ERICSSON REVIEW

ONCE AGAIN AUSTRALIA CHOOSES LM ERICSSON
THE ROLE OF TELECOMMUNICATION
TELECOMMUNICATION PROBLEMS IN DEVELOPING COUNTRIES
REED SWITCH WITH INTEGRATED MICRO CIRCUITS
OPERATION AND MAINTENANCE CHARACTERISTICS OF AKE
GENERATION OF THE BASIC FREQUENCIES FOR FDM SYSTEMS
BRANCHING EQUIPMENT FOR FDM SYSTEMS

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EDITOR GUSTAF O. DOUGLAS

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Contents

COVER
Numerically controlled equipment for automatic mounting of cross point relays on reed switch boards. The equipment places the relays on the board and then bends the soldering and fixing pins on the back of the board

Once Again Australia Chooses LM Ericsson —AXE Becomes the System of the 1980s

The Australian telecommunications administration, formerly APO, now TELECOM, occupies a prominent position among the world's telecommunications administrations. Its reputation is based primarily on its technical knowledge and ability. Decisions concerning the introduction of new systems and new equipment are preceded by very careful investigations of such things as general performance, function, price and delivery potential. LM Ericsson have had the privilege of cooperating with TELECOM (APO) for many years as regards crossbar systems.
In September 1977 TELECOM announced its intention to successively go over to AXE for its telephone exchanges. The decision had been preceded by a thorough evaluation of the systems offered by the various manufacturers.

The article describes past development in Australia in the telephone exchange field and how this has led to a decision to go over to the AXE system.

The Australian telephone network was originally built up using Strowger type equipment in the exchanges. In the middle of the 1950s, however, the telecommunications administration (APO) found that new systems which promised better performance than the Strowger system were available on the world market. In 1958 an international tender competition was announced, which in 1959 led to APO accepting the LM Ericsson AR system as the standard for the whole country. Since then AR systems have been manufactured by the LM Ericsson Australian subsidiary company and under licence by factories belonging to ITT and Plessey.

Up to September 30th, 1977, exchange equipment of the AR system type installed in Australia amounted to:
Local exchanges ARF:
2 836 500 multiple positions
Rural exchanges ARK:
451 700 multiple positions
Transit exchanges ARM:
86 100 multiple positions

In order to exploit the advantages of the SPC (Stored Program Control) technique in its existing and future crossbar exchanges TELECOM decided in 1976 to introduce ARE 11 in the network on a large scale. This applied for both new exchanges and the modernisation of existing ARF 10 exchanges to ARE 11, which was described in more detail in Ericsson Review No. 2, 1977. This decision was based on a searching analysis, which showed that there are considerable technical and economical advantages to be gained by introducing ARE 11. The modernisation of existing exchanges is expected to be completed in 1982 and it is estimated that by 1985 the local networks will contain a total of about 3.4 million ARE 11 lines.

However, TELECOM's plans for a new stored program control system for local exchanges have been of greater interest for the future. After preliminary studies during the early part of the 1970s of the

The number of installed AR system multiple positions distributed among the different Australian states

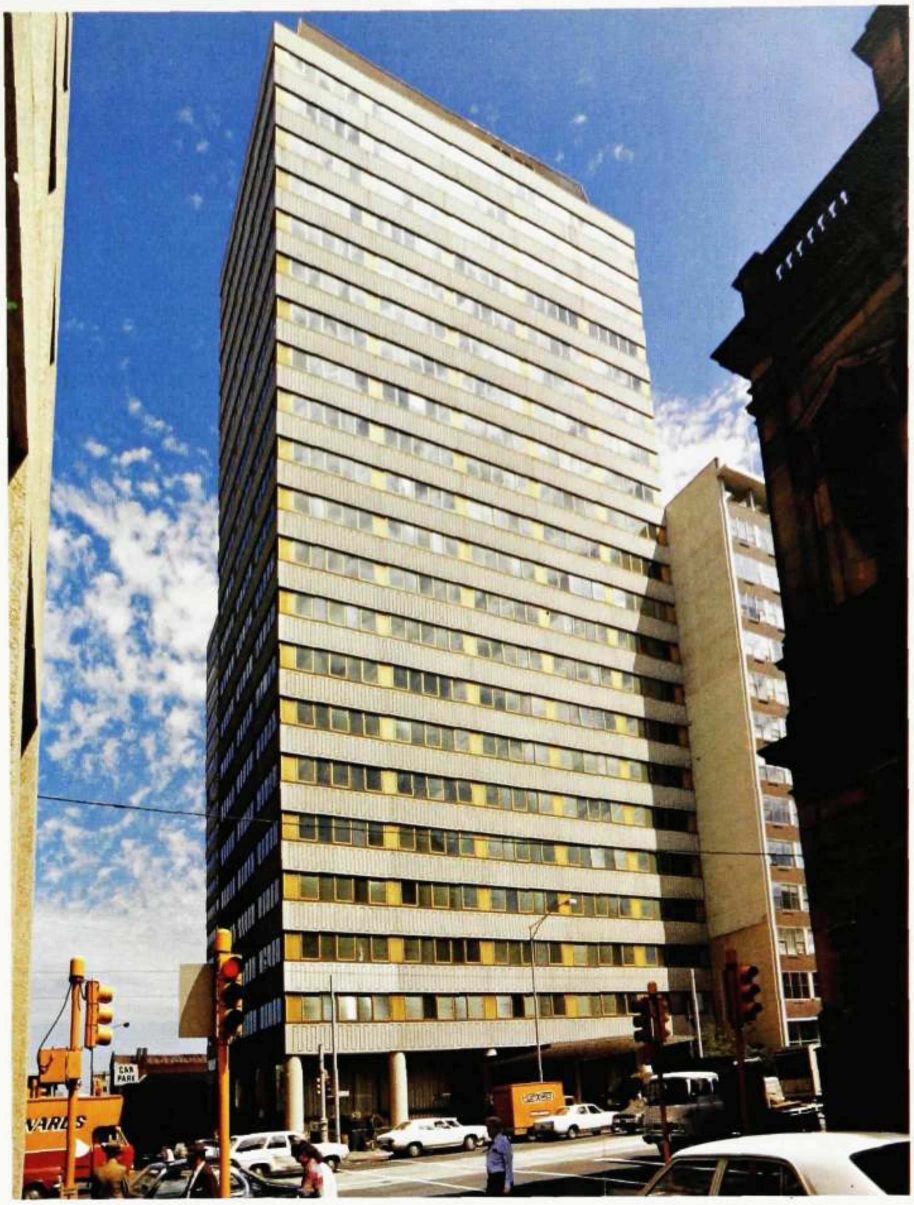
	Number of multiple positions, thousands		
	ARF	ARK	ARM
New South Wales	1238.6	89.8	30.4
Queensland	346.9	93.1	14.4
South Australia	245.0	48.0	5.7
Western Australia	234.8	54.8	7.8
Victoria	716.2	137.5	23.8
Tasmania	55.0	28.5	4.0

general state of the SPC technique, it was decided in 1975 that the time was ripe for the announcement of an international tender competition. All major manufacturers participated. TELECOM's choice of system concerned only the Australian network, but could be a guide for a number of telecommunications administrations who were about to go over to the SPC technique. Conscious of this and since the tender specifications were very detailed, the participating manufacturers spared no efforts when presenting their systems. The submitted tenders were quite comprehensive. After examining the tenders for about 15 months TELECOM announced that two systems were to take part in the final evaluation, namely the LM Ericsson AXE system and ITT Metaconta 10C system. The evaluation, which was carried out with the care that characterizes TELECOM, resulted in the LM Ericsson AXE system being recommended as the standard system for the Australian telephone network during the 1980s. In September 1977 the Government made the final decision to accept the AXE system as the standard system.

The agreement with LM Ericsson includes manufacture under licence in Australia. It is estimated that after some years at least 80 per cent of the equipment will be manufactured in the country.

The decision made by the Australian Government provides further information that AXE occupies a leading position among the different telephone exchange systems throughout the world.

The technical and financial background to the TELECOM decision will be given in a later issue of Ericsson Review.



TELECOM's Headquarters in Melbourne

The LM Ericsson factory in Melbourne

The Role of Telecommunication in the Formation of the Society

Christian Jacobæus

In order to be able to offer readable matter to our readers with a general technical orientation, ERICSSON REVIEW will in future publish articles dealing with subjects of general nature relating to telecommunications. A start is being made in this issue with the following article, based on a paper presented at a symposium held in August 1977 arranged by the Museum of Technology in Stockholm.

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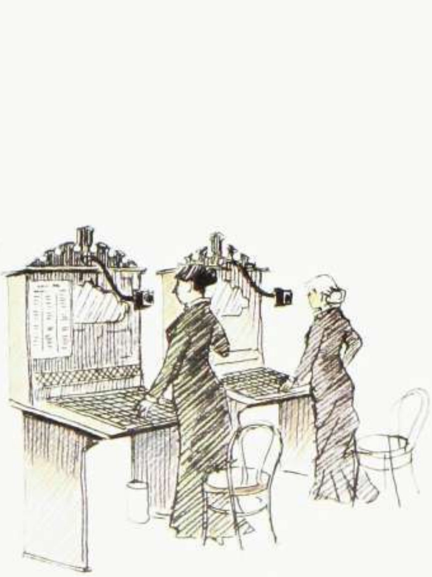


The foundations of industrialism were laid in the 18th and 19th centuries through great inventions—steam engines, various textile machines, metallurgical advances, especially in iron manufacture, chemical processes for large scale production, railways. Industrialism expanded the production of goods and communications, initially to provide the bare necessities of life, but later increasingly to supply other needs, to make life easier and more pleasant. Telecommunication has hardly been associated in people's minds with industrialism—the fundamental inventions in telecommunication came 50—100 years after the great industrial inventions. Nor was it until later that telecommunication became an essential factor in the material running of our life. This was because the technology needed a long time to mature, to be able to render service throughout the world, and because the full benefit of telecommunication can only be attained if people can communicate with all whom they wish.

Industrialism was an entirely material phenomenon. Telecommunication has to do with the transmission and exchange of information. In a way, therefore, it is more closely linked to the distinctive character of man as intelligent being. The growth of telecommunications has also had a very great influence on industry and commerce, on the body politic, and on the situation of the individual human being. The historians of the future will perhaps consider that telecommunication created an epoch in the same way as did industrialism.

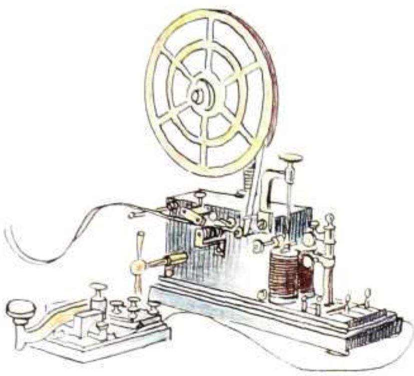
It is quite easy by means of various general statements—all bearing the stamp of truth—to indicate the role of telecommunication in modern life. It is extremely difficult, however, to find direct quantitative evidence for such statements. Researchers have not yet concerned themselves with these subjects. Telecommunications have been regarded by all as positive and beneficial phenomena in our life. There has therefore been no debate on the issue; economic, technological and historical research has been able to find more critical subjects to deal with.

As an approach to the subject, let me first remind you of the feelings which possess us when the telephone doesn't work. We feel dismayed and non-plussed, perhaps angry. We begin to wonder how we shall deal with matters that the telephone has so far managed for us.

We find that we must make personal visits, we write letters, or quite simply put off the matter until the telephone works again. A fire in an automatic exchange in New York City in March 1975, when 100 000 residential and 8 500 business subscribers were without telephone service for quite a long time, gave a drastic picture of how troublesome this can be for almost all categories of people.

I shall now give a brief sketch of how telecommunications have shaped our life in important respects. I do so in the conviction that the development—the interplay between the society and telecommunication technology—will continue to the benefit of people's striving for a better material and spiritual environment.

CHRISTIAN JACOBÆUS
Telefonaktiebolaget LM Ericsson



The business community

The telegraph came into use by the business community at an early stage, perhaps first for trade. Quotations and orders were sent by telegraph. It was the rapidity of this means of communication that was of special value. The telegraph must, in fact, have been one of the most important factors in the growth of world trade at the end of the 19th century. Telex has since taken over the role of telegraphy, but has also extended its scope to comprise a large part of the transmission of information that the postal service had previously undertaken. A contributory factor has been the gradual deterioration of the postal service in the past 50 years. Telex has naturally also come into use for internal information and passing of orders within business enterprises.

The telephone became of very great value to the business community, nationally and internationally, through the personal contact it offered, regardless of distance. The telephone came to a large extent to replace the telegraph (and the postal service).

Data communication is a service which enables firms to draw full benefit from the computer technology. Better control of the enterprise thus becomes possible.

Telecommunications as a whole have a significance for the business community in that they fit the individual firm into the world around it. Contacts and impulses are exchanged with its clients, suppliers, and government authorities. Through the flexibility of telecommunications equipment each firm can have its communication requirements satisfied. The global extent of the telecommunication networks also provides access to all imaginable "correspondents".

Telecommunications are also essential within enterprises. As soon as a firm attains a certain size, it must have recourse to telecommunication for handling its dissemination of information.

The decentralization of business enterprises and their breaking up into several manufacturing, development and marketing units would not be possible without telecommunication. The coming into being of our most effective enterprises, the multinationals, is inconceivable without extensive telecommunication.

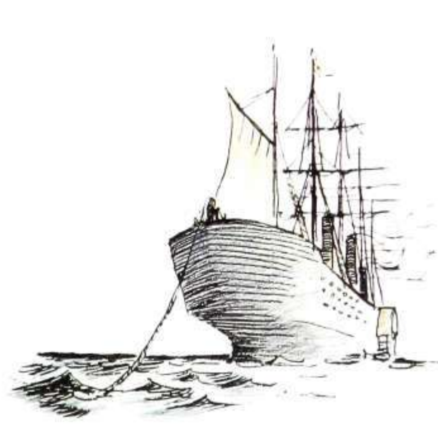
One may ask where the world economy would have been today if telecommunications had not existed. The question cannot be answered – we can quite simply not "think away" telecommunication.

What, then, will be the future of telecommunication for the business community? To a large extent it will continue as hitherto, with more effective use of the already existing services. Telex and data communication, in particular, are likely to have a growing importance, but far from that of telephony. Among the less common services today a heavy growth may be predicted for facsimile. The picture telephone will be of interest only in special cases.

Public administration

Telecommunication has been used in public administration since the days of the telegraph. The telegraph was a means for transmission of information and issuing of orders. Owing to its rapidity it was an enormous advance on the postal service. Public administration was, however, not greatly affected by the telegraph. The creation of the telephone, and later of telephony over long distances, permitted the transmission of more information. This was of benefit also to public administration, even if it was not to any great extent a basis for its work. Written communications were for a long time the preferred method, as copies of communications could be filed.

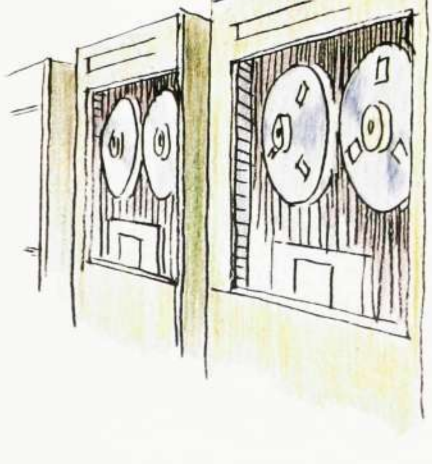
A historical example of the significance of telecommunications in public administration is Australia. This country's situation was radically changed when the first cable linking Australia and the parent country was laid in 1872. The rul-



ing powers in Australia – British officials – had previously been left themselves to deal with whatever problems arose – within the pale of the law. The settlements they arrived at were probably more "practical" and suited to the conditions of the country. After the establishment of the telegraph connection, matters were increasingly referred for decision in London. Decisions thus came, presumably, to be more in line with empire policy and less adapted to the conditions in Australia. A result of the change, it may be supposed, was that the government officials in Australia acted with greater caution and less independently.

In our days we have telegraphy, telex, telephony and data communication – a complex which is becoming increasingly important for public administration. As in the case of the big firms, we see here that decentralization can be associated with stricter centralization. Executive and, to some extent, decision-making units can be moved away from capital cities and main centres. Continuous control from a central point remains possible since there is quick access to records in which everything that has happened is noted. Citizens and authorities at a lower level have a greater freedom of action since the central authority knows that it can intervene without serious delay when required. (Or is freedom of action rendered fictive by the more effective control?)

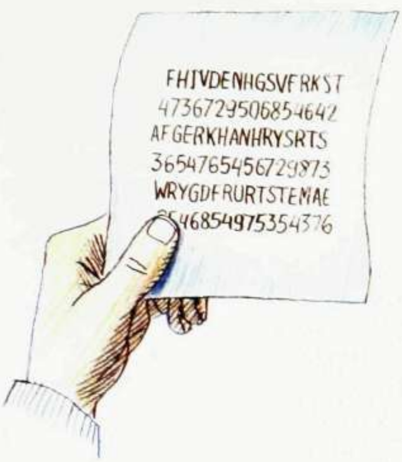
What now appears most important for public administration is the application of computer technology. We have records for practically everything – particulars of persons, personal property, real estate. The records are accessible by means of data communication. The reverse side of the medal – as all are aware – is that so many particulars are collected about individuals that the public obtains too firm a hold on them. There is also the danger that information may come into the wrong hands. The trend, nevertheless, is undoubtedly towards a wider use of computers and data communication. The problem of individual privacy will always be a matter of concern. It will become more difficult, no doubt, to uphold the individual's interests against a power-hungry bureaucracy.



Telecommunications have also brought changes in political life, especially in the case of political crises and threatening armed conflicts. The leaders of the nations are required to make decisions with very little time for consideration. Air forces and armoured troops quickly confront their government and the opposing side with an accomplished fact. On the other hand telecommunications make correct and up-to-date information available at every moment. This is very different from the situation in Napoleon's time. It took two days for an order from the emperor to be de-

spatched from his chancellery. It then usually took a number of days or even weeks to reach its destination. So it made no great difference if the decision-maker allowed himself a little extra time.

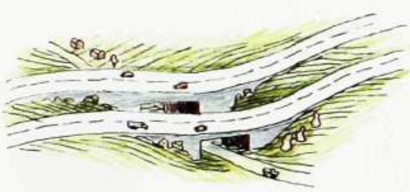
It is perhaps worth while saying a few words also about military communication. Telecommunications played an important role in the second world war and in subsequent military confrontations. Battles have hardly been won by telecommunication but sometimes, perhaps, have been lost for lack of telecommunication. We may expect even more advanced equipment for military purposes. Military technique in this field has often been a precursor of the technique for civil needs. It has been possible to develop and procure equipment which, in respect of materials and functions, contained innovations that could later be adopted in public telecommunication networks.



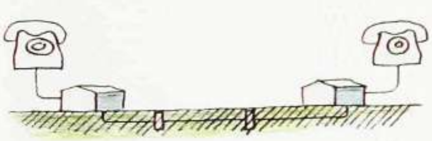
This will undoubtedly be the case in the future as well. An obvious field in this respect is different forms of encryption. Government agencies, and in many cases the business community, have an increasing interest in protecting themselves against, for example, telephone eavesdropping. It is very possible that solutions to this problem may come through ideas from military communication.

Telecommunication and community planning

When one sees how telecommunication can ease decentralization of public administration and the division of business enterprises into small units, one may ask whether the national physical resources could not be grouped in a different way. Would it be possible, in fact, to get away from the large cities and instead spread out the population around smaller centres? This would have many advantages. There would be less traffic in the centres of large cities, with cleaner air and less traffic jams. Less ground would be needed for traffic installations. Public expenditure on streets and roads would be reduced. By systematic use of all facilities offered by telecommunication technology it would presumably be possible to come a bit on the way.



To bring this about, cooperation is needed between urban planners and telecommunication engineers and, of course, also with politicians. No urban community has yet been built in which a systematic use has been made of all the possibilities of telecommunication. The difficulty of doing so, of course, is obvious: entirely new towns are rare and there is a general tendency to limit them even without any major use of telecommunication.



Can telecommunication render personal journeys unnecessary? Great savings would then be possible. It is interesting to look at the costs. In Sweden a motor road costs 4,000 – 16,000 kr/m (in 1974 prices), or on average 8 Mkr/km. A coaxial system costs 5 kr/ channel-m, to which must be added about 7,500 kr/ channel-terminal, which comprises a part of the transit exchanges. For 100 km the figures are

Motor road		800 Mkr
Telephony channel	500 kr	
Terminal	7,500 kr	8,000 kr

The cost of construction of a motor road corresponds to 100 000 telephony channels. It should also be noted that

1. costs for acquisition and operation of vehicles for the motor road are not included. These are considerable.

2. the motor road remains where it has once been constructed. A coaxial cable, on the other hand, can be dug up and moved elsewhere.

3. the motor road involves an interference in nature and often, too, in "culture" by occupying valuable agricultural ground.

On the other hand

1. the motor road is used to a considerable extent for the carriage of goods

2. personal transport is to a large extent unavoidable.

Motor roads cannot be replaced by telecommunication, but a consistent use of telecommunications reduces the need for personal transport. If we take, by way of example, negotiations concerning a business contract, which usually requires a number of personal meetings, it is often possible, by telephone and telex, to come so far that only a few especially troublesome points remain. These can then be cleared up at a personal meeting.

Meetings of several persons are difficult to arrange effectively by telecommunication, due both to technical and human factors. Even the video conference facilities that have been established have difficulty in gaining a market because of the conference studio and of the expence of the service. Nor, perhaps, can the fact be disregarded that a business journey abroad is for many a pleasant interruption in the everyday routine.

Telecommunication in the family

Telecommunication in the family is a matter chiefly of the telephone. Until 1920 the telephone in Sweden existed almost exclusively within social group I. As in many other fields, social group I created a pattern which was later followed by the other classes. Between the world wars the telephone soon spread far down in the income classes. We see here an example of the self-generating effect, in that the telephone becomes of greater use the more people one can communicate with.

For the individual and the family, the telephone has a significance both for economic life and for social and human intercourse. In the former case there is the contact with the job environment, suppliers, official bodies, etc., which of course greatly contributes to the usefulness of the telephone to the business community and public administration. In the latter case it is the contact with friends and relatives. In the Nordic countries and the USA the telephone has really acquired a wide use for these contacts. They take the place of personal visits – many children call their parents every day, people call their homes when they are on journeys. All age groups fill up their leisure moments in telephoning to their friends. The telephone is in this case an innocent form of enjoyment. Some families with especially talkative members have found it necessary to have more than one telephone line (a teenage telephone), and in the future this will perhaps be rather the rule than the exception.

The disadvantage of the telephone from the individual's point of view is that private life (or one's work) may be disturbed. It is always the caller who takes the initiative. And in the way in which our telephone culture has developed, one feels obliged to answer the phone even though one knows that the thing one is doing is probably more important. One is faced with a dilemma: one wishes to be available and responsive to communications which are of interest and importance, but one cannot decide whether they are so until one receives them.

Another negative consequence of telephoning is that the practice of letter-writing between relatives and friends has gone out of fashion. Future research will thus be deprived of a valuable source of knowledge concerning matters of fact and ways of life.

Telecommunications and human valuations

Our fundamental valuations are not affected by telecommunication. This is quite obvious as regards ethical value-judgments. People's pattern of behaviour in relation to others does not change. Nor is there any change as regards life-values, for instance in striking a balance between work and leisure, in attitudes to our environment, in views on fundamental political and economic problems.

On the other hand telecommunication can often help people to live in accordance with their valuations. A person who wishes to live in the country can do so without becoming isolated from the surrounding world, a person on a journey can maintain daily contact with his home, and so on.

Nor should it be forgotten that telecommunication has no harmful side-effects or any waste products.

Telecommunication is an important advance which has come to stay. There is hardly any substitute for it unless means of communication can be opened up on the physic plane. But that brings us into the realm of science-fiction. No scientific backing for such theories can be detected.

Teletraffic Engineering Problems in Developing Countries

Anders Elldin

ANDERS ELLDIN
Telefonaktiebolaget LM Ericsson

During the years 1971–1976 the author served as regional traffic engineering expert with the ITU (International Telecommunication Union) and the ESCAP (United Nations Economic and Social Commission for Asia and the Pacific). The region comprises some thirty developing countries from Iran in the west to West Samoa and Tonga in the east. During these years the author visited several countries within the ESCAP region and gained knowledge of the traffic problems of developing countries on the spot.
When preparing this article the author was greatly assisted by discussions held with officials of the telecommunications administrations and within ITU, ESCAP and other organisations. The auther expresses his warmest thanks for all enlightment received during these visits.
The article is a revised version of an essay published in Telecommunication Journal, September 1977.

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The article discusses the special telecommunication traffic problems that exist in developing countries. The following aspects will be dealt with:

- Subscriber network forecasting
- Traffic forecasting
- Dimensioning, particularly with regard to the subscribers' behavioural patterns
- Traffic measurements: technique, methods, processing
- Planning of subscriber networks
- Planning of multi-exchange networks
- Training in the above-mentioned fields of activity.

The special problems that arise in developing countries with inadequate and overloaded telephone networks will be illuminated. Practically all problems are caused by the fact that the demand for telecommunication services is considerably greater than the possibilities of meeting this demand. In many cases this unbalance between supply and demand can be expected to remain for several decades, since the demand will grow faster than the telecommunication plant can be extended. It is then imperative that the limited resources are used in the most effective way. This requires that the work in the above-mentioned fields is carried out in an efficient and professional way.

The general situation

In order to understand the prerequisites for developing and improving the telecommunications in a developing country it is appropriate to first consider the general situation. Factors of special interest for telecommunications are the economical situation, the technical development level of the telecommunications in the country and available human resources. In addition some typical telecommunication traffic situations are described. The following is not a complete description of the problems of the developing countries; it only aims at presenting some of the factors that affect the assumptions for improving telecommunications.

Fig. 1
Building a telephone exchange in the town of Suva

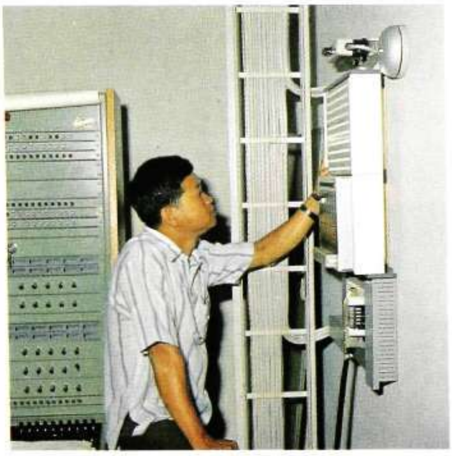


Fig. 2
Reading traffic meters

In order to give a general characterization of the situation in developing countries it will be necessary in the following to resort to some general descriptions of conditions, which may seem exaggerated if applied to a particular developing country. These conditions are, however, more or less pronounced in the developing countries and may therefore serve as an explanation of why the development does not proceed as fast as could perhaps be expected.

Economical conditions

A developing country usually needs to import more commodities than it can export. This gives rise to an adverse trade balance, and attempts are then made to rectify this by such means as import restrictions and protective duties. Since telecommunication equipment must usually be purchased abroad, this type of products is also affected by the restrictions. Investment in telecommunication equipment usually requires that 70–80 per cent of the value of the plant is paid in foreign currency. In order to obtain this type of equipment the country must thus abstain from other useful goods and the telecommunication needs must therefore compete with other urgent needs. Hence the size of the purchases depends on what priority the country gives to the different needs and what importance is attached to the extension and improvement of the telecommunication services.

Telecommunication equipment can also be provided as multilateral or bilateral aid, but even in this case it dependens on what priority the country gives to this particular field. This type of aid generally follows the wishes of the receiving country. Thus if the government considers needs in other fields as more important, the telecommunications administration must limit its extension rate and make the optimum use of what it can get, wait its turn and hope for higher priority in the future.

A higher rate of development is required if a developing country is to be able to reach parity with developed countries. This requires investment capital and sufficient human resources for planning, building and operating the plant. Even if capital is available, which is the case in oil producing countries, the human resources may still be insufficient as regards technical skill and experience. These types of limitations of required resources forces rich as well as poor developing countries to concentrate on certain projects in certain sectors, and to allow other desired projects to be postponed.

Thus, for economic reasons telecommunication plant in many countries has had to be extended at a slower rate than motivated by the actual demand. Since all social and economic development requires improved telecommunications, neglected telecommunication networks retard the development as a whole. Naturally, the development rate in different fields, and particularly within the infrastructure, has to be correctly balanced in order to give the best overall result. In many cases telecommunications have been given a less favourable priority rating because today there are no objective measures for determining which level this field should have in relation to other infrastructures.

If the extension of the telecommunication network is neglected for a long time, the gap between demand and supply is widened. In the long run this naturally has a paralyzing effect on the activity of the telephone administrations, and it might perhaps explain why some countries have no long-term plans, since there is little hope of seeing such plans being realized.

The telecommunications in many countries are thus hampered by economic restrictions caused by lack of foreign currency and unfavourable priority rating. This is irrespective of the fact that telecommunication plant usually gives a very good return on invested capital. Most developing countries also say that the reason why the telecommunications have been neglected is the lack of foreign currency.

The technical level

The telecommunication equipment in a developing country may be as modern as in any developed country. Old, modern and sometimes ultramodern equipment is found together in the telecommunication networks. The problem is that there is not enough equipment in relation to the need as regards subscriber lines and existing traffic. In certain countries the maintenance of the equipment can be as good as in any developed country but there are also cases where the maintenance is less satisfactory. Overloading and unsatisfactory maintenance often cause difficult traffic situations to become even worse. Extension work in progress sometimes makes the traffic situation still more difficult if no attempts are made to avoid disturbance of existing traffic.

Human resources

The telecommunication administrations in developing countries are organised in many different ways. The administration may be a department of the Ministry of Communications, it may be built up on the lines of the British Post Office or it may be separate from the Post Office as is the case in Sweden. There are also administrations that are organised as private companies with the Government as the predominant shareholder. Thus one can say that in general there is no formal difference between the telecommunications administrations of developing countries and those of the more advanced countries.

However, the developing countries have more employees per subscriber, which can partly be explained by the fact that the salaries are considerably lower. The level of knowledge of the staff varies more, however, which means that the number of qualified persons per subscriber in developing countries can be lower than in industrial countries. On the other hand the method of working in a telecommunications administration in a developing country can be entirely different from that in a more advanced country. Decisions of different categories are normally made at a higher level in the developing country. This can be explained by the greater number of less qualified employees, and by the fact that the size of the networks has not yet forced the management to delegate responsibility as far down as is usually the case in advanced telecommunications administrations. It can also be explained by differences in way of life and attitude in the developing countries, and by the fact that traditionally these countries

Fig. 3
Transport of a mobile telephone exchange, Thai-

function in a more authoritarian way. A consequence of this is that contacts and cooperation between different departments or working groups within an administration become more formal, which in some cases may result in a less efficiently functioning organization.

It would be a great mistake to believe that developing countries do not have any qualified telecommunication engineers at all. On the contrary, almost all developing countries have engineers who have received good training abroad and who are just as skilled and able as any engineer in an advanced administration. The problem is that these people are too few and for various reasons they have not been able to train others within their own administration. One reason why the follow-up of competent engineers is so poor within the administration may be because the few qualified persons are overloaded with assignments, and that they are promoted and transferred before they have time to train successors.

In an administration in a developing country the activities within the traffic field are usually fairly modest. Very few administrations have well trained traffic specialists. Usually there is nobody with expert knowledge of this field. In many cases this type of activity has been entrusted either the technical or the operational departments, where it disappears among the many varying tasks that fall upon these units. This means that the tasks are often carried out without continuity or consistency, and that in general there is very little possibility of devoting sufficient time to this type of work. Lately it has been observed, however, that the administrations have become more conscious of the importance of rational planning and dimensioning. This is evident from, for example, the great interest shown in such things as the ITU seminar on traffic engineering and network planning financed by SIDA* and held in New Delhi in 1975 for the ESCAP region. Many administrations also showed great interest in the "Stop Over" seminars organised by the ITU and the International Teletraffic Congress (ITC) in connection with the 8th teletraffic congress held in Melbourne in November 1976.

Many developing countries have "Training Centres" where telecommunication technicians are trained. Engineers and other administrative staff are also given advanced training. Moreover, promising engineers are sometimes sent to more advanced countries for studies. This is often made possible through grants from multilateral and bilateral donors. However, the training of engineers is

*Swedish International Development Authority.

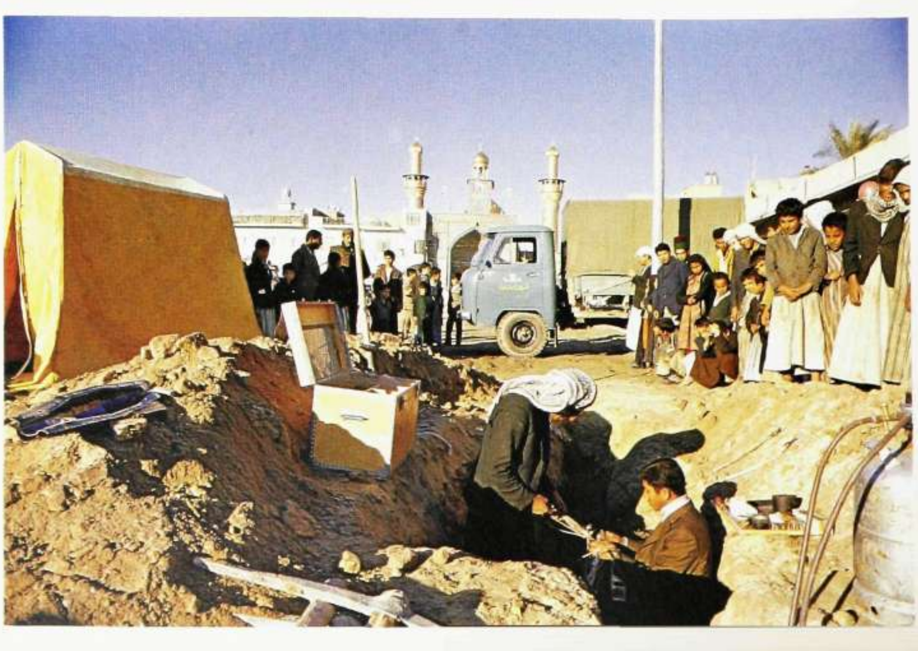


Fig. 4
Jointing a cable in Kerbala, Iraq

clearly inadequate in many countries. This applies particularly to traffic engineering. The courses at universities and technical schools of these countries usually include very little on telecommunication traffic and in many cases the administrations are unable to give new traffic engineers the necessary organised training because of lack of teachers in the subject. The only possibility of training traffic engineers is therefore on-the-job-training and to use grants for studies abroad. However, there is great competition for these grants between various technical sectors within telecommunication engineering, which means that the number of grants available for traffic engineering studies is in reality limited. There is thus an urgent need to increase the training in this field, and this should be started as soon as an administration feels ready to improve and extend this type of activity.

Planning

Almost all the developing countries have general five-year plans for their development. Some countries also have long-term planning, others not. The telecommunications administrations naturally also have five-year plans for their extensions, but where there is no long-term planning for the society as a whole it is rather difficult for the administration to carry out more long-term planning. The absence of long-term planning makes it very difficult for the administration to plan far ahead and this also affects the five-year plans. Thus it is difficult to plan the sites of new local exchanges in a telephone network if it is unknown in which direction a community will grow in future. The absence of town planning further complicates the planning of the networks and may in extreme cases lead to new business complexes having to wait for months before being adequately connected to the telephone network.

The administrations are to an increasing extent using continuous updating of their extension plans. Long-term plans that are updated only infrequently—or not at all—naturally create a gap between planning and reality. This means of course that from an economic point [illegible]ew that available resources will not be used in the best possible way. This is undoubtedly more serious in a country with limited resources than in a wealthy country.

The traffic situation

When the supply of equipment cannot meet the demand, various types of overload situations arise. Overloaded telephone exchanges are also more sensitive to technical faults and in combination with the overloading this leads to other, secondary overloading situations.

An overload situation occurs practically every time a new subscriber group is connected to the network, since as a rule there are more subscribers waiting for a telephone than the subscriber group can accept. A waiting time of 5–10 years for connection to the network is not unusual. The traffic per connected subscriber is usually very high because all available telephones are used for business and administrative purposes. In view of the heavy traffic this means that a subscriber group should not be filled completely, but there is generally such pressure on the administration from the public that it is very difficult to leave any connection free. Most subscriber groups are therefore overloaded right from the start and this overloading naturally results in high congestion and reduced grade of service. This in its turn leads to an increased number of repeated call attempts with overloading of registers, code receivers, markers and other common devices as a consequence. Due to the difficulties in setting up calls the subscribers may then use the telephone in a way that makes the situation even worse. (Thus one can lift off the telephone receiver in the morning when one gets to the office, since one knows that it takes a certain amount of time before one gets the dialling tone. One can also give an assistant the task of calling the numbers one wants, which means that he keeps on trying until he gets the numbers, which naturally increases the load on the common devices.)

Another type of traffic problem arises when the service is improved. A sudden increase then occurs in the traffic, a "service improvement jump". These jumps can be explained by the fact that

Fig. 5
Training in the handling of an operator's set. Thailand

the traffic need is considerably higher than what could be handled by previous circuits. When the subscribers now find that they can get through, they naturally try to satisfy their telephony needs. Thus it has been found on long-distance and international routes that the traffic can increase tenfold, expressed in erlangs, when an improvement has been introduced. If the administration has underestimated the traffic demand, such a jump may come as a complete surprise. Experience from industrial countries regarding how large such jumps usually are does not normally apply in developing countries with their very much greater unsatisfied hidden telephone demand.

Summary of the situation
To sum up, the telecommunications in developing countries are characterized by
- a great disparity between supply and demand because of lack of foreign currency and often also because telecommunications have not been given sufficiently high priority in the development programs
- insufficiently well developed long-term planning
- overloading of existing equipment because of the large demand for telephone service
- maintenance sometimes less efficient
- too few trained and skilled traffic engineers
- inadequate cooperation between different departments within the administration and insufficient coordination between different activities within the departments.

Quality or quantity?

When the demand is greater than the supply the question arises whether available resources are to be used to give a few people good service or to give a greater number of people a poorer service. The problem is thus how to strike a balance between the demands of quality and quantity.

This situation occurs practically every time a new subscriber group is put into service in a developing country, if there are more waiting telephone subscribers than can be connected to the group. The administration knows that the traffic per subscriber will be considerably higher than the group is provisioned for. Hence the group can not be fully occupied if a normal grade of service is to be maintained. On the other hand, if more subscribers are connected more people will have access to the telephone, but with a reduced level of service quality. The question is then how much regard can be paid to the quantity demand without causing an unacceptable deterioration of the service performance.

In order to be able to decide how many subscribers can be connected it is necessary to know how the group behaves with an increased load, taking into account traffic variations and the effect of repeated call attempts. It is also necessary to find suitable measures for describing the degree of overload as well as a measure which describes what the group produces in useful work. This latter measure should be in accordance with the administration's evaluation of quality and quantity in this particular case.

If a group is offered traffic in excess of the amount for which it is provisioned, the congestion will naturally exceed the desired levels and give rise to unsatisfactory service. With a certain amount of overload the group can still handle more traffic at a higher congestion level, but if the load increases still further, the part of the traffic, that consists of successful calls might decrease.

The same type of quality-quantity consideration can also be made for other equipment in the telephone network. This applies for both group selectors and common devices.

In an overloaded network the common devices will be loaded with a large number of unsuccessful call attempts, which prevent other call attempts from resulting in telephone conversations. A rapid release of common devices that have been seized with little probability of success would make room for more productive seizures. It is thus necessary to find an optimum solution that gives the maximum number of successful calls. Such a change in the call handling technique for registers, markers and other devices would probably require more from the equipment in the way of logic and information, and it might therefore sometimes be cheaper to increase the number of devices temporarily if the conditions can be expected to become normal within reasonable time. To this group of problems belongs the question of how to handle calls that have been connected through their own group successfully but have then failed in later switching stages. The failure is often indicated by a long waiting time in a subsequent connecting phase. The longer the waiting time the more likely it is that the attempt will fail. A suitable limit value for the time release could therefore reduce the load on the common devices. On the other hand the shorter this time limit is made, the more likely it is that attempts will be interrupted which would otherwise be successful. An optimum time limit has to be found that takes into consideration conditions in the rest of the network, and which helps to attain the highest possible degree of efficiency.

Automatization of the telephone operation

The following development stages can be discerned in the automatization of the telephone operation:

a. Automatization of the telephone networks in large towns and cities
b. Automatization of the networks in small towns
c. Subscriber trunk dialling between the large towns and cities (STD)
d. Subscriber trunk dialling between all places with automatic telephone operation
e. Automatization of the rural telephone networks
f. Subscriber dialling on international telephone circuits. (ISD)

The development has in general followed the above order but with some overlapping.

In the most advanced telephone countries stage f. is now being carried

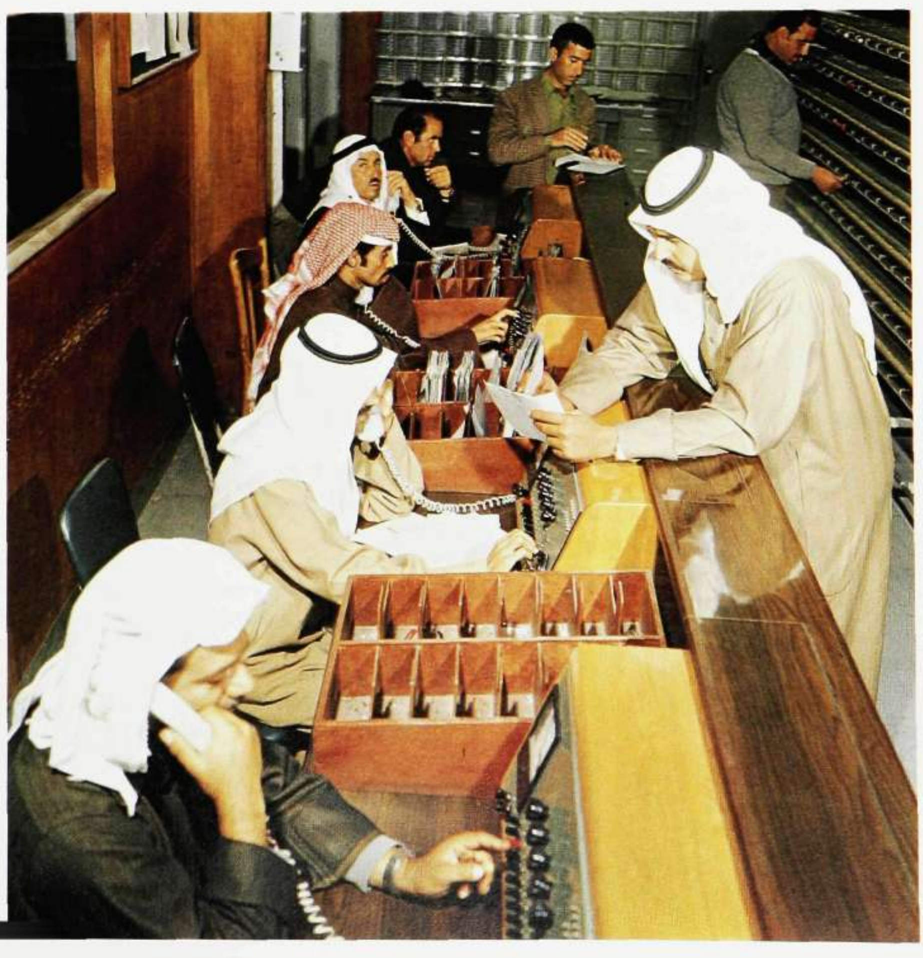


Fig. 6

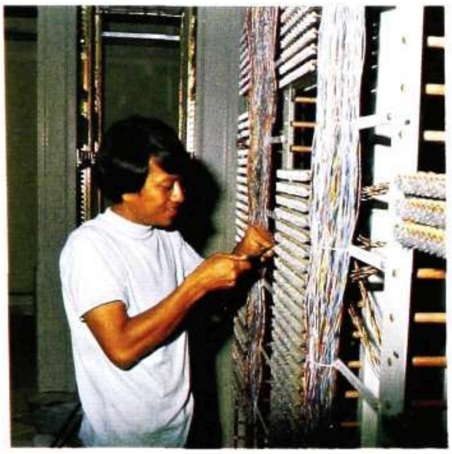


Fig. 7
Wiring of a rack

out at a rate that is determined by the technical standard of the telephone network in the receiving country. In the developing countries stage a. has usually been completed whereas the realization of stages b., c., d. and f. is either in the planning or implementation stage. The realization of stage e., rural automatization, is usually relegated to the future as being the last step in the total automatization of the national network.

As an example it may be mentioned that among the developing countries in the ESCAP region more than half have not yet begun the automatization of the long-distance traffic. Very few countries have even taken up rural automatization as an object of discussion in their long-term plans. As regards ISD (f.) it is expected, that certain international circuits will be available for subscriber dialling within the next 5 – 10 years. This means that the developing countries are now in approximately the same position as Europe was during the 1950's.

Automatization of the long-distance traffic makes great demands on the telephone administration in a developing country. Thus successful automatization requires, for example,

- a sufficient number of long-distance circuits and correct dimensioning of the transit exchanges so that the traffic can flow without too high congestion
- measurement of traffic and congestion in the long-distance network
- possibilities of changing existing allocation of circuits and switching arrangements if unexpected changes in the traffic dispersion occur
- planning of further continued extensions of the network.

Automatization of the long-distance service usually means a great improvement of the subscribers' possibilities of making long-distance calls. The subscribers quickly discover this improvement and this generally results in a considerable increase in traffic, sometimes even to the extent that the traffic expressed in erlangs increases tenfold. The size of the jump naturally depends on the magnitude of the improvement and the size of the suppressed traffic demand. This means that certain routes will remain overloaded after the automatization even if they have been extended substantially. It is therefore necessary to be able to determine, by means of measurements, where in the network the bottlenecks are. It must also be possible to reallocate routes and traffic according to the traffic conditions. Networks with alternative routing facilities will cause less trouble since the final choice routes act as common reserves for unexpected traffic peaks as well.

Since long-distance network will grow faster after introduction of STD than before it will also be necessary to start planning further extensions early. To make reliable forecasts it is necessary to have systematic and reliable traffic measurements in order to obtain as well-founded indications as possible regarding the long-term development.

Successful introduction of STD also requires

- information to the subscribers with sufficient penetration power, for example through distribution of printed information (often in several languages), through newspaper, radio, television, assistant telephone operators, etc.
- a reduction of the number of person-to-person calls to be handled by operators
- clearing the local network of technical faults so that the long-distance calls can get through
- reduction of the traffic per subscriber in the local networks so that the long-distance calls are not met by the busy tone too frequently.

In a country with low telephone density the number of person-to-person calls can be very high. This may be due to the fact that the called person often has to be fetched from a place more or less distant from the nearest telephone. This can only be changed by increasing the telephone density which may take a very long time. The administration must therefore charge an intimidatingly high fee for this service or discontinue it entirely.

The biggest problem is usually how to clear the local networks of technical faults and to reduce the frequency of "engaged subscribers". The latter can sometimes be achieved by giving large

PBXs special subscriber numbers for long-distance calls. This can be a very effective solution since the long-distance calls during the busy hour are mainly from one PBX to another.

Subscriber Trunk Dialling usually means increased revenues for the administration. It is of course desirable that money flows in as early as possible to cover investments already made and to facilitate new payment of further extensions. Automatization therefore usually starts with the most profitable routes and then continues with less profitable ones at the rate permitted by available capital and other resources.

When deciding the order in which the various parts of the network are to be automatized, attention should be paid to such factors as the following:

- the earliest time that the route can be put into operation, with regard to material supplies, installation and technical possibilities
- expected increase in the traffic revenues of the route
- expected saving in operator costs
- the cost of the automatization
- the interest on investments and other expenditures.

It may also be necessary to take into account political decisions and priorities.

The order for the automatization that gives the best possible financial return can be ascertained by analyzing all routes concerned. It is of course necessary to take into consideration how many routes can be automatized at the same time during the same work period, since the automatization rate is dependent on the capacity the administration has available for carrying out the necessary technical work.

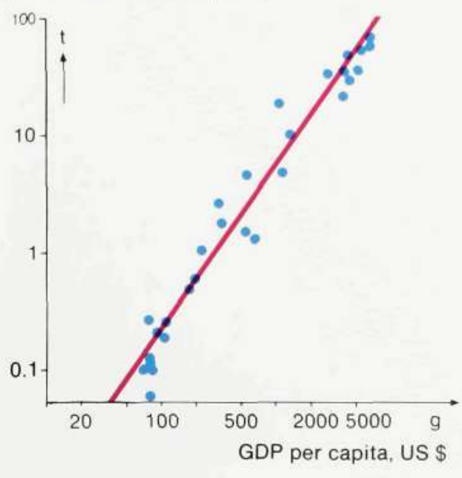
Long-distance automatization undoubtedly makes great demands on an administration's ability to plan and carry out technical work. It is also necessary to maintain routes and transit exchanges satisfactorily despite the fact that extension work is being carried out.

Network planning

Modern methods for planning optimum telephone networks have already been used in several developing countries. This means that computer programs determine the optimum position of local exchanges in city networks, and other programs calculate the most economical solutions for alternative routing networks in metropolitan areas and for long-distance networks. Hitherto the calculations have often been carried out jointly by the administration and the manufacturer or international consultants.

Network planning undoubtedly facilitates the best possible use of the country's limited resources and it is therefore desirable that these methods should be used to a greater extent.

Number of telephone sets per 100 subscribers (1973)



Investment in telecommunication equipment as a permillage of the GDP (1973)

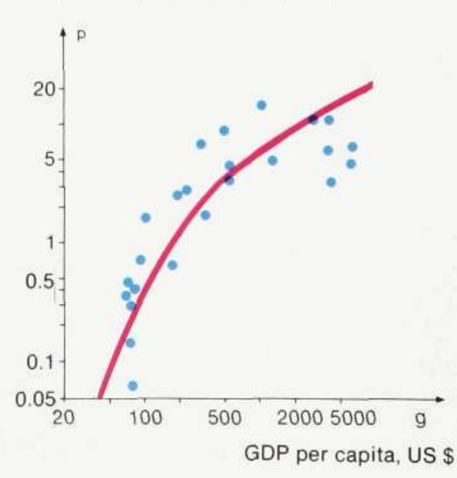


Fig. 8 (left)
The number of telephones per 100 inhabitants increases with increasing standard of living, expressed as the gross domestic product (GDP) per capita. The diagram includes only the countries given in table 1

Regression line:

$\log t = \log t_0 + k \cdot (\log g - \log g_0)$

Fig. 9 (right)
The investment in telecommunications, expressed in thousandths (permillage) of the GDP, seems to increase with increased standard of living, expressed as GDP per capita. The diagram includes only the countries given in table 1

Regression Line:

$\log p = \log p_0 + k \cdot \left(\frac{1}{\log g} - \frac{1}{\log g_0} \right)$

The methods are very inexpensive compared with the saving in investment that can be attained. Access to computers is no problem nowadays since practically all developing countries have one or more medium or large size computers at their disposal. The development in the field of microcomputers provides the countries with additional possibilities of carrying out their own network planning in future.

The computer-based methods will undergo further development, particularly with the aims of making them more realistic and of taking practical requirements into consideration to an even greater extent.

In order to be able to use these methods successfully the network planning must be based on reliable forecasts as regards subscriber growth when planning subscriber networks, and as regards traffic growth when planning alternative routing networks. In many cases this can mean that the administration has to improve its forecasting, methods before the full benefit of the network planning can be obtained.

Subscriber behaviour patterns

During the last 10–15 years there has been an increased interest in the more advanced telephone countries for the observation and recording of subscriber behaviour patterns. Studies in this field have resulted in a successively improved adaption of the telephone systems to their users.

It is a question of how people learn to use a machine and how they adapt their behaviour in accordance with previous experience. Observations of the subscribers' habits thus give valuable information regarding how the systems should be adapted to become as efficient as possible. This applies particularly as regards the time allowed for dialling, reactions and reaction times for different tones, answering times, patience when waiting, what the subscriber does if a call attempt fails etc. Knowledge of how the subscribers behave gives greater possibility of adapting the system to the user and of providing it with what is for the user the correct proportions between, for example, common devices and call-carrying devices. In the long run it will undoubtably result in improved telephone systems.

However, since the subscribers adapt their behaviour to the difficulties encountered in making the calls they want, it is not necessarily certain that experience from countries with a high service level can be applied in cases where the level is lower. It is therefore very important that the subscribers' behaviour is also observed in the developing countries, so that the systems can be dimensioned in accordance with the needs of these countries. Measurements in certain countries have also shown that there are considerable differences between telephone networks

Fig. 10 (left)
The relation between the number of telephones per 100 inhabitants and GDP per capita for the years 1965 and 1974

The curves show that the developing countries have improved their position somewhat during the period.

Fig. 11 (centre)
The number of inland telegrams per telephone as a function of the number of telephones per 100 inhabitants obviously decreases with increasing telephone density. This can be explained by the fact that a part of the telephony demand is satisfied by means of telegrams if the telephone density is low

Regression Line*):

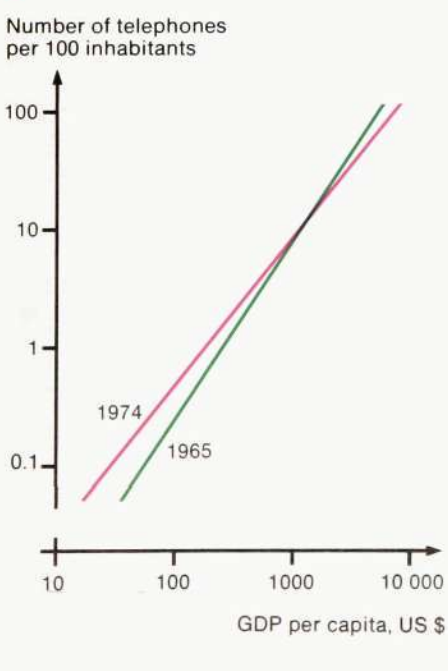
$\log m = \log m_0 + k (\log t - \log t_0)$

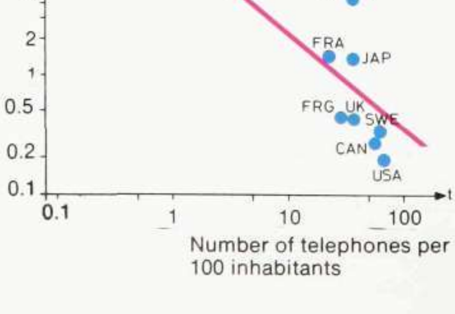
Fig. 12 (right)
The relation between the annual increase in the number of telephones during the period 1963–1973 and the increase of the GDP during the same years is investigated here. Which variable is the dependent one?

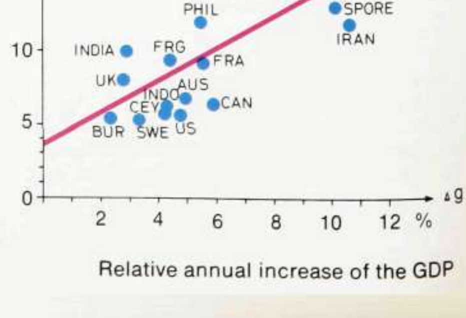
The curve shows that the developing countries have improved their position somewhat during the period.

Orthogonal regression line:

$\Delta t = 9.35 + 1.0597 (\Delta g - 5.78)$







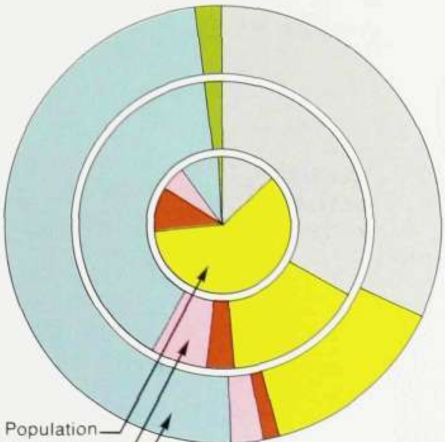


Fig. 13
The number of telephones, in 1973, in the various continents, in relation to population and GDP

- Africa
- Asia
- Europe
- Canada and the USA
- Latin America
- Oceania

with good and bad service performance in this respect.

The effect of a high load is that the number of repeated call attempts increases, with reduced accessibility in the network and with increased traffic per subscriber. More markers, registers and other common devices will therefore be needed in order to handle the same amount of effective traffic. When conditions are really difficult the subscribers' way of dealing with the telephone systems also becomes more desperate, which makes the situation even worse.

Since difficult traffic situations are caused by overloading of the networks, these problems will remain until the networks have been extended sufficiently. When this has been done the subscribers' behaviour can be expected to change for the better. In the meantime, which can amount to more than 20 years, the systems in developing countries should undoubtedly be adapted for handling a higher frequency of repeated call attempts.

Summary and conclusions

The differences in the prerequisites that apply for teletraffic engineering in developing countries and countries with more advanced telecommunications have been discussed above. These differences are due to the fact that the former have been unable to reach a balance between supply and demand, whereas the latter have succeeded in building out their telephone networks to such an extent that the supply-demand situation has become much less difficult.

The gap between supply and demand, which seems to increase rather than decrease in many developing countries, creates overload situations. The problems have also increased because many countries have bought equipment that is not dimensioned for the high loads to which they have then been exposed. The extremely difficult traffic situations that then arise demand expert handling.

The traffic problem areas in developing countries are in particular the long-term planning, network planning, forecasting, purchase of suitable traffic recording equipment, the use of rational recording methods, realistic specification of the traffic in new installations, with consideration paid to the actual behaviour of the subscribers, and the finding of methods for relieving the load on overloaded groups. If these problems are to be solved it will be necessary to have efficient work units for the traffic engineering work and to employ and train suitable staff.

Fig. 14
Introductory address at a meeting for coordination of the extension of the telecommunications between the countries in the ESCAP Region. The Asian Telecommunication Network will in future have continuous telecommunications from Iran in the west to Indonesia in the east. The countries that participated in this particular meeting were the Philippines, Laos, Malaysia, Singapore and Thailand. Participating international organisations were UNDP, ITU and the Asian Development Bank. (Kuala Lumpur in August 1975)

Country	Population millions 1973	GDP per capita[1]	Investment in telecomm. as a percentage of the GDP[2]	Number of telephones, thousands			Number of telephones per 100 inhabitants			Percentage of subscribers conn. to aut. exch. 1.1.75	State of long-distance aut. 1975[3]
				1963	1973	1980 estimated	1963	1973	1980 estimated		
Afghanistan	18.3	73	0.1−0.8	8.7	22.7		0.06	0.12		74	1
Bangladesh	71.6	75	0.06	–	75[75]		–	0.1		85	3
Brunei	0.15	1100	–	0.9	6.9	14	0.8	4.7	7.2	99.1	2
Burma	29.6	69	0.3−0.4	18.8	28.3	44.6	0.08	0.096	0.13	70	2
Hong Kong	4.2	1006	14.8	146	795	1678	4.1	19.1	35.2	100	–
India	574	101	1.3−1.9	603	1479	2870	0.13	0.26	0.42	82	3.4
Indonesia	125	92	0.5−0.9	140	240	835	0.14	0.19	0.56	63	3
Iran	31.3	539	3.5	155	447	2500	0.67	1.43	6.3	94	4
Korea	32.9	295	6.3−7.8	139	850	2092	0.50	2.58	5.56		4
Laos	3.2	–	1.4[72]	0.8	3.6		0.03	0.11			1
Malaysia	11.6	316	1.7	90	211		1.12	1.81		96.6	4
Maldives	0.12	92	–	0.2	0.3		–	0.2		73	0
Mongolia	1.36	–	–	10.5	28.8		1.03	2.12			–
Nepal	12.0	78	0.4	1.2	7.6	28.5	0.01	0.06	0.26		1
Pakistan	66.7	76	2.9	–	175			0.26			3.4
Philippines	40.2	214	2.7	140	410		0.47	1.02		96.0	–
Singapore	2.19	1278	3.8−6.1	68	218	651	3.7	10.0	26.0	100	–
Sri Lanka	13.2	168	0.3−1.0	39	65	86	0.35	0.49	0.56		3.4
Thailand	39.8	192	2.6	50	235	775	0.17	0.59	1.51	96	2.3
Japan	108.3	3782	11.4	8430	38698		8.79	35.7		97.4	4.5
Asia	2204			13577	48045	110000	0.78	2.2	4.2		
Asia excl. Japan and China	1281			5147	9347			0.73			
Australia	13.1	5174	12.6	2553	4659		23.4	35.5		95.2	4
Fiji	0.29	534	4.1−4.9	9	27		2.1	4.5		88.5	3
Papua–New Guinea	2.56	583	9.0		32			1.3		97.9	3
New Zealand	2.96	4207	3.4	902	1444	1813	35.5	47.5	53.0	92.7	4
Oceania	20.6	2950[72]		3595	6463		21	30.6		95.0	
Oceania excl. Australia and New Zealand	4.5			140	360			8.0		61	
Canada	22.1	5438	10.8	6664	11665		35.2	52.8		99.7	5
USA	210.4	6169	6.6	84453	138263		44.6	65.7		99.9	5
France	52.1	3823	6.5	4978	11337		10.4	21.7		94.0	4.5
Sweden	8.14	6185	4.9	3054	4829		40.2	59.4		100	5
Great Britain	59.9	2798	11.5	9272	19095		17.2	34.0		99.9	5
West Germany	62.0	4245	10.2	7600	17803		13.7	28.7		100	5
Africa	374	230[71]		2155	3985		0.77	1.1		83.1	
Canada and USA	233	6140		91117	149928			64.5		99.9	
America excl. Canada and USA	312	560[71]			10812			3.46		97	
Asia	2204			13577	48045	110000	0.78	2.2	4.2	95.6	
Europe	472	3030		50338	102666		11.6	21.7		97.2	
Oceania	20.6	2950[72]		3595	6463		21	30.6		95.0	
Total	3860			161100	336291	539000	5.1	8.6	11.8	97.9	

Table 1
Certain statistical data have been compiled in order to illuminate the situation in developing countries. Figs. 8−12 also illustrate the facts given in the table

It would be very useful if some of the research work in the field of telecommunication traffic in the advanced countries was devoted to the types of overload problems that occur in the developing countries. Such studies might lead to the telecommunication systems becoming better adapted to the traffic situations of the developing countries.

It can also be expected that if the tutors of those receiving fellowships in traffic engineering in developed countries were fully aware of the traffic problems of the developing countries, such studies would be more rewarding.

1. GDP = Gross Domestic Product, market prices, 1973 price level in US dollars
2. GDP in factor costs divided by the number of inhabitants according to ITU Yearbook of Common Carrier Telecommunication Statistics, Heading XIV, 4
   If data for 2 are lacking: GDP according to 1 divided by the number of inhabitants
   If data for both 1 and 2 are lacking: Data obtained from *ESCAP document E/CN.11. Ref. 14*
   US dollar per inhabitant
3. State of the long-distance automatization:
   0 = Not foreseen within the next 10 years
   1 = To be planned in the near future
   2 = At the planning stage but not yet realized any where
   3 = Introduced between a few cities only
   4 = Introduced between the most important cities
   5 = Completed

[71], [72] Data from 1971, 1972 etc.

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Reed Switch with Integrated Micro Circuits

Royne Hjortendal and Toivo Wiklund

A 2-pole reed switch has been developed specially for AXE 10 in which the reed relays and the micro circuits required for controlling them have been integrated to form a printed board unit. The construction, function and design of the switch are discussed in this article. Particular attention is devoted to the patented operation principle and its advantages, the automatized manufacturing process and the comprehensive quality control system. Finally a summary is given of the main characteristics of the switch.

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Guidelines for the design

Within the framework of the cooperation between the Swedish Telecommunications Administration, LM Ericsson and ELLEMTEL, the product committee for switches and relays carried out an investigation in 1970 which resulted in a decision to develop a reed switch. Design guidelines were drawn up as a basis for the development work. The aim was to design a switch for use in the AXE system, but other applications were also taken into consideration. Among the given prerequisites the following, of a more fundamental nature, may be pointed out:

- electronic operation
- monostable function
- low attenuation and crosstalk
- high reliability
- mounted on a printed board
- connection via plug and jack
- low weight and small volume
- automatised manufacture
- possibility of repair.

In addition to the 2-pole switch for AXE 10, a 3-pole and a 4-pole switch with a different operating principle have also been developed. However, only the 2-pole switch will be discussed here. It is characterized by a patented method for operating and holding reed relays by means of special micro circuits. This makes it possible to control the switch direct with TTL (Transistor-Transistor Logic) circuits, after which the cross point relays are operated by the special micro circuits.

Design

The 2-pole switch contains 64 cross point relays, multiplied in a matrix design. The relays are operated, held and released by means of an relay control circuit and eight relay latch circuits, which are integrated in the matrix. The switch connector consists of two 32-pole sleeve jack units.

The switch is built up on a printed board of a paper-based laminate with foil on both sides. The connections that are required between the two sides are made with C-shaped wire jumpers. Fig. 1 shows the switch and the components included.

For grouping reasons the switch has been made available in three matrix sizes, 8×8, 2×(8×4) and 16×4. The

Fig. 1
The 2-pole reed switch with its individual components: printed board, connector, cross point relays, reed contacts and micro circuits

ROYNE HJORTENDAL
ELLEMTEL Development Company
TOIVO WIKLUND
Telefonaktiebolaget LM Ericsson

cross point relays, control and latch circuits are identical and have the same positions in all three variants, and it is only the foil pattern that is different.

A special cross point relay has been developed in order to meet the stringent demands made on the switch. The relay has a frame of glass fibre reinforced plastic with space for the reed contacts and the winding. It has a cover of magnetic material that serves as the return conductor for the magnetic flux. The cover also provides mechanical protection for the winding.

The reed contacts consist of two reeds of an iron-nickel alloy that are encapsulated in a gas-filled glass tube. The inner ends of the reeds are coated with gold alloyed with cobalt as the contact material. The characteristic data of the reed contacts are given in table 1.

The weight of the switch is approximately 530 grammes and its dimensions 222×192×13 mm.

Length of the glass tube	max. 21.5 mm
Non-operate test value	30 At
Operate test value	58 At
Non-release test value	27 At
Release test value	15 At
Insulation resistance	min. 10 Gohms
Contact resistance	max. 150 mohms

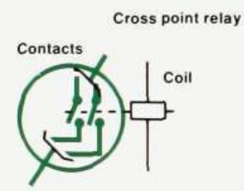
Table 1. Data for the reed contacts in the cross point relay

Functional description

The function of an 8×8 matrix is described below. The other matrices function in a corresponding manner.

The contacts of the cross point relays are connected to the cross points in the matrix formed by the incoming and outgoing speech paths. An input is connected to an output when the cross point relay operates, which gives galvanic through-connection, fig. 2.

The cross point relays are operated with the aid of two types of micro circuits designated control and latch circuits respectively, fig. 3. These micro circuits have been designed for their special functions in the switch. Each switch contains one control circuit and eight latch circuits.



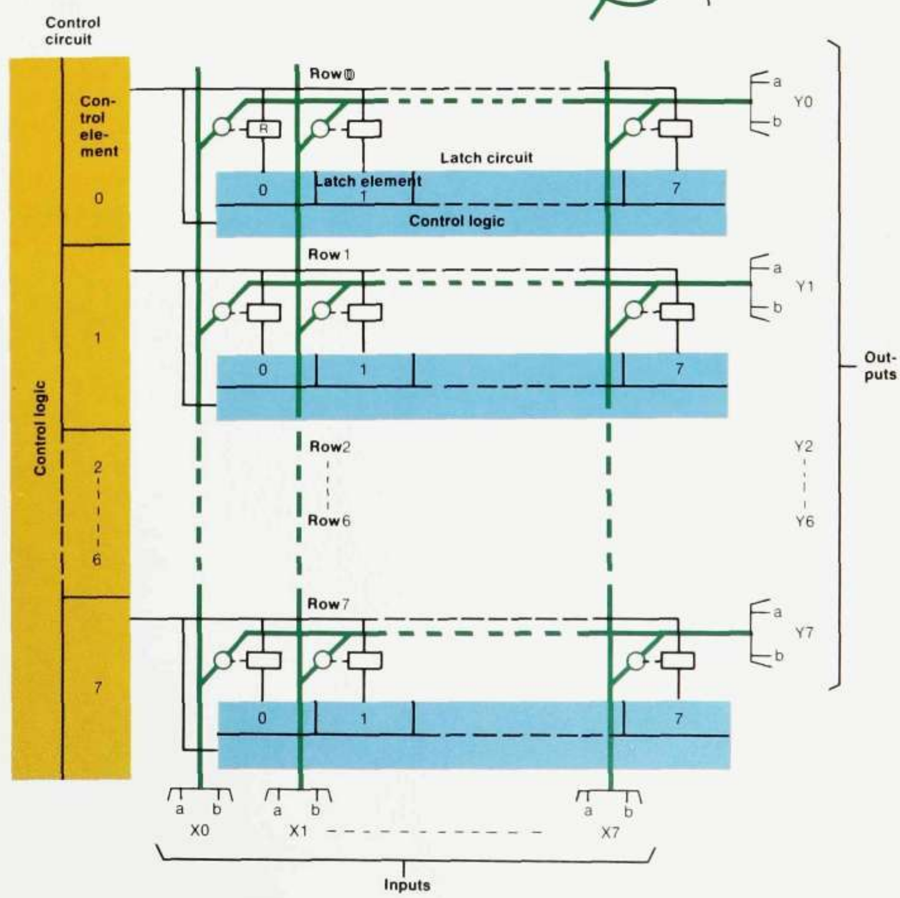
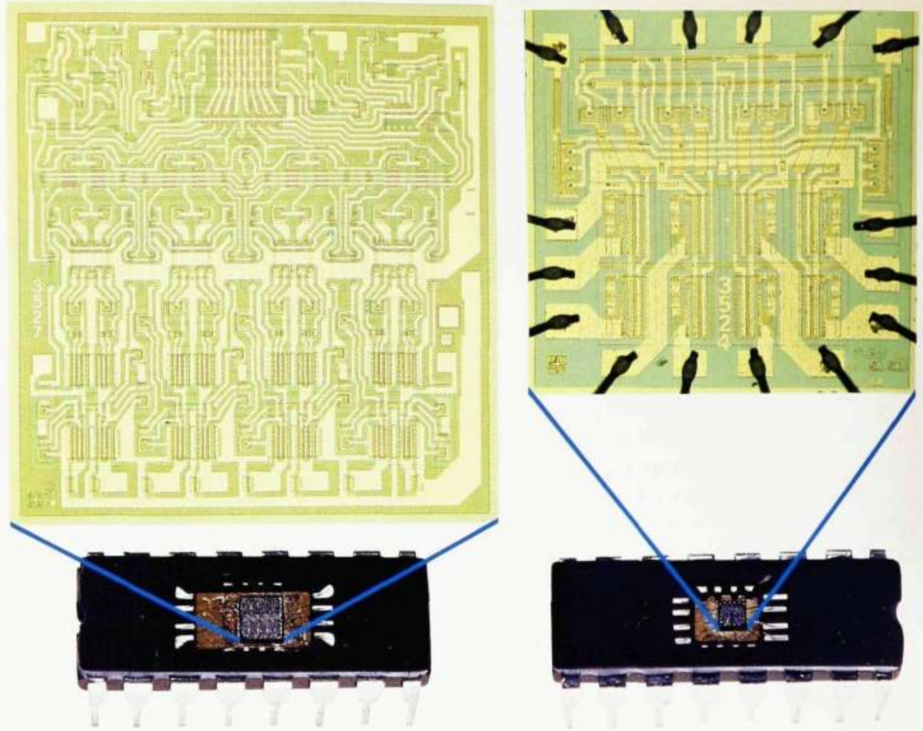


Fig. 2
Two-pole switch matrix with eight inputs and eight outputs (8×8) for setting up a maximum of eight simultaneous connections

Fig. 3
The two micro circuits are custom designed bipolar monolithic low-voltage circuits encapsulated in 16-pin DIL packages

Left: The control circuit. Chip area 2.4×2.5 mm
Right: The latch circuit. Chip area 1.5×1.5 mm
The actual length of the units is 20 mm



The basic principles of the operating method will be described below with reference to fig. 4. The inputs shown on the left-hand side of the figure are connected to internal address wires, which via an address converter are connected to a regional processor.

Control and latch circuits

The operation is carried out by adressing with nine digital address bits and one bit with information about operation or release, which are adapted to TTL logic. The feeding voltage to the control logic is also used as an address bit for selecting an individual switch. It is only connected in during operation so that the switch does not require control logic power in the idle condition.

The control circuit contains control logic and eight operating elements. An operating element serves one row in the matrix, since all relay coils in the row are connected to one and the same element.

Fig. 4
The principle for the operation of the reed switch

- Operating current path (red)
- Holding current path (blue)
- The speech path connected up (green)

OPV	Supervision and operating voltage
CE	Address bit for individual indication and voltage feeding of the control logic
YM0-2	Row address
XM0-5	Column address
Y0-7	Speech path connection, y direction. Output
X0-7	Speech path connection, x direction. Input

The switch construction permits changeover between inputs and outputs

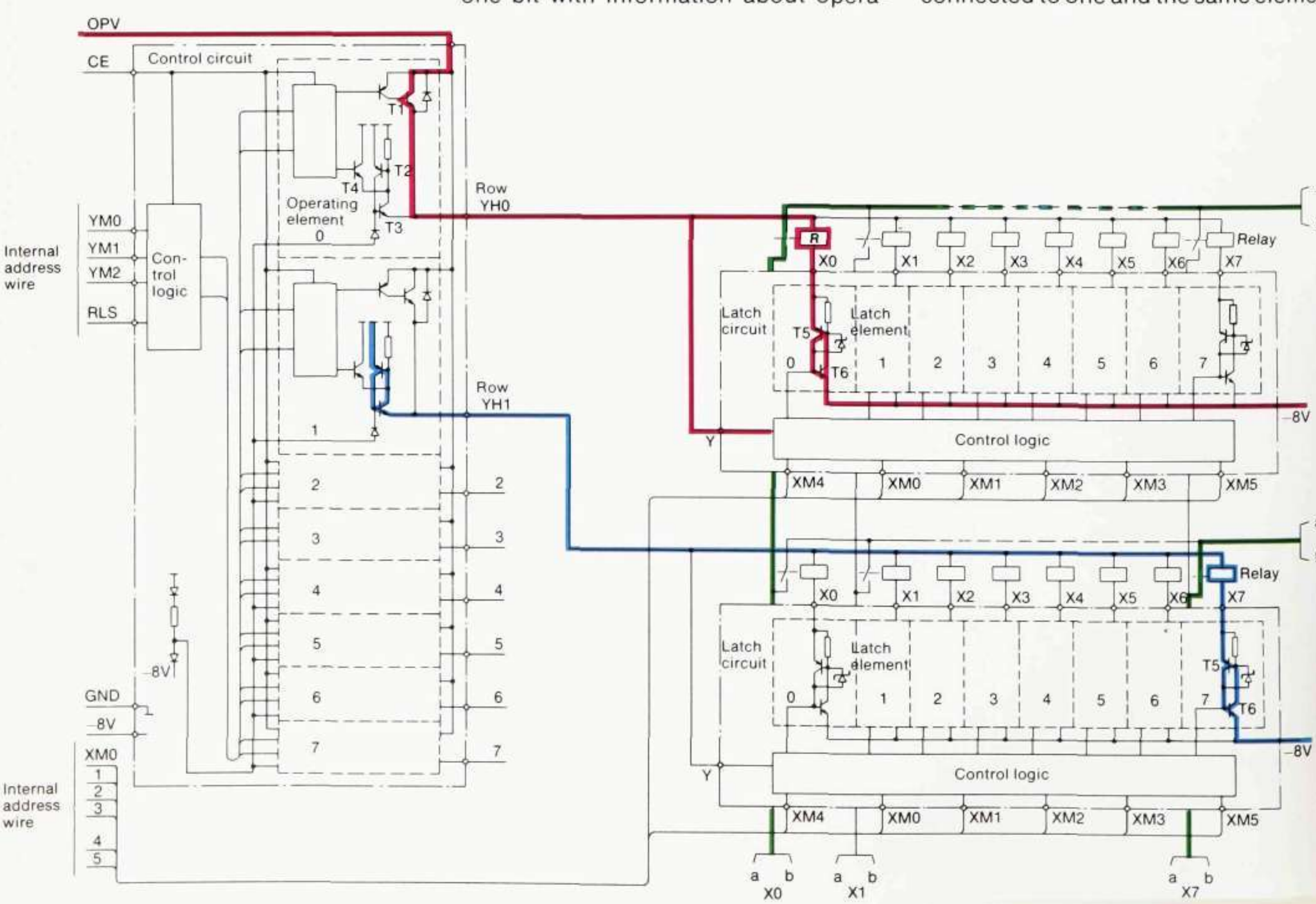


Fig. 5
Equipment for assembling cross point relays

Fig. 6
Numerically controlled equipment for the automatic mounting of cross point relays on printed boards. The equipment places the required relays on the board and then bends the soldering and fixing tags on the back of the board

The latch circuit contains control logic and eight latch elements. The latch elements in a latch circuit serve the same row in the matrix, with each relay coil in the row being connected to an individual latch element.

Operation
A cross point relay is operated by addressing the control circuit with the row address in question, YM0-YM2, together with the marking of operation RLS. The switch is then selected by activating CE. In this case it is assumed that relay R in row YH0 is to be operated, and thus operating element 0 is addressed.

Transistor gate T1 is opened when the logic in the control circuit for relay operation is activated. The voltage from OPV is thereby connected to all relays in row YH0 and to the control logic for the latch circuit.

Latch element 0, which serves relay R in the selected row, is then addressed with two of the address bits XM0-XM5, and the thyristor-coupled transistors T5-T6 are activated. The current through relay R then increases to the value required to operate the relay, under the control of transistor gate T1.

The operating current path is marked in red in fig. 4.

Holding
When the operation of the relay is completed, CE is ordered to its idle conditions. R remains operated, but with reduced power, the operating current being replaced by a holding current. This process is carried out automatically when transistor gate T1 is closed.

The thyristor-coupled transistors T2-T3 in the control circuit are activated by the voltage change that occurs because of the inductance in the relay, when the operating current circuit is broken. The holding current path that is thereby formed does not place any addressing requirement on the control or latch circuit. The thyristors are held conducting by the current that flows through them at a voltage level such that one cross point relay at a time can be operated in any of the other rows. Since the holding current path remains unaffected by any such operation, one cross point relay in each row can be operated, and thus up to eight simultaneous connections can be set up through an 8×8 matrix.

A holding current path via cross point relay X7 in row YH1 is shown in blue in fig. 4.

Release
The relevant operating element is selected in the same way as in the case of relay operation but this time a marking of release is sent to the control logic via RLS. The current through relay R then decreases to zero under the control of, among others, transistors T2-T4, and this completes the release.

Supervision
The control circuit draws current from OPV only when it is in the operate position. If the current to OPV is measured in this position it is possible to carry out several supervisory checks of the state of the switch, for example whether holding current or more than one operating current flow in the addressed row.

Disturbance immunity
Under the environmental conditions prescribed for telephone exchanges the operation of the switch will not be affected by disturbances in the speech paths caused by lightning strokes, disconnection of ringing current etc.

Fig. 7
Minicomputer-controlled equipment for electrical endurance testing of reed contacts. The equipment permits simultaneous testing of 50 reed contacts under conditions that can be varied as regards frequency, contact closure time, contact break time, current, voltage and type of load (resistive, inductive or cable). The contact resistance is measured and the release time is checked for each contact operation

Fig. 8
Minicomputer-controlled equipment for testing the static and dynamic parameters of micro circuits. It is used for the acceptance inspection of the micro circuits for the reed switch

The good immunity against such disturbing currents has been achieved by giving the thyristors a high holding current limit, and also because the disturbing current flows through a relay coil with a high inductance, which attenuates the current changes. In order, for example, to cause unwanted connection the disturbing current would have to be of such long duration and of such a value that it was at least equal to the holding current of the thyristors. Protection against unwanted release is provided by the automatic sequence for activating thyristor T2-T3 in the operating circuit and a similar function in the holding circuit for activating thyristor T5-T6.

In order to improve the disturbance immunity further, the control and latch circuits have also been equipped with functions that eliminate the effects of the direction of the disturbing currents.

Switch unit

In order to perform the traffic functions several switches are connected together in a switch unit.

Owing to the fact that each switch is selected individually, the address information for YM, XM and RLS can be sent over common address wires to all switches in the unit, since the information is only executed in the selected switch. It has also been possible to make the supervision common for a whole switch unit, since the selection is individual and only the selected switch draws current via OPV.

Rational manufacture

The simple design of the switch has made possible a high degree of mechanisation and automatisation of the entire manufacturing process from such details as reed contacts and micro circuits to complete switches.

The cross point relays are assembled in a specially developed machine, fig. 5. There one end of the two reed contacts is first bent, after which they are inserted in a previously wound and tested coil and the other contact end is bent. Special equipment has also been designed that mounts the cover on the relay at the same time.

After the cross point relays have been electrically tested they are automatically mounted on printed boards in numerically controlled equipment, fig. 6.

Finally the printed board assemblies are soldered in an automatic drag soldering machine.

Measures to ensure high quality

A comprehensive quality control system is used in order to be able to guarantee high quality in the completed reed switches. The system comprises, among others, the following activities:

Type testing of micro circuits, reed contacts and complete switches in accordance with the principles described in a previous article in Ericsson Review[1]. When carrying out electrical endurance testing of the reed contacts a minicomputer-controlled equipment is used, in which 50 reed contacts can be tested simultaneously in specified test conditions, fig. 7.

Acceptance inspection of micro circuits, connectors and material in the way described in the above-mentioned article[1], fig. 8.

Production control to prevent details with unacceptable quality from continuing in the production chain. This includes electrical testing of printed boards, reed contacts, coils and cross point relays.

Final inspection of completed switches, comprising visual inspection and extensive electrical testing in special equipment, fig. 9.

Quality checks for continuous supervision of the quality level of micro circuits, reed contacts, cross point relays and complete switches. Special inspectors, who work independently of the production control, then check test samples chosen at random.

Reliability assessment, which is carried out periodically on a small number of micro circuits, reed contacts and complete switches in order to check that they function in the intended way, during the specified time and in the pre-

Technical data

2-POLE REED SWITCH

Winding resistance	300 ohms
Power when idle	0.05 W
Operating power of which 0.40 W in the cross point relay	0.60 W
Holding power	0.16 W
Operate time	2 ms
Release time	2 ms
Speech path resistance, incl. connectors	max. 1 ohm
Crosstalk attenuation, 1100 Hz	min. 110 dB
Insulation resistance	min. 1 Gohm

scribed environment, see also the above-mentioned article[1].

Conclusion

The major advantages of the 2-pole reed switch compared with other analog switches can be summarized as follows:

- the integration of control circuits and cross point relays to form one unit has led to a well coordinated, functional switch with high operational reliability which is of course also obtained from the complete switch unit
- the integrated operation permits a modular division of functions, which simplifies the system design and has the effect that only small units are knocked out when a fault occurs
- the operated cross point relay is not held via any of its own contacts, and thus the reed contacts do not have to make or break current circuits, which increases the operational reliability and life of the switch
- the operation and holding of the cross point relays takes place individually instead of in series, which permits the use of low operating voltages. As a result it has been possible to design the circuits for bipolar low-voltage operation with built-in protection against transients
- individual operation and built-in supervisory function make testing more efficient and simplify fault localization during manufacture, installation and operation
- the switch has good immunity against disturbances because of the joint effect of the inductance of the cross point relay and the high thyristor holding current
- the need for only two contacts per cross point and the utilization of the new operating principle, together with the high packing density, have resulted in a very small volume per switch unit
- the simple mechanical construction of the switch has created the prerequisites for automatic manufacture and simple repair.

Fig. 9
Microprocessor-controlled equipment for the final electrical testing of reed switches that are ready for delivery. The switches are tested with regard to operational reliability, test currents, speech path resistance, double operation, unwanted release and dielectric strength

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Operational Experience of AKE 13

Lars G. Ericsson and Åke Persson

The operation and maintenance characteristics of transit exchange system AKE 13 have been described in a previous article in Ericsson Review[1]. The article also mentioned the operational experience briefly. In this article this experience will be described in more detail.

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The SPC technique makes it possible to register continuously and store centrally information concerning the traffic situation and the telephone network, whereby a far greater number and more efficient aids for operation and maintenance can be offered than was possible in earlier systems. In order to be able to utilize these advantages the telephone administrations have adapted their operating routines accordingly and given the staff the necessary training.

For most administrations the introduction of AKE 13 constituted the first contact with software handling. However, thanks to the modular structure of the system and its division into function blocks this has not caused any serious problems. The blocks are treated as products and have their own individual documentation.

Operation and maintenance

The operation and maintenance of a telephone exchange comprises varying tasks, such as

- network management
- traffic control
- traffic measurements
- supervision of the operation of the various parts of the exchange
- supervision of the function and transmission characteristics of the lines
- fault localization and clearing.

The flexibility and large logic capacity of the SPC technique have made it possible to provide the AKE system with a number of aids (almost 60) that enable this work to be carried out very much more efficiently and easier. Several of these aids are part of the system software, and communication with them takes place via the exchange's own input and output devices, i.e. typewriters, tape recorders etc. The various operations, such as blocking and deblocking of lines, start of operational supervision, transmission measurements and data output and changes in the exchange data, are thus ordered by means of typewriter commands. Detailed and easily interpreted information for the maintenance work is obtained on typewriter or display. Comprehensive data, which provide the basic information for an economical dimensioning of the telecommunication network or for the accounting between the telecommunications administrations, are stored on magnetic tape.

Fig. 1
LM Ericsson carries out extensive training activities with, among others, participants from the operating staff of the telecommunications administrations. Special AKE 13 exchanges with complete control rooms have been built up in Stockholm for training purposes. The picture shows one of these control rooms where two engineers from PTT in Czechoslovakia receive tuition in operation and maintenance


LARS G. ERICSSON
ÅKE PERSSON
Telephone Exchange Division
Telefonaktiebolaget LM Ericsson

An example of aids and their use is given on the last page of this article. It is a summary of the measures taken in an AKE exchange (Fredhäll in Stockholm, Sweden) after a report has been obtained from a preceding exchange that there are disturbances on the route between the two exchanges. (A faulty line is usually detected by the staff in an AKE exchange before the interworking exchanges have had time to react, however. The AKE exchange contains a function that continuously monitors the load on the lines and provides a daily printout of a list of the lines that have not been included in any completely established connections during the preceding 24 hours. It may be mentioned that the AKE 13 exchange in Fredhäll detects about five line faults every week with the aid of this function.)

Extensions and function changes

In several AKE 13 exchanges one or more extensions have already been carried out. These have varied considerably as regards extent and degree of complexity. Experience from these has constituted the basis for further development of the system as regards extensions and the addition of functions. Most extensions have been combined with the introduction of several new functions, so that the connection of new hardware has been preceded by a change of the program package, table 1.

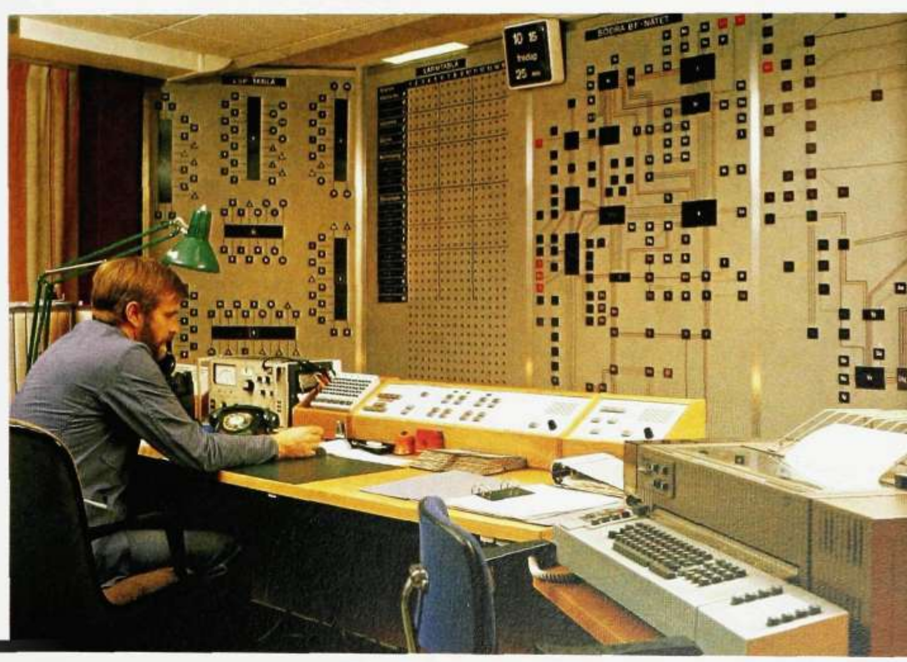
Helsinki	January 1977
Copenhagen	November 1975
Rotterdam DC	March 1973
Rotterdam DC	July 1974
Turku	April 1977
Ålborg	August 1974
Ålborg	February 1977

Table 1
In these AKE 13 exchanges the program package has been changed in connection with an extension

Changing the software in an exchange during operation, without disturbing the traffic more than during a normal system restart, naturally makes very stringent demands on the quality of the software and the reliability of the methods used. Every effort has therefore been made to prepare detailed instructions that cover all stages from the compilation of the program package to the supervision during the first few weeks after the package has been taken into service.

Continuous development of the system has been carried out with the aim of minimising the manual work during the production of the program package as well as the installation of the software and hardware. This has resulted in, for example, automatized compilation of the data tables that control the transfer of traffic data from the old to the new program package. This transfer of data, which takes place between the two separated halves of the system, must be executed without error so that the traffic in progress is not disturbed. The tables were previously produced entirely by hand, and thus the automatisation has eliminated a considerable error risk. Another result has been the develop-

Fig. 2
A large part of the Swedish trunk network is supervised from the Swedish Telecommunications Administration's traffic supervision centre in Stockholm. Remote switching of lines and rerouting of traffic can also be carried out. The centre contains a test desk, which is remotely connected to the AKE 13 exchange in Hammarby (Stockholm). From here measurements and traffic observations are carried out on trunk and international lines. The lines are connected up to the test desk by means of commands on a remotely connected typewriter, which can also be used for other orders and printouts concerning the AKE



ment of a special function block that controls the activities of the operator during an extension. The system then checks that the operator carries out the correct measures in the right order and informs him when the next step is to be taken.

The many extensions of the control system that have been carried out during the years emphasise that the synchronous duplication offers many advantages. Thanks to the duplication it has even been possible to change *central processing units without interrupting the traffic.*

Component characteristics

Much effort has been devoted to the design and choice of the components used in the AKE system, among other reasons to reduce the number of hardware faults to a minimum. Table 2 shows that this work has been successful. The table gives the number of component faults during the first 18 months that the Fredhäll AKE 13 exchange in Stockholm was in operation. The number of replaced components is extremely low, in fact nil for most categories. The highest number is for the reed relays, where 12 have had to be replaced. However, eight of these were of a type that was found to be somewhat unsuitable for this particular application. This type has therefore been superseded.

The replacement rates for particular component categories are shown in column 4 and have been calculated, using the following formulas:

$$\bar{\bar{Z}} = \frac{r}{NT} \cdot 10^9 \text{ for } r > 0$$

and

$$\bar{\bar{Z}} = \frac{1}{3NT} \cdot 10^9 \text{ for } r = 0$$

where

- $\bar{\bar{Z}}$ the number of components of particular category that require replacement during a period of 10^9 hours
- T the observation time, in this case 13 140 hours (18 months)
- r the number of components replaced during the observation time
- N the total number of components in that category

Column 5 contains the corresponding values calculated on the basis of fault rate information from LM Ericsson's

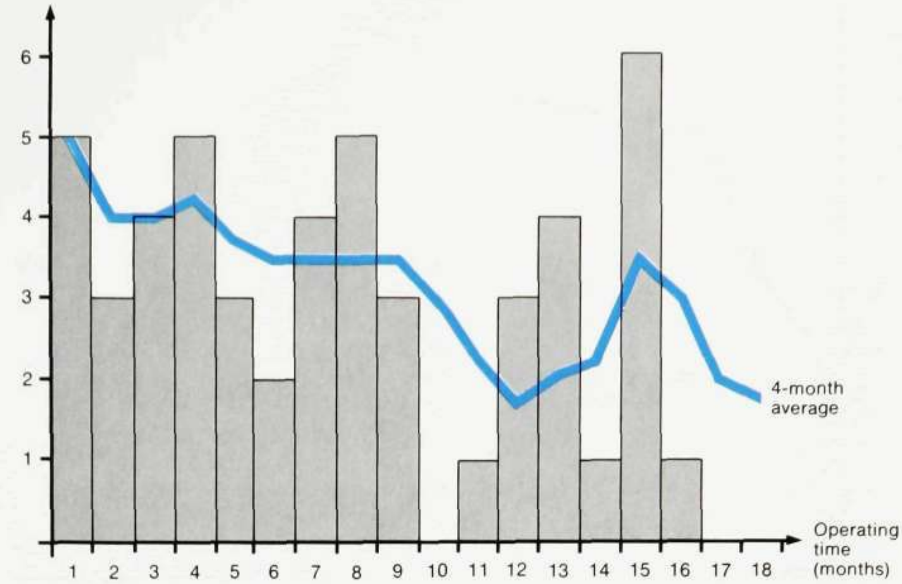
Table 2
The replacement frequency for components in the AKE 131 exchange in Fredhäll, Stockholm

*) Calculated on the basis of the number of components replaced in Fredhäll

**) Calculated on the basis of information from the LM Ericsson's component data bank.

1. Component category, often containing several component types	2. Number of components in operation	3. Number of component replacements during 18 months	4. Number of component faults per 10^9 hours*)	5. Number of component faults per 10^9 hours**)
Silicon transistors, PNP	3 800	0	6.7	9.5
Silicon transistors, NPN	107 000	7	5.0	5.3
Silicon diodes	234 000	2	0.60	2.0
Integrated circuits	2 700	0	9.5	40
Integrated circuits, TTL 7400	2 100	0	12	33
Zener diodes	540	0	47	43
Tantalum electrolytic capacitors	22 000	1	3.5	28
Polyester film capacitors	45 000	0	0.57	2.1
Mica capacitors	95 000	0	0.27	0.23
Metallized paper capacitors	25 000	0	1.03	1.8
Carbon film resistors	472 000	0	0.05	0.79
Reed relays	11 600	12	79	10
Printed boards (not the components)	23 200	2	6.6	2.5
Soldering points on the printed boards	$2.3 \cdot 10^6$	2	0.067	0.01

Fig. 3
Replacement of printed board assemblies in the AKE 31 exchange in Fredhäll (Stockholm) during the first 18 months of operation



data bank for components. The disparities between columns 4 and 5 are due, among other things, to the fact that the number of components replaced in Fredhäll is too low to provide a correct statistical basis. However, columns 4 and 5 illustrate the continuous follow-up of component quality carried out within LM Ericsson.

A component fault often means that the printed board assembly in question must be replaced. During the first 18 operational months in Fredhäll, 50 out of a total of 23 200 printed board assemblies were actually sent for repair, whereas a calculation on the basis of the information in the component data bank gives 55 assemblies. Fig. 3 shows the number of printed board assemblies replaced per month and the 4-month average.

Service quality

A modern transit exchange system must naturally meet very stringent demands as regards operational reliability. The tools placed at the disposal of the exchange staff for achieving this aim and thereby maintaining a high service quality have already been mentioned. Other factors, which have often been in the forefront in connection with the service quality of the system, are discussed below.

System restart

The previous article on the operation and maintenance characteristics of the AKE 13 system[1] contained a description of the system restart and its value in maintaining the operational reliability of the AKE exchanges. It also contained a

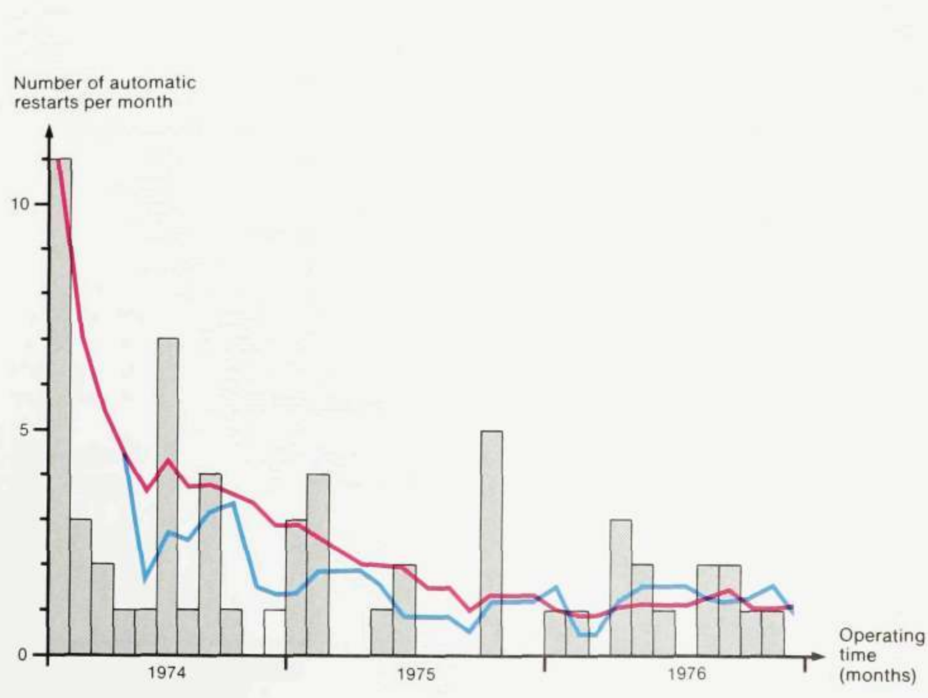


Fig. 4
The system restart rate in the AKE 131 exchange in Fredhäll with one DPB and 2 400 multiple positions
4-month average

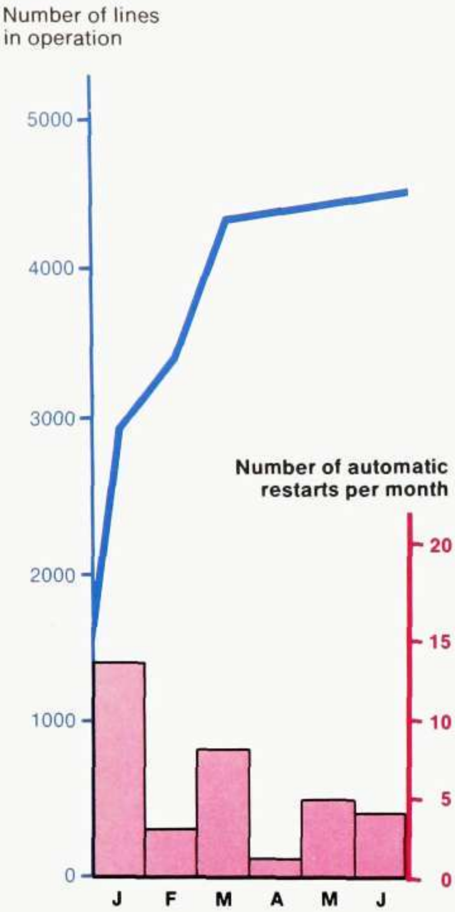


Fig. 5
The system restart rate during the first half of 1977 and the number of lines in operation in AKE132 in Oslo

diagram showing the system restart rate for the first AKE 13 exchange, namely Rotterdam DC. As a complement fig. 4 shows the system restart rate for AKE 131 in Fredhäll, from the start in February 1974 to 1976. The curves for Fredhäll have the same characteristic, rapidly decreasing tendency as the Rotterdam curves, but they start at a considerably lower level. This demonstrates how much the system has been improved since Rotterdam DC was put into operation.

The first AKE 132 exchanges with the new control system APZ 150 were put into operation in 1976. Fig. 5 shows the number of automatic system restarts and the line growth during the first half of 1977 in AKE 132 Oslo, which was put into operation in November 1976. This is Norway's first SPC transit exchange. It is controlled by two processors and comprises 9 600 multiple positions.

System availability

LM Ericsson has specified extremely rigorous requirements for the central units whose functional reliability is of fundamental importance to the operation of the system. This is evidenced by the synchronous duplication and the meticulous choice of components. Clear and well documented routines are also necessary to ensure reliable handling of an SPC exchange in different situations. For this purpose it is also essential that the commands are correctly designed as regards format and plausibility checks. LM Ericsson has successively devoted considerable effort to such questions, based on experience from the various AKE 13 exchanges.

If even so a system fault should occur in an exchange, it is essential that the system is started up again without delay. In order to make the restart procedure fast and reliable a part of it was already automatized in the first version of the system, AKE 131. In the latest version, AKE 132, the whole process is automatised, even the reloading of the stores from magnetic tape and the restarting of the operation by means of a major system restart.

An essential factor is of course how the subscribers experience a telephone system. The effect of system faults on the availability of the system then comes into picture, which is illustrated in fig. 6 for four AKE 131 exchanges. These are Rotterdam INT with one processor, Guadalajara with two, Turku with two and Rotterdam DC with three processors. Thus varying sizes of exchanges and different telecommunications administrations are represented.

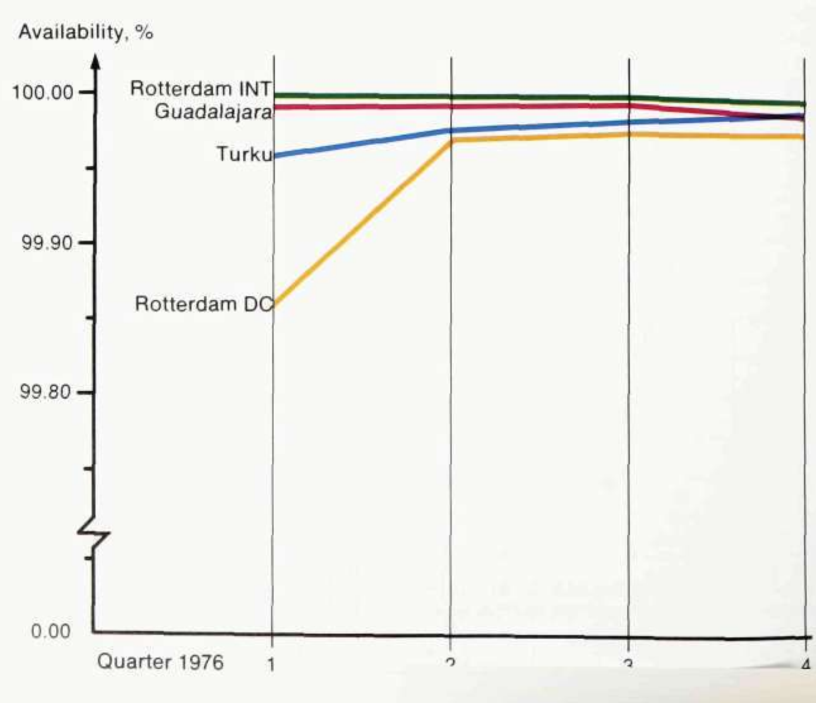


Fig. 6
System availability for AKE 131 exchanges, i. e. the time the system can handle traffic, as yearly averages

Investigation of disturbances on an incoming route

Information is received from a conventional telephone exchange that disconnections have occurred in the register stage in the case of traffic towards the AKE exchange. This leads to the following activities at the AKE exchange:

1. The faulty route is monitored for disturbances. This results in printout of all abnormal switching cases, including the error type code in each case.
2. The faulty route is put under automatic traffic observation. This function randomly selects calls that come in on the route. A printout gives the calls that have been disconnected in the register stage, with the cause of the disconnection (in code).
3. If the printouts in accordance with 1 and 2 give reason for suspecting a certain line an exchange tester is connected in, which makes test calls towards the AKE exchange. In this way the fault source is localized to the line or the exchange.
4. Alternatively the situation on the line is studied with the aid of a special indicator in the control room. This shows the condition in the special data field allocated to the line and also the condition in the associated test and control points. The data field indicates, for example, the line state, whether any device is linked to it and, in certain cases, the received digits.
5. The line can also be investigated by means of a logging function, which gives a printout of all changes in the line state, for example received signals.

Good operational values have also been obtained in the new AKE 132 exchanges. For example, the mean value for the system availability in the Helsinki HT exchange was 0.99974 during the first six months of operation.

Training and staff requirements

Hitherto most AKE exchanges have experienced continuous connection or extension activities. During this period the exchanges have been staffed in an irregular way and in many cases with more employees than normal operation requires.

Against this background it is difficult to say from experience exactly how many people the administrations will require for their SPC exchanges. The exchanges that have been put into operation hitherto have a staff of, on average, 4 to 6 persons. In small exchanges the number is often less. This staff is responsible for all operation and maintenance activities, such as line management, line supervision, function changes etc.

The operating staff usually have a good all-round knowledge as regards the maintenance of the various system parts of the exchange, but there is a certain amount of specialisation in the control system (APZ). It is usually only the operational managers who are fully trained engineers or technicians. The remainder have had varying practical experience of conventional exchanges, and have then been given further training by the administration in electronics, digital technique, telephony etc. Finally training in the AKE system has been provided by LM Ericsson in Stockholm or by a subsidiary company. In most cases this comprises 3–6 months' theoretical training followed by 1–2 years' practical work in an AKE exchange.

The operating staff have experienced the change from older systems to AKE as extremely positive, one of the reasons being that the work does not so easily become routine.

Certain administrations, particularly those with more than one AKE exchange, have set up a special support group of 3–5 people in the administration's technical division. The main task of this support group is to act as an intermediary between the exchange and the various technical departments of the administration and between the exchange and LM Ericsson in questions regarding operation and maintenance. The support group usually consists of engineers with AKE training and very good knowledge of the system. It is not unusual that, in addition to the same AKE training as the operating staff, they also have practical experience of design work in LM Ericsson's technical departments.

Summary

The introduction of AKE 13 has meant that the telecommunications administrations have not only obtained exchanges with high capacity, good transmission characteristics and fully automatised maintenance functions but also considerably more advanced aids for supervision and maintenance of the surrounding network. As a result it has been necessary to modify the operating routines of the conventional systems somewhat in order to achieve optimum utilization of the advantages of the new systems.

The system has undergone continuous development in order to extend the function range, improve the operating characteristics and the reliability and simplify the handling. The experience gained by the telecommunications administrations that have AKE exchanges in operation has been exploited for this purpose. As a result, with AKE 13 LM Ericsson can offer an extremely practical and adaptable telephone exchange system for medium to very large transit exchanges.

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Generation of the Basic Frequencies for FDM Systems

Bertil Lyberg and Istvan Fekete

In the M5 construction practice the volume of the equipment for central frequency generation of the basic and pilot frequencies required for systems of up to 2700 telephony channels has been reduced to one fifth of that of the previous generation of equipment. The equipment has been provided with automatic frequency adjustment of the master oscillators. Unlike any other known frequency control system this equipment for frequency adjustment is based on real frequency detection without phase control. This means that it has been possible to eliminate disturbance and instability problems. In addition the introduction of active distributors has meant greater possibility of adapting the distribution of basic and pilot frequencies to the actual requirement.

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The frequency generating equipment is divided into a central part, which is common for the whole terminal, and local parts that are placed in the various multiplex stages. The central part consists of the frequency reference for the terminal, the master oscillator, from which a few basic frequencies are derived. These are chosen so that the required carrier frequencies can easily be derived. The local parts consist of equipment for converting the basic frequency to the required carrier frequency.

This division into central and local equipment, which was also used in the previous equipment generation, M4, has proved to be a suitable method for keeping down the number of station cables needed for frequency distribution, at the same time that unnecessary duplication of complex frequency generating equipment is avoided.

Since today even fairly complicated frequency conversion can be carried out quite easily using the phase locking technique there is a tendency towards a reduction of the number of distributed basic frequencies. In certain cases it has also proved to be economically advantageous to generate pilot frequencies locally in the multiplex stages.

As in many cases the frequency generating equipment must be able to drive older equipment as well, the central equipment also includes the generation of frequencies that are required in the older systems.

Since there is a central point in the terminal where all pilot and carrier frequencies can be adjusted, i.e. the central frequency generating equipment, it was natural that the equipment for automatic frequency adjustment was also placed there, with the associated equipment for filtering out and through-connecting the frequency comparison pilot.

The development, not least in the component field, has made it possible to reduce the volume of the central frequency generating equipment for systems of up to 2700 channels in the M5 construction practice[1] to one fifth of that of the previous equipment generation.

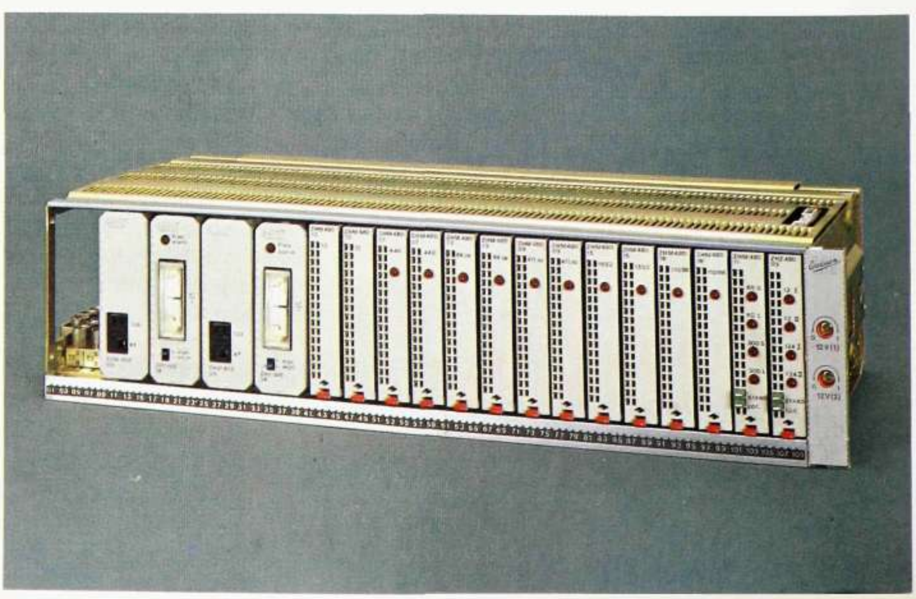


Fig. 1
Frequency generating shelf 12–11 096 kHz for systems of up to 2700 channels

BERTIL LYBERG
ISTVAN FEKETE
Transmission division
Telefonaktiebolaget LM Ericsson

System design

A M5 single shelf, figs. 1 and 2, for system sizes up to 2700 channels contains duplicated equipment for generating

- the basic frequencies 12, 124 and 440 kHz
- the group pilot 84.08 or 104.08 kHz
- the supergroup pilot 411.92 or 547.92 kHz
- the mastergroup pilot 1552 kHz
- the supermastergroup pilot 11 096 kHz

In addition the shelf contains equipment for

- through-connection of the 60 or 300 kHz frequency comparison pilot and conversion of 60 to 308 kHz or alternatively 300 to 60 kHz
- local generation of the 60 and 300 or 308 kHz frequency pilots
- automatic frequency adjustment and supervision of the master oscillators.

Distribution of the generated frequencies takes place in a special frequency distribution shelf, fig. 3, which contains up to ten distributors with eight outputs per distributor. The distribution shelf also contains equipment for level supervision and switching between two frequency generating equipments in the cases where these are duplicated. See the section "Duplication".

A special equipment is available for small systems (120–960 channels) in which the generation and distribution of the basic and pilot frequencies required for these systems has been accommodated in a single shelf, fig. 4.

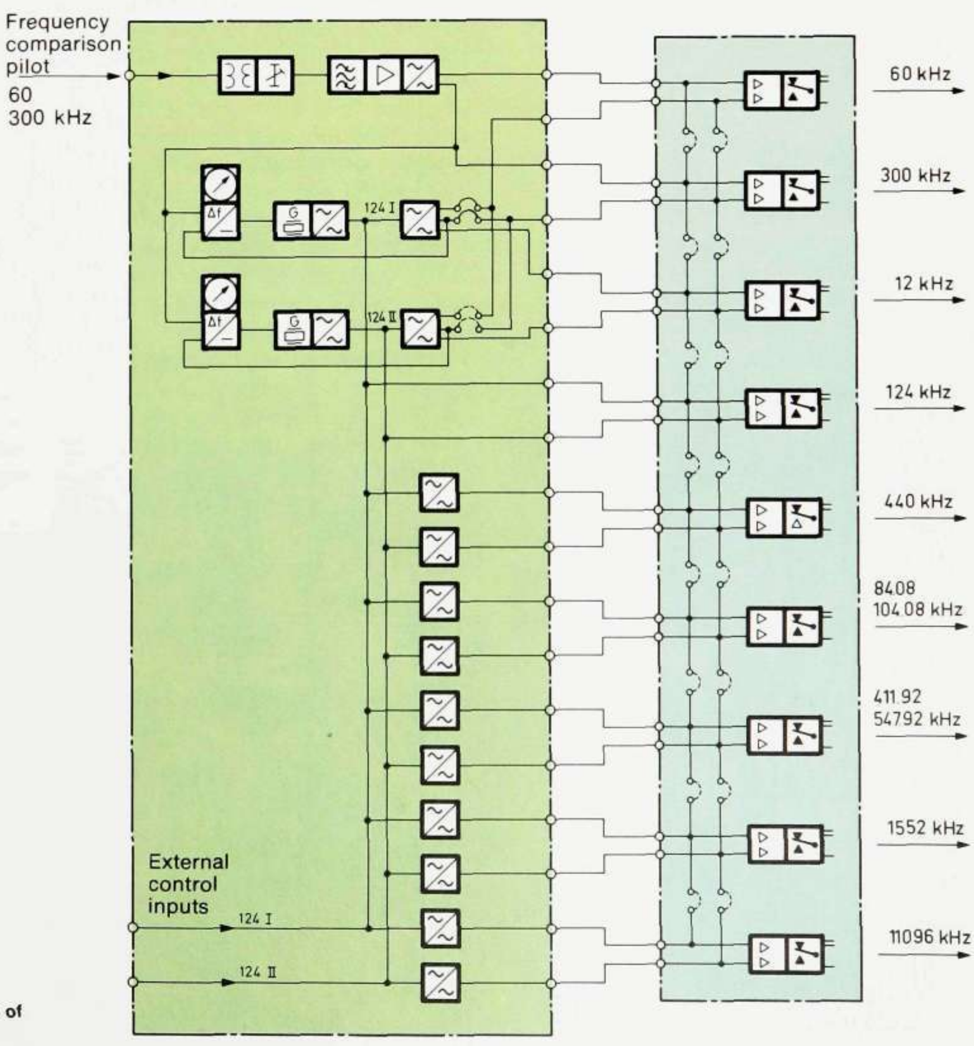
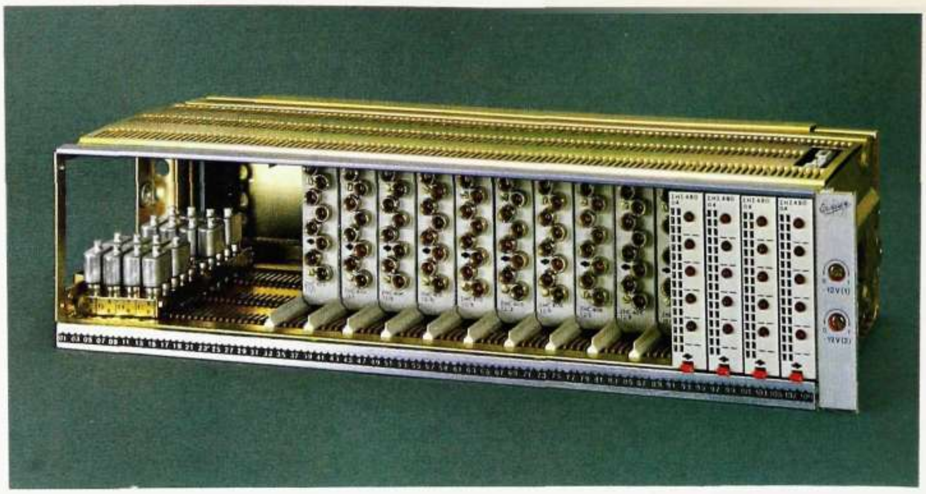


Fig. 2
Frequency generating equipment for systems of

Fig. 3
Frequency distribution shelf



Frequency stability

Since all distributed frequencies have been derived from the master oscillators (equipment I and equipment II), they all have the same high frequency stability as the master oscillators, namely

$$\left|\frac{\Delta f}{f}\right| \leq 5 \cdot 10^{-8}/\text{month}$$

The frequency accuracy $5 \cdot 10^{-8}$ is sufficient for systems with up to 2700 channels.

Adjustment of the master oscillator frequency can be done either manually or automatically. In the case of automatic adjustment, regulation takes place only when the relative deviation of the master oscillator frequency exceeds 2/3 of the value prescribed for the system. This means that frequency adjustment will be carried out very infrequently, since the master oscillators have very high frequency stability. If higher frequency stability than that recommended by CCITT is required, the frequency adjusting unit can be restrapped to a higher frequency accuracy. As this control system is based on real frequency detection[2, 3] without phase control, and since the system, unlike previously known frequency control systems, permits a certain amount of frequency deviation within the regulation limits, it has been possible to effectively eliminate locked phase positions between different stations and systems, with associated problems such as the unfavourable build-up of disturbance in the network.

124 kHz interface

The equipment is designed with a 124 kHz interface. This means that when necessary the equipment can be controlled from other master oscillators that are already available in the station.

Flexibility

All frequency converters in the shelf have standardised connections and a standardised input and output level (0 dBm). This gives great flexibility as regards equipping. Thus for example the 84.08 kHz group pilot can be replaced by 104.08 kHz simply by changing the frequency converter.

Distribution

The introduction of active distributors with built-in changeover and level supervision has meant improved facilities for adapting the distribution of basic and pilot frequencies to the actual requirement.

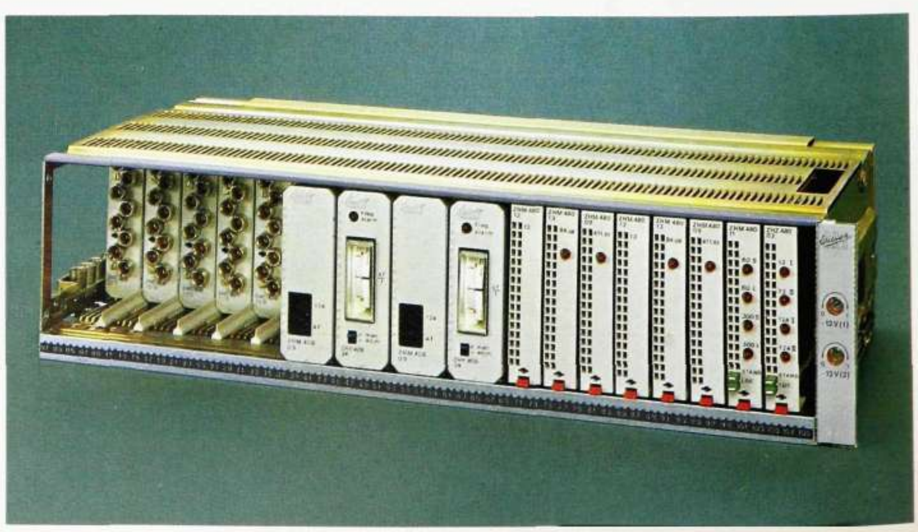


Fig. 4
Frequency generating shelf 12 – 547.92 kHz for systems of up to 960 channels

Since the eight outputs of the distributor have the same level as the input it is possible to increase the number of outputs both in parallel and series form or a combination of the two. It is thus possible to divide up the risks between a number of changeover points, so that a distribution and changeover structure with the appropriate reliability can be obtained for different station structures.

Duplication

The frequency generating equipment can be duplicated or unduplicated. With unduplicated operation the shelf is equipped with a single set of units. When the equipment is duplicated, equipments I and II are considered as equal, that is to say neither equipment has preference over the other. Thus when a fault occurs the number of changeovers is halved, since there is no need for a change back from the standby to the working equipment when the fault has been repaired.

Units

Master oscillator 124 kHz
Master oscillator 124 kHz consists of a 4960 kHz crystal oscillator and a frequency converter from 4960 to 124 kHz, fig. 5.

The oscillator crystal and the other temperature sensitive items are placed in a thermostatically controlled oven, in which the temperature is set to the turning-point temperature of the particular crystal, i.e. the temperature at which the temperature coefficient of the crystal is zero. This reduces the effect of external temperature variations to a minimum.

The oscillator frequency can be adjusted either by hand with a screw on the front of the unit, or automatically with a control voltage on a special input.

The oscillator has a frequency stability of $5 \cdot 10^{-8}$/month.

The frequency conversion from 4960 kHz to 124 kHz is carried out by CMOS type digital dividers.

Frequency converters
All frequency converters from 124 kHz utilize the phase locking technique, which means that even such complicated frequency conversions as 124 kHz to 411.92 kHz can be carried out in one unit.

The introduction of the phase locking technique in frequency converters has made it possible to actively influence the noise level and other disturbing frequencies around the utilized frequency, and thereby reduce the increase in noise power that is unavoidable with frequen-

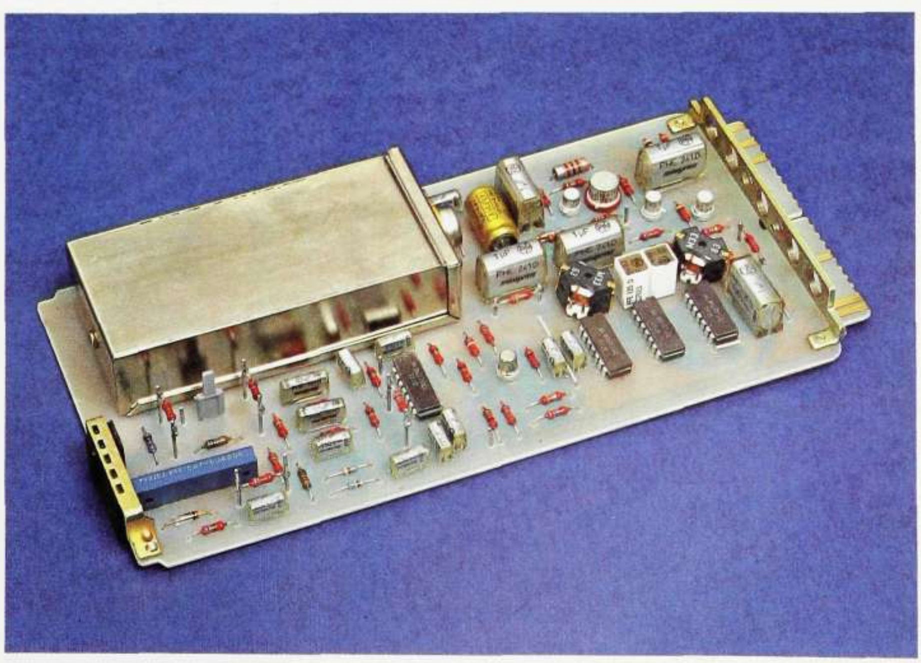


Fig. 5
Master oscillator 124 kHz

cy multiplication. This is particularly advantageous with high multiplication factors, such as frequency conversions from basic frequency to carrier frequency.

Through-connection unit
The 60 or 300 kHz frequency comparison pilot is filtered out from the incoming transmission band by means of regeneration. A simple band pass filter ensures that the level of the frequency pilot is so high in relation to the other frequencies in the transmission band that locking to the frequency pilot is obtained in the phase-locked regenerator. With this technique filtering is obtained with a very narrow passband, and thus the noise level and other interference products can be kept at a sufficiently low level even after multiplication of the frequency comparison pilot. Furthermore pilot frequency conversions can be carried out very easily through the choice of suitable crystal frequency and division chains in and outside the feedback loop.

The output signal is blocked if there is no synchronism between the incoming and outgoing signal, or if the incoming frequency has dropped by more than approximately 5 dB below the nominal input level.

Loop parameters and blocking functions have been chosen so that the system is absolutely stable even when a considerable number of units are connected in series, which is the case in distribution systems for the frequency comparison pilot.

Frequency adjusting unit
The frequency adjusting unit, figs. 6 and 7, has three different functions:
- indication of the frequency deviation of the master oscillator relative a reference frequency
- frequency supervision
- automatic frequency adjustment.

The *momentary frequency deviation* with sign is obtained through derivation of the phase difference of the input signals and is indicated continuously on a pointer instrument that is calibrated in relative frequency deviation. Full-scale reading corresponds to the frequency accuracy required for the system.

The master oscillator receives its control voltage from a memory element with 256 steps, which gives sufficiently accurate frequency resolution.

When the relative frequency deviation continuously exceeds 2/3 of the value prescribed for the system, the memory element steps up or down depending on the sign of the frequency deviation. The stepping continues until the frequency of the master oscillator is correct. A decision time of 10 seconds ensures that the measured frequency deviation is systematic and not caused by any phase jumps in the incoming frequency pilot.

A break in the incoming frequency pilot does not affect the control voltage to the master oscillator and hence it does not affect the oscillator frequency either. The high frequency stability of the master oscillator means that even long breaks in the frequency pilot will not

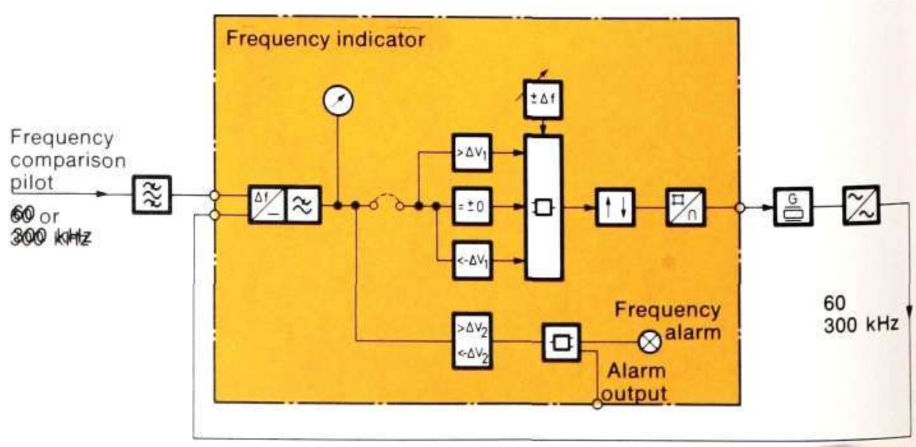


Fig. 6
Automatic frequency adjustment

jeopardize the frequency accuracy required by the system.

An alarm is given when the relative frequency deviation continuously exceeds the value prescribed for the system for more than 10 seconds. In the case of manual regulation the alarm indicates when adjustment should be carried out.

Since the frequency adjustment is automatic alarms are normally not obtained unless a fault occurs in the regulation equipment or the master oscillator cannot be controlled sufficiently to meet the frequency requirement.

Distributor

The active distributor consists of duplicated level stabilizing amplifiers with an electronic changeover device. The distributor also contains equipment for level supervision. The distributor has eight outputs with the level 0 dBm/75 ohms. All outputs are short-circuit proof.

A level alarm is given when the output level deviates by more than 0.5 dB from the nominal level. Changeover takes place for a level drop of 0.5 dB only if the level on the standby equipment is 1 dB better. These changeover requirements ensure that there is no changeover to faulty standby equipment.

The two amplifiers and level supervisors have entirely separate feeding voltages, which makes for high reliability.

Technical data

Frequency stability or accuracy of the generated frequencies

a. Without automatic frequency control of the master oscillator and after 3 months of continuous operation

$\frac{|\Delta f|}{f} \leq 5 \cdot 10^{-8}$/month

b. With automatic frequency control of the master oscillator

$\frac{|\Delta f|}{f} \leq 3{,}5 \cdot 10^{-8}$

Distributed frequencies

Basic frequencies	12, 124, 440 kHz*)
Output level/impedance	0 dBm/75 ohms
Level limits	±0.3 dB

Pilots

Group reference pilot	84.08 or 104.08 kHz
Supergroup reference pilot	411.92 or 547.92 kHz
Mastergroup reference pilot*)	1552 kHz
Supermastergroup reference pilot	11 096 kHz
Frequency comparison pilot	60 and 308 kHz or 60 and 300 kHz
Through-connection of the frequency comparison pilot	60 or 300 kHz
Conversion of incoming frequency comparison pilot	60 to 308 kHz or 300 to 60 kHz
Output level/impedance	0 dBm/75 ohms
Level limits	±0.3 dB

*) Not included in the separate shelf for 120–960 channel systems

Incoming frequencies

Control frequency (if another oscillator replaces the master oscillator included in the shelf)	124 kHz
Input level/impedance	0 dBm/75 ohms
Level limits	$^{+1}_{-2}$ dB
Frequency comparison pilot	60 or 300 kHz
Input level/impedance	−25 to −55 dBm/75 ohms
Level limits	±4 dB

Frequency indication and frequency control

The following frequency accuracy values, which can be selected according to the relevant system requirements, are indicated by means of full scale deflection on a pointer instrument.

Frequency accuracy with full scale deflection $\frac{\|\Delta f\|}{f}$	Indication accuracy $\frac{\|\Delta f\|}{f}$
10^{-6}	$<10^{-7}$
5×10^{-7}	$<5\times10^{-8}$
10^{-7}	$<10^{-8}$
5×10^{-8}	$<5\times10^{-9}$

The master oscillator is automatically adjusted to the correct frequency when the relative frequency deviation is greater than 2/3 of the prescribed value for a period of approximately 10 seconds.

Changeover data

Automatic changeover from the distributing to the non-distributing equipment (there is no preference between the equipments) when the level has dropped by more than 0.5–1.5 dB. Changeover time: 4 ms.

Alarm data

Level supervision
An alarm is given when the level in equipment I or II deviates from the nominal value by more than 0.5 dB.

Frequency supervision
An alarm is given when the frequency accuracy required for the system has been exceeded. Limits: ±10 %.

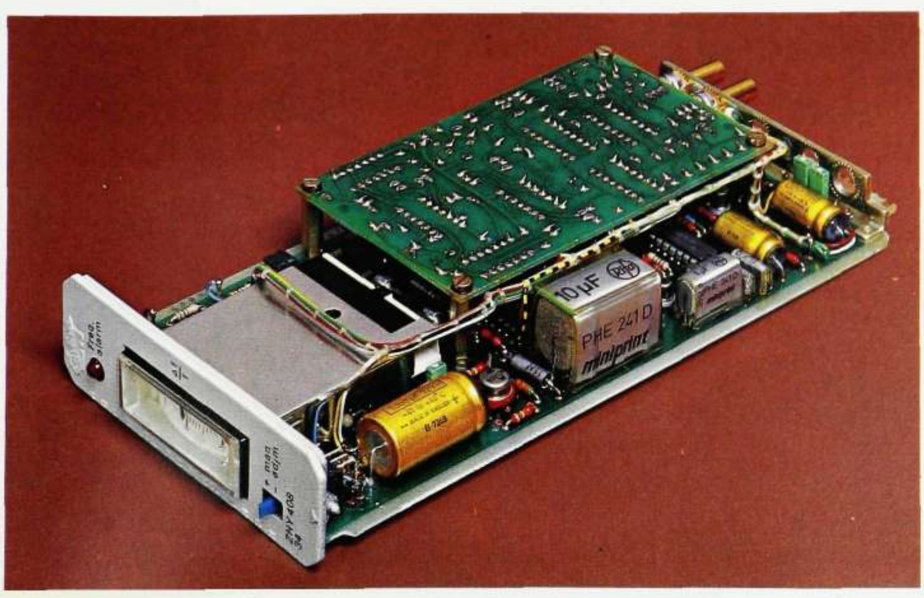


Fig. 7
Frequency adjusting unit. Contains equipment for frequency indication, frequency alarm and automatic frequency adjustment

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Branching Equipment for FDM Systems

Peter Echarti

New equipment for stop and leak branching in the frequency range 6–12 388 kHz have been developed, whereby possibilities have been created for providing technically and economically advantageous solutions for the routing of traffic in long-distance networks. The article describes the principles for branching and the various equipments and their applications. The corresponding equipment for 2-wire systems[1] and 60 MHz systems[2] have been described earlier and are not discussed in this article.
The new equipments, which can be mounted in racks in the M5 construction practice[3], have a high degree of flexibility and can therefore meet the requirements of the most diverse types of traffic encountered in the network.

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In many countries the long-distance network has a mesh-shaped structure. This means that the incoming traffic in a group centre must not only be terminated but must also be transited to one or more outgoing routes, and that provision must be made for the traffic to small stations along a main route. This means that when a network is planned or extended, solutions will be required that are technically and economically advantageous and which make possible the utilization of parts of the assembled frequency band of a long-distance system. In principle this can be achieved by means of through-connection or branching or a combination of the two methods.

The network planning is based on the systems used in the network and their frequency plans. The final network design is also affected by other factors, such as the choice of transmission medium (radio relay link or cable), special branching points determined by geographical factors (e.g. large relay stations for radio links on hill tops), the need for standby routes, traffic requirements as regards conference connection of certain transmission bands between several stations etc.

To summarize it can be said that a very high degree of flexibility is required of the equipment if it is to meet the different user requirements and demands. This will be discussed in more detail below.

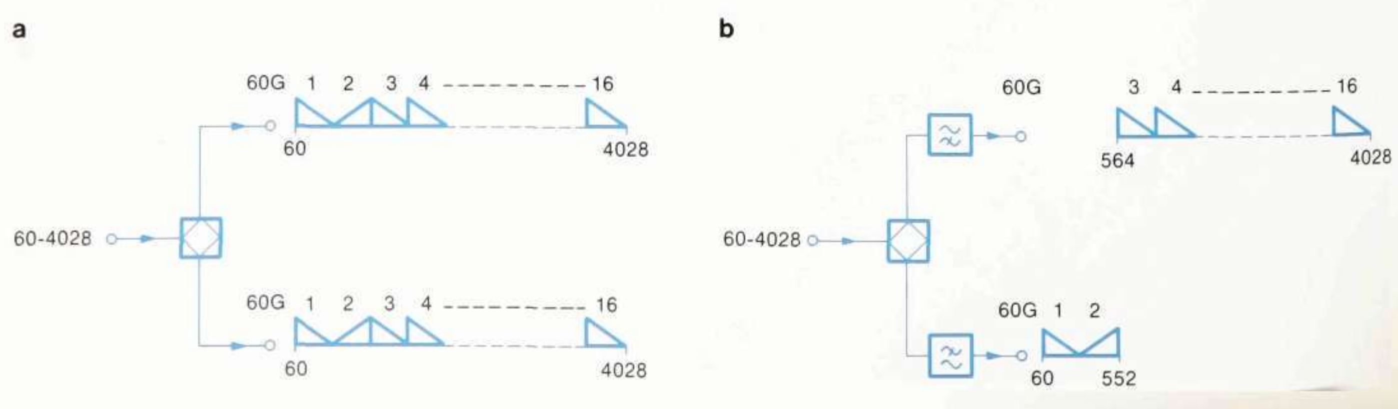
Branching principles

The main advantage of branching (as compared with through-connection) is that no multiplex equipment is necessary for the part of the transmitted line band that is to be transmitted to the next station (and thus is not stopped in the branching station). This means a saving and also improved transmission quality and reliability. There is then a choice between leak branching, with no possibility of using the branched frequency band afterwards, and stop branching, when the branched frequency band is stopped immediately after the branching point so that it can be used again for other traffic, fig. 1. This means that stop branching utilizes the network more efficiently than leak branching but requires more equipment. The branching equipment must be designed so that the administration can use leak branching initially and later, when the network becomes better utilized, easily change over to the more efficient stop branching method.

The main traffic cases where branching may be of interest are shown in fig. 2. The branching points, indicated by circles, can be placed in one and the same

Fig. 1
Examples of branching from 4 MHz systems. (Only one transmission direction is shown.)

a) leak branching
b) stop branching
(Frequencies in kHz)
60 G=SG



PETER ECHARTI
Transmission division
Telefonaktiebolaget LM Ericsson

station or different ones. In the former case we get double branching (i.e. in two directions seen from the station), in the latter case single branching. Cases 2a and 2b can be realized with leak branching but 2c requires stop branching because it is necessary to consider the risk of crosstalk between channels in the different systems that are to be connected together.

The branching equipment should have such flexibility that the interface levels and impedances recommended by CCITT for cable or radio relay link systems are attained, which is a condition for the interconnection of different systems. Moreover the frequency comparison pilot of the system, which is transmitted together with the telephony channels, must be available at each station (where a certain number of channels are to be terminated), both for through-connection to the next station and for supervision of the station's own master oscillator.

Equipments

Basic functions

The branching equipments must include three main functions: hybrid, filter and level matching function.

Hybrid function

The hybrid function makes possible the division of the incoming line band into two parts, or the interconnection of two parts of a frequency band to form an outgoing line band.

Filter function

The band stop filter function is used for stop branching or for power limiting (roof filter) in cases where leak branching requires this. A series of filter variants (for 12, 60, 120, 300 and 900 channels) have been developed, each of which is designed as a combined low pass/high pass filter, table 1 and fig. 3. As can be seen from the figure, a filter combination also contains the hybrid function. The suppressed band attenua-

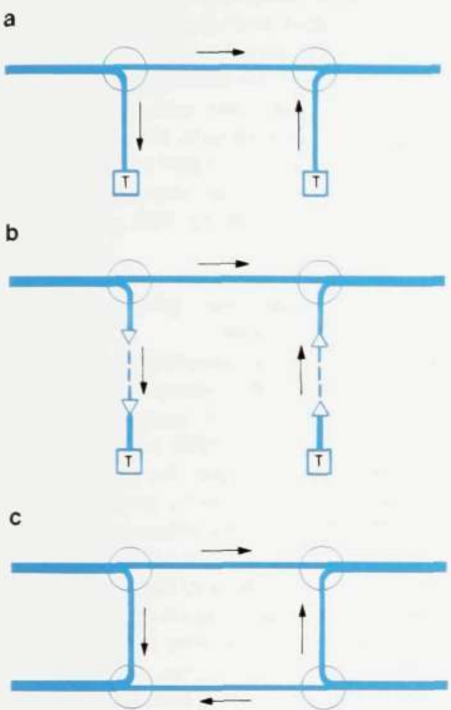


Fig. 2
The main types of traffic for branching. (Only one transmission direction is shown.)

a) Termination of a number of channels direct in the station
b) Termination of a number of channels in a station after transmission via its own line system
c) Traffic between two line systems which also carry other traffic

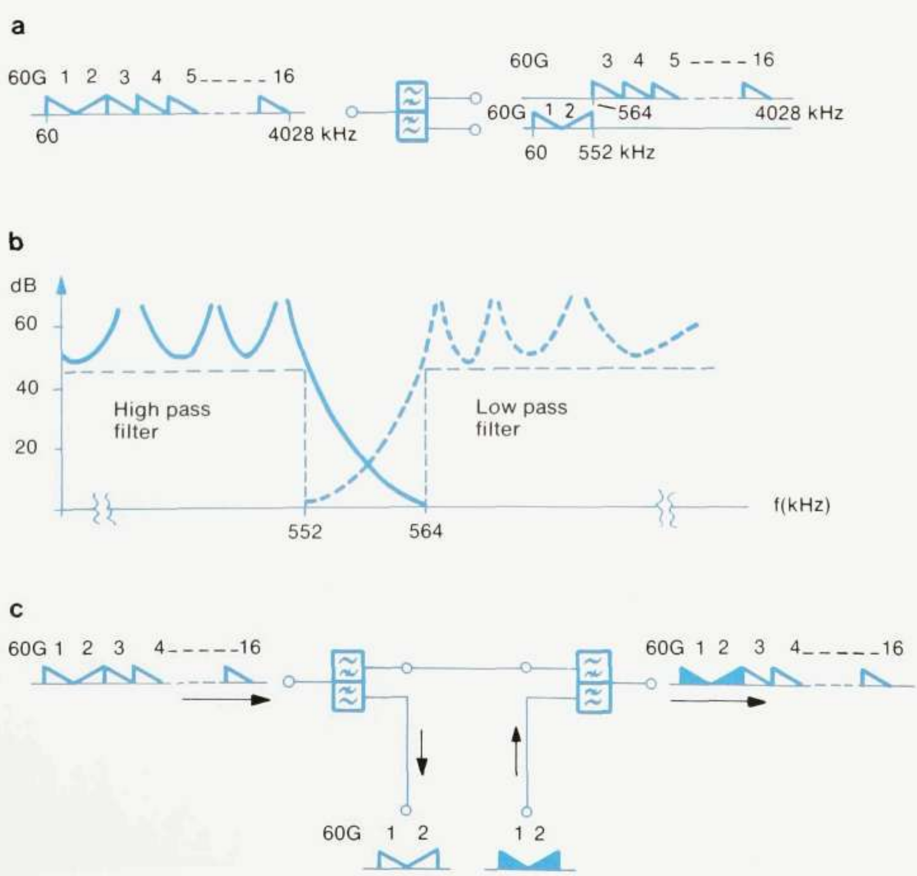


Fig. 3
Example of stop branching of SG1 and SG2 from a 4 MHz system

a) Filter function
b) Stop band attenuation for one filter
c) Series connection of two filters which enable the branched frequency band to be used again for other traffic
60 G=SG

Table 1
Filter for stop branching cases that are technically and economically advantageous

* CCITT plan 1A, 1B or 2

	[illegible]	
Branched groups	Low pass band	High pass band
Group	6 – 54	60 – 552
Group	60 – 108	112 – 4028
SG1	60 – 300	312 – 4028
SG1 – 2	60 – 552	564 – 12388
SG1 – 5	60 – 1300	1404 – 12388
SG1 – 6	60 – 1548	1636 – 12388
SMG1*	312 – 4188	4332 – 12388
SMG3*	312 – 8204	8516 – 12388

tion in each filter part gives satisfactory protection even for only band limiting.

When, in the case of stop branching, two filter parts of the same type (low pass or high pass) are connected in cascade, the crosstalk values will still be in accordance with CCITT recommendations. All filter types have the same attenuation in the pass band and the same positions for the input and output connections, and consequently they can easily be interchanged, fig. 4.

With few exceptions the transition area between the pass band and the stop band (fig. 3b) falls in the gap between channel groups, and thus there is no loss through unused frequencies in the line band. When choosing the different frequency variants consideration has been paid to the frequency plans for various FDM systems recommended by CCITT, and also to the possibility of being able to branch off a number of channels from an FDM system in a simple manner.

Level matching function
The level matching is carried out by a wide band amplifier. The amplifier is also equipped with networks for station cable equalization and double input and outputs, which are decoupled from each other so that they can function as hybrids. In one variant, for frequencies up to approximately 600 kHz, it is also possible to select an impedance of 75 ohms unbalanced or 150 ohms balanced.

Equipment for the 60 – 12 388 kHz transmission band
A shelf, fig. 5, accommodates all units required for both transmission directions and is used in connection with systems for up to 2700 channels. The shelf can be equipped for either single or double leak or stop branching respectively, fig. 6. The filters can be connected with the aid of a connection field on the left-hand side of the shelf so that the low pass (high pass) part is placed either in the path where the branching takes place or in the path of the through-connected band. In this way the filters can be utilized for stop or band limiting purposes.

With the leak branching method a

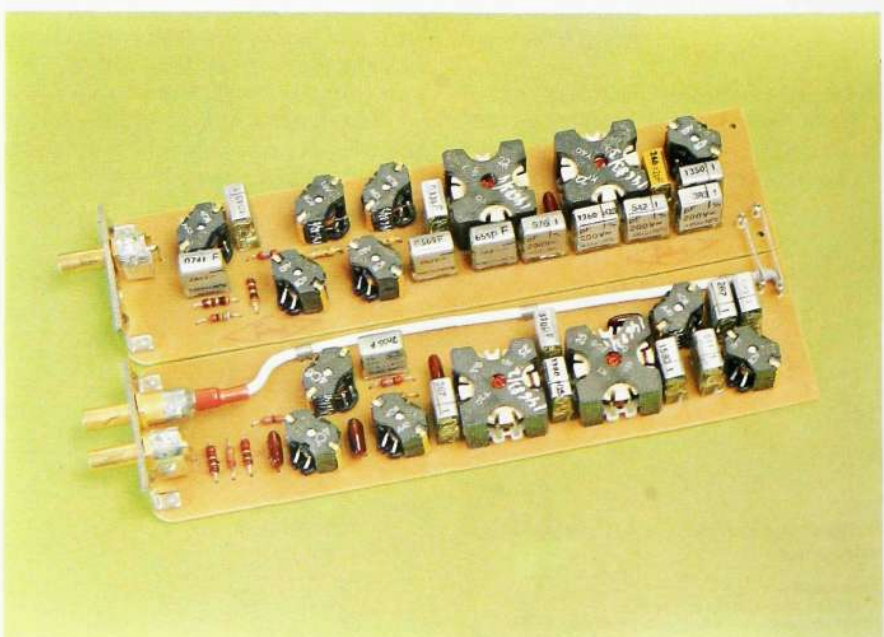
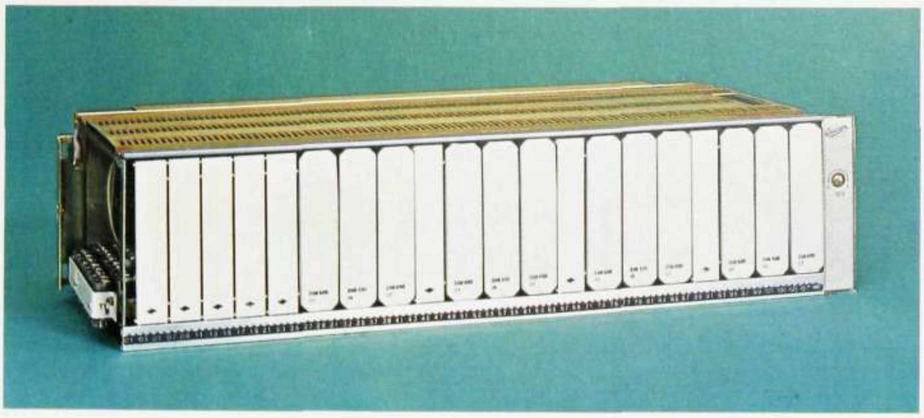


Fig. 4
Low pass/high pass filter 312 – 4 188/4 332 – 12 388 kHz for stop branching

Fig. 5
Branching shelf 60 – 12 388 kHz. A part of the connection field can be seen on the left-hand side, where the station cables are also connected



three-way coupling can be obtained, fig. 6e, that offers two special advantages; the station where the branching is taking place requires only one multiplex equipment for two outgoing directions and the method can be used for conference connection, in which case the same telephony channel(s) is (are) used in several stations.

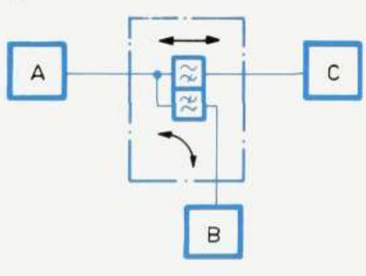
The equipment can be fed with current either from exchange batteries or from the power distribution system in the bay in accordance with the M5 construction practice.

Equipment for the 6 – 552 kHz transmission band

This equipment has been developed for branching in small FDM systems with a capacity of up to about 120 channels. This equipment is built up using the same principles as for the equipment described above, but it has some special characteristics. Junction lines in the frequency range 6 – 552 kHz are often balanced with an impedance of 150 ohms in order to limit crosstalk. This has been taken into consideration when designing the equipment, and the impedance on all inputs and outputs can be set to either 75 ohms unbalanced or 150 ohms balanced. The filters for stop branching can handle 12, 24 or 60 channels (table 1).

In one equipment variant two four-way units (see below) can be combined with the amplifiers included in the equipment to provide an interconnecting point with six equal inputs and outputs. This makes possible cases of leak branching where, for example, up to six radio relay links are connected together in one and the same point.

a



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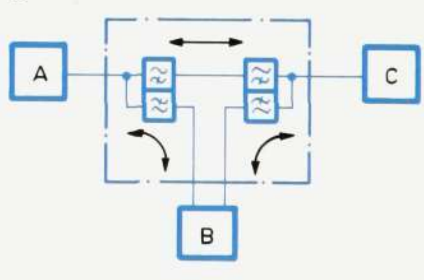
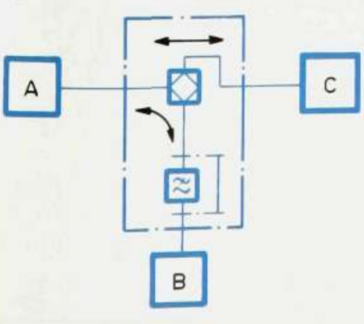


Fig. 6
Different applications for branching equipment. Traffic between stations A, B and C. "Single" branching between stations B and C is of course also possible. The arrows indicate that the traffic is two-way

a) Single stop branching
b) Double stop branching
c) Single leak branching
d) Double leak branching
e) 3-way leak branching

c



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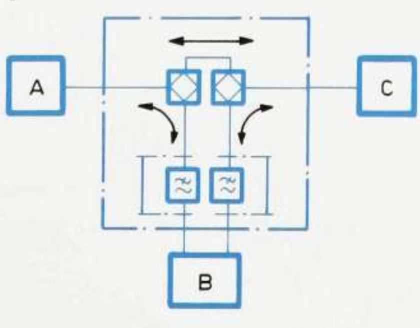

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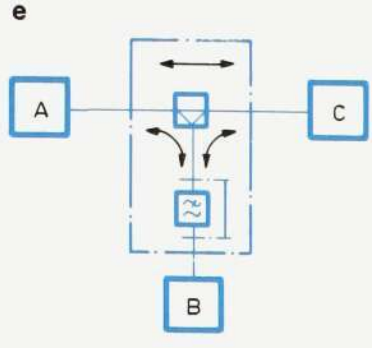

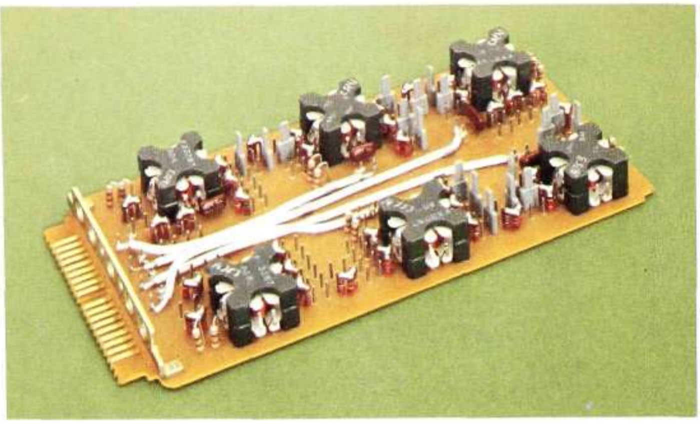

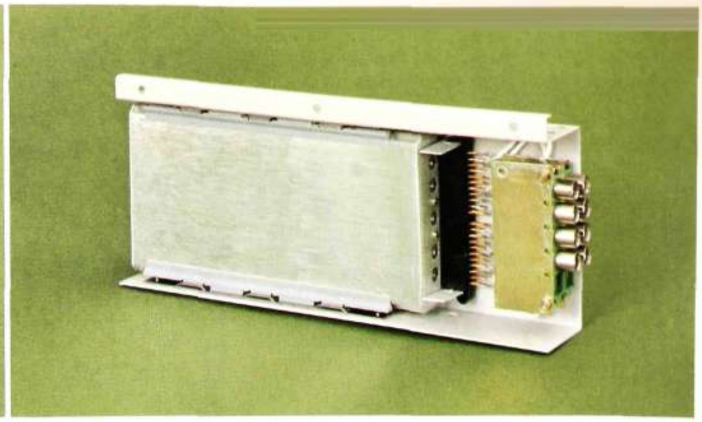

Fig. 7
Three-way unit 6 – 552 kHz with strappable attenuators for level matching. An impedance of 75 ohms unbalanced or 150 ohms balanced can be obtained in the connecting points by strapping on the unit.

Fig. 8, right
Four-way unit inserted in an adapter equipped with coaxial connectors

3-way and 4-way connections

In radio relay link networks the baseband side (transmitter and receiver) of several links often have to be connected together direct, with or without demodulation of a certain number of channels. For this purpose 3-way and 4-way units have been developed for each of the frequency ranges 6 – 552 kHz and 60 – 4 028 kHz. The units are designed as passive networks and hence they do not require any current feeding. This is possible because the difference between the interface levels for the transmit and receive sides is large as recommended by CCITT. The result has been special units, fig. 7, which with the aid of an adapter, fig. 8, can be mounted in an optional position in the station and can be connected to the rest of the equipment via plug-in station cables. These units can also be used for conference connection of telephony channels.

Branching facilities built into multiplex equipment

In small stations, where only a small number of channels are to be branched off from the line system in order to provide telephone connection with other stations, economical solutions are of particular importance. A branching unit for single leak branching has therefore been developed which can be installed in the various multiplex shelves for groups, supergroups, mastergroups and supermastergroups. The unit also takes care of level adjustment, includes facilities for receiving the frequency comparison pilot at the branching station and limits the frequency band towards the modulating equipment so that overloading of this equipment is prevented.

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