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# A United States Air Force Four-wire Electronic Switching Development 

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UDC 621.395 .345
LME 83024
The Central Offices. Telephone, Electronic AN/FTC-27-29 and AN/TTC-19 \& 20 are high speed 4 -wire circuit swith hing equipments which have been implemented by the United States Air Force for universal use in tactical and fixed plant environments. See figs. 1 and 2.

Their design is based on the Time-Division-Multiplex Technique and in association with the Highway Switching Principle to provide the switching and transmission network. They are fully transistorized and adaptable for application in local, tandem and long haul switching nodes.

The transmission characteristics of this equipment are such that it is directly compatible with any transmission network that consists of HF, VHF, UHF, troposcatter, microwave or metallic circuits with or without carrier multiplex or a combination thereof for processing voice, digital data, graphics, etc., with a quality better than present commercial standards. Its high quality transmission characteristics make it useful for insertion into a military communication system consisting of six tandem links of approximately 6.000 miles, where the length of a typical link may be as much as 2,500 miles.

These equipments have been extensively factory and field tested with highly satisfactory results and presently are operational within an integrated system environment performing local and long haul tandem switching functions.

## Introduction

The requirements and nature of military communications systems are radically changing in light of new technology and operational concepts. Until very recently, practically no automatic switching equipment with alternate routing

Fig. 1 X 7891
Tactical version of Central Office showing shelter design and transportation



Fig. 2
X 2751
Equipment bay housing four racks
was in operation in the military network. The military network consisted of direct trunks between manual switching centers and point-to-point trunks (hot lines). When alternate routes were found necessary, manual patching or manual re-routing was adopted as the standard mode of operation. Moreover, in the event of critical requirement in the military network, a duplicating alternate back-up facility which duplicated the normal one was provided; one carrying traffic while the other was on stand-by. This mode of operation was slow, unreliable, inefficient and costly and most important. could not cope with the present as well as future tactical and strategic concepts of communication.

Existing commercial equipments did not possess the flexibility, speed, transmission characteristics, features and survivability required to comply with the unique communication requirements for a quick reaction, positive control and real time communication system as imposed by today's nuclear and space age.

To fulfill these requirements, the United States Air Force, in association with the North Electric Co., and its parent organization, L M Ericsson, undertook a task for the design, implementation and production of a fully solid state switching center. The degree of success achieved by this task resulted in the delivery of six fixed plant and nine mobile switching centers for integration into a system complex. At the present time these switching centers are operational in a six-site system configuration and are satisfactorily supporting the intended system operational requirements.

## Discussion

The AN/FTC and AN/TTC series equipments are electrically, operationally and functionally the same, the basic difference being in the packaging and the degree of complement with respect to line terminations, trunk terminations. number of registers, number of highways, etc. The smallest switching center. which is a nominal 100 -line system, is a suitably depleted version of the nominal 330 line unit. The largest version provides 504 line appearances. allowing 402 external lines, including trunks. The balance is used for registers, conference circuits, test lines, etc.

## Switching Technique

The switching network utilizes the Time-Division multiplexing technique in combination with the Highway Switching Principle. In accordance with this principle a number of subscriber lines, together with incoming and outgoing trunks, are connected to a common highway by means of individual line contacts. Each incoming highway is interconnected with each outgoing by means of inter-highway contact switches. Switching between any input and output is established by closing the respective line and inter-highway contact switches periodically in synchronism during very short time intervals or time slots. By timesharing the common transmission path in this way, a number of connections corresponding to the number of time slots or pulse positions can be established. A total of 36 line terminations and 20 puise positions (links) per highway (Full Duplex transmission path) have been found to be suitable from the transmission and traffic handling point of view.

## Transmission

The voice frequency inputs are pulse amplitude modulated (PAM) at a $12.5 \mathrm{kc} / \mathrm{s}$ repetition rate which is derived from a $250 \mathrm{kc} / \mathrm{s}$ master clock. Each sample is of a 4 microsecond duration and occurs at a frame repetition rate of 80 microseconds. The 4 microsecond sample includes a guard time of 2 microseconds to discharge the highway of any residual charges and ready it for the succeeding pulse position. thus limiting the crosstalk between pulse positions to an absolute minimum. The resonant transfer technique is utilized to transfer energy from input to output with a minimum loss of energy.


## Transmission Characteristics

Typical attenuation distortion (response) and delay distortion curves for a transmission path through the switching center are as shown in fig. 3 and 4.

The attenuation distortion is approximately 0.08 db , while the delay distortion is approximately 10 micro-seconds over the frequency range from 325 to $3,450 \mathrm{c} / \mathrm{s}$.

Insertion loss at $1.000 \mathrm{c} / \mathrm{s}$ resulted in a mean value of 0.044 db with a standard deviation of 0.071 db .

An input return loss average of 32.05 db was attained at the low end of the frequency range and 27.23 db at the high end. Corresponding figures for the output return loss were 26.71 db and 39.55 db . It may be mentioned, since these measurements were taken, that additional adjustments of circuit values have further improved the margins at the ends of the frequency band, which are the most critical frequencies for return loss.

Idle channel noise is better than 15 dba (F1A weighting).
Only the worst cases of equal level crosstalk will be mentioned. Other crosstalk levels have been found to be so low that measurement results were obscured by errors in the test equipment. Contrary to what may have been expected, crosstalk from one time slot to the succeeding one is very low (better than 75 db crosstalk attenuation). The worst case encountered is crosstalk between the send and receive circuit of the same connection, often referred to as near-end crosstalk, where the average of 84 measurements was 69 db . The
corresponding average figure between other transmission paths in the same or adjacent time slots, but between two highways, was 76.7 db .

Other transmission characteristics that may be of interest are harmonic distortion and intermodulation distortion. The total harmonic distortion at -4 dbm test tone level averaged -63 dbm . The r.m.s. sum of intermodulation products due to two equal level test tones of -7 dbm each. averaged -57 dbm .

## Functional Capabilities

The specific requirements placed on the equipment have necessitated the incorporation of many special and unique features. A prime feature of the system design as a whole was, however, the degree of reliability and route accessibility which called for a duplication of control equipment and power supplies together with a dispersion of facilities on a number of highways. These and other considerations made the introduction of the following features necessary.

The MDF patching and cross-connection procedures have been superseded by a number group memory of semi-permanent type which allows an arbitrary association of catalogue and exchange line number. The number group also contains code words designating different features which can be associated with a line.

A memory of similar type is used to store routing information for register use. The registers are capable of automatic alternative routing of inter-office calls. One prime and two alternative routes may be provided by the register. At tandem points a restriction code may be introduced to restrict the number of alternatives.

Each trunk group or route may be divided into two parts, one for data transfer and one for normal telephone traffic. This is required due to the incorporation into the system of a data transmission and switching capability.

A feature of the system is that all requests for feature services are checked before execution by the common control equipment. This makes it possible to use only one type of standardized keyset on all telephone instruments, the allocation of facilities being controlled by the number group.

Priority and pre-emption are features which may be allocated any given extension. If all registers are busy, a call from a priority privileged extension will pre-empt a non-priority extension holding a register. Similarily a priority call will pre-empt any non-priority call in progress, should a switching path not be available at the time. Pre-emption extends even to trunks. The priority override and pre-empt feature is only resorted to at the request of the extension at the commencement of a call. All paths and trunks used in a priority connection are priority-marked.

Only one level of priority is allowed.
A short priority pre-empt warning tone is sent to the conversing parties.
A feature of the switching equipment that is unique is the capability for switched hot-line operation used in order to obtain the operational characteristics of a direct connection while retaining the advantages of efficient trunk utilization and alternate routing.

The number of the party to be called from a stored address extension is stored in the number group. This stored address number is transferred to the
register immediately the calling party goes off hook, thereby allowing the register to establish an immediate connection with a predetermined subscriber by a direct or alternative route. Extensions programmed for this service are assigned priority privilege and receive priority request from the stored address so as to assure availability of a connection in the event of traffic congestion.

An assistance operator is provided. This service may be accessed by keying 00 . From this position foreign networks may be accessed and other operator services performed.

Upon receipt of spurious digits or non-assigned numbers, the calling party is automatically routed to an intercept operator. This also occurs when severe blocking conditions are encountered on trunk calls.

A subscriber may test his own telephone instrument and line equipment by keying a special code ( 02 ) which causes the transmit and receive pairs to be interconnected at the exchange. This feature is also used for routine testing of the exchange.

A further feature of the system is its priority ringing signal. The nonpriority ringing signal is an intermittent signal while the priority ringing signal is continuous, thus enabling the called party to distinguish between the two. There is also a difference in the phase of the ringing tone but this is used only for interpretation purposes in machine subscriber sets.

All subscribers of the electronic switching center can establish conference calls. Each keyset is equipped with a "C" button which is depressed prior to keying the required subscriber's number. The conference originator controls the conference and can add or change conferees at any time without releasing the conference unit. Conferences may be established either on a priority or non-priority basis. Nine five-party conference circuits are provided.

Conference connections are established through the switching center in the normal way between end instruments and the conference unit. The conference unit is equipped with amplifiers in an active hybrid arrangement, thereby maintaining transmission quality essentially at the same level as that for normal party to party connections.

A portable read-write unit may be connected to the number group or the register translator in order to program the switching center. To enter directory number, class of service and "stored address" information it is connected to the number group, while office code and trunk routing may be entered if it is connected to the register translator. The read-write unit may be used to read, write or erase information in the appropriate memories by operating keys on the control panel.

## Instrumentation

In a system using advanced electronic techniques, the problem of "on-line" maintenance must be given special consideration. This is particularly true when the system, unlike electronic computers, is allowed no programmed down-time. To cope with this problem, special emphasis has been given to trouble indication devices and fault location methods. An automatic routine tester is used to continuously monitor the overall performance of the center. It is connected to a line on each highway and sequentially places test calls in all combinations, including simulated trunk calls over a MDF patch loop. It checks levels and frequencies of all supervisory tones encountered and attenuation and phase shift of each established connection, after first testing the noise level on the speech path. Any objectionable crosstalk is also detected in this manner.

Register monitoring equipment enables all registers and receivers to be monitored, tested, blocked and unblocked.

A marker test set is provided to determine the status of the marker at any instant. In the event a marker stops during its program, it will display the address to the instruction memory in the marker at the point of failure. It will also read out the terminal number and directory number of the line involved, and the state of various logic circuits and flip-flop memories, describing the exact state of the equipment at the time of failure. It may also be used to manually step the instruction program and to manually read, write or erase in the contact memory.

While it may appear difficult to trace a call in a TDM switchboard, with the marker test set it is possible to completely trace a call through the center. The marker test set has a built-in search routine which may be applied to the marker. The marker, being able to read the contact memory information, can provide read-outs to the marker test set. Knowing one terminal number to which it is connected, the other may be determined in a matter of seconds as well as the time slot used and other pertinent data.

## Reliability

In order to achieve a high degree of reliability, all common control equipment has been duplicated. In the event of failure of the primary unit, automatic switchover to the standby unit takes place. Included in the common control equipment group for this system are: marker, scanner, number group. pulse distribution, and registers.

## Traffic Metering

An electronic center that uses memory devices is ideally suited for the application of traffic measuring techniques. In this center the line supervision memory contains up-to-date information on the state of any line in the switching center and the number group continuously provides the access number. Advantage is taken of this information storage to provide traffic metering equipment that will, on demand, provide accurate information on the traffic status of the switching center.

## Storage (Memories)

The storage devices are composed of ferrite core matrices. There are two types of memories, the non-destructive and the destructive types.

The non-destructive type is utilized to store semi-permanent information relating to the directory number, class marking, routing, etc., and cannot be destroyed due to power failure or other faulty criteria. The destructive type is utilized to store information which is utilized only for the duration of the call and is erased (cleared) to accept new information for processing new connections. Typical examples are the line supervision memory and the contact memories.

## Numbering Plan

The numbering plan was designed with a maximum number of five digits; the first two for office code and the remaining three digits designating the station number within a particular office.

In order to permit subscribers to key only the 3 －digit station code for local calls，the numbering plan was arranged as follows：

| Office Codes | Station Numbers |
| :---: | :---: |
| 5 X | 1 XX |
| 6 X | 2 XX |
| 7 X | 3 XX |
| 8 X | 4 XX |

## Special Codes

C Access code for conference
P Code for priority
9X Reserved for future use（access to foreign networks，etc．）
0 X Access code to operators and special lines
Note：in the above＂ X ＂indicates any digit．
Although 5－digit numbering is needed for inter－office dialling，calls originat－ ing and terminating within the same office can be completed by keying either the 3 －digit station number or the complete 5 －digit directory number．

## Line Signalling and Supervision

Request for service from subscriber lines is accomplished by means of a direct current loop closure as in conventional systems．

Digit signalling from the subscriber instrument to the central office uses multi－frequency tone signals consisting of a dual－frequency tone for each digit and auxiliary signal．The frequencies used are from two groups of fre－ quencies as follows：

| Group I | Group II |
| :--- | :--- |
| $1,020 \mathrm{c} / \mathrm{s}$ | $1,620 \mathrm{c} / \mathrm{s}$ |
| $1,140 \mathrm{c} / \mathrm{s}$ | $1,740 \mathrm{c} / \mathrm{s}$ |
| $1,260 \mathrm{c} / \mathrm{s}$ | $1,860 \mathrm{c} / \mathrm{s}$ |
| $1,380 \mathrm{c} / \mathrm{s}$ | $1,980 \mathrm{c} / \mathrm{s}$ |

The above frequencies are combined（one frequency from each group）to represent the digits（ $0-9$ ）in addition to the auxiliary signals in accordance with the following table．

Table I

| Digit or Auxiliary Signal | Frequency（c／s） |  | Comments |
| :---: | :---: | :---: | :---: |
| 1 | 1，020 | plus 1，620 |  |
| 2 | 1.020 | 》 1,740 |  |
| 3 | 1，020 | 》 1,860 |  |
| 4 | 1，140 | ） 1,620 |  |
| 5 | 1，140 | 》 1,740 |  |
| 6 | 1，140 | 》 1.860 |  |
| 7 | 1，260 | 》 1，620 |  |
| 8 | 1，260 | 》 1，740 |  |
| 9 | 1，260 | 》 1,860 |  |
| 0 | 1.380 | ＞1，620 |  |
| P | 1，380 | 》 1,740 | Priority Request Signal |
| C | 1，380 | ＞ 1,860 | Conference Access Signal |

To gain freedom from the d．c．circuit limitations of metallic circuits and for compatibility with non－metallic circuits，d．c．／tone signalling converters are provided．These converters automatically detect seize and release signals and convert them to their respective modes．

## Trunk Signalling and Supervision

To handle inter-office calls requiring trunk connections, each trunk line is provided with a voice frequency signal detector in lieu of d.c. loop detecting means. This enables non-physical circuits to be used for trunking. By proper selection of the trunk supervisory signal and by careful design of the voice guard circuit, a single frequency supervision signal has been adopted for both seizure and release between switchboards. The chosen frequency and its characteristic is as follows:

Signal $\quad-$ Frequency $2,400 \mathrm{c} / \mathrm{s}$
Seize Signal $-80 \mathrm{~ms} \begin{gathered}\text { plus } \\ \text { minus }\end{gathered} 20 \mathrm{~ms}$
Release Signal $-600 \mathrm{~ms} \begin{aligned} & \text { plus } \\ & \text { minus }\end{aligned} 75 \mathrm{~ms}$
The seizure signal is transmitted as a continuous tone until an acknowledgement re-start or proceed-to-send signal is received. The register will then proceed to transmit the digital information. Each digit is initiated either by a re-start signal or a proceed signal from the receiving center. The proceed signal indicates that the next digit in the sequence shall be transmitted and the re-start signal indicates that the number shall be retransmitted from the beginning. The inter-register digit signals are the same as those used for the subscriber key sets. Upon receipt of a digit the receiving register sends the frequency complement to the originating register by way of acknowledgement.

The complementary acknowledgement and the proceed-to-send signals for each individual digit provides a means of error detecting and checking and insures that the digit has been correctly received. By this means a digit signal which is faulty when received may be called for repeated!y until correctly received. The employment of specific proceed-to-send signals enables the signalling facility to detect missing digits due to premature or faulty dialling or other anomalies, such as fadeouts. In addition to these safeguards, the uniform two-element content of the two-out-of-eight frequency codes is self-checking in itself because the absence of one of the frequency elements or the presence of a third indicates a false signal. The digit frequencies are the same as outlined under line signalling.

## Terminal Instruments

A variety of subscriber sets are being provided together with the electronic switchboard. These subscriber sets are designed to satisfy the specific demands of the various users. A desk subscriber set with push button dialling and tone ringing will normally serve the administrative requirements of the system. Priority ring signal is distinguished as a continuous rather than interrupted signal. This is, however, a feature of the switching center rather than the end instrument (fig. 5). The set will have a priority button so that priority calls can be originated, and a conference button which provides the user with access to the conference facility in the switchboard.

The second subscriber set is called a field subscriber set. fig. 6, and has all the features of the desk set in addition to being ruggedized to meet all the environmental requirements of a military communication system. In addition, the field subscriber set may be equipped with a local battery for direct point-to-point operation.

The third subscriber set is tailored for radar console usage, fig. 7. It is called a console subscriber set and will be mounted as an integral part of a console. It consists of two parts: a control panel in an island in the center shelf of the console, and a central facility mounted inside the console itself. The control panel provides the operator with a series of push buttons which give him complete control of the audio input and output to his position. The
Desk subscriber set

Fig. 6
X 8447
Field subscriber set Interior view

Fig. 8
X 8449
Machine subscriber set

the radio set to the frequency of his choice. When calls originate from an aircraft, they will always appear at a line unit which is associated with a particular site.

In addition to those stored addresses already mentioned, the console operator may store up to eight other addresses of parties frequently called. The stored address feature will allow ringing to start at the called party within one second from the time the button is depressed. For calls other than those for which an address has been stored, a key punch is provided. The console operator may also elect to place priority calls and conference calls as explained before. He will have a push-to-talk button for radio sets and a special identification code lamp for radio sets which assures that equipment is ready for use. In addition, he will have a hold and a release button.

At a radio set a special device is necessary to take the place of an operator. We call this device a machine subscriber set, fig. 8 . When a call comes in from an aircraft, the ground receiver squelch or carrier operated relay will send a signal to the machine subscriber set which in turn will send an offhook signal to the switchboard. The line circuit in the switchboard will have a stored address for that console subscriber set which is responsible for that radio set. When a ring trip is returned, a special identification code signal will be exchanged. If a ring trip signal and the identification code are not received within five seconds, an alarm will sound at the machine subscriber set so that an attendant may assist. When a call is placed from a console subscriber set, the machine subscriber set will detect ringing, return ring trip, and exchange the identification code. The machine subscriber set also has two detectors for carrier-on, carrier-off control generated by the push-to-talk button in the console subscriber set.

# Crossbar P.A.X. <br> for 16 and 30 Extensions 

G STEIMAR, TELEFONAKTIEBOLAGET LM ERICSSON, STOCKHOLM

UDC 621.395 .2
LME 8354
The high reliability and speed of the crossbar switch has made it one of the most important components both in public and private telephone exchanges. L. M Ericsson has used the crossbar switch in its 16 and 30 line P.A.X., denoted ARD 624 and $A R D 636$.
P.A.X. types $A R D 624$ and $A R D 636$ require little maintenance and are simple to install. Being silent in operation and taking up little space, they can be placed in any office room. Normal dial telephones are used with these P.A.X.

ARD 624 (fig. 1) is designed for 16 extensions and two connecting circuits.

ARD 636 (fig. 2) is designed for 30 extensions and four connecting circuits.
fig. 1
P.A.X. ARD 624
(right) with cover removed



Fig. 2
X 7890
P.A.X. ARD 636
(right) with cover removed

In their standard form these P.A.X. are equipped for the following facilities:
Ordinary dialled calls
Immediate access to extensions 30 and $34-39$ in the 30 -line system by dialling the last digit alone. The extension numbers in the 16 -line system are $2-9,11-18$, and in the 30 -line system 10-39. The single digit numbers for immediate access should be allotted to extensions who receive large numbers of calls.

Priority, i.e. the facility of entering an engaged circuit. Can be provided for any required number of extensions by simple strapping arrangements.

First party release implying that an extension is free for a new call as soon as he replaces his handset.

The following additional facilities can also be provided:
Tie lines $(F D R-X)$ to other private automatic exchanges. Tie line calls are preceded by a single-digit code.

Voice paging, requiring the addition of a relay set PSR.
Triangular calls. One or more extensions can be equipped with a relay set $K F R$, permitting the entry of a third party into an established connection (conference calls). This facility occupies one line position in the multiple, and an extension possessing the facility must have an earth button.

In the course of a conversation he can ring up a third party on the extra line by pressing the earth button, and all three extensions can then converse with one another.


Fig. 3
Battery eliminator BMN 2424
(below) with cover removed


Fig. 4
X 2750
Switching diagram
BR Cut-off relay
ID Identifier
REG Register
SNR Connecting circuit
S Finder
LV Final selector

## Mechanical Design

The components-crossbar switches, relays, capacitors, etc.-are of the same design and high quality as in L M Ericsson's public telephone exchanges. The components are mounted on a wall rack with hinged frame (figs. 1-2) protected by an enamelled steel cover. Owing to the accessibility of the components and the small dimensions of the racks, the switchboards are permanently wired in the factory.

The dimensions of the switchboard are:
ARD 624: height 860 mm , depth 205 mm , width 260 mm
ARD 636: height 840 mm . depth 200 mm . width 620 mm

Fuses and terminal blocks for jumpering and strapping are assembled on a single bar

All details of the switchboard are designed to withstand severe climatic conditions. All cabling consists of plastic-insulated wire.

## Power Equipment

The operating voltage, 48 V , is normally obtained from a battery eliminator which also produces the necessary buzzer tone ( 100 cycles) and ringing current. A suitable battery eliminator is $B M N 2424$ (fig. 3), which delivers a voltage of 48 V and a maximum current of 2 A . The unit has tappings for $110,127,150$ and $220 \mathrm{~V}, 50-60 \mathrm{c} / \mathrm{s}$. The 90 V ringing voltage is obtained from an extra winding on the unit's transformer. If desired, the P.A.X. can be operated off a battery and charging unit for 48 V , in which case a ringing voltage unit will be required in addition.

## Operation

When an extension raises his handset, his line is identified by $I D$ and is connected via an $S N R$ to $R E G$ (fig. 4), which returns dial tone. If dialling does not start within 5 seconds, or if the time between the first and second digits exceeds 5 seconds. REG is released and busy tone is returned to the extension via $S N R$.

After the number has been dialled, REG ascertains whether the called extension is free or engaged. If free, it is connected via $L V$ to the connecting circuit. REG is released and the first ringing signal is sent. This is followed by intermittent ringing signals, and the caller hears ringing tone. When the call is answered, the ringing signals cease and connection is established. If the extension is engaged. REG is released and busy tone is returned to the caller from $S N R$.

If a priority extension calls an engaged extension, $R E G$ releases and busy tone is returned as before, but the caller can enter the connection by dialling an additional digit. A warning tone is then sent to all three parties. If the priority extension replaces his handset, the warning tone ceases and the original conversation can continue.

Since the exchanges are designed for first party release, an extension is free for a new call immediately after replacing his handset.

On tie line calls $S N R$ is through connected and the current feed is taken over by FDR-X.

## Installation and Maintenance

These exchanges with their small dimensions and permanent cabling are very simple to install. The backplate is first erected on the wall and the equipment frame is then screwed onto it. The power leads and extension lines are connected to easily accessible terminal blocks. Once the necessary strapping has been done according to the customer's wishes, the P.A.X. is ready for testing and putting into service.

Switchboards with mechanical selectors require regular preventive maintenance if they are to operate satisfactorily. Preventive maintenance is unnecessary with crossbar switchboards and their maintenance costs are therefore very low. If the P.A.X. has been thoroughly tested at the time of installation, the only maintenance required under normal conditions should be an annual inspection and check-up of the power equipment.

## Technical Data

The operating voltage for the switchboards is 48 V . but voltage fluctuations between 42 and 56 V can be admitted without jeopardizing their operation.

Current consumption about 0.4 A per conversation. Maximum current consumption during switching 1 A .

Line data. The loop resistance may be $1.100 \Omega$ including the resistance of the telephone instrument.

The leakage resistance between the two legs of a line or between one leg and earth may be as low as $25.000 \Omega$.

## Feed

The feed coils have a resistance of $2 \times 400 \Omega$, which can be adjusted to $2 \times 250 \Omega$.

## Main Features of P.A.X. types ARD 624 and ARD 636

1. High traffic handling capacity and rapid switching
2. Practically no maintenance
3. Silent operation
4. Priority for any desired number of extensions
5. Connection of tie lines
6. Voice paging
7. Triangular conversations, i.e entry of a third party into an established connection
8. Immediate access to certain extensions by dialling one digit
9. Wall mounted
10. Supplied by battery eliminator
11. Simple wiring.

# Transistorized Repeaters for Physical Circuits 

L E LARSSON, TELEFONAKTIEBOLAGETLMERICSSON, STOCKHOLM

UDC 621.375:621.395
621.382 .3

LME 84111
Different types of repeaters for physical circuits have been included in LM Ericsson's manufacturing program for a long time. The new repeater which has been developed differs from the earlier ones in that the units have been built up on printed wiring boards and the amplifiers have been transistorized. The layout of a bay with new repeaters has been adapted for use in loaded trunk lines in a network with subscriber trunk dialling.

Repeaters for loaded trunk lines have been in use in the Swedish telecommunications network for a long time. The specifications for this repeater have therefore been worked out in intimate collaboration with the Swedish Board of Telecommunications. In addition, the repeater fulfills the recommendations of CCITT, where applicable.

## Arrangement

Repeaters for two-wire physical circuits can be divided into two types depending on their use.

The first type consists of repeaters for long rural lines. The feature of this type is that the amplifier gain should be high. These repeaters are most suitably designed as 2 wire 2 wire ( $2 \mathrm{~W} / 2 \mathrm{~W}$ ) intermediate repeaters, see fig. 1 .

The second type consists of repeaters for the physical circuits which are included in a trunk connection. The feature of this type is that the amplifier gain should be relatively low. The importance of this group increases at the same rate as subscriber trunk dialling is introduced. In the case of automatic operation over trunks, the requirement that the equivalent of transit routes shall be low is made more stringent.

In general only one repeater is required per line. The best location of such a repeater is usually at one of the ends of the line. There is thus a demand for terminating repeaters. In the case of 4 -wire operation in transit exchanges, the hybrid and balance network which would otherwise be nearest the exchange are omitted. Such a repeater is called 2 wire 4 wire ( $2 \mathrm{~W} / 4 \mathrm{~W}$ ) terminating repeater, see fig. 2. A $2 \mathrm{~W} / 2 \mathrm{~W}$ terminating repeater is shown in fig. 3 .

In order to satisfy the demand for these two types economically, the new repeater can either be mounted in a bay or in independent shelves.

A bay for up to sixty terminating repeaters, see fig. 4, has been arranged with a view to its use in trunk circuits.

A shelf accommodating two intermediate repeaters, see fig. 5, has been arranged with a view to its use in rural circuits. The shelves can be assembled in bays or wall-mounted frames together with power supply equipment.

In order that the field of use of the repeaters shall be as universal as possible, no special type of signalling repeater has been included in the repeater equipment. A facility has instead been provided of connecting the signalling equipment to the capacitors at the middle of the centre tapped transformers.
Fig. 3
X 2730
$2 \mathrm{~W} / 2 \mathrm{~W}$ terminating repeater


Fig. 4
Repeater bay ZDA 801

Line transformers are normally used to match the impedance of the line to the exchange or to make use of the phantom circuit in quad cables. Difficulties may arise when adjusting the amplifier balance if amplification is to be introduced into a circuit with line transformers. In general. an extra line transformer must be included between the hybrid and balancing unit. In the new repeaters, the need for line transformers has been avoided by matching the line and balance windings of the centre tapped transformers direct to the line impedance. To obtain sufficient balancing for the phantom circuit, the transformers have been wound so as to be double balanced. Such a transformer is termed a line and hybrid transformer. The circuit diagram for a transformer with centre tap for direct connection to the phantom circuit is shown in fig. 7. Fig. 8 shows the circuit diagram for a transformer with capacitors at the centre tappings of the line and balance windings. Such a transformer is used in those cases when one has to extract sub-audio frequency signals to a signalling repeater. The output for the phantom circuit is obtained in this case from the signalling repeater.

The line and hybrid transformers are mounted on printed wiring boards with aluminium dust covers occupying one width module, see fig. 6 . The transformers are wound on toroidal cores and two transformers are cast in one plastic block.

The maximum amplification which can be used in a repeater is mainly determined by the capacitive crosstalk in the cables. In practice. not more than about $18 \mathrm{db}(2.1 \mathrm{~N})$ gain can be introduced in the case of a $2 \mathrm{~W} / 2 \mathrm{~W}$ intermediate repeater or about $9 \mathrm{db}(1 \mathrm{~N})$ gain in the case of a terminal repeater. With a hybrid loss of $3 \mathrm{db}(0.4 \mathrm{~N})$, the amplifier in a $2 \mathrm{~W} / 2 \mathrm{~W}$ repeater has to have $24 \mathrm{db}(2.9 \mathrm{~N})$ gain and $12 \mathrm{db}(1.4 \mathrm{~N})$ gain in the case of $2 \mathrm{~W} / 4 \mathrm{~W}$ repeater. If the $2 \mathrm{~W} / 4 \mathrm{~W}$ repeater is to be used with pad switching to provide excess gain toward the unamplified network. then in this case there is also a use for amplifiers with 24 db gain. The amplifier used in the repeater has a maximum gain of 24 db . The gain can be varied in steps of 0.1 N in the range 19 db to 24 db by using U-links. Coarse regulation of the gain can be made with fixed pads in the bay side.

For equalizing the line attenuation at high frequencies the amplifier feedback circuit has been made frequency dependent so that the gain increases at high frequencies. This increase of gain can be regulated by using $U$-links.

The frequency characteristics of the amplifier with and without the equalizing circuits are shown in fig. 12. When changing from one equalization graph to another, the gain at $800 \mathrm{c} / \mathrm{s}$ remains practically constant.


Fig. 6
X 8437


Fig. 7
x 2735
Circuit diagram for line and hybrid transformer without capacitor at centre tap


Fig. 8
X 2736
Circuit diagram for line and hybrid transformer with capacitor at centre tap


The amplifier unit also contains a low-pass filter for giving the repeater a suitable upper cut-off frequency related to the cut-off frequency of the line. This is designed so that the two amplifiers in an intermediate repeater must be provided with filters. In a terminating repeater where the possible gain obtainable in practice is less, only one amplifier need be provided with a lowpass filter.

The frequency responses of the different filters are shown in fig. 13.
An amplifier with filter is shown in fig. 9. On the short side of the unit will be seen the U-links for adjustment of the amplifier gain and for the equalizing circuits.

From the technical point of view, the amplifier can be described as a twostage d.c. coupled transistorized amplifier with bridge negative feedback at the input and output. Not only the gain but also the input and output impedances are thereby stabilized.

The adjustment of the balance has been made particularly clear by its method of mounting on a printed wiring board. It is built as a Hoyt type balance where the values of the different components can be varied by means of straps, see fig. 10 b . The range of adjustment of all components except the inductance is so large that it covers all practical applications. The range of adjustment of the inductance values corresponds to the most usual loading values.

In the case of $2 \mathrm{~W} / 2 \mathrm{~W}$ terminating repeater. the hybrid transformer lying on the exchange side need not fulfill such stringent requirements as the line and hybrid transformer on the line side. Furthermore the balance need not have the same strapping facilities as a Hoyt Balance. For this case a 4 W terminating unit having 600 ohms impedance toward the exchange side with a built-in compromise balance is available.

## The Bay

The repeater equipment in the bay (fig. 4) occupies fifteen shelves containing sixty 2 W 4 W terminating repeaters and four shelves containing supplementary equipment. A picture showing details of a shelf with terminal repeaters is shown


Fig. 9
Amplifier


Fig. 10 a
Balancing unit


Fig. 10 b
X 2737
Circuit diagram of balancing network

Fig. 11
X 8438

[^0]in fig. 11. Each shelf contains four repeaters. The pads for coarse adjustment of the gain are located at the left hand side of the bay front. To the left of these are located test jacks for checking the gain of the repeater amplifiers or for monitoring purposes. The common fuse for all repeaters in one shelf is located at the right hand side of the bay front.

If the repeaters are to be arranged as $2 \mathrm{~W} / 2 \mathrm{~W}$ terminating repeaters, the 4 W terminating units must be placed in the shelves for supplementary equipment. This does not cause any inconvenience as the wiring from the four-wire side of the $2 \mathrm{~W} / 4 \mathrm{~W}$ repeaters is cabled via these shelves. Connection is thus made at the same time as the 4 W terminating unit is plugged into its position in the bay. The $2 \mathrm{~W} / 2 \mathrm{~W}$ intermediate repeater can be built up in two ways. The first way is to connect two $2 \mathrm{~W} / 4 \mathrm{~W}$ terminal repeaters together. This connection is obtained by replacing the amplifiers in one of the repeaters by a special dummy unit. In this arrangement the bay only can accommodate thirty intermediate repeaters. The second way is to place the line and hybrid transformers in the shelves for supplementary equipment. The $2 \mathrm{~W} / 4 \mathrm{~W}$ repeaters are thereby supplemented with line and hybrid transformers on the four-wire side. In this case the extra balances must be placed outside the bay.

As mentioned previously the hybrid transformers are also designed as line transformers. This means that the wires in each incoming quad must be kept together right through to the transformers. The wiring to the transformers in the bay has therefore been made with quadded cable.

In addition to the repeater equipment the bay contains a telephone unit, speaker circuit jacks, alarm unit, terminal strips and power supply equipment.

## Shelf

The shelf fig. 5 provides space for mounting two $2 \mathrm{~W} / 2 \mathrm{~W}$ intermediate repeaters. A $2 \mathrm{~W} / 2 \mathrm{~W}$ terminating repeater is obtained by replacing one of the line and hybrid transformers in a repeater by a 4 W terminating unit and a $2 \mathrm{~W} / 4 \mathrm{~W}$ terminating repeater is obtained by replacing one of the transformers by a dummy unit. The shelf can be mounted in a bay or on a wall-mounting frame with power supply equipment.

## Supervision and Test Facilities

Test equipment is available for checking of balance so as to assist the putting into service of the repeaters. This equipment is in principle designed so that gain is introduced into the repeater until singing occurs.




Fig. 12
Gain of a mplifier without filter
I. without correction

II-IV. with correction together with filters I-V
V-VII. with correction together with filters VI

The balance checking equipment permits the introduction of this gain without having to change the normal setting of the amplifier. The singing margin can therefore be read off directly as the additional gain introduced.

Measuring equipment for checking of gain is also available to assist in maintenance of the repeater. This equipment is designed so that tests can be made without having to remove the amplifiers from service, i.e. they can be made as bridging measurements. So as not to cause interference with a call in progress the measurement is made for a short duration (pulse). Furthermore, the input and output of the test equipment are selective and arranged so that the impedance is low at the test frequency and high at other frequencies. In this way the interference effect of the test signal is further reduced.

## Technical Data

## Bay capacity

Alternative 1. 2 W/4 W terminating repeaters .... 60
Alternative 2. $2 \mathrm{~W} / 2 \mathrm{~W}$ terminating repeaters .... 60
Alternative 3. 2 W 2 W intermediate repeaters ... 30 or 60

Shelf capacity
$2 \mathrm{~W} / 4 \mathrm{~W}$ or 2 W 2 W repeaters ................. 2

## Gain



## Crosstalk

Effective crosstalk attenuation between two repeaters
is greater than

## Power supply

Alternative 1. Mains supply ....................... 127. $220 \mathrm{~V}, 50-60 \mathrm{c} / \mathrm{s}$
Alternative 2. Battery supply ....................... 24 V d.c.
Alternative 3. Battery supply ...................... 36 V d.c.
Power consumption per repeater ( 24 V supply) .... 1.2 W

Fig. 13
Frequency response of the low pass filters of the different amplifier variants

## $1300-2,000 \mathrm{c} / \mathrm{s}$

II $300-2,200 \mathrm{c} / \mathrm{s}$
III $300-2.400 \mathrm{c} / \mathrm{s}$
IV $300-2,800 \mathrm{c} / \mathrm{s}$
V $300-3,400 \mathrm{c} / \mathrm{s}$
VI $300-4,100 \mathrm{c} / \mathrm{s}$


## Amplifier

Gain .......................................2.2-2.9 N
Frequency range
Amplifier without filter . ............... 300-4,100 c/s
Amplifier with filter, either of alternatives: $300-2,000 \mathrm{c} / \mathrm{s}, 300-2.200 \mathrm{c} / \mathrm{s}$, $300-2,400 \mathrm{c} / \mathrm{s}, 300-2,800 \mathrm{c} / \mathrm{s}$, $300-3,400 \mathrm{c} / \mathrm{s}, 300-4.100 \mathrm{c} / \mathrm{s}$
Output power at 5 ; harmonic distortion is greater than ......................... 50 mW
Input/output impedance ................. 600 ohms
Line and hybrid transformer
Frequency range .................................. $300-3.400 \mathrm{c} / \mathrm{s}$
Line impedances, either of the alternatives: ........ 400, 600, 800, 1,200 1.600, 2,400 ohms

Impedance to amplifiers 600 ohms
Attenuation, line to amplifier 0.38 N

Crosstalk attenuation, side-phantom is not less than 11 N
$+W$ terminating unit
Frequency range ................................. $300-3,400 \mathrm{c} / \mathrm{s}$
Impedance, exchange side and amplifier side ...... 600 ohms
Attenuation, line to amplifier ...................... 0.38 N
Balancing unit (see fig. 10 b)


## Loading Equipment

The development of improved soft magnetic ferrite material has provided an opportunity for a thorough redesign of loading equipment made by the LM Ericsson Telephone Company. The use of ferrite pot cores and new methods of manufacturing coil windings and coil units has resulted in great savings in weight and volume of the loading equipment. The following article contains a survey of the new designs and diagrams to assist in the design of loaded cables.

L M Ericsson's first designs of loading coils which were made at the end of the 1920's consisted of a ring core of pressed fine grain soft magnetic iron dust. The magnetic characteristics of the core material led to coil designs having large volume and great weight, in particular for coils intended for the loading of long distance cables.

In subsequent years great improvements were made in the magnetic characteristics of the core material and the methods of manufacturing cores and coils. This resulted in the reduction of the loading coil volume and weight in different stages so that the coils which were made in the beginning of the 1950's had a volume and weight which were only a fifth of those for loading coils of the 1920's and in addition they had better technical characteristics from most points of view.

The technical and practical requirements for design improvements in loading coils built on a ring core were thereby mainly completely exploited.

The rapid development of soft magnetic ferrite material which occurred in the years after World War II has opened up new possibilities also in the field of design of loading coils. Especially in the most recent years, ferrite material has been produced having such magnetic properties that it is particularly suitable for cores of loading coils.

Soft magnetic ferrite material is produced by high temperature sintering of a mixture of extremely finely divided metallic oxides, usually oxides of iron, zinc and manganese.

The sintered ferrite material has high permeability ( $\mu=2000-2500$ ) and relatively low losses.

L M Ericsson has developed a new series of loading coils intended for loading of cables, based on cores of ferrite material. This series comprises the following three different types of coil:

1. Coil type REG 18 , intended for loading long distance cables. It is designed as a coil for loading pair or star quad cables or as a set of coils for loading the side and phantom circuits of multiple twin cables.
2. Coil type REG 16, intended for loading of toll and short distance pair cables and star quad cables.
3. Coil type REG 14. intended for loading of subscribers' cables.

## Cores and Coils

When using ferrite material in cores for loading coils, an air gap must be introduced into the magnetic circuit which reduces the effective permeability to about a tenth of that of the material alone. The reasons for this are the low loss resistance and high magnetic stability which are demanded of the loading coils. For reasons of crosstalk the air gap must be introduced as symmetrically as possible in relation to all the winding sections which leads to a


Fig. 1
X 2717
Section of a ferrite pot core with coil


Fig. 2
Winding diagram of a phantom coil
X 2718
pot type core being the best sorution. The pot type cores which are used in the new coil designs are included in the pot core series with optimum sizes agreed upon by the International Electrotechnical Commission (IEC). A cross-section of a pot core with coil in position is shown in fig. 1 with the air gap placed symmetrically in the centre limb of the core.

The sections of the coil are also wound using a new method which permits the lowest possible effective capacitance in the coil circuits for a given symmetry and balance requirement. The schematic design of the four sections of a loading coil for a phantom circuit is shown in fig. 2. The greater the number of mutual transpositions between coil sections, the better is the side symmetry and thereby the higher the crosstalk attenuation between the three speech circuits of the coil. At the same time the effective capacitance in the speech circuits increases, which is a drawback from the transmission point of view. The number of transpositions is therefore limited as far as the crosstalk attenuation permits and thereby the effective capacitance is reduced. The greatest effect from the point of view of symmetry is obtained if transpositions are made at the points of the coil body which are most affected by the magnetic leakage field from the pot core i.e. nearest to the transition between the cylindrical part of the core and its flat surface and also in the neighbourhood of the air gap in the centre limb.

The three different types of coil are shown in fig. 3. The main difference between the different types of coil is in the d.c. resistance and hysteresis factor; other things being equal, these properties determine the coil volume, the requirements in this aspect are however different for coils intended for different uses. For long distance cables with low attenuation requirements, thick copper conductors are as a rule used in the line cable and it is then justifiable to use loading coils having low loss resistance. For short cable circuits, however, thinner copper conductors are used in the cables and these can with advantage be loaded with coils having a fairly high loss resistance, as the resistance of the loading coils is only a few percent of the resistance of the line cable. A subscriber cable having a copper conductor diameter of 0.4 mm has its line resistance increased by only two percent when loaded with $30 \mathrm{mH} / \mathrm{km}$ and loading coils of type REG 14 .

A lower cost of loading is obtained by such a differentiation of the coil characteristics and suiting these to the requirements for different fields of use.

Fig. 3
Loading coils with ferrite pot cores L. to r., types REG 18, REG 16 and REG 14

The d.c. resistance and hysteresis factor of the different types of coil are given in table 1.

Table 1. d.c. resistance and hysteresis factor for different types coil.

| Coil type | d.c. resistance $(\Omega / \mathrm{H})$ | Hysteresis factor according to <br> CCITT $(\Omega / \mathrm{H} \cdot \mathrm{mA}$ at $800 \mathrm{c} / \mathrm{s})$ |
| :---: | :---: | :---: |
| $R E G 18$ | 35 | $10 / \overline{\mathrm{L}}$ |
| $R E G 16$ | 70 | $17 / \overline{\mathrm{L}}$ |
| $R E G 14$ | 175 | $30 / \mathrm{L}$ |





Fig. 5 X 2720
Schematic diagram showing location of the coils in a coil unit type ZLB 344

Fig. 6
X 8430

Coil units
L. to r., types ZLB 405, ZLB 344 and ZLB 114

Fig. 4 shows the increase in loss resistance with frequency for an 88 mH coil of the three different types.

All types of coil are manufactured in a large range of values of inductance from 20 mH to 177 mH . A special design of type REG 18 with extremely low hysteresis factor is manufactured for values of inductance between 4 and 14 mH for loading of lines intended for distribution of broadcast radio programs.

## Coil Units

Three loading coils are needed at each loading point when loading a multiple twin cable, one in each side circuit and one in the phantom circuit. These three coils must be matched to each other as far as crosstalk is concerned and it is therefore necessary to combine the three coils into one mechanically coherent unit, a quad coil unit.

On the other hand, loading coils for pair cables or side circuits in star quads can technically be made so that each coil forms a separate unit. From the manufacturing economics point of view, it is however, more advantageous to combine a number of these coils into one mechanical unit, a coil unit. Only for special purposes is it suitable to use coil units containing only one or two coils.

Loading coil units are cast in an epoxy resin which after curing forms a solid mechanical protection round the coils and also makes them practically insensitive to moisture.

Coils in a unit are located so that the centre axes of two adjacent coils are always at right angles. In this way, the magnetic coupling between the coils is reduced without the need of having special screening arrangements and the crosstalk attenuation is greatly improved. In addition, this location of the coils permits trimming of their inductance values by means of a ferrite rod which is pushed into the centre hole of the core after being cast in the coil units. The spread in inductance values can thereby be maintained within very close limits.

An example of the location of the coils in a unit is shown in fig. 5.
The outside dimensions of the unit have been determined from a module system. This has great advantages in that the method used for mounting the units in loading coil cases is the same for all types of unit and that one can mount several coil unit types in the same loading box simply. This is desirable for aerial cables containing long distance lines as well as local lines.

The weight and volume of the new coil units is only about a quarter of those of the previous design. Three different coil units are shown in fig. 6.



Fig. 7
X 4885
Loading coil case with joint box, earlier design

The different types of coil unit are given in table 2.

Table 2. Type designations for different coil unit

| Unit type | Contains the following coils <br> Qty |  |
| :--- | :---: | :---: |
| $Z L B ~ 112^{*}$ | 2 | Type |
| $Z L B ~ 1 / 3$ | 3 | $R E G 18$ |
| $Z L B 114^{* *}$ | 3 | $R E G 18$ |
| $Z L B 341$ | 1 | $R E G 18$ |
| $Z L B 342$ | 2 | $R E G 16$ |
| $Z L B 344$ | 4 | $R E G 16$ |
| $Z L B 405$ | 5 | $R E G 14$ |

* Broadcast radio program coils
** Side circuit/phantom coil unit for multiple twin cable.


## Loading Coil Cases

The great reduction in weight and volume of the loading coil units due to the introduction of ferrite pot cores means that loading coil cases can be designed using other principles than those used previously.

## Loading Coil Cases for Burving in the Ground

The earlier design of loading coil cases for cable plant buried in the ground consisted of a cast iron lower part in which the loading coil units were housed and an upper part of tinned sheet brass and shaped as a joint sleeve. In this sleeve the line cable conductors were connected to the conductors of the stub cable leading to the coil units in the lower part of the loading coil case. A cast iron protector was mounted outside the sleeve and this also served to secure the line cable to the loading coil case.

This type of loading coil case design is shown in fig. 7.
The new type of coil case design for buried cables is shown in fig. 8 .
This coil case consists of an inner part, the joint sleeve, of tinned sheet brass in which the loading coil units are mounted in a cradle secured by screws in the bottom of the lower part of the joint sleeve. The joint sleeve is designed with connecting muffs for the line cable and a longitudinal soldering channel for sealing with solder after jointing of the line cable has been completed. The outer casing of the loading coil case is made of sheet steel and provides mechanical protection for the joint sleeve and at the same time secures the line cable to the case.

Fig. 9 shows a case of this design jointed to a line cable. The outer casing of the box has been removed. The two ends of the line cable are connected to the lead-in wires on either side of the loading coil unit assembly.

The coil units are mounted in this assembly so that the axes of adjacent coils in different coil units are at right angles as shown in fig. 10. To make jointing more easy the lower part of the jointing sleeve can be removed from the assembly during this operation. The lid of the jointing sleeve is provided

Fig. 8
Torpedo type loading coil case
Dimensions in mm

Fig. 9 X 8432
Torpedo type loading coil case jointed into a cable
The external sheet protection removed and the case lid lifted


Fig. 10
X 2721
Schematic diagram of the location of coil units in a loading coil case

Fig. 11
X 8433
Loading coil cases for mounting in footway manholes or on poles

with a tapped hole to permit connection of pressurized gas and manometer for pressure test after sealing the whole loading coil joint. No insulation compound is used in the joint. The case design used for cable plant with gas pressure control is available in four different sizes, the largest of which can house up to 512 coils type REG 16.

The new loading case design has several important advantages over the earlier design. The shape and small size of the cases require very much smaller holes in the ground where they are to be installed - a particularly favourable feature when located in rocky terrain. If a coil is damaged by a lightning hit or similar in the cable, it can be easily changed on site without having to remove the case from the cable. The case weight is very low, one case containing 250 coils type REG 16 weighs only 51 kg whereas the corresponding case of earlier design weighed 180 kg .

## Loading Coil Cases for Mounting in Footway Manholes or on Poles

Loading coil cases placed in footway manholes or on poles are, as a rule, manufactured with one or two stub cables which are joined to the line cable in a T-joint or in two through joints, respectively. The previous designs of case for these purposes used cast iron.



Fig. 12
X 2722
Loading coil case installed in an aerial cable

The new case designs for placing in manholes or on poles are all shaped as cylindrical tinned brass tube. Owing to the low weight and volume of the loading coil units, it has been possible to use this case design in practice for up to 720 coils type REG 16 . The box is hermetically sealed and may be used for cable plant with gas pressure control.

The stub cable has copper conductors insulated with two layers of paper The conductors are either of multiple twin type or in pairs, depending on whether the loading coil case contains coils for side-phantom loading or individual coils for loading of the pairs. The cable sheath is of lead alloy and is of extra thickness to be able to withstand the rough treatment to which it is exposed during installation. There is a polythene sheath on the outside of the lead sheath to act as a corrosion protector.

Fig. 11 shows two different sizes of loading coil cases.
Fig. 12 shows one of these loading coil cases mounted on a pole and jointed to the aerial cable.

In a special design of these types of case, the case of the loading coil case consists of a polythene tube and the stub cable has polythene insulated conductors and polythene sheath, intended for jointing to a cable having plastic insulated conductors and polythene sheath.

## Joint Case Loading

When loading a cable having a few circuits it is an economic advantage to place the loading coil units in the jointing tubes used for joining lengths of the cable instead of using a separate loading coil case. The small dimensions of the new loading coil units make this method of loading suitable for up to 50 coils type REG 16 in the same joint.

## Design of Loaded Telephone Cable Plant

Loading of a cable reduces its attenuation in the voice frequency band.
Two typical examples of this effect are shown in fig. 13. The amount of reduction in attenuation is dependent on how the loading is carried out and what transmission properties are otherwise required of the loaded line. The deciding factors for the transmission quality of the loaded cable are its attenuation, cut-off frequency and velocity of propagation. When the permissible values of these primary data have been decided upon, the requisite values of loading coil inductance, distance between coils, cable capacitance and conductor diameter can be calculated.

A diagram is shown in fig. 14 from which can be read the necessary design of the cable and loading to obtain stated cable primary constants and vice versa.

The following symbols are used in the diagram

```
fo}==\mathrm{ cut-off frequency in kc/s
s = distance between loading coils in km
v= propagation velocity in km/s
c = cable capacitance in nF/km
l = amount of loading in mH/km
Z = characteristic impedance of the loaded line
a= attenuation of the loaded line at }800\textrm{c}/\textrm{s}\mathrm{ in mN/km
\mp@subsup{\emptyset}{\textrm{Ca}}{}
```


## Examples

A: A telephone line with

$$
\begin{aligned}
Z & =1600 \Omega, f_{0}=4000 \mathrm{c} / \mathrm{s} \\
\mu & =15000 \mathrm{~km} / \mathrm{s}, \quad \alpha<35 \mathrm{mN} / \mathrm{km} \\
l & =107 \mathrm{mH} / \mathrm{km} \\
c & =42 \mathrm{nF} / \mathrm{km}
\end{aligned}
$$

Diagram 1: $\quad l=107 \mathrm{mH} / \mathrm{km}$

Diagram 2: $s=1.2 \mathrm{~km}$
i.e. loading coil inductance $L=l \times s=128 \mathrm{mH}$

Diagram 3: $\emptyset_{c_{u}}=0.7 \mathrm{~mm}$
B. Given a cable having $c=35 \mathrm{nF} / \mathrm{km}$ and $\emptyset_{\mathrm{Cu}}=0.9 \mathrm{~mm}$, determine the attenuation constant when $v=25000 \mathrm{~km} / \mathrm{s}$
Diagram 1: $\quad Z=1140 \Omega$
Diagram 3: $\quad \alpha=25 \mathrm{mN} / \mathrm{km}$
What distance $s$ between loading coils shall be used with $L=88 \mathrm{mH}$ ?
Diagram 1: $\quad l=46 \mathrm{mH} / \mathrm{km}$

$$
s=L / l=88 / 46=1.91 \mathrm{~km}
$$

What is the cut off frequency $f_{0}$ ?
Diagram 2: $f_{o}=4200 \mathrm{c} / \mathrm{s}$

It will be seen that in the formulae for diagram 3, the attenuation which arises due to dielectric losses in the cable is not included in the stated attenuation graphs. This attenuation lies between 0.5 and $1.0 \mathrm{mN} / \mathrm{km}$ at $800 \mathrm{c} / \mathrm{s}$ for normal paper insulated cables.

The diagram can be used to advantage when making economic decisions in the design of a loaded cable network, when the consequences of tightening or relaxing the transmission requirements can be read off and applied to the


Fig. 14 X 8444
Diagram used for the design of loading on cables

factors which decide the cost i.e. cable design, distance between loading coil cases and the cost of installation of the loaded cable network.

Certain practical limitations should be respected when making a design. The characteristic impedance of the loaded line should not be greater than 2000 ohms. For values higher than this, problems of crosstalk arise which are expensive to solve. Extreme values of cable conductor diameter and capacitance should be avoided.

## Patents

1. Swedish patent 173372
"Method of winding an inductance coil having two or more winding arms, and the inductance coil wound using said method.'
2. Swedish patent application 473/62
"Loading coil case arranged in a casting resin."
3. Swedish patent application 53462
"Method of procedure for impregnation of coils and their casting in hardening resins."

# New Overvoltage Protectors for Subscribers' Installations 

A HENCKEL, TELEFONAKTIEBOLAGETLLMERICS SON, STOCKMOLM

The continued spread of the telephone into remote and isolated places has brought the question of the reliability and safety of line plant into new prominence. This factor. and the increased demands of subscribers for quick service in the repair of faults, has necessitated modern and efficient means of protection for subscribers' installations, which are described in this article.

With the increasing substitution of open wire by cable plant the need for overvoltage protection of subscribers' installations has greatly diminished in cities, especially in the central districts. The conditions are otherwise in the countryside. Even if open wire lines are disappearing there as well and being replaced by overhead cable, damage to telephone sets by lightning or by overvoltages induced from power lines is still very common in rural areas. And there is the attendant risk of fire and danger to human life unless adequate protection is provided.

This, to be sure, is no new phenomenon. Damage to telephone plant by lightning has been known, and lightning protection in one form or another has existed, as long as the telephone itself. But experience has shown that the protection provided has not always been adequate. Modern protector apparatus has therefore been developed which provides a far better guarantee than hitherto of good telephone service and reduces damage from overvoltages to a minimum.

In the telephone set the main risk is breakdown of the insulation in a capacitor or springset, but trouble may occur also in the induction coil, receiver, bell etc. The cause of these faults is usually a potential difference between the two legs of the telephone line. When fire has broken out, it has generally been because of flashover between the instrument cord and, for instance, a radiator, which has set fire to a curtain or the like.

For the protection of telephone sets a transversal overvoltage protector has been designed. This consists of a combination of a gas discharge tube and a low pass filter (fig. 1). The low pass filter, which is connected between the gas discharge tube and the telephone set, protects the telephone apparatus against high frequency transient oscillations of high amplitude which may be set up when the overvoltage protector comes into operation. The gas discharge tube, a rare gas tube, ignites when the overvoltage between the line legs attains or exceeds the striking voltage level and short-circuits the line. As soon as the overvoltage has been eliminated, the rare gas tube is extinguished, the shortcircuit is removed and the line is restored to use. The rare gas tube withstands several hundred striking operations at heavy overvoltage and therefore has a considerable working life. As will be seen from fig. 1, the transversal overvoltage protector is connected across the two legs of the line-hence its name.


Fig. 2
X8445
Circuit diagram of combination of heavy duty protector and transversal overvoltage protector


Fig. 3
Transversal overvoltage protector NFD 50101


Especially when there are earthed objects such as a radiator, water pipe or power conductor in the immediate vicinity of the telephone set, the transversal overvoltage protector should be supplemented by a 3-pole heavy duty protector (fig. 2), placed out-of-doors, to protect the subscriber's installation against high longitudinal overvoltages between either or both legs of the line and earth. The heavy duty protector operates only at voltages of more than three thousand volts. Its earth electrode should be connected to the same point as other earthed objects through which discharge may take place.

## Transversal Overvoltage Protector NFD 50101

Fig. 3 shows a transversal overvoltage protector NFD 50101, the circuit diagram of which is shown in fig. 1. It consists of a block of ivory-white epoxy resin, $8.5 \times 4 \times 2.5 \mathrm{~cm}$, in which the rare gas tube and the filter circuit elements are embedded. NFD 50101 has two screw terminals marked 'L' for connection to the line and two marked ' $A$ ' for connection to the subscribers apparatus. The unit has a styrene dust-cover. It is fitted close to the telephone wall terminal and is connected between the latter and the line.

## Heavy Duty Protector NFA 2022

This longitudinal protector NFA 2022 is shown in fig. 4. It consists essentially of three cylindrical electrodes separated by air gaps. The electrodes are made of a copper alloy which is especially resistant to high power flashover. Should the electrodes nevertheless be deformed by a heavy flashover. they can quickly be rendered operative again. They need merely be unscrewed and turned until new and effective spark gaps are formed between unburnt portions of their surfaces, and are then screwed tight again. If the flashover was so heavy as to weld the electrodes together, new electrodes can be inserted. All this can be done on site without needing to take down the protector from its mounting.

## High Protection-Low Maintenance Cost

As we have seen. subscribers may be exposed to the risk of serious disturbances or even personal injury from atmospheric or other overvoltages induced in their telephone sets. If transversal overvoltage protectors NFD 50101


Heavy duty protector NFA 2022 right) with cover removed
-supplemented, if necessary, by heavy duty protectors NFA 2022-are fitted at the subscribers premises, the subscribers will be guaranteed the best possible protection against service failure and against danger to life and property. The maintenance costs of the telephone administration are also reduced. Rural subscribers are often remote from their telephone exchange or district maintenance service, and the cost of each service turn-out is high. If the telephone itself is damaged by lightning and, consequently, the fire brigade or other urgent assistance cannot be summoned in time, the effect may be catastrophic. The form of protection described can save much time and money. An investment of this kind is always warranted, and the question for the telephone administration, therefore, is generally not: "Can we afford this investment?"-but: "Can we afford to be without modern and efficient subscriber's protector units?"

## Cidfot NEWS from <br> All Quarters of the World



## African Monarch Visits L M Ericsson



## President Nyerere at L M Ericsson

Dr. Julius K. Nyerere, President of Tanganyika, made an official visit to Sweden in September, in the course of which he called on L M Ericsson at Midsommarkransen.

Mr. Sven T. Aberg bid the President and his suite-which included a Swede. Barbro Johansson, member of the Tanganyikan parliament-welcome to L M Ericsson. After a brief account of the Ericsson group and the development of telephony, the visitors were shown over the exhibition. At the conclusion of his visit the President was presented with three Ericofons in white, blue and red.
(Above) Mr. Aberg greeting President Nyerere on his arrival. (Left) The President tries out an Ericofon.

King Mwambutsa IV of Burundi paid a call at L M Ericsson, Midsommarkransen, during his official visit to Sweden. Mr. Sven T. Aberg greeted the King on his arrival (photo, right) and, after a brief presentation of L M Ericsson's activities, the King and
his suite were shown round the Exhibition Room. They also made a tour of the factory; the picture below shows Mr. Eric Lundqvist explaining a detail of the manufacture to the King. At the end of his visit the King was presented with an Ericofon.



## L M Ericsson Factory Opened at Visby

L M Ericsson's new factory at Visby on the island of Gotland was opened on June 28. The ceremony was presided over by the chairman of the county council, Martin Wahlbäck. in the presence of the entire staff and some 40 guests.

The Visby plant is the 19th of the group's Swedish factories outside the Stockholm area. It is a new example of the policy of decentralization pursued by the company for many years.

Its operations will include cable forming; wiring and testing of relay sets; winding. mounting and testing of relays, serial production of mechanical parts, enamelling and electroplating

The Visby factory-45th of ail Ericsson factories-covers more than 100000 sq.ft. on one level. The area of the site is over $500000 \mathrm{sq.ft}$.

In a speech at the opening ceremony. Mr. Hugo Lindberg - in thanking all those who had cooperated in the undertaking-stated that the establishment of a factory in Gotland had aroused some surprise since the island was earlier thought to be more or less "impossible" as an industrial location. But L M Ericsson has every reason to be satisfied with its choice. and the factory will be a valuable asset to the local community. With its 550 employees it will be Gotland's largest industry.

## Rural Automatization in Lebanon

Lebanon was declared an independent state in 1946 and has undergone a rapid development since that time. It possesses a particular importance as financial centre for the Middle East. It is not only its mountains that have earned it the reputation of being the Switzerland of the Middle East.

The rapidity of progress is well illustrated by the development of telecommunications. In 1950 Lebanon had about 13300 telephones, all connected to manual exchanges. The first automatic exchange was opened in 1954, an Ericsson 500 -selector exchange. Since 1950 the number of telephones has been more than quintu-


Appointment to North Electric
Brigadier-General John A. Mc David joined LM Ericsson's subsidiary. North Electric Company, Galion. Ohio, on September 1 as assistant to the president.


Brigadier McDavid recently retired on pension from the United States Air Force, in which he had been Director for Communications-Electronics. He is therefore an extremely valuable asset to the North Electric organization in which he will be in charge of special missions, directly responsible to the president.
pled, being 68500 on January 1, 1962, of which 94.4 per cent automatic. Lebanon occupies a foremost position in telephony among Asiatic countries.

An extensive project of rural automatization is now under way. The project will comprise some 30 Ericsson ARK crossbar exchanges. At the same time the trunk network is being successively expanded, and in December 1963 it is expected that direct connections will be opened between Beirut and Tripoli.

A new automatic exchange ( 2000 lines AGF) has been opened at Zahlé. The Director General of the Lebanese P.T.T., M. Chemali, looks on while the Prime Minister, M. Karamé, cuts the symbolic tape, accompanied by the Minister of Communications, M. René Mouawad (behind the Prime Minister, right) and the Minister of Agriculture, M. Joseph Skaff (behind Prime Minister, left), and other prominent persons.


# New Automatic Exchange Opened in United Arab Republic 

Telecommunications in the United Arab Republic are in a state of rapid development. A further advance was made in July with the opening of a new 10000 -line Ericsson crossbar automatic exchange, Opera, in Cairo.

The switchroom (above) is being inspected by H. E. the Minister of Communications, Dr. Mustafa Khalil, the Director General of UARTO, Dr. Mahmoud Mohamed Riad, and Mr. Arne Stein. L M Ericsson.
(Below) In conjunction with the opening of the Opera exchange Mr. Stein made a visit to UARTO's central archive for installation and maintenance documents. This archive is exemplary in its organization and Mr. Stein was greatly impressed with the meticulous order maintained in this important function.



In August L M Ericsson received a visit from General Pachirn Nimibutr, head of Telephone Organization of Thailand, on a journey with his family to Sweden and other countries. General Nimibutr is seen above signing his name in the visitors' book.

Below are seen the Ethiopian Ambassador to Sweden, Mr. Abate Agede (centre), and Counsellor Assefa Temtim, who were given a glimpse into telephone history by Mr. E. Lundqvist during a visit to L M Ericsson's headquarters.



# Equipment for Long Distance Carrier Circuit in Brazil 

After lengthy planning work by LM Ericsson and the Brazilian telephone company TELEOESTE, one of the longest open wire carrier circuits in the world has been opened between Campo Grande and Sāo Paulo.


The carrier system is type ZAA 8 for eight telephone channels. Over a distance of nearly 500 miles the circuit runs on the only open-wire pair that exists between Campo Grande and Bauru. This line belongs to the railway and was built for telegraphy; it is an entirely untransposed 3.2 mm copper wire line with the wires spaced about 16 inches apart and follows the railway through the most desolate country.

From Baurú to São Paulo, Brazil's second city, a distance of some 220 miles, the circuit runs on open wires of very good quality belonging to Companhia Telefonica Brasileira (CTB).

The circuit is now being prolonged by the addition of a ZAAF 4 system for four telephone channels. also sup-
plied by LM Ericsson. It is to be installed between Campo Grande and Corumba, about 300 miles, again on the railway's open wire line. With this latter section a direct connection will be obtainable from Brasilia via Rio de Janeiro and Sāo Paulo to Corumba on the Bolivian border, a distance of almost 2500 miles.

There have been many difficulties to overcome on the Bauru-Corumba section. No less than 115 filters had to be connected along the line to avoid disturbance of the railway telegraphy. Eight diesel generators were

## Training in C. T. C.

The Swedish Railways have very extensive facilities for training their personnel. Training in signalling technique is given at the Signals School at Ängelholm, where entire interlocking plants have been installed and various types of signalling equip. ment have been got together.

The railway signalling course includes the remote control of signals by C.T.C. The training of personnel for C.T.C. maintenance was previously done at L M Ericssons Signalaktiebolag in Stockholm, but since 1963 the courses have been arranged at Ängelholm. The Swedish Railways have purchased from LM Ericsson a demonstration plant for teaching the methods of fault tracing and maintenance of C.T.C. equipment and also for instructing traffic and engineering personnel in C.T.C. operation.
(Left) Mr. Sigvard Nilsson of the Swedish Railways instructing a group of signal repairmen in C.T.C.
installed for the intermediate repeater stations.

Through precision in planning and installation the quality of the telephone channels has been brought up to international standard, which is a great advance on what would be expected with untransposed line of this type and over such distances.

Mesbla is the name of the largest chain of department stores in Brazil, with branches in all important towns. L M Ericsson has delivered to the main store in Rio de Janeiro a 400 -line crossbar P.A.X., system ARD 231. (Photo right).



## Associated and co-operating enterprises

## - EUROPE.

Denmark
L M Ericsson A/S Kobenhovn $F$ Finsensvej 78, tel: Fa 6868, Igm: ericssons
Telefon Fabrik Automatic A/S Kabenhovn K, Amaliegade 7, tel: C 5188, Igm: automatic
Dansk Signal Industri A/S Kabenhovn F, Finsensvej 78, tel: Fa 6767, tgm: signaler

## Finland

O/Y LM Ericsson A/B Helsinki, Fabianinkatu 6, tel: $48282, \operatorname{tgm}$ :
ericssons, telex: 57-12546
France
Société des Téléphones Ericsson Colombes (Seine), Boulevard de la Finlande, tel: CHArlebourg 35-00 igm: ericsson
Paris 17e, 147 Rue de Courcelles, tel: CARnot 95-30, Igm: eric
Ateliers Vaucanson, Paris XX, B. P. 28.20.1el: MENilmontan1 83-40, Igm: atelcanson

## Great Britain

Swedish Ericsson Company Ltd. London, W. C. 1, 329 High Hol born, tel: HOLborn 1092, tgm: eleric
Production Control (Ericsson) Lid. London, W. C. 1, 329 High Holborn, iel. HOLborn 1092 Holborn, productrol holb

## Italy

SETEMER, Soc. per Az, Romo, Via G. Paisiello 43, lel: 868.854, 868.855, tom: selemer

SIELTE, Soc. per Az. Romo, C. P. 4024 Appio, tel: 780221, tgm: sielle
FATME, Soc, per Az. Romo, C.P. 4025 Appio, tel: 780021, tgm: latme

## Netherlands

Ericsson Telefoon-Maatschappij N.V. Rijen (N.Br.), tel: 01692-555, tgm: erictel, telex: 44-14354

Voorburg-Den Haag, 227 Koningin Julianalaan, tel: 814501 , tgm: erictel-haag, telex: 31109

## Norway

A/S Elektrisk Bureau Oslo NV, P.B. 5055, tel: Centralbord 461820 tgm: elektriken, telex: 56-1723
A/S Industrikontroll Oslo 1 Teatergaten 12, tel: Centralbord 335085, tgm: indtroll

A/S Norsk Kabelfabrik Drammen P. B. 205, tel: 1285, igm: kabel

A/S Norsk Signalindustri Oslo 565494 tgm: signalindustr

## Portugal

Sociedade Ericsson de Portugal Lda. Lisboa, 7, Rua Filipe Folque
fol. 57193, tgm : ericsson

## Spain

Cia Espanola Ericsson, S. A. Madrid 13. Torre de Madrid 3er piso, oficina 9, Plaza de España, tel : 241 1400, tgm : ericsson

## Sweden

Telefonaktiebolaget L M Ericsson Stockholm 32, tel: 190000 , tgm: 1. lefonbolaget, telex: 19910

AB Alpha Sundbyberg, tel: 282600 , igm: aktiealpha-stockholm
AB Ermi, Karlskrona 1, tel: 23010 Igm: ermibolag-kariskrona AB Rifa Bromma 11, tel: 262610, tgm: elrifa-stockholm
AB Svenska Elektronrör Stockholm 20, tel: 440305 , igm: electronics
L M Ericssons Driftkontrollaktiebolag Solno, tel: 272725 , tgm: ericdata-stockholm
L. M Ericssons Signalaktiebolag Stockholm Sv, tel: 680700 , 1 gm : signalbolaget

L M Ericssons Svenska Försäli-
877, tel: $223100,1 \mathrm{gm}$ : ellem
Mexikanska Telefonakliebolaget Ericsson Stockholm 32, tel:190000 tom: mexikan

Sieverts Kabelverk $A B$ Sundbyberg, lel: 282860 , Igm: sieverts-fabrik-stockholm
Svenska Radioaktiebolaget Stockholm 12, Alströmergatan 14, tel: 223140 , tgm: svenskradio

## Switzerland

Ericsson Telephone Sales Corp. AB, Stockholm, Zweignieder lassung Zürich Zürich, Postfach Zürich 32, tel: 325184, tgm: tel-

West Germany
Ericsson Verkaufsgesellschaft m.
b. H. Düsseldorf, Postfach 2925 tel: $84461, \operatorname{lgm}$ : erictel, telex: 41-8587979

- ASIA.


## India

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Calculla, P. O. B. 2324, tel: 45 . 4494, $\operatorname{tgm}$ : inderic

## Indonesia

Ericsson Telephone Sales Corporation $A B$ Bandung, Dialan Dago 151, tel: 8294, 1 gm : javeric

Djakarta, Dialan Gunung Sahari 26, tel: Kola 22255, Igm: javeric

Lebanon
Telefonaktiebolaget L M Ericsson. Technical Office Beyrouth, Rue du Parlement, Immeuble Bisharal, tel: 252627, 1 gm : ellem

Turkey
Ericsson Türk Ticarel Lid. Sirketi Anka.a. Rumeli Han, Ziya Gokalp Cad., tel: $23170, \mathrm{tgm}$ : ellem
Istanbul, Istanbul Bürasu, Liman Han, Kal 5, No. 75, Bahçekapi, tel: $228102,1 \mathrm{gm}$ : ellemist

## Egypt (UAR)

Telefonaktiebolaget LM Ericsson, Egypt Branch Coiro, P. O. B. 2084, tel: $49777, \mathrm{tgm}$ : elleme

## Northern and Southern Rho-

 desia, NyasalandLM Ericsson Telephone Co. (Ply.) Lid. (Branch Office of LM Ericsson Telephone Co. Pty. Lid. in Johannesburg) Bulawayo, Southern
Rhodesia, P.O.B. 1974, tel: 64704 , Rhodesia, P.

South Africa, South-West Africa
L M Ericsson Telephone Co. Pty. Lid. Johannesburg. Transvaal, P. O. B. 2440 , tel: $975-3615$, Igm: ericofon

Tunisia
Telefonakliebolaget LM Ericsson, Technical Office Tunis, Boite Postale 780, tel: 240520, Igm:ericsson

- AMERICA

Argentine
Cla Ericsson S. A. C. I. Buenos Aires, Casilla de correo 3550 , tel: 332071 , Igm: ericsson
Cía Argentina de Teléfonos S. A. Buenos Aires, Perú 263, tel: 3050 11, tgm: catel
Cla Entrerriana de Teléfonos S. A. Buenos Aires, Perú 263, tel: 3050 11, tgm : catel
Indusirias Eléctricas de Quilmes
S. A. Quilmes FNGR, 12 de Oclubre 1090, tel: 203-2775, tgm: indelqui-buenosaires

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Ericsson do Erasil Comércio e Indústria S. A. Rio de Janeiro, C. P. 3601, tel: 43-0990, 19 m : ericsson, telex: Rio 155

Canada
LM Ericsson Lid. Montreal 9. P.Q., 2300 Laurentian Boulevard, City of St. Laurent. tel: 331-3310, tgm: caneric, telex: 1-2307

## Chile

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## Igm: ericsson

Ecuador
Teléfonos Ericsson C. A. Quito Casilla 2138, tel: 16100, igm ericsson
Guayaquil, Casilla 376, tel: 16892, tgm: ericsson

## Mexico

Teléfonos Ericsson S. A. Méxica D.F., Apartado 9958, tel: 464640 tgm: coeric
Industria de Telecomunicación S.A. de C.V. México 6, D.F., Londres No. 47, tel: 250405 , tgm: in dustel

## Peru

Cla Ericsson S. A. Lima, Apariado 2982, tel: 34941 , Igm: ericsson Soc. Telefónica del Perú, S. A Arequipa, Apartado 112, tel: 6060 tgm: telefonica

## Uruguay

Cla Ericsson S. A. Montevideo Casilla de Correo 575, tel: 9-26 11, tgm: ericsson

## USA

The Ericsson Corporation New York 17. N. Y., 100 Park Avenue tel: Murray Hill 5-4030, tgm erictel, telex: NY 224135
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Cla Anónima Ericsson Caracas Apariado 3548, tel: 543121, Igm ericsson
Teléfonos Ericsson C. A. Caracas Apartado 3548, tel: 543121, tgm: tevela

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## Belgium

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## Greece

"ETEP" S. A. Commerciale \&
Technique Athens 143, 57, Aka-
dimias Sireet, tel: 6299 71-75, tgm: aeter-athinai

Iceland
Johan Rönning H/F Reykjovik, P. O. B. 45 , tel: 10632 tgm: rönning
Ireland
Communication Systems Lid. Dublin 4. 138 Pembroke Road, Ballsbridge, tel: 680787 tgm : crossbar

## Yugoslavia

Merkantile Inozemna Zastupsiva Zagreb. Pošt pretinać 23, tel: 36941, 1 gm : merkantile, telex: 02-139

Burma
Burma Asiatic Co. Ltd., Ericsson Department Rangoon, P.O.B. 1008 , tel: $10999, \mathrm{tgm}$ : ericsson

## Cambodia

The East Asiatic Company Lid. Phnom-penh, P.O.B. 129, tel: 762-1070-1071, tgm: pyramide

## Ceylon

Vulcan Trading Co. (Private) Ltd. Colombo 1. New Caffoor Building. 40. Church Streel, tel: $36-36$, tgm:

Cypru
Zeno D. Pierides Larnaca. P.O.B. 25, tel: 2033, tgm: plerides

Swedish Levant Trading (Elie
Hong Kong
The Swedish Trading Co. Lid. Hongkang, P. O. B. 108, tel: 35521-5, tgm: swedetrade

Iran Swedish Company AB Teheran, Khiabane Sevom Esfand 28, tel: 36761 , tgm: iranoswede

Iraq
Usam Sharif Comnany W.L.L.
Baghdod, Sinalk-Rashid Street, tel: 870 31, 1 gm : alhamra

## Japan

Gadelius \& Co. LId. Tokyo C,
P. O. B. 1284, tel: $408-2131, \mathrm{tgm}$ :
goticus, telex: 22-675
Jordan
The Arab Trading \& Development Co., Lid. Amman, P. O. B. 1,

## Korea

Gadelius \& Co. LId. Seoul, I. P. O.
Box 1421,tel: 2-9866, tgm: gadeliusco
Kuwait
Latiff Supplies Ltd. Kuwait, P. O. B. 67, tel: 2404, Igm: lalisup

## Lebanon

 fel: 231624, Igm : skefko
## Malaysia

The Swedish Trading Co. Lid. Singopore 1, 42 Chartered Bank Chambers, Battery Road, tel: 94362 , Igm: swedetrade

Pakistan
Vulcan Industries Lid. Karachi City, West Pakistan, P. O. B.

Philippines
U.S. Industries Philippines Inc. Manila P. R., P. O. B. 125, tel: 8893 51, Igm: usiphil
Saudi Arabia Mohamed Fazil Abdulla Arab Jeddah, P. O. B. 39, tel: 2690 , 1 gm : arab

## Syria

Georgiades, Moussa \& Cie Damas, Rue Ghassan, Harika, tel: 1-02-89, tgm: georgiades

## Thailand

Ericsson Agency Office, Telephone Organization of Thailand Bargkok. Ploenchitr Road, tel: 57036-38, tgm: telthai

## Vieinam

Vo Tuyen Dien-Thoai Viet-Nam, Saigon, 34 Dai-lo Thong-Nhut, tel: 20805, Igm: telerad


[^0]:    Part of the repeater bay

