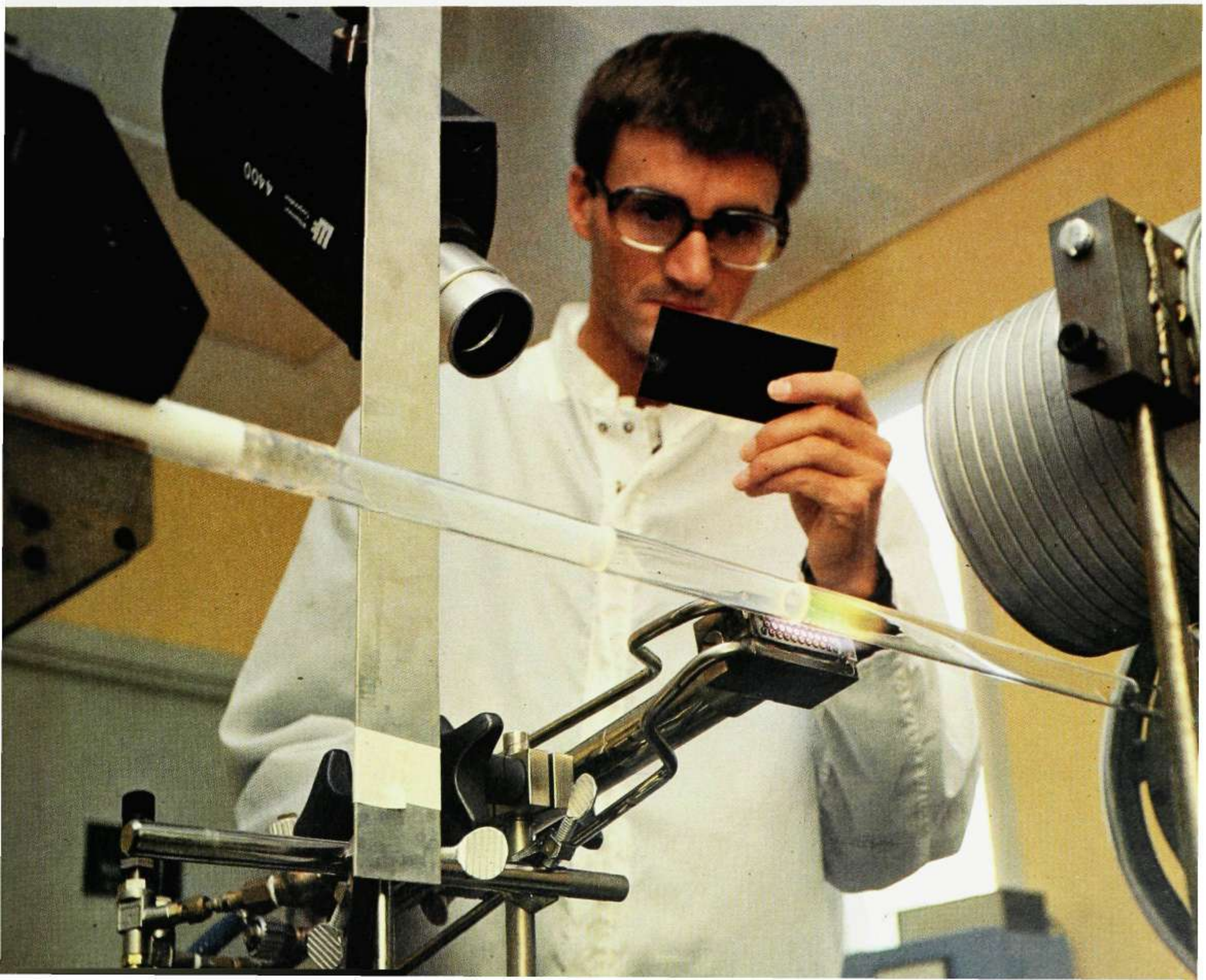
ERICSSON REVIEW

3 1979



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The LM Ericsson Prize Winners 1979

This article is an excerpt from the speech given by Dr. Håkan Sterky, chairman of the Ericsson Prize Committee, at the awards ceremony of the 1979 LM Ericsson Prize, May 7, 1979. The Prize, which consists of a gold medal and the sum of 100 000 Swedish Kronor, was first awarded at the LM Ericsson centennial in 1976, and according to the conditions governing the award of the Ericsson Prize it shall "be awarded to recognize an especially important scientific or technological contribution to telecommunications engineering made during the previous three-year period, or an earlier contribution whose significance has been acknowledged during the period".

By October 1st 1978, 40 proposals involving 44 candidates working in 12 different fields of activity had been submitted to the Ericsson Prize Committee. The Committee consists of three members and is completely independent of the LM Ericsson's Board of Directors and President. It has sole responsibility for selecting the prize winner among the candidates nominated. If an achievement has been shared by two or three persons, these persons may be awarded the prize jointly.

The Prize winners' presentations will be found on the following pages of this issue.

The 1979 Ericsson Prize is being shared by two men, both of whom, while working in separate fields, have made fundamental contributions to the long-distance transmission of information through optical fibres:

Dr. Charles Kuen Kao, who was born in Shanghai in 1933 and is now employed by the International Telephone and Telegraph Corporation in Roanoke, Virginia, and
Dr. Robert Distler Maurer, who was born in St.Louis in 1924 and now works at the Corning Glass Works in Corning, New York.

It would not be fair to all the other highly qualified candidates if I were to state that the Committee faced an easy task in selecting the 1979 Ericsson Prize winners. After extensive interviews with several experts in various fields, however, the Committee selected these two men. The decisive points which attracted the attention of the Committee, and which were influential in our final selection, were the imagination, the perseverance and the competence which Dr. Kao and Dr. Maurer exhibited in introducing the use of light waves as transmitters of information over long distance.

In their presentation the prize winners will describe in more detail how they began their work in the field of optronics, the potential they foresaw in their early visions and discoveries, the current situation in optronics and the developments they foresee in the future.

As a supplement to their presentations, I would like to outline briefly the historical development of the art of transferring messages using light waves.

Transmission of messages by light waves – historical aspects

For thousands of years, beacons have been used to warn people of military actions. The message of Troy's fall was sent across the sea by the same means.Light from fires in lighthouses guided ships through perilous waters. Flares have long been used as danger signals. The content of information conveyed in this manner, however, was severely restricted. It was not until codes were established that these messages could contain more substantial information. About 150 years ago the Morse code alphabet was introduced in electrical telegraphy. In optical telegraphy, the same alphabet has been used from the 1800s up to modern times. One method used in this field was to tilt a mirror to reflect sunrays, the so-called Heliograph method, to convey messages from one point to another tens of kilometers away. In shipping, using the same basic method, signalling lamps have long been used to send Morse signals from one ship to another by keying a blind in front of the light source.

The Morse code, a forerunner to digital technology

As you all know, the Morse code consists of a number of combinations of dots and dashes which correspond to the letters of the alphabet, numbers and punctuation marks. Using this code translated into short and long electric impulses, messages could be cabled over long distances. Morse code was the forerunner of the digital techniques now used in the computer age, in which digital technologies are used on an increasing scale to transmit text, pictures, speech and music via electromagnetic waves. For these applications, however, the number of impulses, or "bits", must be increased from about ten to several millions per second. In other words, the bandwidth must be large enough to permit rapid and extensive transmission of information. This is made possible through optical telecommunication.

Prerequisites for optronics

Another prerequisite for the 1979 Ericsson Prize winners' achievements is the ability of light to be transmitted through a curved path. As you all know, light, like all other electromagnetic waves, is propagated in straight lines through space and the atmosphere. If light is conducted through a tube or a fibre, however, it can be propagated – under certain conditions – along paths other than straight lines. A basic condition for this phenomenon is that the tube must have a reflective inner surface or that the fibre must consist of a material with a higher refractive index than that of its surroundings, for example air. Another basic condition is that the attenuation of the light must be low enough to make it technically and economically feasible for optical methods to compete with other transmission systems.

In physics, it has been known for a long time that certain fibres can conduct light along curved lines. This phenomenon has been utilized for different technological, medical and decorative purposes. One such application has been used in medicine by inserting a glass fibre in the heart to study conditions of this vital organ. Normal optical glass, however, has a high absorption ratio, similar to that of the clouds in the atmosphere, and consequently the range of transmission was limited to ten or twenty metres. A radical change in this restricted capability was necessary if optical systems were to meet the demands placed on today's commercial systems for transfer of information. Another prerequisite was access to suitable electro-optical converters for transmitting information and opto-electrical converters for receiving information. During the past decade, electronic components such as light-emitting diodes, diode lasers, photodetectors and avalanche diodes have been developed and are now produced commercially.

The Prize winners' contributions

In 1966, Dr. Kao, together with G.A. Hockham, published a paper on the possibilities of using glass fibres as conductors for optical transmission of information. His efforts at that time meant that he was proposing a special fibre design for optical transmission of information. He also foresaw that it would be possible to purify quartz glass to such a degree that the conductors' attenuation would be less than 20 decibels per kilometre. The first revolutionary proposal was based on fundamental theories. However, considering that Dr. Kao was not a specialist in various glass materials' optical properties, nor in the production of highly purified quartz fibres, his second proposal on the development of optronics must be regarded as visionary. For the benefit of experts in this field, I would like to point out that optical glass available in the mid-1960s had an attenuation minimum of 1,000 decibels per kilometre and now, near the end of the 1970s, quartz fibres have been produced with an attenuation of less than one decibel per kilometre for certain light wavelengths. For laymen, these figures may be clearer if one considers that about ten years ago, the interior of the heart could be studied over a distance from one-half to one metre. Today, the transparency of an optical fibre is so high that the same observation could be made by a physician who is situated tens of kilometres away from the patient.

As the Director of Research at Corning Glass Works, Dr. Maurer realized, despite the doubts of many experts, that it would be worthwhile to attempt to develop a fibre made of such highly purified quartz that it could be used in telecommunications systems. Within an exceedingly short span of time, as early as 1970, the Corning research laboratory staff developed and produced several hundred metres of fibre, about 0.2 millimetres thick, with a core diameter of 3 to 4 μm and an attenuation of 20 decibels per kilometre at a light wavelength of 0.63 μm. At the same time, they also showed that fibres could be bent without significant radiation losses. Consequently, there would be no practical difficulties involved later on in laying fibre cables.

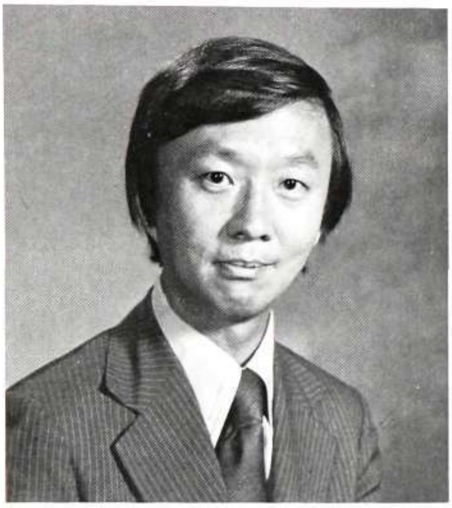
Dr. Kao and Dr. Maurer have through their theoretical research work and technical development of methods for the production of optical fibres opened promising new areas for telecommunications. Test installations for telephone traffic are now in operation and the world's telecommunications companies are convinced that optronics will make it possible for them to place better and less expensive transmission systems at the disposal of society and subscribers.

After many years of research and creativity the prize winners have given mankind access to new technical and economical methods of transferring information. In the true sense of the word, they have shed new light on a field which researchers and engineers will explore further in the fascinating future of telecommunications.

Fig. 1. Dr Robert Distler Maurer and Dr Charles Kuen Kao receive their prizes from His Majesty, Carl XVI Gustaf, King of Sweden. In the background Dr Håkan Sterky.

Optical Fibers and Systems: History and Future

Charles K. Kao



DR CHARLES K KAO

Charles Kuen Kao, who was born in 1933 in Shanghai, China, received a B Sc degree in Electrical Engineering from the University of London in 1957 and a Ph D degree in Electrical Engineering, also from the University of London, in 1965.

He was the Chairman and Professor of Electronics of the Electronics Department of the Chinese University of Hong Kong from 1970 to 1974, and in 1974 he became associated with the ITT Electro-Optical Products Division as a Staff Scientist, which position he presently holds. Dr Kao is a pioneer in the field of optical fiber communications and has worked in this field since 1963. His experience includes theoretical studies and basic research in optical communication systems, fiber optic waveguide communications, circuits and systems design, and quasioptical techniques applicable to microwave systems.

He has been elected a Fellow of IEE (UK) and is a Senior Member of IEEE. He received the 1976 Morey Award from the American Ceramic Society for outstanding contributions to glass science and technology and in 1977 was awarded the Stewart Ballantine Medal by the Franklin Institute for his conceptual work on optical fiber communication systems. He was the recipient in March 1978 of the Sir Arthur Rank Prize of the Royal Society of England for his pioneering work in optical fiber communication. Recently he was honored with the 1978 Morris N Liebmann Memorial Award for making communication at optical frequencies practical by discovering, inventing and developing the material, techniques an configurations for glass fiber waveguides and in particular for recognizing and proving by careful measurement in bulk glasses that silicon glass could provide the requisite low optical loss needed for a practical communication system. He has written many technical papers and holds 11 patents.

In the 1950's the need for vastly improved communication facilities and services was recognized. This led to the search for a means to open up more of the electromagnetic energy spectrum for communication purposes. By late 1959 the laser was invented, heralding the entry of the equivalent of a radio frequency source at optical wavelengths. At last, the optical spectral region with its enormous potential for communication was opening up for exploitation. What was needed was a compatible set of a source, a detector, and a transmission medium. It soon transpired that the myriads of advantages of optical communication were not easily accrued in a practical and economic manner. The components simply did not come together to form a working system.

The early lasers were either bulky and power inefficient or must work at very low temperatures. Even the propagation paths offered unforeseen difficulties. There was the free space. Surely light should travel in a straight line through space. Not so, in our terrestrial domain. The inclement weather severely influences propagation conditions. Fog and snow can cause orders of magnitude change of the light intensity. In fact, even in clear weather, the density fluctuation of the atmosphere significantly alters the properties of the light propagation path. Over a kilometer a collimated beam could dance around in a disc with a diameter as large as a few meters at the destination due to the fluctuation of air density along the propagation path.

The matter of fiber material

The dielectric waveguide in the form of an optical fiber was a very attractive candidate as a transmission medium at optical wavelengths. However, optical fiber waveguide was not considered at that time to be a likely transmission medium since the optical loss was sufficiently high as to attenuate the light level to an unusable value over only several meters. Also at that time, semiconductor light sources and detectors, which matched well with the optical fiber to form the basic system, were in very early stages of development. The magnitude of problems appeared formidable. However, believing that a promising but difficult problem warranted special attention, we started work, in those days, in this area.

The principal tasks at that time were to establish theoretically the waveguide and material properties, and to demonstrate that the material and dimensional requirements were essentially realizable in practice.

While waveguide propagation was rather easily demonstrated by using specially prepared fiber samples, the material evaluation and dimensional tolerance studies presented a far greater challenge. The situation was almost as bad as attempting to measure an object which is less than a millimeter in diameter with a ruler whose smallest increment is one meter. Instruments to measure optical loss had sensitivities several orders less than what was required. Dimensional tolerance requirements had to be established on simulated fibers. In spite of these apparent drawbacks, the work proceeded successfully and encouragingly. The principal findings were published in a series of papers starting in 1966. In 1968 the existence of materials with sufficiently low loss was established experimentally. These events led to an increased interest and eventually to a world-wide activity. It is interesting to note how the fiber loss improved over the years, fig. 1. This is the result of the combined contribution of many talented people who have injected the necessary academic stimuli, management skill, professional talents, and societal concerns.

Today optical fiber systems technology has come of age. Optical fiber, source and detector characteristics have not only exceeded the target optical performances values in the research laboratories, but are also capable of meeting exacting physical and reliability requirements important in a real world environment. Other basic components, such as cable, connector and coupler, are at a similar stage of development. Fiber system technology is poised to step from the R&D phase into the production phase and is ready to vindicate its most important, but yet to be fulfilled promise, of cost effectiveness.

Type of Application	Advantage
Common Carrier Satellite Entrance Link CATV Trunking	High Bandwith, Long Repeater Spacing
Power Utility Communication	No EM Interference
Broadband Distribution	High Bandwidth
Nuclear Power Station Control	No Fire Hazard & EM Interference
Computer System Interlinks	No EM Interference
Private Transmission	No EM Radiation
Guided Weapons	Light Weight, High Bandwidth
Sensors (Pressure/ Temperature)	High Sensitivity
Intra Building Communication	Improved Privacy
Intra Vehicular Communication	No EM Interference Light Weight & Small Size

Table 1

Advantages of optical fiber systems

Let us relook at the major benefits of optical fiber. Those benefits can be grouped into three categories:

Its physical attributes include small size, light weight, high strength, and flexibility.

Its transmission benefits include wide bandwidth, low loss, and low cost.

Its special features are that it will not induce combustion, will not pick up R.F., will not radiate R.F., and will withstand very high temperature.

These advantages and special features can be exploited singularly or in combination to provide system performance and cost benefits to almost all types of applications across the entire modern industrial base. The roles and missions of optical fiber systems penetrate every aspect of communication and control.

A substantial number of systems have already been installed. It will be seen that the various systems installed, exploit in one way or another the main advantages of optical fiber systems, table 1. One aspect is worth noting. The special features are being exploited early. This indicates that a new product is more easily introduced to fulfill a new function than an improved product to fulfill a replacement function. A more important aspect is that the advantages of optical fiber communication systems are opening up new system possibilities. These have far-reaching social and economic impacts beyond the better performance and low cost aspects.

Optical fiber systems give new features

Perhaps the most significant new service optical fiber systems can bring is the wide bandwidth information distribution network. If the cost of bringing services into each home via one or more fibers is not prohibitively high, it is possible to envisage such a network which permits voice, data, music, and TV to be available on an interactive basis.

The mode of introduction of such services is by no means defined. It is only possible to see that such services can have much sociological impact. For example, the remote surveillance of industrial sites or community thoroughfares can improve fire and security

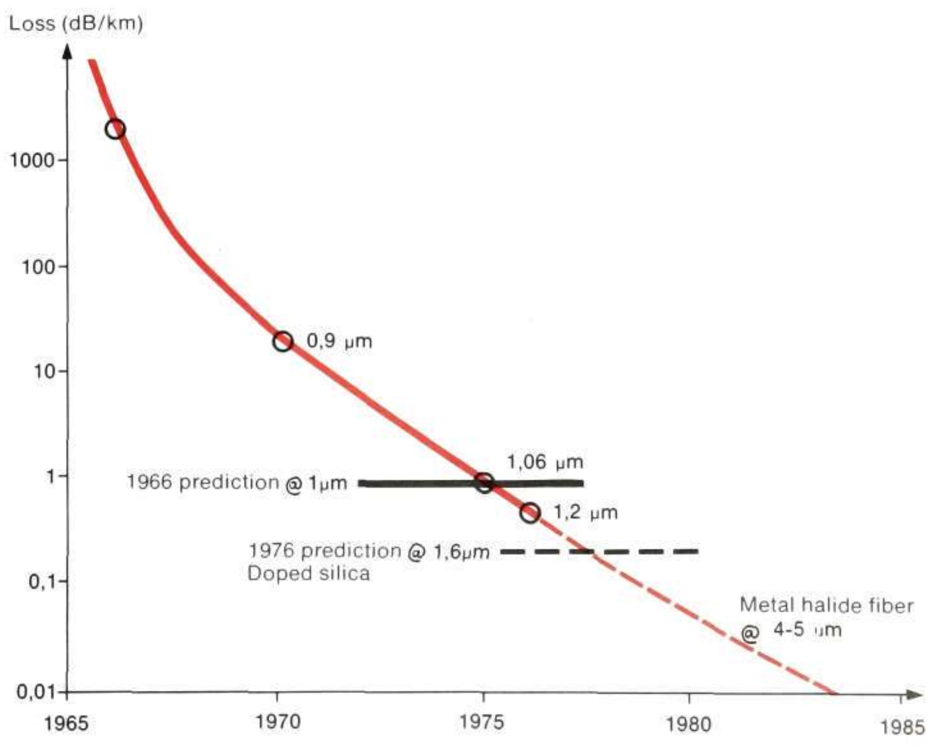


Fig. 1
Best fiber loss

services without the need of extra personnel; the video conferencing and shopping can save time and travel; low speed data services can be provided at reduced cost; and energy management such as preferential load shedding can become a reality. All in all, the existence of wideband distribution network enables the network provider to be the key operator in information distribution. The network is used not only for providing the interconnection of subscribers, but also for distributing the facilities offered by service vendors.

The network with its wide bandwidth capability is powerful enough to improve control and communication functions by leaps and bounds. Moreover, optical fiber, the wide bandwidth transmission medium, is emerging at the same time as VLSI technology which vastly increases the speed and functional capability of control circuits.

These two complementary key technologies are maturing at a crucial time when communication and control are moving into an intensive man-machine interactive phase. It is not far-fetched to say that man-machine interrelationship is a new survival criterion for mankind and that the optical fiber multiservice distribution system will play a major role.

It is evident that the range of optical fiber system applications is broadening very rapidly. In fact, everything associated with optical fiber is growing. The different types of applications, the installed fiber length, fig. 2, the current sales, and the number of people involved are all growing at an exponential rate.

This is a good indication that optical fiber business, indeed, will grow exponentially and will generate the volume demand and result in the necessary cost reduction to sustain the growth and to enable economic introduction of new services, such as the broad band distribution network.

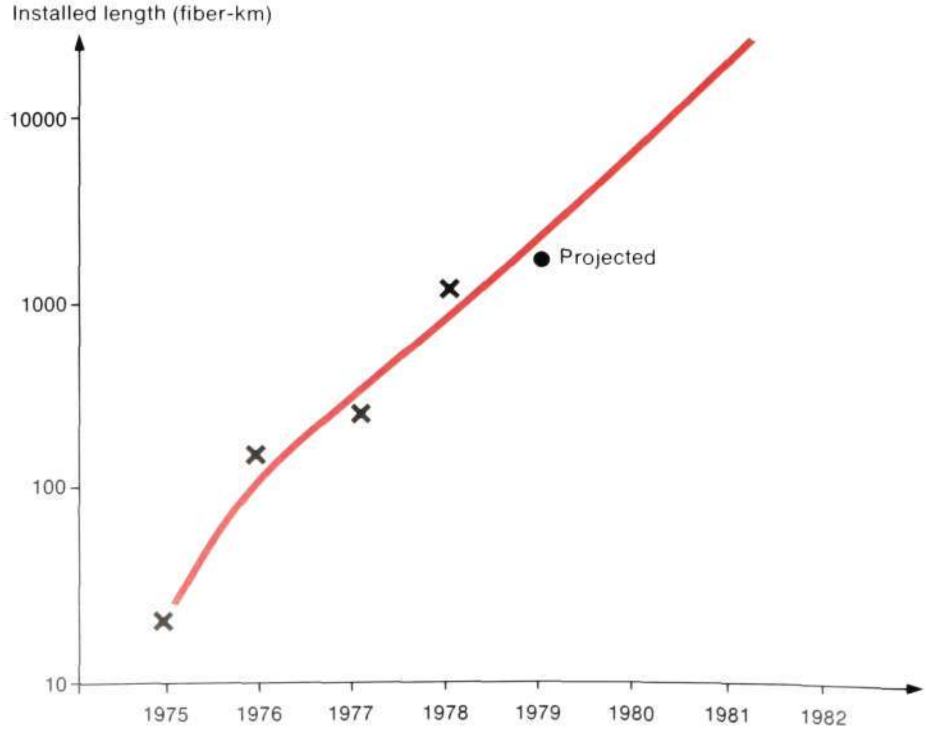
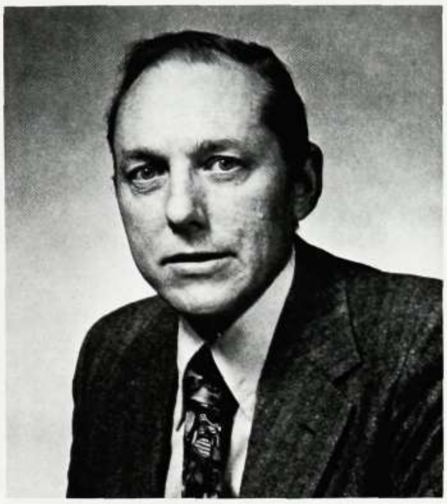


Fig. 2
Total worldwide yearly installed fiber-length

Optical Fibers and Components: History and Future

Robert D. Maurer



DR ROBERT D. MAURER
Robert Distler Maurer who was born in 1924 in St Louis, Missouri, received his B Sc degree from the University of Arkansas in 1948 and the Ph D degree in Physics from M I T in 1951.

He spent a year at M I T in low temperature research and then joined Corning Glass Works to begin work on the physical properties of glasses. Since 1963 as Manager of Applied Physics Research, he was involved in a variety of materials research problems with glasses and crystallizing glasses for electronic and optoelectronic applications, such as photosensitive processes, lasers, and optical shutters. Presently Dr Maurer is a Research Fellow at Corning Glass Works, Corning, New York, where his research activities aim at improving optical waveguide performance.

He has served several years in organizing the Optical Fiber Transmission Conference and is a member of the National Research Council Committee on Telecommunications. He has received the 1976 Morey Award of the American Ceramic Society. In 1978 he was chosen as the first recipient of the American Institute of Physics (AIP) Prize for Industrial Applications of Physics for contributions made to the practical application of optical communications through the understanding and discovery of materials and techniques for the fabrication of glass fiber waveguides. Recently he was honored with the 1978 Morris N Liebmann Memorial Award for making communication at optical frequencies practical by discovering, inventing and developing the materials, techniques and configurations for glass fiber waveguides and in particular for giving an existence proof and demonstration that a vapor deposition process could be used to make guiding silicon fibers with the requisite losses. Dr Maurer is a member of the American Physical Society, a Fellow of American Ceramic Society and former Chairman of its Glass Division, and a Senior Member of IEEE. He has written many technical papers and holds 4 patents.

Optical technology promises to provide our next major advance in telecommunications. In choosing light to carry the signal, technologists are breaking entirely from previous engineering practice. Until now, advances in telecommunications had occurred by gradually changing the electromagnetic wavelength that was used. This gradual evolution continued until wavelengths of about one centimeter were the shortest that were utilized. Now, by using light we have suddenly reduced the wavelength to one micrometer—10,000 times smaller—or one per cent of the diameter of a human hair. This great change has been the source of many benefits, as well as problems, for the new technology and for component construction in particular. For each major component, we can show how the change in wavelength has affected an important characteristic of that component and in this way illustrate the complexity and possibilities of this new technology. These few illustrations will provide less than a complete understanding. In a technical area as broad as optical communication components, a brief discussion can only hope to provide an acquaintance with the topic.

The components I will discuss are the primary ones: glass fibers, cables, connectors, signal sources and receivers. These exert a major influence on the system possibilities in both system architecture and performance. Indeed, no significant systems were feasible, or even considered, before satisfactory fibers had been made. As you know, the use of fibers in early optical systems was impossible because the attenuation was too high. The best fibers that existed at that time, the early 1960's, would transmit signals only about 20 meters. Practical considerations required transmission at least 100 times further—this requirement corresponds to one per cent of the incident light emerging after passing through one kilometer of fiber (20 dB/km). My personal work at that time was concentrated in achieving the large improvement in transmission that was required.

Two decisions were made near the beginning of this research that became the foundation of all that followed. One was to use glasses consisting primarily of silica, with oxides added to the extent necessary to increase the refractive index. These glasses have provided the lowest attenuations yet achieved and have excellent physical properties. The other decision was to use vapor phase processes for manufacturing the glass preform, or rod, from which the fiber is drawn. Vapor phase processes have not only provided the necessary purity but, in addition, have turned out to be surprisingly flexible when adapted to new ways of making the preform. As a result, both ideas seem to have stood the test of time and remain at the heart of today's technology.

A major advantage of vapor phase glass-making is in eliminating the customary step of melting. By eliminating melting, the impurity dissolved in the glass from the melting container is avoided. Liquids, such as chlorine compounds of the glass ions, are vaporized and passed with oxygen gas through a hot region where the liquid vapor is oxidized to form a dust of small glass particles. These are collected and, when heated, consolidate to a dense bulk glass. An added advantage in this process is that the starting liquids can be purified by distillation.

This basic approach, with considerable elaboration, led to steady progress in reducing fiber waveguide attenuation. After some initial experimentation in 1966, the first high silica fibers were made in 1967. By 1970 Corning made the first fibers that met the transmission goal of one per cent through a kilometer (20 dB/km), fig. 1. This sparked a worldwide effort to develop the new technology and further advances have occurred in all aspects of this new area of telecommunications. By 1974, attenuation had been reduced another 20 fold, to one dB/km. It is even lower today.

The evolution of components for the new technology reflects major characteristics caused by the short wavelength of light, as mentioned earlier. Most notable is the small size of all the components. This is one of the major benefits because it conserves both equipment space and material. In accord with equipment size, information transmission with light now becomes more com-

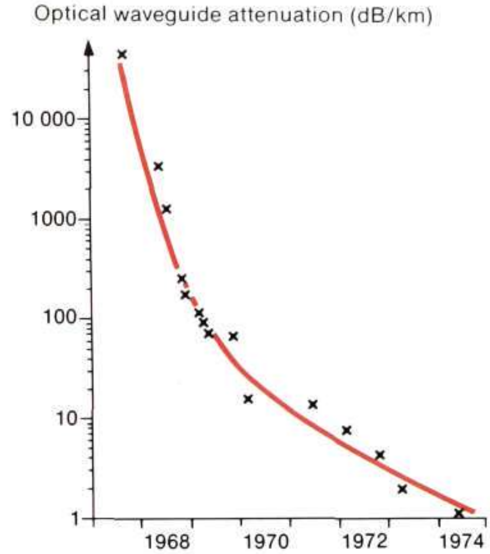


Fig. 1
Progress in reducing attenuation of high silica optical waveguides at Corning. The first waveguides ever to meet the practical goal of less than 20 dB/km were achieved in 1970

patible with information storage and processing which have also been greatly miniaturized.

Fiber Waveguides

Perhaps there is no better illustration of the dramatic change caused by the shift to light than in the search for new materials for fibers. Every research projects begins with considerable uncertainty about what factors have been overlooked or what unknown obstacles will be discovered. Fiber waveguides were no exception. Shortly after this research began, it became apparent that no one had considered some important optical effects. Two of these, absorption by atomic defects and intrinsic absorption, are discussed here.

The inherent transparency of many materials is masked by impurities and imperfections. Recall that windows appear transparent because they are thin; we are surprised when we can see the bottom of a river. The early optical waveguide research answered the question of what remains when these impurities and imperfections are removed. Only then are the fundamental roles of atomic defects and of intrinsic absorption revealed. Of these two, intrinsic absorption has proven of more practical interest.

Atomic defects occur in absolutely pure glass and absorb light to some degree. They arise because of the fundamental tendency to increase entropy, or disorder. This force is pervasive in nature, and we face it every day as the tendency for things to go wrong. In glass-making, entropy is increased by the evolution of oxygen gas during the melting, since the gaseous form of matter is more disordered than the liquid or solid. When oxygen gas evolves in this way at high temperatures, the glass left behind is deficient in oxygen. Defects are thereby generated in the glass structure where oxygen atoms normally would be. In the early glasses, a single defect of this kind absorbed more light than the typical impurity atom. Glasses used today circumvent this problem because the defect absorptions are outside the wavelength region of the signal light.

However, it is of historical interest to realize that the first low loss fibers required finding an answer to the problem of atomic defect absorption. The solution was to utilize a chemical reaction within the glass that re-oxidized the defects. Various time-temperature treatments were required to control the reaction rate. As might be surmised, this was a complicated procedure and finding a workable method proved to be one of the obstacles in reaching the transparency goal. However, the effort was valuable in the end. The work showed that this fundamental absorption mechanism could be overcome to the degree necessary and the existence of high transparency was proved.

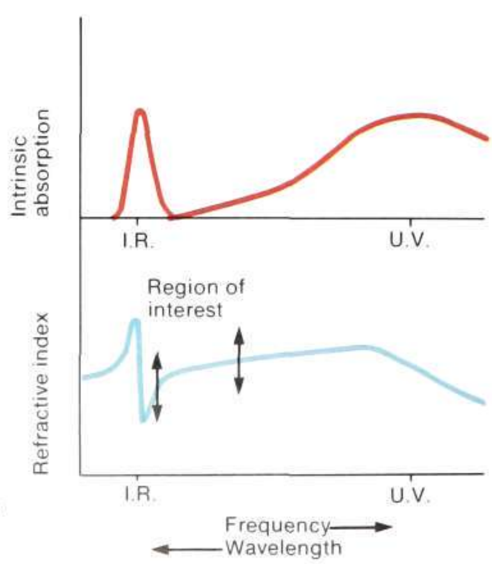


Fig. 2
Schematic diagram showing the intrinsic absorption for a transparent substance. The absorption is present in the transparent wavelength region of even an absolutely pure material

The second fundamental property of material transparency that is reached when impurities are removed is the intrinsic absorption. Glasses, and many "transparent" solids, are not transparent at short wavelengths of light (the ultraviolet) and are not transparent at very long wavelengths (the infrared). In these wavelength regions, the glass absorbs light and only in between them is the wavelength region called "transparent". However, these absorbing regions do not cease absorbing abruptly at the edge of the transparent region. Instead, they gradually decrease and it can even be shown theoretically (by the Kramers-Kronig relations) that their absorption extends entirely across the transparent region, fig. 2. In the transparent wavelength region, the absorption was not known because it was masked by impurities. This lack of knowledge about the magnitude of the absorption, plus the fact that there is no way to alter its magnitude, led to considerable concern. Should the intrinsic absorption prove too high to make a practical waveguide, the whole idea of the research could prove impossible. However, we now know that the intrinsic absorption is essentially negligible in the wavelength region of interest. By measuring the signal loss in the best fibers and subtracting the losses that are known, an upper estimate for the intrinsic absorption is obtained, fig. 3. The answer shows that there is a low minimum for this absorption somewhere in the near infrared (about 1.6 μm). Perhaps the most remarkable result of optical waveguide research has been the discovery of how small the absorption at this minimum is, or how transparent matter can be. We now know that light can pass through 20 kilometers of glass with more than half of it emerging. It has been remarked that if the deepest ocean were this transparent, we could easily see the bottom.

Partly because this minimum intrinsic absorption is at near infrared wavelengths, the best fibers today show their maximum transparency in this region. The highest transparency may be some ten times better than available today. Therefore there is still significant potential for increasing the transparency of fiber waveguides.

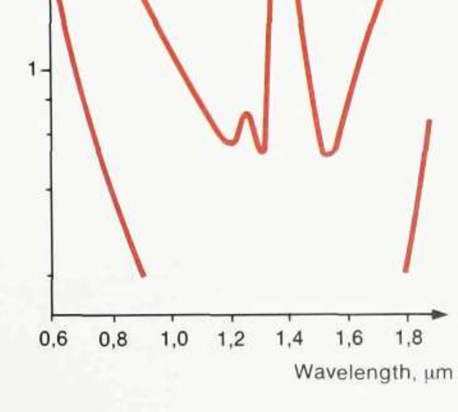


Fig. 3
Upper Curve: Data for a fiber of very low attenuation. Lower Curve: Residual attenuation remaining after substracting known attenuation effects from upper curve. This residual attenuation is the best estimate of the intrinsic absorption

Sources and Detectors

The higher transparency region has encouraged research toward making components for the longer wavelengths, in the near infrared. The sources and detectors for the first generation of optical communication systems came from technology that existed prior to the fiber. Now, work is underway to provide new solid state sources and detectors for an optimum system that utilizes the best possible fiber characteristics.

Lasers have been sought as a signal source for optical communications because of the increased signal power and concentration of this power within a narrow wavelength range. However, progress has been slow in achieving stability that endured over decades of use, so lasers are now only considered for short-lived situations. This degeneration in performance occurs because small defects (again, the order of a wavelength of light in size) develop with use. The new lasers designed for longer wavelengths exhibit much more promising durability than former lasers did at a comparable stage of development. This is attributed to the different materials that are being used. Thus, the shift to longer wavelength light may bring with it unforeseen benefits in the light source.

The signal receiver usually consists of a solid state detector and an amplifier. Present research on receiver amplifiers may also alleviate the problem of making detectors for the longer wavelength light. The present solid state detectors which have the highest sensitivity are complicated in their structure. Making these components from new materials involves considerable experimentation. If amplifiers can be perfected to the extent that simpler (p-i-n) detectors can be used with equivalent sensitivity, materials research would be greatly simplified. In general, it would then be possible to develop receivers for new wavelengths of light much more easily.

Cables

Optical cable technology has been able to utilize existing cabling techniques, materials and design knowledge, and this has been a major benefit. There is one important exception. New techniques have had to be devised to cope with the problem of microbending. The tiny fibers are flexible, and irregular displacements of their axis by as little as 1 % of the diameter can cause serious loss of light, fig. 4. It is no coincidence that 1 % of the diameter is our familiar quantity, the wavelength of light. These minute distortions are called microbends. The discovery of this effect is an interesting story of early optical waveguide research. At the time, experimental fibers were wrapped on cardboard drums. It was noticed that the light loss in travelling through the fiber seemed to vary erratically from day to day. With some searching, this variation was traced to the humidity. Cardboard is notorious for expanding and contracting with changing humidity, and as it expanded the fiber was pressed against the rough cardboard surface, causing microbends.

Microbends can arise from uneven application of the protecting plastic coating on fiber, from differential thermal contraction of the materials in the cable, or from external applied forces. As a result, a great deal of engineering effort is going into this practical problem. No immediate end to this effort is in sight. As the transparency of fibers is increased, especially by shifting technology to the longer wavelength of light, microbending losses must also be reduced in order not to sacrifice all the benefit gained. Thus, cabling technology can be expected to remain an area of active interest.

Connectors

Connectors are mechanical devices for joining ends of fibers, or cables, with negligible loss of light. The wavelength of light leads to both disadvantages and advantages in making these components. The small size of the fiber, a result of the wavelength, makes mechanical control difficult. Again, the fiber position must be controlled to about one micrometer, an extremely difficult task to accomplish with inxpensive devices. As a result, connector development lags in this respect and there is considerable room for innovation. At the same time, crosstalk from one fiber to a neighboring fiber is extremely low in connectors for multiple fibers. This is partly because the short wavelength of the light results in scattering upon reflection within the connector which soon dissipates the power that leaks out of a fiber. Absorption of this leaked power is also stronger for light than for longer wavelength electromagnetic radiation.

Anticipated Progress

The components mentioned above are sufficient to provide simple links, defined as a signal source, transmission line and detector. This limited technology can be utilized in most of today's applications and many of tomorrow's. However, for widespread application, further reduction of costs through manufacturing efficiency is needed. This is a very large task but is so fragmented that it is almost impossible to pick a single point worthy of discussion here. On the other hand, the general importance of this effort cannot be overestimated. The future will see further innovation in manufacturing but it should be realized that as the technology becomes more definitive, the opportunity for innovation decreases. Further progress in this respect is assured only by the large effort now under way – the size of the effort compensating for the restricted opportunity.

Components of the future will include more than the simple types already mentioned. New system forms and functional requirements will suggest new types of devices. One example of this is the star coupler. No analogy of this device has been previously used on systems of high information capacity

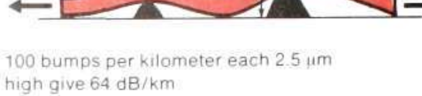


Fig. 4
Schematic showing the effect of microbends on a fiber waveguide. Microbends the wavelength of light in size cause measurable attenuation

100 bumps per kilometer each 2.5 μm high give 64 dB/km

(high bandwidth) because optical wavelengths are needed for the efficient construction of such devices. The invention of the star coupler came about because data bus structures using light were needed. As examples of possible new devices, we may see distributed amplifiers, holographic couplers, optical signal processors, etc. Whatever these future devices may be, and they will be more imaginative than the examples given here, we can only be sure they are largely unforeseen today. These new forms will permit future systems of greater complexity and capability. Here, as in the past, we expect new technologies like optical communications to open avenues and ideas not previously envisioned.

Telecommunication history shows a steady increase over the last 100 years in information transmission capability for a single link. Quantitatively, this increase is represented by a series of gradual steps until the present. In the near future, optical technology will apparently generate a sharp discontinuity – the transmission capability will increase at least 100 times (to over 1 Gb/sec. for a single link). What does this mean? The invention of optical communications provided the means for this discontinuity. However, the increased capability can only arise if the technology is developed to a practical form by thousands of technologists. They are working because of a social need for vastly increased communication in an increasingly complex society. Optics will provide the means for entering this new era.

The Second Stage of the Saudi Arabian Project Completed

Bengt Johansson and Johan-Erik Månsson

A description of how the first stage of the large telephone extension project (TEP) in Saudi Arabia was carried out was the subject of an article in a previous issue of Ericsson Review[1]. The second stage was successfully concluded on 13 June 1979 and this article contains further comments on this vast project.

UDC 621.395.34

Telephone exchanges

For LM Ericsson and Philips the second stage comprises 11 new local exchanges and 4 additions with a total of 95 900 lines. Thus stages 1 and 2 together have almost doubled the country's local network in a period of only 18 months. The number of lines has been increased from 198 800 to 377 300.

LM Ericsson's undertaking in stage 2 consists of two new AXE local exchanges in Mecca, each of 10 000 lines, a new AXE local exchange in Dammam of 8000 lines, the extension of an ARE 11 local exchange in Al Khobar by 2000 lines and the extension of the AXE local exchanges Al Malaz and Al Ulaya in Riyadh by 10 000 lines each. It also includes four new national transit exchanges of type AXE in Mecca, Medina, Jeddah and Dammam, with a total of 22 500 multiple positions, and three international transit exchanges of type ARE 13 in Riyadh, Jeddah and Dammam, with a total of 5000 multiple positions. In 18 months LM Ericsson have thereby supplied ten turn-key transit exchanges of a total of 38 100 multiple positions, which has considerably improved the country's long-distance and international traffic facilities.

A summary of the extent of the whole Saudi Arabian project and the size of the contracted extension stages for exchange lines is given in table 1 (page 103). According to the terms of the contract the agreed completion dates for the 476 000 local exchange lines meant that 75 000 lines had to be completed during the first 12 months, a further 100 000 lines by the end of 18 months and the remaining 301 000 lines by the end of 36 months, all periods reckoned from the date of the Letter of Intent, which was issued on 13 December 1977. As can be seen from the table the total number of lines for stages 1 and 2 is well above the stipulated number.

LM Ericsson's undertaking comprises both local and transit exchanges. All new local exchanges supplied by LM Ericsson are of type AXE. AXE exchanges for both local and national transit traffic are also being supplied.

Philips are providing only local exchanges of type PRX.

Fig. 1
Transit exchange AXE 10 in Riyadh

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LM Ericsson's share of the project also includes an extensive program for the conversion of all existing ARF exchanges to ARE 11. The four existing national transit exchanges in Riyadh, Taif, Jeddah and Damman have previously been converted from ARM to ARE 13 exchanges.

During the second stage of the project a number of AXE exchanges were put in operation in the cities of Mecca and Medina. Since only Muslims are allowed into these cities, the installation and testing of these exchanges were carried out by the Saudi Arabian installation company EPPCO. The work was very successfully carried out by staff whc had been trained by LM Ericsson in Stockholm (Sweden) and in Saudi Arabia.

Buildings

In addition to the telephone exchange equipment the Saudi Arabian project includes the buildings to house the exchanges with the associated equipment for standby power and air conditioning. A total of 29 exchange buildings have been modernised and in some cases enlarged in order to adapt them to the new SPC systems.

Before the expiry of stage 2, work had also started on 11 of the stipulated 36 new exchange buildings.

Subscriber and junction line network

In addition to the installation of local exchanges the project comprises delivery and installation of large quantities of cable and network material for extending the subscriber and junction line networks in the cities. The latter networks are largely extended by means of PCM.

By the end of stage 2 the following work had been carried out and the required PCM equipment installed in the junction line network.

4 million	cable pair joints
700	cable cabinets
400 km	ducting
5000 km	ducts total
3600	manholes
600 km	cable running in ducts
800 km	cable trenches
1200 km	cable running direct in the ground
200 000	cable pairs terminated in main distribution frames
35 000	distribution points of 10 pairs

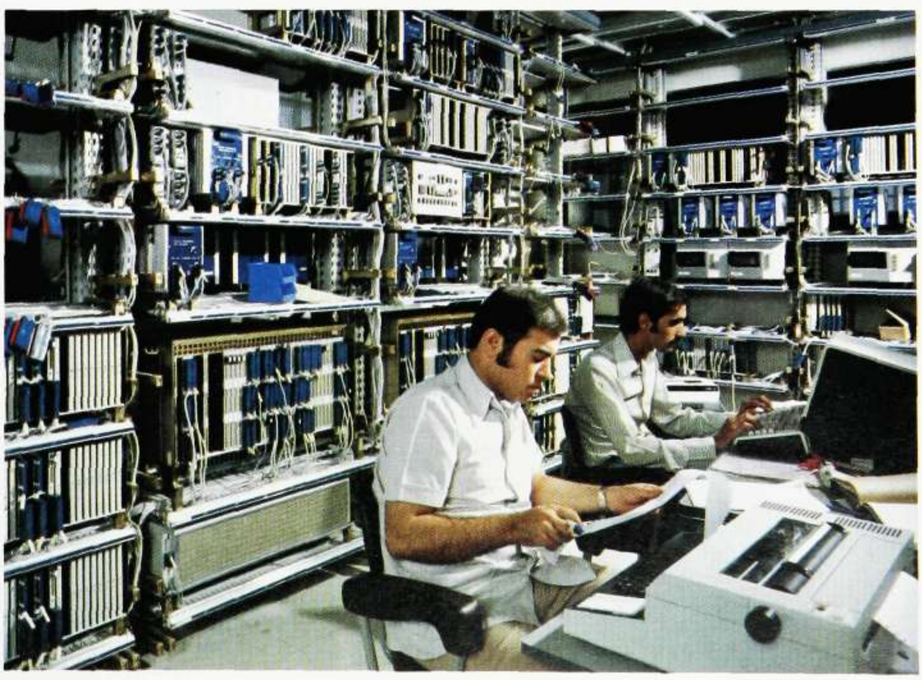

Fig. 2
Installation testing of the AXE 10 local exchange in Dammam

Fig. 3
Building ducting in Riyadh

The networks have been planned so that the ducting will suffice until the year 2000.

Very considerable personnel resources had to be employed to ensure that this vast amount of work would be completed in the short time available. With full installation capacity the work force amounted to 6000 men. Approximately 300 of these belonged to the Joint Venture organization formed by LM Ericsson and Philips and the remainder were subcontractors for duct and cable installation work.

The project has necessitated the preparation of a very large number of drawings. Over 1000 design drawings have already been completed and many more will be required during the course of the work. Drawings are also made showing the various stages of the subscriber and junction line networks. By the end of the project the number of such drawings will be about 20 000.

Telephone sets

The Telephone Extension Project includes approximately 500 000 telephone sets of the new type DIAVOX 100. This set forms part of a family of telephone sets which LM Ericsson are developing in close collaboration with the Swedish Telecommunications Administration. DIAVOX 100 is a push-button set that meets the very stringent requirements for transmission characteristics and stability imposed by the PTT Mininstry. The telephone set has been adapted for local conditions. For example, the push-buttons have both Arabic and western numerals.

105 000 telephone sets were delivered during the second stage, and the total delivered is now 180 000 sets.

Traffic changes in the network

Any change made in an existing telephone network will affect all exchanges in that network, since new traffic routes are introduced and this changes the distribution of traffic between the various exchanges. This means that in all exchanges some of the equipment, for example registers and group selectors in ARF exchanges, must be adapted to the new traffic pattern in accordance

Fig. 4
Building ducts through the centre of Riyadh

Table 1
Telephone exchange lines included in the Saudi Arabian project

Exchange type	Stage 1 (12 months)	Stages 1+2 (18 months)	Stages 1+2+3 (36 months)
AXE local exchange lines	20 000	68 000	161 000
ARE 11 local exchange lines		2 000	3 000
PRX local exchange lines	62 600	108 500	312 000
AXE national transit exchange lines	10 600	33 100	52 800
ARE 13 international transit exchange lines		5 000	8 000
Total number of local exchange lines	82 600	178 500	476 000
Total number of transit exchange lines	10 600	38 100	60 800

The stipulated time for taking the lines into service is given in brackets for each stage above, counted in months from the issue of the Letter of Intent, 13 December 1977.

with a detailed time plan. Naturally this can only be done in well defined stages. Traffic matrices for both the long-distance network and the various multi-exchange areas were therefore prepared, not only for the final network plan after the completion of the TEP contract but also for important intermediate stages, using computerized network optimization calculations. Work plans were then drawn up for the different exchanges on the basis of these matrices.

It may be mentioned that, in conjunction with the radical structural change of the Saudi Arabian network resulting from the project, the charging, signalling and numbering systems will also be changed.

Coordinating the project

Such a rapid extension of a large national telephone network requires very considerable coordination at all stages of the project. A number of entirely different jobs must be completed in accordance with a carefully prepared time plan if it is to be possible to introduce a telephone exchange in the telephone network at the appointed time. If the time plan is not met there will be unnecessary loss of time and delays, which would mean serious financial consequences in a project of this magnitude. The coordination work is carried out by the Joint Venture organization, which has its headquarters in Riyadh.

Operation and maintenance

During the course of TEP the Ministry will gradually take over the responsibility for both the administrative and technical maintenance. Saudi Telephone, a company formed by Bell Canada, will then organize the maintenance on behalf of the Ministry.

LM Ericsson and Philips are building four different types of centres to facilitate the maintenance work:

1. AOM for centralized operation and maintenance activities[2].
2. Software centre, SWC, for handling the software.
3. Documentation centre for copying and distributing documents.
4. Repair centre, with the task of repairing faulty equipment in Saudi Arabia as far as possible.

The first AOM centre is already in operation in the Riyadh district. Three more district centres are to be built (Jeddah, Taif, Dammam), and also a superior national centre in Riyadh for the supervision of the whole of the national network.

The personnel of Saudi Telephone are undergoing instruction and training so that the company can take over the responsibility for operating these centres on behalf of the Ministry.

Experience of AXE exchanges

The positive experience obtained during the installation and cutting in of the five AXE exchanges of the first stage has been reinforced during the work on the seven new AXE exchanges and the two exchange extensions in the second stage.

The AXE system has come up to all expectations as regards installation[3]. The testing, including the final testing for "preliminary acceptance", was completed within the planned time without difficulty.

As regards operational reliability it is of course too early to be able to show any statistically processed material. However, it can already be stated that the general trend is very favourable. Statistics will be published as soon as sufficient information has been obtained.

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2. Nordqvist, G.: *AOM 101, an Operation and Maintenance System.* Ericsson Rev. 56 (1979):3, pp. 116–123.
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Operation and Maintenance of Telephone Networks with AXE 10

Lennart Söderberg

LM Ericsson have always attached great importance to the operation and maintenance characteristics of their telephone exchange systems. Thus methods for controlled, corrective maintenance were developed for the electromechanical systems AGF, ARF and ARM. For example, traffic route testers were used to determine the service quality. It was only when the quality level fell below a preset limit in any part of the equipment that corrective measures were applied.
The introduction of SPC technology meant that the supervision could be automatized and carried out on real traffic instead of test traffic and cover not only the exchange in question but also the surrounding network. The fault tracing could be developed to automatically isolate and indicate faulty functions. The many features of the AXE 10 operation and maintenance system are described in this article.

UDC 621.395.74-7

Telephone exchange system AXE 10, which has been described previously in a number of articles [1-8], is an SPC system intended for all levels in digital and analogue telephone networks. Other members of the AX family are the AXB systems for telex and data networks [9-11]. Fig. 1 shows an AXE 10 local exchange and fig. 2 an AXB 20 telex exchange. Utilizing the extensive product range of the AX family means great advantages for the administrations, primarily as regards uniformity in training, documentation, stocking of spares and software handling. The subsequent article describes how the operation and maintenance activities for these different types of telecommunication equipment can also be coordinated by connecting them to a common, computer-controlled operation and maintenance system, the AOM 101 system[12]. In this article the following characteristics of system AXE 10 will be discussed in more detail:

- The automatic supervision of each connection through the exchange, combined with checking that the service quality remains within the set limits.
- The simple methods for changing and adding functions and data, which are made possible by the functional modular structure of the software and the stardardized signalling interfaces between the function blocks.

Fig. 1
The AXE 10 local exchange for 10 000 lines at Al Ulaya, Saudi Arabia

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- The command-controlled collection of operational data, which are processed by the system before being presented in text en clair.
- The simple methods for clearing hardware and software faults.
- The integrated maintenance of the surrounding network and exchanges.
- Time-saving work methods which are adapted to the personnel.
- The possibilities of centralizing the operation and maintenance functions.

Supervisory functions concerned with the service quality

The system contains functions for supervising the hardware and software functions and the traffic load. The supervision is carried out on real traffic, not test traffic. Faults and overload are immediately detected and are dealt with in a suitable way depending on type and degree of urgency.

Table 1
Important supervisory functions in AXE 10

Digital switching network	Control system APZ 210	Load supervision
Supervision of: Through-connection by means of parity inversion	*Supervision of:* The program handling by means of "watch dogs" in the processors	*Supervision of:* The central processor load by means of a call buffer
Speech paths by means of parity check	The hardware in the synchronously duplicated processors by means of side comparison	The load on the code sender and code receiver groups and the incoming and outgoing routes
Addressing paths by means of parity check	Stores by means of parity check	
Clock pulse paths by means of parity check	Data buses by means of parity check and time supervision of asynchronous signalling	
Clock frequency by means of majority choice	Power by means of voltage supervision in each magazine	
Plane selection by means of routine testing	Maintenance circuits and changeover functions by means of routine testing	
Address path supervision by means of routine testing	Software by means of addressing and signalling checks	
Speech path supervision by means of routine testing		
Clock pulse path supervision by means of routine testing		

Table 1 shows some important supervisory functions.

Hardware supervision

Units that are common to more than 128 subscribers are duplicated. If a fault occurs in such a unit a changeover to the standby etc. is done automatically. For example, if a hardware fault were to lead to malfunction of one side of a processor pair, this side would automatically be stopped and the side that is free from faults would continue to process the traffic without any traffic disturbances. The operating staff would receive an alarm.

However, devices that are built up using analogue circuit technology, for example trunk and junction line units working into analogue networks, are supervised by means of statistical methods. Individual units with the associated lines will be blocked automatically if it is found that they are causing too many time forced releases, too poor transmission quality, unwanted disconnections etc. This normally keeps the service quality within predetermined limits that can be set by means of commands. Fault clearing is not necessary until so many devices have been blocked that there is a risk of too poor service quality during the busy hour. This is indicated by an alarm from the blocking supervision. Thus the principle used here is the same as in LM Ericsson's earlier systems, namely controlled corrective maintenance[13].

In digital networks there is a bit flow regardless of whether the devices carry traffic or not. In the digital parts of system AXE there is therefore supervision at the PCM word level, not only during actual traffic but also during the idle and blocked condition, so that faults can be detected in all situations. The units in question are automatically blocked when a fault occurs and deblocked when the fault disappears.

Automatic routine testing is carried out for some auxiliary functions that are seldom used, but which are nevertheless important, for example the plane selection functions in the digital group selector stage. In addition to the plane selection the supervisory and diagnostic functions concerned are checked.

The method utilized, with service quality supervision on *real* traffic, means that every connection set up through the exchange is supervised. This gives a much better picture of what effect the faults have on the service quality than when using *routinely generated test traffic*, which does not take the subscriber behaviour into consideration.

The method, in combination with automatic fault diagnosing and fault indication, means that the staff are not encumbered by large quantities of fault printouts and analyses of these. Nor is there any need for special test equipments with the associated test programs.

Software supervision
The fault rate in the AXE 10 programs is kept low by means of extensive testing and by using mainly standardized programs. The structure with function modules, in combination with the special addressing principles[3], effectively limits the consequences of software faults, and these are also easy to locate with the aid of special tracing functions.

Nevertheless, automatic restart will take place if implausible data or program derailment should be detected by the supervisory functions. This function maintains the operational reliability of the system by limiting the effects of serious faults. In connection with the restart an informative printout is obtained, which provides the basic data for the necessary corrections.

Load supervision
Automatic load supervision of both the control system and the individual routes is carried out in order to ensure optimum use of the equipment and the best possible handling of occasional load peaks.

If the control system gets overloaded, adjustments are automatically carried out, for example by giving preference to traffic from a transit exchange before locally initiated traffic.

An alarm is given if the sum of blocked and engaged lines on a route exceeds a preset level, since there is then a risk that calls are rejected or delayed. After detailed measurements the staff can decide which measures are to be taken.

Fig. 2
The AXB 20 telex exchange in Malmö, Sweden. AXB 20 contains the same processor, APZ 210, as AXE 10. Moreover the general design, the components and the mechanical construction are the same

Administration of subscriptions and charging
Check of call metering
Reading of call meters
Toll ticketing
Data collection for settling between administrations
Tariff statistics per tariff rate
Service observation for superior quality control

Traffic planning and administration
Traffic measurement on routes
Traffic measurement of different types of traffic, e.g. outgoing and incoming traffic
Recording of traffic interest
Recording of the load on the central processor system
Recording of the call frequency to the central processor system
Recording of the load on the regional processors

Maintenance
Disturbance statistics
Service quality statistics
Transmission quality statistics (ATME)

Table 2
An example of functions for the collection of operational data

For example, if a fault has occurred that results in large rejection, a temporary improvement can be obtained by changing the data. By this means the traffic can be rerouted for a short time and other traffic-limiting measures can also be carried out. More long-term changes, such as moving devices from one route to another, are performed by reallocating hardware or making the relevant data changes.

Supervision of certain subscriber facilities
Immediate operator intervention may be required for certain subscriber facilities, for example tracing of malicious calls and if the alarm call service fails because of a technical fault or lack of answer. In such cases the system supervisory function will give an alarm.

Alteration methods

A main advantage of AXE 10 is that alterations are easy to make. A distinction is made between data changes, where the characteristic in question is altered solely by means of changes in the data, and function changes, which always require the addition or change of programs but often also of data. In rare cases it is also necessary to add or change hardware.

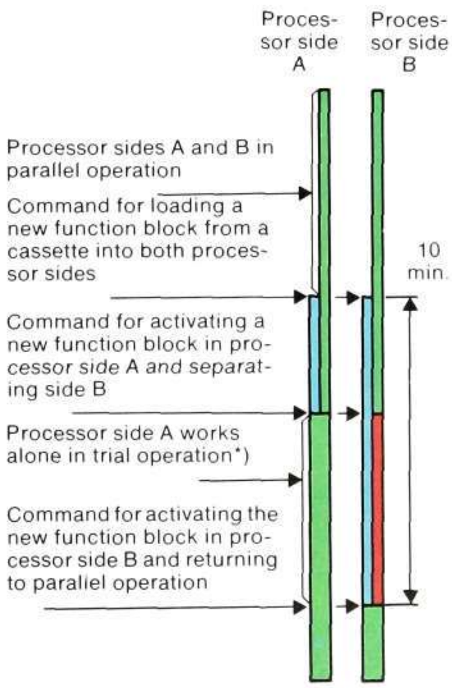


Fig. 3
Adding a new function block in AXE 10.
***If the new software is faulty a changeover is made to side B and the original program package**

Connected processor side
Separated processor side
New function block not yet activated

Data changes
Data changes can concern the connection and disconnection of subscribers and facilities, changes in the characteristics of certain devices and routes, routing and tariff analyses, service quality levels, command authorization, printout routing etc. In the case of subscriber number changes the need of vacant multiple positions is reduced, since new subscribers can be allocated previously used multiple positions in accordance with the principle of free number group.

Small changes are preferably carried out from local or remote terminals, whereas extensive changes are best made with the aid of cassette or magnetic tapes, which have been loaded with the change commands in advance.

In order to prevent critical data changes from causing serious disturbances, a changeover to the old data can easily be made if necessary. Old, well-tried data are retained in the system until the new data have been tested.

Function changes
Function changes include for example the introduction of new or revision of existing subscriber facilities, operation and maintenance functions, signalling systems and I/O functions. These changes are made by introducing new function blocks or changing one or more blocks. The other function blocks are not affected.

The functional modular structure of AXE 10 and the standardized signalling interfaces of the function blocks towards interworking blocks[3] make it easy to include new or revised function blocks in an AXE 10 exchange by means of special alteration functions. Fig. 3 shows the general method for such an alteration: introducing a new function block without causing traffic disturbances.

Operational performance information

The system conveniently provides the required operational information in the form of operational data and alarms.

Operational data
The operational data comprise information concerning charging, traffic,

Table 3
Examples of alarm classes, types and categories

Alarm class	Alarm type	Alarm category	Origin
Immediate action Action the same day Action during the week	Fault alarm Observation alarm which is released by a major manual intervention	Switching system Control system Subscriber line network Transmission network Power Overload Subscriber facilities	Identity of the exchange of origin

service quality etc. Table 2 shows the most important functions for the collection of such data.

The operational data are normally presented processed and edited, and are printed out in text en clair. However, when the data are to be processed further in an administrative computer, for example with toll ticketing, the output is in unprocessed form.

The collection of operational data is always initiated by a command from an operator. The output can either be made immediately or at predetermined times. The data are output to a printer, cassette or magnetic tape, either direct or via a data link.

Alarms

Abnormal conditions that affect the service quality direct are detected by the AXE 10 supervisory functions or, if applicable, are transmitted to the exchange in question from subordinate equipment and connected supervisory systems. The alarms are divided into alarm classes, types, categories and origins, see table 3. Each alarm can then be routed direct to the staff group concerned, i.e. the one responsible for exchanges, transmission, power etc.

In addition to local indication in exchanges, alarms can be given on remotely connected panels in the form of visual or audible signals or they can be handled by the computerized operation and maintenance system AOM 101, depending on the existing maintenance organization.

Detailed information concerning the alarm state of the exchange is given in its alarm list, which can be shown on a display by means of a command.

Spontaneous printouts are made only for alarms that require immediate action.

Fault clearing

The functional modular structure makes it easy to clear faults in the system, both in hardware and software.

Hardware

The hardware consists of printed board assemblies, I/O devices and power modules, placed in magazines in the BYB 101 construction practice. All units are easy to replace.

If a fault occurs, the unit in question is automatically blocked. The fault should be cleared within a certain period of time, depending on the alarm class. A printout guides the repairman to the correct magazine, where the unit is identified by its functional designation, which is given in the printout, fig. 5. The

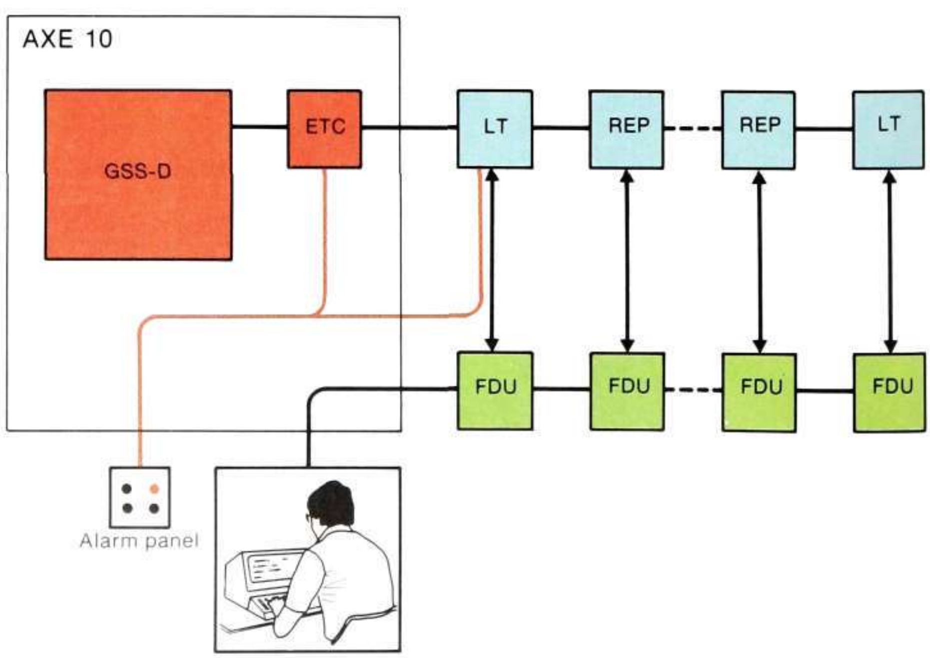


Fig. 4
Supervisory and fault localization functions for digital lines. The most important functions include:
Supervision of frame alignment
Supervision of multiframe alignment
Supervision of alarm indication signal
Supervision of the bit error rate
Alarm collection from the line terminal LT
Command-controlled localization of faulty line repeaters

GSS-D Digital group selector
ETC Exchange terminal
LT Line terminal
REP Line repeater
FDU Fault localization unit

Fig. 5
An example of an alarm printout

A1	Alarm class
APZ	Alarm category
CP UNIT FAULT	Headline in the operating manual
MAG	The magazine that contains the indicated printed board assembly
CARD	Printed board assembly designation, marked on the magazine
WEIGHT	The probability, as a percentage, that the indicated printed board assembly is faulty

```
ORL-AXE-1              TIME 780224 1817            PAGE    1
ALARM A1/APZ
CP UNIT FAULT

MAG          CARD       WEIGHT
PS-B-09      STS-6      020
PS-B-09      STS-14     020
PS-B-09      BFU-1      060

END
```

faulty unit is replaced and the new unit is tested by means of the test functions built into the system. This gives a check that the fault has been cleared.

Software

A software fault in an exchange is cleared by replacing the program in the faulty function block by corrected and well tested software. This method is preferred to making changes in the programs by means of commands (patching). The designer corrects the fault himself, the program is correctly documented and the risk of introducing new faults is minimized.

Maintenance of surrounding networks and exchanges

AXE 10 contains efficient aids for localizing faults in the surrounding digital and analogue networks and in connected exchanges.

Digital networks

The incoming bit stream from digital trunk lines is supervised by AXE 10 in accordance with CCITT recommendations, fig. 4. The supervision covers frame and multiframe alignment and bit error rate. When a fault is detected on such a line all affected devices are automatically blocked. The blocking is removed if the fault disappears. Persistent faults give rise to an alarm.

The trunk line terminal, LT, gives alarms for power faults, faults in transmitted and received digital signals and also for too high bit error rates.

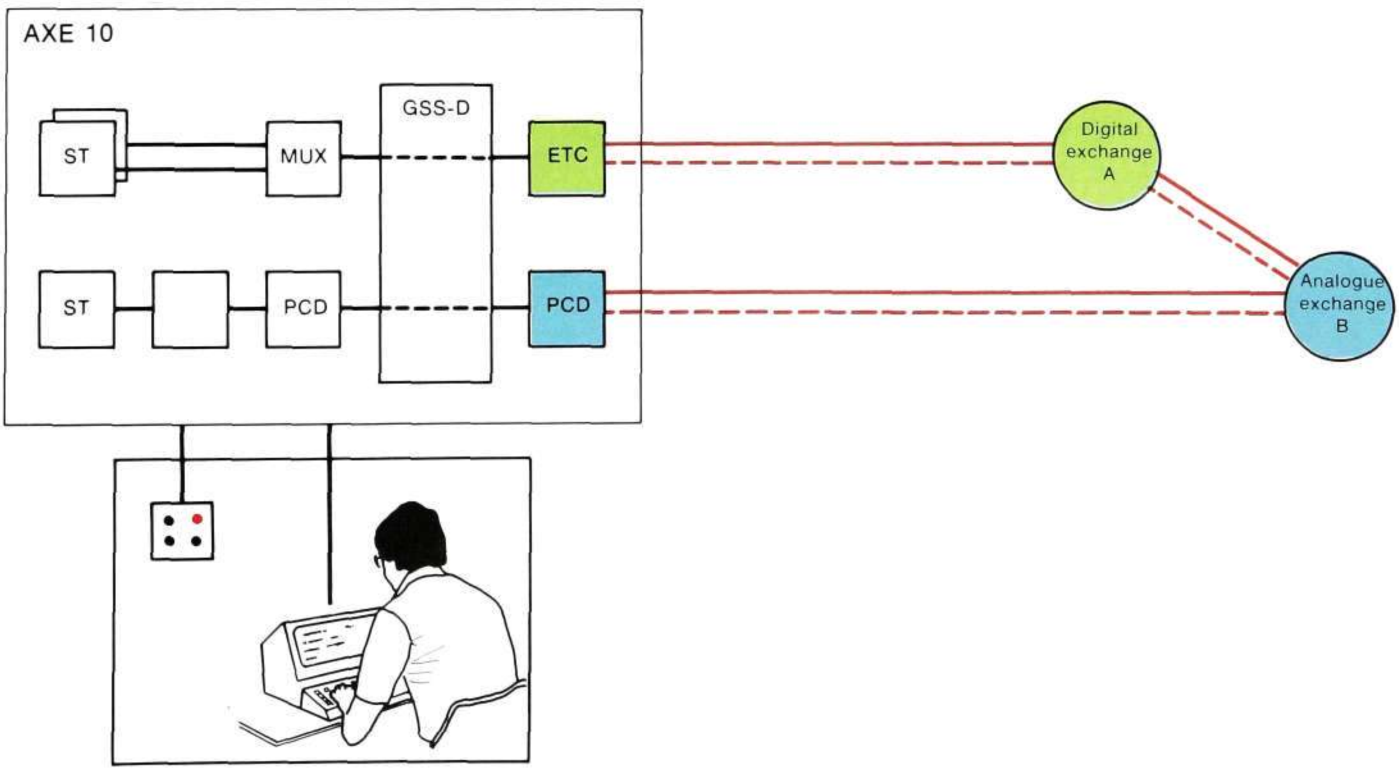
Alarms from AXE 10 and LT are routed either to a position for integrated exchange and transmission maintenance or to a special transmission maintenance position.

When an alarm is obtained, fault localization can be ordered with a command. The distribution of the bit error rate along the trunk line is then measured via a separate pair of wires, which makes it possible to trace a fault to the line repeater REP in question.

Fig. 6
The most important supervisory functions in a network with common channel signalling in accordance with signalling system no. 7.
The most important functions comprise:
Supervision of the bit error rate on the signalling links
Supervision of the load on the send buffers
Supervision of the signalling traffic accessibility towards different destinations
Blocking supervision of the speech channels

Exchange A can serve as the signal transfer point, STP, for traffic from AXE 10 to exchange B

(solid red line)	Speech channel
(dashed red line)	Signalling link
(dashed black line)	Semi-permanent connection through the switching network
ST	Signalling terminal for system no. 7
MUX	Multiplexor
PCD	Digital/analogue converter
ETC	Exchange terminal



Equipment for common channel signalling

AXE 10 can supervise networks with common channel signalling in accordance with CCITT signalling systems no. 6 and no. 7. Only signalling system no. 7, which will be widely used, particularly at the national level, will be discussed here.

Signalling system no. 7 is primarily intended for digital networks, which are supervised in accordance with fig. 6. The signalling equipments for system no. 7 work much faster than traditional line and register signalling (64 kbit/s instead of 10 bit/s), and thus less equipment is needed and the fault rate is lower. However, the introduction of common channel signalling makes very high demands on functional reliability, since a fault in an equipment would affect a large part of the traffic. In AXE 10 the demands for functional reliability are met by means of automatic changeover to a standby channel when the monitoring of the bit stream indicates a fault. The standby channel can either be associated with the speech channel or routed via a signal transfer point. It is also possible to use speech channels as the standby, in which case they are automatically converted into signalling channels.

Carrier networks

Alarms from carrier terminals can be received by AXE 10 and distributed to the relevant staff. In the case of a pilot alarm the exchange devices concerned are automatically blocked. Automatic transmission recording is carried out and indicates groups or supergroups with unacceptable transmission quality. Supervision of individual circuits is carried out on real traffic.

Connected analogue exchanges

In the case of traffic from AXE 10 via digital lines to an analogue exchange it is possible for the system to indicate faulty devices in the latter, fig. 7, alternative a. The system supervises each individual channel and if a fault is detected in any one it must be caused by the connected device in the analogue exchange, since in the digital transmission system there can be no faults in single channels, only whole groups.

Analogue circuits to connected exchanges are also individually supervised by AXE 10, fig. 7, alternative b.

Faults and blockings in the analogue exchange that affect devices which are common to a route, such as code senders and receivers, can be detected by route supervision in AXE 10.

Fig. 7
The most important supervisory and fault localization functions for interworking with analogue exchanges comprise:
Disturbance supervision of IT and OT routes
Blocking supervision of IT and OT routes
Seizure supervision of individual ITs and OTs
Seizure quality supervision of individual ITs and OTs
Signal course recording, by command
Generation of test calls, by command
Disturbance registration, by command
Tracing of connection paths in the case of disturbances, by command
Transmission measurement with the aid of ATME
Transfer of pilot alarm

(blue)	Analogue equipment
(red)	Digital equipment
GSS-D	Digital group selector
ETC	Exchange terminal for digital lines
PCD	Integrated multiplexor with digital/analogue conversion
IT	Relay set for incoming analogue lines
OT	Relay set for outgoing analogue lines
MUX	Multiplexor in the digital transmission system with digital/analogue conversion
LT	Line terminal
CS	Code sender
CR	Code receiver

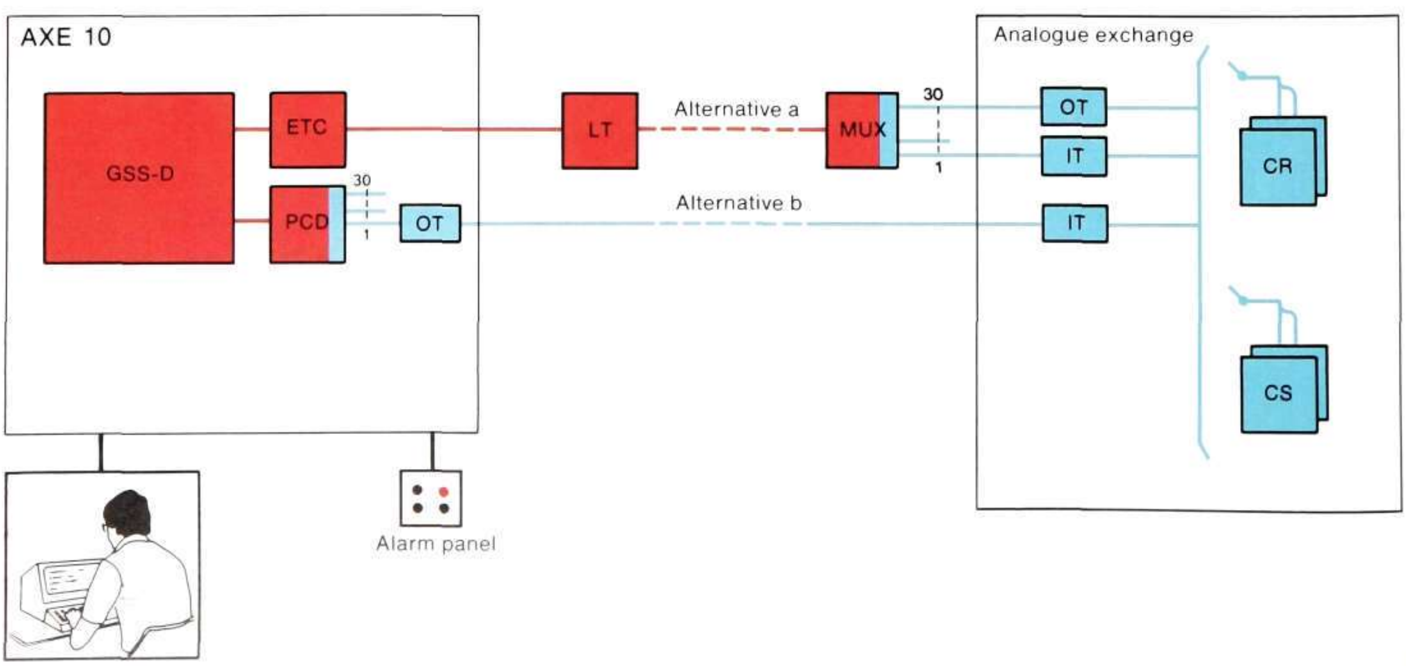


Fig. 7 shows the most important supervision and fault localization functions.

Analogue subscriber line network
The maintenance of the analogue subscriber line network is very labour-demanding and rationalization of maintenance can result in considerable savings.

The subscriber lines are therefore measured and supervised in connection with each call to and from a subscriber as shown in fig. 8. In addition the lines are supervised with regard to occupation, and if a line has not had any traffic for a certain period of time it is automatically tested.

Lines that deviate from the normal are marked as faulty or are blocked, depending on the amount of deviation. They are then automatically tested at regular intervals. When the fault on a blocked line ceases the line is automatically taken back into service. An alarm is given if the number of deviating lines becomes excessive.

Individual lines can also be supervised as regards line lockout. An alarm is given for long blocking. Special supervision is provided for particular subscriber equipment, such as coin box sets. An alarm is obtained if no call of a preset minimum duration is carried out from such a set during a certain period.

System AXE 10 has integrated functions that enable a repairman to test an individual line from a subscriber set equipped with a dial or a push-button set. The line can also be tested by an operator from a terminal, for example when a complaint is received from a subscriber.

Time-saving methods that are adapted to the personnel

LM Ericsson continuously carries out ergonomic studies in collaboration with

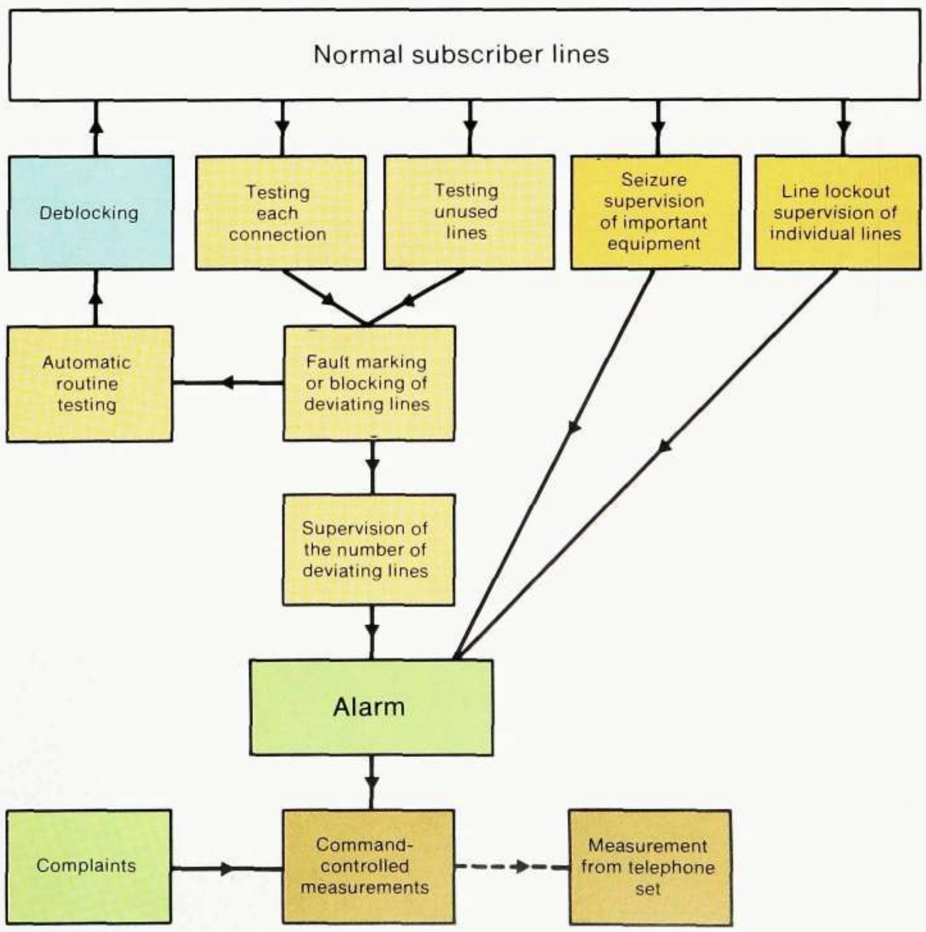


Fig. 8
Supervision and measurement of subscriber lines

experts in order to obtain data for the design of work positions and work methods to provide the best possible working conditions for the personnel. These data have also formed the basis for the design of operation and maintenance methods for telephone networks including AXE 10.

Simple tasks

The operation and maintenance of an AXE 10 exchange depends greatly on application, the surrounding network, the rate of alteration and the organization in question. The figures given below show the operation and maintenance characteristics of a normal AXE 10 exchange.

The operating work, which comprises collections of operational data and alterations, amounts to approximately 55 % of the total operation and maintenance activities, whereas the maintenance work accounts for only about 45 %.

Approximately 80 % of all operating work can normally be carried out by operators without system knowledge. They need to be able to operate the terminals and master the use of a number of commands. The task of these operators consists of carrying out simple alterations and collect operational data. The major part of the work consists of subscription changes.

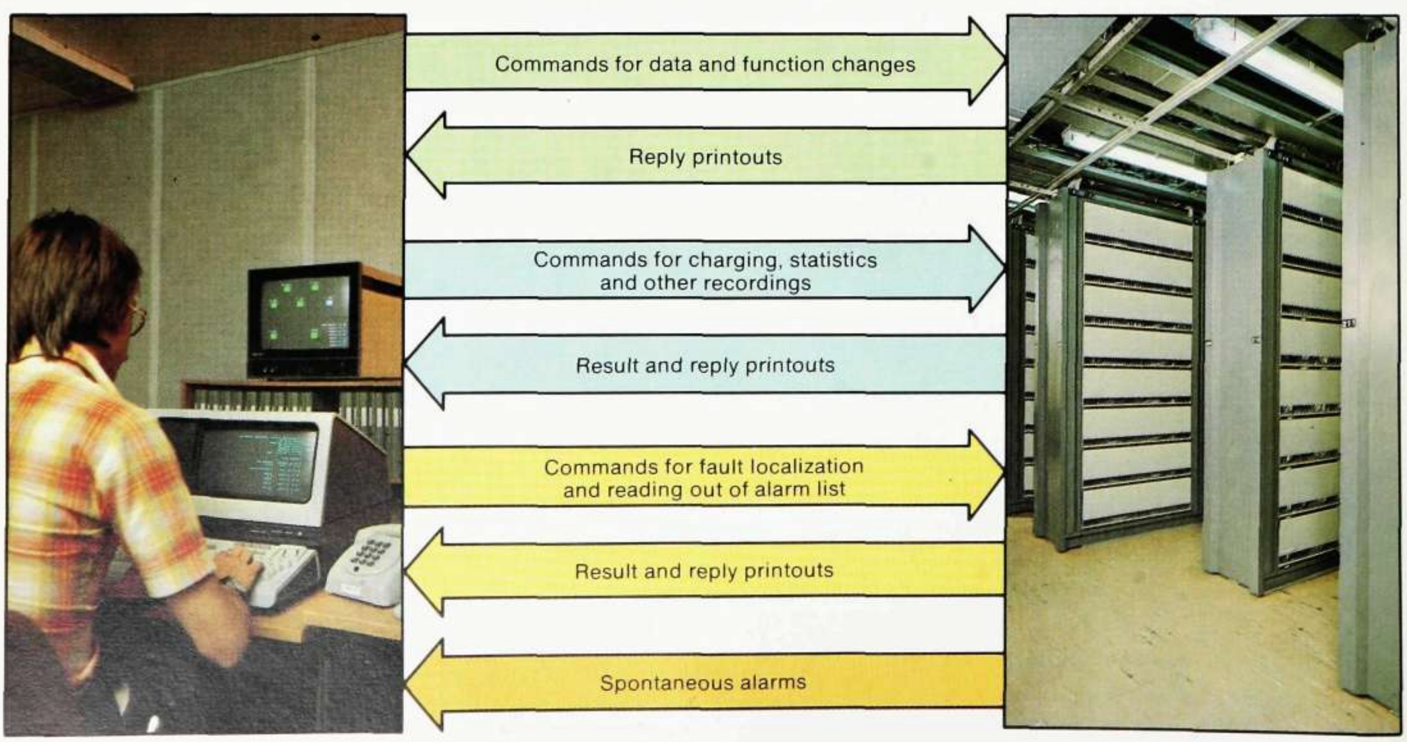
Investigations show that up to 98 % of the maintenance work can be handled by technicians with the operation and maintenance manual as the main aid. Only 2 % of the maintenance activities need be carried out by system experts with knowledge of AXE 10 hardware and software in accordance with the system documentation.

The large part of the maintenance work that consists of localizing faults in the surrounding exchange and network with the aid of the AXE 10 fault localization functions can be handled by technicians with limited knowledge of the system.

Operation manual in flow chart form

Each chapter in the operation and maintenance manual contains instructions for a number of jobs. The alarm printouts refer direct to certain of these jobs. The instructions are given in the form of flow charts with supplementary text, which describes to the operator in detail, step by step, what to do until a fault has been located.

Fig. 9
The most usual command and printout functions in AXE 10



The manual also contains descriptions of commands and printouts.

Man-machine communication
In an SPC exchange most operation and maintenance activities are carried out by means of man-machine communication, which is illustrated in fig. 9. The man-machine language is thus a basic aid. In AXE 10 this language is based on CCITT recommendations, and LM Ericsson participated in their design.

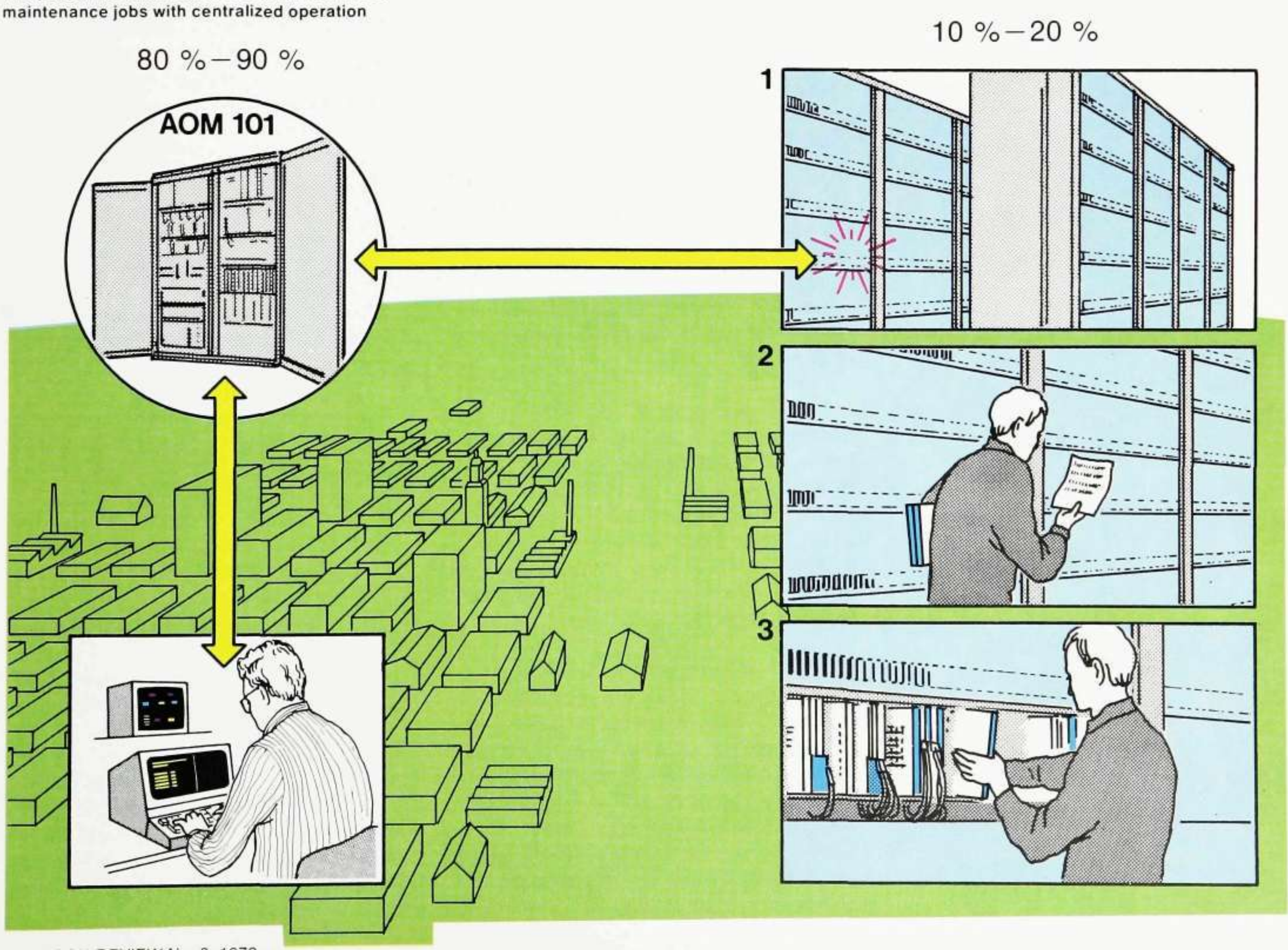
Several requirements were set for the man-machine communication in AXE 10. The five most important ones and the way they have been met are described below.

The language must be easy to learn and use.
It has therefore been given a simple structure and ordinary telephony terms are used as far as possible. Mnemonic abbreviations are always used in commands, and also text en clair in printouts when it will simplify the operator's work.

The various command codes are easy to remember, since they have a set length (five letters) and each letter or combination of these has a meaning that relates to a telephony function. For example, the last letter always indicates the type of action to be carried out, such as connection, disconnection or printing.

The language must offer great security.
Received commands are therefore checked by the software. For example, if the operator has written a faulty command code, a command that does not conform to the existing syntax rules or a parameter with an unreasonable value, a printout is obtained which states that the command cannot be accepted and gives the reason why.

Fig. 10
The percentile distribution of the operation and maintenance jobs with centralized operation



Psychological aspects must be considered.
For example, the system always replies within a short time after a command, so that the operator will not have doubts as to how the system has reacted to the command.

The operator must be in control of the system at any moment.
The operator can therefore interrupt a printout if he needs to send an important command. The input of commands cannot be interrupted by the system.

The operator should only receive the printouts he needs at the time.
This makes it easier for the operator to survey and plan his work. Spontaneous printouts are therefore given only in the case of alarms that require immediate action. All other printouts are the result of commands.

All these requirements, which are met by the AXE 10 man-machine communication, help to make the system simple and reliable as regards operation and maintenance.

Centralized operation

As can be seen from the above, the AXE 10 system contains complete functions for remote control of the operation and maintenance activities. Only 10–20 % of the work requires action out in the individual exchanges, and thus even large exchanges can be kept unmanned, fig. 10.

In areas with only a few AXE 10 exchanges the operation and maintenance of certain exchanges can be remotely controlled from a large, manned AXE 10 exchange or from another suitable centre. For this purpose lamp panels and terminals are used, which are connected to the remotely controlled exchanges via data links.

If a network contains many AXE 10 exchanges, or if the number of such exchanges is expected to grow rapidly, the computerized operation and maintenance system AOM 101 offers additional important advantages in connection with centralized operation, which is described in the following article[12]. Since exchanges of other types in the network in question can also be connected to AOM 101, a uniform operation and maintenance organization will be obtained in the network.

The connection to AOM 101 is made via a data link in accordance with CCITT Recommendation X25. In such a link 16 cannels are used for simultaneous man-machine communication.

Summary

A summary of the most significant operation and maintenance characteristics of AXE 10 is given below.

- The system is part of a complete and uniform family, which also includes exchanges for telex and data networks, and thus the operation and maintenance activities for all these telecommunication branches can be coordinated.

- The supervision, which is based on real traffic, checks that the service quality stays within the permissible limits. It is an efficient method which reflects how well the system serves the subscribers.

- The surrounding digital networks, signalling networks for signalling system no. 7 and analogue networks and exchanges can also be integrated in the maintenance activities. Alarms can then be distributed to the personnel groups concerned.

- Function changes can easily be made without disturbing the traffic in progress.

- 98 % of the maintenance work can be carried out by technicians with the operation and maintenance manual as the main aid.

- Even very large exchanges can be run unmanned. The system is designed to facilitate centralized operation in conjunction with AOM 101.

To conclude, reference is made to fig. 11, which shows how automatic supervision, fault isolation and fault localization by replacing a faulty printed board assembly greatly simplify the maintenance work.

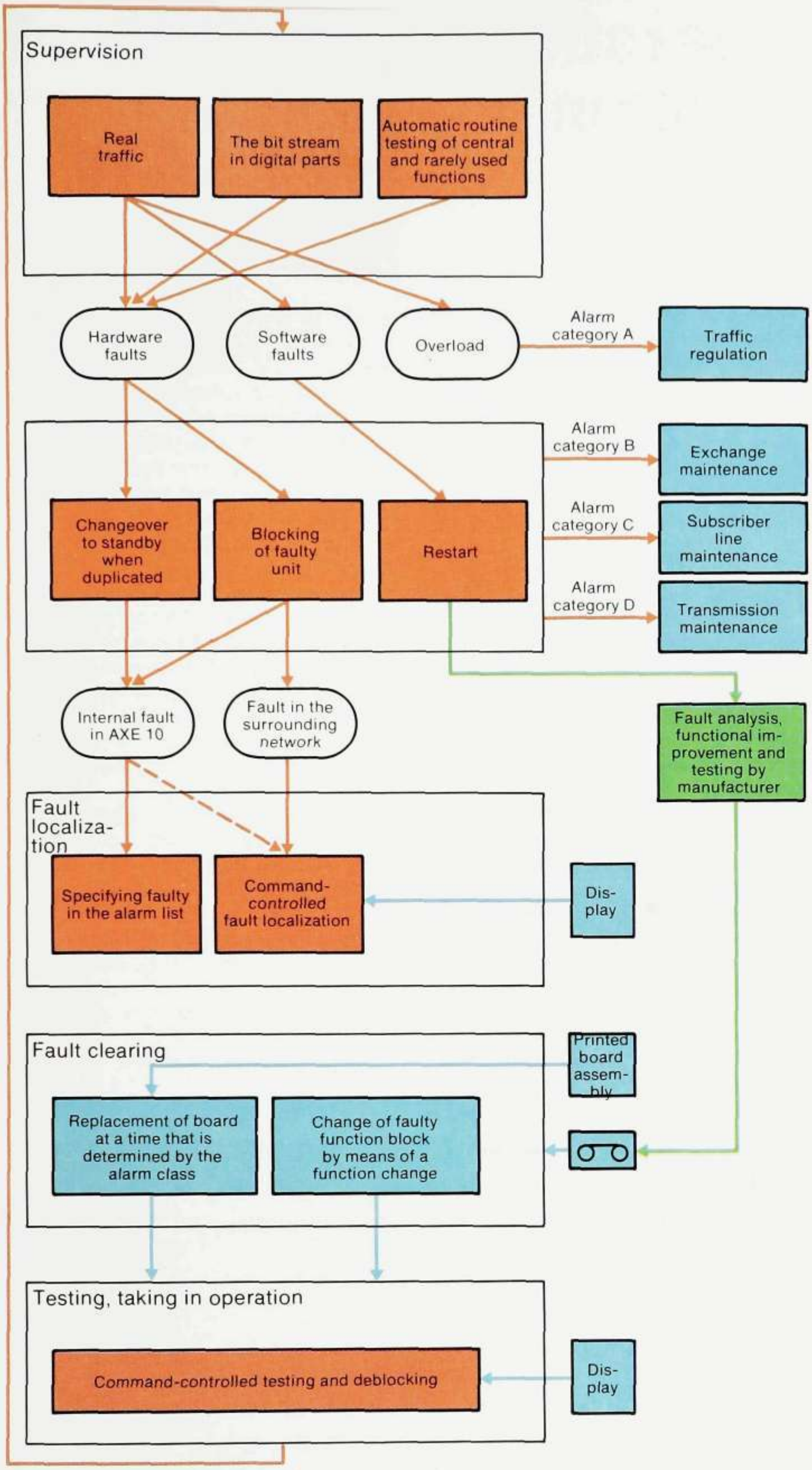


Fig. 11
Principles of the AXE 10 maintenance

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AOM 101, an Operation and Maintenance System

Göran Nordqvist

LM Ericsson have always devoted much effort to all aspects of the development of new telephone exchange systems. A well designed system and equipment of high quality mean that maintenance can be limited to automatic supervision and corrective measures[1,2]. This has been shown at annual maintenance conferences, where experts from the participating administrations have put forward their views and compared notes.

A further step in the rationalization of the operation and maintenance activities is to centralize the supervisory and control functions to a few places. The computer-controlled operation and maintenance system AOM 101 has been designed for this purpose. The system is flexible and can be adapted to individual requirements.

In this article the advantages of AOM 101 are presented, followed by a description of the structure and function of the system.

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In order to be able to manage a telecommunication network rationally and economically it is necessary to automatize the operation and maintenance activities further. This can be achieved by putting the operation and maintenance functions in the actual exchanges under computer control to a greater extent, which has been done in AXE and ARE. The advanced operation and maintenance characteristics of the AXE system have been described in the previous article[3]. Further rationalization can be achieved by centralizing the supervision and control of the operation and maintenance functions. The independent, computer-controlled operation and maintenance system AOM 101 has been designed for this purpose. It provides the telephone administrations with additional facilities for economically maintaining the telephone equipment in such a condition that the subscribers' demands for fast and reliable connection, high transmission quality and accurate charging can be met.

It is not only SPC (Stored Program Control) exchanges that can be connected to system AOM 101. Exchanges of types ARF, ARM and ARK can also be connected via exchange terminals. The latter will also be used if transmission equipments, power plants etc, are to be supervised with the aid of AOM 101.

The computer-controlled operation and maintenance system AOM 101 provides many advantages, of which the following may be specially mentioned:

- Reduced operation and maintenance costs, since the work is simplified because the number of visits to exchanges is reduced: the right man can be sent to the right place and other resources will also be better utilized.

Fig.1
Operation and maintenance system AOM 101. Exchange equipment AXE in the background

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- Overall check at a glance. All telecommunication equipment can be controlled from a suitable place, fig. 2. By means of remote control the traffic flow can be distributed so that overloads and other network problems are reduced. Localization of complicated faults is also simplified.
- Instantaneous and reliable distribution of the required data to the personnel groups concerned, so that they can carry out their work efficiently.
- Coordination between the telecommunication network and existing computer systems for network planning, sales etc., which facilitates such work.
- Improved subscriber service because customer orders and complaints can be dealt with very quickly.

Separate work centres give a flexible organization

The personnel who work with AOM 101 carry out a large part of their work with the aid of terminals consisting of displays and typewriters, which can be located at any place in the network. The work can thus be organized in the best possible way for each individual case, since the terminals can be grouped according to individual requirements.

In the initial stage the existing organization is often retained, but the personnel are aided by the computer in their work. At a suitable time special work centres are then set up, each centre being responsible for a particular job, fig. 3. These centres should be placed in the most appropriate place with respect to organization, travelling distances and the need for contact with the personnel concerned.

Operation and maintenance centre
From an operation and maintenance centre the necessary commands are sent for altering exchange data and functions. A check is also made that ordered changes in the hardware and software are carried out. Finally the faults that occur in the supervised equipment are analyzed, decisions are made on measures to be taken and, if necessary, a repairman is sent to rectify the faulty item. Fig. 4 shows a work position in such a centre.

Centre for the maintenance of the subscriber line network
The staff at this centre receive subscriber complaints and carry out measurements on the subscriber lines in question. When necessary a repairman is sent out, and after the repair the staff check, by means of measurements, that the fault has been cleared.

Fig 2.
AOM 101 makes it possible to control the whole of the network in a large area from one operation and maintenance centre

Local exchange
Transit exchange
Concentrator
Data link

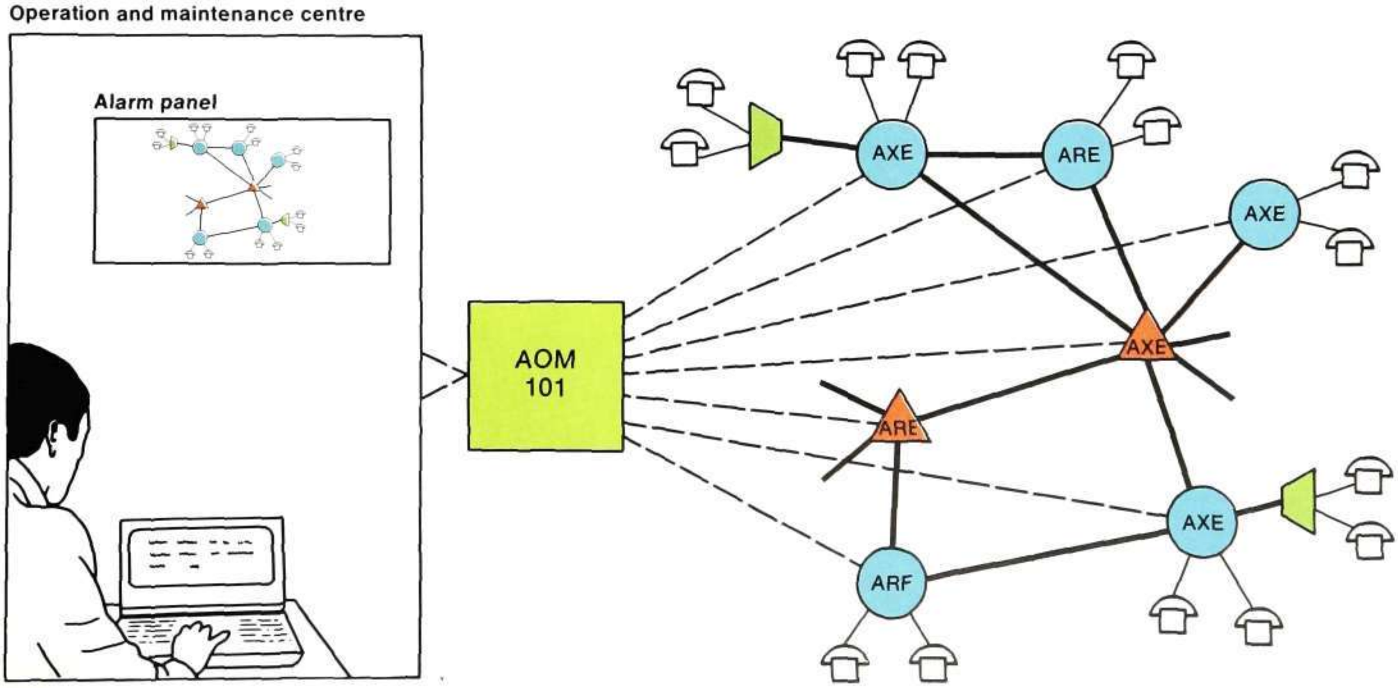


Fig. 4
A work position in an operation and maintenance centre

Sales centre
The staff at this centre recive orders for new subscriptions and request for category changes and also carry out the data changes for such subscribers. They also issue work orders for the personnel who perform the required installation work.

Traffic observation centre
The staff at this centre study the subscriber behaviour and collect and process data for statistics.

Network planning centre
On the basis of traffic recordings the staff at this centre compile information for short-term and long-term network planning. They are also responsible for the necessary action in the case of temporary overload, breakdowns etc.

System AOM 101 and its main parts

System AOM 101 consists of three main parts: work position terminals, a central processing system and exchange terminals, fig. 5.

The work position terminals are equipped with alphanumerical displays, different types of typewriter terminals and colour displays for network information, fig. 4.

The central processing system consists of processors with programs, communication units and external stores.

The exchange terminals, fig. 6, are used as interface and data collecting devices when exchange systems that are not based on SPC technology are to be connected to system AOM 101. These terminals can also be used for remote control of transmission systems, power equipment, buildings etc.

The work position terminals and the central processing system can be installed at different places if desired, since the various parts of system AOM 101 and the telecommunication equipment are connected together by means of data links. They can also be placed away from the telecommunication equipment.

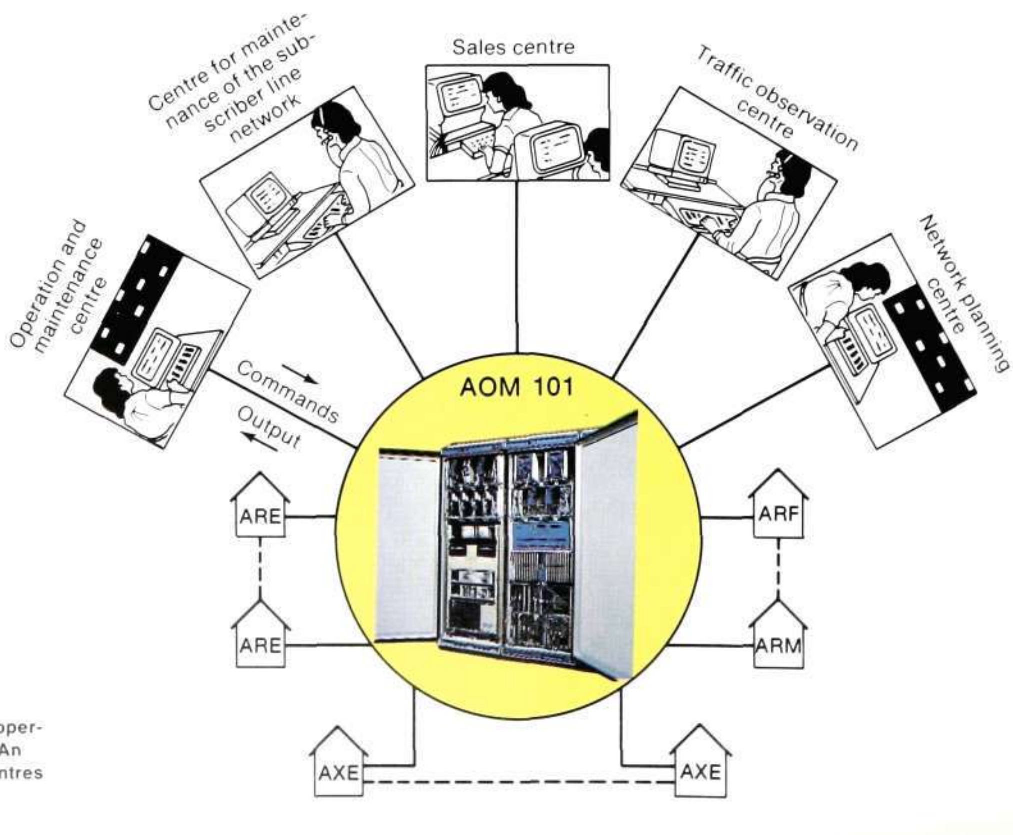


Fig. 3
Computer-controlled system for centralized operation and maintenance activities, AOM 101. An example showing some specialized work centres in the system

Fig. 6
Exchange terminal with OMT equipment (see fig. 5 below)

The central processing system
The central processing system has two main components: the application system APT and the control system APZ. Each of these consists of a number of modules or subsystems, whose main functions are described in fig. 7. The subsystems in their turn consist of function blocks, which are divided into function units, in accordance with the structural principles of system AXE.

The main characteristic of this structure is that both hardware and software are assembled in different modules according to different requirements. Each module constitutes a complete functional unit.

The system contains two types of processors: a central processor and up to fifteen regional processors.

The central processor is a medium-size processor specially adapted for real-time applications. It processes the application programs, which are written in a high-level language (PASCAL).

The regional processors are of the mini type. Each such processor has a special job, for example data communication. The regional processors are often used to relieve the central processor of frequently recurring routine jobs.

The main function of the control part of system AOM 101 are described below.

Man-machine communication
AOM 101 contains the necessary functions for man-machine communication via the displays and typewriter terminals that are connected to the system.

AOM 101 checks each operator's authorization by means of his or her personal code, which prevents operators from utilizing unauthorized commands that could give them access

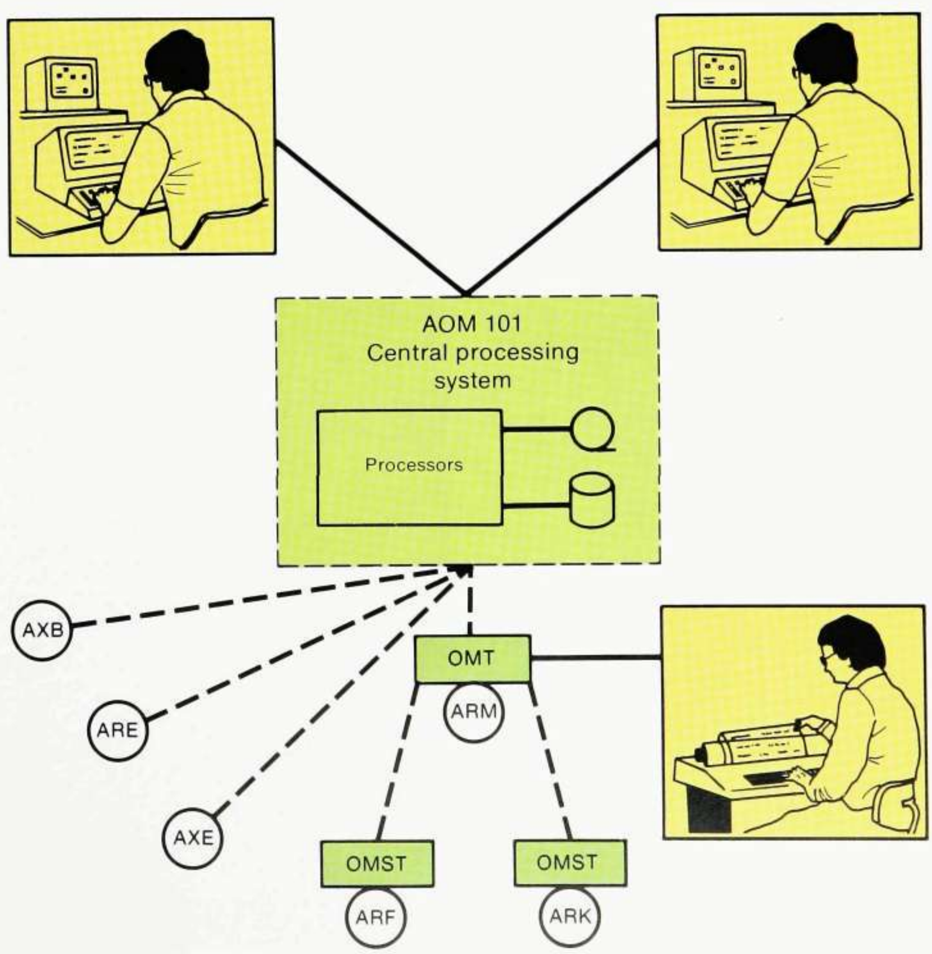


Fig. 5
The main components of system AOM 101
OMT } Terminals for exchanges
OMST } without SPC

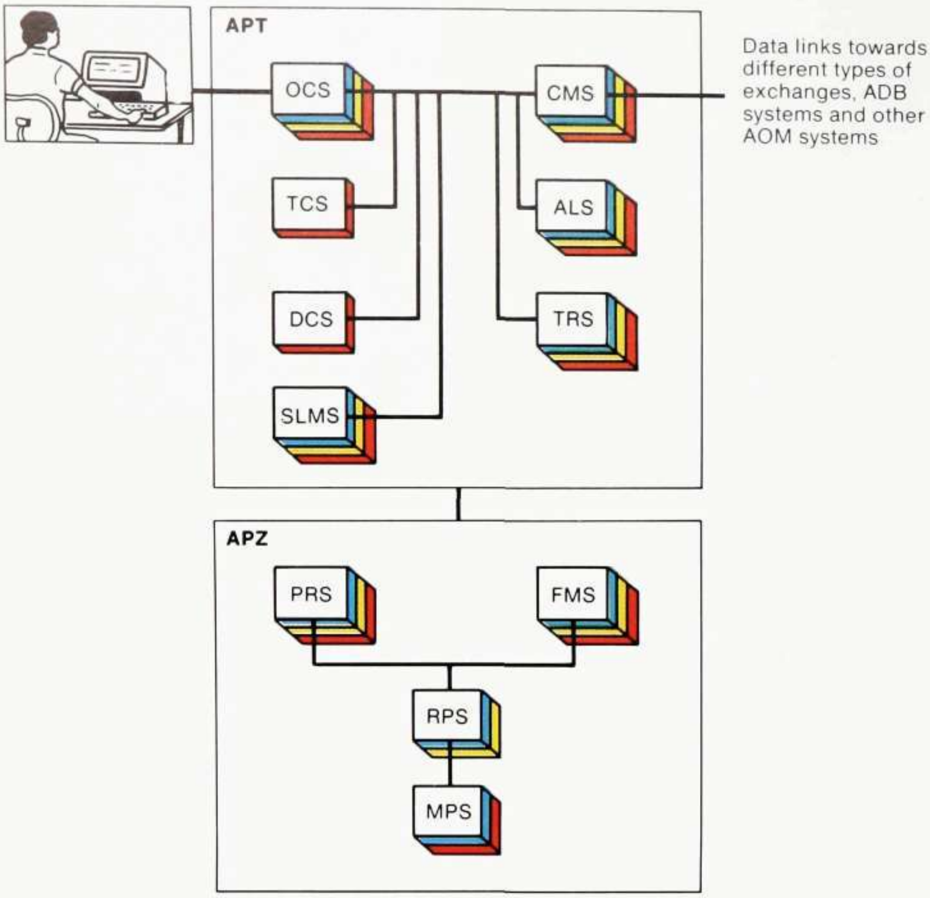


Fig. 7
Application system APT and control system APZ. Division into subsystems

APT contains the following subsystems:

OCS	Permits man-machine communication via display and typewriter terminals
TCS	Permits recording of different types of data. The data are recorded in disk and magnetic tape stores
DCS	Permits collection of data from the telecommunication network, e.g. charging and statistics data
SLMS	Contains functions for the maintenance of subscriber line networks
CMS	Used by system AOM for data link communication with telephone exchanges, ADB systems and other AOM systems
ALS	Contains functions for receiving, analyzing and presenting alarm information
TRS	Permits traffic route testing in accordance with test programs specified by the operator

APZ contains the following subsystems:

PRS	Permits printout of information on a line printer
FMS	For the administration of data files, stored on disks or magnetic tapes
RPS	Regional hardware and software for controlling I/O devices and communications units
MPS	Central hardware and software for processing application programs

to functions which they are not permitted to use. In addition the system checks the format and partly also the contents of the information which the operator provides from his terminal, in order to prevent faulty commands from being sent out in the network. The system also contains facilities for routing the output to an optional terminal and to interrupt the output.

Up to 64 terminals can be connected to AOM 101, with any desired combination of displays and typewriters. These terminals are connected either individually or via concentrators. In the latter case four terminals can share one circuit, fig. 8.

Recording of data
Recording of data means that information concerning for example all changes that are ordered from work position terminals can be stored in data files. This information may prove useful in case of faults or suscriber complaints.

Alarm data processing
AOM 101 contains functions for receiving, analyzing, distributing and displaying alarm data from the telecommunication network, fig. 9.

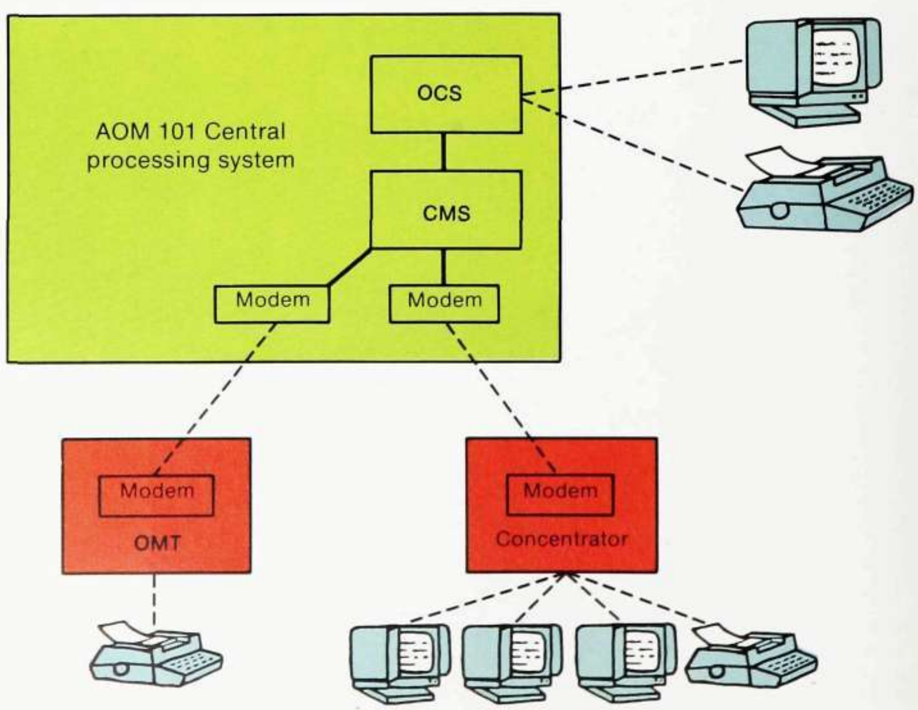


Fig. 8
The connection of operator terminals to AOM 101

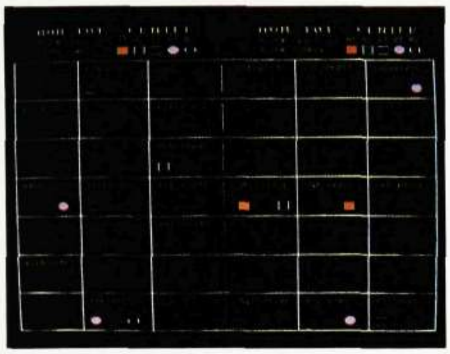
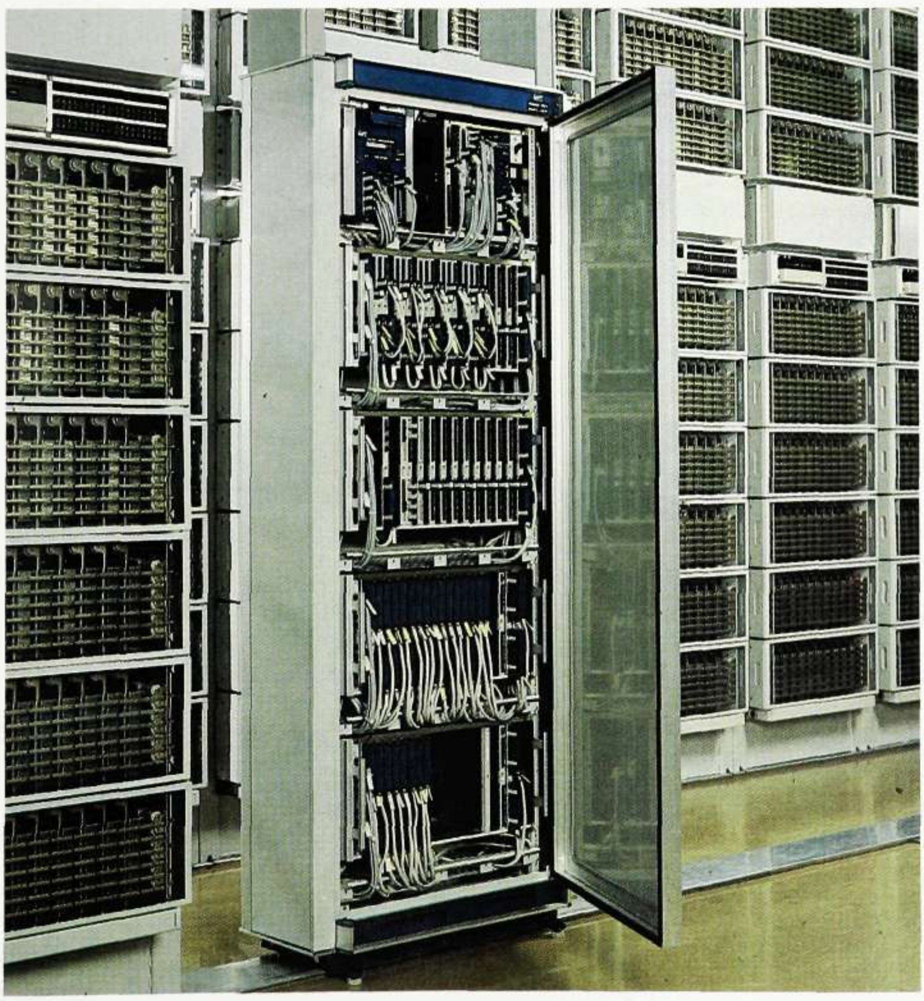


Fig. 9
Presentation of alarm information on a colour display

Fig. 10
Terminal equipment OMT for an ARF exchange in Tammerfors, Finland



The alarm status is displayed in overall form on colour dispalys. The operator can then request detailed alarm information for presentation on his terminal.

Alarm data can be stored in different data files and information from these can be edited and presented to the staff in various ways.

Data collection
This function permits effective and rapid collection of data by means of simple order routines. The information from the network is fed in to AOM 101, where it can be printed out or stored on magnetic tape, which can then be used for processing in an administrative data processing system.

Data communication
System AOM 101 communicates with the connected systems, exchanges, transmission equipment, power systems, administrative data processing systems and other AOM 101 systems via synchronous data communication circuits.

A maximum of 48 data links can be connected to an AOM 101 system. A data link can work at any of the transmission speeds 1200, 2400, 4800 or 9600 bit/s. The data links are in accordance with CCITT Recommendation X25.

Other functions
The central processing system also contains general functions for processing files and for printouts.

Terminals for the connection of exchanges without SPC
The terminals that are used when systems without SPC are to be connected to AOM 101 are designated OMT and OMST.

The terminals consist of a number of hardware and software modules, which can be assembled to meet different requirements.

They collect information via test points. Information concerning states, the number of changes and the seizure times at these test points is stored in the terminal stores. A maximum of 10240 test points can be connected to an OMT, fig. 10, and 512 to an OMST.

In addition to test points, control points can also be connected to OMT and OMST. The control points are used for remote control of any function in a telecommunication system. A maximum of 320 control points can be connected to an OMT and 256 to an OMST.

The information that is collected and stored in the terminal stores can be of several different types and it is processed according to type. The results are either printed on a typewriter connected to OMT or transmitted via a data link to the central AOM 101 system.

A number of function blocks have been developed for systems ARF and ARM. However, there is nothing to prevent certain of these being used for the supervision of transmission and power equipments etc.

Among the functions available may be mentioned: supervision of devices and lines, traffic recording, statistics, alarm data processing, collection of charging data, remote measuring of subscriber lines and remote control.

Some applications

The modular structure makes system AOM 101 economical for a wide range of applications. Some examples of the usefulness of AOM 101 are given below.

Maintenance of AXE exchanges
System AXE contains functions that continuously monitor the traffic handling in the exchange and its own control system.

If anything abnormal occurs, for example the number of time forced releases exceeds a preset value, AXE generates an alarm message. This message is automatically and immediately sent via the data link to system AOM 101.

AOM 101 analyzes the message and updates the overall network information on the colour display concerned. If the alarm has high priority an audible alarm will also be given. This informs the maintenance staff that something has happened which requires action. From his terminal the operator can then request detailed information concerning the fault. He usually obtains sufficient information to be able to decide on the appropriate maintenance action, for example to order a repairman to visit a certain exchange and replace one or more printed board assemblies.

System AXE also contains diagnostic programs which can be activated from the maintenance centre. These programs are used by the staff as an aid for fault localization when the alarm message does not contain sufficient information.

Maintenance of the subscriber line network
Maintenance of the subscriber line network forms a large part of the total maintenance work. However, experience shows that many of the complaints made by subscribers are caused by other things than faults in the subscriber line network, and it ought to be possible to verify this by simple means. It should therefore be possible to supervise the subscriber line network automatically and to carry out measurements by remote control.

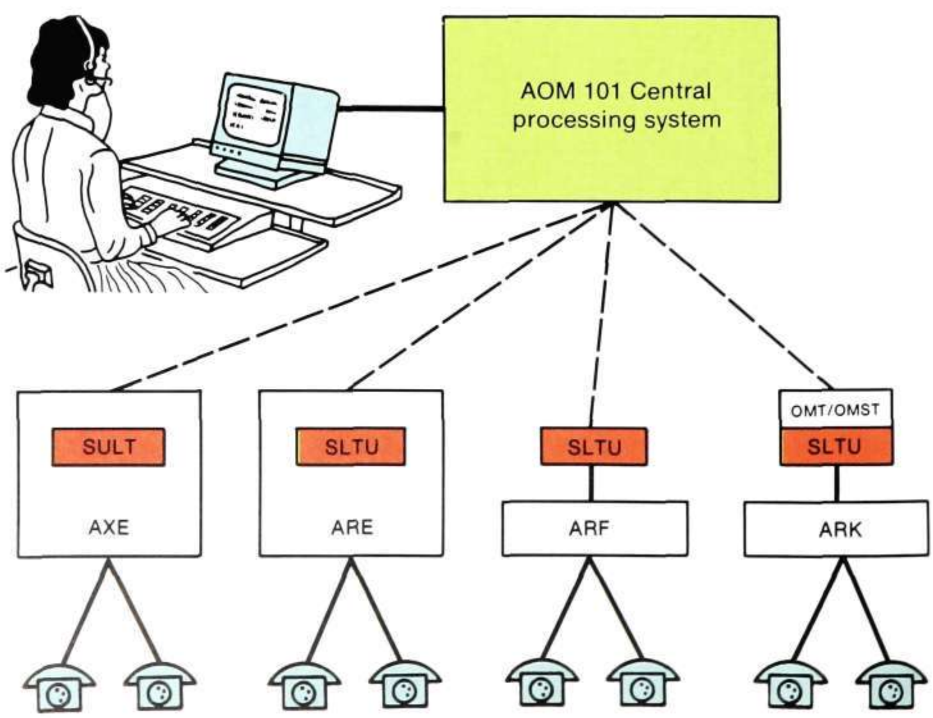


Fig. 11
Remote measuring of subscriber lines with the aid of AOM 101

SULT } Instruments for remote measuring of
SLTU } a large number of parameters

All LM Ericsson's local exchange systems can be equipped with a measuring instrument, which can be connected to any subscriber line by means of a selector. The instrument permits remote measuring of a large number of parameters, such as resistance, capacitance, unwanted voltages and the characteristics of the dial or push-button set.

This instrument is incorporated in exchanges of type AXE and ARE. In other exchange systems the instrument can be connected as a separate unit or as a part of OMT or OMST, fig. 11.

Routine tests of subscriber lines are arranged by the staff, who initiate test programs which automatically test a number of subscriber lines. The routine tests are generally carried out at night.

In addition system AXE carries out a *quick test of the condition of the subscriber line* whenever a call is made.

Changing subscriber data in AXE and ARE

In an SPC exchange the subscriber data are stored in data stores, and can quickly and easily be altered by means of commands. In AXE and ARE exchanges this can be done from work terminals that are connected to system AOM 101. This means that a special sales centre could with advantage be set up for this purpose.

In system AOM 101 all ordered changes are recorded in special files, which can be used for fault localization and for updating subscriber data registers.

Alarm transmission from ARF and ARM

Exchange terminals OMT and OMST are used to transmit alarms from ARF and ARM exchanges. Each exchange is provided with a terminal of its own, prefereably the smaller one, OMST. The exchange equipment is connected to the test point connectors in the terminal. Alarm information can be transmitted to an operation and maintenance centre via a data link. An OMT terminal, fig. 6, can form the central part in the transmission system.

Conclusion

The cost of the operation and maintenance of the telecommunication network constitutes a significant part of the expenditure of the telecommunications administration. Increased automatization and centralizing of these activities would therefore be a natural development. System AOM 101 is an important aid in this process, since it makes such automatization and centralization attainable.

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Office Communication System DIAVOX 824

Greger Jismalm and Sten Magnusson

DIAVOX 824, a new member of the DIAVOX family of instruments, is an electronic Office Communication System operating on three pairs of wires. The system has been developed by ELLEMTEL on a joint commission from the Swedish Telecommunications Administration and LM Ericsson.
Traditional multi-wire key telephones have long been used as line selectors, secretarial systems and as an alternative to small PABXs. A gradual changeover to electronic "few-wire" systems is now taking place. This not only means reduced installation and rearrangement costs, but also added flexibility and facilities.

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DIAVOX 824 is an office communication system for a maximum of 8 trunk lines and 24 extensions. The system consists of a central control unit, to which extensions are connected in a star-shaped network, fig. 1. Each set is connected via three wire pairs, which makes installation and rearrangement easy and inexpensive. The trunk lines can be connected to a public exchange or a PABX or both.

DIAVOX 824 is used when it is desired to route traffic directly to one or a group of extensions without the aid of a special operator. DIAVOX 824 also offers convenience and ease of operation for call forwarding and attendance, inquiries, call transfers, priority calls, conference and switching between several calls in progress. The system is well suited for small offices, banks, travel agencies and airlines and for executive secretarial groups connected to PABXs.

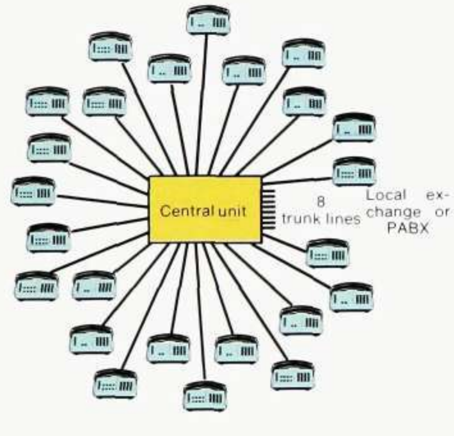

Fig. 1
Office Communication System DIAVOX 824 consists of a central unit and extensions connected in a star-shaped network

System facilities

At present the system contains the following facilities:
- External and internal calls
- Privacy on all calls
- Call transfer
- Call pick-up
- Inquiry
- Automatic hold
- Call waiting
- Priority calls
- Private lines
- Call diversion
- Pooled lines
- Call queueing
- Flexible call routing
- Call restrictions

Extension instruments

The extension instruments have the same basic design and the same speech circuit as the new electronic push-button telephone DIAVOX 100.

In the DIAVOX 824 instruments the trunk lines are represented by a button and a lamp, fig. 2. The lamp flashes rapidly for incoming external calls, slowly for parked calls and glows steadily for an engaged line, i.e. a call in progress.

Parking is indicated at the extension placing the call on hold. At all other extensions the line is indicated as being engaged.

Fig 2
Telephones for DIAVOX 824. Types ALPHA (on the left) and BETA
The push-button set and function buttons in ALPHA and BETA are identical regarding both position and function.

D	Diversion	Diverting an incoming call to an attendance position
T	Transfer	Call transfer
C	*Conference*	*Additional functions* (Three-party conference and external abbreviated dialling)
R	Register	Service button for signalling to the local exchange or PABX
L1 – L8		Buttons for access to trunk lines
F G H		Prefixes for internal dialling
P	Priority	Signalling to a busy extension

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DIAVOX 824 has one type of telephone (ALPHA) where each trunk line is represented by a button and a lamp. The ALPHA set shows the state of *all* trunk lines and gives free choice between all of them. An extension with an ALPHA set can thus be used as an attendance position for any of the trunk lines.

DIAVOX 824 also offers another type of telephone (BETA) with only two buttons with lamps for trunk lines. One button is used to answer calls in a call queue or transferred calls, depending on the type of traffic distribution chosen for the extension. The other button is used to get access to an outgoing private line or alternatively a pool of common lines. ALPHA and BETA sets can be used in any combination in the system.

Operation

The aim has been to make the operation easy and fast, since efficient traffic handling is particularly important in many applications, such as receiving and booking orders. The incoming *external calls* are indicated by double ring signals and a rapidly flashing lamp. These calls are answered by lifting the receiver and depressing the trunk line button.

When an external call has been completed, the extension receiver is replaced, which disconnects the call. If instead another trunk line is selected or an internal call is initiated, the original external call is automatically parked. A parked call is indicated by slow flashing of the lamp, and the call is resumed by depressing the corresponding trunk line button.

An external call is initiated by depressing the button for a free trunk line. The extension then gets dialling tone from the local exchange or PABX, and is free to dial the desired number.

An incoming *internal call* is indicated by a single ring signal and is answered by lifting the receiver.

An internal call is initiated by depressing one of the three internal prefix buttons and one of the buttons in the 12-button set, i.e. F, G or H, followed by one digit. The caller gets the ringing tone if the extension is free and the busy tone if it is busy. In the latter case the caller can depress the priority button (P). The called extension then gets a ring signal even though he is engaged on a call. He must then decide whether he wants to accept the new call, in which case he also depresses the priority button.

All ring signals that arrive when the handset is lifted are reduced to a soft level in the telephone.

In order to make an *inquiry* during an external call it is only necessary to dial the number of the internal extension. The external call is automatically parked when dialling starts. The parked subscriber cannot hear the internal call. The external call is resumed by depressing the trunk line button with the parking indication. If the external call is to be transferred to the called extension, the *transfer* button (T) is depressed.

An external call can also be transferred by depressing the transfer button without dialling any internal number. The call can then be taken by any ALPHA extension, i.e. *call pick-up*. However, parking indication is obtained only on the extension that carried out the parking, and which is therefore responsible for the call. This form of call transfer is convenient when the transfer takes place in one and the same room or when loudspeaker paging is used: "Dave, please take five!"

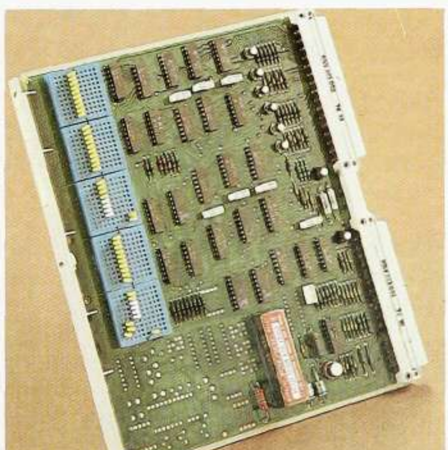


Fig. 3
Programmable exchange data store

Traffic distribution

The external traffic in DIAVOX 824 can be distributed over 1–3 routes and

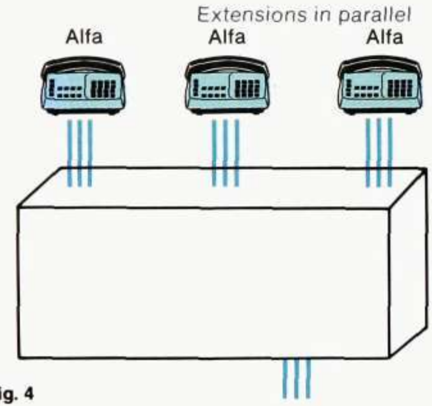


Fig. 4

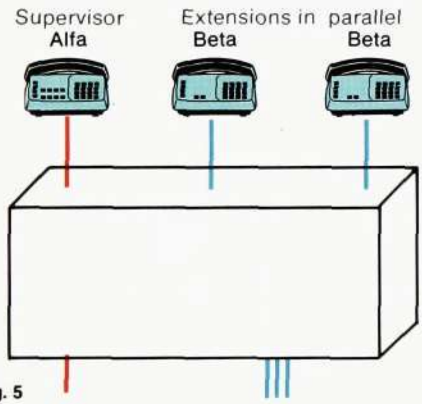


Fig. 5

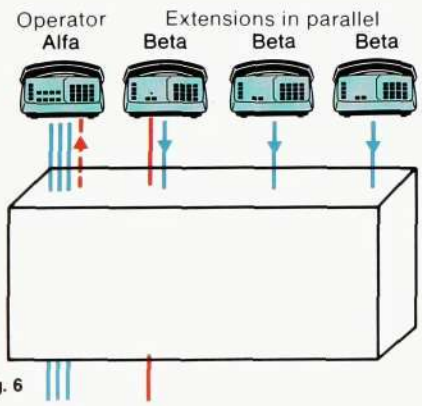


Fig. 6

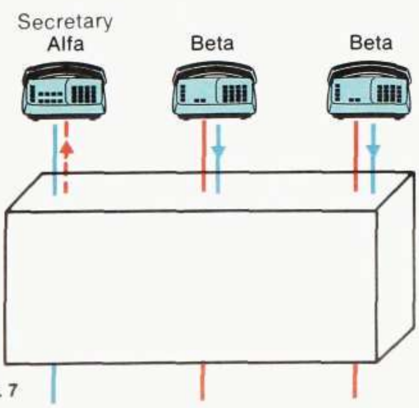


Fig. 7

routed in three ways, in any combination:

- on a trunk line route direct and in parallel to an associated group of extensions
- *on another line route to one or several optional forwarding extensions*
- On lines to specific extensions (private lines). These lines can be temporarily diverted to an attendance position, when the *diversion* button is depressed (D).

The outgoing external traffic can be arranged so that an extension has a free choice of line or is limited to a certain part of the trunk line route.

The following examples show the traffic distribution in some typical applications. The examples show only one of the three possible groups.

The traffic distribution is arranged by programming a plug board, fig. 3.

Line selector system
All free extensions are called in parallel when a call comes in, fig. 4. A muted signal is also sent to all busy extensions *until* the new call has been answered. The first extension to answer receives the call.

This traffic distribution has many *advantages for small organizations* without a special operator. All extensions have ALPHA sets.

Queue system
In this case, the extensions also receive the incoming traffic in parallel. The extensions have BETA sets, fig. 5. The incoming traffic now forms a queue. The first call in the queue is directed to all extensions. The first extension to answer receives the call, and the next call in the queue is presented to the remaining extensions.

A supervisor can be separated from the queue system and given an individual line.

This type of traffic distribution has great advantages for groups that work with order reception, ticket booking, fault complaint reception and similar applications.

Operator system
All incoming traffic on the common lines is directed to an operator, fig. 6. The operator then extends the calls to the other extensions. Outgoing calls can be *made direct, without operator* assistance.

One or a few of the extensions can be allocated a direct incoming line of their *own. The calls can be diverted to the* operator by depressing the diversion button.

Secretarial system
All extensions are allocated private lines, for example from a PABX, fig. 7. Private line calls can be diverted to the secretary by means of the diversion button. The secretarial position is equipped with an ALPHA set, and it is therefore possible for the secretary to see for whom the call was intended.

Adaptation to the telephone network

Adaptation to the over-riding system is carried out by programming the exchange data store and allows for the following:

- external dialling with VF signalling
- external dialling with decadic impulsing
- with impulsing: frequency, pulse/pause ratio, pause between digits and digit standard (corresponding to the order of the digits on the dial)
- type of register calling signal
- the length of the ringing signal pause
- any clear-forward signal on parked lines.

Central control unit, modularity

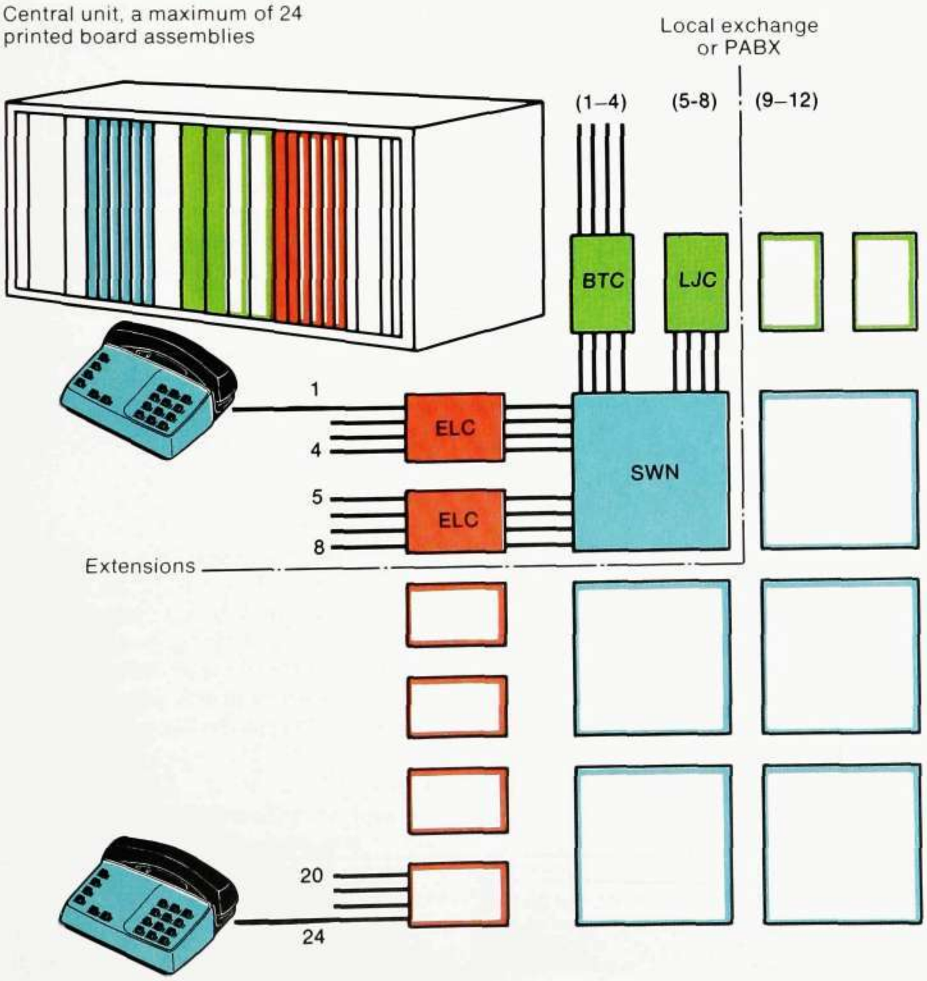
The central control unit can be placed in an ordinary office environment. It is a compact and quiet unit for wall mounting or table location, fig. 8.

The magazine in the central control unit holds a maximum of 24 printed board assemblies, two of which constitute the main distribution frame of the system. Eight of these board types form the basic equipment for all system sizes. The four remaining modular types of printed board assemblies allow a step by step system extension.

Fig. 8
The central equipment can be placed in an ordinary office environment

Fig. 9
The equipment in DIAVOX 824

Central unit, a maximum of 24 printed board assemblies



ELC	Extension Line Circuits	4 extensions per board
BTC	Bothway Trunk Circuits	4 trunk lines per board
LJC	Local Junction Circuits	2 internal links per board
SWN	Switching Network	8×8 cross points per board

The modularity can be employed to obtain the following system sizes:

Extensions	Trunk lines	Internal links
8, 12, 16, 20, 24	4	2, 4, 6
8, 12, 16, 20, 24	8	2,4
8, 12, 16, 20, 24	12	2

In the basic package the system is delivered equipped for 8 extensions, 4 trunk lines and 2 internal links. In fig. 9 the modular printed board assemblies that are included in the basic package are shown within the dashed line.

A trunk line board, which corresponds to four trunk line circuits, takes up one device board position. Alternatively the same position can accommodate two internal links. Within certain limits the device board space is available for trunk lines or alternatively internal links. The central control unit automatically senses which type of device board is installed in each position and reacts accordingly. At present the ALPHA sets can only handle 8 trunk lines, but a system with 12 trunk lines and only BETA sets is possible.

System structure

The system structure of DIAVOX 824 is shown in the block diagram of fig. 11. Each extension is connected to a common central unit via six wires. Two wires are used for analogue speech transmission and four for signalling. The central equipment consists of a switch and telephony devices for internal and external lines. The central unit also contains transmitters and receivers for the internal signalling, and a control system with processor, data and program stores. All units are connected to a system bus. The control system is designed for a maximum of 36 extensions and 28 trunk lines to cater for future applications.

Signalling system

All signalling between the extensions and the control unit is made via the four-wire digital signalling channel. The control unit does not perform any signalling detection on the analogue wire pair, since the key pad, the ringer and the cradle function also use the digital signalling channel.

The line signal is bi-phase modulated with a bit frequency of 62.5 kHz. This frequency is chosen so that a common receiver in the control unit can scan up to 36 extensions in approximately 30 ms, which corresponds to the shortest button depressing time that can occur.

The control unit continously sends 32 information bits towards each extension, and these are updated at intervals of 2 ms. Each information bit can control a light emitting diode or tone ringer. The transmission timing is extracted from the continuously received signal.

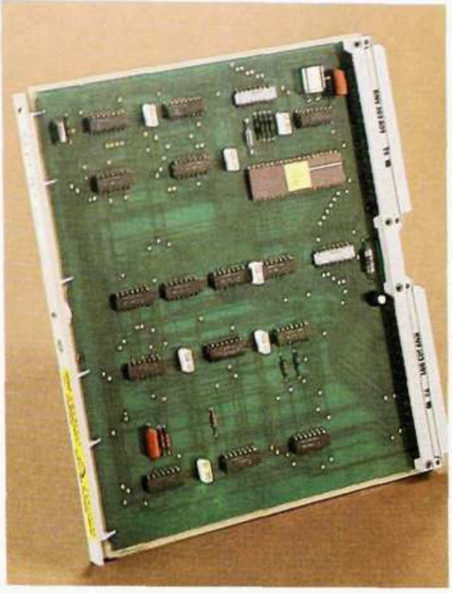
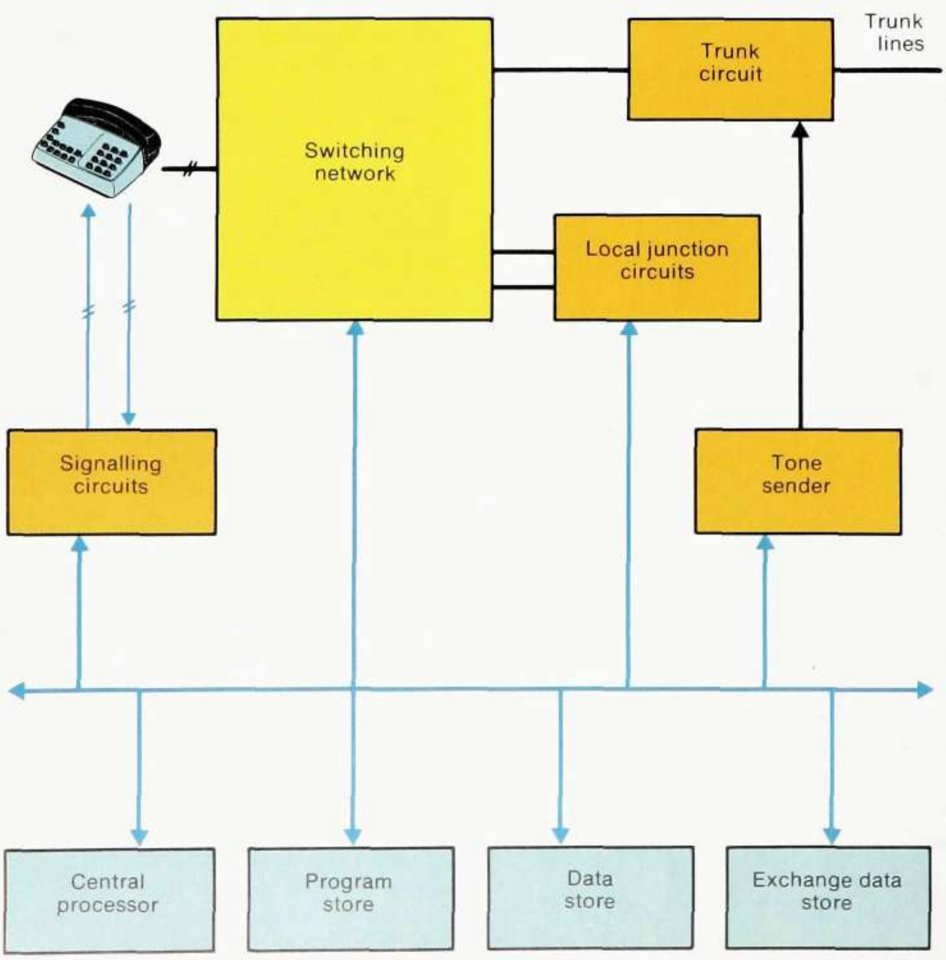


Fig. 10
Processor board, CPU

Fig. 11
Block diagram of DIAVOX 824



The state of all push-buttons and the *cradle is continuously transmitted from* the extensions by means of signal words of 7 information bits. The signalling from the extensions is periodically *scanned by the common signalling re*ceiver. The signalling receiver can scan up to 36 extensions in approximately 30 ms. During each scan the receiver compares two consecutive signal words for each extension. The signal is accepted and transmitted to the data store only if the two words are identical. In this way sporadic line interference is prevented from causing faulty connections.

Control system

The control system consists of an 8-bit microprocessor (CPU), program and data store, clock and counters for generating timing signals, fig. 10. The program store is a mask programmed ROM store comprising 8 k bytes. The data store is a static RAM store of 2 k bytes. Adaptation to individual market and customer requirements is done by *means of programming in the exchange* data store. The block diagram shows how the central control unit hardware is connected to the system bus. A 16-bit *direct and inverted address is used on* the address bus in view of the relatively large number of units that require individual addressing. This leads to simple circuits for address decoding.

A large number of hardware units must be controlled and scanned in real time. The data structure reflects the hardware structure since each unit has been allocated an individual area in the data store. The areas contain data words for signals, stages and link addresses to other units. The CPU provides real time control by addressing and processing the units cyclically and frequently enough to deal with all the desired functions in each unit.

The time limits for certain functions require exact timing. The timing is carried out by software with the aid of a break signal, which initiates the timing routines every 12.5 ms.

Trunk lines

The trunk circuits detect ringing signals, send loop signals and digit information (pulse or tone) to the over-riding system and connect the lines to hold. The tone signals are generated in a common tone oscillator.

During an external call the trunk line circuit is galvanically through-connected. The extension speech circuit is thus fed directly from the over-riding system.

Internal links

During internal calls the extension *speech circuit is fed from an internal* link. The internal link attenuates the speech level by 8 dB to provide levels similar to those of an ordinary external call, the internal link also sends the busy tone and ringing tone for internal calls.

Switch

The switch in DIAVOX 824 is a single-stage congestion-free reed switch with two-pole cross points. The relays are mounted in 8×8 cross points per board module and the switch is electronically controlled and supervised. This switch

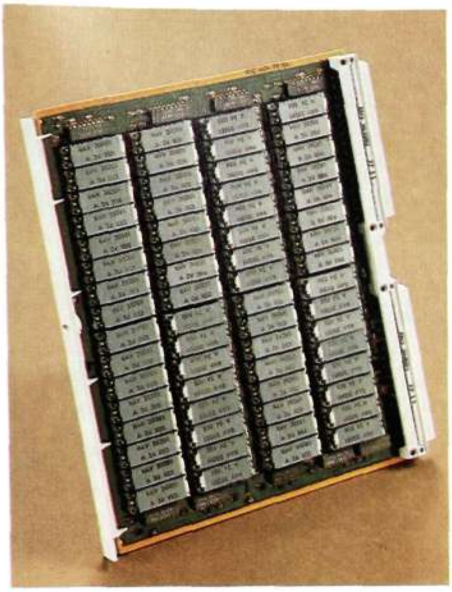


Fig. 12
Reed switches for DIAVOX 824

was originally developed for the subscriber stage in system AXE, fig. 12.

The speech wire pairs from the extensions are connected to the rows of the switch matrix, and devices of the type trunk circuits or local junction circuits are connected to the columns.

Extensions

In addition to the conventional telephone function the extensions also have functions for receiving lamp and tone ringer information and for sending pushbutton and cradle switch information.

The transmission of speech between extension and central equipment is two-wire with conventional feeding. The speech circuit is electronic and located in the handset. The same components are used as in DIAVOX 100.

Light-emitting diodes, push-buttons and components for the transmission of information are mounted on two printed boards in the set. One wire pair is used for each signalling direction. The signalling electronic circuits are fed in phantom over the two signalling wire pairs. The power that can be transmitted in this way over a 2 km line is limited, and low current CMOS circuits are used in the telephone set. Later these will be combined into a custom design circuit. A low current connection method has also been used for the light-emitting diodes in order to save power.

Installation, operation and maintenance

Installation and rearrangement is greatly simplified, since the system uses a three-pair installation cable that is the same for all extensions and applications. No programmable functions are lost if a mains failure occurs. Thus the system is immediately available when the power returns. In the case of a mains failure line 1 is through-connected to an emergency telephone. The system can also be equipped with a back-up battery.

Installation testing and fault localization are carried out with the aid of a simple manual, an ALPHA and a BETA instrument and a set of fault-free printed board assemblies.

Systematic test connections indicate the fault at the printed board assembly level. The voltage is disconnected and the faulty board is changed. The voltage is then switched on and the system is ready for use.

The central unit does not require cooling fans. The same high-quality components and the same system for quality audit are used for DIAVOX 824 as for other LM Ericsson telephone exchange systems.

During normal operation the system will supervise itself in order to limit the effects of electrical interference and component faults. The system also sends an alarm to the instruments if the programming of the exchange data store is clearly implausible.

Gas discharge tubes protect the system from overvoltage on the trunk lines. The extension line circuits are protected by automatic electronic fuses.

The instrument speech circuits are protected against radio interference. Each set contains a special thyristor diode across the speech wires as a protection against transient voltages on the line.

Upgraded version

Due to requests from various markets the system is under further development and will be equipped with more functions, among them the following:
- Abbreviated dialling with up to 30 common numbers
- Trunk discrimination control with up to 4 categories, comprising a maximum of 50 open or blocked directions
- Three-party conference
- Internal direct speech connection (with a loudspeaking telephone attachment)
- Night service and night blocking
- Cyclic call distribution for the queue function (ACD)
- Internal group hunting
- Call diversion if no answer
- Transfer before answer with recall
- Programming of exchange data and directory numbers from ALPHA sets.

Booster Converter BMR 263 as the Active Filter in Power Supply Systems

Folke Ekelund

In order to obtain high quality speech connections in a telecommunication network it is necessary to ensure that any noise voltages generated in the system do not exceed permissible levels. Such noise voltages can originate in for example the power supply equipment, but units that are powered from the equipment can also be noise sources.

LM Ericsson's power supply system type BZD 112 contains DC/DC booster converters with a high conversion frequency (20 kHz). The regulation characteristics of these converters make them suitable as noise suppressors (active filters). The booster converters effectively suppress low-frequency noise generated by the rectifiers in the power supply equipment and also noise from the connected telecommunication equipment.

The attenuation of the booster converters compensates for the lower attenuation of the power feeding circuits for subscriber lines in electronic exchanges, so that CCITT recommendations are satisfied.

UDC 621.311.4

Power supply systems for telecommunications must satisfy a number of requirements so that the telecommunication equipment can operate reliably and the quality of the speech connections can be kept at the desired level[1-3]. The requirements include not only absence of interruptions and limiting of voltage variations (both in the stationary condition and during transient processes) but also limiting of the levels of a.c. noise voltages that are caused by the power supply equipment. These requirements are based on CCITT Recommendations G123C and Q45, which concern transit exchanges but which have to a certain extent also been applied for local exchanges.

Recommendation G123 refers to circuit noise in national networks. In section C, which deals with noise in a national, four-wire, automatic exchange, it is specified that the mean value of noise during a long period in the busy hour should not exceed the following values:

- Psophometrically weighted noise: −67 dBm0p (200 pW0p)
- Unweighted noise: −40 dBm0 (100 000 pW0) measured with a device with a uniform response curve throughout the band 30−20 000 Hz.

At a relative level of 0 dBr

- − 67 dBm0 = −67 dBm corresponds to 0.35 mV
- − 40 dBm0 = −40 dBm corresponds to 7.9 mV

Recommendation Q45, which concerns the transmission characteristics of an international exchange, specifies the same limit values. The requirements are intended to maintain good transmission characteristics for both analogue and digital transmission (PCM). For example, in the case of digital transmission the noise voltage will affect the quantizing distortion.

The requirements given above apply for trunk and subscriber lines and must be converted into values that are applicable to the power supply equipment. The conversion must take into consideration both the attenuation in the power feeding circuits of the exchange and the

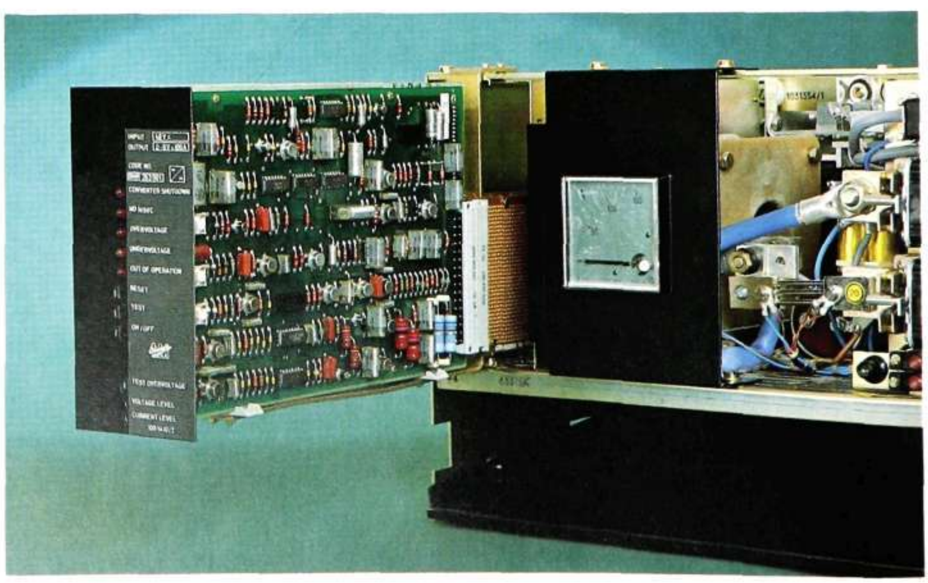


Fig. 1
Booster converter BMR 263, 100 A, 0−8 V.
The extended printed board assembly contains the control unit with regulation circuits for voltages and currents, including circuits for active filtering

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Type of rectifier	Noise	
	Fre-quency Hz	Level (full load) mV
Three-phase thyristor recti-fier BMT 313, 100 A (6-pulse coupling)	50	25
	100	40
	300	2.5
Three-phase thyristor recti-fier BMT 183, 630 A (12-pulse coupling)	50	110
	100	23
	200	5
	600	2.1

Table 1
Measured noise from two types of rectifiers

need of margins for other noise sources in the exchange or transmission equipment.

In electronic telephone exchanges of type AXE the attenuation in the power feeding circuits is lower than in older exchange types. This has led to more stringent requirements for power supply equipment as regards a.c. noise.

The permissible noise on the 48 V distribution is as follows:

for transit exchanges
$<$5 mV (r.m.s.) in the frequency band 30–200 Hz
$<$2 mV (r.m.s.) in the frequency band 200–500 Hz

for local exchanges
$<$10 mV (r.m.s.) in the frequency band 30–200 Hz
$<$5 mV (r.m.s.) in the frequency band 200–500 Hz

These limits apply for an arbitrary part of the power distribution network, regardless of the current output up to full load.

Among the power supply units the rectifier constitutes a noise source in the above-mentioned frequency bands. A pulsating voltage is obtained when the mains voltage is rectified, i.e. there are a.c. voltage components superposed on the d.c. voltage, whose frequencies are whole multiples of the mains frequency[4]. The magnitude of the noise voltages is greatly dependent on the unbalance in the three-phase mains network. The greater the difference between the phase voltages, the greater the pulse voltage obtained. The above-mentioned requirements have therefore had to be qualified to apply only when the network unbalance does not exceed 5 %.

The a.c. voltages generated by the rectifiers in an equipment are not only dependent on the unbalance of the network but also on the rectifier output current and the impedance in the battery circuit. High load and poor batteries give the highest noise levels. Table 1 shows some rectifier noise voltage values.

Booster converter BMR 263 as a filter

LM Ericsson's power supply system contains a booster converter, whose output voltage is added to the battery voltage[1], fig. 2.

The booster converter has to maintain the exchange voltage at the nominal level if the battery voltage falls, for example because of a mains failure. A system with booster converters ensures uninterrupted power supply and a high degree of utilization of the available battery capacity.

The booster converters in system BZD 112 work at a conversion frequency of 20 kHz. The advantages of a high conversion frequency are not only small volume, low weight and silent operation, but also very good regulation characteristics, which can be exploited to give the booster converter a function over and above those for which it was originally intended. Thanks to its high regulation speed the booster converter can neutralize noise voltages in the frequency band in question (0–600 Hz) and at the same time correct any deviations in the d.c. voltage value.

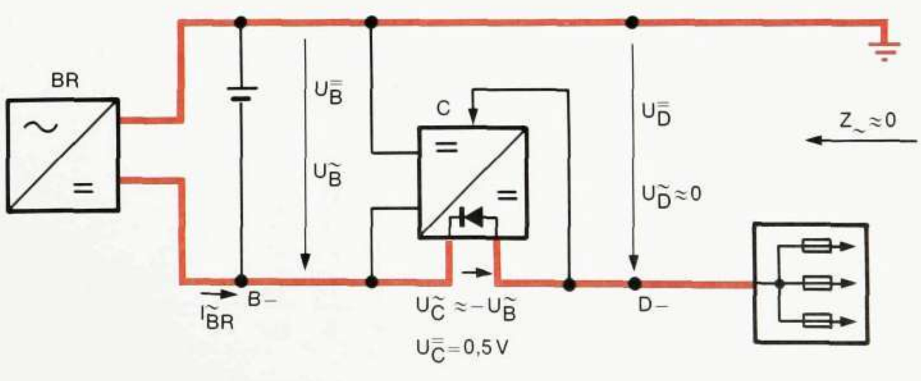
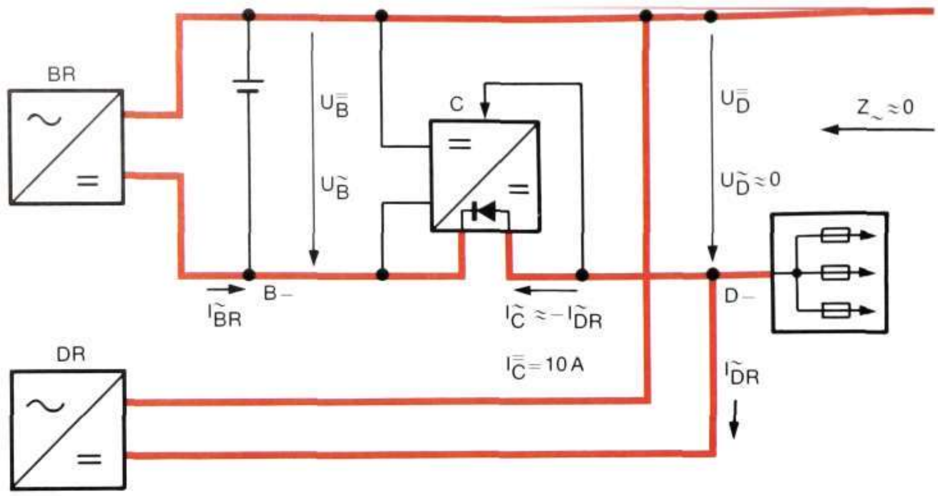


Fig. 2
LM Ericsson's standard booster converter system

BR	Rectifier, which feeds the exchange and also charges the battery
C	Booster converter, which supports the battery, for example during a mains failure, and also acts as an active filter
$I_{\tilde{BR}}$	Alternating current from the rectifiers, which generates a noise voltage across the battery
$U_{\tilde{B}}$	Noise voltage across the battery
$U_{\bar{B}}$	The battery d.c. voltage
$U_{\tilde{C}}$	AC voltage generated by the booster converter to counteract $U_{\tilde{B}}$
$U_{\tilde{D}}$	Noise voltage that reaches the load ($U_{\tilde{D}} \ll U_{\tilde{B}}$)
Z~	The impedance of the system

Fig. 3
Booster converter system with distribution rectifiers

BR	Rectifier that charges the battery (if necessary it can also feed the load via booster converters)
DR	Rectifier that feeds the exchange direct via the distribution network D−
C	Booster converter, which supports the battery and also acts as an active filter for all rectifiers (BR och DR)
$I_{\widetilde{BR}}$	Alternating current from the charging rectifiers, fed to the battery
$U_{\widetilde{B}}$	Noise voltage across the battery
$I_{\widetilde{DR}}$	Alternating current generated by the distribution rectifiers
$I_{\widetilde{C}}$	Alternating current which is absorbed by the converter and fed to the battery. $I_{\widetilde{C}}$ balances $I_{\widetilde{DR}}$ so that $I_{\widetilde{DR}} + I_{\widetilde{C}} \approx 0$. The alternating current that goes out to the load is almost zero.



Operation in the system

Fig. 2 shows the position of the booster converter in the system. The a.c. voltage across the battery, $U_{\widetilde{B}}$, constitutes a noise quantity in the regulation loop of the booster converter. The converter tries to regulate the distribution voltage, $U_{\widetilde{D}}$, to a constant value. With a sufficiently high amplification in its regulation circuit the converter is able to limit the a.c. voltage, $U_{\widetilde{D}}$, to a low level (in the order of 1 mV) by generating an a.c. voltage, $U_{\widetilde{C}}$, on its output that is in opposition to $U_{\widetilde{B}}$ and of the same amplitude. The a.c. voltage $U_{\widetilde{C}}$ is superposed on the d.c. voltage, $U_{\overline{C}}$. In principle $U_{\overline{C}}$ could be zero, but the best filter effect is obtained if it is at least half a volt. When the booster converter is used as a filter, a special regulator in its control unit ensures that $U_{\overline{C}} \geq 0.5$ V. The filter function of the converter results in very low output impedance for frequencies in the band 0−600 Hz (tenths of a milliohm). Both the noise that originates from the power supply equipment itself and the noise from other equipment is therefore effectively suppressed.

A system with booster converters can also be built up in accordance with fig. 3. Most rectifiers (DR) then work directly across the output of the equipment−giving the distribution voltage U_D. The branch formed by the battery and converters in series is then connected in parallel with these rectifiers. Charging rectifier BR keeps the battery charged. The alternating current $I_{\widetilde{DR}}$ generated by rectifiers DR is then absorbed by the battery and converters. This requires that the d.c. load on the converters is not less than the peak value of the alternating current $I_{\widetilde{DR}}$. When the converter is used as a filter in this system a special regulator in the control unit ensures that the condition $I_{\overline{C}} \geq I_{min}$ is met. The value of I_{min} has been set to 10 A in view of the magnitude of the alternating current per rectifier.

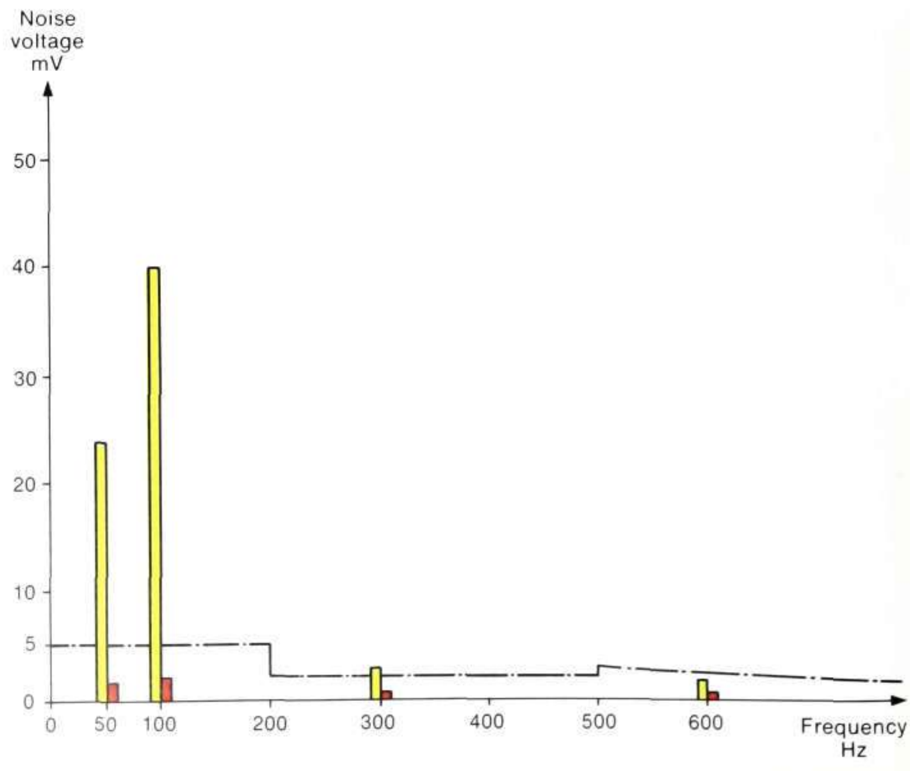


Fig. 4
Noise levels in BZD 112 with a network unbalance of 5 %

- Noise voltage across the battery
- Noise voltage across the load
- Limit values according to LM Ericsson's requirements specification

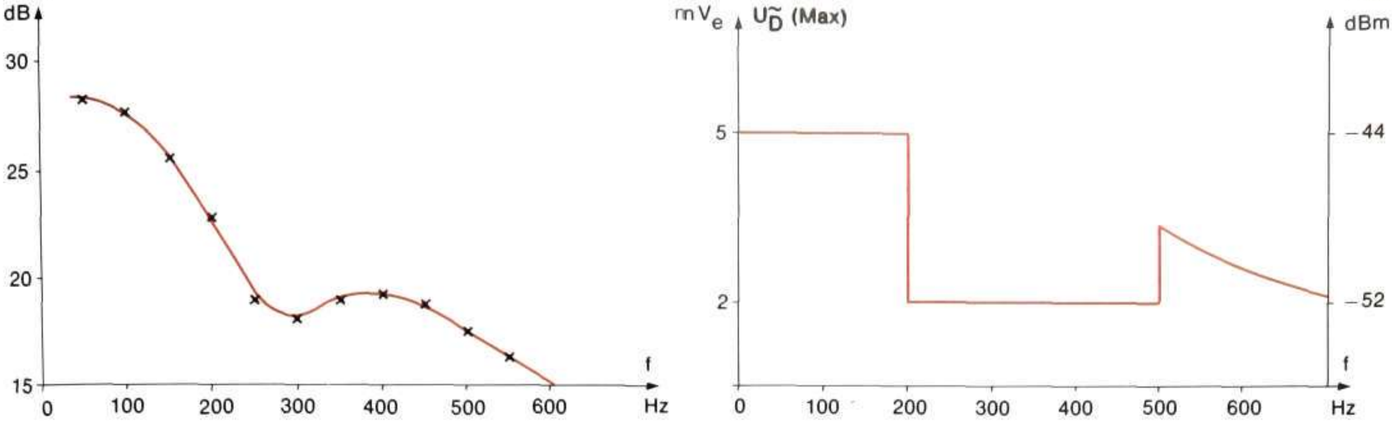


Fig. 5
The noise suppression capacity of the booster converter

The diagram on the left shows the noise suppression (Q) caused by the converter

- Q — $20 \cdot 10 \log (U_B^{\sim}/U_D^{\sim})$
- $U_B^{\sim}$ — The noise voltage across the battery
- $U_D^{\sim}$ — The noise voltage across the distribution network
- f — The frequency of the noise voltage

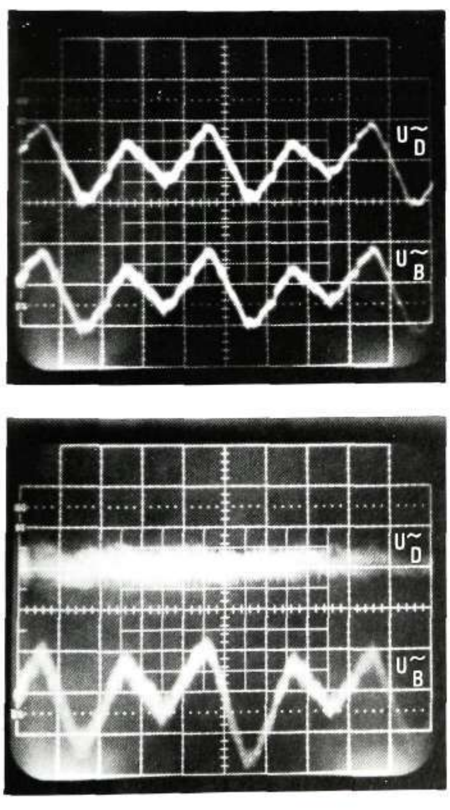
The diagram on the right shows the noise voltage across the distribution network ($U_D^{\sim}$). If these levels are reached (maximum permissible values for transit exchanges), the noise levels at the battery may be Q dB higher because of the noise suppression capacity of the converters

Fig. 6
Noise voltages, without and with active filtering

- $U_B^{\sim}$ — AC voltage across the battery
- $U_D^{\sim}$ — AC voltage across the distribution network

The top oscillogram shows how the noise voltage across the battery reaches the distribution network without being attenuated when the converters are passive.
The lower oscillogram shows how the low-frequency noise across the battery is prevented from reaching the distribution network when the converters work as active filters

Scale factors:
Vertically 50 mV/cm
Horizontally 5 ms/cm



Performance

Fig. 4 shows the noise levels that were obtained in a BZD 112 system with a network unbalance of 5 %. The system contained four 100 A rectifiers and four 100 A booster converters with full load. (The noise levels are lower with smaller load.) The impedance in the battery circuit was R = 20 milliohms, L = 17 μhenry, values which are higher than is the case in actual installations.

The noise suppression capacity of the booster converter is shown in fig. 5, and the noise voltages, without and with filtering, in fig. 6. The diagram to the right (fig. 5) shows the permissible noise voltage levels on the output (distribution network) of a power plant for transit exchanges. From the diagram it is thus possible to read off the highest noise levels that the rectifiers are permitted to give across the batteries without exceeding the limits. For example, for a noise voltage at a frequency of 100 Hz the level across the battery (before the converters) must not exceed −44 dBm +28 dB = −16 dBm, which corresponds to 120 mV.

Conclusion

The use of the booster converter as an active filter results in noise levels across the 48 V distribution network that are far below the limits given in the relevant CCITT recommendations. Low-frequency noise from the power unit rectifiers, which increases with increased unbalance in the mains network, is effectively suppressed and also noise from the connected telecommunication network.

The new function of the booster converter does not involve any additional costs and gives a power supply system that effectively utilizes all facilities offered by the equipment in order to meet the set requirements.

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Further Development of the ARE Systems

Jan Christensson and Håkan Jansson

Local exchange system ARE 11 and transit exchange system ARE 13 are continuously being improved in order to meet the advanced requirements of today and tomorrow. This article describes the main improvements introduced during the last two years. They comprise new subscriber facilities, rationalization of the control system, faster and more efficient testing, greatly increased storage capacity, a new advanced I/O system, magnetic tape units and common channel signalling.

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The situation at present

A large number of administrations introduced LM Ericsson's crossbar exchanges during the 1950s and 1960s. More than 50 per cent of these exchanges, which now comprise a total of approximately 23 million equivalent lines, are less than 10 years old. From the technical and economical viewpoint it is therefore advantageous to modernize these exchanges to SPC exchanges of ARE type, which is achieved by adding the control system ANA 30. The advantages of such modernization and the positive operational experience obtained have been described previously in a number of articles in this magazine. This applies primarily for the following three countries:

- *Denmark*, where the ARF exchanges in the Århus multi-exchange area were modernized into ARE 11[1]. An account of the operational experience has also been given[2]. The first national ARE 13 exchange was put into service in Nyköbing-Mors in October 1977, fig. 1.
- *Australia*, where the ARF exchanges are being modernized to ARE 11, and new ARE 11 exchanges are being installed throughout the country. It is estimated that the network will contain approximately 4.5 million ARE 11 lines when the work is completed[3, 4].
- *Saudi Arabia*, where work is in progress on the modernizing of all ARF exchanges to ARE 11, comprising ca 200 000 lines[5]. Furthermore the country's four ARM exchanges have been modernized to ARE 13 and supplemented by the latest type of toll ticketing and operator system[6].

The table on the last page of this article gives a survey of the number of installed and ordered ARE 11 and ARE 13 lines on 1st July 1979, divided into modernizations and new exchanges.

Fig. 1
The first national ARE 13 exchange was put into service in Nyköbing-Mors in Denmark on 5th October 1977


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The first ARE 11 exchange of stage 2 design was handed over in Spain according to plan, fig. 2. In this design the switching system and control system are supervised in accordance with the same advanced method. Electronic charging has been integrated into the system and the processor capacity is larger than before. Thus the operation and maintenance processor OMP now has a more efficient operating system, and the central devices are routine tested to a greater extent than before. ARE 11, stage 2 design, has been described previously in this magazine[7].

A few modifications have recently been carried out in order to improve further the interworking between control system ANA 30 and existing equipment.

Further development

The ARE systems are developed further in step with technological advances. For example, modern semiconductor memories are to replace the present ferrite core memories in the central store of the system and micro processors are to be introduced to control the stores. Moreover the system functions are being improved in accordance with the specifications of the administrations.

PUSH-BUTTON DIALLING AND SUBSCRIBER-CONTROLLED FACILITIES

Push-button sets are becoming more and more common. They give faster dialling and are a prerequisite for most new subscriber facilities. Thus it is important to have a small and simple tone receiver that can be connected without selectors. The new tone receiver for ARE 11, which is designed in accordance with the new CEPT specification, satisfies these requirements. One receiver is required per signal transfer unit STU. A rack holds 135 receivers, which is quite sufficient for a normal exchange of 10 000 lines.

ARE 11 subscribers with push-button telephones can operate the following facilities:

- Connection and disconnection of barring categories
- Connection and disconnection of interception service from operator, machine announcement or a special tone
- Change of numbers for abbreviated dialling as shown in fig. 3. The common abbreviated dialling list for PABX extensions can be changed via an exchange line.

The CEPT recommendations for subscriber procedures are followed.

A four-figure personal code can be used to prevent unauthorized connection and disconnection of facilities. When the subscriber has completed the dialling the system carries out an authorization check before the change is made. The subscriber is then informed, by means

Fig. 3
Changing the number for abbreviated dialling. The subscriber dials *51*3*08182906# and receives tone information

*	Connection order and separator between different digit codes
51	The order for abbreviated dialling as recommended by CEPT
3	The abbreviated dialled number
08182906	New B-subscriber number, including the area code
#	End of message code
tone information	Informs the A-subscriber whether the change has been carried out or not

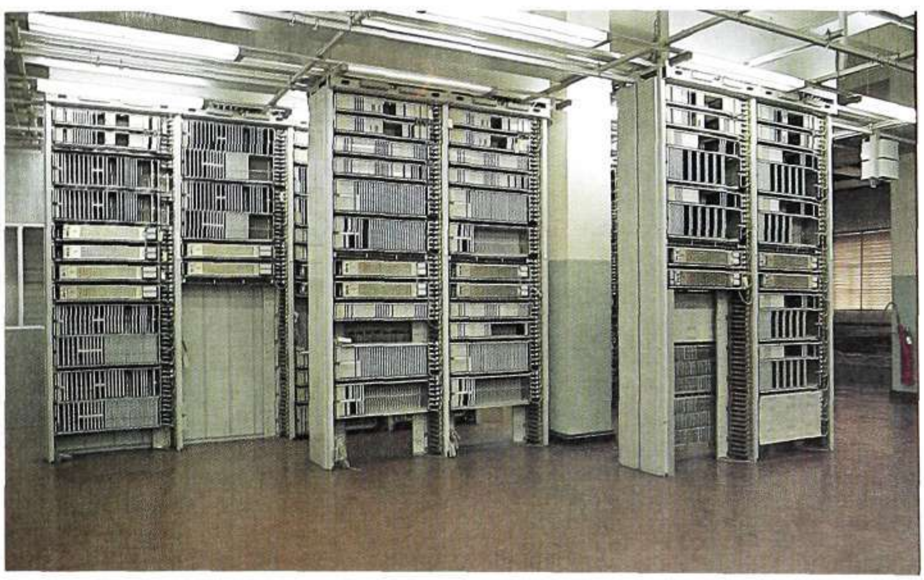
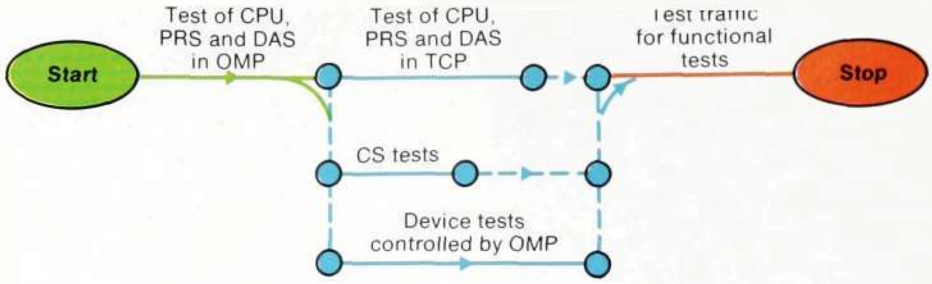


Fig. 2
The first ARE 11 stage 2 exchange design was handed over in Manoteras, Madrid, on 30th August 1978

Fig. 4
The various testing stages during the installation of ANA 30.

Test programs in OMP are used to test the associated CPU, PRS and DAS. Similar tests are then carried out in TCP, controlled by its test programs, and at the same time OMP initiates tests of CS and the other devices in the control system. The subsequent functional testing is carried out by means of test traffic from an ordinary exchange tester

OMP Operation and maintenance processor
TCP Traffic control processor
CPU Central processing unit
PRS Program store
DAS Data store
CS Central stores



of a tone or a message, whether the order has been executed or not. These functions have been realized by means of new programs in the processors TCP and OMP. Such examples show how SPC technology facilitates the introduction of new functions with no changes in the existing hardware.

RATIONALIZATION OF THE CONTROL SYSTEM

When a complete ARE 11 exchange is supplied, the MFC equipment is included as an integral part of the ANA 30 electronic equipment. When an ARF exchange is modernized to ARE 11 it has often proved profitable to design ANA 30 so that it can also control existing MFC code senders and the associated sender finders, which are also supervised by the same methods as other devices. This cuts down the material consumption considerably, and also reduces the installation and testing work.

A new multiplexor, MUX, has been introduced for both ARE 11 and ARE 13. This has been designed so that it can address both its own devices and those in the adjacent rack, which is particularly advantageous for the STU racks where only every second STU rack need be equipped with a MUX. This also reduces the material, and the addressing capacity is fully utilized, which is an advantage in large exchanges.

IMPROVED INSTALLATION TESTING

Testing of ANA 30

Previously ANA 30 was mainly tested using manual methods. In ARE 11 and ARE 13 it has been possible to automatize the installation testing of ANA 30 by using its own processor, the operation and maintenance processor OMP. The time required for testing and fault finding has now been reduced by two thirds. The tests are initiated by means of commands from I/O devices, which also prints out the result. If a fault occurs, a fault printout code is obtained. The faulty printed board assembly can then be identified with the aid of a test manual and be replaced. The various test stages are shown in fig. 4.

Interworking devices and multiplexors, which constitute the major part of the hardware in ANA 30, are tested in accordance with fig. 5. In this case test equipment, mounted on two trolleys, is used, which interworks with special test programs i OMP. The trolleys are used for testing separate devices or for joint testing of various devices. In this way several types of devices can be tested

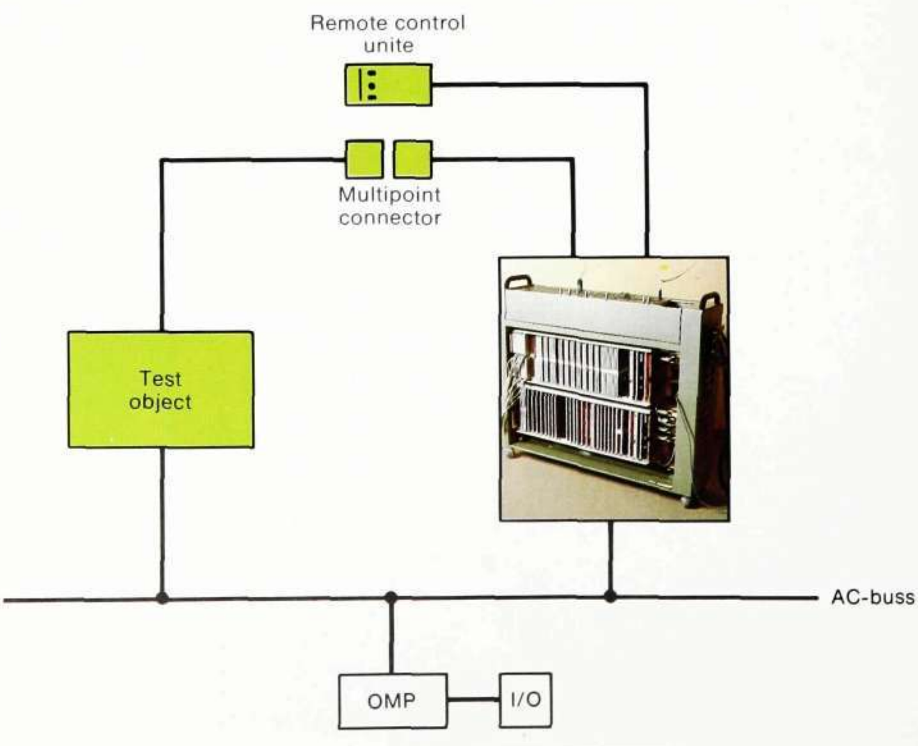


Fig. 5
Testing interworking devices and multiplexors using portable test equipment.
The test object is connected to the test equipment, which simulates a normal environment. OMP controls the test object and the test equipment via the AC bus, which is connected to both these units. The testing is started by means of a remote control unit RCU, which contains lamps that indicate whether the test has been successful or not

simultaneously and the fault indication can be improved. The automatic testing makes less demand on the technical and system knowledge of the staff.

The test trolleys with the associated documentation are delivered in special containers, which are re-used to send the trolleys on the next exchange.

Link testing in ARE 11

A new, electronic link tester LT 11 has been designed, which is used in new exchanges and extensions and in modernized ARF exchanges, fig. 6. It is used to test all links in each 1000-group and group selector, and tests loop resistance, leakage etc. This is done in a third of the time previously required, including the tracing and clearing of faults. It is also possible to carry out more extensive testing than before, and the test quality is higher.

INCREASED STORAGE CAPACITY

The storage capacity can now effectively and economically be increased as required, thanks to the use of modern semiconductor memories. Previously ARE 11 had ferrite core memories in three of the central stores in the exchange, namely the translation store TRS, subscriber store SCS and abbreviated dialling store ADS. The fourth central store, charging data store CDS, has always been of the semiconductor type.

These four store units can now be replaced by a single storage unit, consisting of an electronic shelf, which has over twenty times the capacity of the previous shelf type using core memories (now 256 k words, previously 12 k words). The unit also contains a micro processor for controlling the store, so that the address functions of the large processors need not be changed. The store unit can be placed in an existing rack in an exchange that is already in operation. The increased storage capacity can for example be used to introduce abbreviated dialling and the number group function. The latter gives better multiple utilization and the number of multiple positions can be reduced.

An ARE 13 exchange to which no terminal exchanges without registers are connected, is equipped with only one central store, TRS. However, the amount of data in the exchange is so large that even in this case it is economical to change to semiconductor memories. For example, the amount of data in an international exchange is approximately 36 k words.

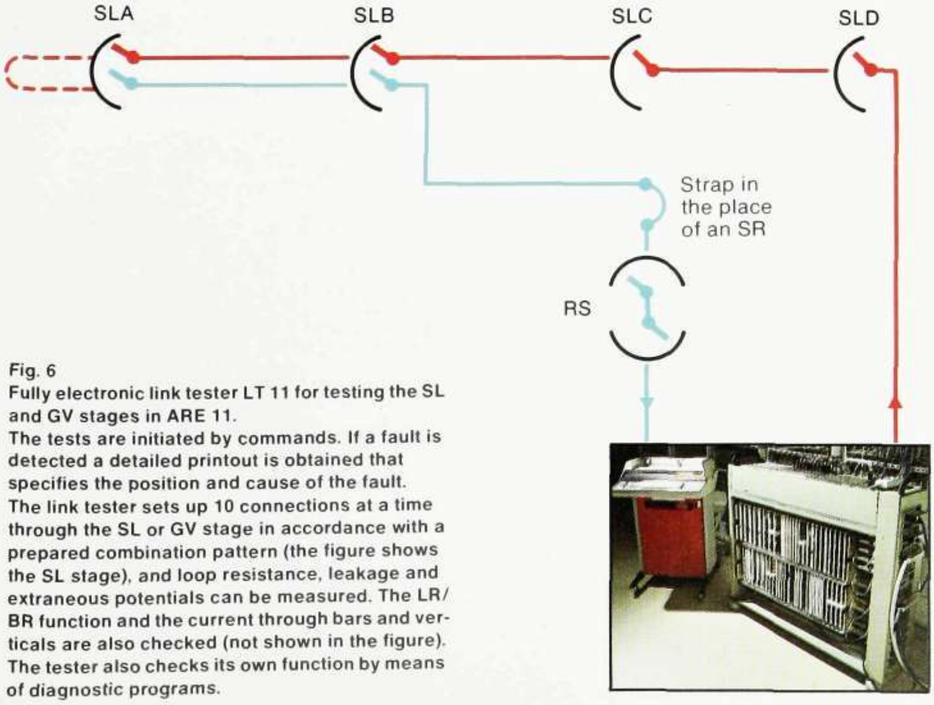


Fig. 6
Fully electronic link tester LT 11 for testing the SL and GV stages in ARE 11.
The tests are initiated by commands. If a fault is detected a detailed printout is obtained that specifies the position and cause of the fault.
The link tester sets up 10 connections at a time through the SL or GV stage in accordance with a prepared combination pattern (the figure shows the SL stage), and loop resistance, leakage and extraneous potentials can be measured. The LR/BR function and the current through bars and verticals are also checked (not shown in the figure).
The tester also checks its own function by means of diagnostic programs.

NEW I/O SYSTEM

It must be possible to connect ARE 11 and ARE 13 to the computerized operation and maintenance center AOM 101[8]. It is also desirable to simplify the loading of the central and processor stores in the exchanges. The new I/O system, associated with OMP, fulfills this desire, and is equipped as follows:

The number of local I/O inputs has been increased so that eight such devices can now be connected instead of four.

Cassette tape recorders will be used as an alternative to punched tape for the input and output of data and programs to the central and processor stores, if these are equipped with RAM instead of PROM. Cassette tape recorders will also be used for regular output of data regarding electronic charging.

ARE exchanges contain advanced operation and maintenance functions,

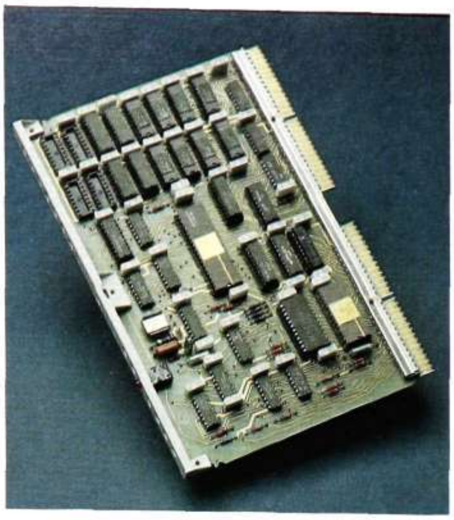


Fig. 7
Micro computer printed board assembly for the new I/O system

which can be controlled locally or from a special centre. When ARE 11 and ARE 13 are connected to AOM 101 the activities are concentrated into different specialized work centres according to the need, which means rationalization of the operation and maintenance work.

The interworking is carried out via data links, and the signalling interworking with AOM 101 satisfies the requirements of CCITT Recommendation X25.

Up to eight I/O processes can be exchanged simultaneously between an ARE exchange and an AOM 101 via each data link. Fig. 8 shows the general structure of the new I/O system.

MAGNETIC TAPE UNITS

When specified charging is required, magnetic tape units are used, which are connected to ANA 30 and can store the required data volume for further processing. The output function is dupli-

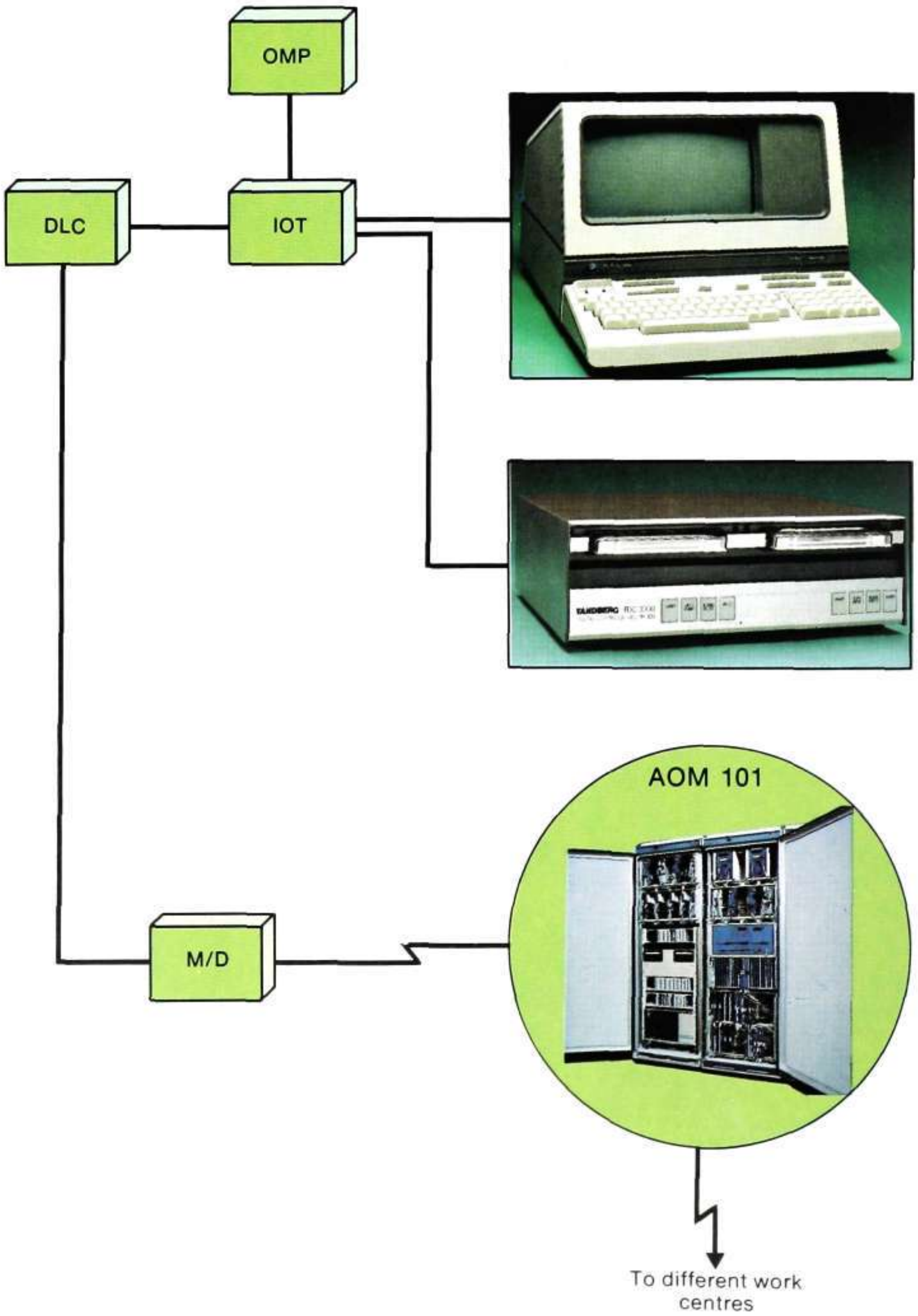


Fig. 8
The general structure of a new I/O system for ARE. Eight I/O devices can be connected and the system can interwork with AOM 101. It contains primarily:

- IOT — Micro processor controlled unit for direct connection of display unit, printer and cassette tape recorder
- DLC — Micro processor controlled unit for interworking with AOM 101 via a data link in accordance with CCITT Recommendation X25
- M/D — Modem for remote connection of AOM 101 and I/O devices
- *OMP* — *Operation and maintenance processor* in ANA 30, which is supplemented by certain programs for interworking with the new I/O system

Fig. 9
Magnetic tape unit for ARE exchanges

cated for reliability reasons. Magnetic tape is also used as an alternative to cassette tape for the output of data when electronic charging is used. Tape units as shown in fig. 9 will be used as output devices in ARE 11, for both specified and electronic charging. At a later stage these units will also be introduced in ARE for toll ticketing.

COMMON CHANNEL SIGNALLING

LM Ericsson have great experience of common channel signalling in accordance with CCITT signalling system no. 6. This has previously been described in this magazine[9-11], both in connection with local exchanges ARE 11 and transit exchanges AKE 13. The signalling system is now being introduced in ARE 13, which is well suited for common channel signalling. The first application will be the international exchange in Hong Kong, where the ARM 20 is modernized to ARE 13.

The new subsystem for signalling system no. 6 uses LM Ericsson's minicomputer APN 163, to which microcomputer-controlled units are connected, fig. 10. The use of this signalling system will give faster and more reliable connection and will lower the operating costs.

The control functions for signalling system no. 6 are included in the traffic handling processor TCP, and the operation and maintenance functions are included in the operation and maintenance processor OMP, which makes it necessary to extend the translation store.

Conclusion

The advantages of updating local and transit exchanges, ARF and ARM, have been described by several administrations, for example in Ericsson Review[1-4]. Wishes have been expressed from various sources for the introduction of certain additional functions in the exchanges that have been evaluated in collaboration with the various administrations. This has led to the further development of the ARE system described above. The development work will continue when and as necessary so that the system is able to meet new demands and requirements.

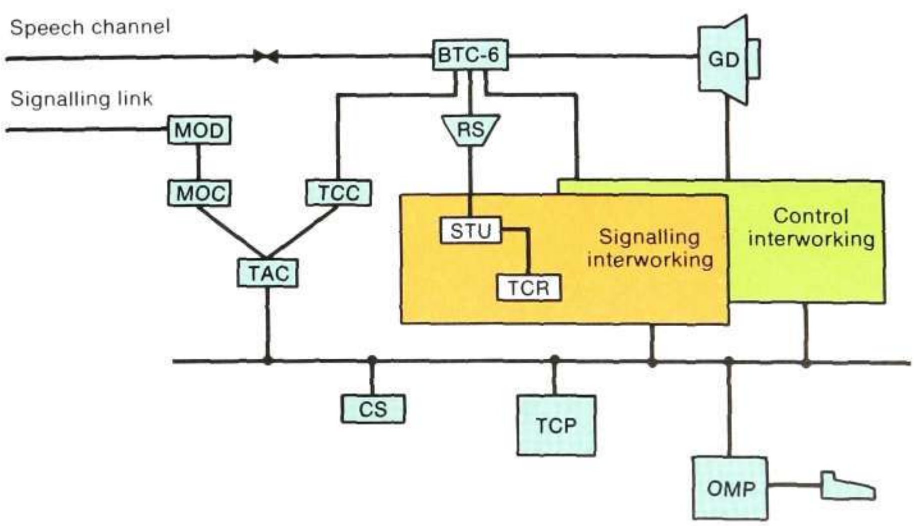


Fig. 10
The basic structure of signalling system no. 6 in ARE 13

- MOD — Modem for connecting a signalling link
- MOC — Micro processor controlled unit for sending and receiving data via the signalling link, for generating and decoding check bits and for supervision, testing etc.
- BTC-6 — Both-way international trunk circuit for signalling system no. 6
- TCC — Micro processor controlled unit that is common for 32 BTC-6. The interface between TCC and BTC-6 consists of test and operate points, which are controlled by the micro processor. TCC also contains functions for supervision, settling of accounts and plausibility checks on received signals
- TAC — Unit which is controlled by the miniprocessor APN 163 and intended for communication between the ANA 30 processors and the micro processor controlled units TCC or MOC as well as between TCC and MOC. TAC handles the transfer between external and internal addressing, selection of line, collection of statistics, supervision of routes and choice of international signalling code. TAC and the associated bus system are duplicated for greater reliability
- TCR — Unit for checking the continuity in speech channels
- TCP — Traffic control processor in ANA 30 which has been supplemented with particular programs for interlocking with signalling system no. 6
- OMP — Operation and maintenance processor in ANA 30 which has been supplemented with particular programs for interworking with signalling system no. 6

ARE exchanges, the number of lines in operation and on order, July 1979

ARE 11

Country	New	Modernized to ARE 11	In operation	On order
Argentina	11 000			11 000
Argentina		2 000		2 000
Australia	74 000		10 000	64 000
Australia		526 400	155 200	371 200
Colombia	30 000		20 000	10 000
Denmark	37 000		28 000	9 000
Denmark		228 000	101 000	127 000
Egypt	20 000			20 000
Finland	33 000		9 000	24 000
Finland		61 200	26 400	34 800
Iceland	1 000			1 000
Kuwait	45 000			45 000
Saudi Arabia	3 000			3 000
Saudi Arabia		198 800		198 800
Spain	84 000		8 000	76 000
Jugoslavia*	79 000		10 000	69 000
Total	417 000	1 016 400	367 600	1 065 800

ARE 13

Country	New	Modernized to ARE 13	In operation	On order
Argentina	18 200		1 600	16 600
Curacao	700			700
Curacao		700		700
Denmark	1 000		1 000	
Egypt	2 400			2 400
Hong Kong	1 400			1 400
Hong Kong		2 000		2 000
Iceland	400			400
Ireland	18 000			18 000
Kuwait	4 400		3 600	800
Libya	3 200			3 200
Nigeria	2 600			2 600
Panama	800			800
Panama		2 000		2 000
Saudi Arabia	17 600		9 800	7 800
Saudi Arabia		6 000	6 000	
Sri Lanka	600			600
Total	71 300	10 700	22 000	60 000

*Via N. Tesla

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