to drive the clock continuously for a year in the case of a power loss. The battery life is normally in the order of seven years.

Fig. 7
Reading a meter installed outdoors in a cabinet

Changing the battery
The battery is changed by the meter reader. When it needs changing, a signal is sent to the reader via the terminal at the next reading.

Clock

The unit is equipped with a clock in order to be able to change rates. The clock is a real-time clock with calendar for YEAR, MONTH, DAY, TIME, MINUTE, so that the meter knows whether it is a leap year, Saturday, Sunday, summertime etc.

The clock is crystal-controlled and has a maximum error of ±15 minutes per year. It is set automatically when the meter is read.

Meter reading

The reading of the meter is quick and easy. A hand-held terminal is used, which is connected to the electricity meter via an optical interface, fig. 7.

Each morning the terminal is loaded with information regarding the subscribers to be read. A display on the terminal can then show the name and address of the subscribers that have to be visited by the meter reader.

When an electricity meter is to be read, the number given on the front of the meter is fed into the terminal. The terminal then generates a code that initiates communication.

Next the terminal shows the value that the summation register should have, i.e. the old reading plus the sum of the values read off the four registers. The latter registers are reset to zero when the reader has acknowledged that the sum is correct.

Summary

The all-electronic electricity meter, ZTE 351 01/1, has been developed in order to meet the demands for differentiated electricity tariffs. It has many advantages, for example:
- The electricity meter and tariff unit form a single unit.
- The unit has standardized DIN measurements.
- The meter is easy to program and read with the aid of a hand-held terminal.
- The accuracy of the electricity meter is in accordance with class 2.
- The meter has facilities for technical control.
- If the battery needs changing, an indication is given to the meter reader at the next visit.

Technical data

Transducer	
Voltage	3×220/380 V
Current	5 (30) A
Accuracy	class 2
Ambient temperature	−40 to +60°C
Dimensions	240×170×110 mm
Weight	3.5 kg approx.
Tariff unit	
Number of energy registers	4
Number of power registers	2
Latest reading	YEAR MONTH DAY
Indicator test	8888888
Current time	DAY TIME MINUTE

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ISSN 0014-0171

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