ERICSSON REVIEW

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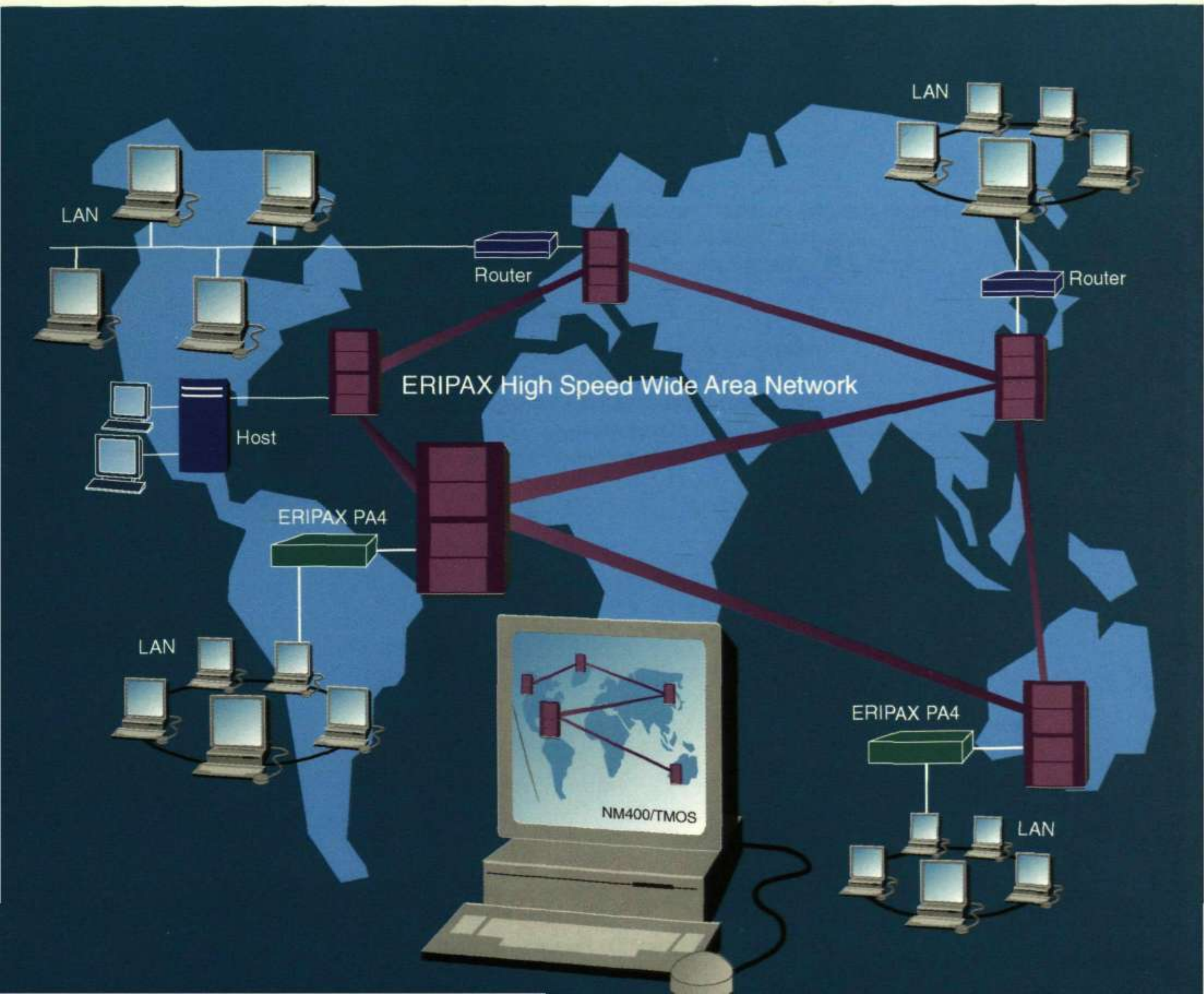
A New Method of Testing Optical Fibres and Cables
The AXE Transgate, a New Transit Exchange
TELECOOL, a New Generation of Cooling Systems for Switching Equipment

4 1992



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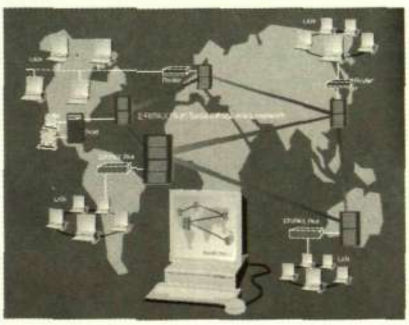

Cover
ERIPAX is a new-generation wide-area data network. It combines high-performance X.25 data networking with the new, high-speed frame relay standard, to provide backbone networks with the high capacity and short response time needed in today's distributed computing environments

Frame Relay service in ERIPAX

Göran Ingemarsson and Bo Karlander

ERIPAX is Ericsson's data network system for packet switching. The first network was put into operation in 1983; today, 150 customers in 35countries are operating ERIPAX networks.

The authors describe ERIPAX and its use, and discusses the ongoing and future development of the system: improved packet switching service and introduction of the new communications service called Frame Relay.

data communication systems
computer networks
packet switching

In the late 70s, CCITT drew up its recommendation X.25, which provided a platform for the development of data networks based on packet switching and using virtual connections. During the 80s, packet switching was introduced in many public and private data networks, and it is now a well-established, dependable and globally accessible network service.

The introduction of workstations and client server technique has increased the transmission speed in Local Area Networks from a few kbit/s to several Mbit/s. This, in turn, has created a need for effective methods of handling higher transmission speeds in Wide Area Networks (WAN) as well.

A solution in the form of a new type of general data communications service called Frame Relay has been widely adopted. In 1991, ANSI (a US standardisation body) established a set of standards for this service, and CCITT has adopted new recommendations compatible with the ANSI standards. An article in Ericsson Review 1-2 1992,[1] describes the basic principles of Frame Relay service.

ERIPAX – Ericsson's packet switching network

Ericsson's packet switching system, ERIPAX, comprises a family of packet switching exchanges for use in WANs. ERIPAX features open, standardised interfaces between network and terminal. The main standard for these interfaces is CCITT's recommendation X.25. In addition, ERIPAX offers interfaces for a number of de facto standards, including protocols defi-

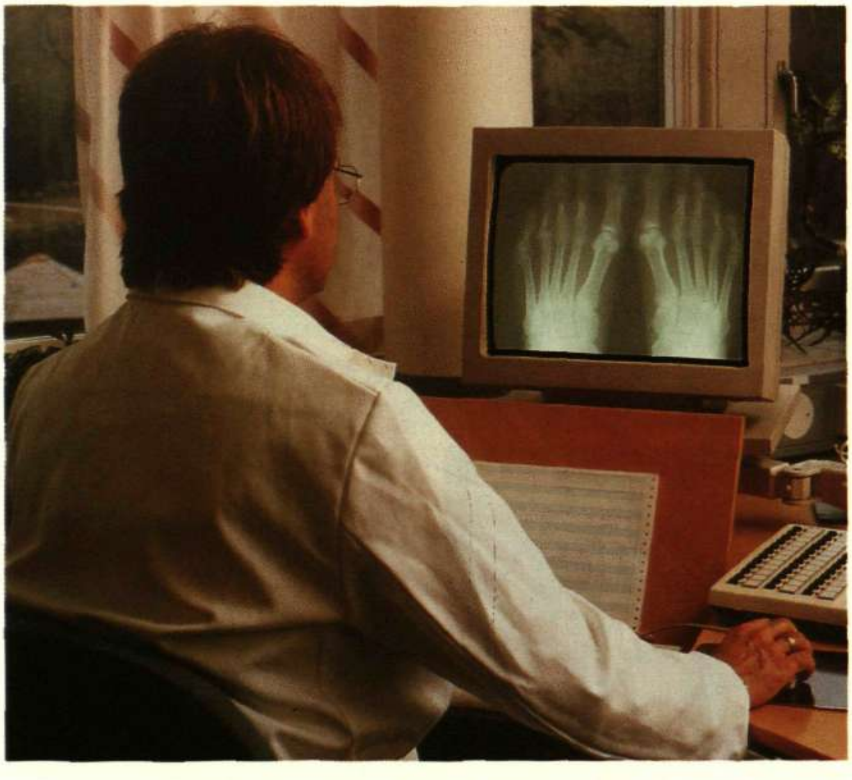

Fig. 1
Broadband applications require high-speed inter-LAN communication through the Wide Area Network

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BO KARLANDER
Ericsson Business Communications AB

ned by IBM's communications architecture SNA. An ERIPAX network can cooperate with other packet switching networks by using CCITT's X.75 protocol for intercommunication between X.25 networks.

ERIPAX functionality

In an ERIPAX network, data communication is performed over permanent or switched virtual connections. Addressing procedures for switched traffic include selection by name and hunt group. Allocation of priorities to individual users and closed user groups is another example of a basic function provided by an ERIPAX network. Additional services and adaptation to the communication protocols of different terminals are implemented by means of optional functions, Fig. 2. An example is Packet Broadcast, which permits simultaneous transmission of the same information to a large number of terminals in the network, and checking that the information has reached all recipients.

Other optional ERIPAX functions are connection to public packet switching networks, the use of password and call-back procedures for authorisation checks, and charging and statistics functions.

The software is modular in design, and existing ERIPAX nodes can be upgraded with optional functions as required.

System architecture

The basic components of an ERIPAX network node are line units and computer modules. By combining these units and modules in different ways, the nodes can be adapted to varying requirements in terms of capacity, functionality and fault tolerance.

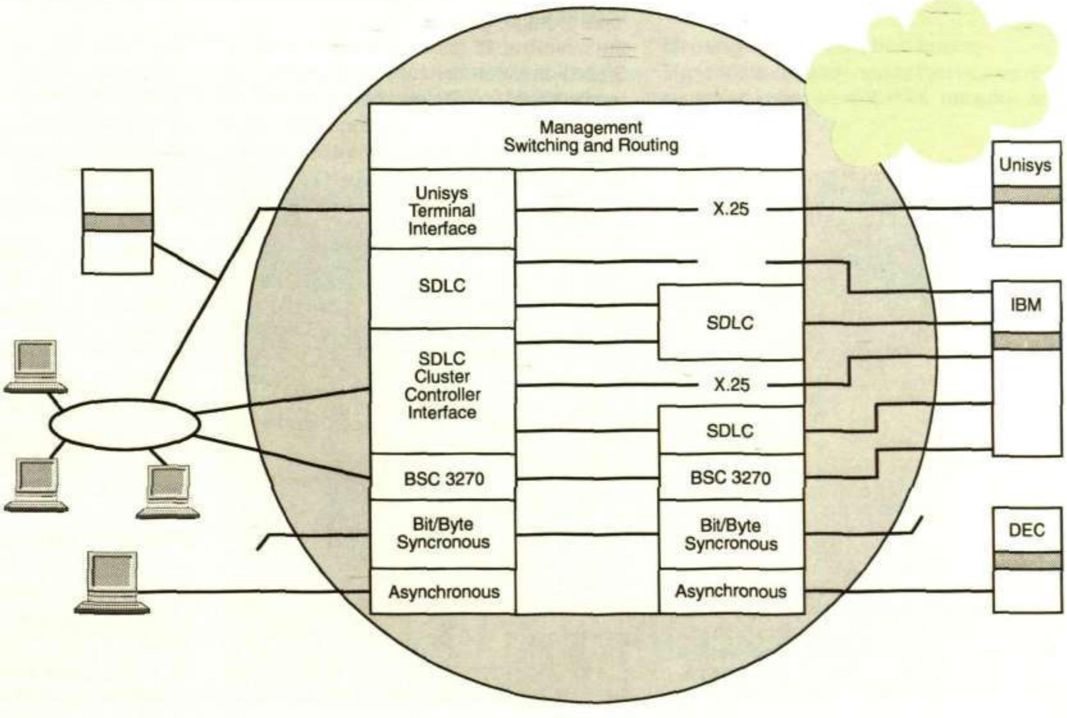
Connections

Connections can be made via standard interfaces – V.24, V.35, V.36, X.21, G.703, etc. – for leased circuits, and via public telephone networks, circuit-switched data networks or ISDN.

Line units

External lines are connected to ERIPAX's line units, which contain processors for the handling of protocols. The line units are connected to the central system parts in

Fig. 2
ERIPAX supports a broad range of communication protocols enabling different vendors' equipment to utilise a common network



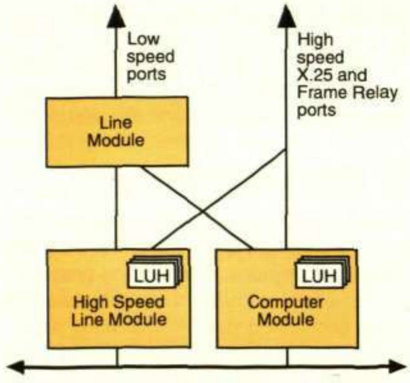


Fig. 3
The FPS 550 model is based on a flexible and fault-tolerant architecture

different ways, depending on the application and on the performance requirements.

One family of narrowband line units (LU) is optimised for line speeds of up to 64 kbit/s, and each LU can connect 2 to 8 ports, depending on the capacity for which it has been equipped. A group of LUs connected to the same I/O bus forms a line module (LM). The line module can be connected to duplicated computer modules to provide enhanced dependability.

A new generation of line units, called LUH, incorporates a 32-bit processor, a 2 Mbyte local storage, and powerful LSI circuits for the handling of protocols. An LUH has 3 ports and can connect bit-oriented protocols (X.25/X.75) for speeds of up to 2 Mbit/s; in some applications the maximum speed is 8 Mbit/s. LUH is a basic component for the implementation of Frame Relay service in ERIPAX. Because of the need for greater bandwidth, line units of the LUH type are not connected to the I/O bus but directly to the same backplane bus as the computer module. Very high system and port dependability is achieved by duplicating both computer modules and line units.

Computer modules

In the smallest node configuration, a computer module handles both the node administration functions (operator & network management centre communication, configuration handling, error supervision, statistics, charging, etc.), the traffic control functions (establishment of connections, address analysis, routing analysis, etc.), and the switching of data packets.

A second computer module provides the necessary redundancy. Either of these modules may act as "master" in the node and have overall responsibility for all node administration. Computer modules with responsibility for node administration have directly connected secondary storages containing a configuration database for the node and program backup for all processors in the node. The single or duplicated basic configuration is supplemented with more computer modules (or pairs of computer modules) to reach the desired traffic handling capacity. A node may have a maximum of 16 computer modules.

The new computer module version is accommodated on a single printed board assembly containing a powerful 32-bit processor (M68030), an 8 Mbyte storage, and connections to the backplane bus, to the secondary storage (SCSI) and to the bus for inter-computer communication.

Node configurations

The ERIPAX family currently includes two hardware configurations: PS10 and PFS550.

PS10 is a small unit which contains one computer module and up to three line units. PS10 can be upgraded with the more advanced 32-bit processor to provide space for another two line units of the LUH type.

PFS550 is designed for using the new computer module and the new line units (LUH) but also contains an I/O bus for connection of narrowband line units. In other words, PFS550 features very high flexibility in that it can meet different application requirements, both in packet switching and

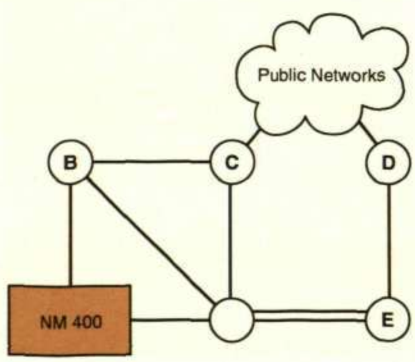


Fig. 4
An ERIPAX network consists of switching nodes and maintenance centre(s), usually interconnected in such a way that a faulty trunk only causes re-establishment of effected virtual circuits or the establishment of an alternative link via the public network. Users are connected directly or via the public network

in Frame Relay service. Fig. 3 shows the structure of the PFS550 configuration.

Network structure
Fig. 4 shows the way an ERIPAX network is built up with physical network resources in the form of network nodes and connections between the nodes. The terminal equipments, DTE, are connected either directly to the nodes or over public or private switched networks.

The term "route" denotes the connection between two nodes. A route may contain one or more physical transmission links, or trunks. Each trunk may in turn carry a large number of virtual connections for packet switching. Routes between network nodes and to other networks usually contain leased circuits, but switched connections may also be used; for automatic setup of reserve connections (often 64 kbit/s) between network nodes, for example.

Each DTE in a network is allocated a number from the network numbering plan. The numbering plan can be designed according to CCITT's recommendation X.121, but a high degree of flexibility is allowed in the handling of different numbering plans in private network applications.

Network administration
A separate network administration system called NM400, Fig. 5, has been developed to meet the need for an effective and easy-to-use system for the administration of private communications networks based on ERIPAX and/or Ericsson's PABX system MD 110. The NM400 system can also be used for supervising and administering other products installed in the network.

NM400 uses powerful workstations for graphic presentation of network topology and current states of different network elements. In addition to handling alarms and logging network events, NM400 supports the handling of configuration changes, software distribution, and collection/processing of statistics and charging information.

Fields of application

ERIPAX has been developed for use in organisations with wide-ranging communication needs, and most of the networks have been installed in environments of this kind. These organisations often have an IBM-dominated computer map, but they also have a pronounced interest in being able to communicate with other environments. Such facilities are provided by an X.25 network, which also improves the SNA/SDLC environment – by offering more effective polling procedures, for instance.

Meeting communication needs
The communication needs that can be met by introducing an ERIPAX network are

Fig. 5
NM 400 is the user-friendly network management centre used for administration of ERIPAX networks as well as Ericsson's PABX system, *MD 110*

best illustrated by describing some examples of customer installations.

ENEL, Italy
The Italian company ENEL (Ente Nazionale per l'Energia Elettrica) is the world's third largest producer of electric power and has been using an ERIPAX network since 1985. Today, some 12,000 terminals and more than 40 host computers are connected to the network, which covers the whole of Italy, Fig. 6.

ENEL's computer system is used for two main tasks: control and supervision of the production and distribution of electric power, and handling of administrative systems.

The administrative systems are run on IBM computers installed in 26 locations all over Italy and carrying some 80 per cent of ENEL's total data communication traffic. The computer systems for control and supervision of the production and distribution of electric power are run on Unisys, HP, DEC and Honeywell computers.

The Stockholm Stock Exchange, Sweden
Today, the ERIPAX system is used by the stock exchanges in Stockholm, London, Madrid, Helsinki, Frankfurt, Barcelona, Milan, Mexico City and Caracas. In Stockholm, ERIPAX handles a service called SAX (Stockholm Automatic eXchange), which is a computerised system for buying and selling shares and bonds.

SAX includes a broadcast system, a facility which was one of the main factors that determined the choice of ERIPAX and X.25. The *Packet Broadcast* function in ERIPAX enables the network to simultaneously copy and distribute information from a sender to a group of recipients. This is a very important function for stock exchanges and financing companies, which can use the network both for routine transactions and for the distribution of stock exchange information that should reach all brokers simultaneously.

The Stockholm Stock Exchange can also use ERIPAX to access the Swedish public

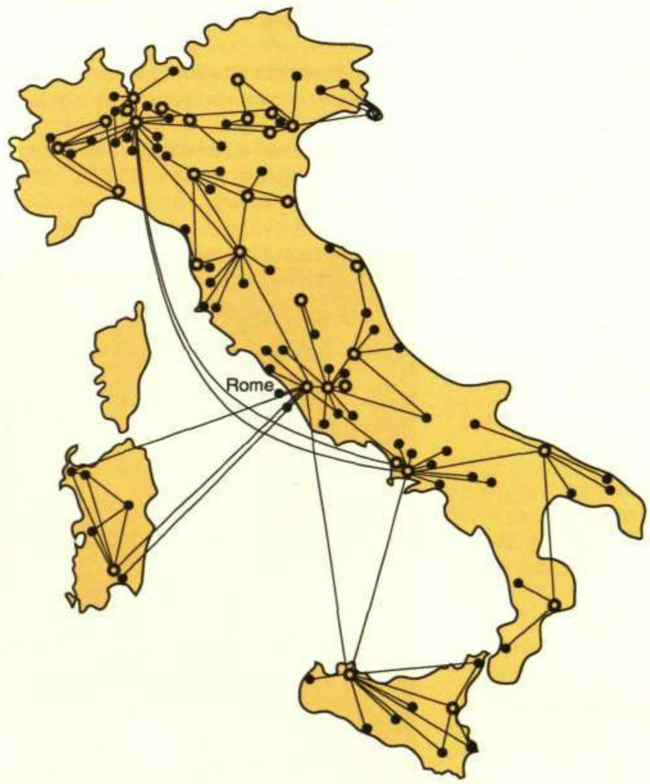


Fig. 6
ENEL's ERIPAX network with its over 340 nodes connects about 12,000 terminals all over Italy to IBM, DEC and Honeywell hosts

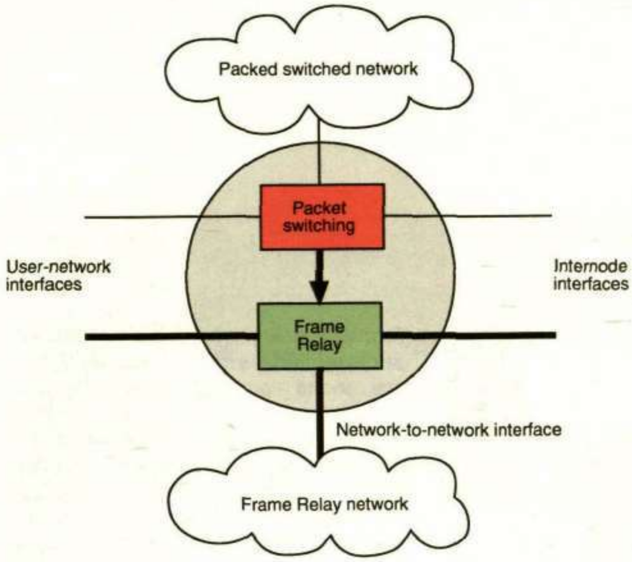


Fig. 7.
The blockdiagram illustrates how packet-switched and Fame Relay services can co-exist in a network node. The packet-switched services can utilise the Frame Relay service via internal software interfaces

packet switching service, DATAPAK, which in turn gives the Exchange access to other public X.25 networks all over the world.

Frame Relay service in ERIPAX

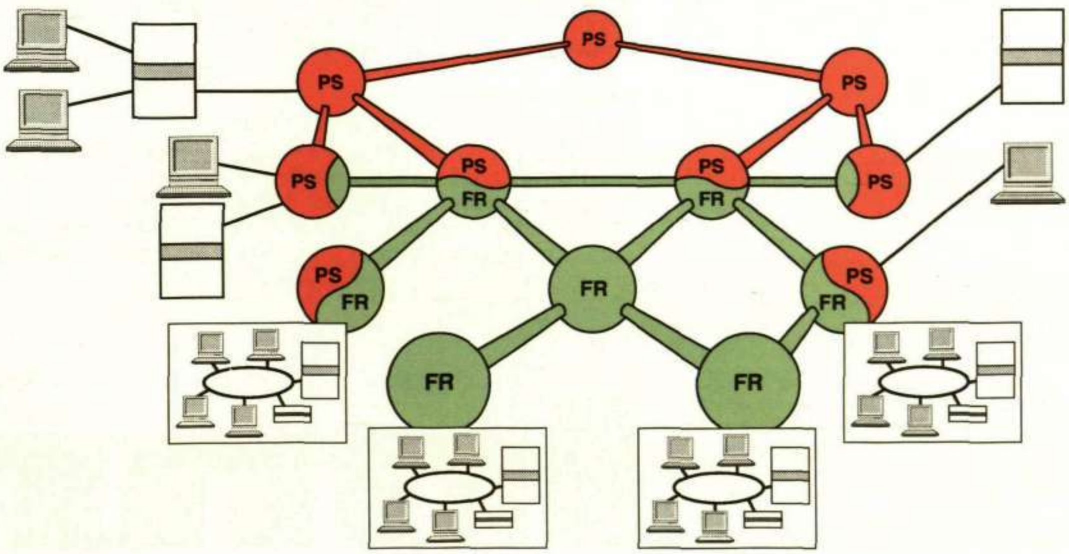
Today, local environments are dominated by LANs of the Ethernet and IBM token ring types. Information is transferred in the form of bursts and at high speed. To link these local environments into larger units we need a WAN capable of transferring short information bursts from one LAN to another in an efficient manner, at high speed and with a short delay. The solution is Frame Relay.

The principles underlying Frame Relay are described.[1] The implementation of Frame Relay service in ERIPAX complies fully with the standard specified by the Frame Relay Forum, with the addition of some supplementary functions (such as priorities) that are useful in many applications. Frame Relay service is an effective method of handling data traffic in the form of bursts. A simple protocol and simple flow control permit high bit rates, resulting in short delays in the network.

Packet switching and Frame Relay *service in the same node*

Frame Relay service will be offered to customers as an integral part of ERIPAX. This means that existing packet switching services (X.25, SNA/SDLC, etc.) can use *Frame relay as a bearer service in the network*, thus shortening throughput times. Frame Relay service can be introduced step by step, starting in one part of the network, and the packet switching traffic can gradually be diverted to Frame Relay trunks, Fig. 8. Packet switching and Frame Relay traffic can co-exist in a node, as illustrated in Fig. 7.

Fig. 8
Frame Relay service can be gradually introduced in an ERIPAX network



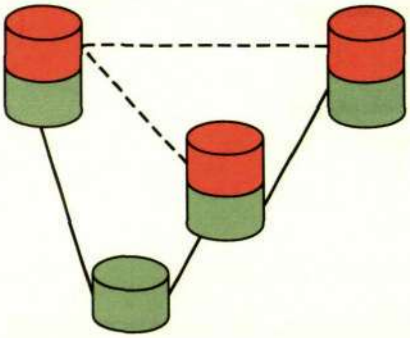


Fig. 9
The figure illustrates how the nodes in the packet-switched network are inter-connected via permanent virtual circuits in the Frame Relay network. The packet and frame switch capability co-exist in the hardware, controlled by configurable software

Terminals are given access to the standardised interface for the Frame Relay service, and to a protocol-independent interface which allows terminals with protocols of the HDLC type to use the network as a substitute for point-to-point connections.

The node has an internal interface between the Frame Relay service and the packet switching services, thus enabling the latter to use Frame Relay as a bearer service.

The physical network resources (nodes and links) form a primary Frame Relay network, on which a secondary packet switching network is superimposed. Trunk connections in the packet switching network are set up by using virtual connections in the primary Frame Relay network. As before, a route between two nodes in the superimposed packet switching network may contain several parallel logical trunk connections. Each packet switching network trunk uses a separate virtual connection in the Frame Relay network, thus permitting distribution of different packet switching network trunks over different physical transmission links.

Because Frame Relay connections can be established via transit nodes in the Frame Relay network, logical direct routes between packet switching network nodes can be set up even if these nodes are not interconnected by physical transmission links, Fig. 9. In this way, the packet switching network protocols need only be handled in the terminal nodes of the network, resulting in higher capacity and shorter network delay time for packet-switched traffic.

Smooth migration

Because an ERIPAX network can offer alternative packet switching and Frame Relay services, the network operator can use the communication protocol that is best suited for a specific application. This state of co-existence permits smooth migration from today's often centrally implemented applications and communication protocols to the more open solutions planned for the future, without the WAN being changed discontinuously.

Frame Relay performance

Frame Relay service presupposes use of the new generation of line units. These units have the processor power and storage capacity necessary to handle a large volume of Frame Relay traffic with its relatively simple communication protocols and flow control. The computer module takes part in the set-up and clearing of virtual connections, while traffic-carrying frames are transferred directly from incoming to outgoing line units over a backplane bus. As opposed to packet switching where the protocol termination at packet level and the forwarding of user data are handled by the computer modules in each node, Fig. 10. The transit switching of traffic-carrying frames does not engage the computer modules, whose processor power can be used for other tasks, Fig. 11.

Another result of the simplified traffic handling is short internal delays in nodes, which is important when there are several transit nodes along the path between the sender and the recipient.

High transmission speeds and short delays in the network mean that the total delay will be determined by the time it takes to transfer a packet over the connections to and from terminals. As shown in Fig. 12, the advantage of Frame Relay service becomes evident only when high speeds are used on the connection between network and terminal.

Integrated numbering plan

Each DTE is given a number from the network's numbering plan. This plan is independent of the network service used; that is, packet switching DTEs and Frame

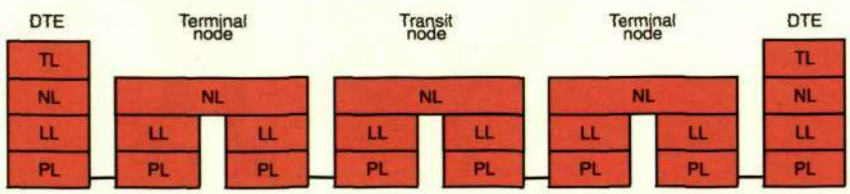


Fig. 10
Protocol execution for data transfer on a packet mode virtual circuit between two DTEs passing an access, a transit, and a terminating node

DTE Terminal equipment
TL Transport Layer
LL Link Layer
PL Physical Layer
NL Network Layer

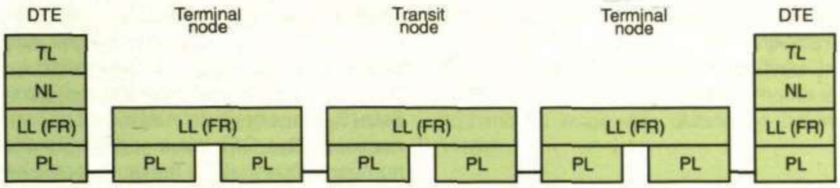


Fig. 11
Protocol execution for a Frame Relay virtual circuit established over terminating and transit nodes
LL(FR) Link Layer

Relay DTEs can be freely mixed in the numbering plan. Different parts of the numbering plan can also be used for different network services, of course.

The ERIPAX system's flexible methods of handling and storing addressing plans for alternative routing are also used in Frame Relay traffic. Terminal addresses, address analysis tables, routing rules, etc. in the database of a node can be changed during normal operation.

Set-up of connections

The Frame Relay service in ERIPAX is implemented in the form of permanent virtual connections, which are set up and administered by the network operator via the network management centre. To ensure that the required service quality is provided when setting up virtual connections, a separate logical channel (DLCI=0) is used for signalling over the network links. The establishment of a connection through the network is indicated by the sending of status signals over the terminal interface.

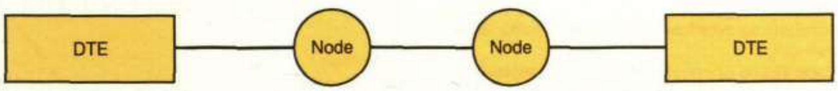
If the path established through the network is rendered inoperative because of a link fault, for instance, then the connection is released. As a result, the originating node automatically initiates a new set-up bid, and the connection is re-established over a faultless path.

Priorities

To ensure the best possible distribution of transmission capacity in the network, each connection is assigned one of four set-up priorities. Connections with high priority are the first to be offered use of the bandwidth of the primary route, whereas connections with lower priority may be set up over indirect paths. In addition, each connection is given either normal or high dataphase priority. This type of priority is primarily a tool for reducing the damage caused when frames are discarded in overload situations. By first discarding frames belonging to non-priority connections, the system limits the number of connections that may lose data in an overload situation, which means that the number of retransmissions in the network will also be reduced.

Allocation of bandwidth for the set-up of connections

Most datacom applications are characterised by burst traffic at widely varying burst frequencies and a great difference bet-



Bit rate, Access line	64 kbit/s	64 kbit/s	64 kbit/s	64 kbit/s	2048 kbit/s
Trunk	64 kbit/s	2048 kbit/s	64 kbit/s	2048 kbit/s	2048 kbit/s
Access line transfer	16 ms	16 ms	6 ms	16 ms	0.5 ms
Switching time	20 ms	20 ms	2 ms	2 ms	2 ms
Queue in trunkbuffer	16 ms	0.5 ms	16 ms	0.5 ms	0.5 ms
Trunk line transfer	16 ms	0.5 ms	16 ms	0.5 ms	0.5 ms
Switching time	20 ms	20 ms	2 ms	2 ms	2 ms
Access line transfer	16 ms	16 ms	16 ms	16 ms	0.5 ms
Total delay	103 ms	73 ms	67 ms	37 ms	6 ms

Packet/frame size 1000 bit

Fig. 12
The delay trough the network is built-up by three parts: transmission service time, switching time and time spent in queues waiting for transmission. The table shows that at lower rates the major part of the delay is caused by transmission time. The benefit of Frame Relay in terms of delay are significant for high transmission rates

ween momentary and average bit flows. To meet different users' demand for service quality, the concepts Committed Information Rate (CIR) and Excess Burst Size (B_e) have been defined for virtual connections. The CIR value represents the number of bits that the network should be capable of receiving and forwarding within a sliding time interval of a predetermined length. The B_e value represents the upper limit of the additional number of frames that the user is allowed to send within the same time interval but which the network will forward only if capacity is available. Any frames above the B_e limit are immediately discarded by the network, while frames above the CIR limit are provided with a Discard Eligible (DE) mark. In an overload situation, the latter frames are discarded first.

A prime advantage of Frame Relay service is that a predetermined minimum bit rate per connection can be combined with the possibility of momentarily using the considerably higher bit rate that is normally available because other connections are passive at the moment.

When a connection is set up through the ERIPAX network by the network management centre generating a command, the originating node will initiate set-up of a virtual connection of the predetermined service quality to the destination node. The set-up route is chosen autonomously in the network, taking into consideration all available links and their current free capacity.

Handling of overload situations

When projecting a Frame Relay network it is important to take into account a prerequisite for successful use of the technique: the traffic-carrying routes in the network should not be underdimensioned. Burst traffic and requirements for short delays mean extremely poor utilisation of direct connections. Even jointly used connections in a Frame Relay network have a low degree of utilisation, as compared with X.25 connections. The demand for economic operation of such networks is met by the relatively cheap but high-quality connections that have become available as a result of the introduction of public digital transmission services. The packet

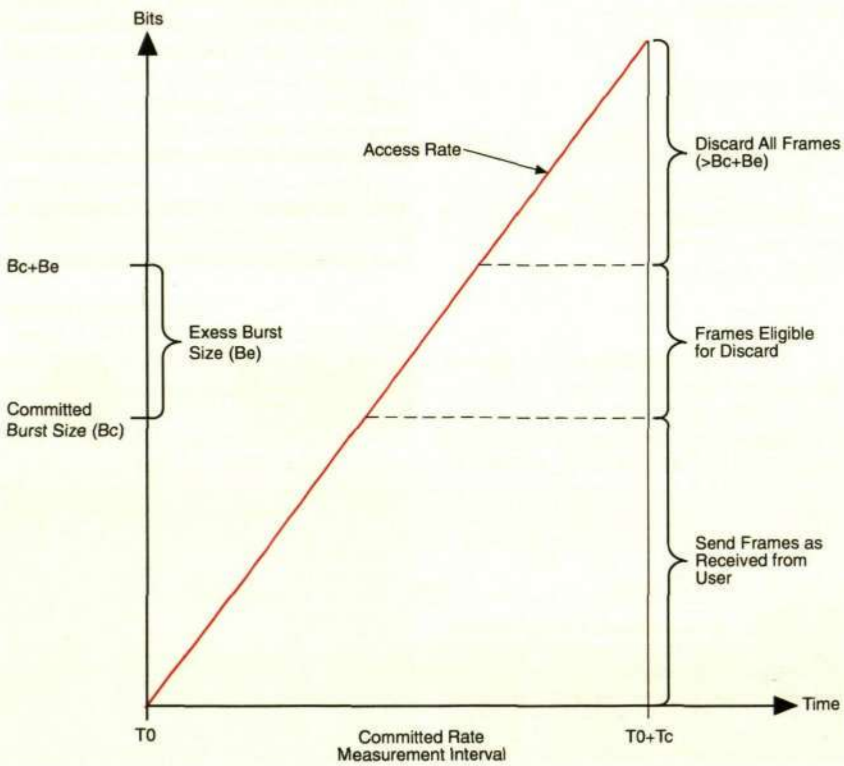


Fig. 13
Handling an overflow situation in a Frame relay-network.
Each Virtual Connection through the network is assigned a Committed Information Rate (CIR). The CIR value is generated by the network and indicates that the DTE on this connection is capable of sending a given amount (Committed Burst Size, Bc) of data during a given period of time (Tc), CIR = Bc/Tc.
Provided the network is not overloaded, the DTE is allowed to send a somewhat larger amount of data (Exess Burst Size,Be) on the connection. But if an overload situation occurs, this extra amount will be cancelled and any frames above the CIR value discarded.
If the DTE exceeds the maximum permissible quota (Bc + Be) for a given connection, the network will always discard the exess number of frames

switching technique, characterised by effective buffer procedures and robust flow control functions, permits a high degree of utilisation even of relatively poor connections, and it often constitutes a satisfactory alternative when no high-quality connections are available.

If overload occurs in a Frame Relay network, the first frames to be discarded are those sent by users in addition to the CIR value, resulting in the terminal node setting the DE (Discard Eligible) bit of the frame header. If the overload situation remains after all such frames have been discarded, any frames that do not belong to connections with high data-phase priority will be discarded too.

Overload situations are detected by continuously supervising two limit values for the number of frames in the send queue to each outgoing port. When the queue length reaches the first limit value, all frames whose DE bit is set are discarded until the queue length reaches a point below the critical value. If this action does not prevent the queue length from increasing, all frames that do not belong to connections with high data-phase priority will also be discarded when the upper limit value is reached. These mechanisms create the conditions required to mix traffic with different demands for accessibility in the same network.

The Frame Relay service does not normally feature internal error correction in the network. If a frame with incorrect frame checking sequence is detected, it will be discarded. This emphasises the importance of high-quality transmission links in Frame Relay traffic. The rule of thumb is that the bit error ratio should be below $1 \cdot 10^{-6}$.

To permit use of the Frame Relay service on occasional links of low quality, ERIPAX can be equipped with an error-correcting function in the form of retransmission on individual transmission links.

Administration of the Frame Relay service

On the whole, the administration of an ERIPAX network via the network administration system NM400 is always the same, regardless of the protocol used when transferring information. Departures from the basic procedure primarily concern differences in the configuration parameters for the different services, and differences in the handling of statistics and charging information. When Frame Relay service is introduced in an existing ERIPAX network, its administration via the existing NM400 system will only require slight modifications to administrative routines.

Summary

The development of the ERIPAX system towards better in-service performance and enhanced functionality, as described in this article, will strengthen the system's position when it comes to meeting the new demands that an effective Wide Area Data Network must meet today and in the future.

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A New Method of Testing Optical Fibres and Cables

Tarja Volotinen, Leif Stensland and Anders Björk

A new method, the $\alpha 11_b(\lambda)$ method, has been developed for the testing of single-mode fibres and single-mode fibre cables. The method – which is based on the measurement of second higher-order mode bend attenuation – makes it possible to investigate the bending situation of a fibre in a cable and to estimate, for the fundamental mode, the attenuation increase caused by the bending. For a fibre sample, the bend sensitivity of the fibre and its refractive index profile parameters can also be determined. The method has proved useful for fibres in lengths down to 2 m and for cables down to 30 m. In particular, it is useful in the development of manufacturing processes and in type tests of fibres and cables. The method can also be used for dispersion-shifted fibres and cables.

The authors describe the method and its use in fibre and cable tests.

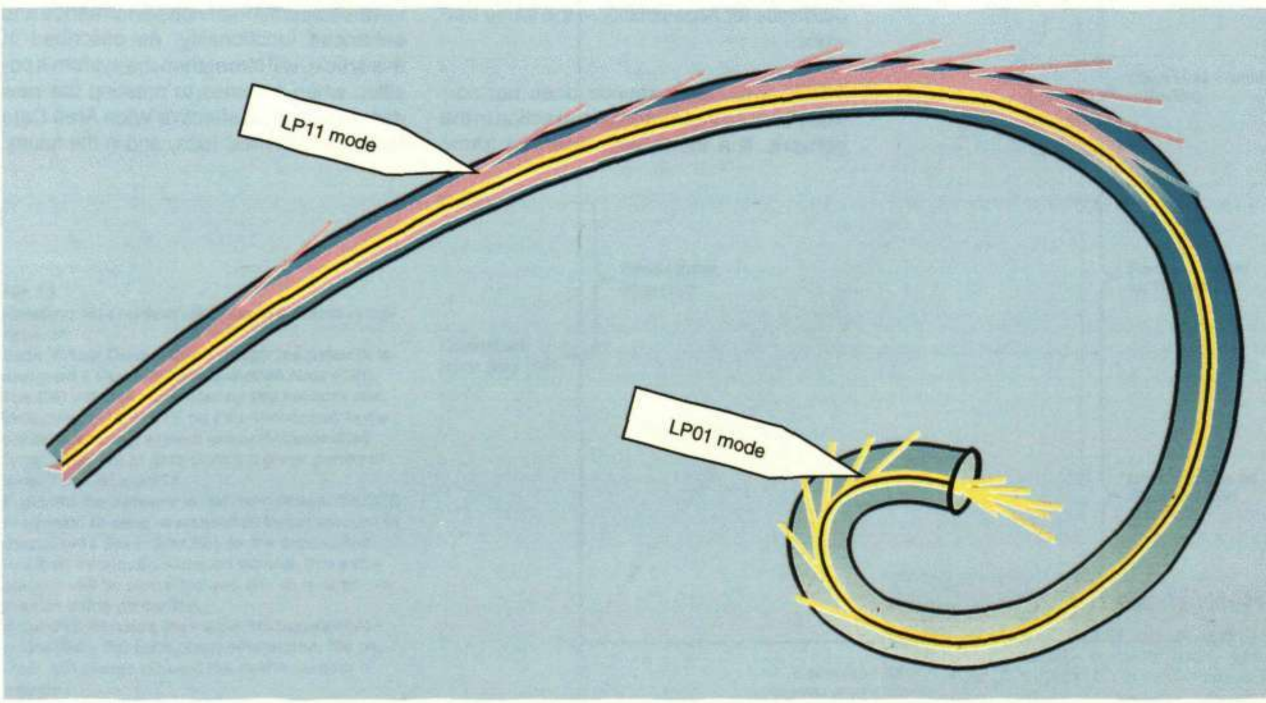
optical cables
optical fibres
bending
attenuation measurement

The signal attenuation of standard single-mode fibres used in today's telecom cables is very low – about 0.34 dB/km at 1310 nm wavelength, and about 0.19 dB/km at 1550 nm – which means that single-mode fibre links may have a length of 40–50 km at 1310 nm, or 70–80 km at 1550 nm. However, the use of such long cable links requires that the initial low attenuation of the fibres is maintained in the manufacture and installation of the cable, and throughout its 40-year service life. No excess loss over and above 0.01 dB/km can be allowed. Telecom cables are therefore tightly specified; stringent requirements are placed both on cable properties and test methods.

In order to maintain the accuracy of 0.01 dB/km in testing, long fibre and cable samples (about 2 km) must be used, irrespective of whether attenuation is measured during development, in type tests or in the final manufacturing process inspection. Shorter samples can be used for rough testing only. Tests are therefore expensive and time-consuming – especially environmental tests in which cables are cycled between extreme temperatures. Even in long cables, attenuation increases can only be measured at extreme temperatures and there is very little information on the fibre situation in the cable. It cannot, by standard methods, be determined whether the fibre situation is critical or not; in other words, the risk of increased attenuation will be an unknown factor. There is a need for a test method capable of being used for short cables and giving valuable information about the fibre situation in the cable.

A new method[1,2] of testing cables has been developed at Ericsson Cables' Hudiksvall

Fig. 1
The LP11 and LP01 modes in a bent single-mode fibre



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factory. The bend attenuation of the next higher-order mode – the LP11 mode – in the fibre is studied; hence the name of the method, the $\alpha 11_b(\lambda)$ method. It can be used for fibre lengths down to 2 m, whereas 10–30 m cable lengths are often necessary to obtain the same characteristic situation of the fibres as that in a long cable. The $\alpha 11_b(\lambda)$ method, as described in this article, is applied to fibre bend sensitivity investigations, to ribbon tests and to the optimisation of an SZ-stranded loose-tube cable design.

Single-mode fibre cables

A single-mode fibre, Fig. 1, maintains its low attenuation unless it is too much bent. There are two different types of bending: macrobending and microbending. Both types exist in cables but quite often one of them dominates, which makes it relevant to discuss them separately.

Macrobending (Fig. 2a) – or pure bending – of a fibre means that the bend diameter is larger than a few millimeters. The most interesting bend diameters for standard single-mode fibre are those ranging from 30 to 150 mm, and it is worth noticing that cables are designed so that fibre bend diameters will be larger than 120 mm. In the case of smaller bend diameters, some single-mode fibres show large attenuation increases.

Macrobending causes an increase in attenuation, since the wavefront of the transmitting mode in the cladding of the bent fibre is not straight. Some optical power leaks out (is lost by radiation) on the outer side of a bent fibre; the reason is too high local light velocity as a result of the bending, Fig. 2b. The attenuation increases rapidly at longer wavelengths due to the wider mode field. That is why macrobending is of much greater significance at 1550 nm than at 1310 nm.

Microbending occurs when the fibre is pressed against an uneven surface or deformed by some inner mechanical tension,

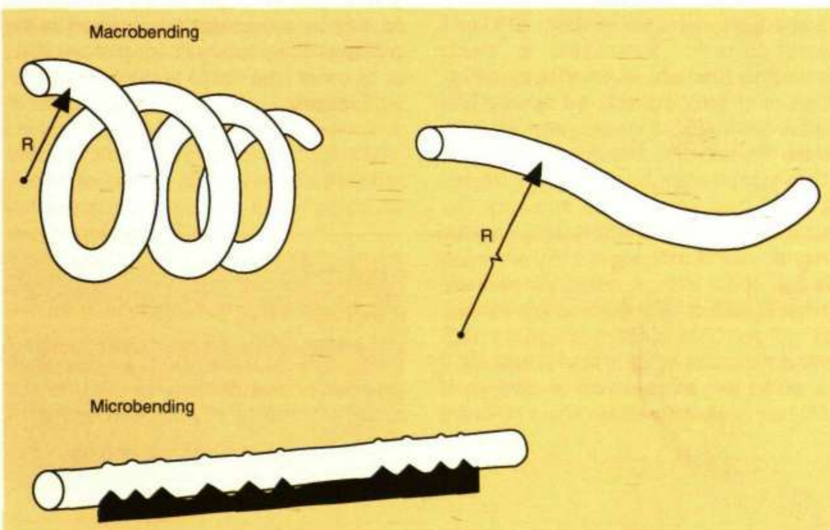


Fig. 2a
Macrobending and microbending of fibre
Macrobending, radius R: 0.5 mm–1 m
Microbending, "radius" 0.01 –1 mm

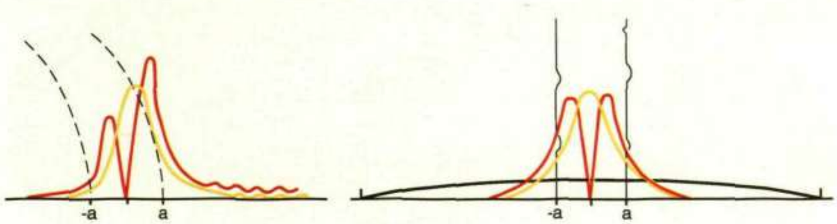


Fig. 2b
Macrobend and microbend attenuation of the LP11 and LP01 modes.
Optical power distribution of the modes (left).
Optical power distribution under microbending in a bent fibre (right)

a — Core radius
r — Distance from core centre
(yellow line) — LP01 mode at a wavelength around 1550 nm
(red line) — LP11 mode at a wavelength below cut-off
(black line) — Cladding mode with high attenuation

uneven coating, etc. Typical microbending, Fig. 2a, has a small, randomly varying amplitude (only some nanometers to a few micrometers) and a mean "periodicity" of 10–500 micrometers.

In the case of microbending, the attenuation increase is caused by light scattering (mode coupling to high-attenuation cladding modes), Fig. 2b, in a way similar to light reflection against rough surfaces or against diffraction gratings. Microbend attenuation also increases at longer wavelengths, but not as rapidly as macrobend attenuation. Microbending thus causes an attenuation increase both at 1310 nm and 1550 nm.

In a cable, the fibre may be subjected to both forms of bending. There is always some macrobending of fibres in cables, because fibres are stranded around a central member of the cable. Furthermore, macrobending can increase and microbending may occur when the cable is subjected to changes in temperature or strain. Both macrobending and microbending can also be caused by a cable construction fault or by a manufacturing defect in the primary or secondary coating of the fibre, or at some later stage in the manufacturing process.

There are three main types of optical fibre cable, depending on the secondary protection of the fibre: loose-tube cables, tight-buffered fibre cables, and the now popular ribbon cables. In the first-mentioned type, fig. 3 and Box 3, the primary coated fibres (diameter 0.25 mm) are laid loosely in rather thin plastic tubes (diameter about 2–3 mm) that are filled with grease. The tubes are stranded helically around a central strength member, which usually takes up both tensile and compressive strains. In the tight-buffered fibre cable type, fig. 4 and Box 4, the fibres have an extra coating layer on the primary coating (up to 0.9 mm in outer diameter). These fibres are also laid helically around a central strength member; in cables with only one or two fibres they may be surrounded by tensile strength members of aramid yarn (Kevlar) or a similar material in a cable sheath tube. In ribbon cables, finally, the fibres are bonded together into ribbons; usually 4, 8 or 12 fibres in each, fig. 5 and Box 3. These ribbons are then stranded helically, with a long pitch, around the central strength member.

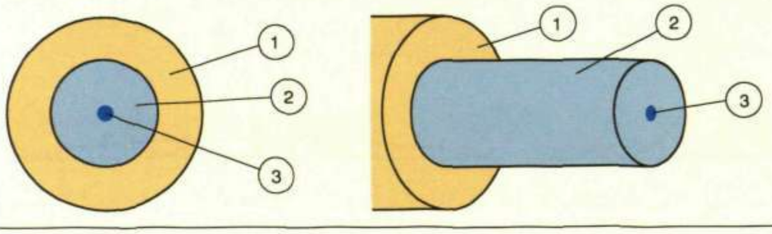
It follows that, even in a perfect cable, the fibres are helically bent to bend diameters ranging from about 150 mm to 1 m (ribbon cables). If the cable is subjected to cool-

Box 1
SINGLE-MODE FIBRE

- *consists of pure quartz glass (fused silica) cladding, a germanium-doped quartz glass core, and a protective primary coating*
- used for telecommunication at 1310 nm and 1550 nm
- attenuation at 1285–1330 nm: average ≤0.40 dB/km
- attenuation at 1530–1570 m: average ≤0.25 dB/km
- chromatic dispersion at 1285–1330 nm: ≤3.5 ps/nm.km
- chromatic dispersion at 1530–1570 nm: ≤19 ps/nm.km
- primary coating, double layer UV-curved acrylate
- diameter of primary coating: about 250 µm
- diameter of cladding: 125 µm
- step-index type of refractive index profile with core radius around 4.2 µm, refractive index difference between core and cladding around 0.005 and cladding refractive index ≈ 1.447 (= refractive index of fused silica at 1300 nm); or a depressed-cladding type of refractive index profile in which some part of the inner cladding has a lower index than the outer cladding, the core diameter and refractive index difference being of the same order as in a step-index type of profile
- mode field diameter at 1310 nm: around 9.4 µm
- cut-off wavelength of the LP11 mode: 1150–1330 nm (for one turn at 280 mm bend diameter)
- transmission and geometrical properties are standardised by CCITT, IEC, ETSI, CECC

Fig. to Box 1

1 Primary coating, acrylate; diameter 0.25 mm
2 Cladding, fused silica; diameter 125 µm
3 Core, doped fused silica; diameter around 8 µm



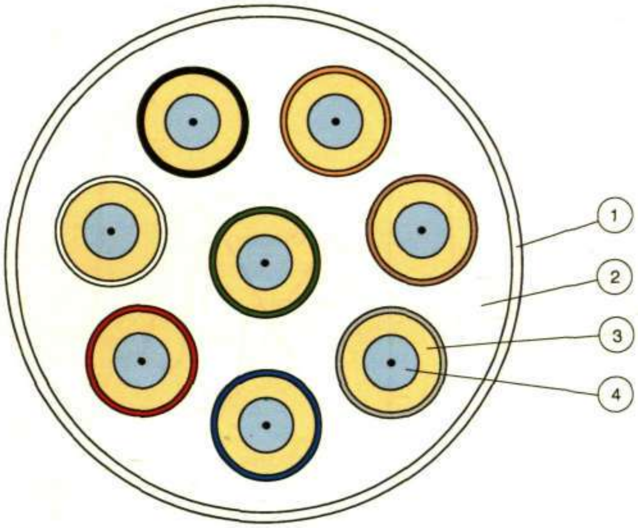


Fig. 3
Fibres in loose-tube secondary coating

1 secondary coating tube, polyamide; outer diameter 2.4 mm
2 filling compound
3 primary coated fibre including a colour layer, diameter about 0.25 mm
4 standard optical fibre, cladding diameter 0.125 mm

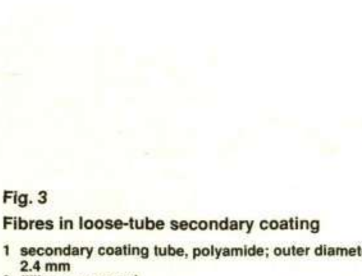


Fig. 4
Tight-buffered fibre

1 secondary coating, polyamide; diameter 0.9 mm
2 primary coating, silicon and/or acrylate; diameter 0.4–0.5 mm
3 standard optical fibre, fused silica; cladding diameter 0.125 mm

ing, for example, it will shrink considerably because most of the cable consists of plastic material. The fibres (which consist of quartz glass) do not shrink and, consequently, will be longer than the rest of the cable. This excess length may be counteracted by allowing the fibres to move outwards in the cable structure (e.g. inside the loose tubes), which, however, means that they will be bent to a smaller bend diameter and possibly pressed against the inner surface of the plastic tube. If so, the fibres will first be exposed to macrobending and, subsequently, microbending as well. If the cable is stretched mechanically or heated, it will be elongated and so make the length of the fibres inadequate. The fibres will be pulled inwards and exposed to microbending if pressed against the strength member.

In ribbon cables and tight-buffered fibre cables, the fibre is embedded in plastic material. If this material is not homogenous – and especially if it shrinks in axial direction in the extrusion process – it too may cause microbending.

Obviously, there are several possible causes of macrobending or microbending of the fibres in a cable. There is also one more complicating factor: the fibre itself may be more or less sensitive to bending. A reliable diagnosis of the risk of increased attenuation requires a test method that answers the following questions:

- Is the attenuation increase caused by macrobending or microbending?
- What is the bend diameter of the fibre in the cable?
- Can the bending be quantitatively evaluated?
- Are the fibres that show increased attenuation especially sensitive to bending?

Fibre theory and the measurement of $\alpha 11_b(\lambda)$

In single-mode fibres, Fig. 1, only the fundamental mode, the LP01 mode, is used and no other modes are expected to exist. The LP01 mode exists in two independent states of polarisation, although these states usually have identical properties and cannot be distinguished from each other in measurements. But if the wavelength is decreased, the cut-off wavelength, λ_c, of the next higher-order mode will sooner or later be reached. Thus, at wavelengths shorter than λ_c, the fibre can guide the LP11 mode, too. At wavelengths immediately below λ_c, this mode has an outside-the-core field distribution similar to that of the LP01 mode at 1550 nm, Fig. 2b. If the fibre is bent in some manner it is very likely that, at wavelengths just below λ_c, the LP11 mode reacts similarly to the LP01

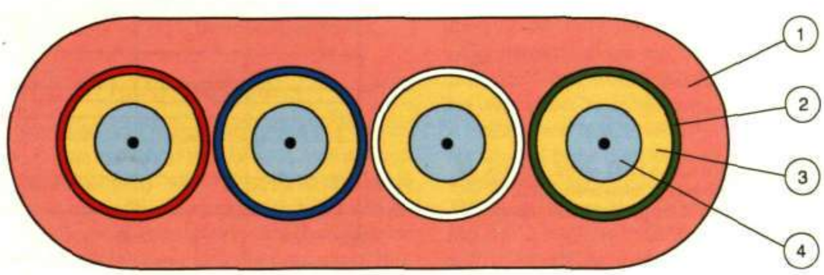


Fig. 5
Optical fibre ribbon

1 ribbon coating, coloured acrylate, dimensions 1.1 × 0.4 mm
2 colour layer, outer diameter ≤0.265 mm
3 primary coating of fibre, acrylate
4 standard single-mode fibre or multi-mode fibre, diameter 0.125 mm

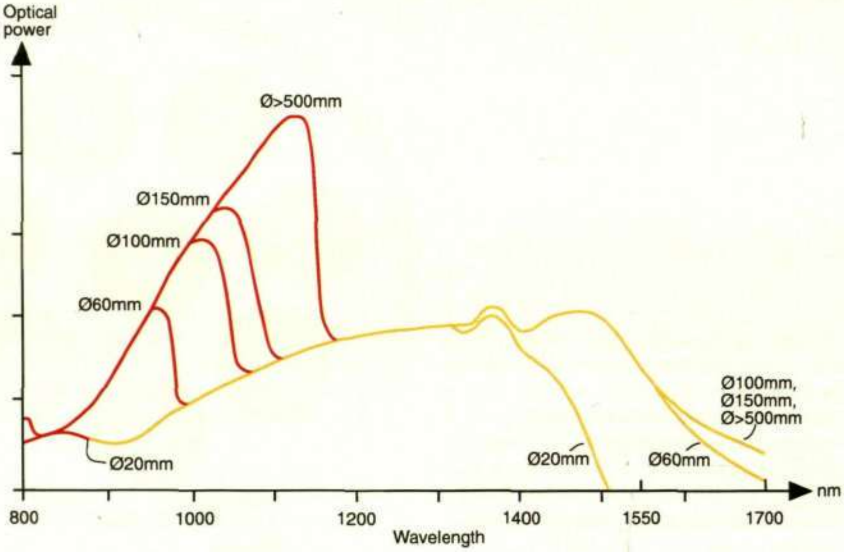


Fig. 6a
Transmission curves for a macrobend test on various bend diameters

Ø Bend diameter, mm
Yellow line: Power of the LP01 mode
Red line: Power of the LP11 mode

mode at wavelengths around 1550 nm – from an attenuation point of view. The attenuation increase of the LP11 mode caused by bending is called $\alpha 11_b$.

In the neighbourhood of λ_c, the value of $\alpha 11_b$ increases rapidly – although in a predictable way – as a function of the wavelength. It is thus possible to choose a wavelength region where $\alpha 11_b$ is sufficiently large to be measured in a very short fibre, Fig. 1, or – when needed – a region where $\alpha 11_b$ is sufficiently small to be measured in a long fibre. A log-lin diagram is usually

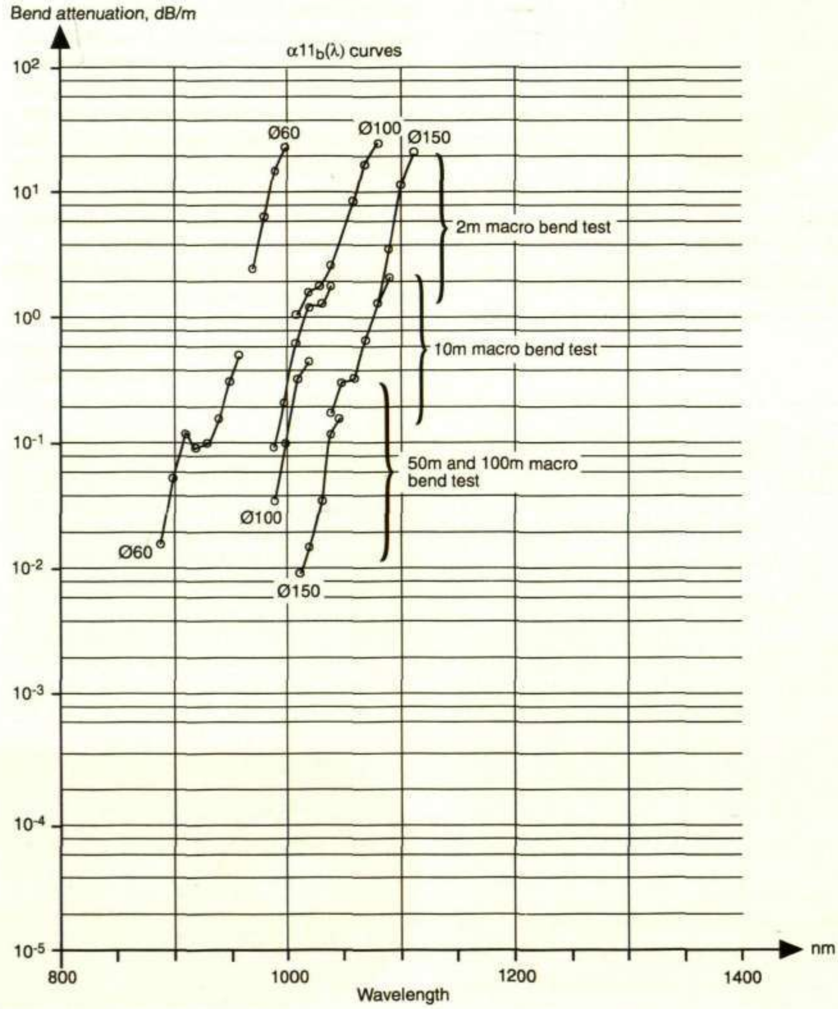


Fig. 6b
Bend attenuation of the LP11 mode, $\alpha 11_b(\lambda)$, on various bend diameters measured with 2 m, 10 m, and 50–100 m long samples of the same fibre

Ø Bend diameter, mm

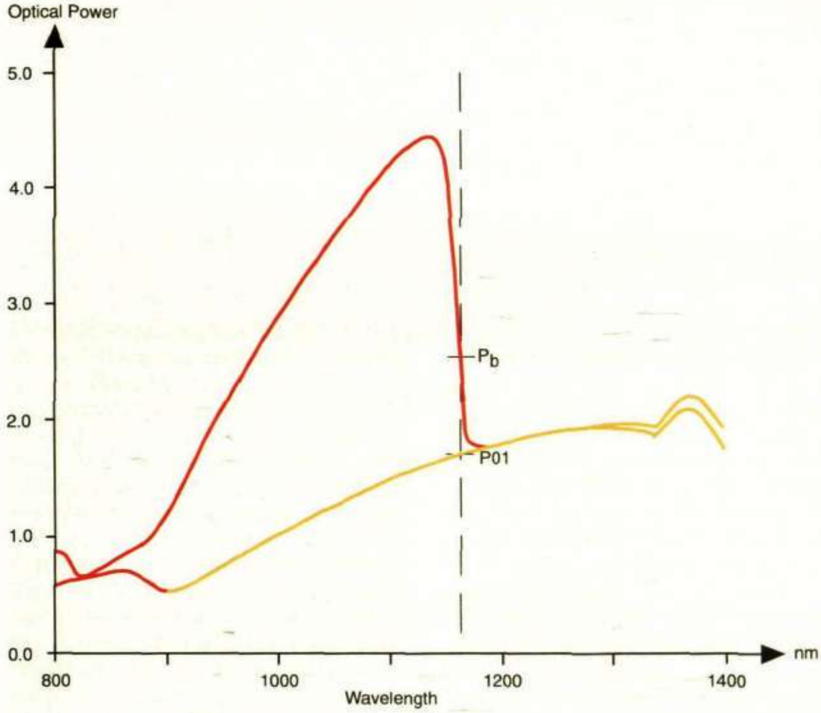


Fig. 7
Measurement and calculation of $\alpha 11_b(\lambda)$, LP11 mode bend attenuation

$$\alpha 11_b(\lambda) = 10 \cdot \log\left(\frac{P_b - P01}{2\,P01} \cdot \frac{1}{L}\right)$$

L = Length of the bent fibre section

P_b Output power of the fibre sample (LP01 + LP11)

P01 Output power of the LP01 mode (reference mode measurement with mode blocking filter, lower curve)

Power of the LP11 mode dominant

Power of the LP01 mode

chosen to plot $\alpha 11_b(\lambda)$ for the purpose of illustrating its strong dependence on wavelength. In this kind of diagram, $\alpha 11_b(\lambda)$ can be plotted for different bend diameters and different lengths of fibre, Fig. 6b. Since – as has been shown[1,7] – curves for short fibres agree with those for longer fibres, short pieces can be tested and the results extrapolated to represent long samples.

The $\alpha 11_b(\lambda)$ for a fibre sample can be measured by first measuring the transmission of the sample at wavelengths shorter than the cut-off wavelength and then the reference transmission – after adding some extra turns with a small (normally 20 mm) bend diameter – at the same wavelengths, Figs. 6a, 7. In this way the LP11 mode is filtered off and only the LP01 mode remains. Theoretically, the power of the LP11 modes should be twice that of the LP01 modes (there are four LP11 modes and only two LP01 modes, if both states of polarisation are taken into account). In fact, this relationship is almost obtained in the measurements, which makes it easy to calculate $\alpha 11_b$ from the measured transmission values at wavelengths slightly below the cut-off wavelength by using the equation given in Fig. 7.

A standard cut-back measuring instrument is used for all $\alpha 11_b(\lambda)$ measurements.

The $\alpha 11_b(\lambda)$ method

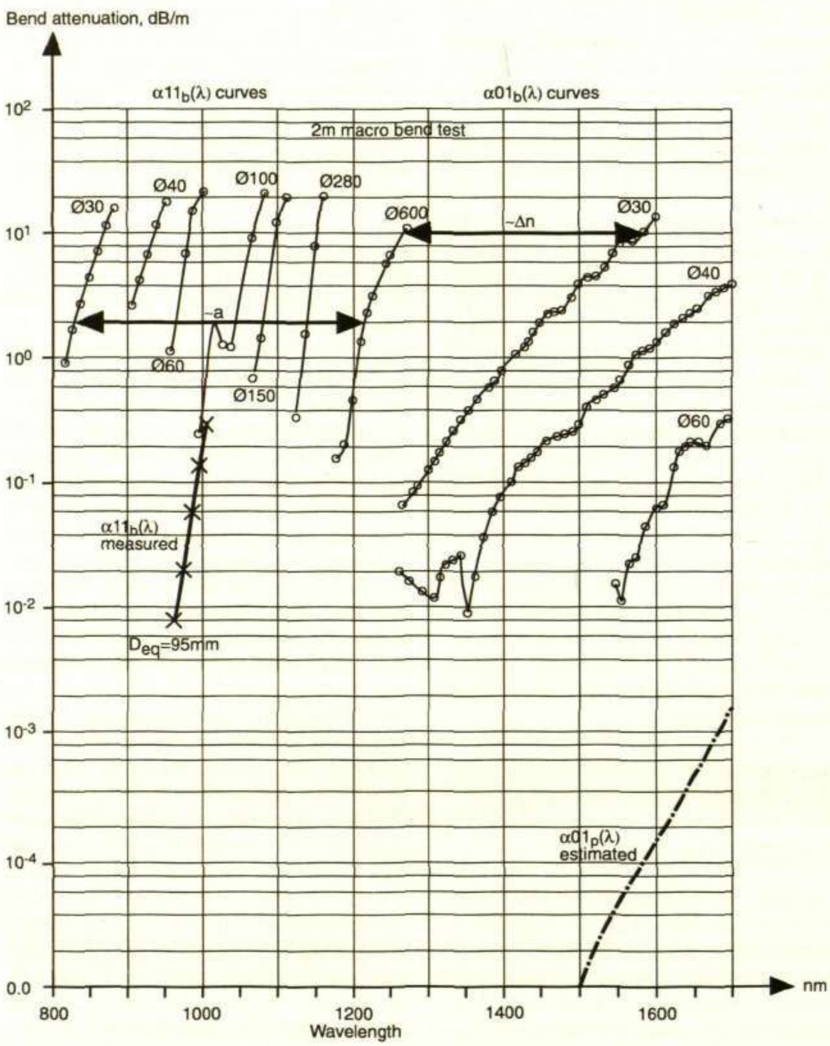
In cables and ribbons in which the low initial attenuation of the fibres is maintained, macrobending with a sufficiently large bend diameter dominates and there is no significant microbending. It is therefore relevant first to measure the equivalent microbend diameter of the fibre in the cable (the constant bend diameter that would cause the same total bend attenuation) and then check whether there is any microbending. Both these procedures can be performed by measuring the $\alpha 11_b(\lambda)$ curve for the fibre in a cable and comparing it with the $\alpha 11_b(\lambda)$ curves of the same fibre when exposed to various known bend diameters.

To estimate the equivalent bend diameter of a fibre in a cable, the $\alpha 11_b(\lambda)$ curve is first measured. Then the macrobend test with a 2 m sample of the fibre itself is carried out, at least on bend diameters ranging from 60 to 600 mm. The results of this test are used as a reference bend diameter scale for determining the equivalent bend diameter of the fibre in the cable. If the fibre is influenced by microbending, the slope of the measured $\alpha 11_b(\lambda)$ curve is less steep than that of the reference macrobend curves. In such cases the equivalent bend diameter has to be determined by using the highest bend attenuation points of the measured $\alpha 11_b(\lambda)$ curve at which macrobending is usually dominant.

Standard single-mode fibres can be characterised by two structural parameters: the core radius, a, and the refractive index difference, Δn, between the core and the cladding. It has been shown, both in theory and practice[1,7] that these two parameters can be evaluated by subjecting 2 m of fibre to a macrobend test, in which $\alpha 11_b(\lambda)$ curves for several bend diameters and $\alpha 01_b(\lambda)$ for some small bend diameter are measured. The parameters can be found by comparing the 2 m fibre macrobend test curves with the theoretical curve series[1,3] calculat-

Fig. 8
The $\alpha 11_b(\lambda)$ method: the $\alpha 11_b(\lambda)$ measured for the sample, the 2 m macrobend test of the same fibre and the $01_p(\lambda)$, the estimated attenuation increase of the LP01 mode

D_{eq}	Equivalent bend diameter
a	Core radius of the fibre
Δn	Refractive index difference of the fibre (core – cladding)
∅	Bend diameter, mm



ed with different structural parameters. A quick analysis can be made in the simple way shown in Fig. 8. The width of the $\alpha 11_b(\lambda)$ curve series is linearly proportional to the fibre's core radius, and the distance between a specific $\alpha 11_b(\lambda)$ curve and the $\alpha 01_b(\lambda)$ curve is linearly proportional to the refractive index difference.

When these two structural parameters are known, the bend attenuation at any bend diameter for both the LP11 and LP01 modes of the fibre can be theoretically calculated at any wavelength. The same theory as the one applied when evaluating the structural parameters is used. For the fibre in the test cable, the attenuation increase at 1550 nm can thus be calculated by using all the evaluated parameters, i.e. the equivalent bend diameter, the core radius and Δn.

Microbend attenuation is dependent on the same structural parameters of the fibre, and on the buffering properties of the primary coating used, which means that the microbend sensitivity of a fibre can also be roughly estimated with these parameters. However, it is difficult to estimate the magnitude of a microbend attenuation increase of the LP01 mode with the $\alpha 11_b(\lambda)$ method, because microbending cannot be characterised with one parameter (in the same way as macrobending can be characterised with one bend diameter). It can probably be done experimentally by using the known macrobend sensititivy of the fibres and the assumption that the LP11 mode's equivalent microbending is also equivalent for the LP01 mode.

The relationship between the LP11 and LP01 modes' microbend attenuation should be further studied experimentally.

It can be concluded that, with the $\alpha 11_b(\lambda)$ method, at least the following factors can be determined in a cable test:

- The equivalent bend diameter of a fibre in a cable
- The attenuation increase of the fundamental mode, due to the actual macrobending
- Whether there is any microbending in the fibre
- The bend sensitivity and structural parameters of the fibre.

Measurements

Fibre measurements

A large number of fibres have been tested[1] in 2 m sections, and in greater lengths, with various bend diameters. The purpose of these tests has been to prove that the behaviour of long fibres (Figs 6b, 8) can be extrapolated from the results of the 2 m tests, and to show that the theory and method applied are reliable with real fibres.

Fibres under microbend influence have also been studied; it is obvious that the slope of the $\alpha 11_b(\lambda)$ curves for such fibres is less steep. For a quantitative estimate of microbending at least two parameters

Fig. 9
The development of the $\alpha 11_b(\lambda)$ method required extensive measurements on cables and fibres. The picture shows a 2 m reference test being performed

are needed, which may be difficult to obtain with the $\alpha 11_b(\lambda)$ method. Qualitatively, it is quite simple to see whether or not there is any microbending.

Measurements of fibre ribbons

Fibre ribbons from ECA have been tested[8] with the $\alpha 11_b(\lambda)$ method during development work. The $\alpha 11_b(\lambda)$ was measured for the fibres in 9 m long ribbon samples when exposed to 600 mm bend diameter. The 2 m reference measurements were made for the same fibres with only primary coating.

The $\alpha 11_b(\lambda)$ curve of each fibre in the ribbon was compared with the corresponding 2 m reference test curves. If no fibre bending is introduced by the ribbon, the $\alpha 11_b(\lambda)$ curve of the fibre in the ribbon agrees completely with the $\alpha 11_b(\lambda)$ curve in the 2 m test on a 600 mm bend diameter. Thus, the difference (in position and slope) between these curves is due to additional bends along the fibre in the ribbon. It can roughly be concluded that the larger the difference in position, the smaller macrobends along the fibre; and the less steep the slope of the ribbon $\alpha 11_b(\lambda)$ curve, the more microbends have been generated in the ribbon. In a perfect ribbon, neither macrobends nor microbends should occur, but both types of bend may occur.

Cable experiments

Two cable designs were tested with the $\alpha 11_b(\lambda)$ method. The first design was a slotted-core cable for duct installation with six secondary tubes (each including 4–6 fibres) placed in helically stranded slots; the second was a similar design but slots and tubes were SZ-stranded[4]. The single-mode fibres in the cables were of standard type (CCITT G.652).

Several different samples of both cable types were tested for the purpose of finding out the relationships between process parameters, fibre bending at room temperature and attenuation increases in extreme temperatures, as well as the relationship between the fibre bending and the tensile performance window. Six samples of the helically stranded design, with various excess lengths of fibre, and eight samples of the SZ-stranded version were investigated[1]. The latter design was examined in varying excess lengths, pitches and reverse lay lengths of stranding.

Cable tests

The cable samples were tested using the $\alpha 11_b(\lambda)$ method; in room temperature in 30 m sections with two different bend diameters of cable: 120 and 65 cm. The 65 cm coils were then cycled ten times in a temperature test[1] from –40 to +70°C. At least two fibres from two tubes in each cable were tested. The same cables, in straight 25 m sections, were subjected to tensile performance tests[1]. The results obtained with the $\alpha 11_b(\lambda)$ method were compared with standard test results measured in long fibre or cable tests.

Fibre bending in loose-tube cable designs

Equivalent bend diameter

The equivalent bend diameter for a fibre in a test sample is the constant bend diameter to which the whole fibre section should be bent to show the same total bend attenuation[1]. (See section The $\alpha 11_b(\lambda)$ method above.) Such a parameter is necessary in order to describe fibre macrobending in cables by one discrete parameter. In most cases, fibres are more or less randomly bent inside cables.

Macrobend attenuation is strongly dependent on the bend diameter, and the smallest existing bend diameter will give the largest contribution to the total bend attenuation. It is therefore necessary to use 'the equivalent bend diameter' in cable analyses, even though it is smaller than the mean bend diameter of a fibre when the fibre bending varies considerably in the cable.

For a fibre wound without microbends on a mandrel, the equivalent bend diameter is the mandrel's diameter. A helically bent fibre also has a constant bend diameter equal to its equivalent bend diameter, which can be easily calculated from the helix parameters[5].

Fibre bending in cables under varying tensile and temperature conditions

The bend diameter of a curved fibre at an arbitrary point in a cable, and the fibre length up to this point, can be calculated only if the curve – the fibre position – can be described mathematically. For fibres in real cables this can seldom be done with sufficient accuracy because of the statistic nature of the fibre position in a loose tube or the ribbon position in a slot, etc.

Along each cable there are always small structural variations due to variations in the manufacturing process and in the material properties. In factory tests, cables are also wound on drums, with varying tension.

In a typical loose-tube cable the optimum position for a fibre at room temperature is at the centre of the tube. If the cable shrinks or expands, the fibre will move to the tube's outer wall (the fibre bend diameter decreases) or to its inner wall (the bend diameter increases). Within this bend diameter range – the allowed bend diameter window – the fibres can move without pressing against the tube walls, and without being subjected to microbending or too strong macrobending, which both could cause attenuation increases. If the cable shrinks further, the fibre will start to buckle inside the tube, which will further decrease the fibre bend diameter.

The allowed bend diameter window can be evaluated in cable tests by the $\alpha 11_b(\lambda)$ method, or it can be roughly estimated by measuring each cable construction parameters and using the simple helix equation[5] and the theory of reverse lay stranding[6]. In the reverse sections of an SZ-stranded loose-tube cable there may be variations of about +20 to –80 % of the fibre bend diameter in addition to the bend diameter of a helical section with the same stranding pitch of the tubes[6]. A slight buckling of the fibres down to almost 100 mm equivalent bend diameters can be allowed in some designs without causing attenuation increases[1].

The equivalent bend diameter of the fibres in the tested cables decreased in the theoretically predicted way at low temperatures and increased, as predicted, at high temperatures and when the cable was exposed to tensile elongation. Thus, the fibre position and bending situation in the cable can be determined by measuring the equivalent bend diameter and comparing it with the estimated allowed bend diameter window. After a few samples of a design have been tested, in temperature and tensile performance tests, the $\alpha 11_b(\lambda)$ method can be used to estimate – at room temperature – the tensile and temperature performance of any cable of the same type.

The $\alpha 11_b(\lambda)$ method does not answer all questions that cable designers may have, but it is a valuable addition to the standard methods. It gives much more information than standard attenuation measurements of the LP01 mode do. It provides ample opportunity to investigate cable designs without causing attenuation increases of the LP01 mode, which cannot be done with any other known test method.

Box 2

LOOSE-TUBE CABLE DESIGN OPTICAL CABLE, DIELECTRIC, DUCT GNSLDV 4–48 fibres

Cable Properties

Temperature range	operation	-30 – +70 °C
Temperature range	storage	-40 – +70 °C
Temperature range	handling	-10 – +50 °C
Bending radius, no load	min	10 · cable diam
Bending radius, at 2.5 kN	min	20 · cable diam
Crush resistance (<0.1 dB attenuation increase)	IEC-794-1-E3	5 kN
Tensile strength (<0.1 dB attenuation increase)	IEC-794-1-El	1.5 kN
Pulling force during installation	max	2.5 kN
Cable net weight		170 kg/km
Factory length		2, 4 or 6 km
Drum flange diameter		1.2, 1.6 or 2.0 m

Construction

The fibres are distributed in the tubes with 4, 6 or 8 fibres/tube for cables with up to 24, 36 and 48 fibres respectively. The last tube may have fewer fibres.

Three of the ridges are coloured on top as shown in the figure.

Colours of the fibres in each tube: Red – Blue – White – Green – Yellow – Grey – Black – Brown

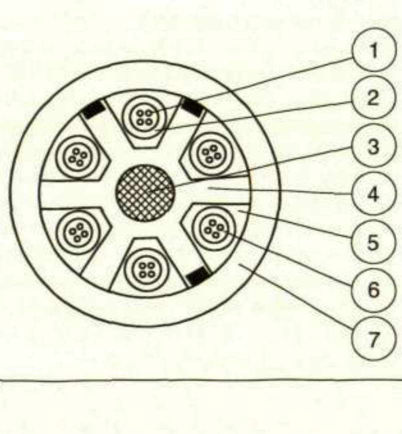


Fig. to Box 2

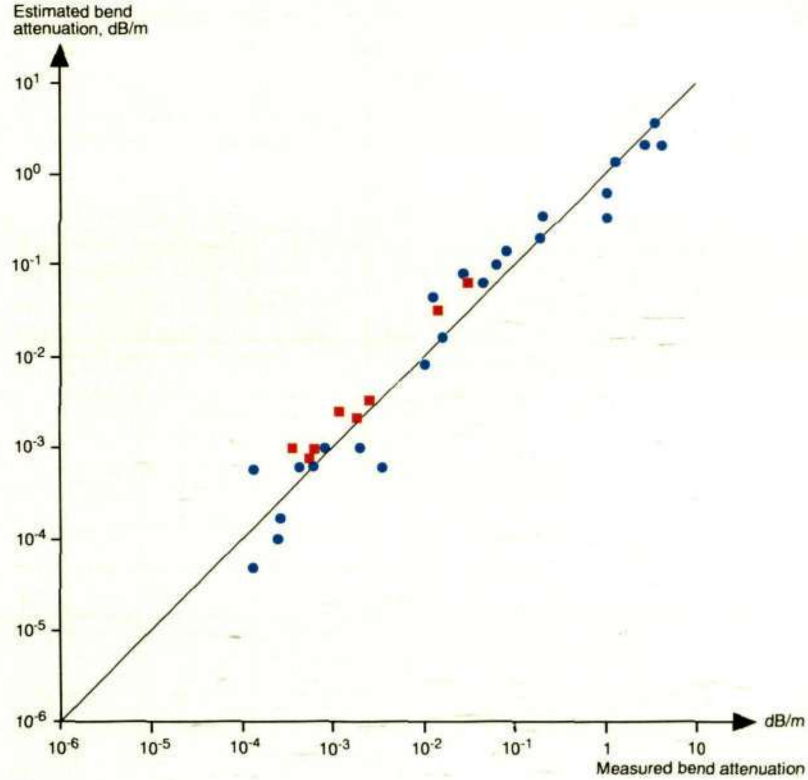
	Diameter
1 Primary coated fibre, four, six or eight/tube	0.25 mm
2 Secondary coating tube, polyamide uncoloured	2.4 mm
3 Strength member, fibre-reinforced plastic	3.0 mm
4 Slotted core, polyethene	11 mm
5 Filling compound	
6 Filling compound	
7 Outer sheath, polyethylene, black	t = 1.5 mm, nom 14 mm

Results

Fibre tests

Macrobend sensitivity varies by several powers of ten and microbend sensitivity by about one power of ten between individuals of standard single-mode fibres of good quality. This means that fibres with the same bending can show widely differing attenuation increases.

Fibre bend sensitivity and structural parameters can be reliably determined from the results of the 2 m macrobend tests by



Fig, 10
Correlation between the measured and the estimated attenuation increase at 1550 nm (measured in macrobend tests and cable tests with random fibre bending, and estimated with the $\alpha 11_b(\lambda)$ method)

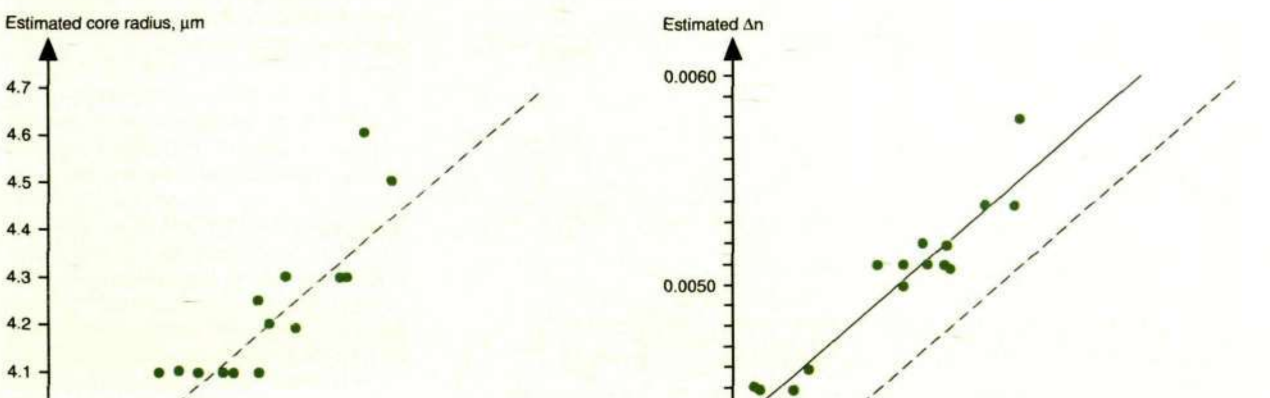
Cable test

Macrobend test

the $\alpha 11_b(\lambda)$ method. The reliability was studied with cables and loose tubes (random bending) and in macrobend tests of 20 different fibres (constant bend diameter). The equivalent bend diameter of a fibre in a sample can be estimated with a repeatability of 10 %, and the corresponding macrobend attenuation of the LP01 mode can be estimated with 20 % accuracy, Fig. 10. Only those $\alpha 11_b(\lambda)$ measurements in which macrobends dominated were used. The $\alpha 11_b(\lambda)$ values can be measured by at least 5 % repeatability (corresponding to 5 nm repeatability at a wavelength scale); in most cases even by 1 % repeatability.

Regarding the correlation between the measured and the estimated bend attenuation, Fig. 10, it should also be noted that – in relation to what is measurable (in the order of 10^{-1}–10^{-2} dB) – much lower attenuation increases of the LP01 mode can be reliably estimated. This means that the method is an efficient way of estimating the margin for attenuation increases in cables.

Fig. 11
Correlation between the measured (using the $\alpha 11_b(\lambda)$ method) and the estimated structural parameters, core radius and retractive index difference, of standard single-mode fibres (matched cladding type of refractive index profile)



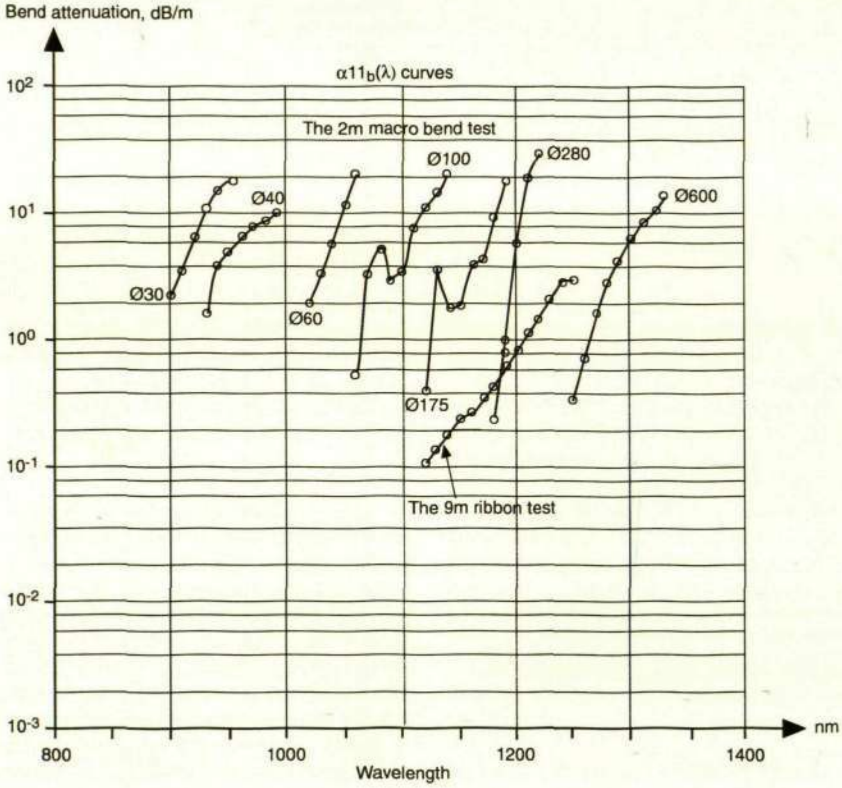
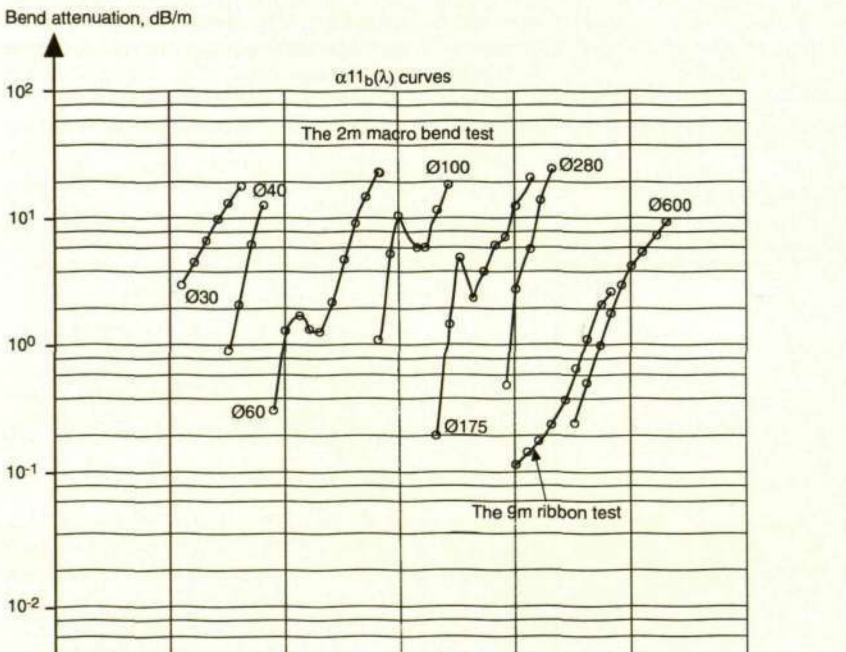


Fig. 12a
Ribbon test results, a fibre in a ribbon with some extra microbending
Ø = bend diameter, mm

Fig. 12b
Ribbon test results, a fibre in a ribbon with macrobending



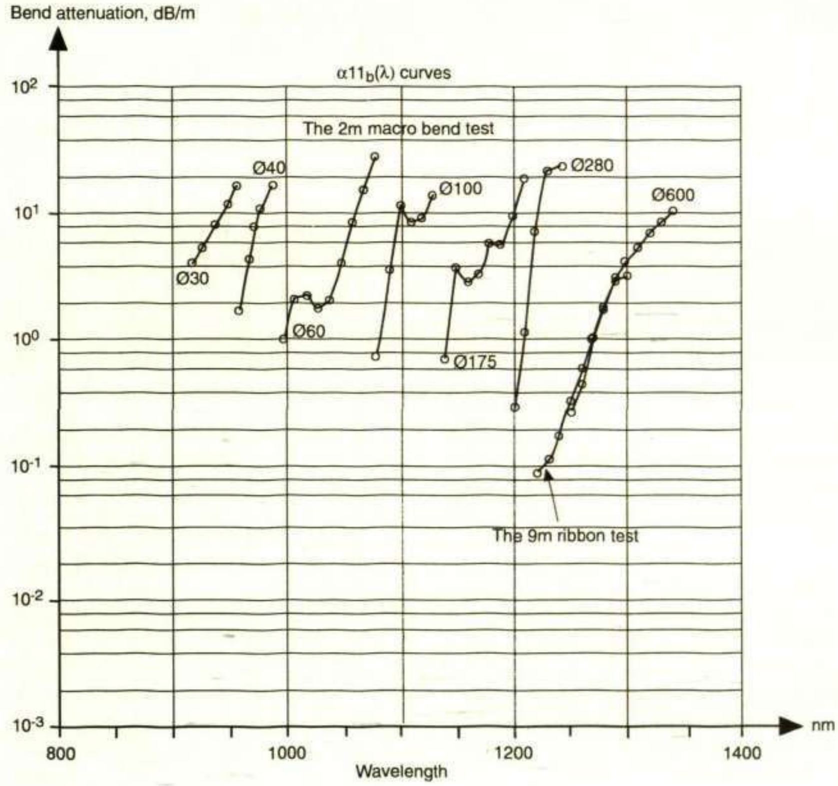
The structural parameters, core radius and refractive index difference of matched-cladding type single-mode fibres can be estimated from the 2 m macrobend tests. It can be concluded from the results shown in Fig. 11 that there is a systematic correlation between the measured and the estimated values. The fibres used in these tests differed from each other and included the characteristic profile variations and deformation typical of good-quality standard fibres. The small systematic disparity between the measured and the estimated refractive index difference does not disqualify the method or introduce any errors in the estimated attenuation increases, because the increases are calculated with the same theory as the one used to obtain these parameters.

Ribbon tests

The 9 m ribbon test[8] has proved to be reliable, indicating a marked difference between favourably and unfavourably situated fibres. Both microbends (Fig. 12a), additional macrobends (Fig. 12b), and ideally situated fibres (Fig. 12c) were found. The results correlated with the attenuation increases measured in standard temperature cycling tests and in cable tests.

If necessary, the method's reliability for ribbon tests can be improved by using a longer fibre sample in the reference test, in order to get at least two turns with 600 mm bend diameter, and by measuring several bend diameters between 280 and 600 mm in the reference test. In this way, the accuracy of determining the equivalent bend diameter can be improved. For microbending investigations, some longer ribbon samples (300–500 m, with 400–600 mm bend diameter) could be used. It should give a situation in which microbending is dominant in $\alpha 11_b(\lambda)$ and the pure micro-

Fig. 12c
Ribbon test results, a fibre in a ribbon ideally situated



Box 3

RIBBON CABLE DESIGN OPTICAL CABLE, DIELECTRIC, DUCT GASLDV 4–96 fibres

Cable Properties

Temperature range	operation	-30 – +60°C
Temperature range	storage	-40 – +70°C
Temperature range	handling	-15 – +40°C
Crush resistance (<0.1 dB attenuation increase)	IEC-794-1-E3	3 kN
Bending radius, – temporary, no load	min	10 · cable diam
– permanently and during installation	min	15 · cable diam
Pulling force during installation	max	2.0 kN

24 fibres, 1 ribbon/slot
48 fibres, 2 ribbons/slot
72 fibres, 3 ribbons/slot
96 fibres, 4 ribbons/slot

Construction

	Diameter 4–48 fibres	Diameter –96 fibres
Acrylate-coated ribbon, 1–4/slot	1.1 · 0.4 mm	1.1 · 0.4 mm
Strength member, fibre-reinforced plastic	3.5 mm	3.5 mm
Slotted core, polyethene, black	8.5 mm	10.5 mm
Filling compound		
Sheath, polyethene, black, t = 1.5 mm, nominal	12 mm	14 mm
Cable net weight	130 kg/km	175 kg/km
Factory length	2-4-6-8/km	2-4-6-8/km

Colour Scheme

Colours of fibres in a ribbon,
4 fibres: Red – Blue – white – Green

Colours of ribbon coating in each slot,
4 ribbons: Red – Blue – white – Green

Colour marking on top of ridges,
2 · Black – Uncoloured – Black – 2 · Uncoloured

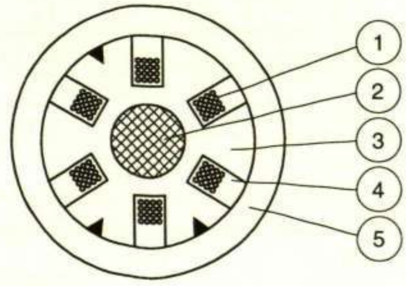


Fig. to Box 3

1 Ribbon
2 Strength member
3 Slotted core
4 Filling compound
5 Sheath

bend attenuation of the LP11 mode can be determined.

Cable tests

The $\alpha 11_b(\lambda)$ method has proved reliable in all the cable tests performed on samples from different cable designs and fibres. A 30 m sample is sufficient for temperature cycling tests and tensile performance tests, but cables up to several kilometers – even some tens of kilometers – can be investigated with this method. The modified short-sample test methods also look promising for type testing of cables.

The equivalent bend diameter range within which the fibres move in an SZ-stranded cable in temperature tests was found to be dependent on the number of helical turns between the reverse points, on the fibre excess length in the tube, and particularly on the cable core construction. The bend diameter range in the temperature test for the optimised SZ-stranded slotted-core cable was as narrow as for the good-quality, helically stranded slotted-core cables[1] (Fig. 13a), and even the tensile performance window was wide, 0.5 %. The slight variation of the fibre excess lengths in different tubes was seen as a shift of the bend diameter window on a bend diameter scale in the temperature test.

Temperature test results for a good-quality, SZ-stranded loose-tube cable design are shown in Fig. 13a. There were no attenuation increases at 1550 nm, and the fibres were moving inside the cable only within a narrow bend diameter window. The $\alpha 11_b(\lambda)$ method also shows that there is a good margin for attenuation increases caused by temperature, because the predicted bend diameters are far above those that would cause increases for this fibre.

In SZ-stranded cables without a slotted core, Fig. 13b, the equivalent fibre bend di-

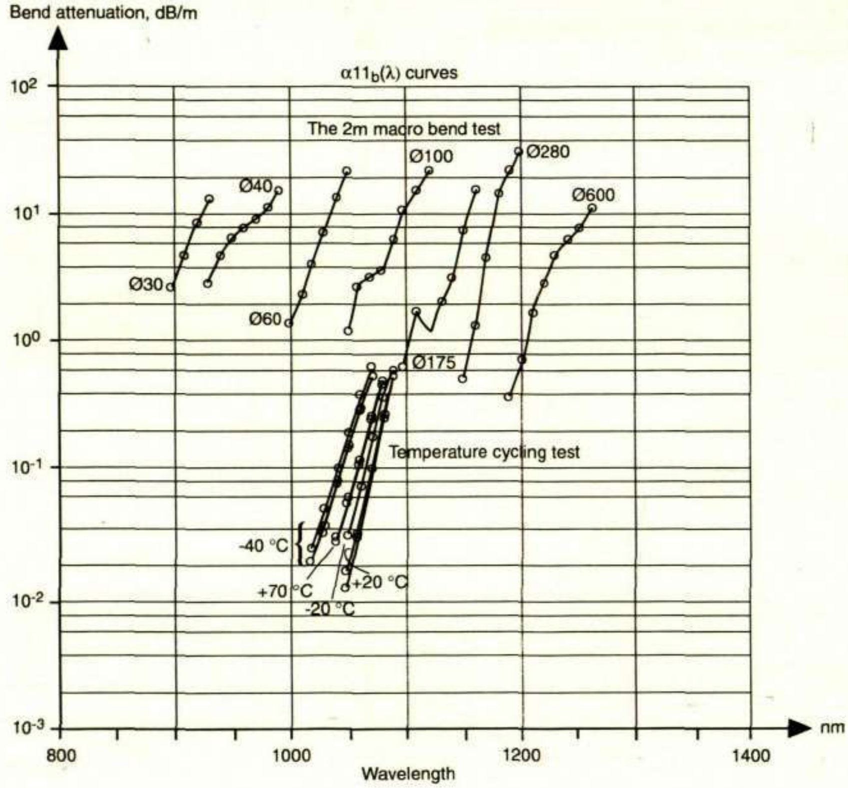


Fig. 13a
Temperature cycling test results obtained with the $\alpha 11_b(\lambda)$ method for a good-quality loose-tube cable with SZ-stranding
B = bend diameter, mm

ameter changed within a very large window in the temperature test. A 30 m long sample of the cable was tested in ten cycles between –40 and +70°C, Fig. 13b. A 2 km long sample of the same cable was also tested by standard methods. The attenuation increases of the LP01 mode at 1550 nm were only observed at –40°C. However, we can clearly see how much the equivalent bend diameter – and the fibre bending – varied in the cable during the test: 35–170 mm. In further tests of this design it was noticed that a lower fibre excess length did not decrease the bend di-

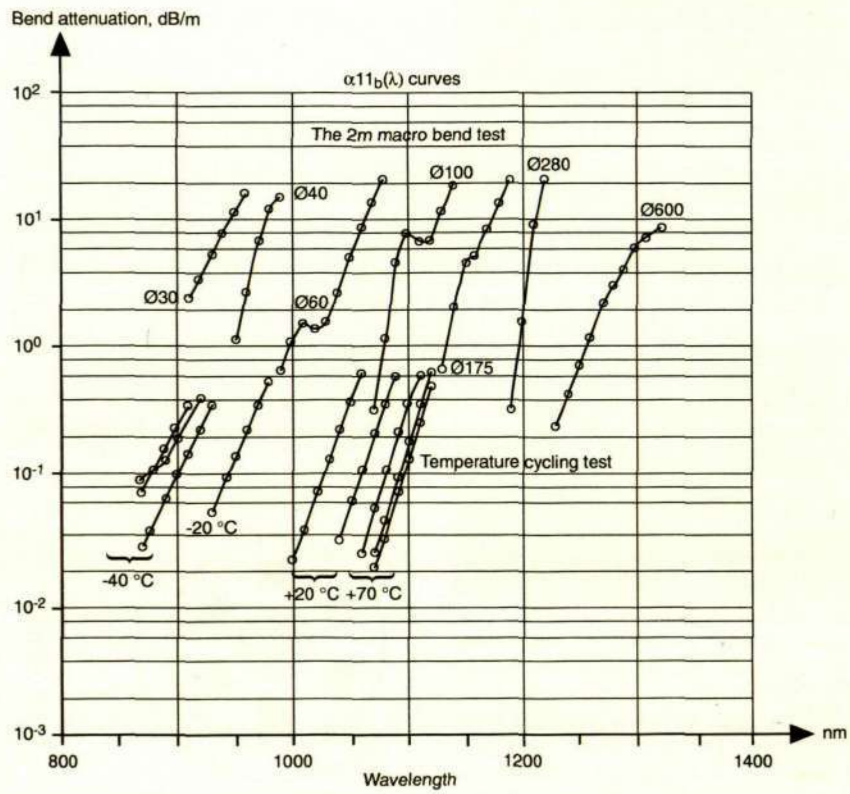


Fig. 13b
Temperature cycling test results obtained with the $\alpha 11_b(\lambda)$ method for a bad-quality loose-tube cable with SZ-stranding

ameter changes; the large variation window was only slightly shifted towards the larger bend diameters.

The $\alpha 11_b(\lambda)$ method applied to dispersion-shifted fibres

In addition to the single-mode fibre and cable tests described above, the method's usefulness has been examined for dispersion-shifted single-mode fibres. Dispersion-shifted fibres will probably be more widely used in telecommunication cables, for long distances and for high-capacity networks. These fibres are much less sensitive to bend attenuation of the LP01 mode than standard single-mode fibres, which means that the usual cable test methods are not sufficient. The fibres in a cable can be bent – without causing any attenuation increase – to such small bend diameters that their useful life might be endangered; i.e. the stress caused by the bending can break the fibres after some time. The $\alpha 11_b(\lambda)$ method looks promising for dispersion-shifted fibre cable development.

Some dispersion-shifted fibres with different refractive index profiles were investigated in 2 m macrobend tests. The $\alpha 11_b(\lambda)$ curves can be measured with a standard instrument, as in the case of standard fibres, and curves for different bend diameters can be clearly distinguished from

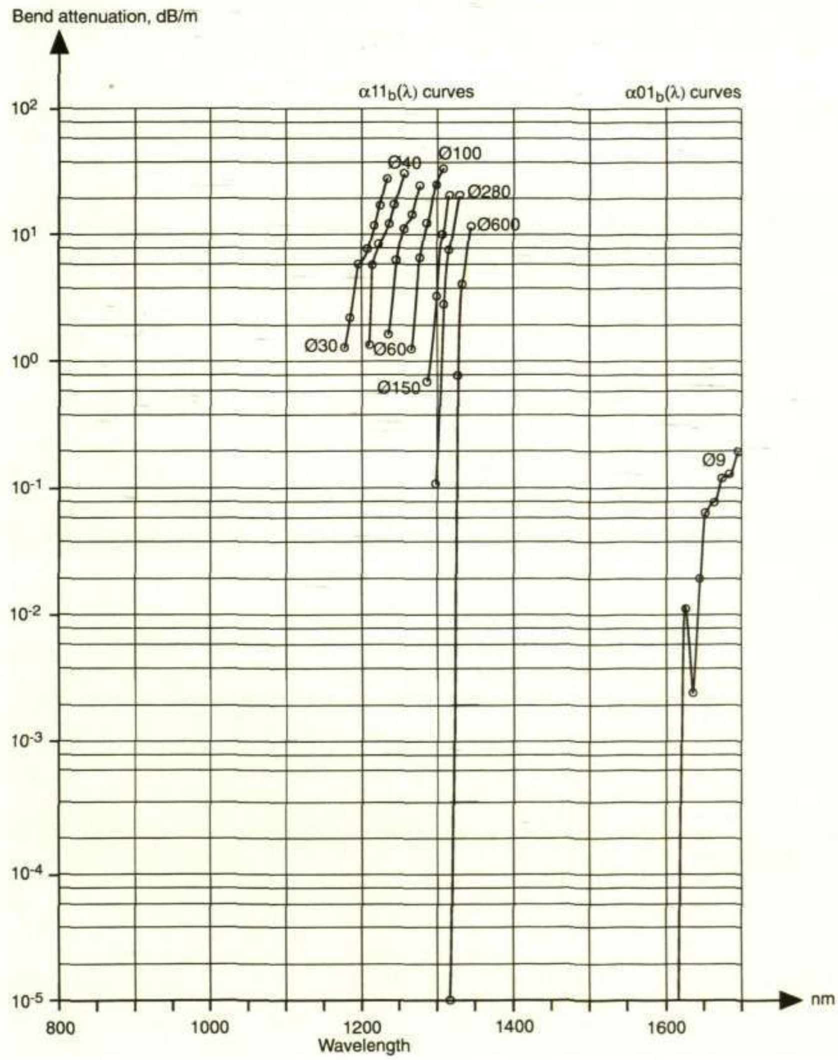


Fig. 14
The 2 m macro bend test results for a dispersion-shifted fibre
The $\alpha 11_b(\lambda)$ curves measured for bend diameters from 30 mm to 600 mm and $\alpha 01_b(\lambda)$ on a 9 mm bend diameter. The bend attenuation the LP01 mode for 30–600 mm was negligible (smaller than 10^{-6} dB/m), and even for a 9 mm bend diameter it is on the limit of measurement resolution

Ø = bend diameter, mm

each other. The results for one dispersion-shifted fibre are shown in Fig. 14. The fibre is much more insensitive to bend attenuation of the LP01 mode than standard fibres (cf. Fig. 8). It can be bent to 9 mm bend diameter without showing any measurable attenuation increase at 1550 nm.

Summary

The $\alpha 11_b(\lambda)$ method has been used to investigate fibre bending in short fibre and cable samples. Valuable information has been obtained without the samples being exposed to the extreme conditions at which attenuation increases of the LP01 mode could be detected. For loose-tube cables, fibre bending, attenuation increases caused by macrobends, and temperature and tensile performance windows could be estimated from room temperature measurements on 30 m cable samples together with 2 m fibre samples. The method does not answer all possible questions, but it gives much more information than standard LP01 mode attenuation measurements do.

In addition to cables, fibre ribbons have been tested in 9 m samples. Even for ribbons the fibre bending situation – in particular, whether microbending was present or not – could easily be determined with the $\alpha 11_b(\lambda)$ method. The reference test of the method (the 2 m macrobend test) is a quick, informative and reliable way of testing the bend sensitivity of a fibre and can be used for comparison between different fibre manufacturers, different types of fibre, etc.

Future applications of the $\alpha 11_b(\lambda)$ method could include testing of dispersion-shifted fibre cables (as discussed above, these fibres are very insensitive to bending) and testing of high fibre-count cables. The latter may consist of hundreds of fibres, and the testing of them is normally very expensive and time-consuming.

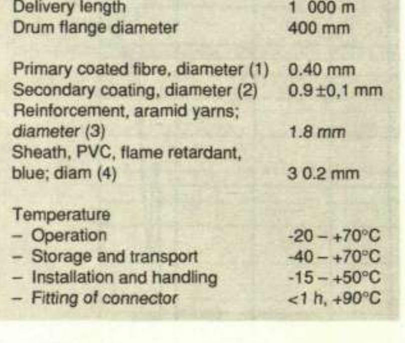
Box 4
TIGHT-BUFFERED CABLE DESIGN

This Box contains data of a cable with one single-mode fibre and an outer sheath of PVC. The fibre has a primary coating of a mode-stripping acrylate, mechanically strippable, and a secondary coating of polyamide.

The cable is reinforced by aramid yarns and, in axial direction, will withstand a maximum force of 300 N for one hour and a maximum static axial force of 50 N for a long time without any damage. Provided that no other forces are acting on the cable, the minimum bending radius is 35 mm for one turn and a minimum of 50 mm in the case of more than one turn. The cable will withstand vibrations of 10 to 500 Hz, amplitude 0.35 mm, with an acceleration of 50 m/s² during 10 sweeps in either direction, and 90–95 % relative humidity at 40°C for 21 days.

Data

Outer diameter, nominal	*3 mm*
Net weight	9 kg/km
Delivery length	1 000 m
Drum flange diameter	400 mm
Primary coated fibre, diameter (1)	0.40 mm
Secondary coating, diameter (2)	0.9 ±0,1 mm
Reinforcement, aramid yarns; diameter (3)	1.8 mm
Sheath, PVC, flame retardant, blue; diam (4)	3 0.2 mm
Temperature	
– Operation	-20 – +70°C
– Storage and transport	-40 – +70°C
– Installation and handling	-15 – +50°C
– Fitting of connector	<1 h, +90°C



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The AXE Transgate, a New Transit Exchange

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As business becomes more international, there is an increasing need for new services to be provided on a worldwide basis, for example ISDN. With the evolution of intelligent networks, more services can be offered from the transit network – Virtual Private Network, to name one. Such demands necessitate a major evolution of the switching systems used in transit applications.
The author describes the principles and features of the AXE source system APT 210 11, which is intended for ISDN transit switches including international gateways.

ISDN
electronic switching systems
telecommunications computing
intelligent networks

AXE 10 consists of two systems, the control system APZ and the application system APT. The APZ contains the processors, I/O functions and the operating system.[1] There is a range of application systems (APT) which implement telephony functions, and which make use of the APZ. This article focuses on the application source system APT 210 11 for advanced gateways, with its current functionality. The commercial name of this system is AXE Transgate.

Ericsson has supplied a large number of switches for transit operation. The principles and features of AXE 10 as a POTS

Fig. 1
The presentation of calling line identity is a popular service.
The number of the calling subscriber is presented on the display of a telephone set allowing the called subscriber to decide whether to answer the call or not. The number can also be noted and used for calling back at a more convenient time.
With international ISDN, the calling line identity can also be presented when calls from abroad are received

transit switch are described in Box 1. APT 210 11 retains these features and, in addition, provides significant enhancements for the handling of ISDN traffic with full interworking with the PSTN. Ericsson's intelligent network (IN) technology is integrated in APT 210 11, which means that sophisticated services can be offered from the transit layer of the network.[3]

APT 210 11 has been developed in a series of projects called BM phase 1, BM phase 2, etc. The source system is designed in a flexible way in order to allow more features to be added.

Fig. 2 shows some of the important features of APT 210 11.
- CCITT and ETSI standards for network signalling are essential in a multi-vendor environment
- Wideband provides digital transmission with bit rates higher than 64 kbit/s and is used for video-conferencing, for example
- International Virtual Private Networks use equipment from the public network to build cost-efficient long-distance networks for large corporations
- Integration of IN, ISDN and PSTN means that these different networks must be capable of coexisting in the same node. Full interworking between them is supported
- Improved Operation and Maintenance, particularly in the area of ISDN, is required. More network traffic management control actions have been defined in order to limit/prevent disturbances in the network. Measurements on trunk lines are improved through the addition of more advanced preprogrammed activities

Box 1
Transit POTS applications

The most important functionality in AXE 10, used as a transit POTS switch, is summarised.

Digital Group Selector
The switch fabric is a Time-Space-Time (TST) structure. It can be configured in sizes up to a maximum of 65,535 ports. It is not sensitive to uneven loading and provides full availability irrespective of route size.

Synchronisation
Three different clock modules control the group selector and the digital transmission. Several modes of synchronisation are supported:
- Plesiochronous operation
- Master-slave network synchronisation
- Mutual single-ended network synchronisation.

Call Control
The digits of the called party (B-number) are analysed, and the result of this analysis provides input to routing, charging, etc. The routing analysis can be set up in a flexible way, allowing a number of alternative routes if there are no available circuits in the first choice route. The traffic can also be distributed over a number of routes, either on a random basis or based on time, type of day, etc. The call control function monitors the connection once it has been set up, and it also controls its release.

Echo control
Echo suppressors (or cancellers) can be switched on/off depending on:
- Static route data. For instance, echo suppression may always be applied to a route
- The type of incoming route
- Signalling information as to whether echo control has been applied in preceding or subsequent nodes.

Signalling
Standard international PSTN signalling systems are supported:
- CCITT R2
- CCITT No. 5
- CCITT No. 6
- CCITT No. 7 with MTP and the Telephony User Part, Box 2

A large number of national signalling variants are also supported. Digital Circuit Multiplexing Equipment (DCME) can be used with the signalling systems above.

Charging
Two modes of charging are supported:
- Sending of meter pulses to subordinate exchanges
- Detailed billing output (toll-ticketing) including called party number, calling party number, duration of call, etc.

Accounting
The number of call minutes are recorded on a per route basis. The call is first analysed with respect to its characteristics, and then it is decided to which group of counters the duration of the call is to be added.

Operation and Maintenance
The description is limited to functions of particular importance for transit applications. More descriptions can be found in References[2,5].

Functions for supervision of hardware and software as well as of live traffic are provided. Alarms are issued if predetermined quality levels are no longer reached, and faulty units are automatically blocked. An example of a supervisory function is the monitoring of seizure quality, which indicates faulty devices that cause abnormally short seizure time.

Test and fault localisation when alarms and faults occur is supported. Functions include test calls for testing telephony devices and switching paths. Another example is the possibility of connecting external Automatic Transmission Measuring Equipment (ATME) for supervision of the transmission quality. These functions can also be used for routine testing.

Statistics to be used for planning purposes are provided. Functions include traffic recording on routes and number directions. The traffic in erlang, number of calls, number of seized devices, number of blocked devices and call congestion can be recorded.

Network traffic management
Network traffic management comprises functions for supervising the network and for initiating control actions in case of disturbances. Supervisory functions include destination Answer-Seizure-Ratio (ASR) supervision, which gives the traffic efficiency calculated as the share of seizures that lead to B-answer for a destination. An example of control actions is the restriction of accessible outgoing circuits, which makes it possible to restrict the number of accessible circuits in a trunk route for outgoing traffic. This function can be used to restrict the traffic towards an overloaded exchange or area.

Tones and announcements
Tones and announcements can be generated from the transit network in case of congestion, for example.

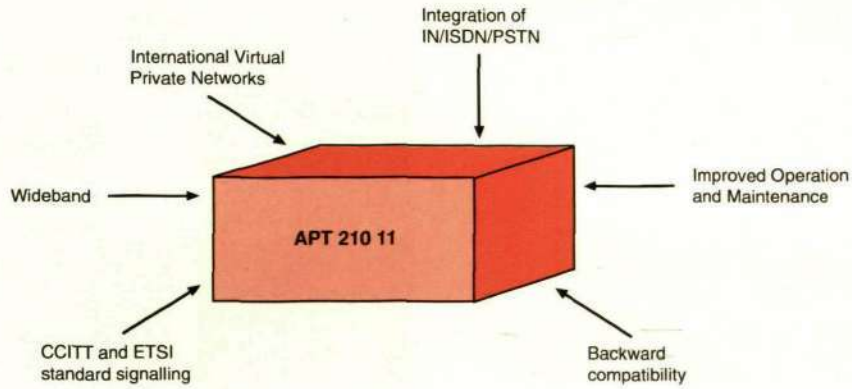


Fig. 2
Paramount APT 210 11 features

- Backward compatibility with previous versions of AXE 10 transit switches is ensured through retained functionality. The operational interface is also the same, except in cases where changes are motivated by new functions.

Switching nodes for network applications

APT 210 11 can be used in different applications, Fig. 3. Several applications can be combined in one physical node.

International switching centres
International switching centres are the gateways for interconnection between countries and must be capable of offering reliable, high-quality voice circuits. To accomplish revenue-sharing between international carriers, inter-administration accounting is required. International signalling systems and special functions such as translation of numbers to an international format are also needed.

National transit
A consequence of the current liberalisation of the telecommunications in many countries is that several operators are competing with each other. This means that a national transit switch may also serve as a gateway to the networks of other operators and therefore needs the same kind of functionality as an international gateway.

Service switching point
The Service Switching Point (SSP) is a node in an intelligent network that handles the service switching functions: it detects events which require IN functions to be invoked and handles circuit switching.

Service control point
The Service Control Point (SCP) is a centrally placed node that contains the logic and data needed for offering IN-related services.

Signal transfer point
The Signal Transfer Point (STP) is used for transferring CCITT No. 7 signalling information in an efficient way. Security functions are required in order to prevent unauthorised use, especially in international applications.

Logical structure of APT 210 11

APT 210 11 consists of a number of subsystems with central processor software, Fig. 4. Basically, there is a core which handles call control, charging, and operation and maintenance. The core interacts with different signalling systems and imple-

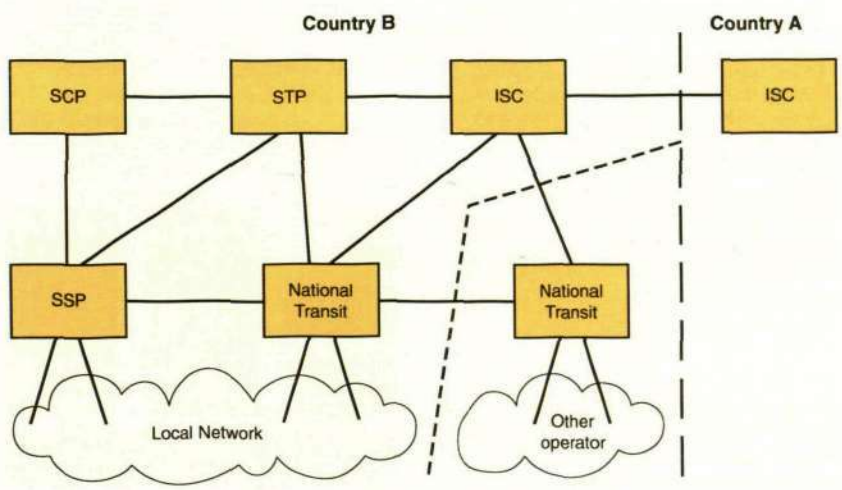


Fig. 3
Different network applications of APT 210 11

ISC	**International Switching Centre**
SSP	**Service Switching Point**
SCP	**Service Control Point**
STP	**Signalling Transfer Point**

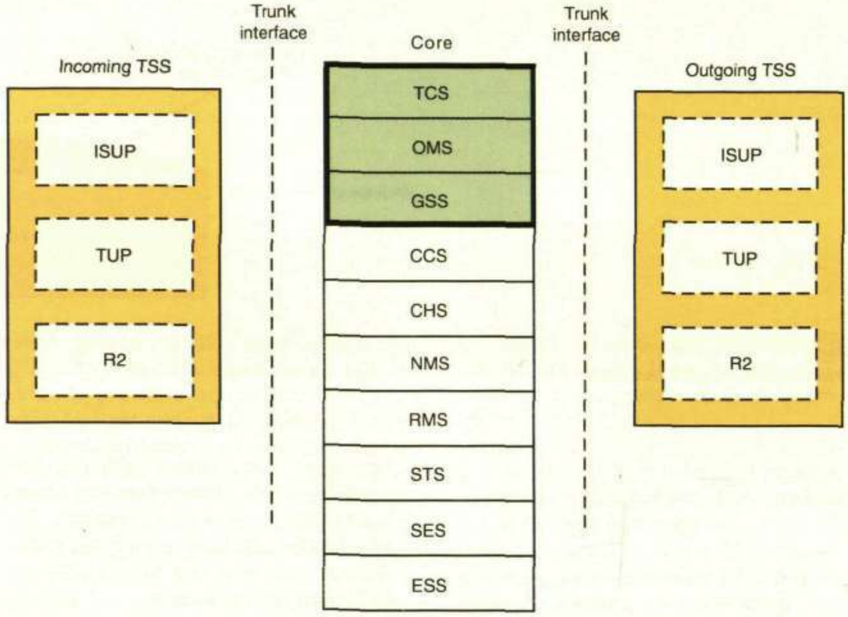


Fig. 4
Logical structure of APT 210 11

TSS	Trunk and Signalling Subsystem
TCS	Traffic Control Subsystem
GSS	Group Selector Subsystem
OMS	Operation and Maintenance Subsystem
CCS	Common Channel signalling Subsystem
CHS	CHarging Subsystem
NMS	Network traffic Management Subsystem
RMS	Remote Measurement Subsystem
STS	STatistics Subsystem
SES	SErvices Subsystem
ESS	Extended Switching Subsystem

ments functionality common to the signalling systems, e.g. number analysis. The core is structured to permit different subsystems to be developed independently of each other.

Three subsystems in the core – TCS, GSS and OMS – are mandatory and necessary for all applications. The others are optional and only added if required by the customer.

APT 210 11 can easily be adapted to any existing international and national signalling system. The most important international PSTN signalling systems are CCITT No. 5, No. 6, No. 7 and R2. The signalling protocol for CCITT No. 7 is implemented in the Telephone User Part (TUP) and the ISDN User Part (ISUP), both of which are based on the Message Transfer Part (MTP), Box 2.

The signalling systems are implemented in the Trunk and Signalling Subsystem (TSS) and have a common interface to the core. Translations between the inter-exchange signalling and the internal format of this common interface is performed in the TSS. Other subsystems are therefore unaffected by adaptations to a new signalling system. The core interface allows all ISDN- and PSTN-related information to be passed through the core. The interface is structured so that a signalling system need only implement parts of it, depending on how much information can be passed in the inter-exchange signalling. This principle also ensures backward compatibility of signalling system software so that when new versions of the core are released, older versions of signalling system software can be reused.

The incoming and outgoing signalling systems interwork through the core, which

Box 2
Signalling system No. 7

Signalling system No. 7 consists of a Message Transfer Part (MTP) which defines the interfaces and procedures used for transfer of signalling data between exchanges. The MTP transfers data without having any association with a telephony circuit, which means that it is similar to a packet network. Data is sent on special signalling links between the switches.

The services offered by MTP are used by the User Parts (UP) which contain functions for the control of calls and circuits. Since the UPs are controlling circuits they can be said to be connection-oriented.

MTP is also used for connection-less signalling, when the signalling does not have any association with a physical circuit between the two switches. An example of connection-less signalling is when an SSP makes an enquiry to the SCP (no voice circuit is set up between the SSP and SCP; only messages are sent). MTP is thus used by the Signalling Connection and Control Part (SCCP), which in turn is used by the Transaction Capabilities Application Part (TCAP), Fig. A. Several applications are based on TCAP, for example INAP, the signalling protocol used in Intelligent Networks. The MTP, SCCP and TCAP functions are provided by the subsystem CCS, whereas the UP functions belong to TSS.

The first user part specified was the Telephony User Part (TUP), which supports the same functionality as previous PSTN signalling systems. In addition, some more services are specified including the possibility of indicating digital connections. The TUP is now mature, and no significant enhancements to the protocol is expected beyond its present status.

For ISDN, a new user part was specified with greater flexibility than the TUP: the ISDN User Part (ISUP). ISUP supports a wide range of services, including voice and data transmission. A large number of supplementary services are also supported. Below is a list of those supported for international ISUP, Q.767:

- User-to-User Service 1
- Closed User Group
- Calling Line Identity Presentation
- Calling Line Identity Restriction
- Connected Line identity Presentation
- Connected Line identity Restriction

APT 210 11 presently supports two versions of CCITT ISUP (besides a number of market versions), the international Blue Book (Q.767) ISUP and a full Blue Book ISUP enhanced with some White Book features, such as the new compatibility procedures. The standardisation bodies are adding more features to the recommendations, so ISUP will continue to be developed for quite a while.

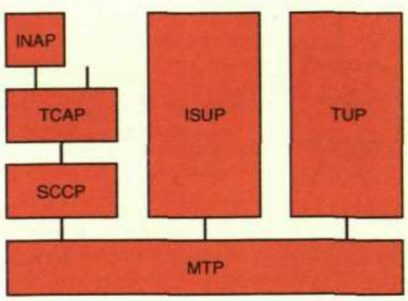


Fig A
Signalling system No.7, Structure

Box 3

Interworking for the CLIP/CLIR services

Different signalling capabilities

The signalling systems on the incoming and outgoing sides of a switch often have different capabilities. An example is when the incoming side is of type R2, capable of transferring Calling Line Identity (CLI), and the outgoing side is of type ISUP. In ISUP, the setting of a Presentation/Restriction Indicator is mandatory; the setting indicates whether or not it is allowed to present the CLI to the called party. Since there is no such indication in R2, the gateway exchange has to make a decision. Normally this indicator is set to 'restricted', since the number may belong to a subscriber who has requested that his number is not to be revealed

National/international aspect

When the call passes through an international gateway, the CLI must be modified to an international format, adding the country code to the calling party number. For instance, the CLI in a call from Ericsson, Sweden, will be modified as follows:

8 719 00 00 –> 46 8 719 00 00

At the same time, the indicator in ISUP indicating national or international number is modified to 'international'.

When the call passes an incoming international gateway, the CLI may be checked as to whether it has the network's own country code, in which case that code will be removed. The international access code used in the destination network may also be added to the CLI, so that the number presented to the called subscriber can be used for calling back. For instance, a call from Sweden may, in Holland, be modified as follows:

46 8 719 00 00 –> 09 46 8 719 00 00

Bilateral agreements

Depending on bilateral agreements between different administrations, the CLI may be passed to country A but not to country B. It is possible to set the exchange data regarding the transfer of CLI to a particular destination in three different ways:

- Always send CLI
- Send CLI if the presentation/restriction-indicator says 'allowed'
- Never send CLI.

is adapted to handle ISDN information. The core effectively conceals from the outgoing side which signalling system is used at the incoming side. This means that no special interworking software need be designed for each case and that any signalling system can interwork with any other one. The different subsystems are:

TSS Trunk and Signalling Subsystem
handles the trunk hardware and protocol aspects and provides a standardised interface to the core

TCS Traffic Control Subsystem
handles call control functions such as routing, digit analysis and supervision of connection

GSS Group Selector Subsystem
handles the switching of calls, and synchronisation

OMS Operation and Maintenance Subsystem
contains supervisory, statistical and administrative functions

CCS Common Channel signalling Subsystem
contains the CCITT No. 7 signalling system except the User Parts, i.e. the Message Transfer Part (MTP), Signalling Connection Control Part (SCCP) and Transactions Capabilities Application Part (TCAP)

CHS CHarging Subsystem
contains functions for toll-ticketing, pulse metering and inter-administration accounting

NMS Network traffic Management Subsystem
collects data on the performance of the network and invokes certain network traffic management controls

RMS Remote Measurement Subsystem
contains functions for measurements on trunk circuits. Measurements can either be initiated by means of commands or be preprogrammed

STS STatistics Subsystem
is used for output of statistics from some functions, for instance CCS

SES SErvices Subsystem
contains functions needed for Intelligent Networks

ESS Extended Switching Subsystem
handles announcement machines and equipment for three-party calls.

Concepts

Transmission Medium Requirements

The Transmission Medium Requirements (TMR) reflect the bandwidth a call needs. TMR – conveyed as a mandatory parameter in ISUP – are used in various ways in the system, e.g. in the selection of an outgoing route. Charging and accounting also use TMR as an input. TUP has an indicator which, when activated, shows that a digital connection is required. Towards the core this indicator is mapped to the TMR value 64 kbit/s.

Interworking

Interworking between different signalling systems/networks is what characterises a gateway. Three different aspects of interworking can be identified:

- Different signalling capabilities on the incoming and outgoing sides
  The incoming and outgoing sides may have different capabilities to transfer information
- National/international call
  The call crosses the border between the national and international networks, which means that certain number translations are required
- Bilateral agreements regarding the service level between different administrations
  The amount of information transferred may differ depending on the destination.

Extensive examples of the interworking aspects of the CLIP/CLIR service are presented in Box 3.

Transparency

ISUP specifications include provisions for how to deal with unrecognised information, i.e. information sent to the switch in ISUP format but not recognised because the new message, the new parameter or the new parameter value is unknown to the switch. The ISUP recommendations in the Blue Book specify that unrecognised information should be passed on in certain cases, and APT 210 11 contains mechanisms to meet this requirement.

ISUP preference indicator

Since there are services which can only be supported by ISUP, it is necessary that only ISUP routes are used for certain calls. A new indicator, called the ISUP preference indicator, has therefore been introduced in the signalling. In APT 210 11, mechanisms are provided so that an IN-based service, for example, can set this indicator correctly. The values of the indicator are

- 'ISUP required', when ISUP must be used all the way because some information transfer is crucial
- 'ISUP preferred' is used when ISUP signalling is preferred all the way, typically because some ISDN information is to be transferred. The information transfer is not crucial, however
- 'ISUP not required' is typically used for POTS type services.

Functionality of APT 210 11

The functionality used in AXE 10 as a transit POTS switch has been retained in APT 210 11, and a number of new features have been added. Some of them are described in the following sections.

ISDN User Part – ISUP

Signalling within ISDN is based on CCITT No. 7 with a specially adapted user part, ISUP, which supports several applications, such as data and telephony, Box 2. Many supplementary services, e.g. Calling Line Identity Presentation (CLIP), are also supported. However, POTS traffic can also be carried on ISUP, which simplifies the network since only one signalling system is needed.

The ISUP version used for international interconnections is Q.767, which was approved by CCITT in 1990. It is a subset of the functionality specified for national use in ISUP recommendations Q.761–Q.764.

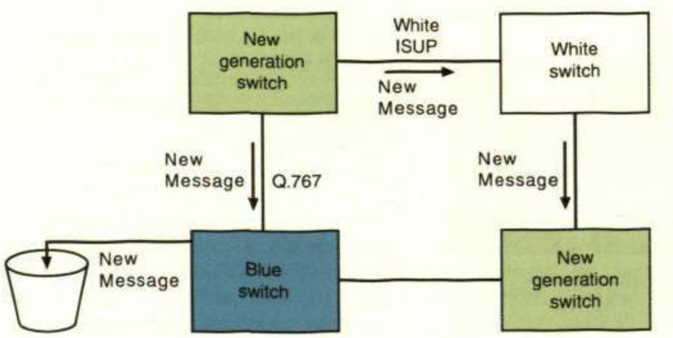
The CCITT White Book ISUP (ISUP'92) recommendations include many more services and functions. The most significant difference in relation to the Blue Book is the new compatibility mechanism, which enables the network to change signalling system gradually by making some switches transparent to the new information. This new mechanism allows two different versions of White Book ISUP to interact on a peer-to-peer basis, Fig. 5. Any new message or parameter must be accompanied by compatibility information stating how a switch that does not recognise the message or parameter should react. This compatibility information must be generated by the respective applications, using the new parameters/messages. That is why the APT 210 11 features mechanisms that provide information on the coding to be used for a specific application, for instance an IN service.

Some ISUP versions are subsets of another ISUP version. Q.767 is a subset of the Blue Book ISUP. A new function, called 'ISUP screening', is introduced in APT 210 11. It allows the standard ISUP protocol to be modified so that it will fit into a different specification. The function is used for creating international versions of ISUP and can also be used for creating national versions, Box 4.

ISDN routing

The ISUP preference indicator and Transmission Medium Requirements (TMR) are used as inputs to the routing analysis so that the optimum route can be selected. In order to simplify the setting up of routing tables, a new function – 'compatibility check' – is introduced. It ensures that the characteristics of the chosen route are adequate for the call; otherwise an alternative route is tried. The value of the ISUP preference indicator is used to separate POTS-level traffic from ISDN traffic.

Fig. 5
ISUP compatibility procedures
Any new message in White Book ISUP must be coded with a new parameter – Message Compatibility Information (MCI) – that instructs the subsequent exchange what to do if the message is not recognised. The different actions are
– Transfer transparently across the switch
– Discard an unrecognised message
– Release call.
The figure shows what happens if the MCI is set to 'transfer transparently'. In the White Book exchange, the new message will be passed on to the subsequent exchange. However, if a new message is sent to a Blue Book exchange it will be discarded. A similar mechanism exists for parameters



Box 4
ISUP screening

Screening is a function that can modify both sent and received information transferred in ISUP. Screening means reducing the amount of information by discarding certain messages or parameters or by altering the information. The standard ISUP protocol provides a basis for the creation of a new ISUP version by means of commands. This can be useful when creating a national ISUP that is close to the standard specifications. The function can also be used to filter out certain information when interworking with a node that does not support the full protocol specification. Typical actions that can be taken are:
- Discard messages
- Discard parameters
- Alter parameter field values
- Treat the information as unrecognised.

Interworking for supplementary services

With ISDN, many more supplementary services will be run on a network-wide basis, and more interworking functionality is therefore required. The interworking function for supplementary services is structured in accordance with the three aspects outlined in the concepts; that is, there is functionality to cope with cases of different signalling systems, incoming or outgoing international calls, and cases where the information transferred is to be restricted on a destination basis. Interworking is supported for services that can be networked via ISUP.

The signalling systems send information regarding their signalling capabilities for supplementary services to the core, enabling it to determine whether interworking is required. Each route is marked as either international or national. By combining the marks of the incoming and outgoing routes, the core can determine whether the call is an incoming or outgoing international call or a transit call.

Intelligent networks

The Intelligent Network platform is adapted to ISDN.[3] The service- independent building blocks of which the services are built are extended with parameters such as TMR and the ISUP preference indicator. This allows services to be adapted to ISDN.

With the separation of switching from the logic and data for services in an Intelligent Network, a new signalling protocol, INAP, is introduced for communication between SSP and SCP. INAP is a No. 7 signalling system based on TCAP.

International Virtual Private Networks

An International Virtual Private Network (I-VPN) is a network dedicated to a private user – typically a large corporation – using public network resources. To the users it appears to be their own network, but its resources are in fact shared with others, including public users. In this way, resources can be more efficiently utilised, and large corporations need not build and maintain their own physical networks.

Some of the driving forces behind International Virtual Private Networks (I-VPN) are
- Cost reduction for long-distance calls by volume discounts to large customers
- Private numbering plans for large customers.

APT 210 11 supports these requirements by using a combination of IN technology and ISDN. There is a special service logic program, based on the IN platform and implementing I-VPN with all logic needed for validation of users, private numbering plan, etc. This service logic generates a VPN indicator that indicates whether the call is a VPN call or not. The VPN indicator is then used as input to charging and accounting, which makes it possible to differentiate the billing for this type of traffic. Fig. 6 shows how several nodes can interact by means of the VPN indicator, which is conveyed in ISUP.

With ISDN, an enhanced service level is achieved for end users, since all services

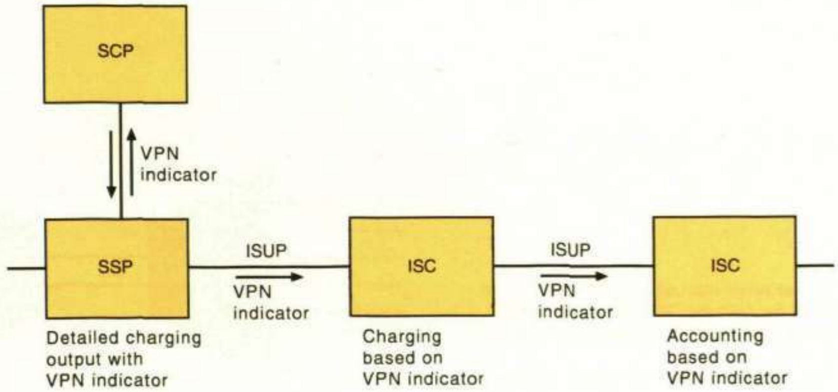


Fig. 6
An I-VPN scenario
The VPN indicator is supplied from the SCP when the call has been verified as a VPN call and sent on in the network. Subsequent nodes can use it to control charging and accounting

Fig. 8
Automatic Congestion Control
The processor load is continuously monitored, and when a predefined threshold is exceeded, automatic congestion level parameters are inserted in the release messages sent out from the affected node. Two different congestion levels can be indicated. The nodes receiving such indications will reduce the number of new call attempts to the affected node by invoking a response program

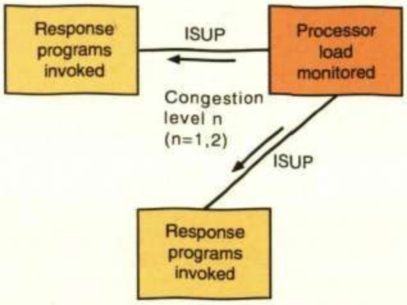
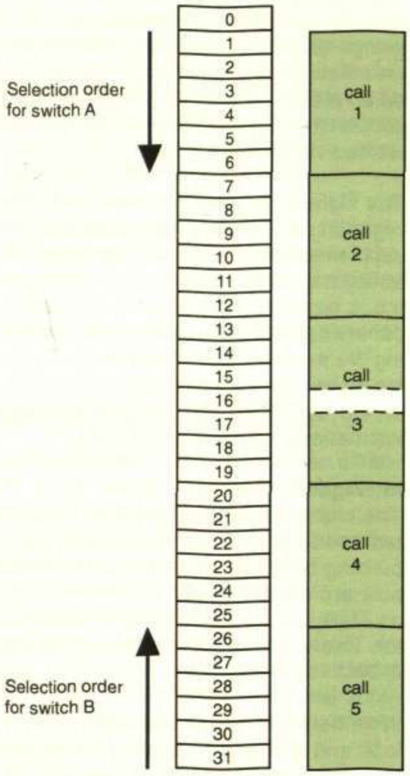


Fig. 7
Layout of wideband calls
The figure shows how 384 kbit/s (six 64 kbit/s channels) calls are allocated in a PCM system. There are fixed starting positions for each call: call 1 always starts in time slot 1, call 2 in time slot 7 etc. Time slot 16 is not used by on-demand connections since it may be used for Q.33 supervision. There is such a layout for all wideband values of n.
Since a wideband call cannot proceed if one of the time slots in the 'window' is busy with a single channel call, there is a risk that all 'windows' are congested even if the traffic level is low. Therefore, only sequential selection of channels is allowed, which means that a call always tries to seize a free position as close as possible to the upper or lower end of the range (which can expand over many PCM systems for a large trunk). In this way the middle range is kept clear for wideband calls unless the traffic is high



Box 5
Response programs

A response program is used in conjunction with some network traffic management control, for instance Automatic Congestion Control (ACC). It defines the type of traffic to be restricted, i.e. which call attempts are to jump to the next alternative route or be discarded. The percentage – in steps of 10 per cent – of the traffic to be restricted is also defined. Different types of traffic can be treated differently. Examples of types of traffic are

- Direct route
  Call attempts to the first choice route to a destination
- Alternative route
  Call attempts that meet congestion on the first choice route and, consequently, are trying a second, third, etc. alternative
- Priority
  Certain subscribers, or traffic originating from or terminating at certain destinations (for instance emergency calls), can be assigned priority. The priority indication can be transferred in some signalling systems.

Table 1 gives an example of how a response program for the ACC function can be specified for a particular switch. Different response programs can be defined for different adjacent switches in the ACC function. The table shows that alternative traffic is reduced by half at the first congestion level and totally at the second, more severe level. Priority traffic in progress is only slightly affected at the second level.

Table 1

Type of traffic	ACC level 1	ACC level 2
Direct route	20	80
Alternative route	50	100
Priority route	0	20

Fig. 9
The exchange must send a TMR value to the DCME for each call. This informs the DCME whether to compress the call or give it a 'clear channel'

DCME Digital Circuit Multiplexing Equipment

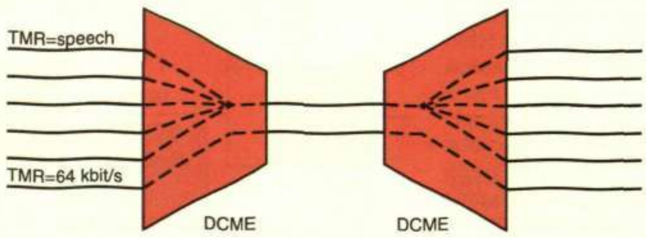


Fig. 10
Video conferencing – an increasingly popular service – is one of the applications of wideband connections

supported by ISUP will be available on a network basis. In the White Book ISUP, there is further support for private numbering plans. These enhancements are used by Ericsson's I-VPN implementation.[4]

Wideband

Wideband covers bandwidths between 64 kbit/s and 2 Mbit/s. It is used for videoconferencing, high-quality sound, LAN interconnect, etc. Both on-demand (dial-up) and semi-permanent connections are supported. For these connections it is essential to maintain Time Slot Sequence Integrity (TSSI), which is achieved by a special algorithm for selecting the path through the group switch. Existing switch fabric can be used.

Network signalling for wideband is defined in the White Book ISUP. To put it simply, new TMR values and some new procedures have been added. Wideband calls can be mixed with ordinary calls on the same trunk in order to optimise the utilisation of transmission capacity. Fig. 7 shows how wideband calls are allocated within a PCM system.

Automatic Congestion Control

The Automatic Congestion Control (ACC) is a means of preventing overload situations in the network and, thus, reduces the need of manual intervention. In APT 210 11, the function is implemented by means of response programs, Box 5. The ACC works as shown in Fig. 8.

DCME interface

Digital Circuit Multiplexing Equipment (DCME) is used for compression of speech so that several voice calls can use the same 64 kbit/s channel. Typical ratios are five voice calls on one 64 kbit/s channel. However, digital calls cannot be compressed, and that is why – in APT 210 11 – the switch is capable of signalling the TMR value to the DCME equipment as specified in CCITT recommendation Q.50, Fig. 9. The DCME must then select a 64 kbit/s clear 'channel'.

Summary

APT 210 11 fulfills the needs of many different types of node in the transit network, including IN nodes and international gateways. All functionality can be integrated in one node as a Service Switching and Control Point (SSCP) combined with strong international capabilities. New services, such as wideband and I-VPN, are supported.

The major international signalling systems are supported. There is extensive interworking functionality, especially in the area of supplementary services. ISUP is designed according to Blue Book specifications and further enhanced with White Book features. As AXE's modular concept allows for easy growth of functionality, ISUP and other parts of the system will be enhanced as specifications evolve and new market demands arise.

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TELECOOL, a New Generation of Cooling Systems for Switching Equipment

Lennart Ståhl and Håkan Zirath

Since the end of the 1970s, Ericsson has developed and marketed cooling systems for switching equipment. Today, these systems are installed in many countries. Altogether, some 450 plants are in operation. Now, Ericsson introduces a new generation of cooling systems: TELECOOL and TELECOOL Compact. The authors describe the design, characteristics and functions of these systems.

cooling
electronic switching systems

Electronic switching equipment is characterised by its compact design and high power density. The power dissipation per square metre of the floor in a densely equipped switching room is fully comparable with that of a sauna (300–700 W/m²). The temperature will rise rapidly if the cooling system stops working, Fig. 1. This problem was envisaged at an early stage in the introduction of AXE.

Since the end of the 1970s Ericsson has developed and marketed cooling systems that are capable of meeting stringent availability and operational requirements, even during a mains outage. In order to comply with these demands, cooling capacity must be stored. From a technical and economical point of view, water is optimal as a means of storing cooling capacity.

Today, Ericsson's cooling systems are found in many countries around the world. Some 450 systems have been installed.

Now, Ericsson introduces a new generation of cooling systems for switching equipment – TELECOOL – which consists of two systems: TELECOOL and TELECOOL Compact. Like the previous cooling system ERICOOL, the new generation is based on the principle of natural convection. An extensive description of the function of a cooling system is given in Reference 1.

Common features of the two systems are:
- The heat in the switchroom is absorbed by a Climate Ceiling, where the heat from the equipment is absorbed in water-cooled, natural-convection Cooling Coils
- The room temperature is very even
- There are no local heat pockets
- Free cooling is applied – an energy-saving cooling principle. It often constitutes the redundancy of a Cooling Unit
- Modularity – extension in parallel with AXE
- High reliability – redundancy is provided for vital components
- The systems are also suitable for the cooling of operators' rooms, power rooms, etc
- The same dimensioning principles are used for both systems.

The main differences between the two systems are:
- TELECOOL has a cooling backup function that is utilised during mains outages, Fig. 2
- TELECOOL Compact can be installed in the switchroom. No separate room is needed for the cooling plant, Fig. 3.

Climate Ceiling
The Cooling Coils are water-cooled. Water has the important property of being able to absorb heat and store cold very effectively. The energy cost of transporting heat by means of water pumps is considerably lower than the corresponding cost when air fans are used, Box 1.

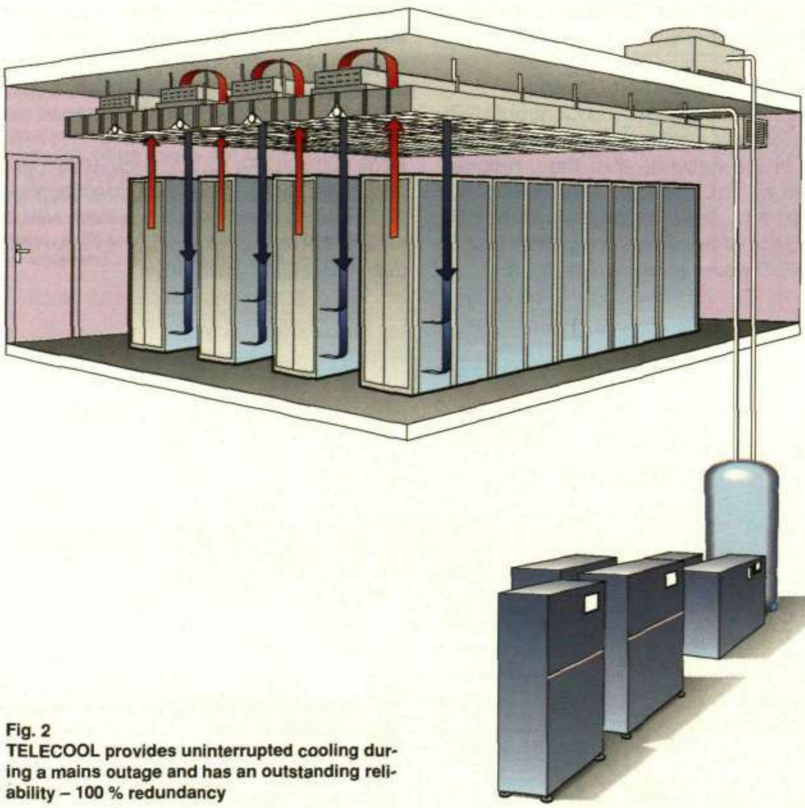

Fig. 2
TELECOOL provides uninterrupted cooling during a mains outage and has an outstanding reliability – 100 % redundancy

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HÅKAN ZIRATH
Ericsson Components AB

A Climate Ceiling is formed through the integration of the Cooling Coils in a false ceiling. With this Climate Ceiling, the heat-absorbing capacity of the Cooling Coils is considerably enhanced due to the chimney effect, Box 2. The Climate Ceiling also accommodates lighting fittings, Fig. 4.

Free cooling saves energy and constitutes redundancy

Free cooling means that the low outdoor temperature is utilised to cool the water in a cooling system. In a temperate climate, where the temperature is low during the greater part of the year, considerably reduced operation costs can be achieved, thanks to great energy savings. Free cool-

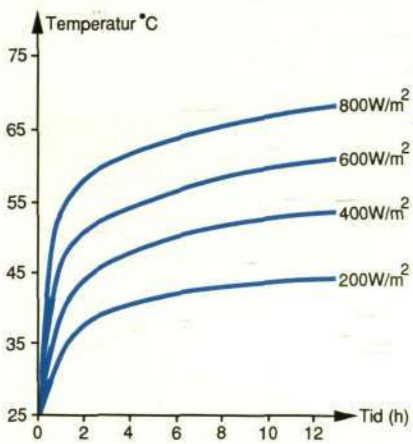


Fig. 1
Without cooling, the temperature in the switchroom rises quickly. Cooling during a mains outage can only be maintained if the cooling system contains cooling reserves

Box 1
Some physical characteristics of air and water

The suitability of a medium to transport and store energy is determined by certain physical characteristics.

Thermal capacity
The thermal capacity of a medium (specific heat) has the dimension *energy per mass and temperature unit* and is expressed in J/Kg K in the SI-System. Sometimes this constant is indicated per volume unit.

	Water	Air
Thermal capacity (kJ/kg K)	4.2	1.0
Thermal capacity (kJ/m³K)	4200	1.2

From these data it appears that water is superior to air as a storage medium.

Transport efficiency
Not only the capacity of a medium to transport heat must be considered but also the cost. Let us assume that 50 kW is to be transported from a switchroom to a Cooling Unit.

In a TELECOOL system, this transport is accomplished by means of water that is pumped around in a sealed system. The power consumption of the pump is 1.0 kW. In a conventional air conditioning system, air is circulated by means of fans in a system of air ducts. The power consumption of the fans is 7.0 kW.

The transport efficiency (T) is calculated as the transported power divided by the power required by the pump or the fan. T is 50 for water and 7 for air. Accordingly, the transport efficiency of water is seven times better than that of air.

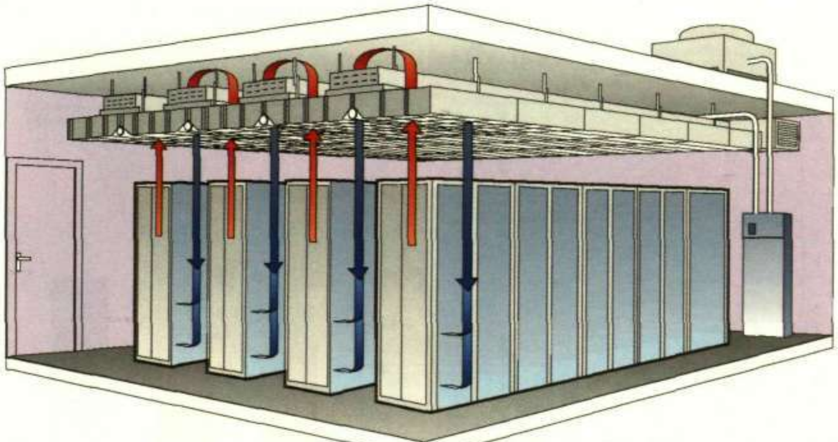


Fig. 3
TELECOOL Compact can be installed in the switchroom. No separate room is needed for the cooling plant. TELECOOL Compact offers a superior price/performance ratio, and installation is simple

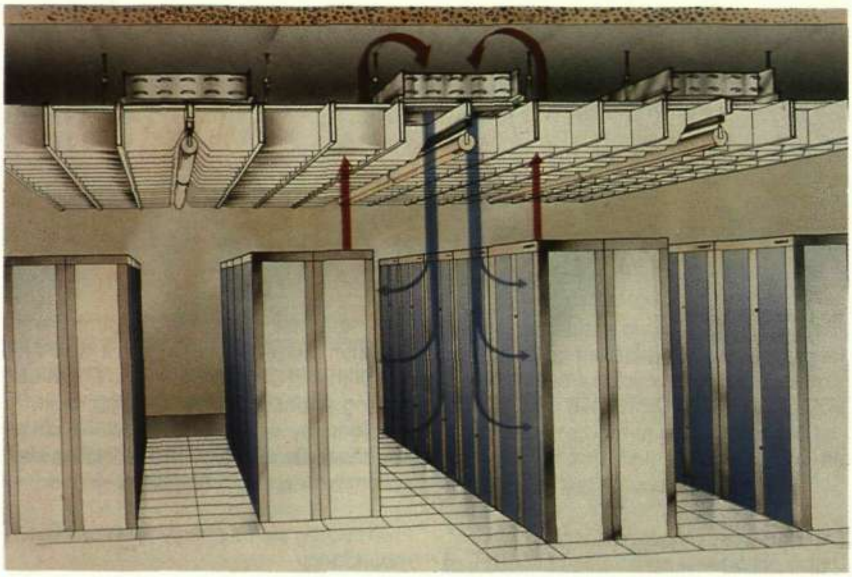


Fig. 4
Climate Ceiling
Hot air from the racks rises and is cooled by the Cooling Coils. The cooled air then descends towards the floor between the racks. The chimney effect provided by the Climate Ceiling gives the system very high efficiency

Box 2
Climate Ceiling

The Ericsson Climate Ceiling comprises
- Cooling Coils
- false-ceiling sections
- lighting
- suspension structure.

The Cooling Coils, which consist of copper tubes with aluminium fins, are placed in the row aisle, above the equipment, Fig. B1. The thermal transport between the electronic components of the racks and the water of the Cooling Coils is accomplished without fans, according to the principle of warm air rising and cold air sinking; what is called *natural convection*. High heat density increases the airflow, which means that better cooling will be achieved. This means that the cooling is self-regulating.

By integrating the Cooling Coils in a false ceiling, which form a raster covering the whole of the cooled room, the heat absorbing capacity of the Cooling Coils increases considerably due to the chimney effect.

A number of parameters that affect the cooling capacity of the climate ceiling has been studied, Fig. B1.

When analysing one parameter, the other two parameters are locked as follows: A 400 mm, B 250 mm, C 600 mm. The row spacing is 800 mm

With the above values of parameters A, B and C, a total enhancement of the cooling capacity of about 60 % is achieved, compared with Cooling Coils without a Climate Ceiling, Fig. B2.

The Climate Ceiling is mechanically separated from the equipment to be cooled, which makes for more flexibility as regards cooling of different types of equipment (not necessarily AXE). The lighting fittings in the Climate Ceiling give the ceiling an attractive appearance. Other installations – cabling, for instance – are also effectively hidden.

Natural convection and chimney effect
"Chimneys" increase the momentum of the air movement and thereby the capacity of a cooling system that works with natural convection.

The efficiency of the chimneys depends on geometrical and physical quantities such as flange height, fin spacing, thermal conductivity, heat capacity, density, viscosity, gravitation, temperature differences, etc. In the Climate Ceiling application, all material constants are given. Other parameters must be optimised to a total solution where due consideration must be given both to the efficiency in relation to cost, and to industrial and installation engineering aspects.

This optimisation problem has been studied at Ericsson by Arvidsson and Vesterberg who have solved the problem by means of a finite difference method and computer calculations.[2,3]

The design of the Climate Ceiling is based on this study.

Fig. B1
A number of parameters that affect the cooling capacity of the climate ceiling have been studied

- **A** Distance between ceiling and the top of the cooling coil
- **B** Height of the false ceiling section (chimneys)
- **C** Distance between top of rack and bottom of false ceiling

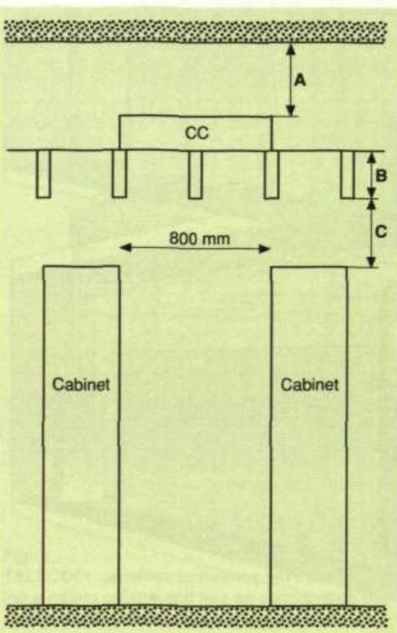
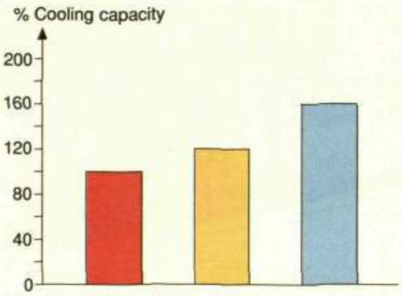


Fig. B2
With the Climate Ceiling, the heat-absorbing capacity of the Cooling Coils is considerably enhanced

- (red) **No chimney**
- (yellow) **Chimneys covering only the Cooling Coils. Only the cold air stream is controlled**
- (blue) **Chimneys (the Climate Ceiling) cover the Cooling Coils and the area above the racks. Both the warm and the cold air streams are controlled**



Box 3

Free cooling

In this context, the first and second thesis of thermodynamics could be expressed: "Energy is indestructible" and "Energy automatically passes from a body of a high temperature to a body of a lower temperature".

This means that if energy is conveyed into a room, it must also be removed from the room, unless the room temperature is allowed to rise (1st thesis). If the temperature outside the room is higher than the room temperature, the heat cannot be conveyed from the room to the surroundings (2nd thesis) without the use of a Cooling Unit, for example.

If 25°C is desirable in a room although energy is brought in and the outdoor temperature is higher – for instance 35°C – an active cooling system with a compressor must be used. If the outdoor temperature is lower than the room temperature – for instance 15°C – a system with Free Coolers can be used.

The free-cooling function is accomplished through heated water from the Cooling Coils of the Climate Ceiling passing a heat exchanger, where the heat is conveyed to another water circuit. This circuit, to which glycol is added for protection against freezing, is in turn cooled by an outdoor Free Cooler, where the heat in the next stage is emitted to the outdoor air.

At an outdoor temperature of 11°C or lower, all heat can be cooled off by means of the Free-cooling system. This applies to normal dimensioning of the TELECOOL systems.

Energy Saving
The efficiency of a process is expressed as the relation between the emitted power and the received power.

For a Cooling Unit, efficiency is expressed as the relation between the absorbed power and the electrical input power. The efficiency of a Cooling Unit is approximately 3.

For a Free Cooler, which could be described as a heat exchanger with a fan, efficiency is expressed as the relationship between the conveyed power and the electrical input power. The efficiency of free cooling in the TELECOOL systems is approximately 10.

A considerable amount of energy could be saved by using a Free Cooler when the outdoor air temperature is sufficiently low. How profitable a Free Cooler is depends primarily on the length of periods with low outdoor temperature. The variation of the power consumption with the outdoor temperature in a cooling system with only Cooling Units is compared with that of a system with both Cooling Units and Free Coolers, Fig. C1.

Redundancy
Redundancy in a cooling system is usually achieved through dimensioning according to the n+1 method. In this method, an extra unit is included for redundancy. If, for instance, the necessary cooling capacity of a system is 150 kW, and Cooling Units of 50 kW are used in the system, four units (3×50 kW + 1×50 kW) are required.

In a temperate climate, the free-cooling function of a system can be used for redundancy of the Cooling Units. Fig. C2 indicates the geographical area where this is possible. The switchroom temperature is allowed to rise temporarily, but will nevertheless be within the temperature specification for the electronic equipment.

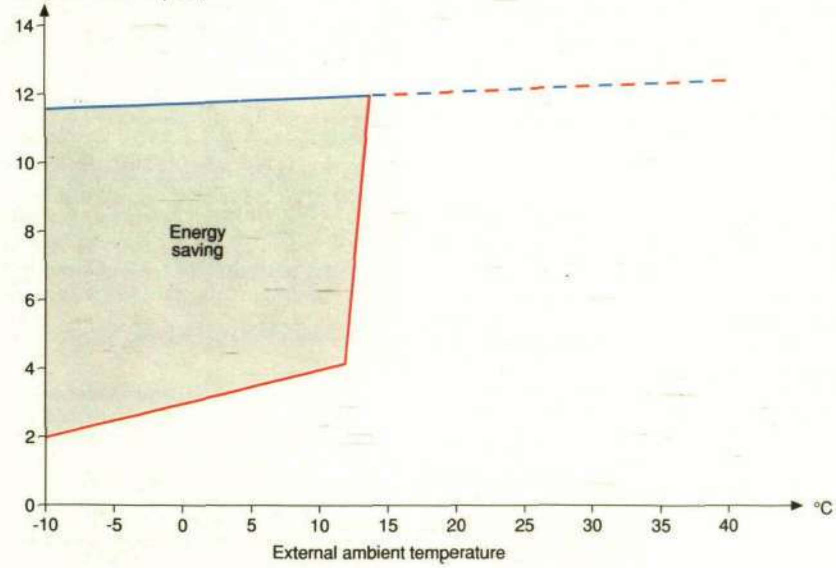


Fig. C1
The variation of power consumption with the outdoor temperature in a cooling system with only Cooling Units is compared with that of a system with both Cooling Units and Free Coolers

Only Cooling Units (blue line)
Cooling Units and Free Cooler (red line)

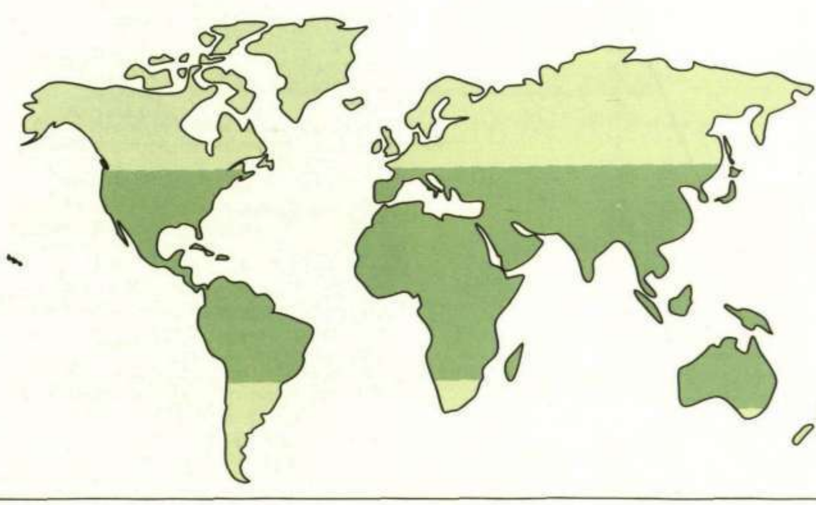


Fig. C2
In a temperate climate, the free-cooling function of a system can be used to provide redundancy of the cooling units

Recommended Free Cooler area. Local climatic variations must be considered (light green)

Free Cooler cannot be used (dark green)

Fig. 5
Computerised systems are used for design of Telecool in plant engineering

ing can also serve as redundancy for the Cooling Unit of the system, Box 3.

Modularity
The TELECOOL systems are modular and all units are connected in parallel. This means that the cooling systems can easily be extended in pace with the switching equipment and without affecting normal operation.

Dimensioning
When dimensioning a cooling system of a telephone exchange, due consideration must be given to *all* heat that is conveyed to the exchange and which must inevitably be cooled off, Box 4.

TELECOOL

TELECOOL features the following new characteristics:
- A Cooling Unit is designed as a packaged unit and contains a limited amount of refrigerant. The electric and mechanical interfaces between the Cooling Units and the other parts of the system are designed to allow the use of standard cooling units from other manufacturers
- The Control and supervisory system is based on microcomputers. It provides analog presentation of temperature and relative humidity. TELECOOL is prepared for connection to a central management system, such as Ericsson's PMAS
- Customised system solutions can be offered, ranging from direct connection to an existing chill water system to a complete new plant with redundant Cooling Units and cooling backup
- Optional functions – for instance humidification in dry climate, free cooling and different function levels of the supervisory system – are offered.

Configuration
The TELECOOL system is built of different units which can be combined into four basic systems, Table 1.

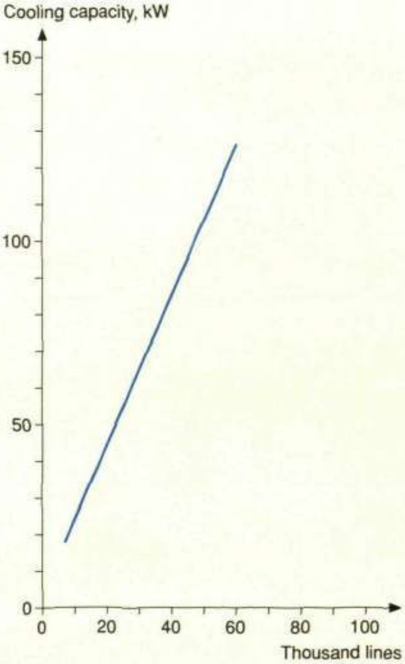
Function
The Pump Unit (PU) maintains a constant water flow to the Cooling Coils (CC) of the Climate Ceiling, Fig. 6. When passing through the Cooling Coil, the heat dissipated from the switching equipment is absorbed, and the water temperature rises.

The water temperature is again reduced, since part of the heated water is recycled and mixed with cold water from the Cooling Unit (CU) and the Water Tank (WT).

The water temperature and the dew point temperature of the cooled room are continuously compared, and the water temperature is adjusted, if necessary, to assure that there will be no condensation on the Cooling Coils.

The Free-cooling system (optional equipment), represented by a Free-Cooling Pump rack (PUF) and a Cooler (C), is activated when the difference between the temperature of the return water from the Climate Ceiling and the outdoor tempera-

Fig. D1
Typical cooling capacity required in a normal telephone exchange



Box 4
Dimensioning

The heat to be cooled off in a telephone exchange is normally generated by:

Switching equipment
Almost all electrical power supplied to the switching equipment is transformed to heat

Control room equipment
The heat is dissipated from e.g. terminals and printers

Power room equipment
From modern power supply equipment, normally 10–15 % of the power of the equipment is dissipated to the surroundings because of conversion loss

Heat, leaking into the building
The heat that leaks in (P) depends on the insulation (k) of the building, the building areas (A) and the difference between the outdoor and the indoor temperature (dt) according to the formula $P = k \times A \times dt$

Staff
Normally, each person emits approximately 120 W

Lighting
Practically all the rated power of the lighting must be cooled off

Ventilation
If the supplied ventilation air needs dehumidification, this fact must also be considered in the dimensioning

Miscellaneous
There may be extra equipment installed locally which is normally not included in a telephone exchange.

The heat dissipation from the switching equipment accounts for the greatest portion. Under certain circumstances, however, the sum of the heat from other sources may be equally large.

From the diagram in figure D1 it appears what cooling capacity is normally required for a telephone exchange with due consideration given to the factors mentioned above.

Table 1

	System BPA 101			
	010	011	012	013
Climate Ceiling	X	X	X	X
Pump Unit	X	X	X	X
Cooling Unit	X	–	–	–
Heat exchanger	–	X	X	–
Water tank backup time	X	–	X	–
Supervision	X	X	X	X
Installation material	X	X	X	X
Ventilation	(X)	(X)	(X)	(X)
Humidification	(X)	(X)	(X)	(X)
Free Cooling	(X)	(X)	(X)	(X)

X Mandatory equipment
(X) Optional equipment

ture is sufficient for cooling purposes, Box 3.

During a mains outage, the cooled water stored in the water tanks is used to maintain the cooling of the switching equipment.

The Cooling Unit (CU), with the attached Pump Unit (PUC) and Cooler (C), cools down the absorbed heat and keeps the water in the tanks at a temperature of approximately +8°C (+47°F).

The air handling unit (AU) takes cold water from the water tank to dehumidify received ventilation air.

Description of units

Climate Ceiling
The Climate Ceiling is described in Box 2.

Pump Unit
The Pump Unit provides the Cooling Coils of the Climate Ceiling with water at a temperature that corresponds to the cooling requirements of the room. The main components are a mixing valve and two pumps connected in parallel. The valve regulates the temperature of the water to the Cooling Coils through the mixture of cold water from the tank and warm return water from the coils.

Both pumps are powered either from the mains or from a battery via an internal inverter. In systems without backup time function, no inverter is included.

Cooling Unit
The liquid-Cooling Unit (CU) is a packaged unit containing a limited amount of refrigerant. Each Cooling Unit is connected with a Pump Unit and a Cooler (or part of a cooler).

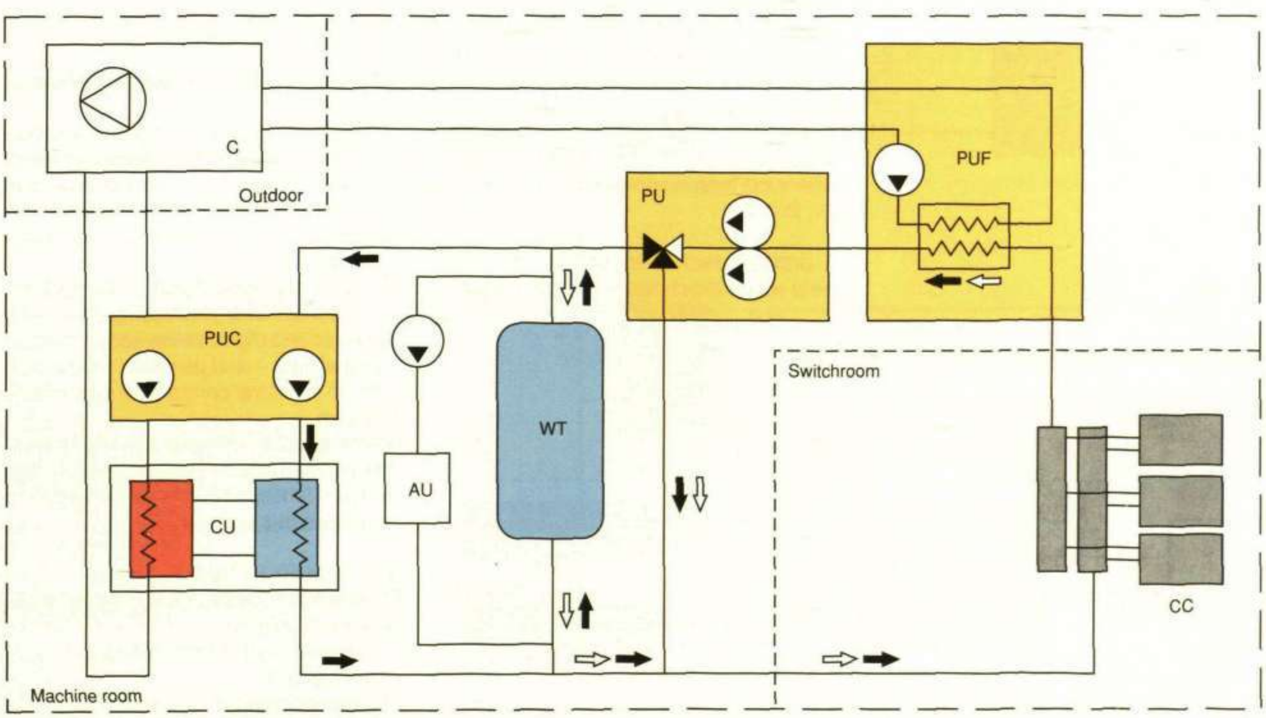
Heat exchanger
If the building already has a chill water system, this can replace the Cooling Unit, the Pump Unit and the Cooler. A heat exchanger must be used as an interface when cooling backup (water tank) is required, or when the water pressure in the chill water system of the building is too high.

Backup time
Cylindrical, well insulated steel tanks are used to store cold water at approximately +8°C. The number of the tanks and their size are determined by the desired cooling backup time.

Fig. 6
Block diagram for the TELECOOL System

PUF	Pump Unit for the Free Cooler
PU	Pump Unit
C	Cooler
PUC	Pump Unit for the Cooling Unit
CU	Cooling Unit
AU	Ventilation Unit
WT	Water Tank
CC	Cooling Coil in the Climate Ceiling

➡ Water circulation during normal operation
⇨ Water circulation during a mains outage



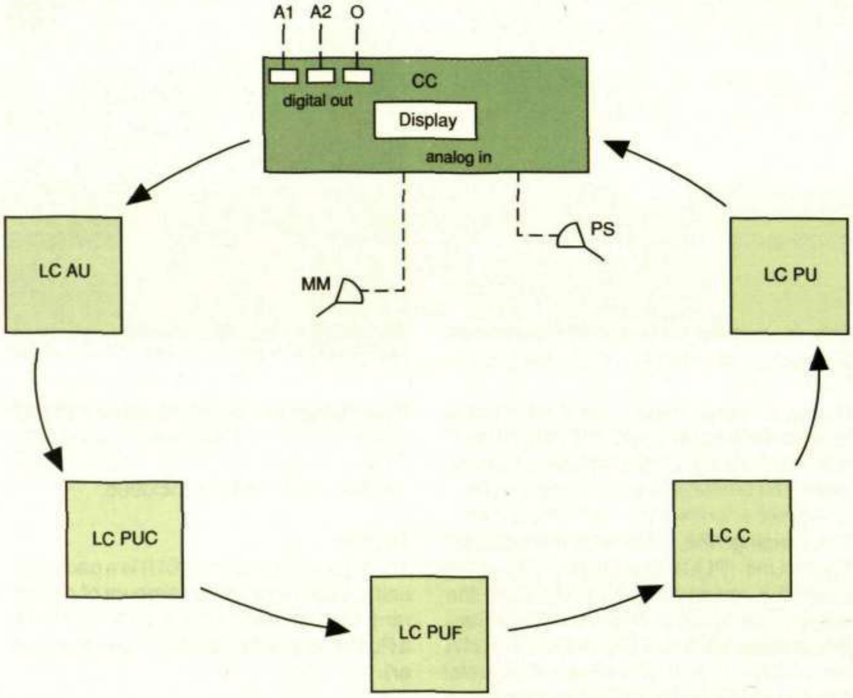


Fig. 7
Block diagram of the control and supervisory system
A central master computer co-ordinates all the local computers and handles the input/output. An optocable loop is used for communication with the local computers. The central computer can send three categories of alarm – A1, A2 and O – to a central management system

CC	Central Computer
LC	Local Computer
AU	Ventilation
PUC	Pump Unit for the Cooling Unit
PUF	Pump Unit for the Free Cooler
C	Cooler
PU	Pump Unit
PS	Pressure Sensor
MM	Mains Monitor
→	Optocable communication loop

Ventilation
The purpose of the air handling system is to dehumidify and filter the air, create overpressure in the room and add fresh air. The air handling unit comprises a fan, a filter, a cooling coil and a control unit for speed regulation, etc.

Humidification
The humidification unit generates water vapour which is conveyed to the room through the ventilation system.

Free cooling
The free-cooling function is accomplished by heated water from the Cooling Coils passing a heat exchanger where the heat is conveyed to another water circuit. This circuit, to which glycol is added for protection against freezing, is in turn cooled by an outdoor Cooler, or part of a cooler, where the heat is conveyed to the outdoor air, Box 3.

A prefabricated Free-cooling unit, complete with pump, heat exchanger and control equipment, is installed in the water circuit, Fig. 6.

Supervisory unit
A distributed computer architecture has been chosen. Each unit in the system has a powerful microprocessor for control and supervision of the unit. A central master computer co-ordinates all the local computers and handles the communication with them, Fig. 7.

All computers are connected to an optocable communication loop, which makes the units insensitive to external interference and complying with stringent EMC requirements for peripheral equipment. Each local computer maintains its basic function even in the event of an interruption in the communication loop.

Room temperature, relative humidity, outdoor temperature etc. can be read on an LCD display. The central computer issues three categories of alarm – A1, A2 and O – to a central management system.

Installation material
To integrate all units in one complete system, installation materials like couplings, cable, insulation, suspension structures etc. are included.

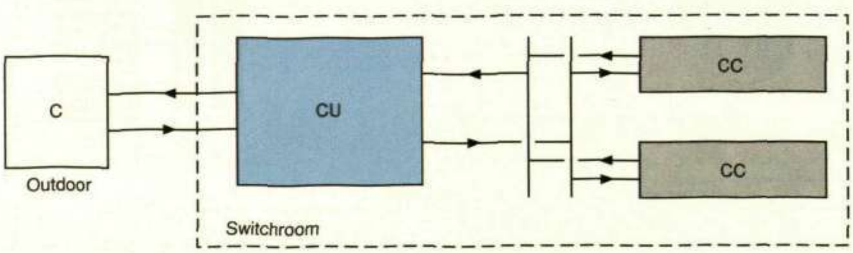
TELECOOL Compact

TELECOOL Compact has the following new features:
- The Cooling Unit of the system is a compact prefabricated packaged unit which is easy to install, has low sound level and can be placed in the switchroom. This new concept is called Switch Room Cooling
- Control and supervision of the Cooling Unit are based on microcomputers – with graphic and digital presentation of operational data – and prepared for connection to a central control and supervisory system
- In a temperate climate, Cooling Units in the system can be provided with a free-cooling function which saves energy and provides redundancy.

Unit Description and Function
TELECOOL Compact consists of three main parts, Fig. 8:
- Cooling Coils/Climate Ceiling
- Cooling Unit
- Outdoor Cooler

Fig. 8
Block Diagram for the TELECOOL Compact system

CC	Climate Ceiling with Cooling Coils
CU	Cooling Unit
C	Cooler



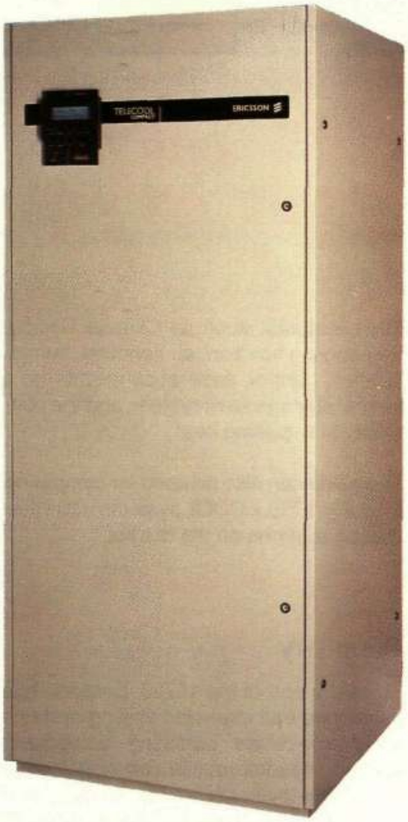


Fig. 9
Cooling Unit in TELECOOL Compact
The compact design makes the Cooling Unit easy to install. It may be placed in the switch-room

TELECOOL Compact is a complete system which can be used with or without the free-cooling function.

The Cooling Unit is built up on a frame that contains pumps, a compressor, a free-cooling heat exchanger, an evaporator, a condenser, valves and pipes and circuits for refrigerant and water. The unit incorporates microprocessor-based control and supervisory equipment with a display.

The unit contains a limited amount of refrigerant, is very compact and provided with sound-insulating cover plates. This means that the Cooling Unit need not be placed in a separate machine room; it can be placed in the switchroom. The unit, Figs. 9, is easily installed, since it is a complete unit which has been assembled and function tested at the factory.

The unit includes an outdoor Cooler which is a heat exchanger – from water to air – provided with fans.

The Cooling Unit circulates water through the Cooling Coils where thermal energy is absorbed from the air and conveyed to the water.

In units without a free-cooling function, the heat is conveyed from the water in the Cooling Coils to the refrigerant circuit of the evaporator, Fig. 10. In the condenser, the heat is then transferred at a higher temperature from the refrigerant circuit to the water in the outdoor circuit, which then conveys it in the Cooler to the ambient outdoor air.

In units with a free-cooling function – when the outdoor temperature is below 11°C – the heat is conveyed to the water in the outdoor circuit through a heat exchanger which then emits it in the Cooler to the ambient outdoor air. The free-cooling function is automatically activated at the correct temperature level as well as upon a failure in the refrigerant circuit.

Since no water tank is included in TELECOOL Compact, the Cooling Unit is power-controlled to keep the room temperature at the correct level. The cooling power is controlled by means of a by-pass function in the refrigerant circuit.

The unit has double water pumps in both water circuits for high reliability to be achieved, Fig. 10.

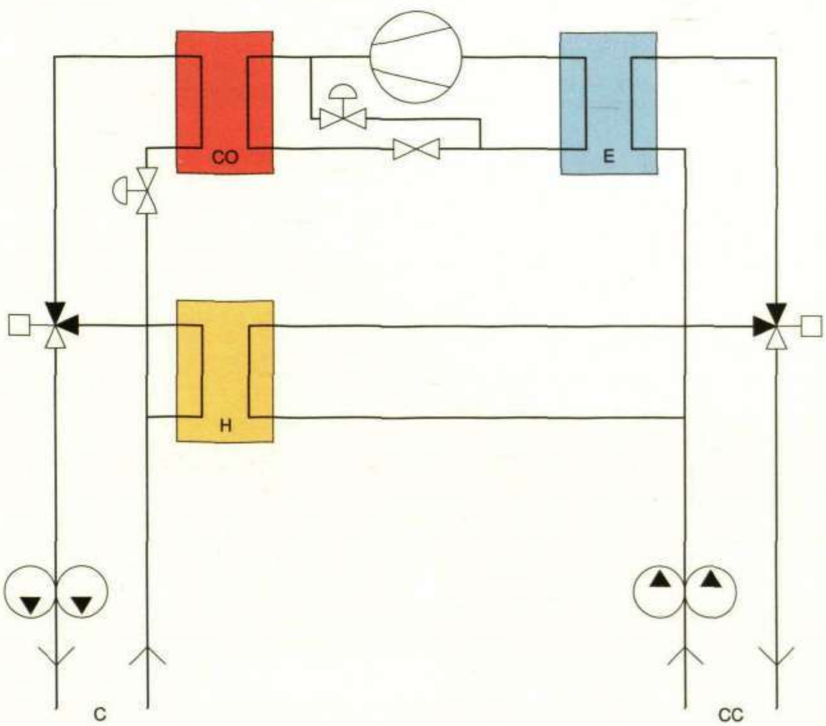


Fig. 10
Flow Chart of Cooling Unit

C	Outdoor Cooler
CC	Climate Ceiling with Cooling Coils
H	Heat exchanger
E	Evaporator
CO	Condenser
(symbol)	Compressor
(symbol)	Valve
(symbol)	Water Pump

Fig. 12
No chain is stronger than its weakest link
The reliability, efficiency and redundancy of the cooling system must be in accordance with the corresponding requirements for the telephony and power equipment

Characteristic	TELECOOL	TELECOOL Compact
Backup time	F	–
Interface towards existing cooling system	F	–
Switchroom Cooling	–	F
Easy installation	S	F
Volume requirement	S	F

F First choice
S Second choice

Fig. 11
Choice of system – a comparison between TELECOOL and TELECOOL Compact The guide shows which of the two TELECOOL systems should be chosen, depending on the weight attached to the different characteristics

The unit has control and supervisory equipment which performs the necessary changeovers and initiates alarm in the event of a component failure. The type of alarm is indicated on the unit and can also be sent to a central alarm centre. Both digital and graphic values can be read on the display unit of the equipment.

If the system contains more than one Cooling Unit, all control and supervisory equipments are interconnected. This means that the same display unit can be used for up to eight Cooling Units.

In order to integrate all units in one complete system, installation materials like couplings, cable, insulation, suspension structures etc. are included.

Choice of system – a comparison between TELECOOL and TELECOOL Compact

The technical characteristics of a cooling system is valued differently depending on local conditions. The technical guide, Fig. 11, shows which of the two TELECOOL systems should be chosen, depending on the weight attached to the different characteristics.

The two systems are equal with respect to reliability and modularity and a number of other features, such as Climate Ceiling, free-cooling function, air handling, humidification, control, ease of connection to a central management system, and the possibility of regaining heat.

The guide can also be used for comparing Ericsson's TELECOOL systems with other cooling systems on the market.

Summary

Since the end of the 1970s, Ericsson has developed and marketed cooling systems for power-dense switching equipment. Ericsson now introduces a new generation of cooling systems – TELECOOL and TELECOOL Compact. These systems offer great possibilities of providing customised system solutions. Moreover, an entirely new concept is introduced – Switch Room Cooling – which means that the cooling system is placed in the switchroom.

The retained basic principle of heat absorption through water-cooled, natural-convection cooling coils also means that the new system generation is energy-saving, modular and reliable.

The communication interfaces of the control and supervisory equipment facilitate cost-saving remote supervision.

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