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TELECOMMUNICATIONS SYSTEMS MEASUREMENTS

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EDITORIAL

This issue of the Journal on Communications comprises papers presented at the international seminar on Telecommunications Systems Measurements held on November 9 and 10 in Budapest. The idea of publishing a special issue of the journal with a simultaneous seminar with oral presentation of the topics is a new initiative of the editorial policy of this journal. The special value of talks presented at a seminar is well known for engineers and managers. The flavour of meeting important people and discuss various details of a technical problem is obvious and gives an efficient way of obtaining substantial new informations. The organizing committee of the seminar invited representatives of eleven important Western companies to present their results on new measurement techniques of modern telecommunications systems. We are sincerely grateful for getting positive response and significant contributions from Siemens AG, Hewlett Packard, Wandel & Goltermann, Anritsu Wiltron Ltd., Consultronics Europe, Alcatel Str AG, Rohde & Schwarz, Clemessy Electronique, Schlumberger Technologies, Marconi Istruments Ltd. and Seba Dynatronic. The participation and contributions of Hungarian institutions is also emphasized. The experts from the Department of Telecommunications and Telematics and the Department of Atomic Physics, both of the Technical University of Budapest and the Hungarian Telecommunications Ltd. presenting their new results and general methodology of telecommunications systems measurements were significant in promoting the success of this issue.

The most important topics include the measurement of

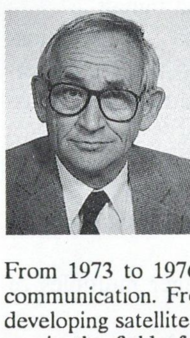
- Synchron digital hierarchies
- Digital data transmission
- Telecommunication protocols
- Digital exchanges and networks
- Digital mobile radio systems
- Optical transducers

During the seminar a panel will be organized on new measuring and test methods in telecommunications.

And last but not least an exhibition will take place concurrently with the seminar presenting measuring equipments of exhibitors listed at the end of this issue.

The seminar and this special issue could not be realized without the substantial help and activity of the Scientific Society for Telecommunications, Hungary and the financial aid provided by the PHARE program.

A. BARANYI



András Baranyi graduated in electrical engineering from the Technical University of Budapest in 1960. He received the Candidate of Technical Sciences degree from the Hungarian Academy of Sciences in 1976. Since 1960, he has been with the Research Institute for Telecommunications, Budapest. He has worked on circuit design of microwave FM systems, FM disortion analysis and transistor modelling problems. From 1973 to 1976, he was head of a section working on data communication. From 1980 to 1986, he was heading a department developing satellite communication systems. His present interests are in the field of nonlinear circuit modelling and analysis. He has given several courses at the Technical University of Budapest, where he is an associate professor. In the academic years of 1970-71 and 1980, he was research visitor at the University of Maryland, Collage Park and the University of California, Berkeley, respectively. Since 1991, he is editor of the Journal on Communications.

SDH, THE SYNCHRONOUS DIGITAL HIERARCHY, A CHALLENGE FOR THE MEASURING TECHNIQUE

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The paper outlines the differences between the testing of PDH and SDH transmission systems. The challenges in the measuring the SDH systems are shown considering the large number of built-in supervisory and management functions. The special measuring tasks in SDH tests are topics like SDH PDH analysis, pointer stress tests, BIP tests, etc. are explained.

1. THE ADVANTAGES OF THE SYNCHRONOUS DIGITAL HIERARCHY

Before the next decade is out, telecommunications will be based on flexible networks and will have made the change from PDH-systems to SDH-systems. For this purpose the multiplex signal requires adequate bit reserves/overheads for controlling and managing the networks. In order to create sufficient transmission capacity to accommodate the additional information, the interface standard SONET (Synchronous Optical Network) was devised in USA.

The CCITT proposed this standard as the basis for an international specification for the Network Node Interface (NNI). This gave rise to a new international standard, the Synchronous Digital Hierarchy (SDH), which took into account the CEPT, ETSI hierarchies in Europe.

The transmission with SDH is a decisive step towards a high-capacity, internationally standardized digital transmission network. For the first time, the optical transmission line characteristics will also have been standardized so that sections from different vendors can be interconnected without problem (mid-span-meet).

The advantages of SDH transmission are summarized as follows:

- Bit rates above 140 Mbit/s standardized
- Capable of transmitting future wideband signals
- Large additional bit capacity ("overhead") in the transmission signal for additional information and for supervision, maintenance and control functions in the transmission network
- Capable of synchronous and plesiochronous operation (pointer method)
- Capable of transmitting all signals of existing plesiochronous hierarchies
- Higher-order multiplex signals are integer multiples of 155.520 Mbit/s basic bit rate
- Access to individual transmission channels
- Optical signal on the line standardized for first time

SDH features are given in Fig. 1 by comparing them to PDH characteristics.

Plesiochronous Digital Hierarchy

- Plesiochronous network
- Asynchronous multiplexing
- A different frame structure for each muiltiplexing stage
- Bit interleaving
- Timing adaption by positive bit justification (stuffing)
- Access to individual interleaved channels only possible after demultiplexing
- Bit rates above 140 Mbit/s not standardized

Synchronous Digital Hierarchy

- Synchronous network
- Synchronous multiplexing with pointers
- Same frame structure for all multiples stages
- Byte interleaving
- Timing adaption by positive-zero negative byte justification
- Access to individual interleaved channels after evaluation of the pointer
- Bit rates above 140 Mbit/s standardized

Fig. 1. PDH and SDH features

The principle of SDH multiplex transmission is illustrated in Figs 2 and 3, respectively. Plesiochronous signals are adapted with stuffing bits or bytes to the relevant higher container. Overhead and pointer information are added to the content of the container.

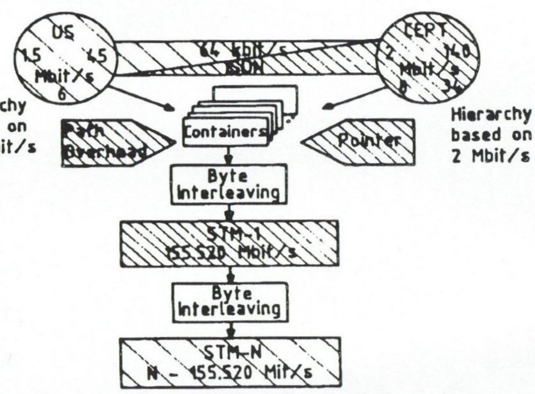


Fig. 2. Multiplex transmission principle

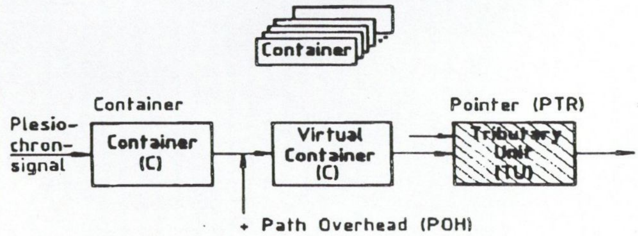


Fig. 3. SDH system blocks.
Path overhead (POH)......
Pointer (PTR).......

The construction of the STM-1 frame is given in Fig. 4. The first 9 bytes of the rows 1 to 3 and 5 to 9 are overhead informations. The remaining 9×261 bytes contain the payload. It is synchronized to the STM-1 frame with the pointer (PTR).

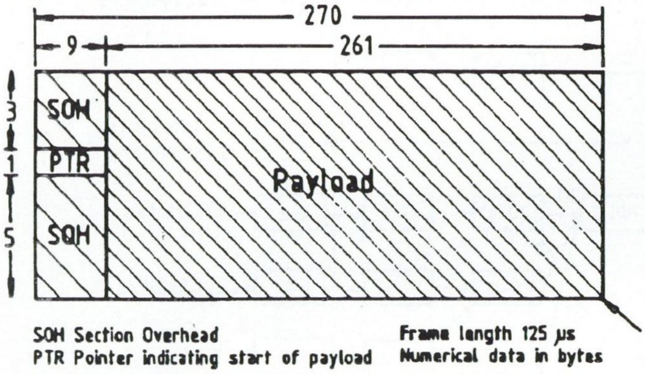
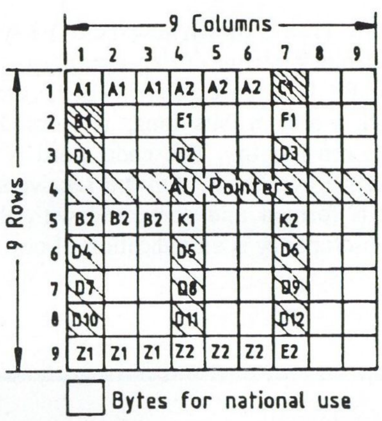


Fig. 4. STM-1 frame

2. THE OVERHEAD FUNCTIONS, MEANS TO SUPERVISE, CONTROL AND MANAGE THE SDH SYSTEMS

Overhead bytes provide additional information enabling the network operator to transport the payload reliably and safely from source to sink. The overhead bytes contain information such as frame alignment, status monitoring, fault location, maintenance and control functions. This is the basis for the TMN, the Transmission Management Network, which should allow independent operation of the systems. In Fig. 5 the SOH bytes are given with the listing of their purpose.



A1,A2: Frame synchronization
B1,B2: Parity words for fault detection
C1: STM-01 identification in STM-N
D1-D12: Data channels for in-service monitoring
E1,E2: Service channels for voice transmission
F1: User channel
K1,K2: Control of protection switching
Z1,Z2: Reserve channels
All bytes which are not identified are reserved for national purposes

Fig. 5. SOH block

The SOH block consisting of 8×9 bytes is connected to the payload as shown in Fig. 4.

The international standard provides for plesiochronous signals from bit rates used in USA, Japan, Europe being transmitted in Synchronous Transport Modules (STM). With 64 kbit/s as the basic bit rate in both hierarchies, the STM-1 (Synchronous Transport Module 1) with 155 Mbit/s and integral multiples thereof (STM N), has been defined as standard. The hierarchical network depicted here shows the ways of transmitting existing plesiochronous signals in the STM-1 signal. There is a suitable container for each individual plesiochronous signal in both the US and ETSI hierarchies.

Adding the path overhead produces the virtual container (VC). If a virtual container is adapted directly to the STM-1 by means of a pointer the result is an Administrative Unit (AU). Pointers are employed to synchronize the payload to the parent frame. There is no fixed relationship between the frame and the payload.

Some Tributary Units (TU) are, before being mapped into the next higher container, combined to a Tributary Unit Group (TUG).

Fig. 6 shows the SDH multiplexing structure as defined by CCITT.

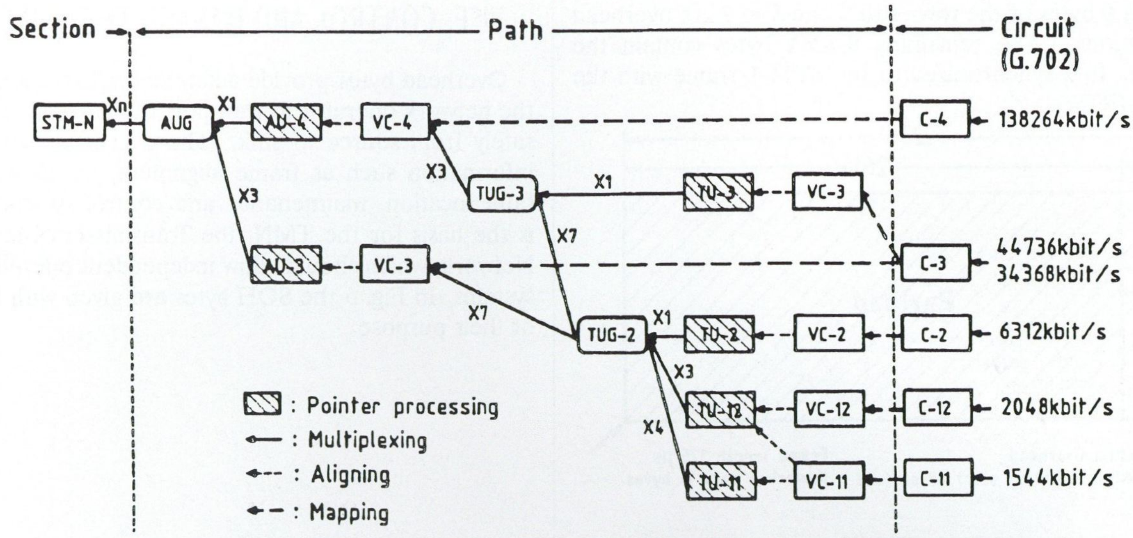


Fig. 6. SDH multiplexing structure

3. MEASURING TASKS ON SDH SYSTEMS

As indicated above, the SDH systems have a large number of embedded monitoring, testing and management functions. These functions, in conjunction with a future TMN (Transmission Management Network), could, in principle, provide virtually autonomous self-management of the network including protection switching, fault location and even some degree of fault elimination.

Below here is shown how the SDH systems measure and report block errors during operation. This procedure is called Bit Interleaved Parity (BIP). On the transmit side a code word, *n* bits long, is formed over a bitstream of a given length. The code word is transmitted in the respective overheads. On the receive side the same code word is formed and compared with the incoming word. Any discrepancy is an indication of one or more bit errors.

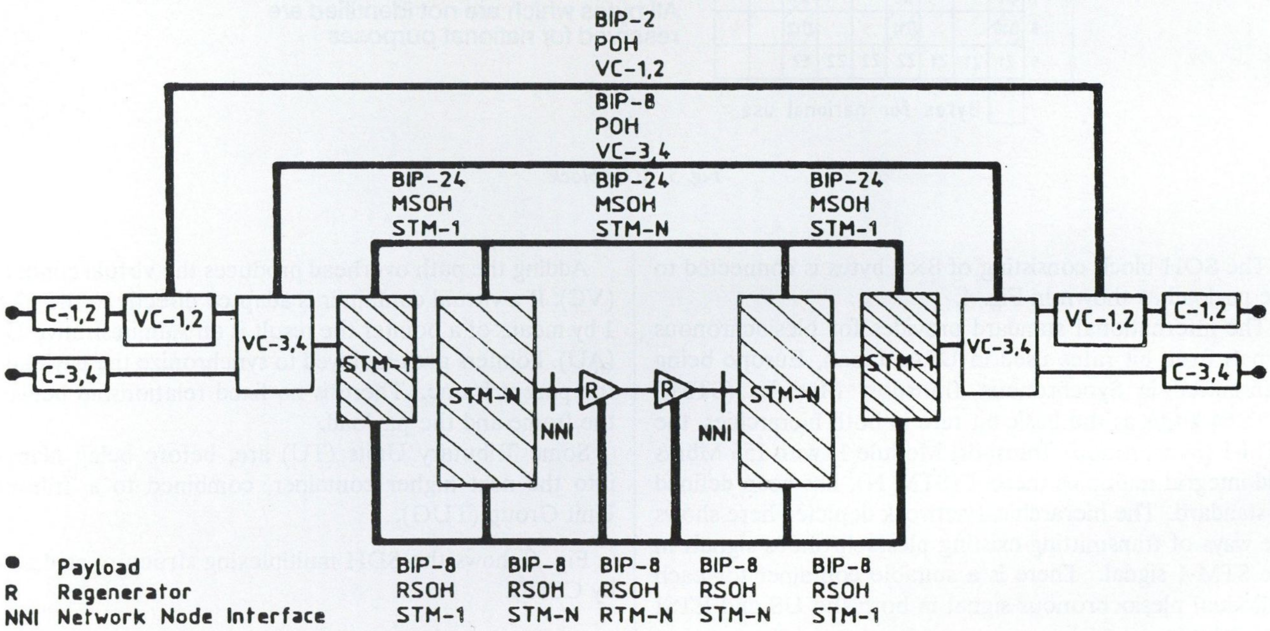


Fig. 7. Supervising sections in SDH systems

Fig. 7 shows the supervising sections within SDH systems. One sees the plesiochronous ends, the mapping into containers and various transmission sections. For error supervision serve the BIP-2, BIP-8, or BIP-24 depending on the importance of the section. For example BIP-8 means 1 byte (8 bits) for supervision of a VC4 (140 Mbit/s).

The question arises, why do we need test equipment at all when the SDH systems manage by themselves? There are several answers: First of all the Transmission Management Network will not by fully operable for some time to come. Then, SDH is a completely new transmission system with a lot of "teething problems" which nobody can foresee. Furthermore, for many years there will be a mixture of SDH and PDH systems in the network. Which means that a piece of test equipment should be capable of measuring both hierarchies.

Last but not least, there are always development, manufacturing, commissioning and maintenance for which test equipment is needed.

Here is a list of measurement tasks for SDH (PDH) systems:

- Bit error tests in the payload, evaluation according to CCITT G.826 including CRC, BIP and FAS errors.
- Defined stress test of the pointers.
- Manipulation and analysis of the overhead bytes.
- Defined disturbance of the payload and or the frames with a through modulator for error injection and jitterising.
- Generation and analysis of error signals such as OOF, LOF, LOS, FEBE, AIS, FERF, etc.
- Jitter tolerance, jitter transfer function, jitter.
- Protocol tests in the data channels.
- Delay measurements.
- Measurements of optical parameters, OTDR, POWER.

4. TEST INSTRUMENT FOR SDH AND PDH MEASUREMENTS

The Siemens test instrument K 4302 covers all bit rates in the classic PDH ranges plus the SDH ranges STM-1 (155 Mbit/s) and STM 4 (622 Mbit/s).

In the test configuration shown in Fig. 8, the instrument measures over the line, which means, almost all payload and overhead test can be made. The respective measured path is out of service. The transmitter and receiver functions in this configuration are as follows:

Transmitter
- Framed SDH signals
- PRBS as PDH signals
- Bit error insertion
- Jitter modulation
- SDH interference
  - SOH manipulation
  - POH manipulation
  - Pointer actions
  - Insertion of zeros

Receiver
- Bit error measurements
- BIP monitoring B1, B2, B3
- SOH, POH and pointer analyses
- Alarm indications

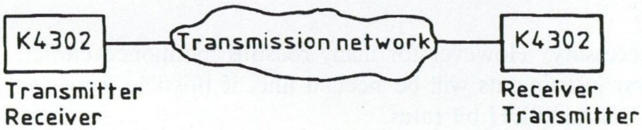


Fig. 8. End-to-end measurement

In the monitor operating mode shown in Fig. 9, the instrument supervises the overheads, the alarms and traffic of the transmission system in service. In this configuration the following tests can be performed:

- SOH, POH and pointer analyses
- Drop function for 64 kbit/s channels from SOH and POH
- Alarm detection
- Bit error measurements
  - PRBS, 140 Mbit/s payload of STM-1/4 signals
  - FAS from PDH signals

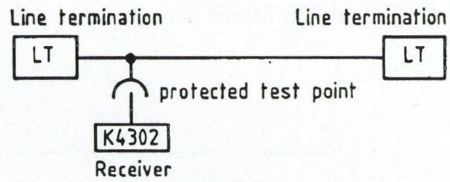


Fig. 9. In service monitoring

In the SDH systems the testing of the SDH overhead is important. The instrument K 4302 is suitable for direct testing as shown in Fig. 10, where manipulation and analysis of the overhead bytes is shown. The respective bytes are in the POH and SOH blocks.

- □ Insertion of service or data channels in SOH-POH bytes
  - D1-D3 192 kbit/s
  - D4-D12 64 or 192 or 576 kbit/s
  - Selectable channels in SOH or POH 64 or 192 or 576 kbit/s
- □ Manipulation of SOH and POH-bytes
  - A1,A2 every bit manipulable
  - Every byte manipulable bit-by-bit
  - Duration of manipulation
    - Programmable number of disturbed frames for alarm test and BIP monitoring
    - Continuously

Fig. 10. SDH overhead tests

Additional feature of the instrument is the Alarm and BIP monitoring as given in Fig. 11. The alarms and error messages are part of the SDH built in supervisory functions. The test instrument is capable of measuring the same parameters.

OOF/LOF:	Out of frame/Loss of frame
PTR/Loss:	Pointer Loss
FERF:	Far end receive failure
PRAI:	Remote Alarm
FEBE:	Far end block error
NO SIGNAL	
SYNC LOSS	
AIS	
B1,B2,B3:	Bit interleaved parity monitoring BIP8 and BIP24.

Fig. 11. Alarms and BIP monitoring

The jitter performance of SDH components and systems is an extremely important parameter. Fig. 12 shows the measurement of jitter tolerance. Here, the payload or the complete signal is jittered to find out from which jitter amplitude or jitter frequency the item under test produces bit errors.

Fig. 13 shows the SDH/PDH analyzer K 4302 in an SDH/PDH environment for various measuring tasks. All plesiochronous bit rates up to 140 Mbit/s and the SDH bit rates 155 and 622 Mbit/s are covered by the instrument.

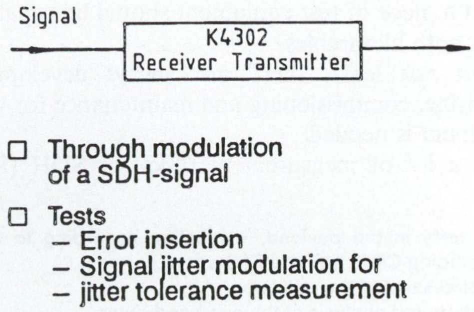


Fig. 12. Measurement of jitter tolerance

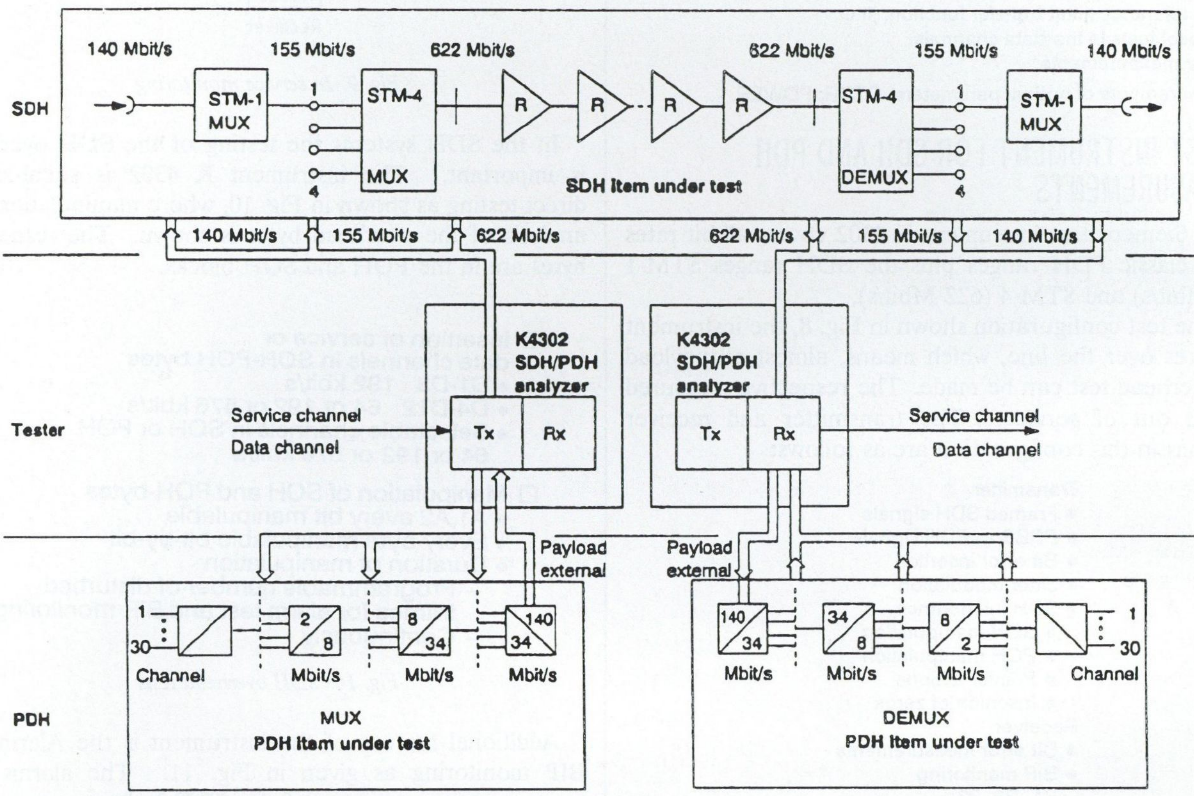
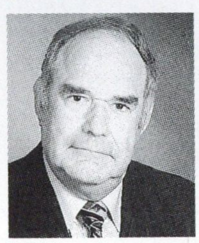


Fig. 13. Typical applications of K 4302 SDH/PDH analyzer: route measurements.
DEMUX – Demultiplexer; MUX – Multiplexer; PDH – Plesiochronous digital hierarchy; R – Regenerator; Rx – Receiver; SDH – Synchronous digital hierarchy; STM – Synchronous transport module; Tx – Transmitter

5. CONCLUSION

The new Synchronous Digital Hierarchy is a challenge for the measuring technique in as much the SDH systems have a large number of built in supervisory and self repair functions. External test equipment does not seem to be necessary. However for many reasons mentioned earlier, test instruments will be needed and, if possible, covering SDH and PDH bit rates.

Our new instrument was designed to measure both hierarchies because in many countries they will coexist for many years.



Dieter Seidel has been employed by the Siemens AG for 38 years in the field of communications measuring instruments. Between 1960 and 1971 he was head of the Siemens sales and service organization for test equipment in the USA. He is now a consultant to Siemens in the same field.

SDH TESTING IN THE REAL WORLD

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Network operators are eager to adopt synchronous transmission technology because of the great benefits of flexibility and managability. However the equipment and systems are considerably more complex and embody numerous innovations which require new types of test. This paper describes the tests needed to install and troubleshoot synchronous equipment and networks.

1. SDH AND ITS ADVANTAGES

SDH, the Synchronous Digital Hierarchy, grew out of work in the US to define a standard optical transmission format which would allow interconnection of optical transmission terminals from different manufacturers. The resulting format, with its family of rates, has applications in all parts of the network: in access connections, in the local, long distance and international parts of the world's telecom network.

One key departure from existing systems is in the use of synchronous multiplexing which allows much easier demultiplexing of bandwidths as small as 64 kbit/s from high-speed trunks, so making economic the add-drop multiplexer or ADM which is characteristic of many SDH network architectures.

Another change is the fraction of the SDH signal bandwidth devoted to overhead or management functions — about an order of magnitude more than in existing systems. This places much more intelligence in the transmission network and facilitates much more automated remote programming, monitoring and management of network elements (NEs).

SDH has been designed to carry all significant existing and new signals, both European and North American — from 2 Mbit/s through ATM, as well as 1.5 Mbit/s and 45 Mbit/s. As a result, it is very easy for a network to migrate from a plesiochronous to a synchronous architecture: SDH can be added even on a single link, simply as a way to carry more 140 Mbit/s signals for example. As migration takes place we can expect "islands" of SDH to appear within the network.

Finally, SDH contains an explicit mechanism for handling clock failures, or connections between networks timed from different sources. An SDH network can accommodate synchronization anomalies like these without introducing errors or delay.

2. TESTING SDH

SDH has a layered architecture and each of its layers presents specific test needs.

First there are tests to show that a tributary signal can be carried through an SDH network and delivered uncorrupted to its destination. These include tests to see that the signal can be mapped into and out of the synchronous bearer at the boundaries of the SDH island, and also tests to see that intermediate NEs correctly process those parts of the SDH signal containing the tributary information.

The next category of tests prove the network reacts correctly to synchronization anomalies without losing data or generating too much output jitter.

The complex array of monitoring and maintenance functions built into SDH requires tests ranging from framing to alarm timing and protection switching.

Finally, at a parametric level, the signals on the line have specifications to meet on properties like power, pulse shape and jitter. The interrelations of these tests are shown in Fig. 1.

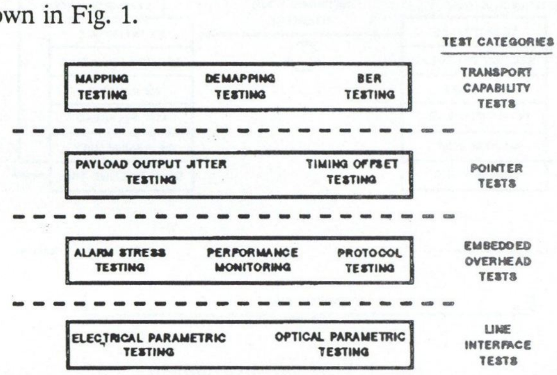


Fig. 1. SDH test requirements

Some of these tests would be carried out in the main during design or conformance testing; others would form an appropriate part of an installation or troubleshooting test procedure. We will return to these in a moment in more detail. First we will briefly review some fundamentals of SDH technology and terminology.

3. SDH NETWORK

The SDH signal contains powerful built-in maintenance functionality, which can be traced in Fig. 2.

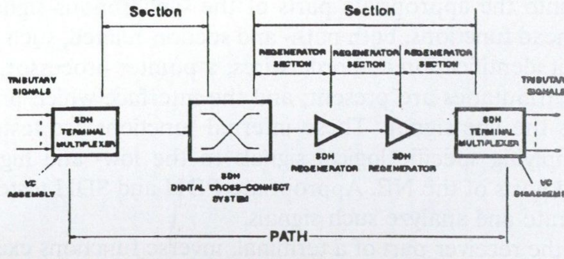


Fig. 2. SDH network segments

The regenerator section (RS) is the lowest level maintenance entity and is between points where framing occurs. The regenerator section is important for fault localization.

Next comes the multiplexer section (MS), which is the segment between network nodes — where multiplexing, cross-connection, protection switching and synchronization take place. The multiplexer section is important for network management.

The other entity is the path. This is the network segment from the point where a tributary signal is first mapped into SDH, right through the SDH island, to the point where the tributary is reconstituted as a plesiochronous signal.

If the tributary rate is 34 Mbit/s or above, the path is called a high order path; otherwise it is called a low order path.

High and low order paths are tributary-related entities with great significance for maintenance of a customer's service.

Fig. 3. shows an SDH terminal and its key components from a test perspective: the interfaces and main functional blocks within the NE.

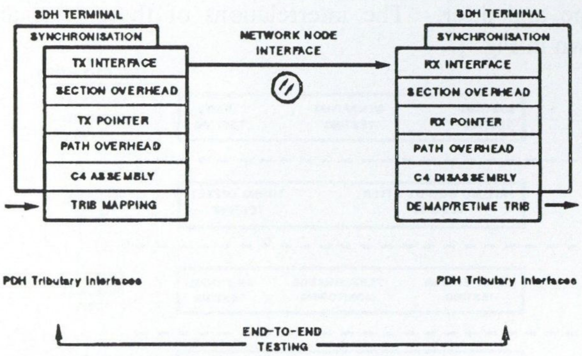


Fig. 3. SDH test environment

The interfaces to the plesiochronous network are the tributary or low-speed interfaces, which encompass signals from the plesiochronous hierarchy (PDH) such as 34, 140, 1.5 and 44 Mbit/s; new signals such as IEEE 802.6 Metropolitan Area Network signals and Asynchronous Transfer Mode signals; and here we can also find SDH signals, either optical or electrical, typically at 155 Mbit/s. The high-speed side, or network node interface, has an SDH format, and is generally optical (though possibly electrical for 155 Mbits/). Interface tests are generally parametric and use test gear such as power meters, oscilloscopes etc.

Blocks inside the transmitter part of the NE include the mapping function which reformats the tributary information into the appropriate parts of the synchronous signal; overhead functions, both path- and section-related, such as circuit identification and orderwires; a pointer processor, if SDH tributaries are present; and the interface which produces the line signal. These internal functions are tested by applying specific logical signals to the low- and high-speed ports of the NE. Appropriate PDH and SDH testers generate and analyze such signals.

In the receiver part of a terminal, inverse functions exist. We should note that the demapper, or desynchronizer, has the task not merely of recovering the tributary information from the SDH signal but also of smoothing its timing before delivering it to the low-speed interface. This block presents one of the greatest design challenges of the SDH NE.

Other types of NE such as ADMs and digital crossconnect systems (DCSs) contain additional blocks to accomplish their switching functions.

From a service perspective, an SDH island can be viewed simply as a means of transport from one point to another. It is often argued that an SDH island can be adequately tested from tributary interface to tributary interface end-to-end, without any testing at high-speed SDH interfaces. This view originates from the test methods applied to current optical systems which are intrinsically point-to-point and have a proprietary signal format. End-to-end testing is not enough in an SDH environment. We will consider this point in more detail later.

4. SDH SIGNAL STRUCTURE

Here we review some terminology.

The base level SDH signal is called Synchronous Transport Module Level 1 (STM-1), and has an aggregate bit rate of 155.52 Mbit/s. Higher speed SDH signals, designated STM-n, are formed by byte-interleaving n STM-1s. Conventionally drawn in two dimensions, the top row in Fig. 4. represents the first bytes transmitted, in order from left to right. Each frame contains section overhead, which handles network-related functions; and a virtual container (VC4), which carries the tributary information together with path overhead which handles tributary-related functions. Section overhead originates and terminates in regenerators and multiplexers; path overhead travels with the tributary information from end-to-end through the appropriate SDH path. The part of the VC4 which contains the tributary information is called the container, in this case C4.

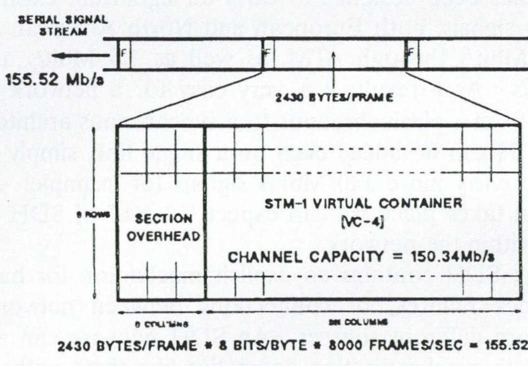


Fig. 4. STM-1 frame structure

A 140 Mbit/s signal maps directly into a C4. Lower speed signals (between 1.5 Mbit/s and 44 Mbit/s) are first mapped into structures called tributary units or TUs which are then multiplexed into a C4.

The SDH mechanism for handling synchronization impairments is to allow the start of the VC4 to float with respect to the start of the frame, keeping track of it using a pointer kept in a fixed place in the frame. In a node with SDH inputs and outputs (like an ADM or DCS), the pointer mechanism copes with differences in phase or frequency without buffers or slips.

It allows outgoing STM-1s in an STM-n signal to have their overhead aligned while carrying VC4s in different positions in the frame reflecting the arbitrary phases they had when they arrived at that node as shown in Fig. 5.

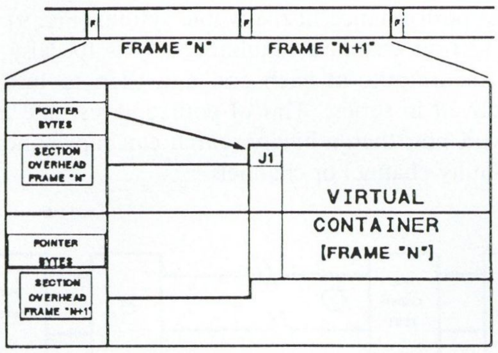


Fig. 5. Link between section overhead and VC

In the case where an incoming VC4 has a different frequency than the node clock, that VC4 will drift with respect to the start of the outgoing frame. The consequent changes in the values of the pointer are called pointer movements. Each time the VC4 moves, there is one frame with three bytes more or less than nominal. Justification bytes are reserved to allow this to happen without losing any data.

An SDH desynchronizer consequently has to smooth phase steps of up to 96 bits so that the resulting jitter at the output of an SDH island is tolerable by the plesiochronous network.

A similar pointer mechanism allows TU structures to float within a VC4.

Overhead exists for RS, MS and paths. The term "section overhead" is used to refer collectively to RS and MS overhead, and it resides in the first 9 columns of the STM-1 frame, as shown in Fig. 6. High order path overhead is also shown which resides in the first column of the VC4.

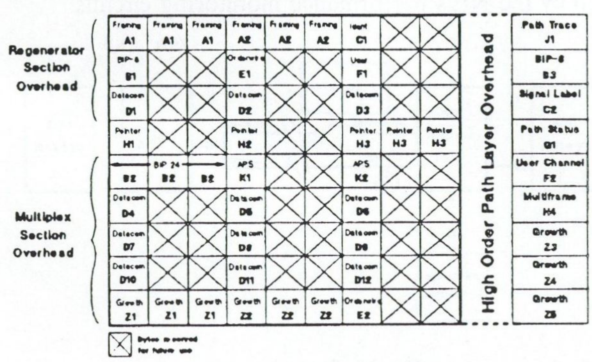


Fig. 6. STM-1 overhead bytes

Section overhead handles framing, pointers, network-related maintenance signals, orderwires for humans and datacom channels for network management computers. High order path overhead handles circuit identification, tributary type identification, a user channel and maintenance signals which apply to the whole VC4.

SDH provides maintenance signals for bothway performance monitoring and surveillance of RS, MS and paths. Fig. 7 shows where the signals are originated and terminated and the relationships between them.

As an example, a loss of signal detected in an MSTE results in two actions: MS-AIS is sent downstream to the high and lower order PTEs; and a Far End Receive Failure (MS-FERF) is sent upstream to alert the peer MSTE at the other end.

Error monitoring is provided for RS, MS and paths by Bit Interleaved Parity bytes. In the case of path errors a Far End Block Error (FEBE) indication is returned to the other end. In this way path performance can be measured in both directions from each end of a path.

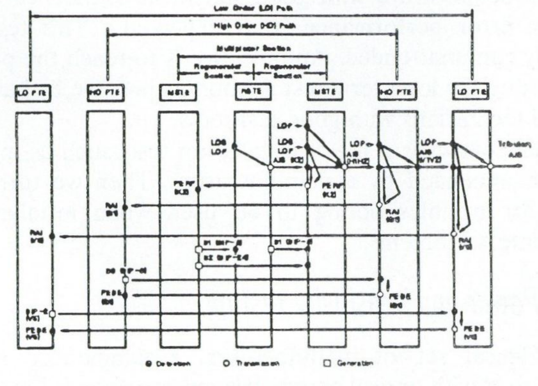


Fig. 7. In-service maintenance signals

Based on these signals, sophisticated in-service performance monitoring is built into NEs which allows them to send threshold alert messages or regularly scheduled reports to network management systems.

5. SDH STANDARDS

The CCITT has been issuing SDH standards since November 1988, and all necessary standards are now in place to build equipment which is compatible at the transmission level. Work is now focused on standard messages for the network management channels, which at present carry proprietary formats and preclude multi-vendor interworking.

Key standards include those for logical level of the Network Node Interface: G.707-G.709, on rates, formats and mappings.

G.781-G.783 define the operation of SDH multiplexers.

G.784 defines SDH performance monitoring and network management.

G.957 defines SDH optical interfaces, and G.958 the other characteristics of line systems, including jitter.

6. INSTALLATION TESTING

6.1. Objectives

We turn now to test methods for installing SDH equipment. Test applications vary based on their objectives and starting assumptions. In the case of installation, the assumption is that the design is correct and the equipment is working before it is installed. The objective is to discover installation-related faults and to carry out an overall go/nogo test to show that everything is working.

The first step therefore is to connect the equipment to the network and see if it works. The next is to carry out the tests recommended by the manufacturer.

If these two steps do not succeed, it is necessary to localize the problem to the optical path or the equipment being installed by testing each in isolation; and if the equipment being installed is discovered to be the cause, then the objective is to find and repair the fault by replacing the appropriate module.

Once immediate problems have been fixed, it is time for a longer test to find and eliminate intermittent problems and to demonstrate with good statistical confidence that system error performance is as expected. This test is usually run unattended. An objective is to reach the point of starting the long term test as soon as possible by having skilled technicians with good test tools.

What follows is a list of installation tests such as might be recommended by a manufacturer. Then we turn to tests for troubleshooting to be used when installation encounters problems.

6.2. Power and sensitivity testing

A typical set of manufacturers recommended tests might start with optical parametric measurement of output power and input sensitivity as illustrated in Fig. 8.

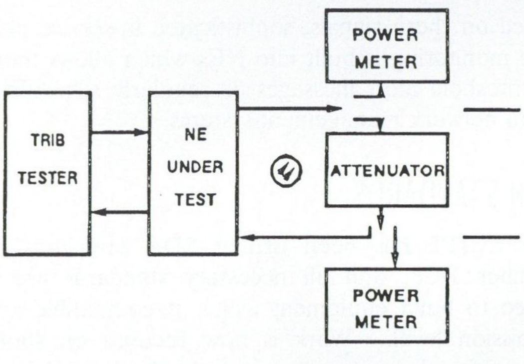


Fig. 8. Optical output and Rx sensitivity testing

It is straightforward to measure the output power with a power meter. The SDH signal is scrambled and so has a fairly constant power.

There are various ways to measure input sensitivity. One way which eliminates some causes of misleading results due to attenuator problems or cabling is to connect the NE's own output signal to its input via an attenuator, being careful to avoid overload, and adjusting the attenuator until the NE detects loss of signal or the error rate reaches some predefined level. The attenuated signal can then be measured with the power meter. The error rate in this case can be measured by a tributary tester connected to input and output on the low-speed side.

Another method uses the optical signal from the far end if available. This method gives as a by-product a direct reading of the loss margin in the circuit.

6.3. End-to-end testing

With the NE under test connected as intended, the next step is to check that both ends are free of failure indications both on the equipment and when interrogated with service terminals. This requires co-ordination with the far end.

Tributary channels are then briefly tested end-to-end with tributary testers to prove their continuity and check the error performance of the whole system (Fig. 9). One way to test all channels simultaneously is to daisy chain inputs and outputs at each end and then to test them effectively all in series. This of course saves time if they all work; if not, then a binary search can rapidly home in on the faulty channel or channels.

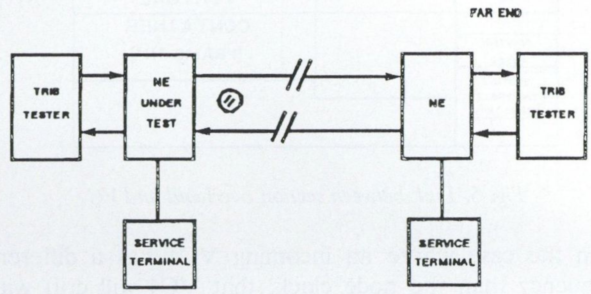


Fig. 9. Low-speed end-to-end error testing

In the case where the low-speed signal is itself SDH, then it is not sufficient to test that port using a service carried within its VC4. Overhead functions must also be tested, since the NE under test will be terminating and originating MS overhead and possibly path overhead. This requires testing with and SDH test set.

In cases where the high-speed interface has a protection system, a rapid functional test can be accomplished by adding optical attenuation before the working line input as shown in Fig. 10. A good signal must be connected to the standby line input of the NE under test. When the error rate reaches the preset level, the NE under test should switch to standby. The error rate can be monitored during the test using tributary test sets end-to-end. The error rate seen on a tributary is a good estimate of the error rate seen by the NE's performance monitoring circuits.

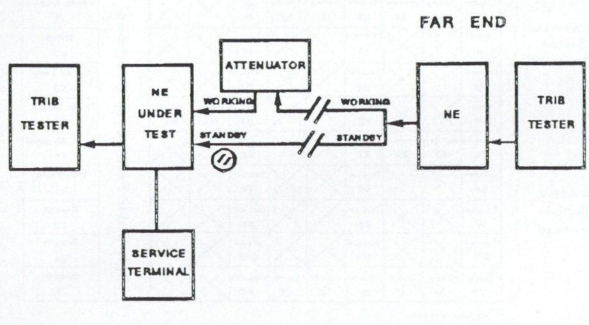


Fig. 10. Protection testing

Other protection tests are to send manual swith commands from a service terminal or simply to remove a working line module terminal or simply to remove a working line module from the equipment, verifying in each case that the equipment switches to protection.

A more direct, thorough and single-ended protection test is possible with a suitable SDH tester as shown in Fig. 11. Such a test set is able to generate the error rate required to stimulate the switch. It can also observe that the correct response in the K1, K2 overhead bytes is sent to the far end. In addition it can simulate switch commands sent by the far end.

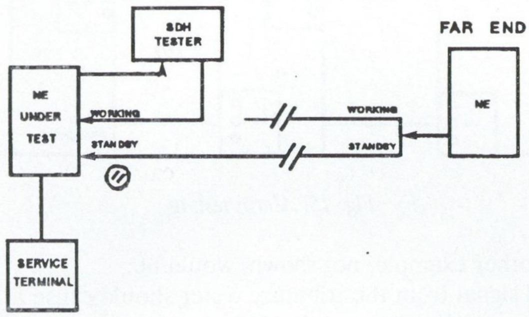


Fig. 11. Protection testing with an SDH tester

The final longer test of error performance can take anything between an hour and 14 days depending on the interfering influences that the test is intended to observe. If "weekly" influences are a possibility, then at least that long will be needed to show they have no undesirable effect on the systems under test. In most cases a few days should be enough.

This test is done unattended, so a means of logging is needed. Sometimes a hard copy record is required, but in many cases a memory-based graphic display, as provided by some SDH testers, is much easier to interpret (Fig. 12).

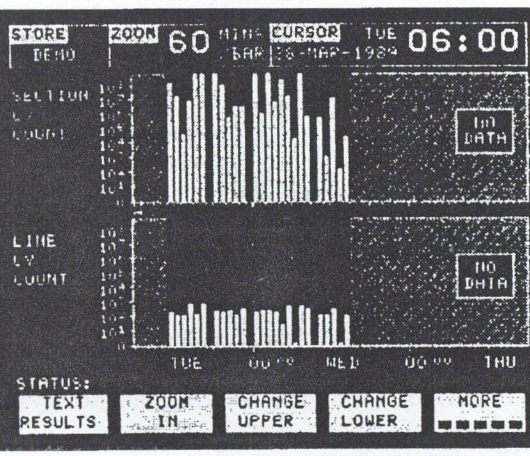


Fig. 12. SONET tester

7. TESTING AT THE HIGH SPEED INTERFACE

The installation tests we have just described are typical. They are similar to those carried out when optical systems were all proprietary and used point-to-point, connected to equipment made by the same manufacturer. No testers were available from the optical interface, and indeed to entire performance of the system related only to its ability to carry the low-speed signals.

Today's situation is different. A primary motivation for the creation of SDH was the standardization of the high-speed optical Network Node Interface or NNI. In the long term, we look forward to the possibility of connection between equipment from different manufacturers. This requires that the NNI be correct each time a new connection is made.

Even in the short term we need to recognize that SDH systems are more interconnected than existing systems, for example with path overhead continuity throughout an entire SDH island. The NNI is no longer a matter for each individual manufacturer. Perhaps the most powerful illustration of this is in the ring architectures that SDH makes possible. Observing such a ring of ADMs from the outside, looking only a tributary interfaces, gives no clue about a whole variety of important signal conditions on the ring.

SDH enables the integration of switching and transmission beyond what we have seen to date, and this means that we expect to see STM-1 and STM-4 optical interfaces directly on crossconnect machines — possibly even faster ones. These are likely to be connected to terminal multiplexers made by a different manufacturer. The old point to point architectural assumption is broken.

For these reasons we need to recognize that traditional tributary-based testing of optical systems is not enough for today's environment.

The NNI standard has raised a new test issue but also provided the means of solving it: it has enabled test equipment manufacturers to develop testers to verify performance at the NNI.

In a number of ways NNI testing has clear advantages over tributary-based testing: it can isolate a fault in a link to one end or the other; it can isolate a fault in an NE to the transmit or receive side; and it can observe protection switching events and other similar overhead events which are just not visible any other way.

In the next section, we describe tests used to repair SDH equipment once a fault has been encountered. For reasons of test philosophy outlined above, we expect tests like these to become more and moire a part of standard installation procedure.

8. TROUBLESHOOTING

8.1. Objectives

The starting assumption for troubleshooting is that some malfunction is known to exist, either in a system which is being installed or in a system which was working; and the intent is to localize and repair the underlying fault as quickly as possible.

The steps are first to establish which equipment or system is at fault; second to find and repair the fault, preferably by exchanging a module; and finally to verify the repair. The overall intent is to restore service (or complete the installation) as rapidly as possible.

Modern equipment has a high level of built-in selftest and can often indicate a faulty module by itself. However, such indications cannot be totally accurate and are sometimes misleading. Stories, sometimes from manufacturers' own people, tell about fault indications on equipment which was working perfectly; or about a situation where a fault was indicated on one rack but actually was due to a connector problem in a different rack with no fault indication. In situations like these, independent test equipment is an indispensable tool which can save a lot of time.

8.2. Optical path testing

Usually the symptom will be a powerful pointer to the cause of the problem. Does the fault apply to a single tributary or to the whole line system?

A very common cause of problems in installing an SDH system is the optical path. Breakages, excess attenuation and reflectance can cause problems ranging from complete absence of signal to poor error performance.

Faults like these can generally be found by straightforward tests with a power meter and an optical time domain reflectometer (OTDR) (Fig. 13).

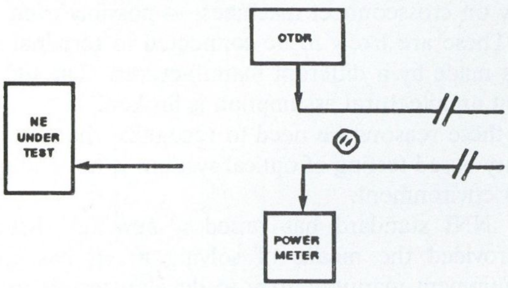


Fig. 13. Optical path testing

8.3. NE testing

If the optical path looks good we turn our attention to the NE. With an SDH tester connected to transmit and receive ports on the high-speed side, and a tributary tester connected to transmit and receive ports on the low-speed side, we are ready to check for a variety of problems.

In an installation and maintenance role, it is desirable to carry the minimum of test equipment; some testers combine SDH and PDH test capability in a portable package, which is a great advantage in this application.

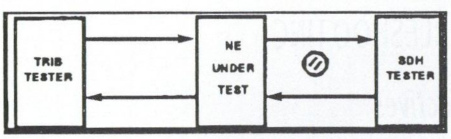


Fig. 14. NE troubleshooting configuration

So although in Fig. 14 we have drawn them separately for convenience, in principle these two SDH and tributary testers could be one and the same unit.

8.4. Alarm testing

The built-in maintenance functionality of SDH is a key part of its value to the network operator. It is vital that it functions correctly.

Using the test configuration described earlier, it is possible to test the responses of the NE to conditions on both the low and high-speed sides.

SDH and tributary testers are able to generate and detect maintenance signals. One example of a test is shown in Fig. 15:

An SDH tester is generating bad framing into the SDH NE. We expect to see the NE indicate Loss of Frame, send MS-FERF back to the high-speed side and send AIS on the tributary interfaces.

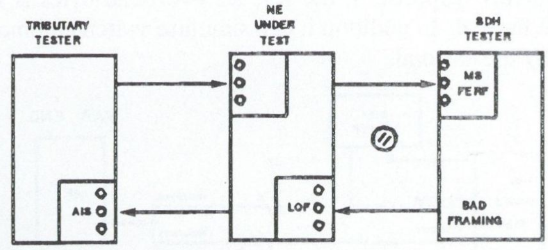


Fig. 15. Alarm testing

Another example, not shown, would be:
A bad signal from the tributary tester should cause a Loss of Signal indication on the NE, causing it to send AU Path AIS towards the high-speed side and the appropriate remote alarm to the tributary side.

8.5. Tributary testing

In the test arrangement shown in Fig. 16 the intent is to establish error free operation across the NE from SDH to and from the tributary side. An SDH generator and receiver capable of both high and low order tributaries is needed to prove correct mapping and demapping. For full testing, some NEs require the tributary being carried to be structured to the 64 kbit/s level. Corresponding tributary testers are needed on the low-speed side.

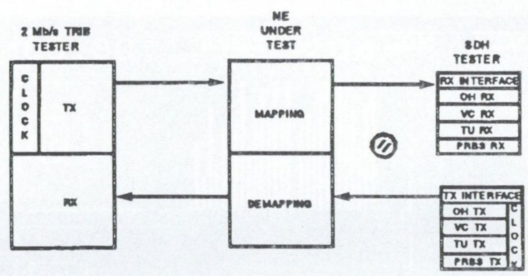


Fig. 16. Tributary continuity stress testing

Some NEs can be programmed to check their tributary inputs and outputs for framing or errors, and so rely on the correct format of tributary signal being present. Although some NEs are intelligent enough to draw attention to incompatible settings, sometimes the erroneous settings appear valid and cause trouble. This test can verify that NEs are set to pass the intended tributary signal.

A simple stress that can be applied in this configuration is to offset the frequency of the SDH or tributary signals to make sure the NE can handle the required range without introducing errors.

Tributary output jitter is always present due to the mapping/demapping process. However, jitter due to pointer movements is much greater than this. Standards describe patterns of pointer movements intended to represent realistic worst case pointer movement events encountered in the network, such as might be due to a synchronization failure coupled with a randomly timed extra movement.

The SDH tester applies a test signal containing such a pattern to a desynchronizer. The jitter output is measured against a specified limit while the tributary is checked for error-free reception (Fig. 17).

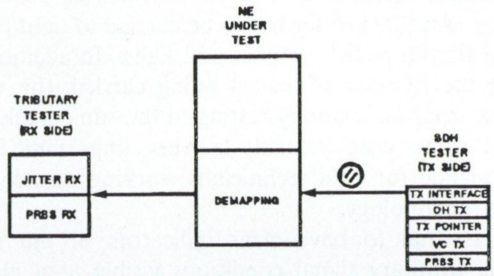


Fig. 17. Tributary output jitter testing

8.6. Timing test

This test applies to an NE with SDH inputs and outputs such as an ADM or DCS. It verifies the pointer processing circuitry within the NE. The frequency of the input SDH signal is offset in a controlled way from the timing reference of the NE under test. This causes the NE to generate pointer movements, the pattern of which can be analyzed. In addition, the information content of the output signal can be tested to be error-free (Fig. 18).

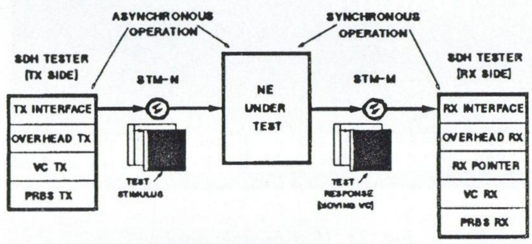


Fig. 18. Timing offset testing

This test can discover synchronization errors.

A whole array of tests come under the heading of parametric (Fig. 19). Some, like waveshape, are unlikely to fail. Others are mainly tested at conformance testing time. However line jitter is a candidate for a troubleshooting test since many installation-dependent factors can cause jitter. Parametric interface test results require careful interpretation since the correlation between parametric test outcomes and system error performance is far from straightforward.

OPTICAL INTERFACE TESTING

TRANSMITTER

- Optical Spectrum
- Mean Launch Power
- Laser Extinction Ratio
- Eye Pattern Mask
- Transmitter Signal-to-Noise Ratio
- Output Jitter

RECEIVER

- Sensitivity
- Overload
- Reflectance
- Jitter Tolerance

ELECTRICAL INTERFACE TESTING

- Pulse Mask
- Eye Diagram
- Jitter

Fig. 19. Parametric test requirements

9. MIDSPAN MEET TESTING

Troubleshooting at the Midspan Meet deserves a special mention. This term generally means testing at an NNI between NEs from different manufacturers.

The objective here is to diagnose problems specifically due to incompatibility between equipments. Faults are typically design errors, usually in overhead functions. These are now so complex, and offer so many options, that conformance testing cannot totally eliminate the problem. Problems may arise only in particular combinations of circumstances.

The desired outcome of midspan meet testing is to describe the symptom as closely as possible and identify the faulty equipment and preferably function.

Incompatibility problems can be particularly hard to solve, and often require a tester capable of very powerful overhead analysis. Advanced triggering functions help track down rare conditions.

NEs are sometimes upgraded in the field to track evolving standards. As a result, opposite ends of a link can get out of step in their overhead use. This can be true even on a link with the same equipment at either end where, for a variety of reasons, firmware upgrades have not taken place in step.

Fig. 20 shows the screen of a SDH tester capable of bit by bit programming and capture of SDH overhead.

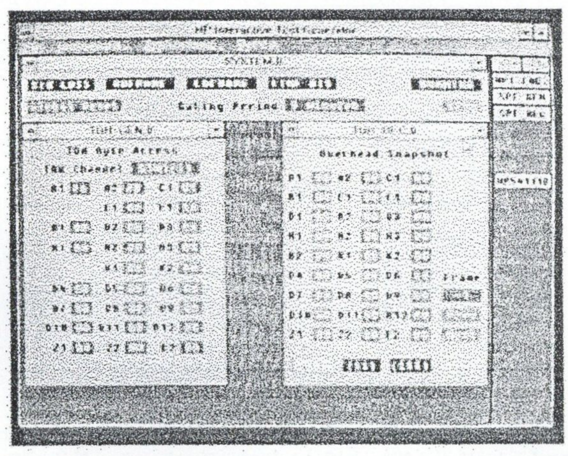


Fig. 20. SDH tester in programming mode

The overhead carries a number of channels specifically for different kinds of communication: orderwires for humans, datacom channels for network management computers, a user channel and other spare bytes which are sometimes used in a proprietary or customer-specific way.

These form part of the compatibility test. For simple channels, an SDH tester should be able to check continuity; in others it should be able to drop and insert the desired channel for testing by an external piece of test gear. A protocol analyzer can be used to test datacom channels and an NE's response to maintenance messages and network events (Fig. 21).

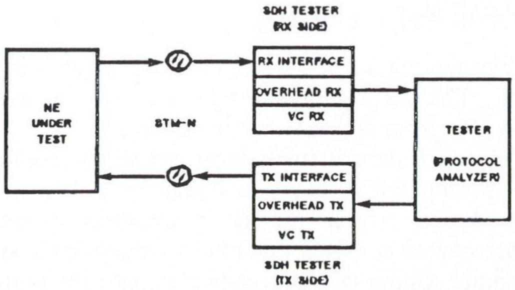


Fig. 21. Embedded communications channel testing

The test shown in Fig. 22 checks the performance monitoring built into the NE. The SDH tester inserts errors at a known rate into a parity byte corresponding to one of the maintenance entities (for example the high order path). The NE's reponses are observed: in this case, the NE would transmit FEBE signals back towards the high-speed side.

In addition it should be possible to use a service terminal to check the NE's internal performance monitoring registers are doing what is expected. Because of the unknown timing of the NE's performance monitoring real time clock, there is some uncertainty in checking the exact values of time-based analysis parameters like errored seconds.

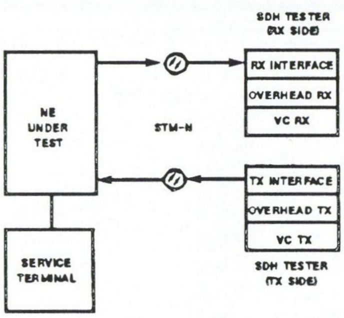


Fig. 22. Performance monitoring testing

There are cases where it is necessary to observe events on the high-speed line with the connection in place. One way to do this is to connect an SDH tester to a bridged protection line carrying an identical signal to the working line. This is a non-intrusive way to monitor events.

Another configuration is to connect an SDH tester in line as part of the connection. Some testers can be used in this way, often called "through mode", to simulate an SDH NE (a regenerator or ADM) and help to track down elusive faults (Fig. 23).

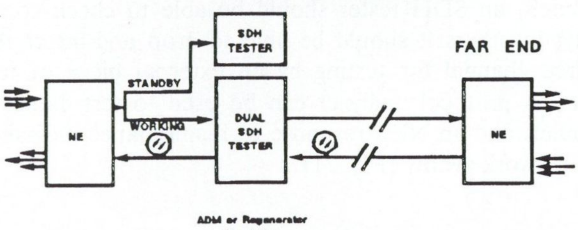


Fig. 23. In-service testing in through mode

10. FIELD TESTING

We have described test methods for installation, troubleshooting and midspan meet testing. In field applications, human factors must also be considered, especially portability. An SDH tester has to be carried to tight places and must therefore be compact and light. In addition, to minimize the number of testers being carried, the tester should incorporate tributary testing in the same package.

In the same way, usability is very important for a tester designed for field technicians working on new and unfamiliar technology.

It is essential to have clear indicators of the many SDH and tributary signal conditions visible at a glance. It is essential to have simple push-button control that technicians are comfortable with. And a screen capable of graphic display is useful to show long term monitoring results and provide help in setting up the tester controls in a user-friendly way (Fig. 24).

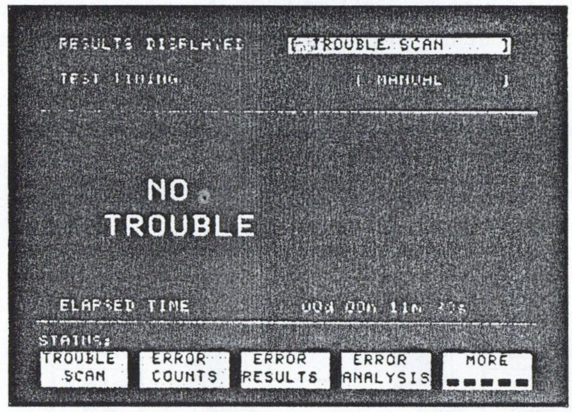


Fig. 24. User-friendly display

11. SUMMARY

SDH embodies several major advances on existing optical transmission systems which give it the flexibility, managability and robustness that network operators want. It is unlikely that existing test methods will be able to meet the challenge of installing and maintaining SDH networks, particularly as rings and midspan meets become common.

NNI test capability will be a valuable weapon in the hands of the installer and maintainer, both of whom will face the need to troubleshoot. Finally, NNI testing is the only way to verify compatibility where it counts — at the NNI.

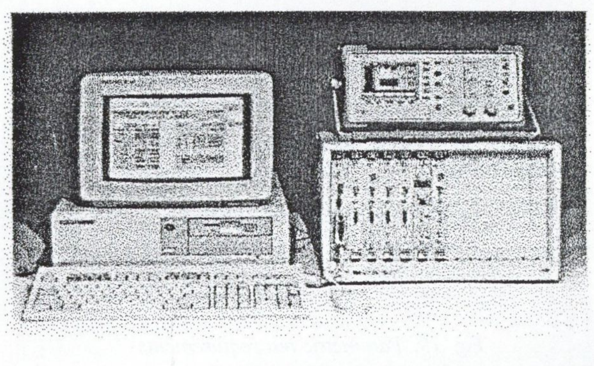


Fig. 25. SDH analyzers

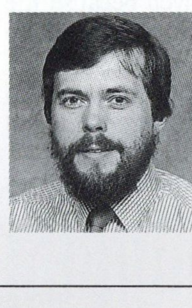
HP offers two powerful analyzers for testing SDH network equipment and transmission services:

- The HP 37724A SDH Test Set — a rugged, portable tester designed for comprehensive testing during installation and troubleshooting. It includes both SDH and tributary test capability, and is designed for the technician user (Fig. 25, upper right).
- The HP 75000 Series 90 Modular SONET/SDH Analyzer — a modular, upgradable tester which can be tailored for today and expanded for tomorrow (Fig. 25, lower right). This analyzer has very powerful overhead analysis. When equipped with a laptop PC controller (not shown), it has field applications in trials and midspan meet testing.

Both of these analyzers have flexible and upgradable designs to allow them to track SDH test needs as they evolve.

HP also offers a range of tributary testers, optical power meters, attenuators, OTDRs and oscilloscopes.

HP is committed to providing a full range of test solutions for SDH today and into the future.



Mark Dykes studied engineering at the University of Cambridge. He joined Hewlett Packard in 1973. He has worked in R & D and Marketing on a variety of analog and digital test products. He is currently product manager responsible for HP's SONET and SDH test sets.

MEASUREMENTS ON PDH AND SDH COMMUNICATIONS SYSTEMS

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Public and private network operators are working towards consistent expansion of their digital networks at ever higher bit rates. Implementation of a powerful network management system is also underway. In the future, systems in the plesiochronous hierarchy (PDH) with bit rates of 2, 8, 34 and 140 Mbit/s will operate alongside of synchronous communications sytems based on the SDH standard at bit rates from 155 Mbit/s to 2.5 Gbit/s. The synchronous hierarchy will not replace the plesiochronous hierarchy, however. Instead, both standards will exist in parallel during a transition phase which will last a number of years due to economic constraints. The implementation of synchronous cross connects, which act as gateways between SDH and PDH, will also increase the flexibility of plesiochronous networks.

1. AN ABSOLUTE NECESSITY: TEST EQUIPMENT

Test equipment is essential wherever systems are installed and maintained. The demands placed on test equipment are changing as the networks expand, new services are implemented and network quality requirements grow. Test equipment should not be oriented towards the technical capabilities of the systems. Instead, it must adapt to the concrete needs which arise in system commissioning and troubleshooting.

Taking into account the evolution of the networks and the concrete requirements for in-service test equipment, the following consequences result:

- A modular instrument design is necessary to allow upgrades which keep pace with the system expansion and applications while minimizing the investment. In the future, synchronous communications sytems will be installed wherever PDH systems are currently maintained.
- The test equipment must provide tailored and easy-to-interpret solutions for the typical problems in system installation and maintenance. Operation of the test equipment should not mirror the complexity of the communication systems!
- The test equipment should handle long-term monitoring (detection of gradual changes) as well as quality assessment and troubleshooting.
- Instruments should have versatile test capabilities to make certain that more complex projects are possible. In some cases, problems cannot be solved because the instrument is under-equipped. A delibarete compromise is necessary in this area.
- The instrument design must be practical enough to meet user requirements with respect to size, weight and ruggedness for field operation.
- Its should be possible to operate the instrument with no special knowledge of PDH or SDH.

2. HOW IS A FRAME CONSTRUCTED?

The bit rates of source signals can range from a few bits per second (modem) to 140 Mbit/s (transmission of high-resolution moving images). Bit rates to users generally lie between Nx64 kbit/s and 2 Mbit/s. For larger traffic volumes or widely separated connection points, 4 or 16 signals at 2 Mbit/s are multiplexed into a single 8 or 34 Mbit/s signal or mapped directly into STM-1 transport modules. The next hierarchy level has a rate of 140 Mbit/s for a multiplex signal (4x34 Mbit/s) or a source signal (transmission of moving images).

In almost all cases, signals at the higher hierarchy levels are structured, meaning they contain tributary signals from the lower levels. A structured signal with a bit rate of 140 Mbit/s can contain up to 64 tributaries at 2 Mbit/s. These 64 signals are contained within four frames at 34 Mbit/s, which themselves are composed of four frames at 8 Mbit/s.

Each frame in each hierarchy level begins with a frame alignment signal and a non frame alignment signal to indicate alarm states. In the 2 Mbit/s frame, error checking (CRC-4) and signalling (channel associated signalling, CAS, or common channel signalling, CCS) are also implemented. Since the clocks of the individual tributaries vary about a nominal value, a process known as stuffing or justification is required at 8, 34 and 140 Mbit/s to ensure correct transmission even for unstable system clocks.

The signals are encoded prior to transmission to avoid long sequences of zeroes no matter what sequence is transmitted and to eliminate any d.c. component when balanced transmission is used (2, 8 and 34 Mbit/s). Ternary HDB3 encoding is used for transmission of binary signals up to 34 Mbit/s; CMI encoding is used at 140 and 155 Mbit/s. Fiber optical transmission is increasingly common on critical links. Line termination equipment adapts the signals to the transmission medium and provides back-up for the power supply to the regenerators if necessary. Digital exchanges allow re-interleaving of Nx64 kbit/s user channels, while regenerators equalize and amplify the signal to its nominal level. Network terminations ensure defined termination conditions to the subscriber.

For transmission via synchronous systems, plesiochronous signals at bit rates of 2, 34 and 140 Mbit/s are mapped into containers of a fixed size. Supplementary information such as a path overhead and section overhead ensures synchronization and communication between synchronous cross connects. Pointers mark the beginning of the containers, which can shift about within the STM-1 frame.

3. UNWANTED YET UNAVOIDABLE: BIT ERRORS

The cost-effectiveness and quality of transmission are influenced considerably by impairments and the system failures which they cause. Impairments can result from external factors or from the system itself. Digital crosstalk, atmospheric interference in radio-hop transmission and momentary electromagnetic fields can all cause bit errors.

The distribution of errors vs. time provides one indication of the source of the impairment. For example, faulty clock recovery in a regenerator produces a more or less even error distribution, while momentary external interference (e.g. a lightning bolt) produces error bursts. The conventional method of measuring transmission errors by count and error ratio does not provide an ample indication of the error source. By recording the error distribution as well, the error source can be isolated much more easily.

To minimize the impairments which occur during system operation, test equipment must provide answers to the following questions:

- What is the error ratio for the overall link and the individual tributaries?
- Which voice or data channels are impaired?
- What error distribution is present: Uniform or burst? (This provides an indication of the error source.)
- Are the errors repeated at a certain time of day?
- Which alarms are detected by the system and reported using appropriate bit combinations?
- Are there any system impairments which are producing a gradual decline in transmission quality?

Basically, measurements can be performed either while the system is in operation or out of service.

4. LINE-UP OF COMMUNICATIONS SYSTEMS

Communications links can be lined up using end-to-end or loop-back measurements. By performing a bit-by-bit comparison of the transmit and receive patterns, the transmission quality of the link can be assessed over an appropriate period of time. The measurement time should be selected so that the impairment profile of the link, a direct function of the traffic characteristics, is recorded as completely as possible. It is best to perform the measurement over an interval of one or more days.

Quality analysis using standardized methods (CCITT Recommendation G.821) allows a direct comparison of the quality of different transmission links. International criteria for evaluation of transmission quality are currently under discussion. Some recent recommendations (M.2100 and G.826) provide new evaluation criteria. If these new recommendations are implemented in the test equipment, a future-proof solution is ensured.

When making long-term measurements, detailed documentation is a must for proper evaluation and verification of the system and error behavior of a transmission link. It should be possible to make a hardcopy of results so that a verification of quality is available at any time. The graphical display format (bargraph with selectable time resolution) allows detailed evaluation and serves as a basis for further discussion and implementation of any necessary measures.

5. IN-SERVICE MONITORING: ERROR STATISTICS AND QUALITY ANALYSIS

During operation of a system, transmission errors can be detected by measuring bit errors in repetitive bit patterns (e.g. frame alignment signals). These bits represent only a fraction of the bits in the frame, however. In practice, the most disruptive error bursts have a duration of several milliseconds, which clearly exceeds the duration of a single frame. Monitoring of the frame alignment signal over a longer test interval is a good way to obtain a statistically reliable assessment of system behavior.

With 2 Mbit/s frames, single bit errors anywhere in the frame can be detected by monitoring the CRC-4 checksums and E bits (used to report CRC errors recorded at the far end). The parity (B) bytes found in STM-1 frames can also be used for error monitoring.

Besides monitoring bit errors, it is also very important to record any alarms. Resolution down to the millisecond range is useful, even though this might seem excessive at first glance. In practice, however, alarm events such as (repetitive) sync losses last only a few milliseconds. Knowledge of the exact time of occurrence of the alarm can also help to find the source of the disruptive event (e.g. a micro-interrupt) and speed up the troubleshooting process.

Error bursts are particularly critical when making measurements. A high error ratio can be caused by external interference or by bit slips within the test pattern. Bit slips are produced by the system, while error bursts arise predominantly though external factors.

The ability to distinguish between error bursts and bit slips is critical when assessing the source of a fault. By measuring the receive bit rate, ongoing or gradual deviations of the multiplexer from the nominal bit rate can be detected.

Long-term measurements produce such a heap of output that it can be difficult to manage the results and interpret them. A large result memory is required which allows presentation of the results in an easy-to-interpret format. Storage of the measurements results and settings on a standardized storage medium (e.g. a RAMCard) makes it possible to perform the evaluation at any time and with any instrument.

6. LOOP-THROUGH MODE: REALISTIC SIMULATION OF IMPAIRMENTS

When impairments occur, it is best to test the system using realistic signals (or ideally with the system's own signal). A test instrument which includes a "loop-through" mode can be used to intentionally manipulate the system's signal and realistically simulate impairments. Insertion of error bursts is a good way to simulate real-life conditions. For example, the signalling protocol contained in one of the 2 Mbit/s time-slots can be intentionally disrupted using this method. Simulation of realistic error distribution requires a very flexible error insertion function which permits selection of the following: Error type (e.g. frame alignment signal/partity/CRC) and error distribution (error ratio, error burst, number of impaired frames).

7. FLEXIBILITY IS THE KEY

The only way to avert the economic side-effects of impairments is through rapid diagnostics and fault correction. What is needed is a test scheme which produces quick, reliable and precise measurement results. To provide useful support, the test equipment should take into account the difficulties of modern measurements and provide the right settings with just a few keystrokes.

A scenario which currently emphasizes bit error measurements and quality assessment can — through expansion of the network capacity, for example — be quickly transformed into one where measurement of jitter tolerance, jitter transfer functions and structured multiplex signals is an absolutely necessary component of any test solution. PDH networks will be converted to synchronous sytems in a step-by-step process. It is very important to use instruments which allow implementation of new features. Otherwise, additional equipment must be purchased as the network expands and new measurements come about.

8. INSTRUMENT WITH VERSATILE APPLICATIONS: W-G PF-140

The instrument PF-140 has been developed to perform various transmission system measurements both for PDH and SDH systems.

In the tests for commissioning link segments loop measurements and point-to-point measurements are encountered as illustrated in Fig. 1. These options can be performed in the operational mode "UNFRAMED".

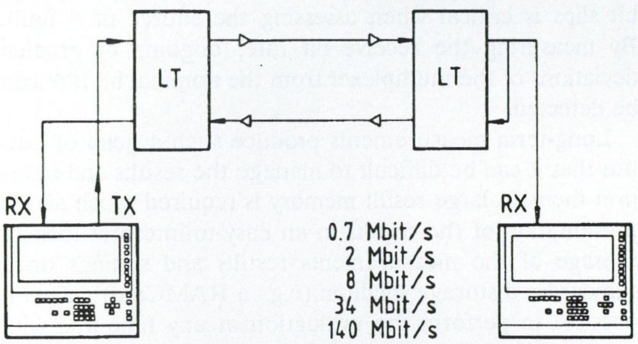

Fig. 1. Measurements on transparent channels

The PF-140 can monitor SDH communications systems without disrupting the system operation by using the framing information. The operational mode "MONITOR" is intended for this application as shown in Fig. 2.

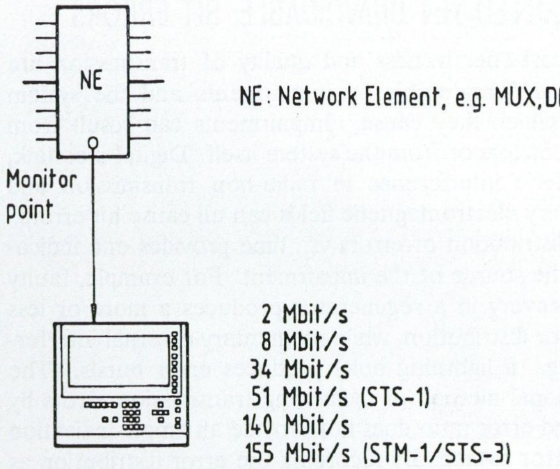

Fig. 2. In-service-monitoring of framed signals

The instrument display and the menu options in the "UNFRAMED" mode are shown in Fig. 3.

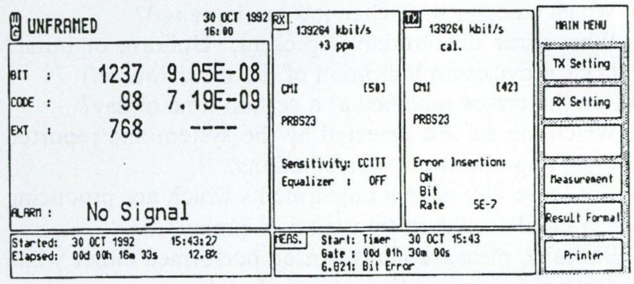

Fig. 3. Display and menu in the UNFRAMED mode

The choice of the operational modes is controlled by special function.

The operational modes of the instrument are selected by special touch controlled keys as shown in Fig. 4.

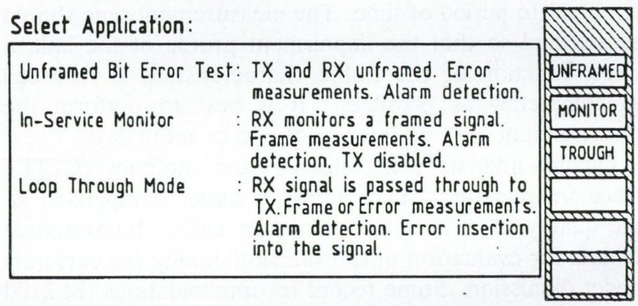

Fig. 4.

In Fig. 5 the results of a measurement performed on a 140 Mbit/s line in operational mode "MONITOR" are illustrated by the corresponding displays of the PF-140.

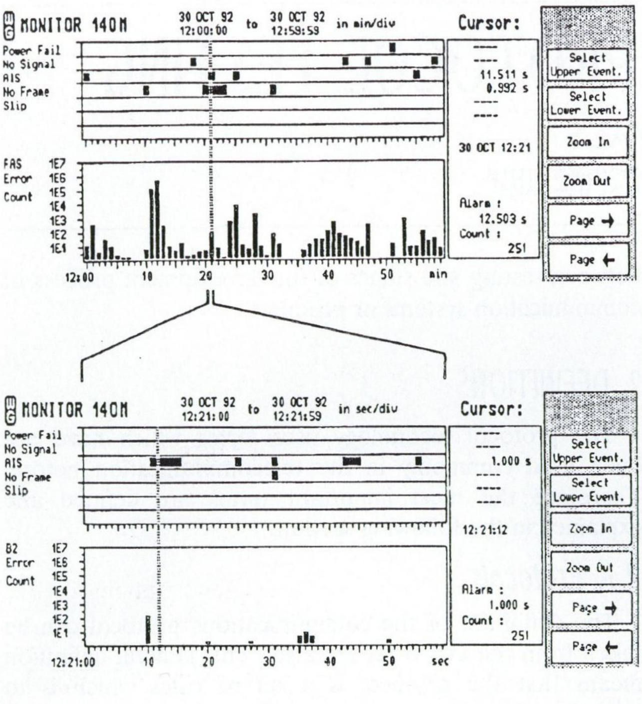

Fig. 5. 140 Mbit/s line measurement in operation mode MONITOR

In Fig. 6 examples are given of future PF-140 enhancements.

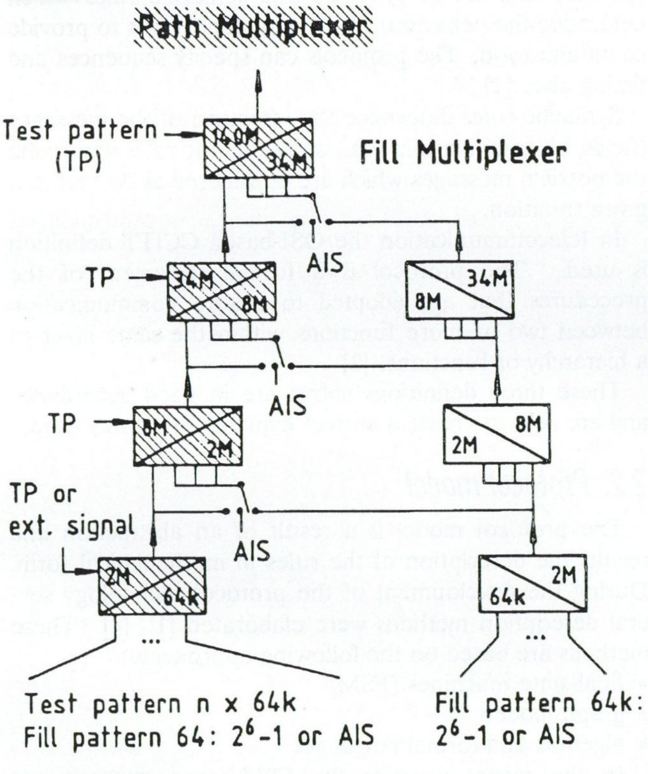

Fig. 6. Option Frame Generator/Analyzer with Multiplex Chain

Fig. 7 shows the testing of network elements with "live signals". Here PF-140 loops the received signal to the generator and inserts errors as required for test purposes. The "live signals" contain everything that can occur during actual operation.

These are some typical applications of the cost-effective and future proofed digital communications analyzer PF-140.

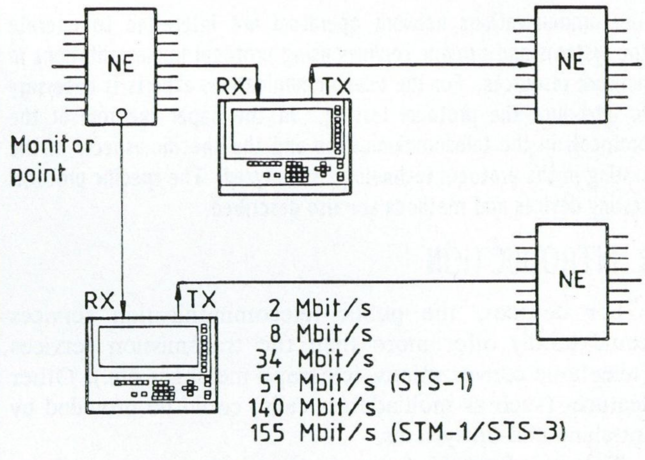

Fig. 7. Operational mode "loop-through"

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SPECIFIC ASPECTS OF PROTOCOL TESTING

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Telecommunications network operators are interested to operate the systems and provide services using protocol implementations in network resources. For the telecommunications experts is necessary to introduce the protocol testing. In the paper the role of the protocols in the telecommunication and the specific aspects of the testing in the protocol technology is analyzed. The specific protocol testing devices and methods are also described.

1. INTRODUCTION

For decades, the public telecommunication services could hardly offer more than the transmission services (telephone converzations, telegraph messages etc.). Other features (such as multiaddress calls) could be provided by installing add-on systems.

The introduction of the stored program control of the network resources (mainly in switching systems) opened the way for the increase of the intelligence of the telecommunication networks and for provision of more flexible, sophisticated services. In the eighties the demand for the new services increased very rapidly. These developments have also created a competitive situation among network operators and equipment suppliers.

1.1. The role of protocols in telecommunications

Due to the increased complexity of the systems the necessity of the interoperability of different systems is emphasized.

The requirements were to be standardized, and as a result the openness of the systems became and important feature of the implementations. The open systems interconnection (OSI) standard of ISO provided a new conceptual approach of the communication.

A new technology was derived from the OSI concept: the protocol technology.

Protocol technology has size an impact on the testing therefore

- the testing methods are developed in accordance to the protocol development methods
- a new generation of the test tools were necessary, since the evaluation of the working of complex systems needs computer based test tools. Sometimes the test results need to be post processed.

1.2. Objective

This paper intends to introduce this new test technique for those experts who have a general knowledge on telecommunication. It contributes to help them to identify the possible requirements of the practice and how to fulfil these needs.

The paper gives a basic tutorial overview of the most important knowledge and describes the mutual relations between testing and stages of the development process of communication systems or products.

2. DEFINITIONS

The protocol technology uses terms which have not been used commonly in the telecommunication before. Therefore the most important terms are defined and explained in the following section.

2.1. Protocols

The definition of the communications protocol can be taken from the every-day life also. This general definition means that the protocol is a set of rules which is to be followed in a given environment to provide a correct interaction relation.

For engineers developing or using OSI products a protocol is a set of syntactic and semantic rules which determine the behaviour of the functional units to provide communication. The protocols can specify sequences and timing also. [1]

Syntactic rules determine the structure of the messages (fields, bit combinations etc.) and semantic rules determine the possible messages which are considered as correct in a given situation.

In telecommunication the OSI-based CCITT definition is used. The protocol is a formal statement of the procedures that are adopted to ensure communication between two or more functions within the same layer of a hierarchy of functions. [2]

These three definitions above are in good accordance and are able to create a correct explanation of this term.

2.2. Protocol model

The protocol model is a result of an abstraction and results the description of the rules in mathematical form. During the development of the protocol technology several description methods were elaborated [1], [4]. These methods are based on the following approaches:

- final-state machines (FSM)
- graph models
- algebras and formal languages

In the recent practice the FSM-based methods are commonly used. The other two groups of methods have still theoretical importance.

2.3. Protocol implementation

The protocol implementation is the product which provides the specified functionalities of the protocol. The implementations can be divided into the following groups:

• hardware (firmware) implementations
• software implementations

This grouping is classical in the development in communications or in other fields. The firmware implementations are sometimes closer to the software ones but from the testing point of view it is better to consider them as hardware implementations because of their accessibility via interfaces.

The importance of the software implementations — especially in the higher OSI layers — is dominant and permanently increases.

3. THE DEVELOPMENT PROCESS OF PROTOCOL TECHNOLOGY

The development of a complex product has several stages which are generally described in the literature, therefore it is not necessary to discuss them in this paper. Such steps are combined with among others the conceptual design of the system and design of the environment in which the given implementation should be implemented. In the following sections only the protocol-specific development steps are discussed.

3.1. Specification

This step contains the series of the technical decisions based on the design objectives.

As mentioned in the sections above, protocols are widely standardized. The standards are in most cases the basis of the specification.

Some requirements in the standards reflect a matter of compromising result of discussions or even debates based on different interests in the standardizing bodies. This results options in the standards and these options are sometimes exclusive.

Recent standards are written mostly in textual form so the abstract specification is not yet general.

On the other hand the standards does not specify all of requirements which are necessary for implementation. The most. important area of such requirements the behaviours of the implementation in abnormal situations. These procedures (sometimes called as recovery procedures) determine the robustness of the implementation.

All of the requirements are to be specified and as a result a document in abstract form of a mathematical model is produced which is called specification.

3.2. Implementation

This is the step when the first version of the product (or the protocol-specific part of the product) is realized.

3.3. Installation (Provisioning)

This is the action when a given product (protocol implementation) is inserted into a system and finally is taken into use. In telecommunications the provisioning is a very frequent action, when networks are extended or developed in a multivendor basis.

3.4. Maintenance

This term is used in the same sense as in other fields of telecommunications.

4. THE ROLE OF THE PROTOCOL TESTING IN THE DEVELOPMENT PHASES

To achieve the design objectives the whole development process should be verified. Each phase of the development process has to be tested. The test purpose in the different situations are different, so the development process is strictly combined with various protocol tests. These relations are shown in Fig. 1 and explained in the next section.

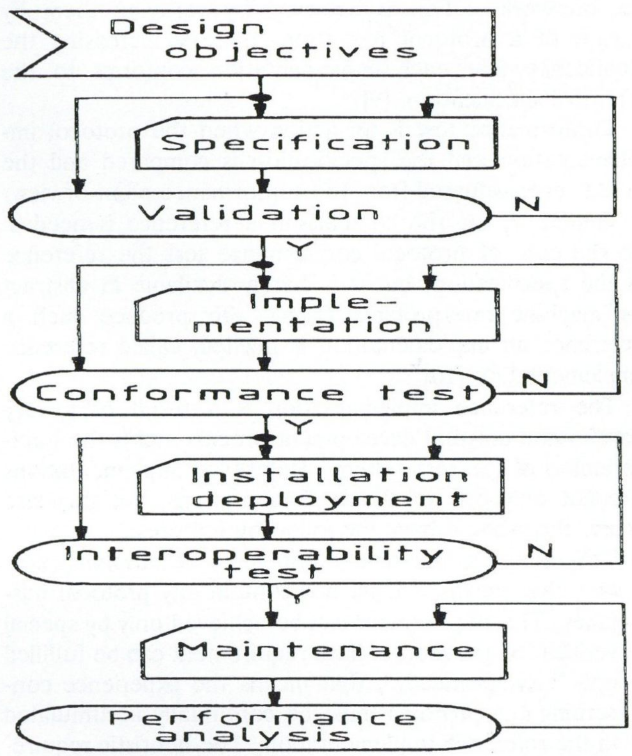

Fig. 1. Protocol development process and tests

4.1. Validation

The main objective of the validation is to see whether the specification itself is in correspondence with the design objectives and is able to be implemented. The latter means that validation process targets to get predictions on the behaviour provided by the specification of the protocol.

This latter means in the FSM model:

• the state machine has no deadlock(s)
• any state can be reached from any other state
• it can handle abnormal situations and can return to its normal operation after suspension of the abnormal conditions

In connection with validation it is necessary to define the term verification. [1] Verification means the checking of the logical correctness and proper operation. It is less general and connected rather to the protocol design than the specification. Verification can be considered as a part of validation.

The result of the validation is such kind of a specification which has no semantic errors nor specification mistakes and the predicted values of its performance parameters fulfil the design objectives. So the validated specification is the basis for the implementation.

4.2. Conformance test

Interoperability of two or more different products is an essential requirement in communication networks especially in public networks. Customer premises equipment for example should interoperate with the network, or network nodes are installed by different equipment vendors. These show that conformance testing plays a key role in telecommunications.

The purpose of the conformance test is to increase the probability that different implementations are able to interwork. This is achieved by verifying them by means of a protocol test suite, thereby increasing the confidence that each implementation conforms to the protocol specification. [9]

Conformance test is an action when the protocol implementation and the specification is compared and the results are evaluated from the conformance point of view.

Generally, for the comparison a reference is needed. In the case of protocol conformance test the reference is the specification, but it is hardly available in abstract or machine interpretable form. To produce such a reference an implementation is needed, called reference implementation [10].

The reference implementation is a result of a very careful and unusual development process and is the built-in etalon of the test system. Reference implementations are not only one of the implementations, but they are more. they should have the following features:

- The reference implementation must be *absolutely correct*, that means it must not contain any protocol mistakes. This requirement can be achieved only by special verification procedure. This requirement can be fulfilled only "asymptotically", that means the experience concerning the protocol must be continually accumulated in the reference implementation. The heuristic requirement for correctness is a conformance test with positive result. In the practice this can be substituted by a series of conformance tests where in case of an erroreneous situation the evaluation can result the error of the IUT or the reference.
- The reference implementation must have all the possible options fixed in the standard. A complete set of options is necessary only for the reference since other usual implementations doesn't implement all of the options. The decision between these options is based on the parameters in the PICS (Protocol Implementation Conformance Statement), and must be set before the test.
- If such a universal reference implementation is used, special features are necessary to align the options before testing. The reference implementation therefore must have additional *special interface*, where the setting, parametrization and other specialized functions are realized.

The documentation of the conformance test results are realized mainly in abstract form.

The main result of the conformance test is the conformance statement in which the interworking capability of the given protocol implementation is predicted.

Special conformance area is protocol conformance testing as a part of a certification system. In this case three players are in context:

- the *customer*, who implemented the product to be certified
- the *testing laboratory*, which carries out the test by means of standardized test tools using standardized test methods
- the *certifying body*, which issues the certification document as a response to the customer's application

The details of the certification processes are legally regulated by telecommunication authorities and are not the subject of this paper.

4.3. Interoperability test

Although positive conformance statements on different implementations of the same protocol predict that these implementations will interoperate properly, the practice requires to test the real interoperability.

Basic requirement of the interoperability of two implementations is that each implementation should be based on the same specification. This implies that the same options are implemented. If this is not the case, only a limited interoperability is possible. The methods to specify the area of such a limited interoperability is the subject of the study.

4.4. Performance analysis

Operation and maintenance in real systems in operation are important functions in the telecommunication to provide a relative high degree of service quality. This needs a continuous system monitoring which should work independently from the monitored systems.

The main objective is to get numerical values which characterize the implementation from practical point of view. These values can be compared with the error criteria to alert the errors in the network.

Performance analysis data and maintenance objectives are the technical input to the management for the medium and long term network development. In several cases the evaluation is supported by a knowledge-based system.

Although the above described arts of protocol testing are dedicated to specific development phase, different methods can also be used depending on the protocol development phase and the purpose of the test. Table 1 shows the possible tests.

Table 1. Test methods and test purposes in the development phases

Development phases	Test purpose		
	Logical correctness	Error-less	Performance parameters
Specification	verification	simulation	simulation
Implementations	conformance test	conformance test	measurement
Installation, provision	–	measurement	measurement
Maintenance	–	measurement	measurement

5. PROTOCOL TEST METHODS

In most of the protocol tests the basic scenario is when the testing system sends test sequences to the implementation under test (IUT) and receives messages or protocol data units sent by the IUT to the test system as reactions to the test sequences.

5.1. Structure of the tests

Protocol testing is a highly complicated task, therefore the tests are arranged in a special hierarchial structure. The elements of the testing are described below [9]. The structure is shown in Fig. 2.

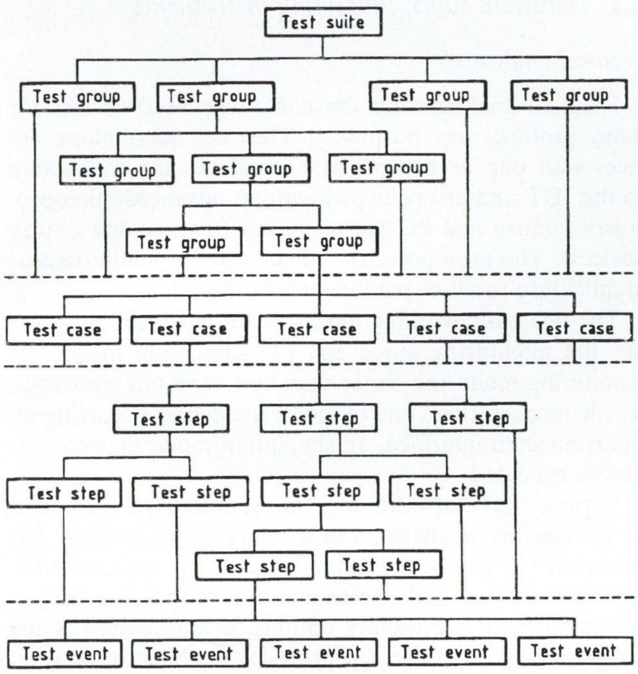

Fig. 2. Test suite structure

Test suite

This is the complete set of entire tests which can be executed.

Test group

Within the test suite test groups are used to provide a logical ordering of the test cases. Test groups may be used to aid planning, development, understanding or execution of the test suite.

Test case

Test case has a narrowly defined purpose, such as that of verifying that the IUT has a certain required capability (e.g. the ability to support certain function) or exhibit a certain required behaviour (e.g. behave as required when a particular event occurs in a particular state).

Test step

Test cases are subdivided into test steps. Each test case consists of at least one test step. Test steps to put IUT into the state required for the test purpose are called as "preamble" and to return to the quiescent state are called as "postamble". Test steps covering the purpose are called as "test body".

For practical reasons common test steps may be structured into a test step library. Test steps may be associated with the whole test suite or with a particular test group or test case.

Test event

Test events are the elements of a test step. They are similar in structure to the test steps, but are elements of other steps.

5.2. Test sequence generation

The protocol tests are based on test sequence generation. Test sequences are developed in the basis of the protocol model. The main problems in the test generations are discussed in [1].

The *transition tour methode* is based on FSM model and means that during the testing every transition between states should be reached at least once.

Test sequences can be generated automatically [4] or in case of widely used protocols separate standards were elaborated specifying the standardized tests.

5.3. Test coverage

Exhaustive tests are theoretically by complete. Since the protocols used in practice are relative complex, such exhaustive tests need to execute a large number of test cases (sometimes several thousands), which can not applied in all cases. This problem requires a compromise, so the number of the test sequences must be reduced.

In the practical testing the test cases are sometimes grouped:

- basic interconnection tests
- provocative tests
- etc.

The groups have a priority to find a compromise between the test coverage and the testing costs.

5.4. Formal description technique for protocol testing

In order to execute protocol test in a computer-based environment, it is necessary to support the design of the test strategy (test generation) and the evaluation of the responses of the IUT.

The literature discusses several abstract methods. Some dedicated specification languages are elaborated (ESTELLE, LOTOS etc.).

In the international standardization bodies (ISO, ITU–TS) the TTCN (Tabular Tree Combined Notation) method is used [11].

TTCN describes the possible reactions in different situations by means of a tree. This means that TTCN tables contain all formal descriptions of the test. The description consists of the following parts:

- Introduction, where the references, the test methods and the structure of the test suite are given

- Declaration, where elements and parameters are specified
- Dynamic part, where the test trees are specified with reference to the limitations. These tables contain the verdict also which can be:
  pass
  fails
  inconclusive
- Limitations, where the values of the parameter limits are specified

On the basis of the abstract test description finally the executable test sequences are generated.

5.5. Abstract methods in OSI testing

The protocol test methods in OSI environment are based on the architectural concept, the 7 layer reference model. The PDUs are transferred by a standardized OSI service provided by lower layers of the system. The CCITT Recommendation X. 290 [9] defines the basic methods.

Local test methods are useful for systems under development, when their architecture permits the separation of the IUT.

External test methods are useful for testing complete or partial end-systems which can attach to telecommunication networks.

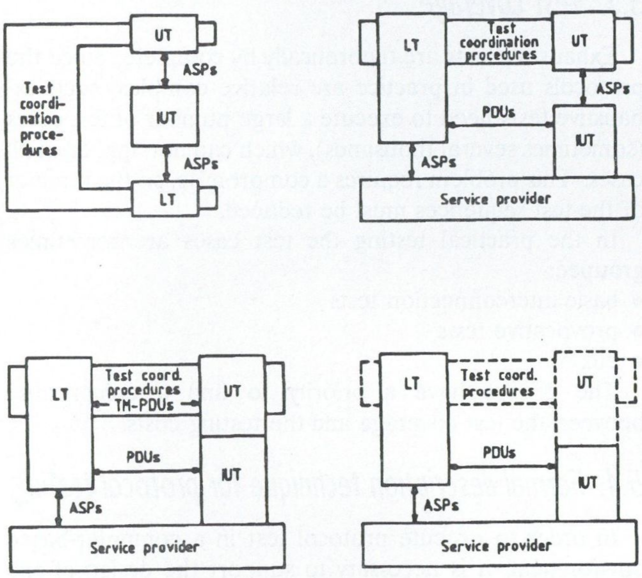

Fig. 3. Abstract test methods
UT – upper tester,
LT – lower tester,
IUT – implementation under test,
ASP – abstract service, primitive

Coordinated test methods are applied where it is possible to implement standardized test management protocol in an upper tester in the SUT above IUT.

Remote test methods are applied when it is possible to make use of some functions of SUT to control the IUT during testing, instead of using a specific upper tester.

Distributed test methods are applied when it is necessary to allow complete freedom of the implementation of the test coordination procedures.

Fig. 3 shows some examples of the most important combinations of OSI test methods.

6. PROTOCOL TEST TOOLS

Modern protocol test tools are no more universal. They are developed and dedicated to a specific test purpose. This means that different tools are used for example in maintenance and in conformance tests.

6.1. Hardware tools, measuring instruments

Protocol analyzers

Protocol analyzers are the commonly used devices for many protocol test purposes. They are stand-alone devices with one or two physical interfaces for connection to the IUT and are equipped with an advanced microprocessor control and PC-like resources (storage and display devices). The most powerful models have a multiprocessor architecture to allow parallel processing.

The two basic working modes of the protocol analyzers are the monitoring mode and the simulation mode. In monitoring mode the tester does not send any messages, it only receives them and observes the events occurring on the connected interface. In simulation mode the real test can be executed.

Various test software for the standardized protocols as options are available, which contain standardized test suites. If the protocol analyzer is used for testing a non-standardized protocol implementation or protocol implementation with proprietary options, a key feature is the programming support of a protocol analyzer to support the test suite development.

Message generators, traffic generators

This type of the instruments is used mainly in the maintenance for the performance parameter measurements, when a high amount of similar or identical test cases should be executed or if many ports of the tested system should be connected, and observed. The evaluation of the test results consists of calculation of statistical values.

6.2. Software tools

The general characteristics of software test tools are:

- test sequence database
- sophisticated evaluation system for automatization of test strategy

The software tools which are used certification also must support the standardized documents (PICS, PXIXT, PSTR, SCTR).

Corresponding to some expert's opinion validation tools are not real test tools because the specific requirements of the validation process.

Limited correctness of simulation for example: real time operation.

7. THE IMPORTANCE OF THE PROTOCOL TESTING FOR A TELECOMMUNICATIONS NETWORK OPERATOR/SERVICE PROVIDER

The network operator or service provider itself hardly implements protocols. It operates on the equipment market as a buyer and system integrator.

Interests of the network operator:

- to provide international (or multinetwork) connectivity (interoperability tests between networks)
- to connect a wide choice of terminal equipment
- to use network resources from different vendors (conformance test)

The network operator has serious general responsibility for the network integrity. However its interests requires to be involved in the protocol testing.

If the network development is based on a single equipment vendor the network operator's commercial risk is high but the vendor should carry the responsibility for the network integrity.

Public network operators today follow a multi-vendor strategy, so they have to specify the protocol implementations and to test them for acceptance before installation in the network. In this case the equipment vendor's responsibility is limited to the conformance between the specification and the delivered product. Service quality and network performance parameters have an indirect impact on the equipment, and the network operator should be able to specify the network elements ensuring the objectives.

The most of the public and private network operators establish their own test house to provide testing services for the different branches of the company. Some test houses provide public conformance test services for the certification systems operated by the telecommunications authority.

In Hungary a telecommunication certification system is operated by the Telecommunication Inspectorate of the Ministry of Transport, Communication and Water Management. This system is based on a laboratory accreditation system which corresponds to the European standards. In current status cca. 10 laboratories are accredited for different test purposes. The number of accredited laboratories allows to achieve an independent certification process.

Hungarian Telecommunication Company as the dominant national network operator and service provider is deeply involved in the national certification system as testing laboratory, and, sometimes as customer. Its own testing laboratories in the PKI Telecommunication Institute cover almost all of the most important areas of telecommunication. PKI elaborates specifications for the HTC provisioning and executes the conformance tests on the products delivered by the equipment manufacturer. Test laboratories carry out acceptance tests also for the HTC investments.

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DSP-BASED TELECOMMUNICATION TESTING, A UNIVERSAL APPROACH

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The architecture, the operating principles and the most important facilities of two digital signal processor (DSP) based test systems are presented. Both systems use a personal computer (PC) as the man-machine interface. The PCM Multiplex Analyzer EP-1 is an automatic test system for the measurement of almost all parameters of PCM multiplex systems between various combinations of analogue and digital ports. The Signalling Generator and Analyzer SGA-2 provides both passive monitoring and active emulation of multi-frequency coded (MFC) and channel associated signalling (CAS) sequences simultaneously. Although both test systems are intended mainly for PCM systems, they can be used efficiently in an analogue or mixed, analogue-digital environment, too. The combination of a DSP and a PC results in a universal, cheap and very flexible programmable test hardware which can provide many facilities in the future by merely developing the software required for new features.

1. INTRODUCTION

The Department of Telecommunications and Telematics (DTT), and its predecessor, the Institute for Communication Electronics, Technical University of Budapest (TUB), have been active long in developing telecommunication test equipment. In the seventies and eighties various microprocessor controlled automatic systems were developed for analogue multiplex channel testing in cooperation with the Hungarian firm Elektronika Coop. where some of these systems are still in production.

In 1989 a new concept was formulated. It was recognized that a general purpose digital signal processor (DSP) is capable to perform all signal generation and measurement tasks required in low and medium frequency telecommunication testing. This approach is particularly advantageous in the case of Pulse-Code Modulation (PCM) channels because digitised signals can be handled directly in digital form, so all errors associated with analogue-digital conversions are eliminated.

Another idea is the application of a general purpose personal computer (PC) as a cheap programmable controller and man-machine interface. A combination of a DSP and a PC thus can form a universal test hardware which can be adapted to special tasks by using appropriate measuring interfaces and — of course — by loading some particular test software. Since the application of a hard disk in the PC removes memory limitations, the range of manual and automatic functions can be extended almost endlessly, new measuring, evaluation or control functions can be added any time as required.

In the case of testing, true real time operation is seldom required, but processing time should not slow down testing considerably. This requirement determines the type and speed of DSP hardware to be selected for a given application. Some non-time-critical computation can even be performed by the PC which is otherwise used mainly for interpreting commands, displaying results and preparing logs.

In this paper a short overview is given on the architecture, operating principles and the most important facilities of two test systems developed at DTT, TUB, using the concepts mentioned above. The PCM Multiplex Analyzer EP-1 is an automatic test system which performs the measurement of both the voice-frequency and the digital parameters of PCM multiplex systems. The Signalling Generator and Analyzer SGA-2 is a semiautomatic debugging system that can be used both for passive monitoring and active emulation of multi-frequency coded (MFC) and channel associated signalling (CAS) sequences simultaneously between various analogue and PCM exchanges.

2. HARDWARE ARCHITECTURE

A timing analysis of the signal processing tasks has shown that a first generation TMS320C1X (Texas Instr.) DSP is sufficient for all voice-frequency and digital measurements required, so it has been chosen for economy reasons. Although this DSP chip is quite powerful for signal processing operations, it is neither convenient nor very efficient for controlling interfaces and complex measurement sequences. So this type of tasks should be performed either by a general purpose microcomputer or by the PC itself. Accordingly, either two or three processors are needed in a test system.

2.1. *Three processor architecture*

In Fig. 1 a three processor architecture is shown. This has been chosen for the PCM Multiplex Analyzer EP-1 which is intended mainly for automatic testing, but it is useful also as a manual tester. It can control or can be a part of an automatic test system including various measuring instruments connected via an IEC 625 (GPIB) interface bus. In stand alone or portable applications a small notebook PC without IEC 625 interface can also be used and can be connected to the EP-1 via a simplified V.24 serial line.

The principle of sharing the workload for the processors is the following. All signal processing tasks, i.e., test signal generation and measurements are performed by the DSP. The control processor is used merely to schedule the tests and to control the hardware interfaces providing internal and external connections. Individual tests or test sequences are controlled ultimately by the PC and it performs also the final evaluation and presentation of the results in numerical or graphical form.

In the case of PCM multiplex testing typically 30 channels or a multiple of 30 channels need to be tested therefore a channel selector is required for automatic operation. A Channel Selector EC-1 is available in the same construction as EP-1 for this task. Other instruments, e.g. level generators and selective receivers can also be connected to the IEC 625 bus if the necessary software is developed. In small, portable systems where only a single V.24 line is available to control the EP-1, the EC-1 can be controlled indirectly by the EP-1 via a simplified IEC 625 connection.

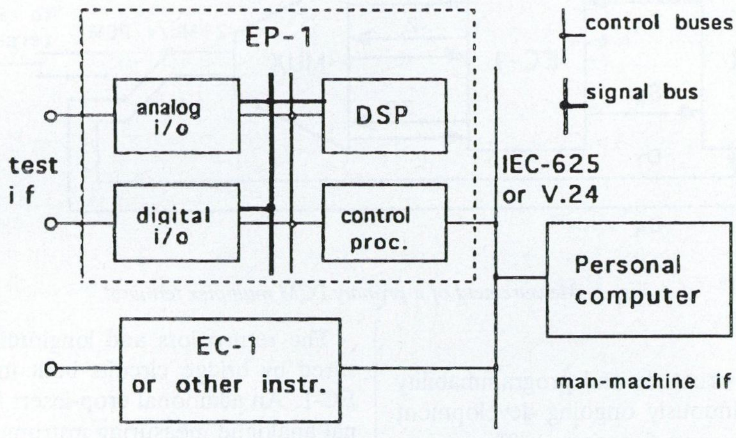

Fig. 1. The three processor architecture of EP-1

2.2. Two processor architecture

In the case of a simple tester the DSP hardware and the specific I/O interfaces can be directly connected to the PC internal bus and then the additional control processor is not needed. Although this solution is very economical, it requires a free extension slot either within the PC or in an extension box (docking station). This architecture proved to be the most suitable one for the rather simple hardware of the Signalling Generator and Analyzer SGA-2.

Due to the close coupling of the functional units to the PC, the control of measurement sequences can be performed directly by the PC itself. Although this results in a slight overhead only, time critical operations may delay the display of events noticeably. In the case of SGA-2, e.g., the timers of the PC are reprogrammed to provide a 1 ms time-base which is needed for recording signalling events with fine resolution but a burst of events can be displayed only with some delay depending on the speed of the PC, too.

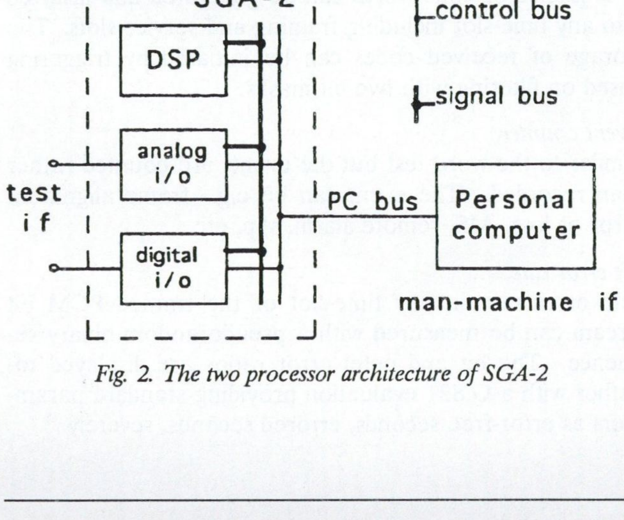

Fig. 2. The two processor architecture of SGA-2

3. THE PCM MULTIPLEX ANALYZER EP-1

The architecture shown in Fig. 1 is suitable for a high performance automatic test system. All measuring functions are realised by the DSP, so the combination of the control processor and the PC can facilitate sophisticated automatic measuring sequences with intelligent evaluation and logging.

3.1. Measuring configurations

The basic measuring configuration using EP-1 and EC-1 is shown in Fig. 3. If the voice-frequency parameters of a single primary PCM multiplex terminal (MUX) are measured between analogue and digital ports, then both analogue (S_T, S_R) and digital (D_T, D_R) outputs and inputs of EP-1 are needed. In this configuration analogue-analogue (A-A), analogue-digital (A-D) and digital-analogue (D-A) measurements can be performed. In the case of A-A measurements D_R is looped back to D_T within EP-1. For the measurements of 2-wire channels the EP-1 can shift the PCM time-slots by 16. In the case of voice-frequency D-D measurements, S_R should be looped back to S_T via an external attenuator which matches input-output relative levels.

In the case of low-level measurements, as the idle channel noise or crosstalk e.g., an auxiliary low level tone is also generated in EP-1 (S_A) and applied to eliminate errors due to coarse quantization.

In end-to-end measurements of two interconnected terminals two test systems can be applied. The synchronization of the receiver to the transmitter is accomplished by a special FSK signalling. For the maintenance of a network, a master-slave communication between controlling PCs via modems can be applied.

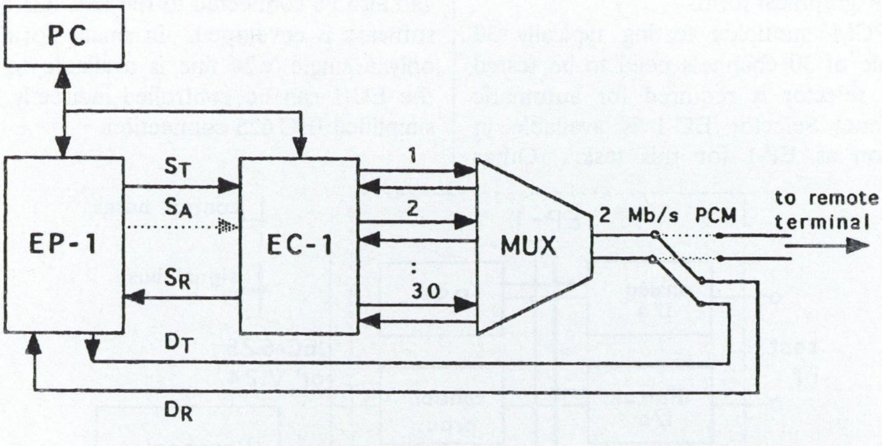

Fig. 3. Measurement of a primary PCM multiplex terminal

3.2. Measuring functions

The universal hardware structure and programmability of the EP-1 allows a continuously ongoing development and addition of new measuring functions. The voice-frequency measurements that have already been realised at the time of writing this article are listed in Table 1.

Table 1. Voice-frequency measurements provided by EP-1

Parameter	A-A	A-D	D-A	D-D	Notes
Gain, loss	+	+	+	+	
Level (absolute)	+	+	+	+	
Transmit level		+			
Receive level (digital mW)			+		
Attenuation vs. frequency	+	+	+	+	
Variation of gain vs. level (with tone or noise)	+	+	+	+	
Total distortion (with tone or noise)	+	+	+	+	
Idle channel noise (psophometric)	+	+	+		
Near-end crosstalk	+			+	
Far-end crosstalk	+	+	+		
Dual-tone intermodulation	+	+	+	+	
Peak code detection (positive or negative)		+			
Coder offset		+			
Return loss	+				with EC-1
Longitudinal balance	+				with EC-1
Drop-insert signal transfer		+	+		ext.meas.

The specification of these measurements is covered in sufficient detail by CCITT Recommendations Series O and G (O.133 and G.712 [1]) and the realization by a DSP is also straightforward. The reader interested in this topic can find further information in the references (see e.g. [2]-[5]). In fact, there is some freedom in the selection of the testing algorithms, but the efficiency of FFT can be fully exploited here because both the sinusoidal and the pseudorandom test signals can be analysed over an integer number of periods. This means that windowing is required only for noise measurements. Although the application of a DSP would allow new and efficient types of measurements, conventional tests are realised by the digital signal processing algorithms in order to provide results that can be compared directly with standard tolerance limits.

The return loss and longitudinal balance can be measured by bridge circuits built into the Channel Selector EC-1. An additional drop-insert facility ensures that external analogue measuring instruments can also be applied if special testing functions are required.

3.3. Digital testing functions

In many applications digital testing is also necessary like monitoring of PCM digital paths, framed end-to-end testing of PCM time-slots, multiplexer equipment testing, channel associated signalling monitoring, etc. For such tests a digital signal generator is also realised by the DSP which produces either sequences of specified patterns or pseudorandom bit sequences or inserts bit errors with given probability. At the receiver side selected events can be recorded or counted and the complex evaluation of bit error distribution is also supported as specified in CCITT Recommendation G.821.

The presently available main digital testing functions are listed below.

Frame monitoring:
Frame and multiframe alignment words, maintenance and alarm information are presented, framing errors and also slip and CRC4 errors are counted and displayed.

Word test:
A sequence of code words can be generated and inserted into any time-slot including framing and service slots. The storage of received codes can be initiated by triggering based on filtering with two bit masks.

Event counter:
Similar to the word test but the events are counted rather than recorded. The event can be e.g. frame alignment error or loss, AIS, remote alarm, slip, etc.

Bit error rate:
The error rate in any time-slot of the framed PCM bit stream can be measured with a pseudorandom binary sequence. The bit and octet error ratios are displayed together with a G.821 evaluation providing standard parameters as error-free seconds, errored seconds, severely

errored seconds, degraded minutes, available time and unavailable time.

Signalling distortion:
Delay distortion of signalling pulses can be measured at the digital side, e.g. by looping back analogue E&M signals.

Signalling status:
All signalling bits in time-slot 16 are sampled at a given rate and displayed.

3.4. Automatic testing facilities

The wide range of programmable facilities makes the EP-1 particularly advantageous for automatic testing of voice-frequency parameters of PCM channels. (Digital testing functions are used in manual mode). In addition to the detailed set-up available for individual measurements, the chaining of any number of tests including various displaying and logging possibilities provides a very flexible system. On one hand the usage of interactive soft key menu can be learned easily by even an untrained operator, on the other hand the various options satisfy the need of specialists. Several evaluation facilities are also provided such as averaging, comparison of results with each other or with tolerance limits, etc.

Since a large number of set-up, tolerance and measurement data are handled by the system, they are stored in a custom designed data base providing easy access to all data grouped on the basis of a general pointer (so called key) system. Both set-up information and former results can be readily accessed by this key system and can be documented in short or detailed format on the screen, on disks, or on a hard copy.

4. THE SIGNALLING GENERATOR AND ANALYZER SGA-2

The simple architecture shown in Fig. 2 is very economical and can be efficiently used for the one-card Signalling Generator and Analyzer. All in-band signalling tones are generated and detected by the DSP, while the PC facilitates the generation and detection of channel associated signalling (CAS), controls and monitors the PCM maintenance and alarm status and provides the man-machine interface at the same time. In addition, the PC clock is used to generate a 1 ms time-base for event detection.

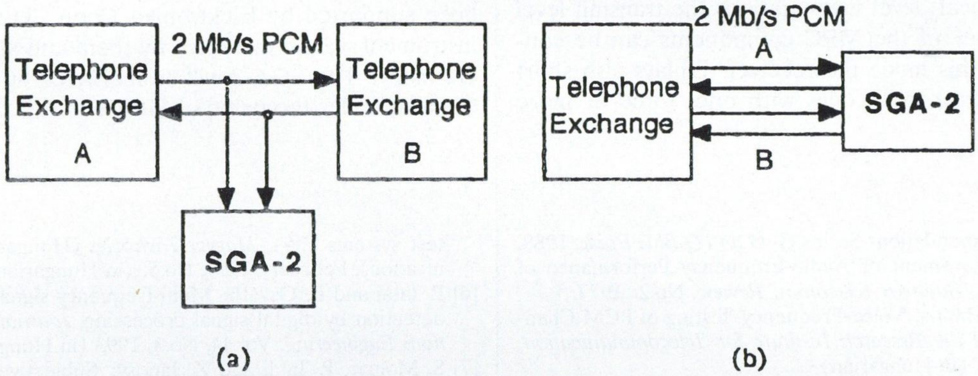

Fig. 4. Testing configurations with SGA-2. Passive monitoring (a) and active emulation (b)

There are two basic configurations in signalling tests, namely the passive monitoring and the active emulation as shown in Fig. 4. Since a signalling process establishing a telephone connection involves both directions of transmission, called forward and backward signalling, the SGA-2 has two inputs and in passive monitoring these are connected to the PCM lines with high impedance. If the SGA-2 is used for active emulation of an exchange, then two input/output can be used although in most cases one input/output is needed only. In this case the inputs and the outputs are terminated with 75 or 120 Ohms. PCM parameters conform to CCITT Recommendations G.703, G.732 and MFC signalling parameters conform to Recommendations Q (Q.454, 455 for MFC-R2). It should be mentioned that the MFC transmit/receive software has passed intensive field tests in the Hungarian telecommunication network. Although the SGA-2 is intended mainly for PCM applications, all functions are available also at two voice-frequency analogue interfaces supplemented with E&M analogue signalling.

4.1. Passive monitoring functions

Conventional telephone signalling on PCM lines is based on a combination of channel associated signalling (CAS) and MFC signalling. CAS is used basically to seize and clear the connection while in-band MFC signalling carries detailed information about the connection to be established over the portion of channel already established. The SGA-2 displays both CAS and MFC codes simultaneously therefore the call process of a selected PCM channel can be followed on the screen of the PC. The time resolution of the signalling events is 1 ms.

There are various signalling systems in use between exchanges. In Europe the signalling system MFC-R2 (analogue and digital) is used most widely. In addition to this the SGA-2 presently handles the signalling systems MFC-R1, AON and DTMF (Dual-Tone Multi-Frequency). The latter is used for the push-button telephone sets. Further signalling systems can be added any time by modifying the software. The DSP-based MFC signalling generation and detection methods are discussed in [6].

In addition to CAS and MFC signalling codes and their timing information, the level of the received MFC signals is also detected and displayed. Up to 1000 signalling events are stored in memory and can be examined on the computer screen or can be saved on disks at any time. For longer continuous tests an automatic record facility is also provided which initiates a save after every 1000 lines. The files are saved in ASCII format and can be viewed, edited or processed by other programmes.

For higher level analysis user-defined states and messages are displayed, and call statistics can also be collected simultaneously for all 30 channels by counting successful and unsuccessful calls as well as the busy time in % for every channel.

4.2. Active emulation functions

Any combination of signalling codes with practically any timing can be generated by a macro facility which simplifies repetitive testing procedures. Macros can be nested in any depths therefore complicated signalling events can be assembled and reproduced by some simple keystrokes. Macros are stored on disks so they are practically unlimited in lenght. A simple automatic transmit-receive function is also provided for testing MFC sequences.

For low (physical) level investigations the transmit level and the frequency of the MFC components can be controlled, too. In this mode the receiver displays also short transients and erroneous codes with one, three or more components out of the six. In other modes only the valid codes appear on the screen.

5. CONCLUSION

Two DSP-based telecommunication test instruments have been introduced. The PCM Multiplex Analyzer EP-1 is an automatic test system for the measurement of voice-frequency and digital parameters of PCM multiplex systems. The Signalling Generator and Analyzer SGA-2 facilitates testing of multi-frequency coded (MFC) and channel associated signalling (CAS) sequences simultaneously.

Both test instruments combine a DSP with a PC resulting in a very flexible and economical solution which can be efficiently applied to various telecommunication test problems in the future. Two further DSP-based tester using the same principles are also mentioned in the references [7], [8], which have also been developed at DTT, TUB.

ACKNOWLEDGEMENTS

Thanks are due to many people who have contributed to the development of EP-1 and SGA-2. Among them the names of Pál Kovács, László Osváth, Tibor Temesi and Gyula Marosi, all are with DTT, TUB, should be mentioned on the first place. The development of EP-1 has been supported by Elektronika Coop., Hungary and the instrument will be marketed by them and also by Siemens, Germany. The SGA-2 will be marketed by Consultronics, Canada, under the name of SIG 3600.

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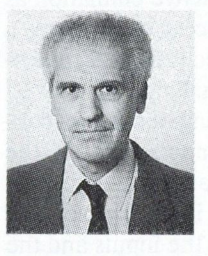

Péter Tatai graduated in 1964 at the Faculty of Electrical Engineering, Technical University of Budapest, in Telecommunications. From 1964 to 1986 he was employed by the Research Institute for Telecommunications, Budapest, where he was involved in the research and development of various communication equipment and automatic test systems. In 1976 he became the Head of Code Modulation Systems Department and took an active part in the development of the Hungarian PCM system. He has studied telecommunications, digital signal and speech processing altogether about 2 years abroad: at the University of Tokyo, at the Imperial College, London, at the Royal Institute of Technology, Stockholm and at the University College, London. Since 1986 he is with the Department of Telecommunications and Telematics, Technical University of Budapest. He gives lectures both in Hungarian and English on telecommunications and digital signal processing. Most of his time, however, is devoted to research including the guidance of undergraduate and graduate students. His present research interest includes telecommunication testing, digital signal processing in general, speech recognition and coding, etc. He has more than 35 publications.

TESTING OF DIGITAL TRANSMISSION SYSTEMS

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Within many European telecommunication networks, the deployment of digital transmission equipment is very common place. Due to this, the types of datacommunication services that Network Operators offer include digital private leased point-to-point circuit. Testing of both the 'digital transmission systems' and the 'digital datacommunication services' has become an important function for the Network Operator. The types of measurements and the information available to determine the quality of a system varies with the technologies and system deployed. It is therefore important to consider the functions and use of the multiplex equipment to determine the type of testing required.

1. TYPICAL DATACOMMUNICATION SERVICES OFFERED BY TELEPHONE COMPANIES

The typical digital datacommunication service operates at rates of 2.4 kbit/s to 9.6 kbit/s, 48 kbit/s, 56 kbit/s, 64 kbit/s and Nx64 kbit/s (where N=1 to 31). The network interfaces used for these circuits vary, the most common being V.24, V.35, V.36 and X.21. There is a growing demand for the Telephone Company or Network Operator to offer these types of services. Therefore, the testing of the datacommunication circuit and the multiplexing equipment used to transport the circuit is of increasing importance.

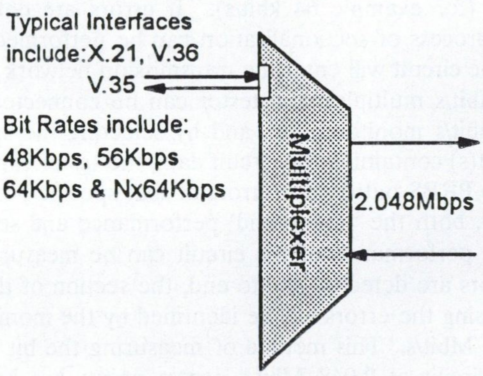

Fig. 1.

2. THE 2.048 MBIT/S MULTIPLEXER

The 2.048 Mbit/s multiplexer can transport both telephony traffic or datacommunication services. The datacommunication services described above enter the transmission network as tributary signals (or circuits) of the 2.048 Mbit/s multiplexer. A datacommunication circuit operating at 64 kbit/s will be multiplexed directly into a time-slot of the 2.048 Mbit/s datastream.

As previously mentioned, the 2.048 Mbit/s multiplexer usually uses the 'Frame' structure described in the CCITT Rec. G.704. The multiplexer supports up to 31 tributary channels, each operating at a rate of 64 kbit/s. This tributary channel data is multiplexed together to form part of the 'Frame' structure. The 'Frame' is made up of 32 time-slots, each operating at 64 kbit/s and numbered '0' to '31'. Timeslot '0' contains the 'Frame Alignment Word'. There exists the option to include an 'error performance' signal known as Cyclic Redundancy Check (CRC) within this signal. This is used for the detection of errors while the 2.048 Mbit/s signal is carrying live data within the information channels (time-slots 1 to 31).

We can therefore see that the 2.048 Mbit/s multiplexer and transmission system is a fundamental tool for the transportation of telephony and datacommunication services.

3. TESTING OF DIGITAL DATACOMMUNICATION CIRCUITS

The diagram below indicates the various interfaces that are commonly used for digital datacommunication circuits. Bit Error Rate Testers (BERTs) are used to determine the quality of the circuit. This is performed by connecting a tester directly to the interface concerned and sending a test pattern at the specific bit rate, i.e. 64 kbit/s. By applying a 'loop' or another tester at the far end, a 'Pseudo Random Bit Sequence' (PRBS) is generated by the tester(s), emulating as near as possible the data flow that would be generated by live traffic. 'Bit' errors detected on the receiving tester give a measure of the 'Error Performance'.

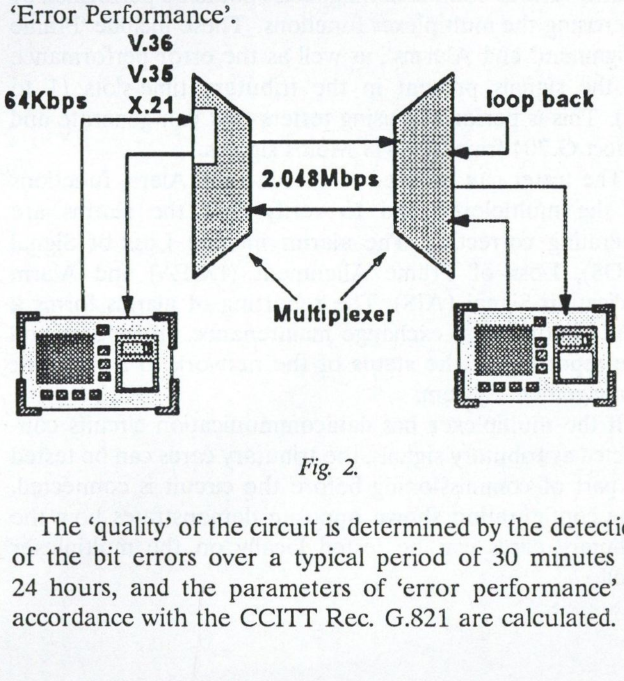

Fig. 2.

The 'quality' of the circuit is determined by the detection of the bit errors over a typical period of 30 minutes to 24 hours, and the parameters of 'error performance' in accordance with the CCITT Rec. G.821 are calculated.

4. CCITT G.821 ERROR PERFORMANCE

The use of G.821 helps to identify the error performance characteristic of the circuit. For example, if two circuits having the same configuration are measured over the same period of time with the same amount of errors present, the values for both circuits of 'Error Count' (number of bit errors) and 'Error Rate' (number of errors divided by the quantity of bits transmitted) will be the same. G.821 allows the characteristic and distribution of the errors for each circuit to be identified. The tester breaks up the measurement into 1 second periods, and then reports the quantity of seconds that had no errors (Error Free Seconds) and those that contain errors (Errored Seconds). In addition, if the quantity of errors detected in any one second exceeds a pre-defined threshold, it may also be regarded as a Severely Errored Second. G.821 also includes the capability to further characterise the performance into periods of service Availability and Unavailability.

For commissioning purposes, the Network Operator can determine if the circuit meets the 'bringing into service' criteria by setting performance limits agains the various measurement parameters contained within G.821. As a maintenance function, the circuit can be measured to verify that the circuit is operating within these 'Performance Limits'.

Within CCITT, there exist recommendations that define both the 'Bringing into Service' and 'In-service' Performance criteria.

5. TESTING THE 2.048 MBIT/S DATACOMMUINICATIONS MULTIPLEXER

We have looked at the testing of the datacommunication circuit on an 'end to end' basis. However, both a datacommunication or telephony switched circuit will enter the transmission network at the 2.048 Mbit/s multiplexer.

Before a 2.048 Mbit/s multiplexer is suitable for carrying traffic, various commissioning tests should be performed by exercising the multiplexer functions. These include 'Frame Alignment' and 'Alarms', as well as the error performance of the signals present in the tributary time-slots (1 to 31). This is performed using testers that can generate and detect G.704 framed 2.048 Mbit/s signals.

The tester can be used to exercise the Alarm functions of the multiplexer and to verify that the alarms are operating correctly. The alarms include Loss of Signal (LOS), Loss of Frame Alignment (LOFA) and Alarm Indication Signal (AIS). The reporting of alarms forms a part of both local exchange maintenance procedures and the reporting of the status of the network to a Network Management System.

If the multiplexer has datacommunication circuits connected as tributary signals, the tributary cards can be tested as part of commissioning before the circuit is connected. The configuration shown opposite demonstrates how the tributary cards can be tested locally on the multiplexer itself.

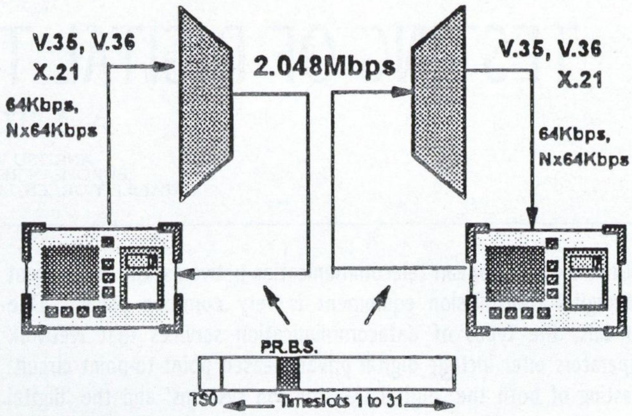

Fig. 3.

Using a tester that is a capable of interfacing with the tributary card and operating with a framed 2.048 Mbit/s signal, a test pattern can be generated on the tributary interfaces (i.e. X.21) and measured for bit errors within the time-slot of the 2.048 Mbit/s. Furthermore, a test pattern can be generated in a specific time-slot of the 2.048 Mbit/s signal and received by the tester via the tributary card. The same G.821 Error Performance parameters can be applied.

6. MAINTENANCE TESTING

When a circuit is reported faulty, the same procedure used for commissioning the circuit can be adopted. This will require the circuit to be taken 'out-of-service' and testers to be connected at the circuit end. The tester is configured to send a PRBS test pattern at the circuit bit rate (for example 64 kbit/s). If errors are detected, then a process of sectionalization can be performed. Because the circuit will enter the transmission network at the 2.048 Mbit/s multiplexer, a tester can be connected to a 2.048 Mbit/s monitor point, and by selecting the specific time-slot(s) containing the circuit data, the tester can measure the PRBS pattern for errors at that specific point. In this way, both the 'end-to-end' performance and selected 'section' performance of the circuit can be measured. If any errors are detected end-to-end, the section of the circuit causing the errors will be identified by the monitoring at 2.048 Mbit/s. This method of measuring the bit errors of the circuit at 2.048 Mbit/s access points has become standard practice in many maintenance procedures.

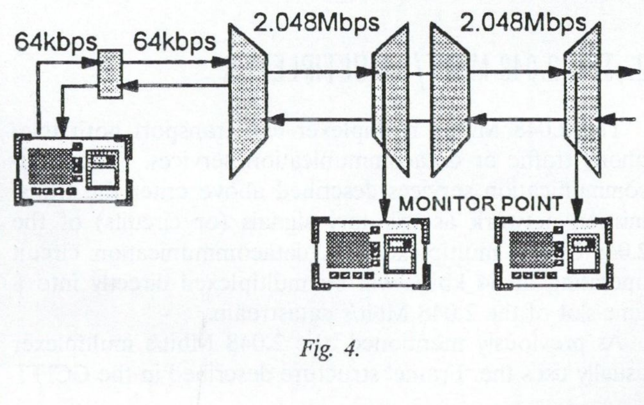

Fig. 4.

The above action, however, involves the use of engineers connecting test equipment to the circuit and manually performing the tests. This can cause a delay in the testing and repair of the circuit. In addition, it requires engineers to be present at the circuit end and possibly, at the intermediate exchanges.

Maintenance policies are evolving so that the test resources are present within the network and are operated from centralised maintenance test centres. Within these centres, engineers have the ability to remotely access the circuit via computer terminals and carry out the required testing.

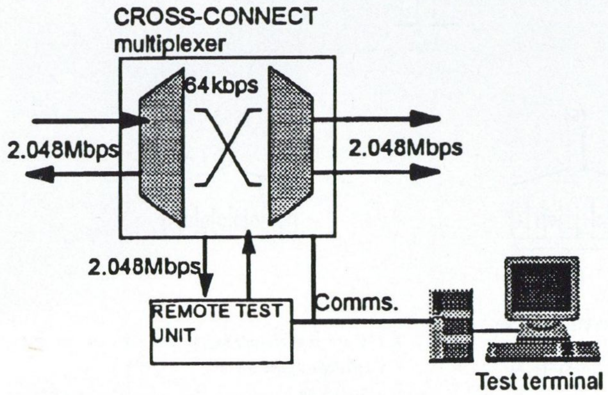

Fig. 5.

The remote testing of digital circuits utilises the capability of 'cross-connect' multiplexers. Network Operators deploy 2.048 Mbit/s '1-0' cross-connect multiplexers to allow switching and network management of the 64 kbit/s time-slots. By having test resources connected to specific 2.048 Mbit/s port, the time-slot switching capabilities allow the PRBS pattern to be inserted into the circuit and errors to be detected by the remote test unit. By having 'cross-connect' multiplexers with test resources distributed within the network, the 'end-to-end' testing and 'sectionalization' of a circuit can be performed with very little delay after a fault has been reported.

Many Network Operators worldwide have already deployed centralised test systems for maintenance of digital circuits. As the network expands, the same test system is used for the commissioning of circuits on both new and existing 2.048 Mbit/s systems.

With the use of centralised Network and Test Management systems and by utilising the 'Cyclic Redundancy Check' (CRC) capabilities within the framing of the 2.048 Mbit/s datastream, the centralised test system can be enhanced to perform 'Full Time Performance Monitoring' (FTPM) of the 2.048 Mbit/s. Over a period of time, the monitoring of the 2.048 Mbit/s can indicate if there exists a 'degradation' of service, which plays a major role in 'preventative' maintenance.

The use of 'error performance' analysis is fundamental for the commissioning and maintenance of both digital circuits and transmission systems. In addition, we can see that the testing capabilities at 2.048 Mbit/s play an extremely important role in the maintenance of both the transmission system and the circuits carried as tributary signals. With the development of the international standards for error performance, the use of CCITT recommendations such as G.821 and the deployment of centralised test systems, we can see that they will play a practical role in the 'testing of digital transmission systems'.

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TESTING DIGITAL DATA NETWORKS

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Full digitalization of non-voice services has become a reality by extending digital links from customer to customer. The paper reviews the problems of testing Digital Data Networks providing rapid information exchange in public data networks.

1. INTRODUCTION

Data transmission at low bit rates, for example 200 bit/s, using both leased private circuits and public switched telephone networks was introduced in the mid 1960's. Customer demand for new services requiring higher bit rates was met by more complex designs of modems to cope with the impairments of the analogue transmission networks. At the same time the need for improved facilities and service quality led to the introduction of digital techniques for switching and transmission.

Digital transmission in the UK began with the introduction of 24 channel Pulse Code Modulation (PCM) systems in 1968. These were quickly superseded by the 30 channel PCM systems meeting CCITT recommendations both in the UK and the rest of Europe. This is now the basic building block for fully digital transmission networks using the Plesiochronous Digital Hierarchy (PDH), and the emerging Synchronous Digital Hierarchy (SDH).

By the mid 1980's the full digitalization of trunk transmission network in many countries was well underway. Full digitalization of non-voice services from customer to customer, with its consequent advantages had become a reality by extending digital links between local exchanges and the customers premises.

The demand for the services provided and the commercial exploitation of rapid on-line information exchange has led to the provision of public data networks using packet-switched and leased or circuit-switched techniques.

On example of this is a Digital Data Network (DDN) providing end to end digital connectivity using time-division multiplexing.

2. THE 2.048 MBIT/S DIGITAL DATA FRAME STRUCTURE

The underlying design of the DDN relies on the availability of primary level Pulse Code Modulation (PCM) highways but with the eight time-slots representing each channel containing binary data rather than encoded speech information, as shown in Fig. 1. The term PCM is somewhat a misnomer now that we are considering data transmission because pulse code modulation refers specifically to the process of modulating or encoding speech or other analogue signals. However the term is widely used in the context of data transmission at the primary rate of 2 Mbit/s.

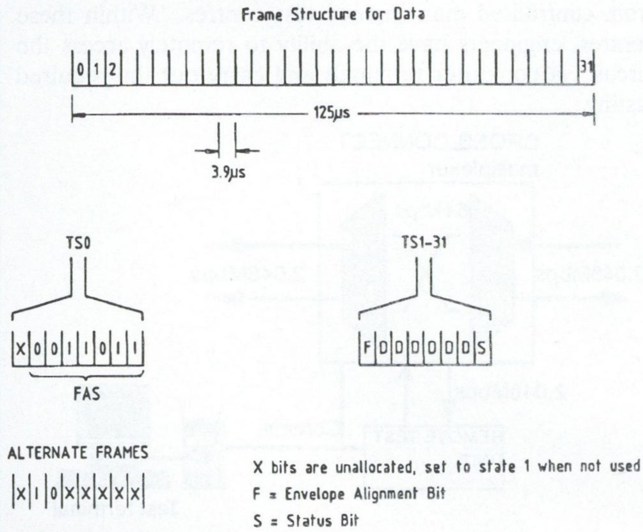


Fig. 1. Frame structure for 2.048 Mbit/s data signal

A frame consists of 32 time-slots of 8 bit envelopes. Time-Slot 0 (TS0) is allocated to the frame alignment signal and operational information as in the normal speech encoded PCM system. The remaining 31 time-slots carry 64 kbit/s tributary channel data. Time-slot 16 which is used for channel signalling information in a speech PCM system is now available for customer traffic and no multiframe structure is necessary.

The 8 bits comprising the data channel information may be further structured at the local end for example as shown having an envelope alignment bit for network control and monitoring use and a status bit to indicate the state of a certain interchange circuit at the customer's premises, for example control C in the CCITT X.21 interface. Alternatively the 64 kbit/s channel could be unstructured.

3. CONFIGURATION OF A TYPICAL CIRCUIT-SWITCHED DIGITAL DATA NETWORK

Fig. 2 shows the overall layout of a typical digital data network with manually switched cross-connection arrangements.

The 64 kbit/s time-slots are extended to the customer's premises on standard local telephone lines using WAL 2 diphase transmission. The local line may be configured as a 2-wire or 4-wire circuit. In order to provide full duplex transmission on 2-wire circuits echo cancelling techniques are usually employed. Burst mode or frequency division multiplexing could be used.

The customer is provided with an interface unit or Network Terminating Unit (NTU) which offers standard CCITT data interfaces to the customer's equipment. Interfaces commonly provided are X.21, V.24 and V.35. The data rates can be any of the standard rates for exmple 2.4, 4.8, 9.6, 19.2, 48 or 64 kbit/s.

The NTU encodes the data for transmission to the local telephone exchange. If any structuring of the data signal is required this takes place in the NTU together with re-iteration if necessary to increase the customer's data rate to 64 kbit/s for forward transmission over the local line to the telephone exchange. The reverse processes take place in the return direction of transmission. Alternatively time-slot submultiplexing according to CCITT Recommendation X.50 could be provided. Nx64 kbit/s services may also be used.

In the local telephone exchange a 2 Mbit/s with 31 channels of time-slot access combines the 64 kbit/s channels for transmission through the digital transmission network at 2 Mbit/s and then at the various multiplexed rates of 8, 34 and 140 Mbit/s as required and back down again to 2 Mbit/s at the distant end.

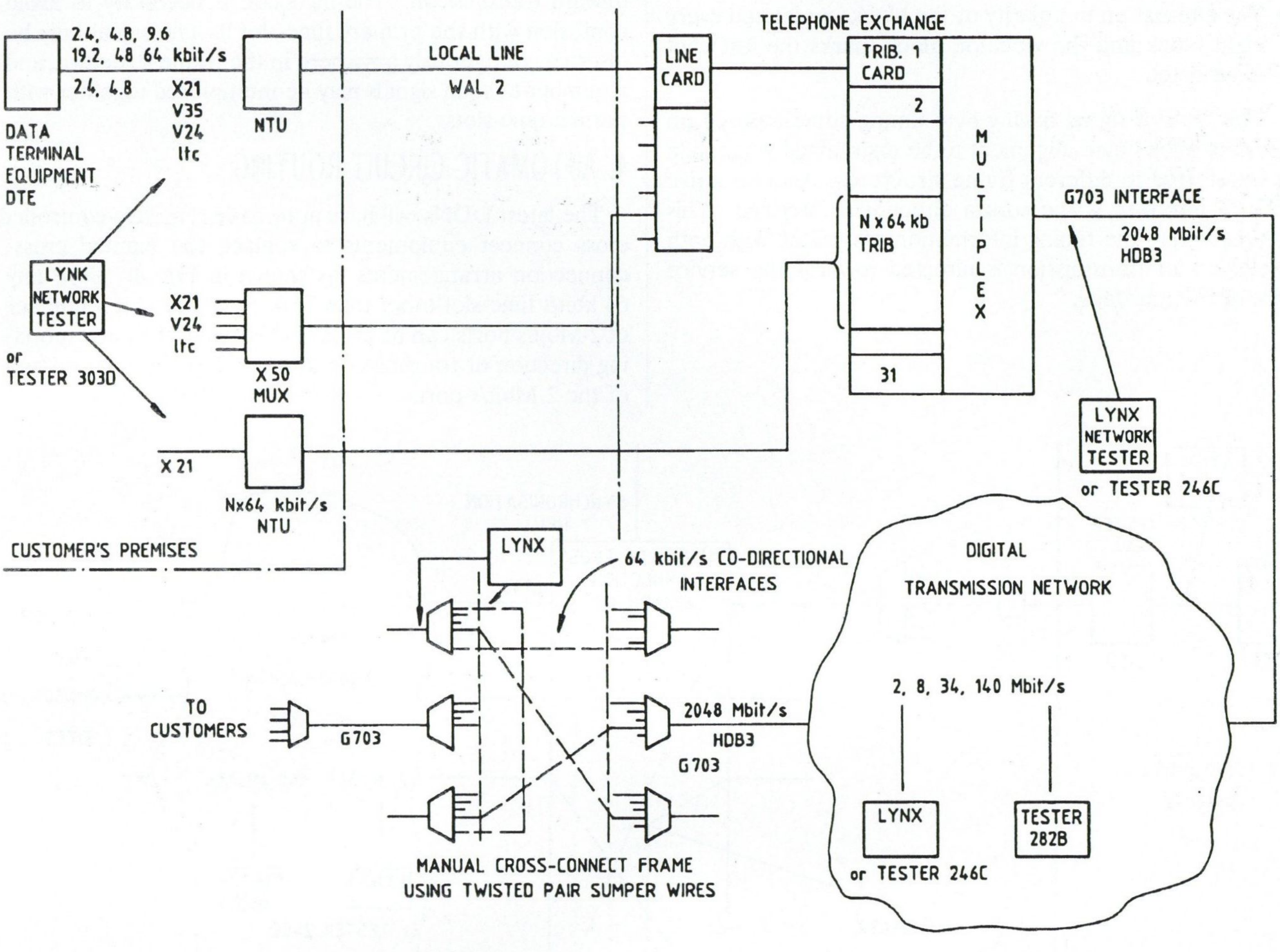


Fig. 2. Typical digital data network, manual cross-connect

The routing of individual 64 kbit/s channels can be effected manually on a cross connect frame at designated sites, where synchronization facilities may also be introduced in order to provide a fully synchronous service. At the cross connect site individual circuits are demultiplexed and encoded into 64 kbit/s co-directional signals meeting CCITT Recommendation G.703.

3.1. 64 kbit/s co-directional signal

The characteristics of a 64 kbit/s co-directional signal are shown in Fig. 3.

This is a digital signal where the information and its associated timing signals of 64 kHz and 8 kHz are transmitted in the same direction.

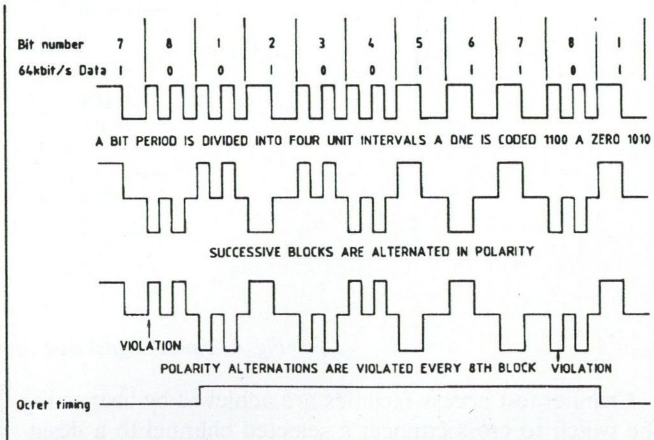


Fig. 3. 64 kbit/s co-directional signal characteristics

The data is encoded into a four times information rate ternary signal whose rate is 256 kbit/s. The pulse amplitude is ±1.0 Volt. The code conversion rules are as follows:

- A 64 kbit/s bit period is divided into four unit intervals.
- A binary one is coded as a block of four bits 1100.
- A binary zero is coded as a block of four bits 1010.
- The resulting binary four times information rate signal is converted into a three level signal by alternating the polarity of successive blocks.
- The alternation in polarity of the blocks is violated every eight block and the violation block marks the last digit in an octet.

This type of signal having byte-timing superimposed on the data allows byte alignment to be maintained when data is transferred to different frame structures. An alternative CCITT interface is the contra directional interface. This is used where the timing information associated with both directions of transmission is directed towards the service side of the interface.

3.2. Nx64 kbit/s Service

Nx64 kbit/s signals can also be transmitted, where N equals any value in the range 2 to 30, using a special NTU at the customer's premises. A conventional PCM frame alignment signal is inserted by the NTU for supervisory purposes and to mark the beginning of the contiguous time-slots. The complete (N+1)x64 kbit/s signal is inverted before being inserted into the frame structure of the primary multiplex at the local telephone exchange for onward transmission. The inversion is necessary to avoid confusion with the primary time-slot 0. The signal may be inserted contiguously anywhere in the frame structure, and a number of such signals may be multiplexed together with normal time-slots.

4. AUTOMATIC CIRCUIT ROUTING

The latest DDNs will have automatic remotely-controlled cross connect equipments to replace the manual cross-connection arrangements, as shown in Fig. 4. Here any 64 kbit/s time-slot other than TS0, on any one of a number of 2 Mbit/s ports can be cross connected in the corresponding direction of transmission to any other time-slot on any of the 2 Mbit/s ports.

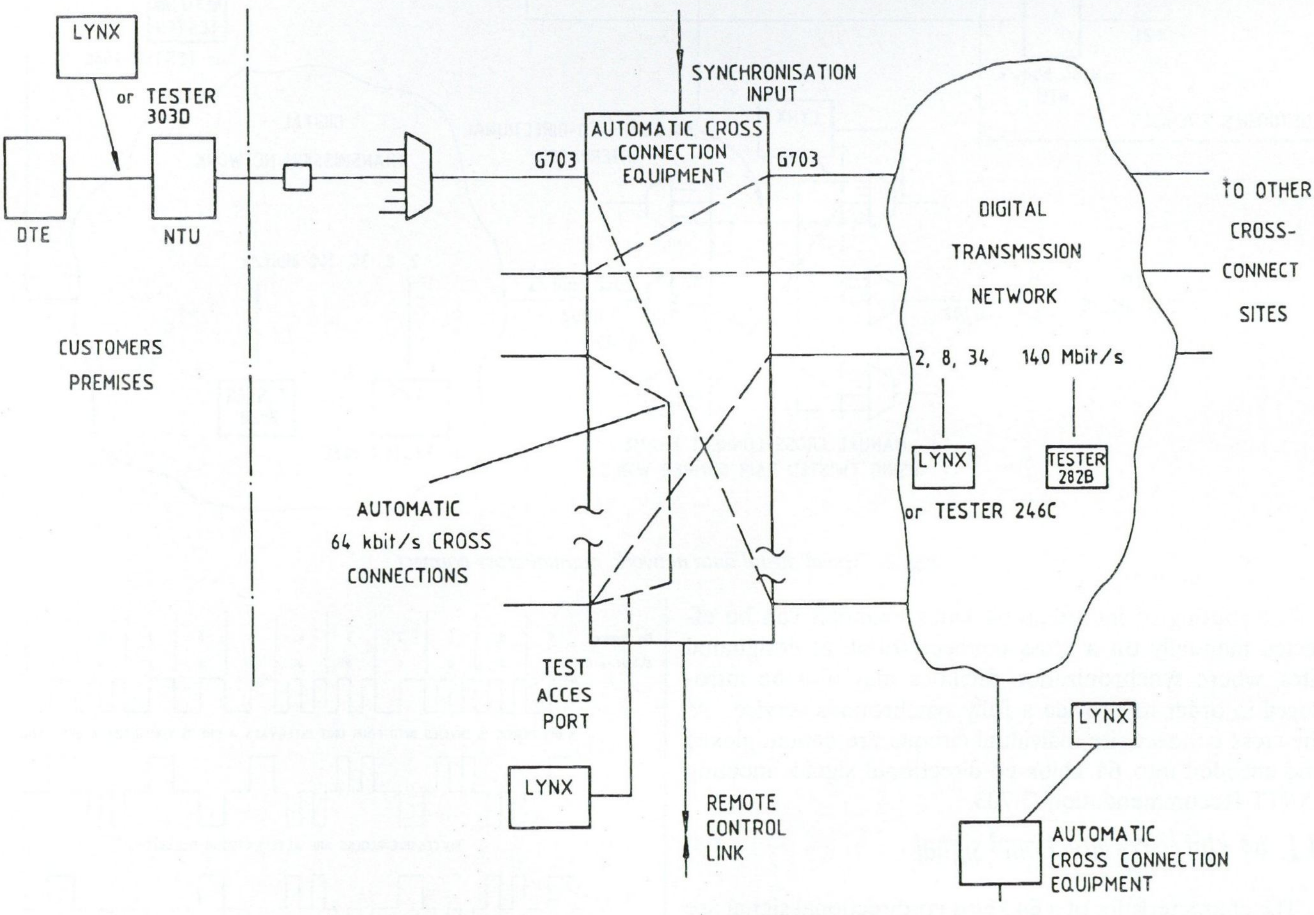


Fig. 4. Typical digital data network, automatic cross-connect

Channel test access facilities are achieved by instructing the switch to cross connect a selected channel to a designated test port which can be terminated with appropriate test equipment. The arrangements can be such that monitor mode testing (channel not interrupted) is performed or both ends of the channel can be connected to test equipment.

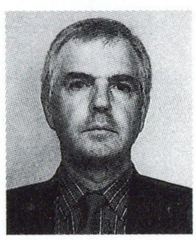
5. TESTING

The type of testing performed and measurements carried out on circuit switched digital networks, as with any other type of telecommunications system, will to some extent depend on where and when the testing is taking place. This can be divided broadly into five categories as follows:

- Research and Development Stage.
- Production Testing at the Factory of Constituent Elements of the Network.
  For example: NTUs
  Cabel
  Multiplexers
  Line Systems etc.
- Equipment Installation Testing.
  Performed when the various items are installed into the telephone exchanges and other buildings.
- Provisioning Stage.
  Tests carried out on complete circuits end to end just prior to the individual circuit or circuits being handed to the customer for service.
- Maintenance Testing.
  - In-Service Testing
  - Out-of-Service Testing

6. CONCLUSION

The continuing spread of data communication using digital networks will include a growing demand for test equipment. Advances in technology have enabled test equipment to become smaller and easier to carry. This is obviously beneficial but when this trend is coupled with the increasing need for more testing functions in a single item it can give rise to difficulties in operation unless the equipment is carefully designed with ease of operation in mind from the outset. It is, therefore, of paramount importance that providers of test equipment to field users take great care to choose equipment that is as simple as possible to understand and use. The penalties of not addressing this will be that tests will not be performed properly or, at worst, not performed at all.



Bob Stroud joined the UK Post Office (later to become British Telecom) as a Youth-in-Training on leaving school in 1952. From 1954 to 1962 he was employed as a technician and then a technical officer maintaining Strowger type telephone exchange equipment in the London Centre Area. From 1962 to 1964 he was working at the London Television Network Switching Centre maintaining transmission equipment. From 1964 to 1970 he was employed as a Manager in the Engineer-in-Chief's Office working on the development of Carrier Generating Equipment for the FDM network. In 1970 he became Manager of Transmission Test Equipment Development in BT World-wide Networks Headquarters. Retired from BT in July 1992. Joined CONSULTRONICS EUROPE as a part time product marketing specialist in September 1992.

TELECOM TESTING

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Today telecommunications is increasingly becoming a key factor contributing to the economic growth of most countries. The telecom testing segment will play a vital role in this expanding market. As new transmission technologies are introduced in pilot networks, as conventional networks are modernized, and as additional services are increasingly being offered, sophisticated and flexible test equipment is becoming an intrinsic necessity.

1. THE NEED

Today telecommunications is increasingly becoming a key factor contributing to the economic growth of most countries. A healthy, competitive economic environment is highly dependent on a solid infrastructure of telecommunications networks and services which allow virtually instantaneous transfer of information across cities as well as continents.

It is predicted that in Europe alone, the telecom industry will account for approximately 7 % of the EC's gross domestic product by the year 2000. It is evident, from these figures, that the telecom testing segment will play a vital role in this expanding market.

Tremendous investments in equipment and facilities are therefore being made to keep up with the accelerating demans. For example: As new transmission technologies are introduced in pilot networks, as conventional networks are modernized, and as additional services are increasingly being offered, sophisticated and flexible test equipment is becoming an intrinsic necessity.

What is a typical test object in today's network?

The network can simply be split into two major areas of technology:

- Narrowband – comprising non ISDN, ISDN, Intelligent Networks (IN) and Mobile Networks (GSM).
- Broadband – encompassing Asynchronous Transfer Mode (ATM), Sonet/Synchronous Digital Hierarchy (SDH), and Frame Relay technologies.

In conventional non ISDN and ISDN networks, a System Under Test (SUT) may vary from being an entire central office or toll exchange to a specific interface on the network, to even a new supplementary service. In the new Pan European Digital Cellular Network — GSM for example — a typical SUT may be a Base Transceiver Station (BTS), a Mobile Switching Centre (MSC), a Home Location Register (HLR) etc.

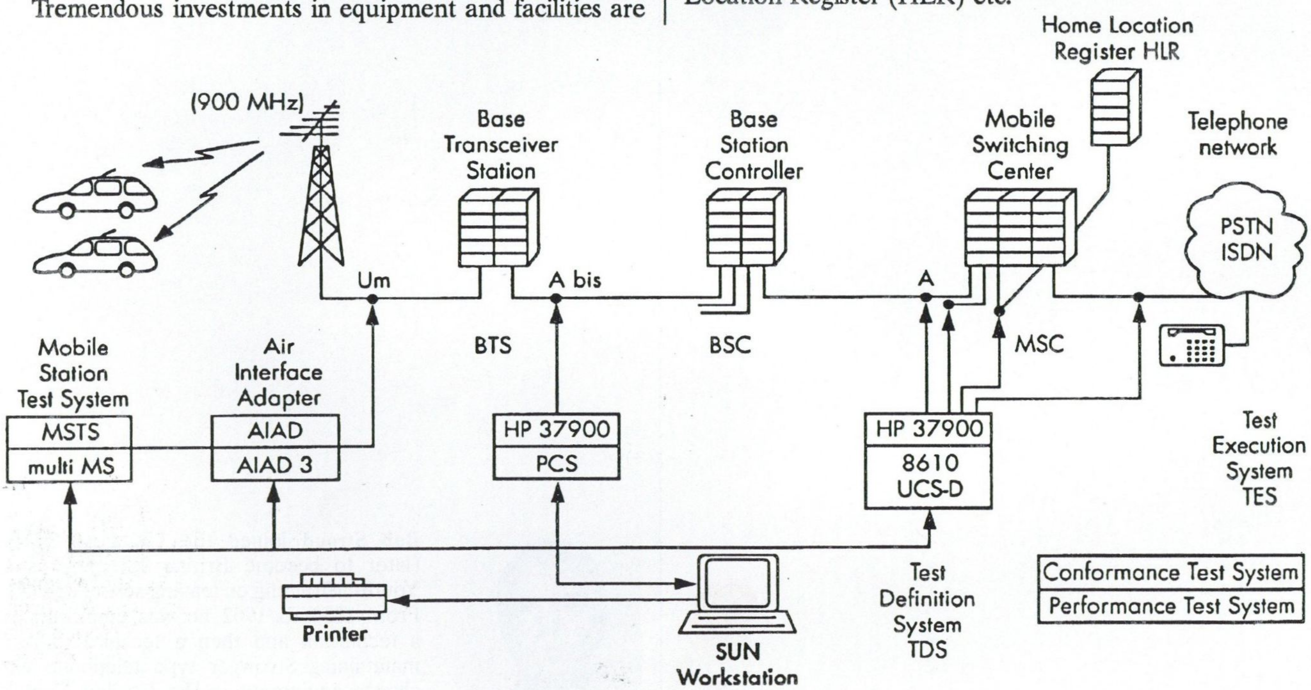

Fig. 1. GSM network elements and test points

2. THE BENEFITS

While in the past, a strong orientation towards stand alone test equipment existed, today a standardized approach based on a common platform is more attractive. This approach presents benefits to the operating companies, in both, economical and system flexibility points of view.

Today's trends in test system design enable the validation and verification of new implementations in the network by means of sophisticated test tool kernels which can be adapted and enhanced to the existing platform for several different types of tests. This approach eliminates additional capital investments every time a new protocol or service is to be tested. Such systems are normally operated under centralized computer control and man-machine interfaces.

Sophisticated test and maintenance methods, often through automated techniques, must yield advantages to network operators in terms of:

- Possibility to perform tests automatically on various interfaces (analog, PCM, ISDN...) from installation through integration, to acceptance, and finally maintenance.
- Possibility to emulate realistic traffic and signalling conditions on interfaces to verify the operation of a new exchange or component.
- Reduction of installation costs, time and resources.
- Maintenance of networks is performed more efficiently.
- Improved Quality of Service.

3. THE COSTS

Testing and maintaining today's telecom networks requires a large percentage of a company's operating costs. The primary aim of test equipment suppliers is therefore to provide systems with capabilities which ultimately reduce expenses through flexible architectures and automation of test methods and programs.

A recent study conducted to evaluate the size of the market for telecommunications conformance testing services in Europe, revealed that the aggregate annual market value for the supply of test tools alone is estimated to be 15 MECU (1). As this figure represents only the costs of test tools provided to third party laboratories for conformance testing purposes, it can be estimated that overall costs incurred for testing are of much greater magnitude.

4. LIFE CYCLE OF TEST OBJECTS

The lifetime of telecommunications exchanges and networks comprises various phases which can be grouped into three major areas: Development, Manufacturing, and Maintenance. Each phase demands specific test functionalities from the employed test system as illustrated in Fig. 2.

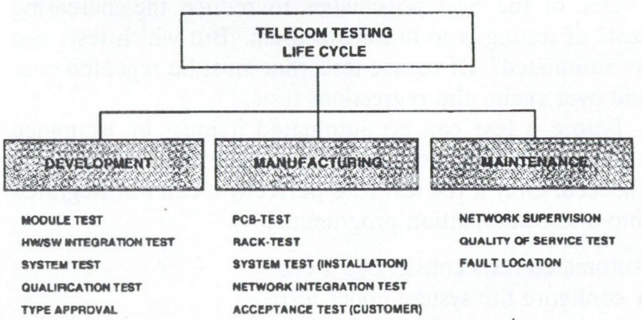

Fig. 2. Life cycle

During development, the functionality of the various modules must be tested, and conformance to the relevant design specifications must be verified. HW/SW integration; one of the most important activities before installation, requires specific tests with regards to traffic relations, signalling conversion and interworking.

In the manufacturing phase, a typical system undergoes PCB, rack, and system integration tests. Modern exchanges are often assembled in the factory where they undergo an "in factory test". Finally, acceptance tests are performed usually in house or at the customer premises.

As last stage in the life cycle, maintenance activities require frequent tests to be performed regularly by the customer in order to ascertain the specified level of quality. Load tests, Network Supervision, and Quality of Service tests are among these, when long term performance is the issue.

5. TYPES OF TESTS

The testing domain can be subdivided into three areas as shown in Fig. 3:

- Conformance Testing
- Performance Testing
- Functionality Testing

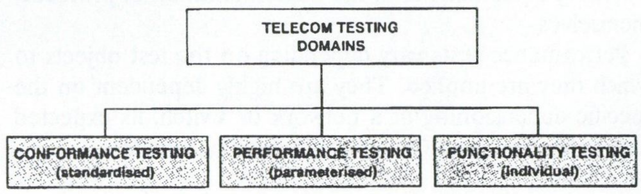

Fig. 3. Test domains

5.1. Conformance Testing

Assurance of conformance to standards and specifications must be met through testing, certification and inspection. However, until recently, telecom users and operators have been buying products and services without them necessarily being tested or certified. Why the need to do so now?

The basic reason is that more and more demands are being placed on products often through externally defined standards in order to ensure certain levels of quality and interworking with products of other suppliers in any given network. There is now in Europe a common Conformance Testing Methodology specifically defined by ISO/IEC 9646 (Conformance Testing Methodology and Framework) addressing the precise requirements of telecommunications.

Product suppliers need conformance tests throughout the development phases of their products. Operators of networks — public or private, local or wide area — need conformance tests to ensure that their networks are not harshly affected by connected products. Buyers need conformance tests to give them confidence that products have the required functional capabilities.

Conformance tests have well defined limits, their purpose is not to check the quality of a device or system (e.g. Call failure rates), its logical functionality, or its reaction to stress. Instead, the term Conformance may apply to the electrical and safety parameters of a test object, and most frequently it is referred to in the context of OSI protocols, where a specific test is defined for each of its seven layers.

A test object normally signifies a device or a complete system. However, the abstract conformance test standard defines as its test object a smaller unit, namely an Implementation Under Test (IUT). This can be assumed to be an individual OSI protocol layer (i.e. a software module) in a device or system.

With the help of predefined Test Cases, conformance tests can guarantee that different protocol implementations of different suppliers can interwork (e.g. layer 2 of an ISDN terminal to layer 2 of a switch).

5.2. Performance Testing

Performance testing involves the verification of the performance factors which are described and expressed in the form of parameters. These tests are not standardized as in the form of parameters. These tests are not standardized as in the conformance domain, but nevertheless perform a vital function in testing the general performance and quality of service parameters of an exchange or test object. Their goal is to discover deviations from normal predefined specifications which often point to problems in the switching equipment or in the implementation of protocols themselves.

Performance tests vary depending on the test objects to which they are applied. They are highly dependent on the specific dimensioning of a network or switch, its expected load behaviour, and Quality of Service parameters.

Load Test

Information on the behaviour of an exchange under load conditions enables the operating company to identify weak points in the network, as well as general software related malfunctions. Of course, modern exchanges are equipped with extensive self test functions which provide precise information on system weaknesses and configuration faults. These functions, however, are inherent components of the system software and hardware, and thus subject to a certain degree of system blindness. An objective and external system independent load test eliminates possible ambiguities and limitations.

The following points should be considered when defining load testing:

- It must be automated in order to achieve high numbers of call attempts in a limited time.
- It can be defined as a number of call attempts during a predefined time period.
- It should be evenly distributed among the given resources of the network under test.

Quality of Service (QoS) Test

These tests are performed in order to obtain statistical information on the QoS of an exchange, and to determine if the exchange actually meets the quality requirements of the customer. Typically they include:

- Call success rate
- Network response time
- Bit error rate
- Incorrect charging or accounting etc.

As these tests are normally repetitious and require a high degree of accuracy, it is obvious that the equipment must be of high reliability providing substantial traffic capacity and detailed fault reporting mechanisms.

5.3. Functionality Testing

These tests involve checking functions of a test object which are not necessarily defined or quantified. Functionality tests encompass a large variety of possibilities depending on national specifications, network and customer specific implementations etc. For example, they include the verification of:

- Interworking/Gateway functions
- Supplementary services
- National signalling
- National traffic relations
- Interoperability
- Fault recovery

6. TELECOM TESTING — AN UNAFFORDABLE LUXURY?

The telecom market is changing faster and faster. Deregulation forces the network provider to offer more new features and services. This leads to a continuous and fast change and update of the systems is service.

The system manufacturers must test each new release of their systems thoroughly in order to prevent faulty systems being delivered. The new features and services must be tested very carefully before the product can be released. But this is not everything: in addition to testing new features all the features and services introduced before must be tested again in the new context. These tests are called regression tests. They verify that the old features and services are not affected by the new ones.

Testing such complex systems becomes not only more and more time consuming but also more and more costly, as we have already mentioned before. The costs have in fact bvecome a major factor for the supplier of telecom equipment. What can be done to prevent testing from becoming unaffordable?

7. COST REDUCTION THROUGH AUTOMATION

One of the best possibilities to reduce the increasing costs of testing is to automate them. But which tests can be automated? Of course tests that must be repeated over and over again: the regressions tests.

Before a test can be automated it must be examined itself. It must be executed in the usual way while being checked. Only if the test runs perfectly it can be integrated into a test automation programme.

Automated tests consist of 5 steps:

- configure the system under test
- load the test equipment
- run the test
- collect the results from the test equipment and from the system under test and make a combined report

- reset the test equipment and the system under test to idle conditions

These 5 steps can easily be repeated several hundred times. So it is possible to perform a complete regression test during one night, for example.

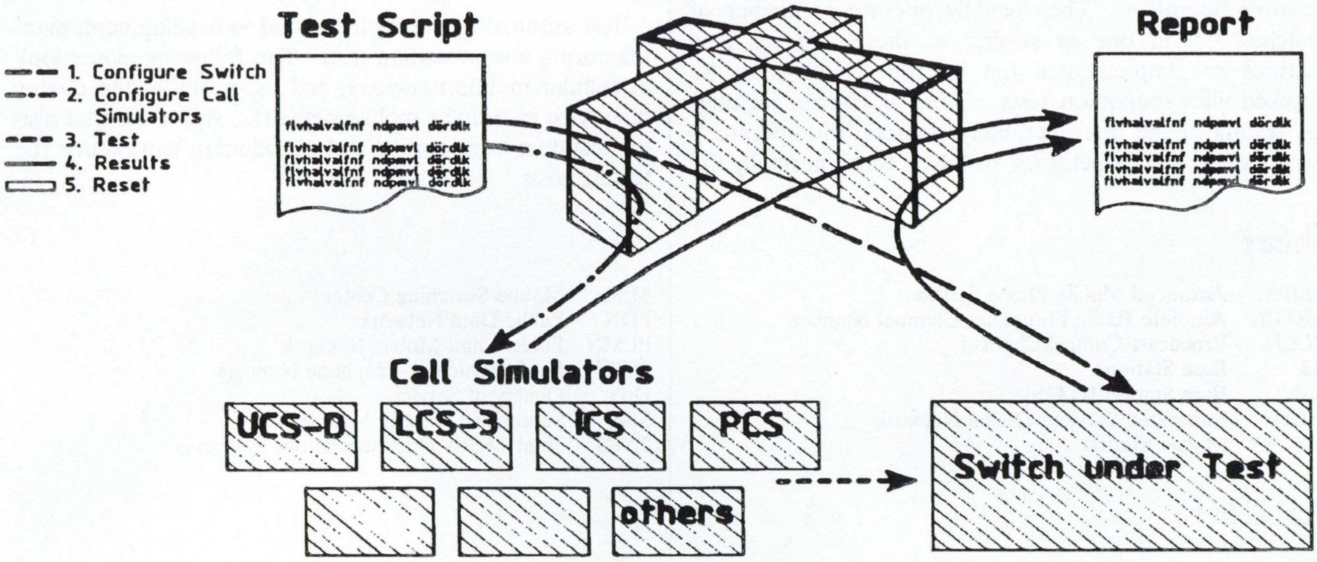

Fig. 4. The 5 Steps of test automation

8. EVOLUTION OF THE TEST EQUIPMENT

In the past the test equipment that was used for telecom testing consisted of stand alone units. They were easy to use but they were limited to simple test scenarios.

With the introduction of automated tests the following two domains of telecom testing have changed dramatically:

- There was a change from a simple front panel operated test equipment to a test equipment with a machine – machine interface. This allows the equipment to be integrated in a test system. With the machine – machine interface regression tests can be controlled by a machine and thus easily be repeated automatically.
- There was a change from simple test equipment with fixed built in test scenarios to test equipment where the test scenarios can be defined and loaded. In other words: the generation of tests is supported. In the future test equipment will be available where a specification can be changed into test cases by using compilers to generate them.

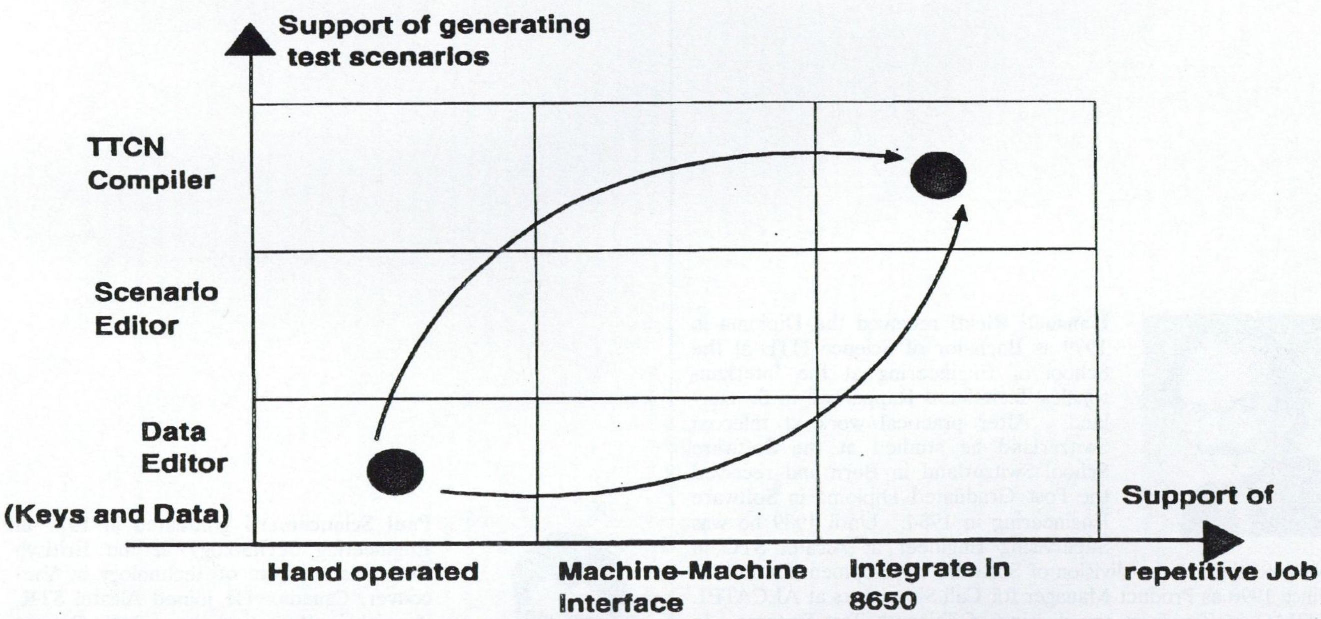

Fig. 5. The 2 dimensions of test automation

8.1. Automated Testing for Network Operators

Automated testing is useful not just for the designer and manufacturer of telecom test equipment but also for network operators. They usually operate a number of switches. If in one or several of these switches new features are implemented the interoperability must be checked with regression tests. This, of course, includes the testing of the interoperability between the operator's switches and other operators' switches. Since normally the different operators do not update their services at the same time these regression test must be performed very often.

8.2. Test Automation for a System in Operation

Test automation is usually related to development, manufacturing and acception tests. The following closer look at cellular mobile networks, and especially at the quality of service in cellular mobile networks, shows us, that also for a system in operation test automation can reduce the testing costs.

Glossary

AMPS	Advanced Mobile Phone System
ARFCN	Absolute Radio Frequency Channel Number
BCCH	Broadcast Control Channel
BS	Base Station
BSIC	Base Station ID Code
ISDN	Integrated Services Digital Network
MS	Mobile Station
MSC	Mobile Switching Center
PDN	Public Data Network
PLMN	Public Land Mobile Network
PSTN	Public Switched Telephone Network
QoS	Quality of Service
SIM	Subscriber Identity Module
TACS	Total Access Communications System

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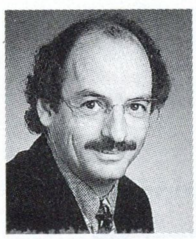

Hansueli Rickli received the Diploma in 1979 as Bachelor of Science HTL at the School of Engineering at the Interkantonales Technikum Rapperswil in Switzerland. After practical work at telecom Switzerland he studied at the Software School Switzerland in Bern and received the Post Graduated Diploma in Software Engineering in 1984. Until 1989 he was Supervising Engineer at Alcatel STC in New Zealand in the division of Software development for PABX. Since 1990 as Product Manager for Call Simulators at ALCATEL STRAG in Zurich in the division of Telecom Test Systems. In 1992 received the Post Graudated Diploma of Management of the University of St.Gallen Switzerland for Business Administration, Economics, Law and Social Science. His field of interest is to support the economic use of test systems and the implementation of test-automation for telecom.

Paul Sciancamerli graduated in 1977 in Engineering Technology at the Britisyh Columbia Institute of Technology in Vancouver, Canada. He joined Alcatel STR, Zuerich in 1991, and is currently Project Manager of GSM Test Systems. His previous assignments include several years in development and system design of Cellular Mobil Network with a Canadian Telecommunications Corporation.

GSM SYSTEM FEATURES AND TEST REQUIREMENTS

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The basic aspects of the GSM cellular radio network are outlined. New test requirements resulting from the system of the digital radio transmission are discussed.

1. THE GSM NETWORK

With the growth of conventional analogue cellular radio networks within Europe (Fig. 1) it became clear at an early stage that plans were needed for a future system of much greater capacity. The aims were:

- calls possible within the whole coverage area (at first Western Europe) with the same mobile telephone
- low mobile telephone price due to mass production

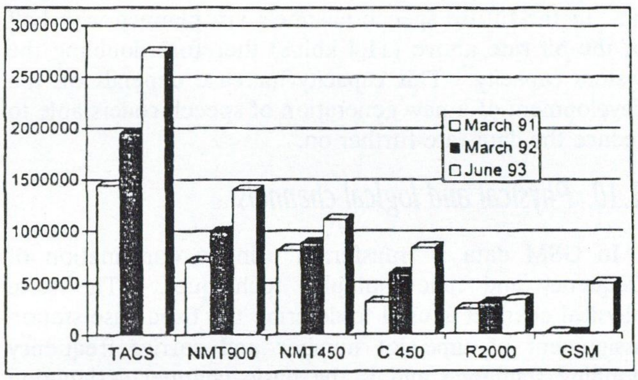


Fig. 1. European subscribers of cellular radio networks

The European network operators and mobile radio manufacturers have worked very closely together under the umbrella of the CEPT working group GSM (Groupe Speciale Mobile) in order to produce a concept for a Pan European Digital Mobile Radio System. Over a period of 5 years the principles and specifications, running to more than 5000 pages, have been defined.

The very tight time scales and high investment involved due to the new technology being applied has resulted in a very close co-operation between all companies involved.

1.1. GSM Network – Technical aspects

- Fully digital transmission
- Both time and frequency multiplex (TDMA and FDMA) used
- Compatible in all European countries

1.2. Services offered

- Speech
- Data transmission e.g. fax, user data
- Compatibility with ISDN planned

1.3. Market Forecast

- It is expected that more than 13 million mobiles will be in operation in Europe by the year 2000 (Fig. 2).

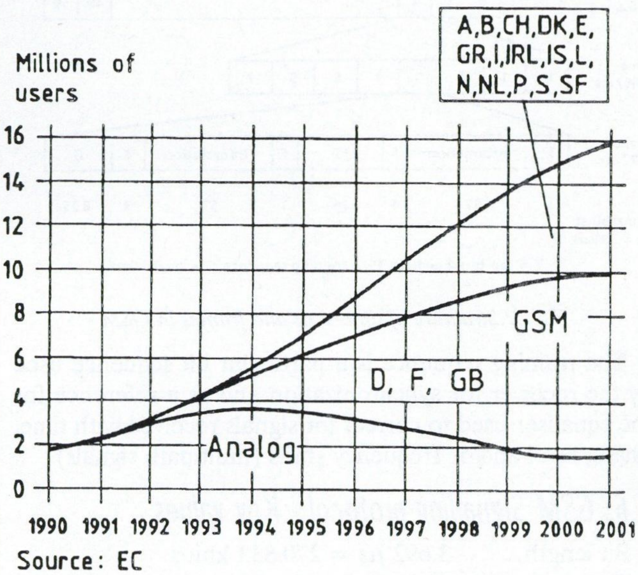


Fig. 2. Forecast growth of cellular networks in Europe

1.4. GSM Network – Important system parameters

• Mobile transmitter	890-915 MHz (Uplink)
• Base station transmitter	935-960 MHz (Downlink)
• Duplex spacing	45 MHz
• Timing	3 time-slots between Tx and Rx
• RF carrier spacing	200 kHz
• Data rate	270.833 kbit/s
Bit length	3.692 μs

Each RF carrier normally carries data for 8 channels (8 time-slots) in time multiplex operation, where the length of each time-slot (burst) is 576.9 μs. In normal operation each mobile station will receive and transmit using the same time-slot number. A time difference of three time-slots between transmit and receive ensures that the mobile station need not transmit and receive simultaneously and therefore can be manufactured more cost effectively (a small disadvantage is that the synthesizer used must be able to re-tune quickly).

The RF carrier is modulated with a binary signal, whilst the modulation type is GMSK (Gaussian Minimum Shift Keying). This modulation type is a derivative of MSK (Minimum Shift Keying) which itself is a derivative of FSK (Frequency Shift Keying). GMSK was chosen in order to optimize the used bandwidth. MSK is simply FSK with a modulation index of 1/2. This means that the phase of the carrier changes by π over 2 during each bit interval. When the modulating signal is first shaped using a Gaussian filter the result is GMSK.

1.5. Data Transfer Organization

All transferred bits are organized in time-slots and frames. The length of each time-slot is 156 1/4 bits = 576.9 μs (156.25 $\times$ 3.692 μs). A frame made up of 8 time-slots has therefore a length of 8 $\times$ 576.9 μs = 4.615 ms (Fig 3).

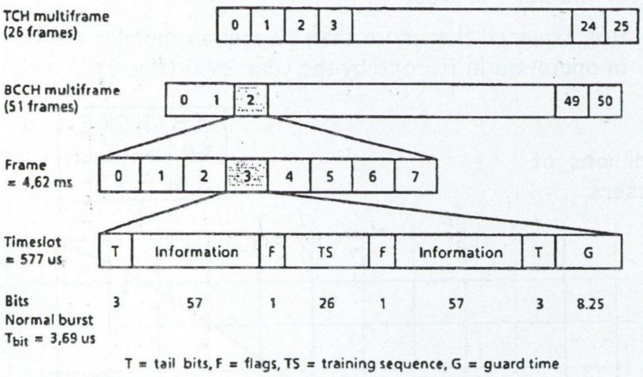


Fig. 3. Structure of time-slots and frames in GSM

The training sequence is a particular bit sequence used by the receiver for synchronization and as a reference for the equaliser used to correct for signals received with time, phase, level and/or frequency shifts (multipath signals).

1.6. GSM Signalling protocol - Key values

- Bit length 3.692 μs = 270.833 kbit/s
- Time-slot 576.9 μs = 156.25 bit
- Frame 4.615 ms = 8 time-slots
- 26 Multiframe 120 ms = 26 frames
- 51 Multiframe 235.38 ms = 51 frames

1.7. Error protection coding

In general two different types of error protection coding are used in GSM. Block-Codes, similar to the well known parity check bits used by computers, allow transmission errors to be quickly detected. Convolutional codes are, in addition, able to correct transmission errors. Such codes use a high level of redundancy (typically two additional bits for each information bit).

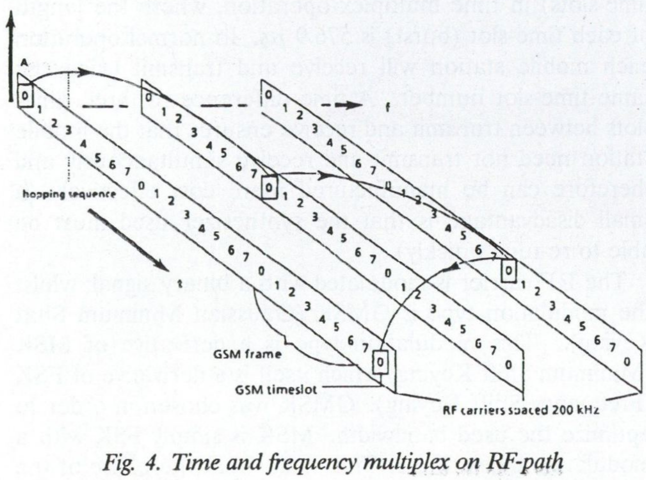


Fig. 4. Time and frequency multiplex on RF-path

1.8. Interleaving and Frequency Hopping

In order to minimize the occurence of failures the transmitted bits are spread over several bursts (time-slots). In addition, each burst is transmitted on a different frequency using a frequency hopping synthesizer (Fig 4).

1.9. Speech coding

In order to optimize the use of the frequency spectrum a method was needed to reduce the number of bits required for coding speech from the 64 kbit/s used by conventional techniques (e.g. PCM) to 16 kbit/s or less. (Speech band width of 3.4 kHz, sampled with 4 kHz and digitised with 8 bit resolution = 64 kbit/s). The solution lays in concentrating the speech into its basic components. The basic components and not the speech are then coded and transmitted. A mirror image of the coding process then performed by the receiver thus recovering the original speech signal. In this way the bit rate has been reduced to 13 kbit/s. The bits are transmitted as 260 bit speech blocks, 20 ms each. This is increased of 22.8 kbit/s by the error protection coding before actual transmission over the air. In the future speech channels are planned with half of the bit rate above (11.4 kbit/s) therefore doubling the system capacity. This capacity increase depends on the development of a new generation of speech coders able to reduce the data rate further on.

1.10. Physical and logical channels

In GSM data is transferred using a combination of frequency and time multiplex techniques. The term physical channel is used to describe the fixed base station assignment of time-slot number and carrier frequency hopping sequence and is the basic channel designation for all signals. Logical channels on the other hand, are particular time-slot numbers within a multiframe sequence. A traffic channel operates inside a 26 frame multiframe, control channels within a 51 frame multiframe structure.

Two main kinds of logical channel are defined by GSM:

1.11. Speech Channels

for the transmission of digitised speech or data.

1.12. Control Channels

for signalling and synchronization of the mobile station.

The control channels are further defined as:

- Broadcast channels – for frequency correction, synchronization and base station identification.
- Common control channels – for calling mobile stations (paging) and to allow access to the network by mobile stations.
- Dedicated control channels – used together with traffic channels for general organizational activities.

2. TEST REQUIREMENTS FOR GSM

2.1. New aspects of testing

The new technology used by GSM networks demands new measurements not possible with previously existing measuring instruments. The main differences between analogue and digital test requirements are:

- The transmitted information is completely digitised and subdivided in discrete time intervals. Continuous analogue signals, as used previously, are virtually unobtainable.
- The information blocks are carried in exactly defined time-slots. The time multiplex (TDMA) system provides an exact synchronization for all mobile stations operating in the network. The GSM measuring instrument must therefore also simulate this synchronization pattern.
- Modern digital modulation methods influence the phase and amplitude of the RF carrier at every moment in time.

The transmission and analysis of such signals is beyond that of conventional test instruments such as signal generators, modulation meters and power meters.

In order to obtain good measurement resolution the signal must be sampled at four times the data rate. In addition, the amplitude range of the RF-signal causes difficulties for the measurement equipment. The minimum dynamic range required by GSM for mobile stations is 70 dB thus severely stretching the capabilities of commonly available A/D converters (Fig. 5).

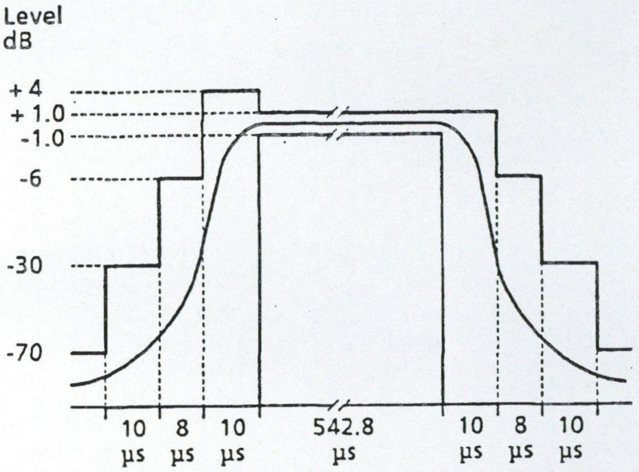


Fig. 5. GSM mobile power ramping (from GSM recommendation 11.10)

Frequency hopping is relatively new problem for test and measuring equipment. Such signals must be produced and in addition measured at exactly the right moment in time.

Because of the speech coder used by GSM, AF-measurements are now much less important. Single frequency test tones are a poor substitute for normal speech, especially when complex speech codecs are used as in GSM. In this area new test methods using both digital and analogue techniques are necessary.

2.2. Signal generation – Measurements on the receiver

A GSM specific signal generator has the task of modulating the prepared bit stream on to a specific RF carrier signal. Normal synthesizers are not well prepared for this task as they mostly do not offer the correct modulation bandwidth, have no direct control over the RF carrier phase (I/Q modulation) and are not able to change quickly their transmit frequencies. Signal generators from Rohde & Schwarz, the SME (5 kHz to 3 GHz), the SMGU (0.1 MHz to 2160 MHz) and SMHU (0.1 MHz to 4320 MHz), together with GSM radio test sets CMTA94, CRTS and CRTP are however able to produce such signals.

2.3. Signal analysis – Transmitter Measurements

Conventional power meters and modulation analyzers work exclusively with continuous test signals. Their use for the analysis of data packages (TDMA time-slots) is therefore extremely limited. Only by quickly sampling the RF-signal, or the associated I/Q-signals, an exact analysis of the phase and amplitude is possible. Such samples can be collected, stored and then processed to provide the required measurement values.

The most important transmitter measurements are:

- Power level (as low as 13 dBm for mobile stations)
- Power ramp profile against tolerance mask
- Phase error, both RMS and peak
- Frequency error
- Unwanted emissions

2.4. Simulation and Analysis of the Bit coding

In order to ensure the error-free transfer of bits, error protection coding of the binary data is necessary. Such functions are known in GSM as channel coding. Highly integrated solutions for the coding and decoding functions are being developed by industry. Use of such ICs in measuring instruments unfortunately is not possible as too few possibilities exist to influence the behaviour of such chips. When testing mobile stations it is very often necessary to introduce deliberate failures into the signalling in order to check that the mobile produces the correct response. This is only possible when using non-integrated solutions such as software running on DSPs together with specially developed hardware. Where exact simulation and analysis is necessary, e.g. in development or type approval, access must be possible at all levels of the signalling. By using fast digital processors (DSPs) Rohde & Schwarz has developed test instruments and systems which are capable of simulating and analysing the GSM protocol in real time together with the necessary error implantation and message logging facilities.

2.5. The Network Level

The network level specifies the intelligent exchange of data telegrams between the relevant partners. Each exchange of data telegram (handshake) happens at an exactly predefined state during the connection. At this point we can begin to use terms which are more familiar from the analogue cellular networks, e.g.

- registration (location update)
- call set up
- call clearing
- channel change within a cell or from cell to cell
- control of the power level

The complete simulation of the necessary signalling requires a great deal of memory space inside the measuring instrument. Such memory is not only required because of the necessary software for the simulation process but also in order to log each individual message exchange for later analysis of possible failures.

2.6. Audio measurements

The type approval specifications regard audio measurements as completely separate from RF-measurements. This has resulted in a new measurement technique whereby acoustic and digital interfaces are combined in order to make a measurement.

2.7. Measurement configuration

Most measurements specified by GSM have to be made on a mobile station as it would be delivered to customers. This means that measuring equipment has to be capable of measuring a mobile in this state using whichever signals are then available.

Receiver sensitivity is one of the most critical measurements to be carried out. As measurements directly after the demodulator are not possible and would anyway produce various results depending on the mobile itself, particular test methods have been defined.

The Loop-Back method uses the mobile station itself as a part of the measurement solution. Should the decoder in the receiver receive a faulty telegram (error in the synchronization word) then this information is transmitted back to the measuring instrument. The error message is indicated as a bit called the Bad-Frame-Indication bit (BFI) contained within each transmitted telegram (Bit 58 as BFI-flag). The so-called Frame-Erasure-Ratio (FER) is then used as a criteria for the receiver sensitivity in the same way as SINAD or S/N has previously been used.

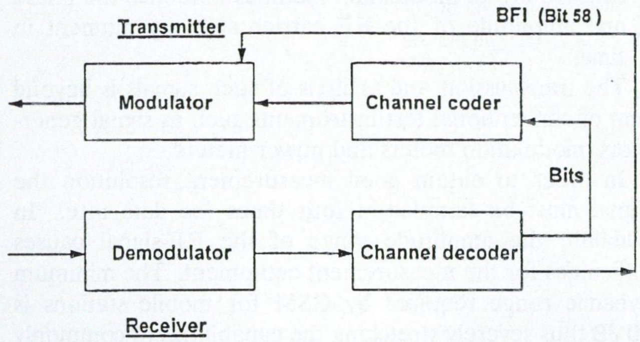
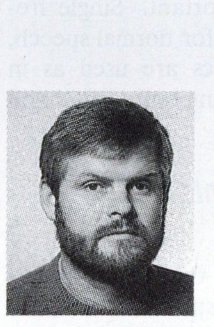


Fig. 6. Indication of faulty frames in GSM Mobile Station



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THE OBJECTIVES AND APPLICATIONS OF TRAFFIC SIMULATION

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Traffic simulation is widely used by operators and manufacturers for testing public or private exchanges or telecom networks. Test applications are numerous, as debugging tests, factory tests or maintenance tests, including interworking conditions. Performance tests have also an important place in the testing of exchanges, outlined by the CCITT recommendation Q543, particularly adapted for testing the ever more complex exchanges, regarding their capacity, multiple signallings and services.

1. INTRODUCTION

Two widely used methods are applied for telecommunications test purposes:

- monitoring,
- analysis of the effects of simulated artificial traffic.

This overview of traffic simulation presents a general survey of the major applications, whilst taking a closer look at one of the most significant of them.

2. THE CONCEPT OF TRAFFIC SIMULATION

Simulation makes it possible to test a piece of equipment or network by replacing all or part of the environment in order to reproduce its static and dynamic characteristics. It is thus possible to generate specified calls, possibly by superimposing them on real calls, for the purpose of specific tests, and to monitor the effects on the system or the network being tested.

Traffic simulation particularly covers tests where the traffic volume and characteristics of the calls generated are representative of the real working conditions of the equipment being tested.

Some of the characteristics of traffic simulation:

- the types of entities simulated (user/network),
- incoming/outgoing/mixed calls,
- the medium/signalling (analog, ISDN, PCM/subscriber code, D protocol, MF, CCITT7),
- the type of calls (successful, unsuccessful, with conversation, type of clearing, type of selection...),
- density and rate of calls (random, bursts, repeated bursts),
- the directions called,
- the measurements performed during/outside conversation (time, QoS on the B channels).

Simulations can be performed on any type of equipment (terminal, network equipment...), but in the rest of this overview, we shall primarily be looking at exchange tests (Switches, PABX, RSU,...) and network tests.

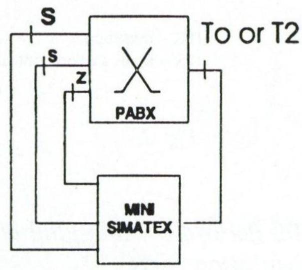

Fig. 1.

3. TRAFFIC SIMULATION – TO MEET WHICH REQUIREMENTS?

Manufacturers (of exchanges):

- Simulating the future working environment of the exchange: either because this environment is not available or because there is insufficient traffic on a newly created network, or because of the prohibitive costs of real traffic,
- integration tests, benchmark tests, doing away with the environment's working limits and faults (objectivity of the tests).
- Tests after manufacturing the exchange: checking the equipment operates properly.

Operators:

- Prototype validation/acceptance tests,
- inspection when the (public or private) exchanges are installed, Quality Assurance procedure audit),
- preventive maintenance in the network, finding faults with the switching, changing, traffic flow, QoS on the B channels...

4. THE SIMULATION APPLICATIONS

4.1. *Interworking test*

With the introduction of ISDN, interworkings of signallings and services are becoming more and more widespread: Analog, ISDN, CCITT7, PCM, MF, which particularly contributes to the growing commplexity of subscriber exchanges.

An interworking test requires traffic to be generated on all the types of access available on the equipment, while covering all the combinations of signallings. This type of tests, which is limiting in terms of call processing, is particularly useful for benchmarking purposes (transit time...).

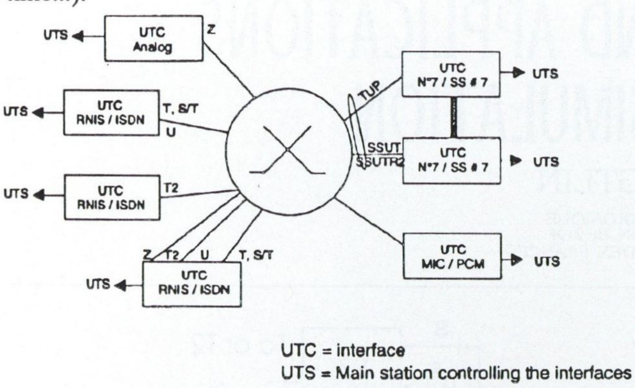

Fig. 2.

4.2. Software and hardware debugging and non-decrementation tests

Using a traffic simulator offers the following advantages:

- it is possible to generate predetermined call sequences, especially sporadic phenomena in real traffic,
- the same behaviour can be reproduced accurately and a considerable number of times which allows an easier diagnosis to be made,
- test costs can be cut: by eliminating network access costs and real traffic communication costs,
- testing in traffic conditions considerably increases the tests' scope while increasing the probability of quickly pinpointing problems.

Take the example of the variation in CET (call establishment time) depending on the traffic, on the exchanges equipped for CCITT7. The simulator makes it possible to check the improvement achieved with the new software versions.

4.3. Quality of service test

These tests are designed to measure and check:

- the charging: charge accounting and verification according to the charging rates,
- the response times: timestamping events,
- the switching: checking the call ends up at the right equipment called, continuity test,
- the quality of the medium: G.821 type tests in conversation phase.

ISDN, which can rely on new structures or those of the digitized telephone network, which must then offer highly reliable transmission of data other than digitized speech, is paving the way for Quality of Medium tests to be developed.

Pinpointing/detecting faults in a network

Quality of Service faults can be detected by a network supervisor. The traffic simulator, which performs measurements simultaneously on a large number of channels, can be used in addition to the supervisor to accurately and quickly pinpoint the fault causing inadequate Quality of Service.

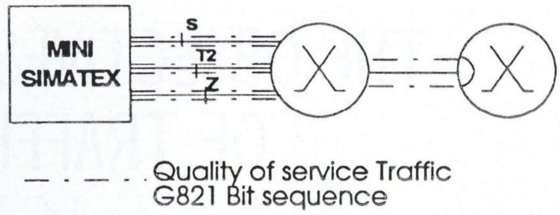

Fig. 3.

4.4. Performance tests on exchanges

This part of the overview is based on a method used to measure Performance developed and implemented in the CNET's laboratories, for the on-load tests performed on subscriber exchanges, using the CCITT's Q543 recommendations as a reference to go by.

Definitions and principles of Performance

In this section, the abbreviation PT means Performance Test.

Performance Test (PT) covers the tests on public or private exchanges in order to check they operate properly in traffic conditions, according to fixed parameters and to determine the working point relating to one of these parameters.

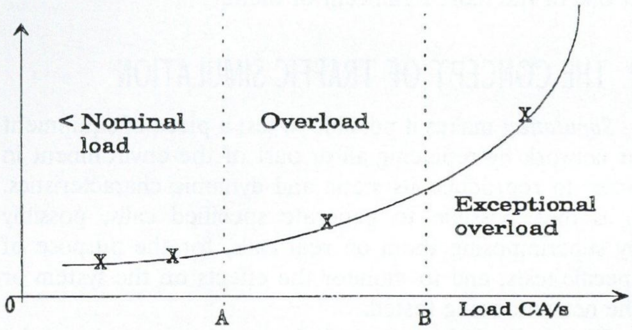

Fig. 4. Incoming call indication time
CA/s = Call attempt per second

For a long time, the only criterion taken to assess PT was the maximum rate of calls with faults (non establishment, premature break...); however this criterion proved to be insufficient to benchmark exchanges which were becoming increasingly powerful both in terms of call processing capacity and the functions/services offered.

Indeed, to benchmark a system whose structure and the protocols implemented make it more and more complex, working indicators have to be employed which will provide a precise picture of its behaviour. Furthermore, by quantifying these indicators, the system's performances can be benchmarked and its consistency monitored as the system is developed.

Some time criteria have thus been introduced such as the pre-selection, selection, and call clearing times.

Finally, in its 1988 session, the CCITT drew up specificaiton Q543 – Digital Exchange Performance Design Objectives – which defined reference loads and Quality objectives able to be used by manufacturers and operators.

Performance is determined by 11 time parameters and their nominal value which is not to be exceeded in the reference load conditions A and B.

Example: Objectives relating to the alert indication time for an incoming call to a digital subscriber coming from an analog subscriber.

CCITT Recommendations	Load A	Load B = A + 35% CA/s
Average value	≤ 650 ms	≤ 100 ms
Value not to be exceeded in 95% of cases	900 ms	1600 ms

Cases of working quality applications:

PT is particularly used for the following requirements:

1. *Validation under predetermined load conditions:*
The manufacturer announces the exchange's maximum performances, in terms of the number of CA/s, which is taken as reference load B.
The measurements are then performed under load conditions which are generally less than nominal load A, which is deducted from B; A = B – 35%.
These tests, carried out by the *operator*, are of direct interest to the *manufacturer* for an internal validation of his product.

2. *Benchmarking the behaviour of the exchange by measuring the development of the parameters according to the load varying from 0 to B and above.*
The measurements performed above load B provide information as to the system's behaviour, after switching to an exceptional overload, make it possible to validate the possible regulation mechanisms and determine the operating conventions which it is advisable to adopt in these cases.

Example: variation in the preselection time according to the load.

3. *Technical inspection of installation or Audit when Quality assurance contracts are used between manufacturer and operator.*

Implementing the method:

The traffic on subscriber exchanges is characterized by 4 criteria:
- the type of call (local, outgoing, incoming...),
- the access signalling (pulse, DTMF, D protocol) and the additional services associated with it,
- the network signalling (multi-frequency, CCITT7, decimal, ...),
- call effectiveness.

The measurements have to be performed under *traffic conditions* which are representative of a site in the network, i.e. for the French network:
- 10% local traffic,
- 40% outgoing traffic,
- 40% incoming traffic
- 10% transit traffic
- with all the cases of interworking (subscriber, ISDN, MF, CCITT7).

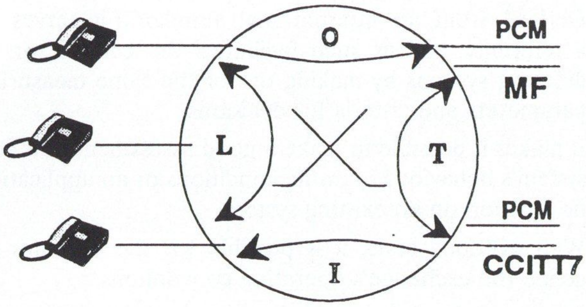

Fig. 5.

The measurements are performed using simulators connected up to the various types of subscriber equipment and circuits.

Distinctive features of the bechmarking tool:

In addition to its traffic possibilities, with all types of interworking, the simulator must be able to measure in a sufficiently accurate manner, the times between events on any 2 accesses, whatever the signalling used. The SIMATEX simulator, which offers this possibility, is fully suited to this type of tests, as the measuring accuracy required is approximately 10 ms.

Example: Measuring the Selection time between an ISDN subscriber at S_0 Interface and a CCITT PCM access.

The time between when the SET UP (block dialling) message is sent and the CCITT7 IAM is transmitted on the PCM access therefore has to be measured.

Measurements to be performed (on successful calls):
- measuring the time parameters such as preselection time, alert indication time, clearing time...,
- measuring the calls processed inadequately (accounting and rejecting faulty calls).

This methodology has been implemented for testing new generation subscriber exchanges, for both outgoing and incoming traffic.

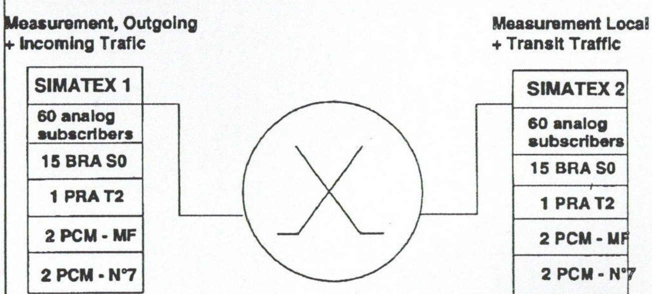

Fig. 6. Test configuration

- 16 groups of measures each corresponding to one case of interworking, with 5-6 time measuring points per group, and approximately 2,000 samples of each for a statistical analysis,
- with traffic corresponding to 8 CA/s on each SIMATEX.

Strengths and limits of the method:

The method shown offers numerous advantages even if it can not cover all the real cases of overload (unit failures):

- Derived from an international standard, it serves as a reference and as such facilitates the comparison of different systems by making use of the same measuring parameters and criteria for decisions.
- It makes it possible to make a good assessment of a new system's behaviour in traffic conditions or an application or function on an existing system.
- With overload tests, it is possible for the operator to define the exchange's operating conventions.
- On the basis of these measurements, the operator can determine the impact (technical, economic, financial) of a new function on the exchange. By way of example, adding the function whereby the calling party is identified will lead to a notable increase in the selection time. Measuring this time makes it possible to know which means have to be allocated (additional equipment) to maintain Performance on the operator's system or network.
- As it is an overall test method, it is suited to the AUDIT test for technical inspection purposes.
- The method becomes particularly useful if it makes use of external test means (measurements, traffic) which are independent of the system being tested, which then allows an easier diagnosis to be made thanks to identical measuring points and test scenarios, in order to objectively compare different systems or the different applications of the same system.

5. CONCLUSION

- This method is particulaly suited to measure complex systems' performance. It provides greater possibilities in terms of diagnoses than those based simply on a fault rate. It will thus sometimes be possible to measure a temporary degradation, while the fault rate remains unchanged or would not be affected until much later after the phenomenon has arisen.
- The Q543 standard defines the nominal performance design objectives by setting thresholds for the various time parameters measured. These values are indicative and should be adjusted according to the equipment and the latter's possibilities. Putting the method into widespread use with various switching equipment will make it possible to improve some of the standard's values.
- To implement the method, simulation tools are required which make it possible to measure times in interworking mode (user/network, analog/digital, channel/common channel signallings); CLEMESSY ELECTRONIQUE's SIMATEX and MINI-SIMATEX meet this requirement.
- To go even further, measurements on sites and one over a long period of time (1 – 3 months) will make it possible to check how consistently the system operates properly as time passes.
- It is worth noting that the method which is applied here for validating public exchanges can be easily switched to validating PABXs.
- The growing complexity of telecommunications systems in terms of their capacity, services/functions, particularly with the introduction of ISDN, make suitable test methodologies and aids a necessity. The international standardization authorities have taken this into consideration. Furthermore, applying a test methodology recommended by the CCITT in recommendation Q543 illustrates the possibilities offered by traffic simulation both in terms of the manufacturers', installers' and operators' requirements.

ACKNOWLEDGEMENT

The contributions of Dominique Mathieu CNET–LANNION are gratefully acknowledged.

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SPECIFIC AND REGULAR TESTS OF TELEPHONE EXCHANGES AND NETWORKS

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Measurements play an important role in the testing and operation of switching equipment and switching network. There was a dramatical change in the technology of the digital switches and it was followed by the change in the measuring equipment and the measuring technics. This article gives an overview of the changing in the type approval and operation measurements of switching equipment and network.

1. INTRODUCTION

Similarly to electronic technologies, the technology of telephone exchanges underwent a significant transformation in the eighties. The first generation of fully digital telephone exchanges appeared widely during this period. But this was the beginning of a new era since technological development of software and hardware considerably accelerated and — in the case of telephone exchanges — replacement of technology also came about sooner. This replacement involved a significant change in measurement technology as well. In the following part of the article, I would like to speak about the transformation of measurement technology in the fields of specific (qualification, type approval testing) and regular (operation and maintenance) tests of telephone exchanges.

2. QUALIFICATION TESTS OF TELEPHONE EXCHANGES (TYPE APPROVAL TESTING)

During qualification tests the user and the test laboratory check if the characteristics of the telephone exchange fulfil international and national standards, regulations and requirements. Tests are generally made with instruments of high precision since these serve as references during futher tests and measurements. Measurements can be classified into two major groups:

- measurements made at the manufacturer's premises and with the manufacturer's instruments;
- measurements made in the user's laboratory (usually in a pilot exchange).

In the first group, measurements requiring sophisticated, customized (special) instruments and configurations are performed by the user's expert together with the manufacturer's experts. Even the manufacturers make these measurements generally at specialized sites, therefore it is inexpedient and unprofitable for the user to make arrangements for such purposes. Such measurements are e.g. the testing of the load of control unit and the protection against transient voltages. This group includes observations and checks made by the user's experts in order to examine the measurements, tests and quality assurance during the manufacturing of the exchanges. In the course of this activity, the user's experts can decide on the tests that may be made only occasionally those being regularly checked during manufacturing.

In the second group we find measurements made by the user's experts in a laboratory (usually in a pilot exchange established for this purpose). These measurements have two purposes: on the one hand, the exchange can be qualified on the basis of the measurements performed, on the other hand, following the measurements, it can be defined what and how to measure during acceptance (realized in the course of not specific but regular investments), as well as during operation and maintenance. Measurements are performed by the experts with reference instruments of high precision. A further characteristic of such instruments is that they are programmable and their data can be retrieved and processed by a computer. This is important because these data can serve as references or — should a fault occur later — make possible a later analysis of test results and, on the basis of the analysis, the performance of further detailed and new tests.

In the case of SPC (Stored Program Controlled) digital exchanges it shall be also taken into account that exchanges include a number of built-in test programmes replacing certain instruments or manual measurements. These measurements have been built into the exchanges in the course of the continuous software and hardware development of the exchanges. The number of tests and measurements increases continuously and their precision is improved. In this way, numerous measurements can be replaced by automatic ones (built into the exchange). The significance of this arrangement becomes evident during operation and maintenance. This item is addressed in the following chapter.

3. OPERATION AND MAINTENANCE TESTS

Since SPC exchanges are widespread, different measurement methods are to be applied for the exchanges and for the networks built up of exchanges. Built-in test equipment and automatic test programmes promote the introduction of controlled maintenance. The general introduction of controlled maintenance requires the application of test configurations instead of test equipment. When preventive maintenance was used, specific measurements played a significant role since maintenance had to be planned and organized on the basis of specific measurements. On the other hand, the application of a corrective maintenance method emphasized fault detection and forecast based on the measurements performed by automatic measuring equipment, on the basis of which fault can be cleared or prevented. Fault indication and detection did not always define the exact location of the fault, therefore further measuring equipment had to be used in order to discover the reason of the fault. In the case of certain exchanges operated on the basis of corrective maintenance principles, it is profitable to complete the electromechanic exchange with automatic test equipment, to enhance it electronically. Afterwards, controlled maintenance of electromechanic exchanges also can be partly or fully implemented.

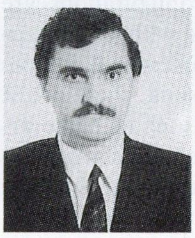
Controlled maintenance principles are basically applied in SPC exchanges. All SPC exchanges include the necessary built-in test equipment and the software operating them. Automatic (built-in) measurements render certain specific, earlier widely applied measurements unnecessary. On the other hand, due to complexity, demand appears to use sophisticated test configurations. The configurations aim at simultaneously checking several inputs and outputs of an exchange, as well as collecting and storing data. Data collection and storage are significant requirements because this makes possible a later analysis of the data or, based on the data, the repetition of a test with nearly the same conditions. Another important requirement for test configurations is the possibility for simulation. Simulation makes possible to model real traffic situations and, by doing so, perform directed measurements. Consequently, test configurations are tools controlled by an external computer. Manufacturers continuously build in experiences gained and, consequently, detailed user's software packages are also available for each test configuration. These software packages serve two purposes:

- tests and data collection are preformed according to a preset programme;
- stored data are processed and test documents are prepared.

Consequently, operation and maintenance tests of exchanges have been significantly transformed and this transformation continues in the near future, too.

4. SUMMARY

Telephone exchanges determine network capabilities in each telephone network. The sudden development of exchanges and the spreading of SPC exchanges require a similar rate of development of test methods, test equipment and test configurations making possible the testing of exchanges. Concerning measurement technology in the exchanges, test equipment making possible specific measurements of high precision will be needed in the future as well but the prospective solution is by all means to use test equipment enabling integrated tests, and capable of the collection, storage and processing of data.



Béla Kozma graduated in electrical engineering at the Technical University of Budapest in 1981 and received the Special Engineer of Telecommunication degree in 1985. From 1981 to 1987 he has been working at the Hungarian Post and its successor the Hungarian Telecommunications Company. He was a specialist at the Austria Telecom from 1987 to 1990. He became the head of Switching Technology Department in February, 1990 and the head of Telecommunications Networks Department in August, 1990. Presently he is director of Operations and Maintenance Department of HTC.

NEW MEASURING-AND-TEST METHODS IN TELECOMMUNICATIONS

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INTRODUCTION TO THE PANEL DISCUSSION

In the last quarter of this century the role of telecommunication has been enhanced significantly. The development was supported or initiated by the new technology. Every part of telecommunications is influenced by the research and development results of electronics, photonics, satellite systems, computer hardware and software. As a consequence of the above mentioned facts the whole telecom is changing: transmission is primarily digital, long-haul connections are based on optical fibres, switching systems became also digital and stored program controlled. In general reliability improved that is the number of failures and faults has decreased significantly. Here we arrived to the problem of maintenance.

Economic considerations are pressing the operating companies to concentrate the maintenance staff not only in space but also in tasks. The small number of faults does not allow to have specially skilled maintenance personnel. Furthermore if they have an excellent education without practical use of it they will not be able to find quickly any kind of outages. In some cases the network or system redundancies help to shorten the downtime of the services. In spite of it, it is necessary to support the maintenance work with measuring-and-test equipment of extremely high intelligence. On Fig. 1 the large variety of check points can be seen.

The first problem which must be solved is that the types or measuring equipment should be minimized, and their intelligence should be maximized. This can help the maintenance staff to find the failure in highly sophisticated systems; the same failure occur seldom or only once in the life-time of the system. The manufacturers are developing different test equipment to simplify the maintenance, the operating companies are preparing specifications and system unifying policy. The question is that the development result do meet the users' requirements or both side must change their directives and find a good compromise.

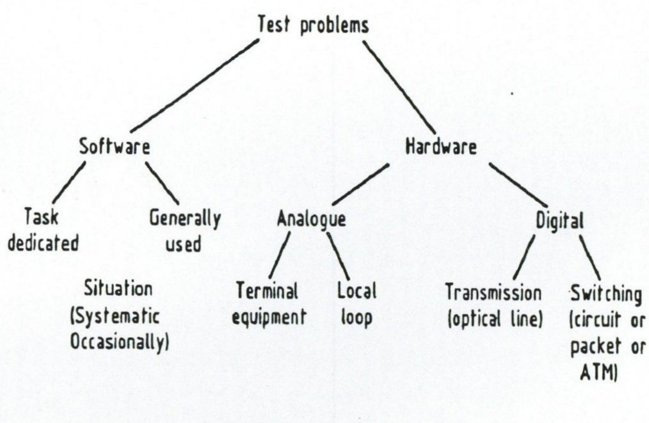


Fig. 1. Test problems

Due to the highly sophisticated telecom systems, and the large variety of services the need of "simple to use" measuring equipment is arising not only in the maintenance field but also in R&D laboratories. In the manufacturers' workshop and also in the course of licensing a new system the most important question is: does the telecom system meet the international standards and recommendations. The next stage of the production procedure is the demonstration of the quality. During the approval test which has great economic and legal consequences the repeatability of the measurements is very important. This is a further requirement in buying new telecommunication measuring equipment. The stability of the measuring system in time must be much better than the stability of the measured system. By checking continuously the quality of the production both the repeatability and reliability of the test system is a requirement of high priority. This series of measuring procedure can be seen on Fig. 2. To develop 5 different kinds of measuring systems whould be an extremely high load. It is not only financially disadvantageous to develop equipment which can be produced only in small series, but the number of the necessary experts is also limited. So a further question is: what is better to integrate all the necessary knowledge in a single equipment or to develop a modular system controlled by a commercial computer with different softwares for the different applications. Is it possible to produce different sensors for the special service with different grades of precision and combining the necessary sensors, and evaluate the result by a computer, or to use them on the field by pocket calculators which have several input parts.

All this question are quite actual. But the answers are depending on several influencing factors, such as the salary of the experts, the forecasted demand on the different equipment, the estimated development time of the chosen solution, the opinion of the market and several further uncertainties. In spite of these contradictory factors I hope that the discussion of this session of excellent experts coming from every player of this job will provide a probable good solution for us, sketching the tendencies in the telecom measurement field for the next few years.

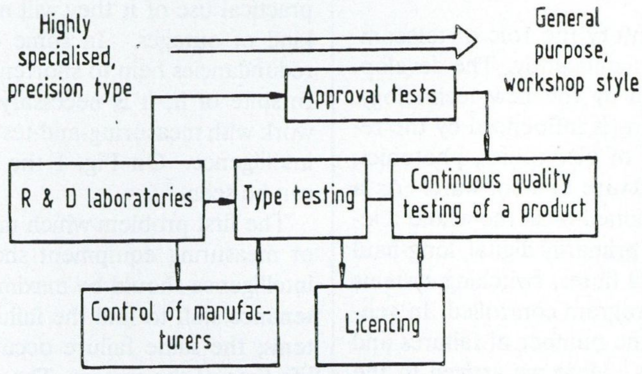
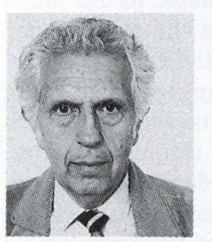


Fig. 2. Measuring procedure



György Lajtha received the Master of Engineering degree from the Technical University of Budapest in 1952. After the University he is the engineer of the Post Office Research Institute. Scientific Vice Director of the PKI from 1974 to 1986. From 1986 to 1990 adviser of the Hungarian Telecommunications Co. Research fields: data transmission, maintenance, reliability, optical network planning, optical fibre, PCM. Ph.D. in 1963. Doctor of Technical Science in 1977. He got the highest prize in Hungary the Széchenyi Award in 1992. He is retired in 1990. Presently he is the editor-in-chief of the Hungarian Telecommunication Journal (Magyar Távközlés).

CONSULTRONICS TEST EQUIPMENT FOR DIGITAL DATA NETWORKS

The test equipment described here can be used in all stages digital data network development, production installation and maintenance. The emphasis is however on the equipment installation and network maintenance stages.

1. THE CONSULTRONICS LYNX DATA NETWORK TESTER

1.1. General features

The Lynx is a simple to operate very compact portable tester especially suitable for carrying to the customer's premises where it will emulate a DTE or DCE (or NTU). Figs. 1 and 2 show the panel layout and interface connections of the Lynx. It can also be used within the network at the G.703 interfaces, 2 Mbit/s or 64 kbit/s Co-directional, using accessories. It is a combined error detector and pattern generator and includes a wide range of additional facilities. In the paper by B. Stroud, in this issue examples are given of the connection of the Lynx for testing the network.

It may be used to check a data link in a network by performing bit error tests from end to end by using a tester at each end. Alternatively the local Lynx could initiate a loop in the remote NTU for error monitoring in a loop back mode from one end only. The local NTU could also be checked by operating a local loop.

Lynx testers connected at suitable points within the network may also be used to send and receive known data patterns to check the various parts of the data channel.

By using an add on module a drop and insert feature is provided. Here the 2 Mbit/s signal is passed through the Lynx and the data in any selected channel (except TSO) may be removed and replaced by a test pattern generated locally within the tester without affecting other working channels. This process may be carried out at various points in the network to localise fault conditions in the network. The Lynx is also capable error monitoring in a selected channel or with its adapter generating and monitoring a 2 Mbit/s framed signal (digital data frame or normal speech PCM type frame with TS16 channel associated signalling and multiframe). Another adapter is available for generating and detecting errors in a 2 Mbit/s unframed signal.

Pattern generation and error monitoring on N x 64 kbit/s services is also possible at various points in the network.

It should be noted that the Lynx is not restricted in its use to digital networks it can be used on analogue data circuits at the customer's side of the modem or NTU provided the interfaces are suitable.

1.2. Technical data

1.2.1. Interfaces/Data Rates

Synchronous

Full/Half-Duplex	X.21/V.11	1.6 kbit/s – 2048 kbit/s (from 30 bit/s with external clock)
	V.24/V.28	1.6 kbit/s – 128 kbit/s (from 30 bit/s with external clock)
	V.35	1.6 kbit/s – 2048 kbit/s (from 30 bit/s with external clock)
Adapter Option	RS-449	1.6 kbit/s – 2048 kbit/s (from 30 bit/s with external clock)
Adapter Option	G.703/1	2048 kbit/s Unframed 2048 kbit/s Framed
Adapter Option	G.703/2	64 kbit/s Co-directional

Asynchronous

Full/Half-Duplex	V.24/V.28 (RS232)	50 baud – 57.6 kbaud

Synchronous Data Test Patterns	PRBS of length: $2^6 - 1$ (63), $2^9 - 1$ (511), 211 – 1 (2047) $2^{15} - 1$ (32,767) G.703 only, $2^{18} - 1$ (262143) and $2^{20} - 1$ (1048575) bits All 1s, All 0s, Alt 1010, Programmable 3,4,12 or 16 bit repeating words G.704 Frame format (G.703/2 Adapter)
Clock	External, Internal (Auto fall back to internal) From received data G.703 only)
Asynchronous Data	4 Fox messages, fixed words, programmable messages and PRBS
Synchronous Block Length	512, 2048, 8192 and 32768 bits
Measurement Length	2^{13} to 2^{48} bits or continuous
Error Injection	Single Erros, Code Errors (G.703/1 Adapter only) FAS Alarm conditions (G.703/2 Adapter only)

1.2.2. Bit Error Rate Tests

Displayed Results	*Synchronous*	*Asynchronous*
	Bits Received	Characters Received
	Bit Errors	Character Errors
	Average Error Ratio	Average Error Ratio
	Blocks Received	Blocks Received
	Block Errors	Block Errors
	Clock Frequency	Baud Rate
	HDB3 Code Errors	(G.703/1, G.703/2
	Adapters only)	
	FAS Errors	(G.703/1 Adapter only)
	Multiframe Errors	(G.703/1 Adapter only)
	Distant Multiframe Errors	(G.703/1 Adapter only)
	CRC-4 Errors	(G.703/1 Adapter only)
	FAS, NFAS, MFAS Words	(G.703/1 Adapter only)
	TS16 CAS Signalling Bits	(G.703/1 Adapter only)
	Pattern Slips	(G.703/1 Adapter only)

CCITT G.821 Performance Analysis	EFS, %EFS, ES, %ES, SES, %SES, DM, %DM, Test Time, Available Time, Unavailable Time, Sync Losses, Sync Loss Secs

1.2.3. Test Facilities

V.24 Breakout Box	Including 24 LEDs
Monitor Mode	Monitors DCE-DTE interface without affecting transmission.
V.28 Level Check	
Voltage Level Measurement	
Delay Measurement	Turnaround delay between any two control signals.
Mark/Space Ratio	
Printer/CRT Test	Barber Pole Pattern

Results Storage
Programmable Test Configurations
Control Circuit Settings — From the keypad
Clock Phase Measurement
Drop and Insert — (G.703/2 Adapter only)
Inserted signal source
a) PRBS from Lynx
b) 64 kbits Co-directional on G.703 Adapter
c) Audio Input on G.703 Adapter
Received Channel Routed to:
a) Lynx for PRBS error detection
b) A 64 kbit/s Co-directional output
c) An audio output socket
Other features:
1. Transmit PRBS or fixed words in selected channel, idle code in all other channels.
2. Operation from recovered or internal clock
3. Transmit PRBS or 8 bit word in selected contiguous (Nx64) selected channels, idle cod or PRBS in unused channels
4. PRBS inserted into all channels, idle code in selected channels.

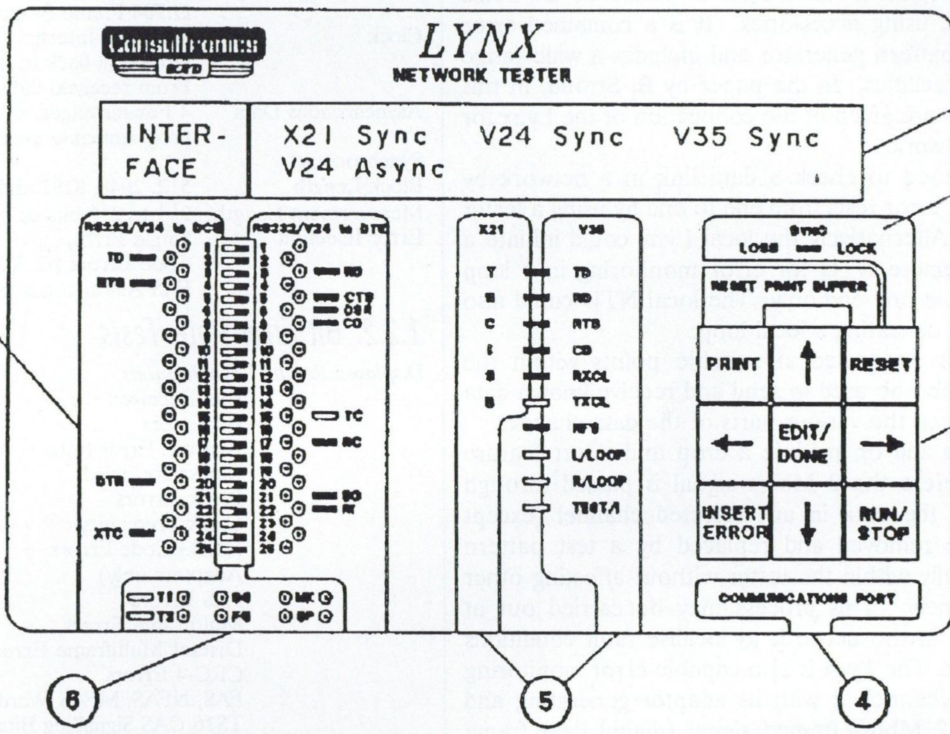
Automatic Test Sequence (Half-Duplex)
Test Loops

1.2.4. Features

LCD Display
Printer Output
Remote Control
Flow Control
Test Data Display
Real-Time Clock
Self Test
Buzzer
Power Supply — 240/115 V, 50/60 Hz 6 W, Rechargeable Battery

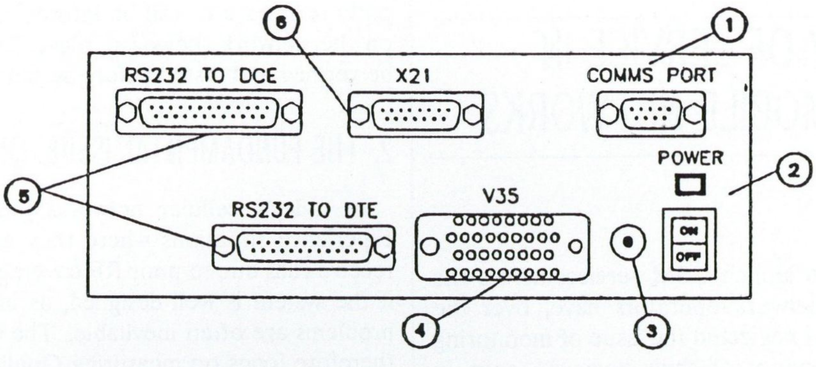
1.2.5. Dimensions

Tester/Case	230x210x97 mm approx.
Tester only	130x200x83 mm approx.
Weight	1.8 kg (Tester only but inc. power module).



1. DISPLAY – 2 line x 40 character LCD for display of configurations and results.
2. SYNC INDICATOR – bi-colour LED. GREEN ('Lock') indicates synchronization, RED ('Loss') indicates loss of sunchronization, GREEN/RED indicates synchronization lost and then regained, OFF indicates that no test is running.
3. KEYPAD – all configurations, controls and tests are set via the nine front panel keys.
4. COMMUNICATIONS PORT – RS-232 interface connector on the front face of the LYNX for connection to a printer.
5. X.21/V.35 INDICATORS – bi-colour LEDs which indicate the states of the main interchange circuits.
6. TEST INPUTS, MARK/SPACE OUTPUTS – allow the user to check the state of any breakout pin or to set the level on any V.24 circuit.
7. V.24 (RS-232) BREAKOUT BOX – full breakout facility with 24 switches, 24 pairs of terminals and bi-colour LEDs.

Fig. 1. LYNX Front Panel



1. COMMS PORT – 9-way female 'D' Type connector for the RS-232 Communications Port. Allows connection of any serial printer.
2. POWER ON/OFF – power ON/OFF switch with a green LED indicator. The LED is illuminated when power is switched on.
3. POWER INPUT CONNECTOR – 18 VD.C. power input plug, which should be connected to the A.C. mains adapter supplied with the Tester. The adapter must be connected to a mains supply of the correct voltage and frequency. The mains version of the LYNX has a mains power input connector.
4. V.35 INTERFACE CONNECTOR – 34-way female MRAC connector.
5. V.24 (RS-232) INTERFACE CONNECTORS – two 25-way female 'D' Type connectors. One connector provides DCE connections and the other DTE connections, via the Breakout Box.

X.21 INTERFACE CONNECTOR – 15-way femal 'D' Type connector.

Fig. 2. LYNX Interface Connectors

2. CONSULTRONICS TESTER 303D

This is similar to the Lynx but with fewer facilities and designed for use at the customer's premises for Synchronous operation only.

2.1. Interfaces/Data Rates

X.21/V.11	Up to 128 kbit/s
V.24/V.28	Up to 128 kbit/s
V.35	Up to 128 kbit/s
Data Test Patterns	Various PRBS programmable and fixed words
Block Length	512, 2048, 8192, 32768 Bits
Error Injection	Single errors

2.2. Bit Error Rate Tests

Dispalyed results
- Bits Received
- Bit Errors
- Blocks Received
- Block Errors
- Error Free Seconds
- Bit Rate

2.3. Test Facilities

Monitor Mode — Monitors DCE-DTE interface without affecting transmission

Byte Timing Check
Clock Phase Measurement
Activation of loops at local and remote DCE
Automatic test sequence (half-duplex)
Indication of state of interchange circuits
Control Circuit Setting from the keypad

2.4. Features

LCD Display
Printer Output
Real-Time Clock
Self Test

Power Supply	240 V/115 V 50/60 Hz
Dimensions	
Tester/Case	420x330x185 mm
Tester only	130x200x70 mm approx.
Weight	<1.5 kg
Tester/Case	4 kg
Tester only	0.8 kg

3. CONSULTRONICS TESTER 246C

This is a 2 Mbit/s Frame Alignment and Signalling monitor and Error Detector having the following facilities: Monitors a HDB3 Coded signal having G.704 frame structure.

Detects
- Loss of Signal
- AIS
- Loss of Frame Alignment Multiframe Alignment
- FAS Errors
- Distant Alarm
- Distant Multiframe Alarm
- Bit Error Ratio calculated from FAS errors
- TS16 Signalling states displayed
- Output of any selected TS presented as a 64 kbit/s Co-directional signal for further analysis on associated test equipment.
- Can be configured as a HDB3 Code error detector.

4. CONSULTRONICS 282B

This is a 140 Mbit/s frame alignment monitor and provides the following facilities:
Monitors CMI coded signal frame structure on 139264 kbit/s digital paths.

Detects
- Loss of Signal
- Loss of Frame Alignment
- AIS
- Distant Alarm
- Distant Errors
- Indicates Bit Error Ratio
- Calculated from FAS errors

Also operates at 68 Mbit/s.

CONSULTRONICS EUROPE
Chandlers Ford, Hants, SO5 3SE, England

QUALITY OF SERVICE IN CELLULAR MOBILE NETWORKS

1. OVERVIEW

In the frantic race to launch GSM services across the European landscape, network operators have, over the last few years, somewhat neglected the issue of monitoring and testing the performance of their networks once in operation. This was largely justified by the fact that a great part of their efforts was concentrated on the most important issue at the time – GSM infrastructure.

The situation has somewhat changed; network operators and GSM equipment providers are now in the turn up phases of their long awaited digital mobile services, and questions relating testing, monitoring, and quality of service are suddenly emerging.

In Europe, the bulk of GSM subscribers will be concentrated in the Scandinavian countries, Germany, Italy, and France, and in most of these countries, the environment among network operators will be a fairly competitive one, wherein at least two operators will be vying to subscribe users on their "superior" systems. This will mean that greater emphasis will have to be place by operators themselves on monitoring their network's performance at regular time intervals.

The highly competitive market also means that additional supplementary services such as short message, multi party services etc. will be introduced as soon as available on the network, however, these functionalities must first be verified and tested before actual commercial turn-up.

2. THE FUNDAMENTAL ISSUE: QUALITY OF SERVICE

In today's cellular networks, subscribers occasionally experience situations where they are unable to place or receive calls due to poor RF coverage or congestion. Even if the system is well designed, as in most countries, such problems are often inevitable. The cellular operator must therefore focus on measuring Quality of Service (QoS) as perceived by the most important entity in the network – *The Customer.*

In the GSM network the quality of speech and service to the mobile user must be improved in order for the user to justify his/her investment. Unlike its predecessors such as AMPS and TACS which suffer from limited spectrum capacity, GSM promises more effective spectrum usage, thus higher subscriber capacity, privacy, and superior speech quality. And since the competitive environment will enable unsatisfied subscribers to easily switch their service provider by simply changing SIM cards, it is obvious that true marketing advantage in the GSM service industry can only be achieved by those who provide a quality product to the end user.

As a result, the GSM Network Operator is faced with two principal questions:

- Which relevant factors have the most influence on the customer's perception of quality?
- How can he monitor and measure these pertinent factors?

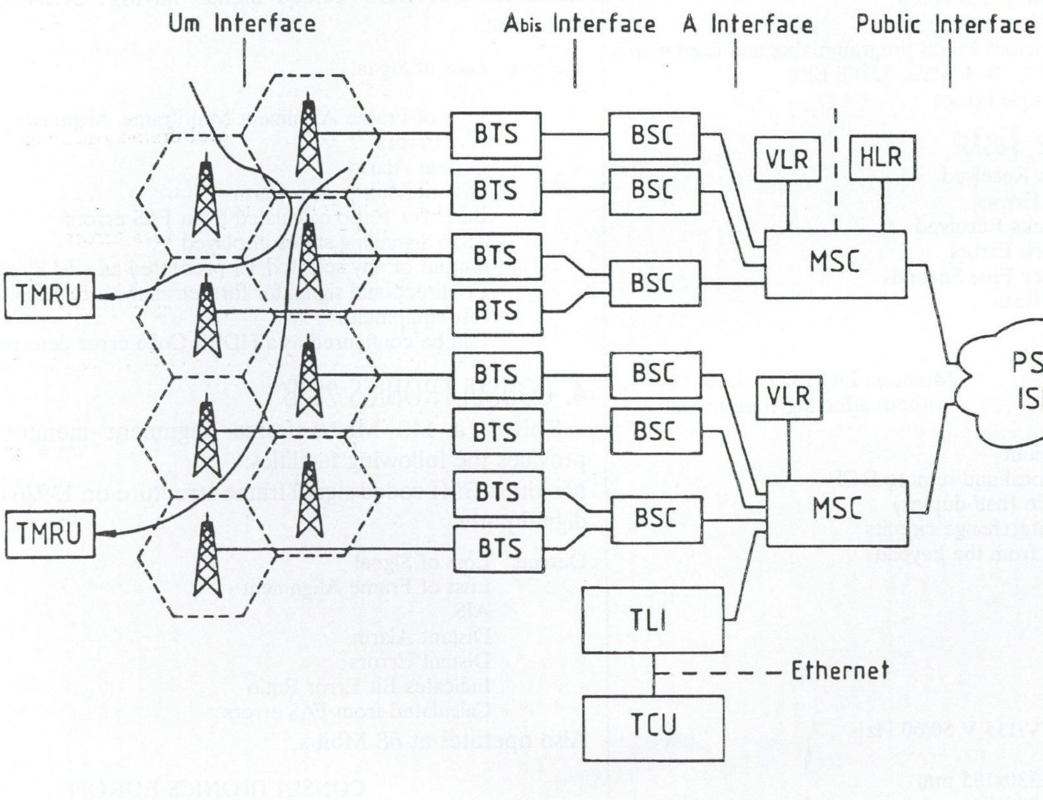


Fig. 1. GSM network elements

3. A CLOSER LOOK AT QoS

Obviously, many factors influence the perceived quality of a given GSM network: the infrastructure implemented by the PLMN (Public Land Mobile Network) operators, such as dimensioning of the Base Station Subsystems, the number of traffic bearing trunks in the MSCs, the targeted volume of traffic to be handled by the system, the quality of the mobile stations, the typical calling patterns of subscribers in a given geographical area etc.

The mobile subscriber, however, is not particularly interested in such complicated theoretical issues, he or she is only interested in the final product and its ultimate performance — i.e. the mobile telephone, and whether he can originate or receive calls uninterruptedly, with good audio quality, and finally receive accurate billing information.

To better understand the factors which impact service quality, a closer look is required:

The typical GSM Network can be subdivided into two functional sections; the Public Land Mobile Network (PLMN), and the connected network (PSTN, ISDN). Consequently, network performance can also be measured in two distinct sections:

- Performance on the Public Land Mobile Network (PLMN)
- Performance on the connected network (fixed telephone networks, data networks etc.)

The focus here is specifically on the performance parameters of the PLMN, as it is beyond the scope of GSM to define the performance of the connected network (PSTN). PLMN performance can be split into two parts:

- The performance of the mobile network expected and perceived by the user.
- Technical performance objectives which should be met for the fixed infrastructure of the GSM PLMNs.

4. NETWORK PERFORMANCE AS PERCEIVED BY THE GSM USER

GSM recommendation 02.08 defines the QoS of the GSM connection part which should be offered to GSM service users. The most relevant parameters are:

- Time to provide service

The maximum time from switching-on the mobile unit to when the user is able to send or receive calls. This should cover both cases: when the BCCHs in use on the PLMN are known to the MS, and when they are not.

- Call Success Rate (mobile originated)

The probability that a call attempt made from a mobile within the coverage area wil be successfully signalled to the called network. This does not include performance characteristics in the called network, or the effects of congestion on the air interface.

- Time to initiate a call (mobile originated)

The maximum time from when the user initiates a Call Set-Up command to when this command is passed to the called network. This includes time for authentication, when required.

- Time to release call

The maximum time from when the user initiates a Disconnect command to when it is passed to the called network.

- Call reception success rate (mobile terminated)

The probability of success when calling a mobile station located in the coverage area (assuming the MS is switched on, ready to receive calls, and that there is no congestion in the network).

- Time to alert MS

The maximum time from when the PLMN receives a call from the MS to when the Alert is energized.
The time specified should be for the case where the first page is successful. When further paging is required, the maximum time should not exceed a maximum specified figure.

- Duration of Interruption of call due to handover

The maximum total interruption of a traffic channel due to a single handover. Different figures may apply for:

MSC to MSC handover
BS to BS handover within an MSC area
Change of frequency channel on a given BS
Change of timeslot within a channel on a given BS

- Handover success rate

The probability of a handover being successful, within the GSM PLMN coverage area, in 90 % of cases.

- Audio Intelligibility

The probability that a speech call within the coverage area is intelligible despite interference.

5. TECHNICAL PERFORMANCE OBJECTIVES OF THE GSM PLMNs

Regarding service aspects to users, the general objectives to be met by the fixed infrastructure of the GSM PLMNs are defined in GSM recommendation 01.02. They are as follows:

- To give users a wide range of services and facilities (voice and non voice) that are compatible with those offered by fixed networks (PSTN, ISDN and PDNs) through standardized access to networks.
- Give certain services and facilities exclusively to mobile users.
- Provide compatibility of access to the GSM network to any mobile subscriber in any country of the CEPT which operates such a system.
- Provide facilities for automatic roaming, locating, and updating mobile subscribers.
- Provide subscribers with better or equal level of quality than conventional analog mobile networks.
- Provide service to a wide range of mobile stations, including vehicle mounted, portable and handheld stations.

6. MEASUREMENT APPROACHES

During the planning phases of cellular networks, digitized topographical maps and theoretical models are often employed to determine optimal RF coverage patterns, cell site locations, cell re-use patterns, and antenna configurations. Although this process often yields accurate results in RF design, the inherent radio coverage and service quality provided to the end user will never reach to 100 per cent figure. This rate of performance is quite difficult to achieve in any radio based communication system.

Operators therefore, need practical and effective methods which verify theoretical data against actual conditions. Only so, can they ensure that their investments in Base Station infrastructure are justified, and optimally allocated.

Once operational, the most common problems in today's networks such as poor radio coverage, congestion, dropped calls, degraded audio quality etc., are normally reported by the customers themselves to the network service center. Here, problem reports are compiled and periodically sent to the operations center for further analysis and correction. Occasionally, teams of field technicians are also dispatched in attempts to localize and verify more serious problems.

Unfortunately this reactive approach to network improvement and tuning results in fragmented solutions which are in turn slow, very costly, and ultimately damaging to the organization's image and its perceived service quality. The need for a systematic and proactive approach in performing QoS measurements and network improvement is becoming even more evident in today's competitive cellular arena.

The operator must be capable of foreseeing potential problem areas in his network by using preventive measurement approaches which are not isolated, but rather of compound and automated nature. This means that instead of reacting as in the past, or tying up resources to perform haphazard tests with field personnel scattered around the network, he shall have the capability of monitoring the network's performance on a regular basis with minimal human and capital investments.

7. AUTOMATED TESTING METHODS

How can automated testing techniques improve the network operator's service quality in a proactive and systematic manner?

It is conceivable, for example, to perform service quality measurements in a given network with minimal human intervention by simply employing a number of "*test*" mobile stations and global positioning devices and programming them to automatically generate and receive calls to/from the network.

This approach could provide quantitative information on each call attempt, for example:

- Pass/Fail verdict
- Receive Level (RxLev)
- Receive Quality (RxQual)
- Base Station ID Code (BSIC)
- Radio Frequency Channel Number (ARFCN)
- Handover information
- Audio Continuity Test
- Bit Pattern Test (data mode)
- etc.

In addition, this information could be coupled with the exact time and geographical location of each call sequence to precisely record all call attempts for further analysis and interpretation.

The simulation of mobile subscribers' general calling patterns could be achieved by placing the test mobile units in service vehicles which normally roam at random in a given area. The information acquired and stored by each mobile unit could then be used to quantitatively measure and assess the end user's quality perspective.

Finally, a centralized control unit may be used to upload and interpret data from the various remote units. Here, appropriate reports on selected QoS parameters can subsequently be compiled and presented to the Network Operations Center on digitized maps or in graphical format for further analysis.

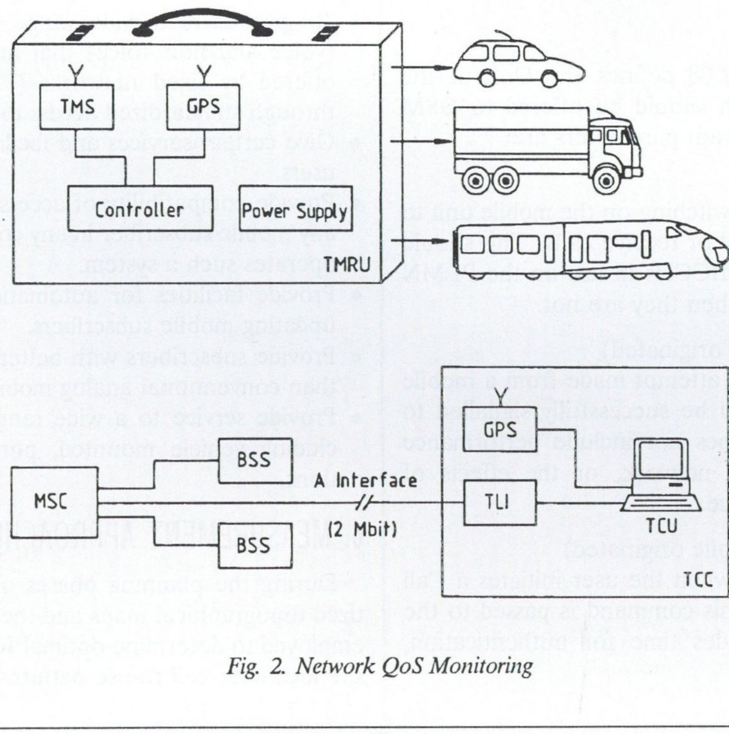


Fig. 2. Network QoS Monitoring

Staff at the Networks Operations Center should be given full flexibility in selecting specific geographical coordinates and QoS parameters which they wish to analyze. This enables them to quickly localize problem areas in their network before the customer does.

8. SUMMARY

Its becoming quite clear that in today's cellular environment, market share can only be sustained and improved by those who provide superior quality to the end user – *the mobile subscriber.*

As seen in many successful service industries, QoS methodologies rank highly among organizational priorities. This concept must also be adopted by Mobile Network Operators in their constant strive towards superior network performance. It is for this reason that a comprehensive Quality of Service monitoring system should be an essential element in Cellular Mobile Network operation. This will ultimately assert the Network Operator's position in the constantly evolving and competitive market environment.

Alcatel is a full-system supplier for GSM networks from the infrastructure to the terminals, including the test equipment. Different services e.g. network planning are provided, supporting the operator.

ALCATEL STR AG.
Friesenbergstrasse 75.
CH-8055 Zürich, Switzerland

NEW TEST CONCEPTS BY WANDEL & GOLTERMANN FOR GSM AND DCS 1800 NETWORKS

The new digital mobile radio networks have given a big boost to mobile communications. Due to the remarkable success fo the GSM standard in Europe, the number of network operators around the world opting for the GSM system has grown steadily. "Roaming agreements" between network operators are making mobile communication across borders a convenient reality, and users can retain their personal telephone number and equipment. The way to a "global system for mobile communications" now stands clear.

Communication in the GSM network is not limited to telephony. Additional services allow brief messages, facsimile transmission and access to videotext. Pure data transfer is provided by various transmission services. Other services such as network user identification, call forwarding and conference calling make for a level of convenience otherwise known only in ISDN.

Existing GSM networks are being upgraded step by step to include these services. New solutions are necessary to handle the measurements required to commission, upgrade and maintain complex mobile networks.

In contrast to conventional transmission and protocol analyzers, Wandel & Goltermann has broken new ground with its MA-10 Mobile Radio Analyzer. The instrument uses modular software running under MS-Windows and a hardware platform based on plug-in PC boards for a straightforward and flexible approach to present and future measurements. The applications of the Mobile Radio Analyzer MA-10 are summarized in Fig. 1. The basic concepts of the instrument are given in Fig. 2. The MA-10 provides on-site support with its measurement-oriented applications and detailed help functions concerning operation, applications and GSM fundamentals. The three applications described below are good examples of how the instrument can solve specific measurement problems.

- Analyzer for terrestrial GSM and DCS1800 network
- Analysis of signalling and traffic channels with one single instrument
- Designed for the needs of on-site service technicians during Commissioning, re-equipping and maintenance
- Market introduction with a monitoring function for Abis Interface
- Phase-in concept for future application upgrades

Fig. 1. MA-10 applications

- The complete measurement hardware, including 2 RX and 1 TX is contained on a single plug-in PC board
- Standard user interface MS-Windows
- Self-explanatory results and ease of use
- Comprehensive help functions covering operation, applications and general GSM knowledge
- Copy of MA-10 software permitted for offline analysis with every MS-Windows compatible PC
- Expandable to 4-port analyzer by adding further plug-in boards

Fig. 2. MA-10 product concept

In the SCANNER application illustrated in Fig. 3, the instrument automatically configures itself to the interface and provides a graphical overview of the individual channels contained in the 2 Mbit/s signal. The direction (uplink or downlink) and the position of the signalling channels in the 2 Mbit/s frame are also displayed. From the SCANNER application, it is possible to jump to other applications and retain the current parameter settings.

The CALL TRACE application (Fig. 4) monitors a connection from set-up to clear-down. Handover, which occurs when a mobile station moves from one cell to another, is a special case when monitoring a connection. This application provides all relevant signalling information in plain test; handovers are also taken into account. Clear graphical presentation of all measurement results for the base transceiver station and mobile station on the selected connection simplifies troubleshooting of handover problems.

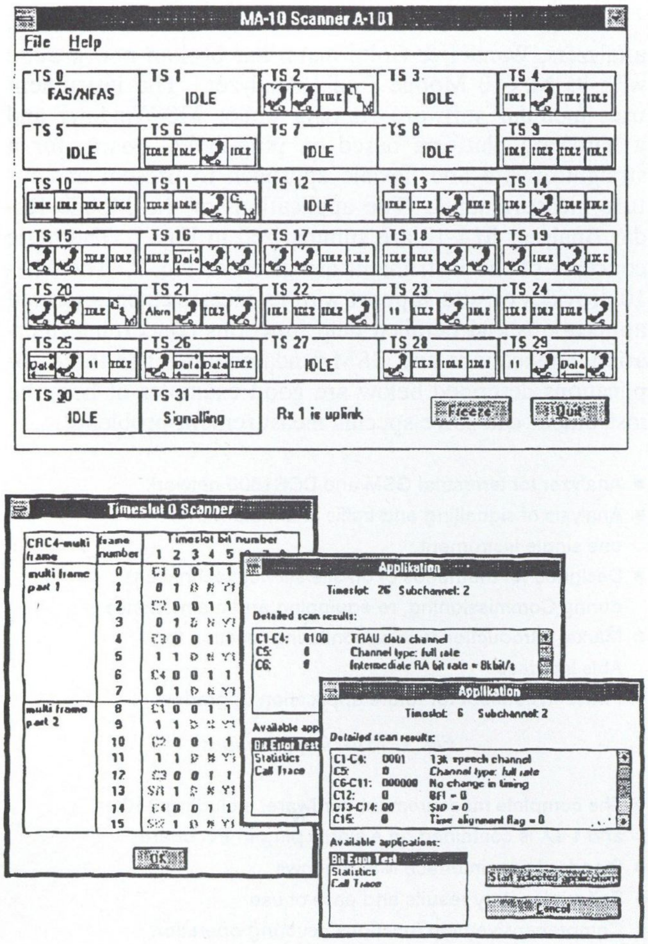


Fig. 3. SCANNER application
a) determining the content of a 2 Mbit/s frame
b) detailed analysis of traffic channels

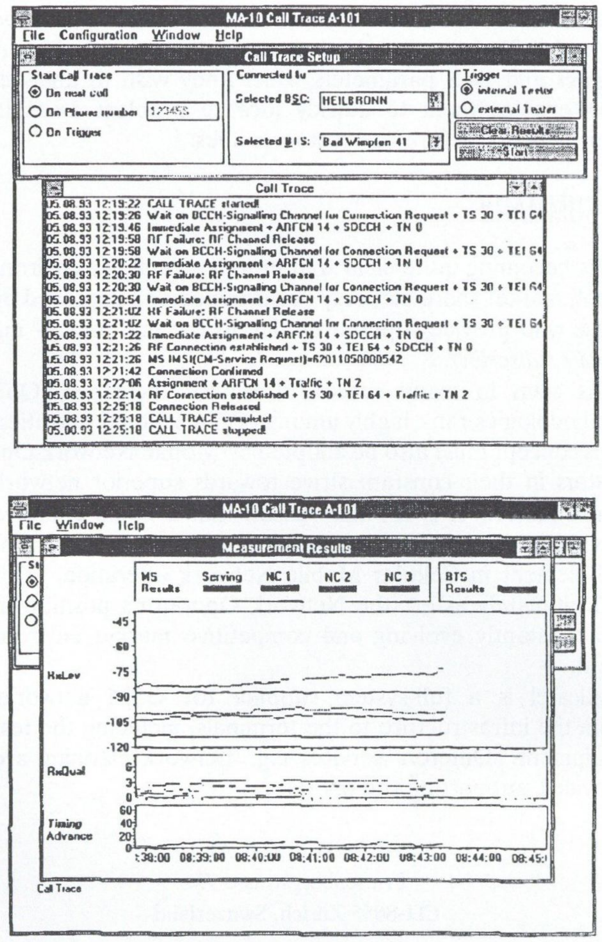


Fig. 4. CALL TRACE application
a) listing connections from set-up to clear-down
b) graphic representation of measurement results

Problems in the GSM network cannot always be isolated based on the signalling information. In such cases, the MA-10 Mobile Radio Analyzer can also analyze the traffic channels. In the BERT application, the instrument can measure bit errors in the frame alignment signal, in the sync pattern and in the data bits. Error measurements are thus possible both in and out of service. Results can be displayed as plain text or graphics, as shown in Fig. 5.

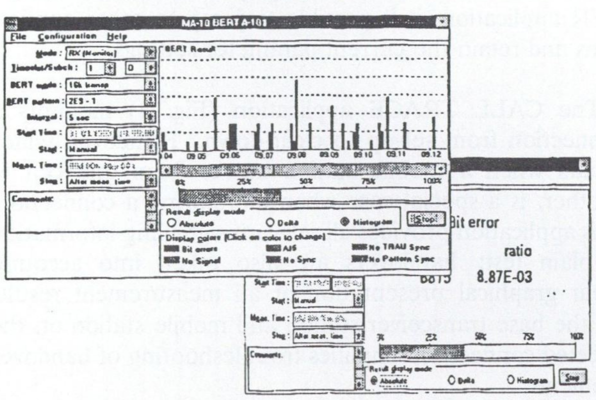


Fig. 5. BERT application, numericl or graphic representations

Interesting features of the MA-10 include the hardware design (the entire mobile radio analyzer is built on a single plug-in PC board) and the software structure (the software provides complete support for MS-Windows, the most common operating system for PCs). The software takes advantage of all the possibilities of this user interface, such as simultaneous display of multiple graphics windows in color, a standard data format for exporting results and context-sensitive help functions.

By using multiple plug-in PC boards, the MA-10 can be upgraded to have up to four ports (8×2 Mbit/s links). This new mobile radio analyzer from Wandel & Goltermann shows that it is possible to present complex procedures in a clear, concise manner for faster solutions to measurement problems.

WANDEL & GOLTERMANN GmbH
72800 Eningen, Germany

ROHDE & SCHWARZ TEST SET FOR PRODUCTION AND SERVICE OF GSM MOBILE STATIONS

The digital radiocommunication test set CMD is a second generation instrument for the production and service measurements of GSM mobile stations.

FEATURES

- easy to use
- extra low price
- small dimensions
- light weight
- rapid go/nogo tests
- important signallization parameters displayed
- options for additional more detailed tests

APPLICATIONS

- Production tests
  - Transmitter measurements
    output power
    frequency
    modulation
  - Receiver measurements
    different bit error rates
- Service tests
  same as in production tests
  supply current and voltage
  microphon and loudspeaker test

The most important signallization procedures are performed simultaneously with the measurements. This includes the build up of the connection from the mobile station to the base station, the frequency selection, the power selection, the time-slot assignment and finally the disconnection of the stations.

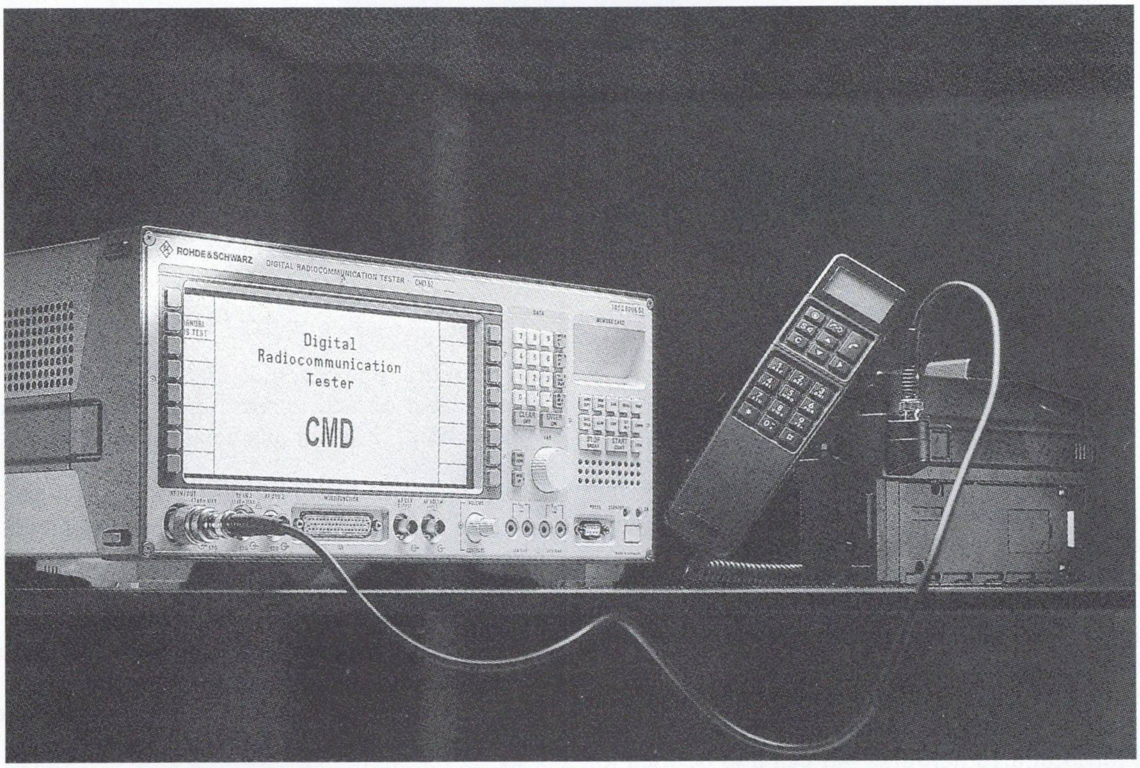


Fig. 1. GSM mobile telephone testing with Digital Radiocommunication Tester CMD

CHARACTERISTICS

- Measurements with the basic instrument
  - synchronization mobile stations/base stations
  - location updating
  - build up of incoming/outgoing connections
  - transmitter power selection
  - channel selection
  - peak power
  - display of RX LEW, RX QUAL, Power level
  - echo test
  - disconnection mobile station / base station
  - supply current — voltage
- Measurements with option CMD-B4
  - phase and frequency error masurement
  - burst-power measurement

ROHDE & SCHWARZ GmbH
Mülldorf-Strasse 15.
München, Germany

CABLE TESTING AND FAULT LOCATION WITH SEBA DYNATRONIC INSTRUMENTS

Seba Dynatronic manufactures and sells test equipment and fault location equipment for symmetrical telecommunication cables, fibre optic cables and power cables.

Out of our range of products we introduce several instruments for telecommunication cables and fibre optic cables, both for local area and long distance applications.

The Kabellux 3T shown in Fig. 1 is a battery powered light weight instrument, designed to locate cable faults with the pulse-echo-technique. The Kabellux 3T is a most advanced, fully digital instrument for locating faults up to 20 km with menu-driven operation.

The test set is equipped with a large LCD display with special Zoom functions and V.24 interface for printout facilities and download functions to a remote computer.

The very rugged waterproof housing is designed for extensive field use.

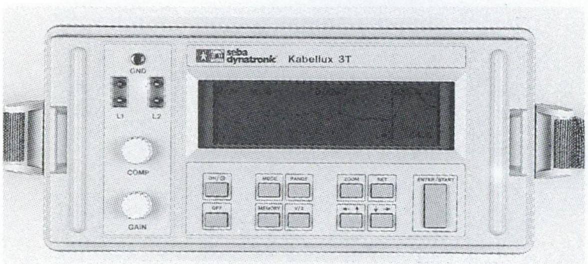


Fig. 1. Kabellux 3T

The cable test set KMK-VI is a general purpose bridge instrument designed for exact fault location, routine and maintenance measurements like counductor resistance, insulation resistance and mutual capacitance.

The instrument is powered either by internal NiCd-battery (battery charger included), external battery or mains supply. The splash proof metal housing protects the test set even under severe field conditions.

The Bartec 10T is fully automatic, menu-driven measuring set for fault location up to 10 MOhms. It is specially designed for local area networks but can also be used for medium distances.

The Ferrolux 8-3Q consists of a transmitter and receiver with search coil. The instrument serves for cable tracing, cable identification and location of faults, joints and coil boxes.

The transmitter provides an output of max. 8 W with automatic matching and frequencies of 480, 1490, 9820 Hz.

The Ferrolux receiver provides search frequencies of 50, 480, 1450 and 9820 Hz with a narrow and wideband microphone channel. A large number of accessories is available for different measurering purposes.

For attenuation measurements of fibre optic cables the test pair OPM-12 and OPS-12 is designed. The instruments are shown in Figs. 2 and 3, respectively.

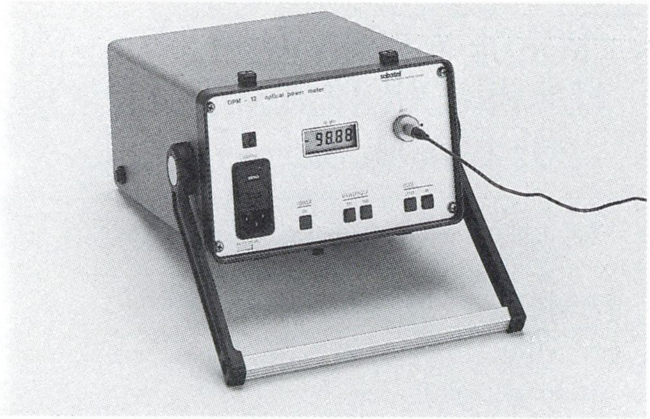


Fig. 2. OPM-12

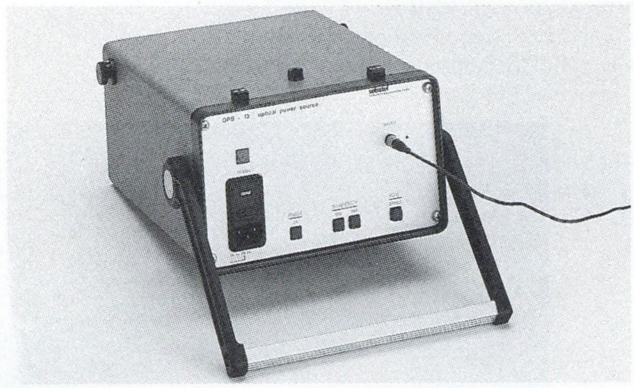


Fig. 3. OPS-12

The optical power source OPS-12 provides an independently stabilized and temperature controlled dual output level at both 1275 nm and 1566 nm with a line width of ± 3 nm.

Wavelengths of 1275 nm and 1566 nm have been chosen as these are the points where fibre attenuation is the highest within the optical window.

The optical power meter OPM-12 has a large dynamic range with high resolution and accuracy.

This design makes the set an ideal tool for all areas of application, from approval measurements on installed fibre optic cable links in the field to precise attenuation measurements in quality assurance and in the laboratory.

The optical time domain reflectometer CAF Lambda uses plug-in-units for different wavelengths. Plug-ins for 850 nm and 1300 nm (multimode), 1300 nm and 1550 nm (single mode) are available. By measurement of the backscatter light intensity, measurements of fibre length (fault location), fibre attenuation, the splice attenuation can be determined.

The CAF Lambda has a high dynamic range and can test fibres up to a length of 100 km.

For further information:

SEBATEL TELEKOMMUNIKATIONSTECHNIK GmbH
SEBA DYNATRONIC MEß- UND ORTUNGSTECHNIK GmbH
Industriestr. 6. D-96148 Baunach, Germany

PORTABLE TELECOM/DATACOM ANALYZER FROM VOICE TO ISDN

As public and private communications systems evolve into complex, integrated networks, user demands for guaranteed quality-of-service creates significant installation, maintenance and monitoring problems. Schlumberger Technologies Communication Test is the first to provide a comprehensive, practical solution with the introduction of the SI 7705 field-portable, telecom/datacom analyzer (Fig. 1).

This cost-effective unit builds on the company's extensive experience and installed base in both low and high bit-rate data transmission analyzers.

This extremely versatile analyzer offers over 50 different bit-rates, frame structures and interfaces for integrated voice, data and telecommunications applications — including ISDN transmission tests. Bit and block error rate testing, detailed timing analysis and comprehensive disturbance generation ensure transmission equipment and networks can be fully qualified and monitored to a wide range of CCITT Recommendations. The combination of easy-to-use operator interface, large graphic display, integrated high-speed printer, programmed configurations and long-term results storage ensure this compact unit is ideal for network installation and maintenance engineers. Built-in RS232C and IEEE 488 interfaces simplify integration into laboratory, production test and in-service network quality monitoring systems, including the company's established VEGA network qualification, surveillance and supervisory system for G.821 and M.550 monitoring.

All interfaces necessary to manage cross-network connections are standard in this multipurpose instrument, including CCITT G.703 at 64 kbit/s, 704 kbit/s and 2 Mbit/s, and synchronous V.36 with adaptation cables for V.35, V.24 and V.11. Analogue investigation is facilitated through bi-directional A/D/A converters which allow voice signals to be digitized to/from a 64 kbit/s codirectional signal or any 2 Mbit/s time-slot. Independent bit-rate operation on transmit and receive channels enables the unit to mux/demux voice and data tributaries with the main signal, and to manage telecom and datacom signals simultaneously. This high level of functional integration — in a portable unit — dramatically eases the overall tasks of network installation and maintenance engineers. Additional interfaces are available for X.21, G.703 co-contra and the Eurocom military network standard.

In addition to conventional telecom and datacom applications, the SI 7705 also addresses the evolution of conventional telecom and datacom networks into full ISDN networks. Built-in ISDN S_0 measurement facilities include automatic call and release, notably the ability to simulate traffic by calling 10 different numbers in sequence, and statistical analyses of network accessibility and transmission quality. Error performance measurement of higher speed ISDN S_2 lines is provided by CCITT G.96y frame management at the T_2 interface.

Comprehensive disturbance generation — necessary for the thorough testing of transmission equipment and networks — includes error insertion at signal, tributary and frame levels, alarm and loss of signal simulation and slip generation. Measurement, capabilities include G.821/M.550 qualification, G.822 slip performance, frequency and delay time propagation at signal and tributary levels. Configuration setups can be stored, identified and recalled at any time, simplifying on-site testing of both in-service and out-of-service equipment. The unit can store up to 2.000 results for retrieval later over the RS232 interface by in-service network monitoring systems, such as Schlumberger's VEGA, or can display graphically on the 7" electroluminescent display.

Qualification of integrated voice/data networks and their interconnection with telecom networks requires the simultaneous management of multiple frame structures. The multipurpose SI 7705 provides this transhierarchical multiplexing, enabling the analysis of, for example, a low bit-rate voice or a data pattern in an X.50 frame structure in a time-slot in a 2 Mbit/s frame.

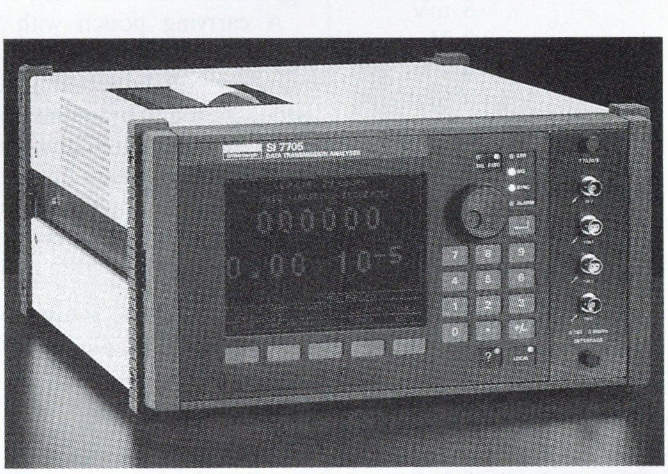


Fig. 1. The SI 7705 analyzer

SCHLUMBERGER TECHNOLOGIES
Budapest office:
H-1991, Budapest, Üllői út 200.

REAL-TIME ACOUSTO-OPTICAL SPECTRUM ANALYZER (RTSA-3)

The equipment is a real-time spectrum analyzer operating in the frequency range of 30–90 MHz within two subbands: 30–60 and 60–90 MHz. Several radio irradiation can be detected simultaneously with pulse duration not less than 10 μs. Rapidly changing as well as frequency hopping signals can also be detected and monitored.

The most advantageous feature of this system is its extremely fast time-to-frequency transformation capability in a broad radiofrequency range utilising acousto-optical method. The input electric signal is converted to a periodic optical phase grating, in an acousto-optical crystal (or Bragg-cell), due to the photoelastic effect. This grating diffracts a laser light beam, incident to the Bragg-cell, with an angle and intensity proportional to the instant electric frequency and power, respectively.

The operation of the system is based on two, high resolution, acousto-optical Bragg-deflector cells.

Technical specifications

General parameters:

Total frequency band:	30-60-90 MHz
Sensitivity:	−110 dBm
Input impedance:	50 Ω
Linear dynamic range:	25 dB
Frequency resolution at -3 dB points:	30 kHz
at 25 dB input dynamics:	40 kHz
at 40 dB input dynamics:	200 kHz
Min. detectable pulse duration:	10 μs

Optical unit:

AO-cell material:	TeO_2
He-Ne laser source:	633 nm
Number of optical channels	2
Detector type: RL2048D (antiblooming)	

Video output:

Analog output channels:	8
pp noise:	8 mV
output range:	0-2 V
Digital output channels:	4
accuracy:	8+8 bits
Data processor: IBM PC/486 & data interface	
Number of storable frames	512

Displaying modes: numerical data list
power-frequency monitoring
power-frequency-time waterfall diagram

Mechanical and electric data

Operating temperature:	-5...+50 °C
Shock and vibration (not in operation):	3 g
Power consumption: 220V/50-60Hz/0.6A	
Dimensions (DxWxH) and weight	
optical unit: 440x300x800	45 kg
electronic unit: 440x530x240	14 kg

TECHNICAL UNIVERSITY OF BUDAPEST
Department of Atomic Physics
H-1521 Budapest, Hungary

THE FIRST CORDLESS MICROWAVE POWER METER

The new 6970 RF power meter from Marconi Instruments is the first RF and microwave power meter to provide accurate benchtop instrument capability in a rugged, hand-held portable unit. This unique cordless instrument covering 30 kHz to 40 GHz provides similar functionality to currently available bench power meters at approximately half the cost.

Measuring power levels in microwave links is just one of a wide range of applications for the 6970. It is also used to measure power in a wide variety of RF and microwave transmitters, receivers and radar systems. Other areas of use include telemetry and communications links used in transport and by public utility organizations.

Compatible sensors

The 6970 uses the same wide range of power sensors as the Marconi Instruments 6900 series benchtop power meters and 6200 series microwave test sets.

With coverage from 30 kHz to 40 GHz at power levels of −70 dBm (100 pW) to +35 dBm (3 W), each sensor is individually calibrated and supplied with calibration data. The optional internal calibrator produces a 0 dBm 50 MHz power reference which is traceable to national standards, giving the 6970 accuracy equal to bench top instruments – an accuracy of ± 0.2 dB can be achieved.

The 6970 features a large four digit LCD display, analog peaking indicator to assist with power adjustments and an audible pass/fail alarm to indicate when pre-set limits are exceeded. Power levels can be displayed in a choice of measurement units which include dBm, dBV or Watts.

Low cost and portable

The instrument is ideal for maintenance purposes because of its low cost and portability – it weighs only 0.5 kg, and measures 88×190 mm (3.5×7.5 in).

A carrying pouch with belt-loop and shoulder strap makes it ideal for field use. Small size and excellent accuracy will appeal equally to development as well as production environments; low cost allows the instrument to be provided on a 'one-per-engineer' basis.

The built-in battery provides up to eight hours continuous operation; the 6970 can be powered from an AC line whilst simultaneously recharging. The 6970 can also be operated from a vehicle's cigar lighter socket.

MARCONI INSTRUMENTS LTD.
St. Albans, Hertfordshire, AL4 OJN, England

COUPLED DIFFUSION IN SEMICONDUCTOR CRYSTALS

H. SOMOGYI

DESIGNSOFT INC.*
H-1104 BUDAPEST, KADA U. 126.

The solid solubility limit of dopants is taken into account directly for explaining the characteristics of coupled diffusion in crystals. One of the anomalous phenomena, occuring in bipolar semiconductor technology, the base-dip formation have been calculated by computer, using a new system of partial differential equations, which is derived from the role of solubility limit. Brief survey of former theories and computational results are presented. As a conclusion, solid solubility may affect seriously simultaneous diffusion, hence it is worth considering beside other known factors.

1. INTRODUCTION

Coupled diffusion occurs during IC fabrications in the steps of diffusion, drive-in or annealling. The coupling is mostly not desired but must be handled and controlled. Here I will show that the generation of a dip in the base profile near to the emitter-base junction can be explained by the solid solubility limit only.

2. EXPERIENCES

The experienced phenomenon to be investigated is the anomalous diffusion of base dopants within the emitter region. At the emitter-base junction the base diffusion is retarded and a local drop in the base concentration is generated (called base-dip). Such phenomenon has been thouroughly measured and reported by Fair [6]. Fig. 1 demonstrates dopant profiles indicating the base dip formation.

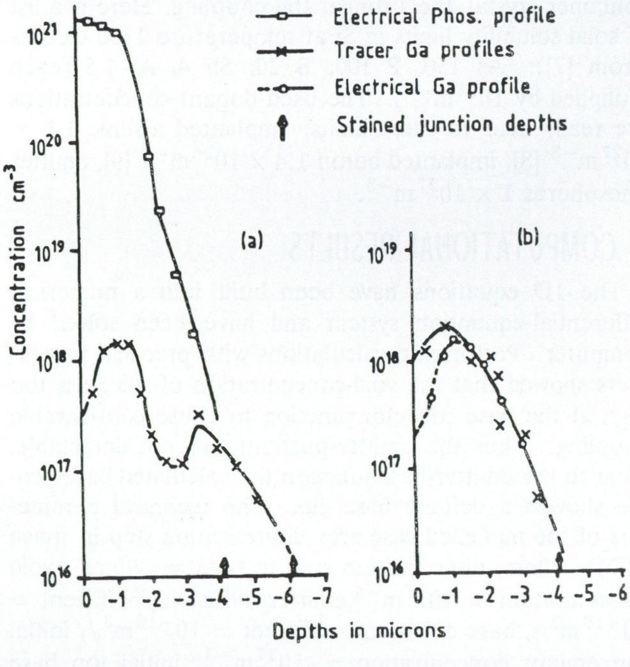


Fig. 1. Experimental profiles from [5]. (a): 15 min/1100C° Ga diffusion followed by 3.5 min/1050C° P diffusion; (b): the Ga diffusion only

Though there have been many diffusion modelling differential equations introduced — none of them gives clear explanation of the case. The most frequently considered subsidiary factors are (beside the basic concentration gradient): dopant concentration, the role of electric field, the ratio of charged dopants, intrinsic electron concentration, electron concentration (conductance band), vacancy concentration, modes of diffusion (interstitial or substitutional), clusterization or precipitation. Any of these factors alone could cause coupling. One of the strongest factors is the electric field (see eg. [1]). However still one circumstantial parameter has been neglected. It is the fact, that there is a limited amount of locations in the crystal for the dopants during their motion. By other words the role of the solid solubility limit has not been taken into account.

3. EARLIER EXPLANATIONS

In [2] the formula of the base diffusivity includes the concentration of lattice sites (via vacancy distribution), the formula is far from being general ("approximate theory"), e.g. it assumes special initial profiles. The same authors in [3] could model the generation of base-dip by the role of the electric field and vacancy concentration. The authors established a continuity equation, with considering the role of the internal electric field and the intrinsic variation of the equilibrium lattice vacancy concentration. Their 1D results for the boron flux (J_B) and arsenic flux (J_{As}):

$$J_B = -D_{B_O} h_1 \frac{\partial C_B}{\partial x} + D_{B_O} (h_1 - 1) \frac{\partial C_{As}}{\partial x}$$

where

$$h_1 = 1 + \frac{C_B}{2n_i} \frac{1}{\sqrt{\left(\frac{C_{As} - C_B}{2n_i}\right)^2 + 1}}$$

where C_B and C_{As} are the appropriate concentrations, x is the spatial 1D coordinate, n_i is the intrinsic conductive electron concentration, D_{B_O} is the boron diffusivity without coupling. We will see how similar this equation is to equation (3) derived later from my model. Both predicts that in addition to the normal boron flux, there is a flux component proportional with D_{B_O}, with C_B, and with grad C_{As}. Many of the characteristics of base-pushout along with measurement are presented in [4] and [5]. The authors studied the phenomenon and made measurements by junction-depth methods and a radiotracer to trace Ga isotopes. By the help of the tracer the base-dip in the emitter region was discovered. The authors introduced a diffusivity enhancement factor but without any physical background.

* This article was written at the Department of Theoretical Electricity, Technical University Budapest

In [5] the mechanism was thought to have excessive mobile point defects generated by high emitter concentration. The base-dip was considered as the result of the existing electric field.

The authors of [6] based their explanation of pushout on the electrically inactive phosphorus atoms, the dependence of the diffusivity on the charge of involved vacancies, the I-V pair dissociation and the excess V^- concentration. Their model is rather empirical. In their another work [10] they derive the following expression for boron diffusivity:

$$D_B = D_{B_O}\left(1 + \frac{C_B - C_{As} + (1/\Omega)^2}{2\sqrt{\frac{1}{4}\left(C_B - C_{As} - 1/\Omega\right)^2 + C_B/\Omega}}\right)$$

where Ω is a constant for the pair-concentration equilibrium. They studied the $C_{As} >> C_B$ case, and found that D_B becomes roughly $D_{B_O}/\left(1 + \Omega C_{As}\right)$. Supposing that $\Omega C_{As} << 1$ we get that D_B is roughly $D_{B_O}\left(1 - \Omega C_{As}\right)$. This indicates that the boron flux has a component proportional to C_{As} and grad C_B — as my equation (3) states it as well.

In [7] there are two main reasons mentioned. The first is the concentration gradient induced electric field that pulls back some base dopants and causes the base-dip. The second is the generation of point defects in the emitter-region by the dissociation of I-V pairs.

4. MODEL OF COUPLED DIFFUSION

In my model the diffusion is affected by the solid solubility limit together with the concentration gradient.

The model is built up from the atomic level, by modelling the random jumps of impurities. Results will conserve Fick's two laws. The analysis is done in 1D, but the results can be easily extended to 3D.

Let us suppose that there are sites for dopants along the x axis with Δx equidistances. Let there be at each site enough room for N dopant atoms.

Atoms can jump at farthest to the adjacent sites. The jumps occur (if occur) simultaneously, one in every Δt time.

The basic idea is that the numer of "succesfull" jumps of certain type of atoms from the i-th site to the $i+1$-th one is proportional to the number of atoms of that type that attempt a jump and to the number of free locations at the destination site.
Thus:

$$\begin{aligned} F^A_{i\to i+1} &= \alpha_A A_i\left(N - A_{i+1} - B_{i+1}\right) \\ F^A_{i\to i-1} &= \alpha_A A_i\left(N - A_{i-1} - B_{i-1}\right) \end{aligned} \tag{1}$$

where F^A is the flux, A_i and B_i are the numbers of dopants at site i, for impurities A and B, respectively. Expressions for F^B are similar.

Let us assume that jumps are attempped — synchronously — in every Δt time interval. Thus the net flux of dopant A between the i-th and $(i+1)$-th sites

$$J^A_i = \frac{F^A_{i\to i+1} - F^A_{i+1\to i}}{\Delta t} \tag{2}$$

Moving into the continuous domain:

$$\begin{cases} J_A = -D_A \dfrac{\partial}{\partial x} a + \dfrac{D_A}{n}\left(b\dfrac{\partial}{\partial x} a - a\dfrac{\partial}{\partial x} b\right) \\ J_B = -D_B \dfrac{\partial}{\partial x} b + \dfrac{D_B}{n}\left(a\dfrac{\partial}{\partial x} b - b\dfrac{\partial}{\partial x} a\right) \end{cases} \tag{3}$$

where $D_A = \alpha_A \Delta x^3 n/\Delta t$, and D_B is a similar expression. Here n is the constant concentration of voids.

The analogous result in 3D is:

$$\begin{cases} \underline{J}_A = -D_A \operatorname{grad} a + \dfrac{D_a}{n}(b \operatorname{grad} a - a \operatorname{grad} b) \\ \underline{J}_B = -D_B \operatorname{grad} b + \dfrac{D_B}{n}(a \operatorname{grad} b - b \operatorname{grad} a) \end{cases} \tag{4}$$

Besides b grad $a - a$ grad $b = b^2$ grad $\frac{a}{b}$.

5.INTERPRETATION OF THE NEW DIFFERENTIAL EQUATIONS

In the absence of dopants B we get Fick's diffusion equation for dopant A. When $n >> b(\underline{r})$ and $n >> a(\underline{r})$ the two equations become independent, as we would expect.

Equations (4) may be easily generalized for cases with more than two types of dopans.

The resulting flux consists of an ordinary part $-D_A$ grad a, and an extra component

$$\frac{D_A}{n}(b \operatorname{grad} a - a \operatorname{grad} b).$$

In regular lattices the void concentration (n) can be derived from the structure of the crystal cell — assuming that interstitial motion dominates. The concentration of point defects may increase this concentration. In silicon there are 8 voids per cell, thus $n = 50 \times 10^{27} m^{-3}$.

According to the new model the nearer the total concentration to the void concentration, which roughly equals with the solid solubility limit of a dopant in the container crystal, the stronger the coupling. Here is a list of solid solubility limits in Si at temperarure 1100 Celsius (from [7]): As 150, P 100, B 20, Sb 4, Al 1.5 (each muliplied by $10^{25}\mathrm{m}^{-3}$). The used dopant concentrations are really near to these limits: implanted arsenic $1.5 \times 10^{27}\mathrm{m}^{-3}$ [8], implanted boron $1.4 \times 10^{26}\mathrm{m}^{-3}$ [9], emitter phosphorus $1 \times 10^{27}\mathrm{m}^{-3}$.

6. COMPUTATIONAL RESULTS

The 1D equations have been built into a numerical differential-equantion system and have been solved by computer. Performing calculations with practical parameters showed that the void-concentration of silicon is too high at the base-collector junction to cause considerable coupling. Thus the emitter-pushout was not detectable. Near to the emitter-base junction the calculated base profile showed a definite base dip. The technical parameters of the modelled case are: discretization step in space (1D)= 10nm, discretization step in time = 300ms , void concentration = $10^{27}\mathrm{m}^{-3}$,emitter diffusion coefficient = $10^{-18}\mathrm{m}^2/\mathrm{s}$, base diffusion coefficient = $10^{-16}\mathrm{m}^2/$, initial top emitter concentration = $10^{27}\mathrm{m}^{-3}$, initial top base concentration = $10^{25}\mathrm{m}^{-3}$.

The collector profile had no role in the calculation at all, it is constant.

At depth = 0 and 3μm the fluxes were zero.

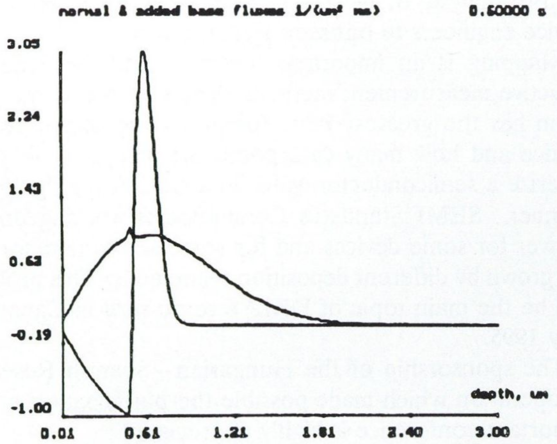


Fig. 2. The ordinary and the additional base fluxes at the start of diffusion. The major peak in the added flux causes the depletion of base impurities, thus the base-dip. See text for more details.

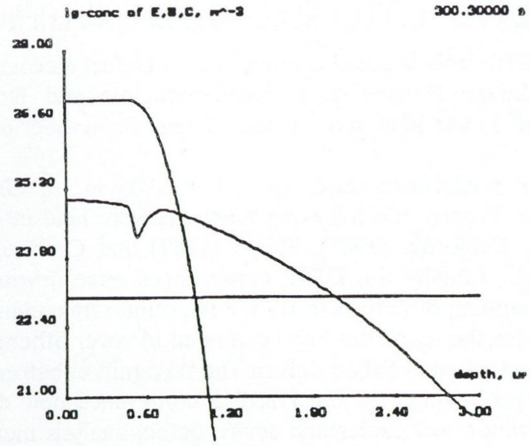


Fig. 3. The generation of base-dip due to coupled diffusion after 300 *s heat treatment. See process and calculation parameters and more details in text.*

7. ACKNOWLEDGEMENT

I have received beside an initial inspiration for investigating diffusivity processes much help from Professor László Zombory — for which I am very thankful. Also, I received valuable hints for literature sources from Prof. Vladimir Székely.

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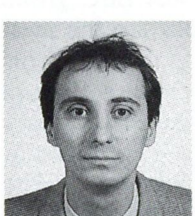

Henrik Somogyi graduated in electrical engineering at the Technical University Budapest, in 1986. His special interest area was the theory of pseudorandom number generators (finalist's report, diploma theme) and statistical system analysis "Frequency-hopped packet telecommunication", Microcoll Conference 1986, Budapest). In 1986 he worked at LM Ericsson in Stockholm. From 1986 to 1989 he did reserch concerning the yield of IC fabrication processes, at the Dep. of Theoretical Electricity of TUB. He held practical lessons at TUB. In 1989 he worked as a CAD expert for RAIR Computers Ltd. From 1990 he studied the 80486 based X25-linked systems in France (CERMP, Nantes). From 1993 he has been working on a digital circuit analysis CAD tool for DesignSoft. He is a member of the Scientific Association for Telecommunications in Hungary.

News-Events

DRIP 5 – DEFECT RECOGNITION CONFERENCE

The Fifth International Conference on Defect Recognition and Image Processing in Semiconductors and Devices (DRIP 5) was held in Santander, Spain, September 6–10, 1993.

The conference series started in 1985 in La Grande Motte, France, the following meetings were held in Monterey, California (1987), Tokyo (1989) and Ceshire, UK (1991). Initially the DRIP conferences were devoted to the mapping of defects in III-V compound semiconductors but later the scope has been extended to cover other semiconductors and of their defects the recognition before and after processing. At the DRIP 5 conference new defect recognition techniques and device defect analysis methods have been presented.

More than 100 participants represented 23 countries: Belgium, Bjelorussia, Canada, China, France, Germany, Hungary, India, Italy, Japan, Lithuania, Marocco, Moldavia, Poland, Russia, Sweden, Switzerland, Singapore, Spain, Tunesia, Turkey, United Kingdom and USA. Nearly each participant had an oral or poster presentation. At the Technical Exhibition Microsciencia S.A., Laser Technology, Lot Oriel, Cryophysics, Microbeam Topometrix, Lasing-Burleigh, Instrumat-Digital Instruments, Carl Zeiss, Photonetics, Ballestro y Cia-MCP, Optilas, Iberia displayed their new instruments applicable for defect recognition near the atomic level.

The most important new measuring methods of the 90's are the followings:

- Scanning Tunneling Microscopy (STM)
- Scanning Tunneling Luminescence (STL)
- Atomic Force Microscopy (AFM)
- Laser Scanning Tomography (LST)
- Extended X-Ray Absorption Fine Structure (EXAFS)
- Interface Image Recognition (IIR) by μRaman spectroscopy
- Emission microscopy

STM and STL are mostly used for investigating nanometric semiconductor structures. AFM is suitable for several defects at atomic level to control the roughness at the Si/SiO_2 interface. In presently used 0,35 μm CMOS design rule technologies the oxide thickness is less than 100 Å, in such cases the roughness of 5 Å has degrading effect on the channel mobility.

LST is especially important in determining dislocations in the production lines of boat grown and LEC grown GaAs single crystals. Further applications are the measurement of diffusion length of minority carriers in silicon, investigation of defects on and just under the surface of semiconductors and insulators. LST is based on elastic light scattering in contrast to the μRaman spectroscopy which utilizes the inelastic mode of light scattering. With the Raman-microprobe investigations can be made with a lateral resolution of about 1 μm. Depth profile measurements are performed by changing the wavelength of excitation. Line shape analysis of the Raman signals gives quantitative information on strains in the materials and on associated defects or doping levels as well.

Emission microscopy is used for chip verification and failure analysis of devices. It provides a technique for device engineers to optimize test structures.

Mapping is an important feature of all these nondestructive measurement methods. The question is which of them has the greatest value for predicting device performance and how many data points are necessary to characterize a semiconductor wafer in a statistically significant manner. SEMI Standards Committee is working on the answer for some devices and for some semiconductor layers grown by different deposition techniques. This problem will be the main topic of DRIP 6 to be held in Canada in July 1995.

The sponsorship of the Hungarian–Spanish Research Cooperation which made possible the participation at this important conference is highly appreciated.

T. KORMÁNY
Dept. of Electron Devices
Techn. Univ. of Budapest

DESSAULT PRESENTS CORDLESS TELEPHONE IN HUNGARY

DASSAULT AUTOMATISMES ET TELECOMMUNICATIONS, a French company represented by TELECOMFORT in Hungary, presented personnal cordless telecommunication systems during the seminar about telecommunications in Sopron the 24th and 25th of August.

These systems are based on the use of the CT2-CAI standard (864-868 MHz) which is used around the world. DASSAULT AUTOMATISMES ET TELECOMMUNICATIONS provides two types of applications:

- The first one grants mobility to the user and uses personnal portable cordless telephones, allowing the access of the public network (PSTN) or private networks (PABX).
- The second one is a fixed radio telephone station. This system, used for remote or rural subscribers is transparent for the user and its installation is quick and economic.

Both systems offer two way calling (incoming and outgoing).

During the two day seminar, DASSAULT AUTOMATISMES ET TELECOMMUNICATIONS installed a base station serviced by Dassault corless telephones.

The participants were able to use the system throughout the hotel. It was a greet success. ■

EXHIBITORS AT THE TELECOMMUNICATIONS SYSTEMS MEASUREMENTS SEMINAR

■ SIEMENS AG

Amt V331
D-81730 München
Phone: (49-89)41447123

Mr. Nagy
H-1036 Budapest
Lajos u. 103.
Phone: (36-1)168-9498

Siemens, a global telecommunication manufacturer, develops its own test equipment. The resulting experience gained, from the whole spectrum of communications technology, is embodied in these test equipment. The result: a complete range of modern high performance products especially for the latest technologies i.e. ISDN, SDH, ATM, GSM. ■

■ ELEKTRONIKA

Telecommunications Test Equipment
H-1135 Budapest, Reitter Ferenc u. 52-54.
Phone: (36-1)140-2136/140-2137; Fax: (36-1)140-2139

ELEKTRONIKA is the largest Hungarian manufacturer of telecommunications test equipment. One of the latest and most sophisticated ELEKTRONIKA products is the PCM Multiplex Analyzer EP-1. This measuring equipment is controlled by an IBM PC developed for automatic testing of primary PCM systems during manufacturing, installation and maintenance according to the relevant CCITT recommendations. It supports user-friendly processing and display. ■

■ ROHDE & SCHWARZ GmbH & Co. KG.

Mühldorfstrasse 15., D-81671 München
Phone: (49-89)4129; Fax: (49-89)4129-2164

Rohde & Schwarz is an internationally active company in the fields of radiocommunications and measuring equipment. With 5000 employees worldwide and an international network of sales organizations, the Rohde & Schwarz company group attained a turnover of around DM 950 million in the business year 1991/92.

Main fields of activity:

- mobile radio, sound and TV broadcasting (communications and measurements)
- radiocommunications
- EMC and general-purpose measurements ■

■ CLEMESSY Electronique

18, Rue de Thann – BP 2499
68057 Mulhouse Cedex – France
Phone: (33-89)323232; Fax: (33-89)323203

Clemessy Electronique offers a large range of equipment: signalling and/or traffic simulators/analyzers, transmission media testers, message diffusers. These pieces of equipment serve the need of exchange manufacturers and network users in validation – certification, reception of equipment and/or software, measurement of maintenance, planning and service quality, and the enhancement of existing services. Traffic analyzers, PCM and CCS-7 trunks will be exhibited. ■

■ ELSINCO BUDAPEST KFT.

H-1136 Budapest, Pannónia u. 8. IV/1.
Phone: (36-1)269-1850; Fax: (36-1)132-6515

ELSINCO is a marketing and service organization with its Headquarter in Vienna, Austria. ELSINCO is active in Austria and the Eastern European countries, being the exclusive distributor of 6 electronic instrument suppliers: Anritsu (Japan), Audio precision (USA), KIKUSUI (Japan), LeCroy (USA), MAGNI (USA) and EMCO (USA). ■

■ CONSULTRONICS EUROPE Ltd.

Omega Enterprise Park, Electron Way, Chandlers Ford, Hants. UK. SO5 3SE. Fax: (44-703)270-333
Hungarian representative: Turáni József
H-1125 Budapest, Dániel út 34.; Phone: (36-1)135-5632

The Consultronics products are available for testing analog, digital, modem, fax, PCM and ISDN services. A number of telecommunications simulators are provided for laboratory applications and production testing. List: Transmission Impairment Measuring Set with Manager Software for fully automatic analysis of 2wire circuits and exchanges. Hand held Data Network Tester for Nx64 kbit to 2.048 Mbit testing with V.24, V.35 and X.21 interfaces. Automatic Modem and Fax Test System. Ruggedized PC for field applications, with Signalling analyzers. ■

■ DEPARTMENT OF ATOMIC PHYSICS

Technical University of Budapest
H-1111 Budapest, Budafoki út 8.
Phone: (36-1)166-6075; Fax: (36-1)185-3230

Research and development of technologies, devices and systems in the field of physical optics, surface physics and environmental sciences. Acousto-optic real-time spectrum analyzer with fast time-to-frequency transformation; acousto-optic RF direction finder for several radio sources will be exhibited. ■

■ SCHLUMBERGER TECHNOLOGIES

Meidlinger Hauptstrasse 46., A-1120 Wien
Phone: (43-1)222-835628; Fax: (43-1)222-832426
Hungarian representative: Miklós Kovács
H-1991 Budapest, Üllői út 200.; P/F: (36-1)127-4877

Schlumberger Technologies is an internationally known manufacturer of measuring instruments in the field of telecommunications. The instruments for digital and optical telecommunication systems have a significant share on the European market. From Schlumberger's new products the digital transmission analyzer family and the universal OTDR are especially well known. ■

■ OPTOTRANS Ltd.

H-1021 Budapest, Pálos u. 2. (Hotel Rege)
Phone: (36-1)176-7090; Fax: (36-1)176-7717

OPTOTRANS Ltd. has four main fields of activity:

- Installation and measuring of optical cables.
- System integration of computer networks.
- Planning and managing telecommunication projects based on fibre optics.
- Trading in optical fibres, connectors, measuring instruments, active and passive devices necessary for the above activities.

OPTOTRANS is the Hungarian distributor of ANDO, JDS FITEL and EXFO products. ■

■ MARCONI INSTRUMENTS LIMITED

St. Albans, Hertfordshire, AL4 OJN, England
Phone: (44-727)59292; Fax: (44-727)57481

Marconi Instruments is a leading manufacturer of test and measurement equipment for the elctronics and communications industry in all areas of development, production, maintenance, servicing and training. An extensive range of products covers the field of radio, data, telecommunications, microwave communications and television, as well as printed circuit board and electronic sub systems manufacture and assembly. ■

Information for authors

JOURNAL ON COMMUNICATIONS is published monthly, alternately in English and Hungarian. In each issue a significant topic is covered by selected comprehensive papers.

Other contributions may be included in the following sections:

- INDIVIDUAL PAPERS for contributions outside the focus of the issue,
- PRODUCTS-SERVICES for papers on manufactured devices, equipments and software products,
- BUSINESS-RESEARCH-EDUCATION for contributions dealing with economic relations, research and development trends and engineering education,
- NEWS-EVENTS for reports on events related to electronics and communications,
- VIEWS-OPINIONS for comments expressed by readers of the journal.

Manuscripts should be submitted in two copies to the Editor in chief (see inside front cover). Papers should have a length of up to 30 double-spaced typewritten pages (counting each figure as one page). Each paper must include a 100–200 word abstract at the head of the manuscript. Papers should be accompanied by brief biographies and clear, glossy photographs of the authors.

Contributions for the PRODUCTS-SERVICES and BUSINESS-RESEARCH-EDUCATION sections should be limited to 16 double-spaced typewritten pages.

Original illustrations should be submitted along the manuscript. All line drawings should be prepared on a white background in black ink. Lettering on drawings should be large enough to be readily legible when the drawing is reduced to one- or two-column width. On figures capital lettering should be used. Photographs should be used sparingly. All photographs must be glossy prints. Figure captions should be typed on a separate sheet.

ERICSSON

A Steady Hand in Telecommunication

Ericsson is one of the leading companies in the market of telecommunication. Its position rests upon the sophisticated technology, the high level system know-how and the experience in adjustment to customers' demands.

The Swedish Ericsson is active in more than 100 countries of the world. The business areas are as follows:

- ☞ Public telecommunication networks
- ☞ Mobil systems, telephones
- ☞ Communication systems for private networks
- ☞ Optical and other networks
- ☞ Components, power supply units
- ☞ Turn-key projects

Ericsson Technika is the joint venture of the Swedish Ericsson and the Hungarian Műszertechnika, and one of the most significant supplier of the Hungarian telecommunication network developing program.