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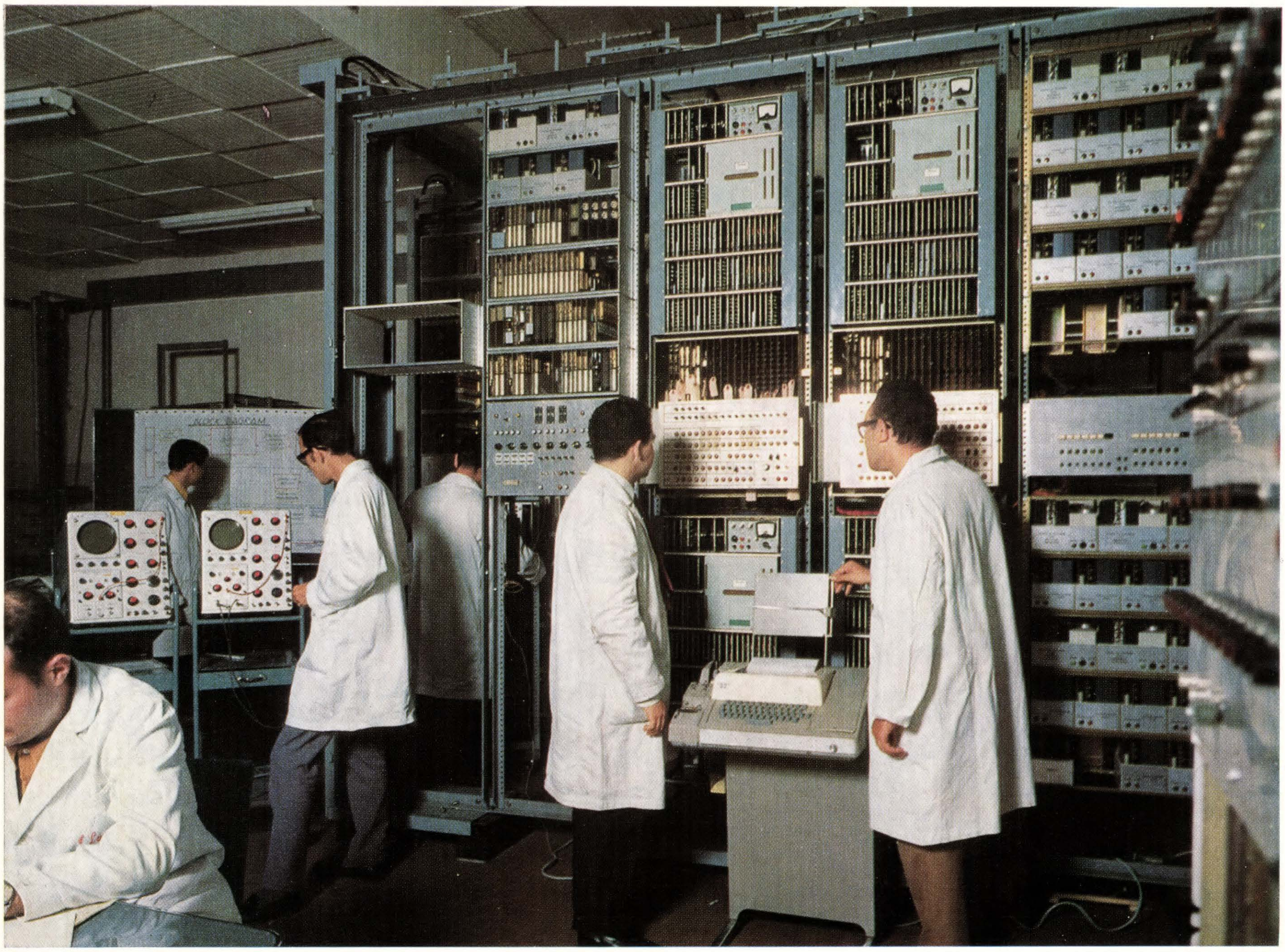

Figure 1 - Spanlab researchers have gained a capability and generated ideas that will contribute to ITT's next mainline electronic switching system. The photograph shows engineers running tests on equipment in the Semi-Electronic Switching Development Laboratory.

Technological Leadership for Newly Industrializing Countries

1. Introduction

Through one of its companies in Spain, ITT has shown how a large, multinational company can contribute to the technological development of newly industrializing nations.

In less than three years, the ITT Laboratorios de España (ITTLS) have developed a research team that has taken a lead position in some important fields within ITT's worldwide laboratory system. In other fields, it contributes routinely to research activities outside Spain. As expected, of course, ITTLS or "Spanlab" carries on regular research and planning support to its associate houses in Spain.

The implications of this are important. The effort not only has developed new research capabilities in a technologically emerging country; it has also developed specialities in which this country now holds a competitive edge in telephony research on a worldwide scale. Moreover, and this is the most promising aspect, it is an effort that can be duplicated in other countries; it could also be adopted by other multinational companies.

Spanlab was established in late 1965 as an arm of Standard Electrica SA at Madrid, one of the largest manufacturing ITT companies in Europe. It operates under the aegis of the technical office of ITT Europe.

Today it is network-design consulting for other ITT companies in Latin America, carrying out traffic studies for Germany and Belgium, developing a Europe-wide engineering information system, training ITT's technicians, and helping develop concepts that will go into the next stage of electronic telephone exchanges.

To be more specific, ITTLS has the "lead house" responsibility in ITT Europe for traffic studies. It is the principal training house for engineers and maintenance technicians in the Pentaconta telephone switching system, serving our own companies and their customers in Spanish-speaking countries. It is project leader for the Engineering Information System within ITTE's Computer-Aided Design Engineering and Manufacturing effort (CADEM).

The primary role of Spanlab is supporting Standard Electrica (SESA), as well as other ITT houses in Spain, such as Compañia Internacional de Telecomunicacion y Electronica SA, in manufacturing a broad range of private telephone switching equipment and telephone subsets.

It is to the credit of the Spanish scientific personnel that the group has been able to broaden its capabilities beyond local needs.

Indeed, a principal reason for the rapid development of these capabilities was the incentive arising from Spain's dynamic telephone expansion program. With just 3 600 000 stations in service now, the Compañía Telephónica Nacional de España (CTNE) is currently increasing the network by 10 percent a year. This has provided the economic underpinning to a research and planning drive, both at CTNE and at ITTLS.

Interestingly, too, the rapid expansion of the network into areas previously lacking service has given rise to network planning problems that did not exist elsewhere during this period. This has proved an advantage, because as often happens in research work, the first group to undertake a given set of problems becomes the leader in solving these problems.

There is another element in the Spanlab success that's worth noting. This is the fact that a country lacking a complex industrial base still may have highly developed human resources. In the case of Spain, it lacks the kind of electronics components industry required to engender or support hardware research. Yet there is strength in the mathematical sciences. For this reason, Spanlab has been able to compete on a worldwide scale by specializing in the software side of telephony — in planning and design.

All of this suggests a point that, while something of a truism, is often overlooked in national aspirations to participate in modern technology. Technology cannot simply be grafted onto a nation; it must be developed locally, based on at least a few indigenous resources.

If Spain provided the dynamic economy and the basic human resources that foster research, what then is the role of the multinational company?

It's certainly not simply the provision of capital, which can be raised in Spain for good projects. The real contribution of the multinational company is to serve as a catalyst in bringing the local elements into play. Partly, the catalyst is the long experience of a company skilled

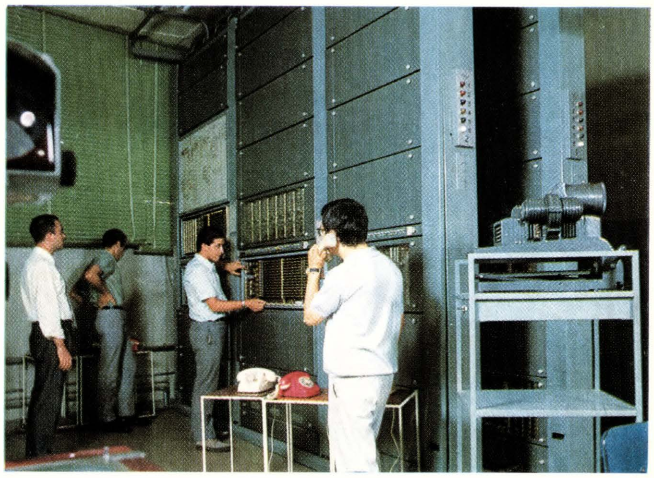

Figure 2 - The Pentaconta Switching System Trainer used for teaching engineers and technicians from the ITT system.

Figure 3 - The laboratory staff have a modern and well-organized library and reading room to research literature.

in organizing research effort. Perhaps more important is the catalytical role of worldwide links among the scientific personnel of a large company.

On the organizational side, ITT brought a number of specialists from its other European and US laboratories to form the core of a research group. Some of these men are already being phased out as Spaniards take over leadership in their four specialities: traffic studies, network planning, transmission, and CADEM. Spanlab started out with 20 professional technical personnel, now numbers 60 — in addition to another 60 or so in support personnel.

Spanlab is very tightly linked to the three other main laboratories of the ITT System, located in England, France, and the US, as well as with all the local manufacturing-company laboratories of ITT Europe. Spanlab scientists are in personal touch with other ITT laboratory staffs typically 25 times a month, through visits in both directions. Spanlab workers are not only receiving ideas and information from other ITT men; they are continually contributing. They are measuring their performance on a worldwide scale, not just against the local scene as a purely local group might have to do. For instance, a design that the Spanlab group develops may become a system-wide ITT standard.

Moreover, Spanlab researchers have gained worldwide recognition in the profession. For example two members of the ITTLS traffic group were invited to present technical papers at the fifth International Teletraffic Congress in New York last year.

The interaction between Spanlab and the rest of ITT — their mutual contributions to each other — can be seen by examining the work of some of the laboratory's divisions.

2. Telecommunications Planning Division

This group is now doing network-design consulting for other system companies in Latin America. Based on their studies of Spain's network, they have developed computer programs for optimizing the location pattern of telephone exchanges — a fundamental contribution to the economic planning of networks.

These programs grew out of the division's close cooperation with CTNE, which has established its own planning group to work on short- and long-term planning of its network expansion.

In another Europe-wide ITT activity of routine nature, the division keys its knowledge of customer requirements into the overall ITT planning for new systems and for developments in existing systems. For example, its members are taking part in programs on such subjects as automatic call charging, subscriber cables, and service quality measurement.

In effect, the division is the focal point at Spanlab for coordinating ITT Europe programs with local programs and with local customer requirements.

3. Training Division

The Training division serves two principal functions. As mentioned, ITTLS is the lead house for training Spanish-speaking engineers and maintenance technicians in the Pentaconta telephone switching system. In 1967, Spanlab trained 204 students from 10 different countries: Spain, Chile, Peru, Mexico, Argentina, Bolivia, Columbia, Nicaragua, Puerto Rico, and Brazil.

The division provides 12-week programs in maintenance and in engineering, preparing men for basic maintenance and job engineering on the Pentaconta 1000-type switching system. Through this division, Spanlab is the lead house in Spain for training university graduate students in preparation for careers in the telecommunications industry.

One reason for establishing ITTLS was to provide opportunities for the scientific and engineering talent of the country. This is done on a continuing basis via a scholarship course tied in with the University of Madrid. Sponsored by Standard Electrica SA, the program provides that company, Spanlab, and other ITT houses with a source of top-level students to draw from.

During a seven-month period, the program provides special lectures and lab training, dovetailed with the last year of instruction, for students in the telecommunications course at the University of Madrid. It is designed to intensify an engineer's background in classical telecommunications engineering and to provide him with an introduction to more modern concepts.

Some 20 students a year — roughly half the University's graduating telecommunications class — participate in this program. The program also includes students from South American universities. When they graduate, they have no obligation to ITT. Yet nearly all of the groups so far have elected to join Spanlab or SESA.

4. Electronic Switching Division

The increasing demand for flexibility in switching systems, along with the rapid advances in semiconductor technology, has led to the need, and possibility, of developing a semi-electronic switching system. The lack of a widely acceptable electronic or solid-state crosspoint has resulted in preference being placed either on a sealed reed contact or some form of crossbar switch to form the crosspoint.

Among the different possible solutions being investigated at the present time, this division has been given the responsibility for the development of the *11C* experimental system. In doing so, Spanlab researchers have gained a capability and generated ideas that will contribute to ITT's next mainline electronic system.

The *11C* system is a semi-electronic switching system that follows the space-division philosophy using a miniaturized crossbar switch in the speech network.

5. Traffic Studies Division

ITTLS also has lead house responsibility in ITT Europe for traffic studies. Theoretical work in this area is now being carried on to determine the optimum principles for electronic and Pentaconta switching system designs. A group of mathematicians, aided by computer-aided design specialists, are working on traffic theory and techniques which will lead to the most effective switching system designs ever produced.

Many of the people in this group have been trained by, and have been associated with, noted specialists in traffic theories from other European ITT Houses where in the past this sort of work was centered. However, the principal traffic-study work is now being conducted at ITTLS.

Traditionally telephone traffic studies were necessarily limited to theoretical studies. The present availability, however, of bigger digital computers — with very-high-speed and large-random-access magnetic core memories — has opened new possibilities that can support and complement theoretical studies through traffic simulations.

6. Computer-Aided Design Engineering and Manufacturing Division

Modern digital computers are increasingly becoming a very powerful tool, not only for management, accounting, and stock control, but also for technical and scientific purposes.

The CADEM division is making a major contribution to the overall ITT effort in this field. It has project leadership responsibility for the Europe-wide Engineering Information System, a computer-based system covering the different aspects of engineering, and interfacing with manufacturing.

This issue in brief

Technological Leadership for Newly Industrializing Countries.

Through its Spanish Company, Standard Electrica SA (SESA) of Madrid, ITT has, in less than 3 years, established a lead position in a number of areas for ITT Laboratorios de España (ITTLS).

The laboratory contributes with network-design consulting to other ITT companies in Latin America, is engaged in developing the most modern semi-electronic telephone switching equipment, and has a lead responsibility in traffic studies using digital computers for simulation techniques.

It has become the principal European training establishment for engineers and technicians in Pentaconta telephone switching techniques.

There is a scheme, operated in cooperation with the University of Madrid, for a 7-month scholarship course for final-year telecommunications students which combines lectures with practical training in the laboratory.

Whilst Spain lacks highly industrialized effort to support hardware research, she has a wealth of talent in the mathematical sciences. This has enabled ITTLS to compete on equal terms in software research. Thus ITTLS excels in computer-aided design techniques where digital computers are applied to solve research, engineering, and manufacturing problems.

Initially the core of the laboratory staff came from other ITT European houses and the USA, but these experts are now being phased out and replaced by Spaniards who lead a staff of about 120 compatriots — professional engineers, scientists and supporting staff.

Mexican Radio-Relay Network at 6 Gigahertz for 1800-Channel Telephony, or Television.

This equipment provides 1800 telephone channels, or a single 625-line color television program with 4 superimposed sound channels, and will be used in a network to be considerably extended to handle the traffic for this month's Mexico City Summer Olympic Games.

The network increase has posed many problems of installation time, climatic-geographic problems, and maintenance.

Radio-frequency channel arrangements have taken into account the need to have less bulky antennas mounted on low-cost towers and the density of traffic converging on Mexico City.

The sound-channel modem, the protection-channel equipment, and the program-distribution equipment are of special interest because this is their first large-scale application.

STAMP Automatic Mobile Public Telephone System.

An automatic mobile public telephone system known in France as the *STAMP* system (Système Téléphonique Automatique Mobile Public) is a fully automatic 2-way telephone system giving the mobile subscriber all the facilities of a fixed telephone subscriber such as multichannel access, traffic capacity, organization of radio-frequency coverage, organization of the switching equipment, concentration-deconcentration versus direct trunk switching, numbering plan and roamer service, nationwide automatic call, metering, and selecto-call system.

An initial capacity of 10 000 subscribers and 12 frequencies have been planned with a compatible extension to 110 000 subscribers and 36 frequencies for full national coverage.

Miniaturized Telemetry Equipment in Space Craft.

The design and construction of satellite-borne instrumentation is much more determined by non-telecommunication requirements than similar ground-based instrumentation. Weight, volume, power consumption, and reliability in adverse environmental conditions of vacuum, mechanical stress, and temperature variation, are important factors influencing the design.

Equipment has now been designed to operate under these conditions for processing telemetry data employing pulse-code-modulation techniques and integrated circuitry in flatpack construction.

Typical units, with their design, production, and testing problems are discussed.

Radar Performance Improved by Digital Processing.

Doppler radar gives a higher discrimination between moving-target echoes and the clutter from fixed targets than conventional moving-target-indication radar. The Doppler envelope produced by the radial velocity of the moving-target echo is detected then identified by a range gate. About 100 range gates each need about 10 Doppler filters for a good signal-to-noise ratio. This means a total of 1000 Doppler filters. To avoid so many filters, 5 sliding gates each with 2 Doppler filters have been used but this technique degrades the radar performance.

Now a digital process has been developed in which the output from each range gate is stored in a memory and examined sequentially. This means only one series of Doppler filters and a matched-filter technique can be employed to give an improved performance.

This improvement to moving-target ground-surveillance radar has been confirmed by a laboratory model whose features will be used in the next generation of radars.

This article was originally published in L'Onde Électrique, no 482, Edition Chiron, Paris, in May 1967 and due acknowledgment is now made to the editor for his kind permission to publish in Electrical Communication.

Initial Experience with the IOC Switching System.

This switching system uses miniature dry-reed sealed contacts in 1024-line modules with 1 set of signaling and peripheral equipment for every 2 modules — a design concept which reduces floor space and gives on-site extensibility.

The stored-program control facility increases both the system flexibility and reliability.

In a stored-program system the hardware is functionally simple and the complexity is in the software.

Months before the *IOC* hardware was completed, the software program was checked out. Simulation techniques were used to create the most intricate and improbable conditions likely to be found in practice.

These conditions were written on call-event forms by engineers, transcribed onto punched tape and fed to the simulation processor. The output was an event tape in machine language describing a series of elementary actions. The processor was then put on-line to simulate the telephone network and checkout the program.

After the Wilrijk exchange cut-over, the *IOC* System performance proved the efficiency of this technique. Computer-aided maintenance reduced servicing to regular adjustments of input-output devices. Furthermore, because the exchange is self-restoring after transient faults, it can operate unattended.

11B Telephone Switching System.

This miniaturized crossbar switching system uses a high proportion of electronics in its common control equipment. Designed for high-speed operation, reduced physical size, and easy installation it covers a capacity range from 16 through 12 288 lines in 2 steps, a 2-stage and a 4-stage exchange. A special feature is the miniaturized crossbar switch.

Transferred-Electron Bulk Effects in Gallium Arsenide.

The transferred-electron effect in gallium arsenide is the basic mechanism of Gunn-effect oscillators whose behavior is radically different from established devices like the transistor, varactor, and tunnel diode.

The active device consists of an electrically uniform and geometrically regular semiconductor with two ohmic contacts for applying bias voltage.

Used with a suitable resonant circuit this small, simple and cheap Gunn-effect oscillator will provide continuous-wave outputs of several hundred milliwatts or pulsed power outputs up to 1 kilowatt over the microwave spectrum 1 to 10 gigahertz. It is more compatible with the use of solid-state bias circuits than are microwave tube oscillators.

Electronic tuning of the oscillator is possible with a varactor and the device can be used in lumped element and integrated microwave-strip resonant circuits.

An additional use for these bulk-effect devices is found as complex-waveform generators. The waveform is created by a number of means; physically changing the cross-section area along the electron-drift path, localized doping in the sample, optical illumination of portions of the sample, and so on.

The key to successful commercial exploitation lies in a complete control over the properties of the device material. Three methods of growth are presently used, melt growth for bulk gallium arsenide, vapor-phase epitaxy, and liquid-phase epitaxy. The latter two methods provide material suitable for commercial devices.

Devices have been realized in coaxial line, wave-guide, microstrip, and lumped elements, all with comparable microwave performances.

Subscriber Stages in Pentaconta PC 1000C Exchanges.

The line-selection elements in local Pentaconta exchanges use the interaid principle combined with the link system, Dimensioning these switching elements involves the calculation of congestion in the speech path and an estimation of congestion in a complex waiting system.

To check the speech-path calculations, simulations were made using the Kosten "roulette" model. Time-true simulation of the control system was also made.

Comparison between the calculated and simulated results shows good agreement.

GH 210 Data Communication System.

For a date communication system to be efficient some method of correcting transmission errors is necessary. The degree of error control will depend upon the class of system and the type of data to be transmitted.

In designing a system this factor is of major importance. The chosen technique uses block transmission and an iterative code based on the theory of polynomials which gives almost 100-percent protection with a minimum of redundant information. The error-correction technique uses backward-channel retransmission at 75 bauds — a technique now established as the most suitable for achieving a high-information transfer rate.

The equipment can operate unattended and despite its complex technical function it has been designed as office furniture.

It is expected to have a wide application in the many industrial fields that use intercomputer communication.

Portable Single-Sideband High-Frequency Transceiver with Military Applications.

This single-sideband military communication equipment designed for tactical communication on 10 000 channels in the 2- to 12-megahertz range has a power output of 15 watts and covers distances greater than those obtained from frequency-modulated very-high-frequency equipment of equivalent size.

The many interesting and novel technical solutions used in the equipment include radio-frequency circuit tuning by variometers and a mechanical digital-analog converter, frequency generation by a voltage-controlled oscillator, a frequency-conversion analysis, a side-step synthesis, and a phase-locked loop using a high-stability oscillator.

The equipment's more important features include the short time required for operational readiness, frequency stability which permits operation in a net of other equipments without preliminary frequency adjustment, compatibility with double-sideband amplitude-modulation equipment, and operation under severe climatic and mechanical conditions.

Clamping Connector for Printed-Circuit Boards.

Large functional plug-in units require many connections which have to be disconnected and reconnected during maintenance.

To avoid the use of noble metals, high contact pressure is needed which makes disconnection and reconnection of boards difficult.

The clamping connector has its high contact pressure released by screwdriver-operated cams during board removal and reinstated when the board is replaced.

This technique reduces contact damage, increases reliability, and reduces maintenance time.

The design principles take advantage of the allocated connector volume on a practical printed-circuit board to produce a high-pressure contact comparatively unaffected by manufacturing tolerances.

The connector has successfully passed ITT electrical and mechanical tests.

Mexican Radio-Relay Network at 6 Gigahertz for 1800-Channel Telephony, or Television

H. CARL
Standard Elektrik Lorenz AG, Stuttgart, West Germany

1. Introduction

In most European countries and also in the USA, long-distance telephone transmission is more or less equally shared by cable and radio-relay systems, both supplementing each other. For television transmission preference is generally given to radio-relay systems.

A notable example of a long-distance network for telephony and television based on practically exclusively radio-relay systems is given by the development of the communications network in Mexico, where, within less than ten years, an extensive wide-band radio-relay network was established between all major cities of the country and with the USA.

The first system was commissioned in the last quarter of 1962. This was two years after the Mexican telephone company, Teléfonos de México, had ordered our link from Mexico City to Monterrey with extension to Nuevo Laredo at the US border, where interconnection at radio frequency was made with the *TD-2* network. The link comprises 21 stations and has a length of 1100 kilometers (683 miles). The equipment employed is the 4-gigahertz system *FM 960/TV-4000* for 960 telephone channels or television with sound. For service channel and supervisory purposes the 24-channel equipment *BFM 24/4000* of the Bell Telephone Manufacturing Company, Antwerp, is used. Both equipments are tube equipments and were developed in the years 1958 to 1960.

Performance achieved on this link expressed in hourly mean noise power per kilometer is better than the 3 picowatts per kilometer recommended by the CCIR. The figures are:

thermal noise	0·4 picowatt	per kilometer
intermodulation noise	0·9 picowatt	per kilometer
total noise	1·3 picowatts	per kilometer.

These figures refer to equivalent white-noise loading for 960 channels. Two go-and-return channels are operating in parallel, one as standby. Standby switching is done automatically at intermediate frequency. All repeaters are unattended but fitted with a remote supervision system. After some initial trouble, in particular with primary power supply, a reliability was achieved with interruptions of about 0·2 percent, or about 15 hours per year. Equipment first designed for continental Europe was proved under subtropical conditions up to altitudes of 4000 meters (1300 feet) and with less sophisticated maintenance than, for example, that provided by the German Bundespost [1].

Extensions of the network were built in 1963/65 from Monterrey to Torreón (345 kilometers or 214 miles), Celaya to Guadalajara (300 kilometers or 186 miles), and Mexico City to Cordoba (260 kilometers or 161 miles). Between Mexico and Celaya a third radio-frequency channel was installed in 1966 (Figure 1) [1, 2]. Cost of the system was about 5 dollars per voice-channel-kilometer including all equipment, towers, primary power, buildings, and access roads.

The system is primarily used for telephony but from time to time television programs are transmitted to and from the USA and Canada.

Planning for further extensions began in 1965 for links from Mexico City south to Yucatan and to the border of Guatemala. In the north a link was needed to Ciudad Juarez and El Paso.

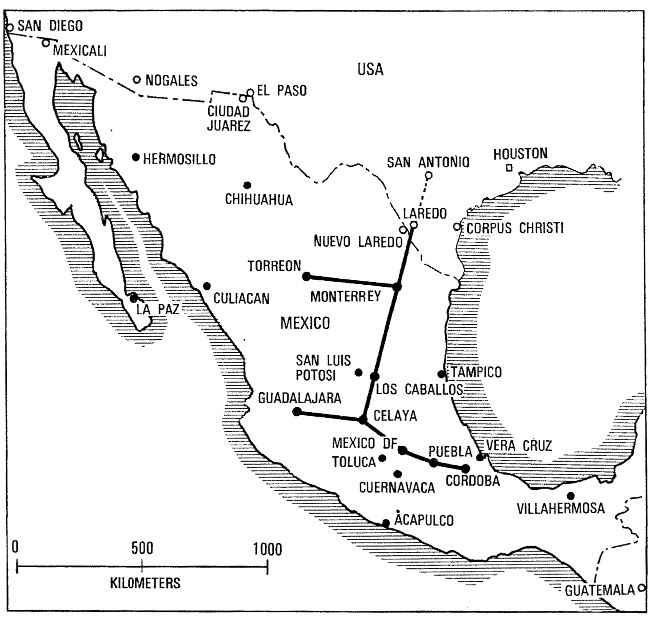

Figure 1 - Teléfonos de México 4-gigahertz radio-relay network, 1962/1965.

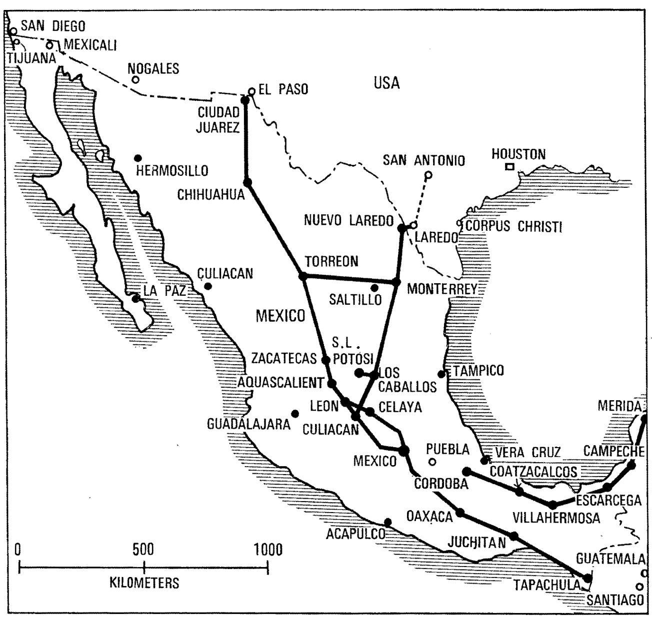

Figure 2 - The 6-gigahertz radio-relay network installed in Mexico in 1967/1968.

For these projects Teléfonos de México ordered a new type of equipment employing solid-state techniques except for a traveling-wave tube in the power stage.

The equipment *FM 1800/TV-6000* operates in the 6-gigahertz band and provides for 1800 telephone channels, or for 1 television program and 4 sound channels. The equipment was designed to the specifications of the German Bundespost and has also obtained type approval by the US Federal Communications Commission, Washington [3].

The narrow-band equipment *BFM 24/6000* is used for service-channel purposes. Output power is 20 milliwatts from semiconductor devices [4].

Requirements for regular long-distance television transmission developed when Mexico City was nominated for the Summer Olympic Games, 1968. Six international television channels will be needed from Mexico City to the USA and from there to Europe and Japan. The installation of a communication-satellite earth station does not reduce this number. After the Olympic Games the new television distribution network (Telmex) will be mainly employed for educational purposes.

The Mexican government ordered for the new television network the same type of 6-gigahertz system that was supplied to Teléfonos de México. The orders were given in the course of 1966. This left little more than 2 years for implementation before the Olympic Games in October 1968. During this time more than a thousand equipments had to be manufactured, shipped, installed and commissioned, some on sites that were totally unknown at the time of the contract, and many in buildings that were not available for installation before April 1968.

Climatic conditions on many stations are more severe than in Central Europe but real tropical climate prevails only in the south, in particular in Yucatan. On the central plateau Mexico City is 2250 meters or 7380 feet above sea level and temperatures are on the warm side all through the year but neither excessively hot nor humid. Station altitudes vary from sea level to 4200 meters (13 780 feet) but this is important only to the emergency power plant.

2. System Configuration

Figure 2 indicates the new 6-gigahertz routes to be installed for both the Government and Telmex. The systems run mostly in parallel and use the same repeater stations, whereas the terminals in the cities are separate. About 100 stations are involved, the majority newly sited. Total route length is about 4000 kilometers (2500 miles).

The basic configuration of a typical modulation section is shown in Figure 3. One operating and one standby radio-frequency-channel pair are provided for telephony, with the possibility of later extension. The television system comprises 2 operating go-and-return channels and 1 for standby. Auxiliary links are used in parallel, one for each main system, but only one common antenna is used for a given direction of radiation. Standby switching is done at the 70-megahertz intermediate frequency as with the earlier 4-gigahertz system. All repeater stations are unattended with central supervision from the principal terminals.

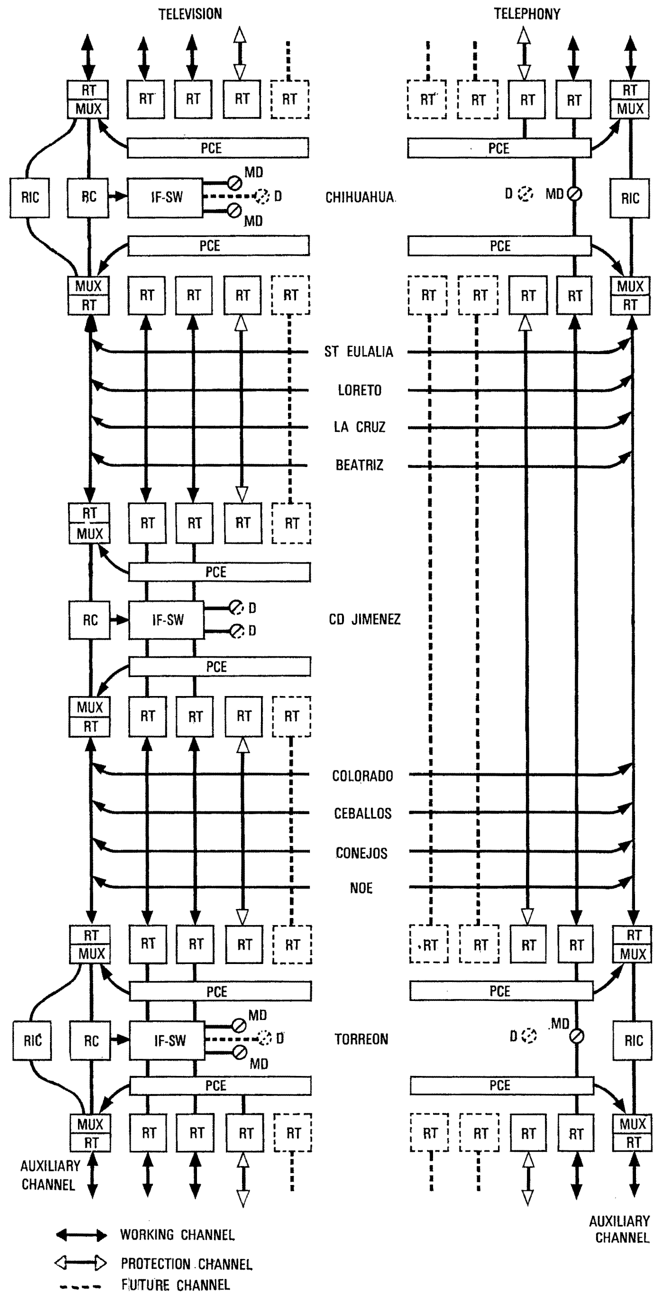

Figure 3 - Typical modulation section of the 6-gigahertz network in Mexico.

RT	- Receiver/transmitter
Mux	- Multiplex for service channel
PCE	- Protection
IF-SW	- Intermediate-frequency switching
RIC	- Remote control and indication
RC	- Remote control for IF-SW
MD	- Modulator-demodulator
D	- Demodulator.

Television program distribution is also done at intermediate frequency by a local- or remote-controlled crossbar arrangement.

The various links with route length, number of modulation sections, number of repeaters, and number of radio-frequency channels are given in Table 1. Total length of operating main radio-frequency channels, go-and-return, is 13 700 kilometers (8500 miles).

Table 1 – Details of links

Link	Type of transmission	Length in kilometers (miles in brackets)	Section	Repeaters	Radio-frequency channels	
					Main	Auxiliary
Mexico — Culiacan	television	233 (144)	1	4	8 + 2	2
Culiacan — Ciudad Juarez	television	1430 (888)	7	27	2 + 1	1
Culiacan — Nuevo Laredo	television	900 (559)	3	13	2 + 1	1
Monterrey — Torreón	television	346 (226)	1	5	2 + 1	1
Mexico — Tapachula	television	965 (599)	4	16	2 + 1	1
Mexico — Celaya	telephone	228 (142)	1	4	2 + 1	1
Celaya — Ciudad Juarez	telephone	1430 (888)	6	27	1 + 1	1
Mexico — Tapachula	telephone	965 (599)	3	17	1 + 1	1
Coatzacoalcos — Merida	telephone	772 (480)	3	16	1 + 1	1

2.1 Equipment Features

The radio-frequency equipment is *FM 1800/TV-6000*, 5·925 to 6·425 gigahertz, or *FM 1800/TV-6700*, 6·425 to 6·925 gigahertz. Both equipments provide 1800 telephone channels, or color television with a maximum of 4 superimposed sound channels. Output power is 10 watts with an option to increase to 15 watts. The noise figure is 10 decibels and the power consumption for one transmitter-receiver pair is 200 watts. Two pairs are housed in a bay 600 by 225 by 2065 millimeters (23·6 by 8·85 by 82 inches).

2.1.1 Modulation-Demodulation Equipment FM 1800/TV-70

This provides a baseband 1800-channel multiplex signal, or color television up to 625 lines and a maximum of 4 sound channels, as output-input signals frequency translated to 70 megahertz. The power consumption is 50 watts. The 4 modems and their power supplies are in a bay 600 by 225 by 2065 millimeters (23·6 by 8·86 by 82 inches).

2.1.2 Protection Switching Equipment SSG 70

Operating at 70-megahertz intermediate frequency with a maximum of 6 operating and 2 standby channels, it has a transfer time from start of defect of less than 35 milliseconds and a switching time of less than 5 microseconds. The power consumption is 200 watts and bay dimensions are 600 by 225 by 2065 millimeters (23·6 by 8·86 by 82 inches).

2.1.3 Intermediate-Frequency Distribution Equipment ZFV-4

This operates at 70 megahertz and is of modular design with a basic module of 4 × 4 = 16 crosspoints. The switchover or transfer time is less than 5 microseconds.

2.1.4 Remote Control and Supervision Equipment IST 6/IST 16

This equipment has available a maximum of 80 signals and a maximum of 40 controls per average substation.

2.1.5 Auxiliary Radio-Link Equipment BFM 24/6000

For a maximum of 24 telephone channels the transmitter output power is 20 milliwatts and the noise figure less than 12 decibels. The frequency bands are the same as for the main-line equipment.

2.2 General Characteristics

Except for the traveling-wave tube in the main-line transmitter output stage, solid-state devices are used throughout as active components. No forced-air cooling is required. Power is supplied from a 48-volt battery. Acceptable voltage variations are +22, −15 percent. Alternating-current power supplies are also available but not used for the Mexican projects. Rated performance is obtained at ambient temperatures up to 50 degrees Celsius but operation without damage is possible up to at least 55 degrees Celsius.

For higher reliability, modest air conditioning or an average ambient temperature of the order of 25 to 30 degrees Celsius is recommended.

3. Radio-Frequency Channel Arrangements

The radio-frequency channel arrangements for wide-band radio-relay systems are based on international agreements. For the band 5·925 to 6·425 gigahertz CCIR Recommendation No 383-1 applies. It provides for 8 go-and-return radio-frequency channels each having a capacity of 1800 telephone channels, or television and accompanying sound channels. Besides this, 2 narrow-band channels are provided for auxiliary systems. This gives a total of 10 radio-frequency-channel pairs, or 20 frequencies which can be employed in parallel. It is customary to transmit several transmit-and-receive frequencies through the same antenna. Antennas are bulky things at least 3 meters (10 feet) in diameter. Their weight is at least 100 kilograms (220 pounds). The fewer the number of antennas a tower or antenna support has to carry, the less rigid it needs to be and hence the cost is lower. In the earlier 4-gigahertz system, 6 or 8 frequencies were operated through one antenna without any disadvantages. Based on this experience, only one antenna was planned for the full frequency band at 6 gigahertz. This means, however, some additional technical effort for rejection filters when all 20 available frequencies are to be accommodated.

On the average section where 5 wide-band channel pairs and 2 narrow-band pairs for the auxiliary channels have to be put on the same antenna, odd and even channels are separated by polarization. There are 14 frequencies and signals covering a wide power range, 5 at 10 watts (+ 40 dBm), 2 at 20 milliwatts (+ 13 dBm), 5 at − 25 dBm, and 2 at − 52 dBm. The latter values are the average powers received. The auxiliary channel frequencies of the 6-gigahertz plan are unfortunately less favorably arranged than in the 4-gigahertz plan. In particular, the inside channels are subject to interference from the wide-band channels *1* and *8*. To avoid this without employing a high amount of protective filtering, the transmit and receive frequencies for one pair of auxiliary channels were rearranged as shown in Figure 4. This sacrifices the wide-band channel *8* but gives a simpler solution. Filter arrangements to accommodate the complete original frequency band on the same antenna are being prepared. The main problem is to provide highly selective intermediate-frequency filters for the suppression of interference from the auxiliary channels.

Because 5 out of 8 available wide-band channels are required, it was necessary to employ at the repeater stations the same set of frequencies for both directions of radiation. This was achieved by the high polarization discrimination of the Cassegrain antenna. More than 60 decibels are obtained for all angles of more than 20 degrees from the main beam. On the rear side the discrimination is of the order of 70 decibels (Figure 5).

Special problems arose on the first sections from Mexico City to the north (Mexico—Culiacan and Mexico—Celaya). A total of 13 wide-band pairs has to be accommodated, 10 on one route and 3 on the other; 11 pairs go to the south. This meant an additional frequency band had to be found. For various reasons the band 6·425 to 7·125 gigahertz was not chosen as recommended by the CCIR Recommendation No 383-1 but the 500-megahertz range 6·425 to 6·925 gigahertz with exactly the same frequency plan as used in the lower range. Basically this allowed the same equipment for the two bands and compatibility with other special frequency-channel arrangements used in the country for other services. In this way 8 additional wide-band channels were obtained.

The number of radio-frequency channels converging in Mexico City produces a density that is rarely encountered in Central Europe, the USA, or Japan.

4. Special Equipment

Some of the equipments employed within the system are of special interest because of their new features and their first large-scale application. They are the sound-channel modem, the protection-channel equipment, and the program-distribution equipment.

4.1 4-Channel Sound Modem

CCIR Report No 289 discusses the possibility of transmitting 4 sound or program channels on top of a television signal by suitably chosen subcarriers between the cut-off frequency of the 625-line television signal and the pilot frequency. The frequencies proposed in the report for the subcarriers are 7·00, 7·36, 7·74, and 8·14 megahertz. Later investigation showed some incompatibility in this arrangement regarding 2nd- and 3rd-harmonic interference. Various modifications of the basic proposal were therefore studied and introduced into some systems but no international agreement has been reached until now. We found the following arrangement to be most favorable: 7·0, 7·36, 7·78, and 8·30 megahertz. This was finally accepted for the whole Mexican network and also for parts being supplied by other companies. In Mexico only 3 sound channels are needed; 1 for the television signal and 2 for feeding broadcast transmitters. The upper 3 were selected with regard to possible intermodulation of the color subcarrier.

Mechanically 4 modulators and 4 demodulators are accommodated in one subrack of 130-millimeter (5-inch) height. They can be assembled with the basic intermediate-frequency modulators and demodulators in the same cabinet.

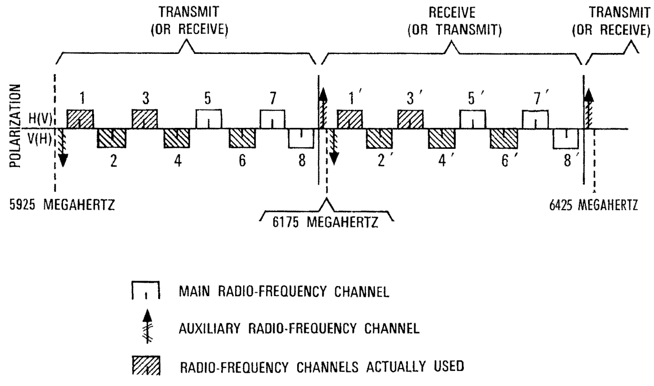

Figure 4 - Radio-frequency channel arrangement in the 6-gigahertz band for the Mexican radio-relay network. As many as 14 transmit and receive frequencies are accommodated on a single antenna, with a possible maximum of 20 frequencies.

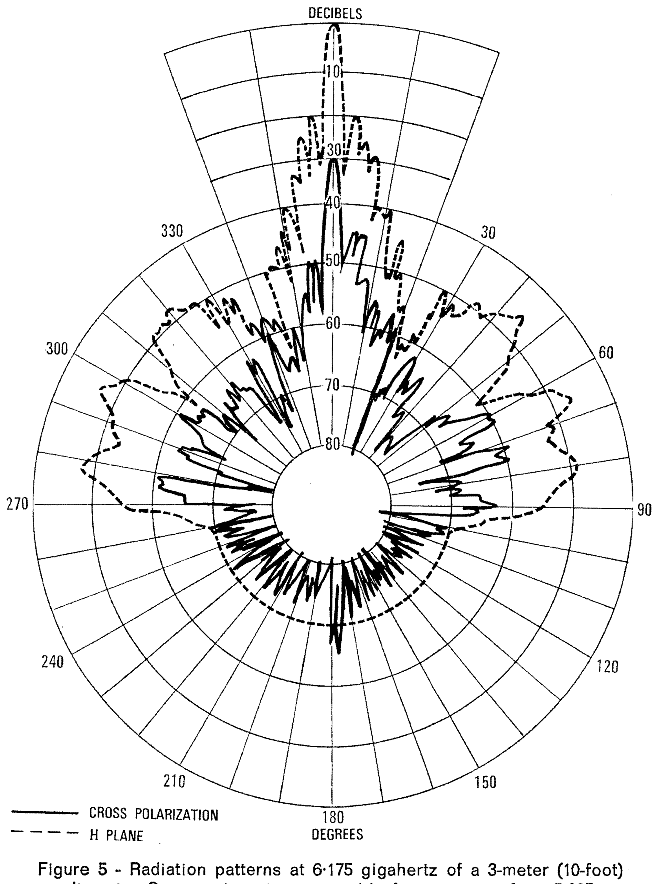

Figure 5 - Radiation patterns at 6·175 gigahertz of a 3-meter (10-foot) diameter Cassegrain antenna suitable for operation from 5·925 to 6·925 gigahertz.

Sound-channel bandwidth is 15 kilohertz. Basic noise is less than 0·5 millivolt weighted. The demodulator output delivers $+3$ to $+9$ decibels relative to test-tone level.

4.2 Protection-Channel Switching

Automatic protection switching is by the well-established principle of radio-frequency channel switching in modulation or protection sections, with 1 standby channel being used for several operating channels.

The equipment provides for 2 times $3+1$ channels, or maximally $6+2$. Switching is done at 70 megahertz. A main feature is the electronic channel switch with a 5-microsecond transfer time. This is short enough to cause no noticeable deterioration to any of the conventional telephone, television, or telegraph signals. The bandwidth of the switch is 70 ± 20 megahertz. Noise and intermodulation introduced by the device are less than 100 picowatts referred to telephone-channel test-tone level.

Operate time from the start of a defect until switchover is 35 to 50 milliseconds. Operate signals are voice-frequency telegraph, transmitted through the auxiliary radio system.

4.3 Program Distribution

Switching at intermediate frequency is also used for the program distribution crossbar arrangement. It serves for manual or remote-controlled program switching at the main centers of the television network. Intermediate-frequency switching was chosen for this purpose because, in general, the deterioration of the signal is less than with baseband switching, and in particular, phase differences have less effect at intermediate frequencies than at the relative wide baseband of 0 to 5 megahertz. The same type of switch is used as in the protection channel equipment. The basic module is a crossbar switch with $4 \times 4 = 16$ crosspoints from which larger arrangements can be made according to requirements. The switching action can be programmed and then released either manually or by remote control.

The remote-control center will be in the new television tower in Mexico City. That means the remote-control system is designed for operation over distances exceeding 1000 kilometers (621 miles).

5. Reliability

The earlier tube systems had a failure rate of about 1 breakdown per year for a complete functional unit such as a transmitter/receiver or modulator/demodulator. This excludes preventive maintenance. The traveling-wave tube has never contributed a significant amount to the failure rate because these tubes have a lifetime of more than 10 000, often reaching 20 000, hours and then normally only go down in output power without sudden breakdowns. Besides the communication equipment, primary power supplies produce a considerable number of failures in the case of alternating-current operation in spite of emergency power plants and flywheel arrangements. Overall down time of a 1000-kilometer (621-mile) system with protection switching can be brought to about 15 hours per year or about 0·2 percent of the time given reasonable maintenance. These figures apply for the 4-gigahertz systems installed since 1962 and also include a few hours' fading. For the solid-state 6-gigahertz system the estimated failure rates for the principle equipments are:

radio equipment	$18{\cdot}2 \times 10^{-6}$ per hour	0·16 per year
modulator	$8{\cdot}0 \times 10^{-6}$ per hour	0·07 per year
demodulator	$5{\cdot}6 \times 10^{-6}$ per hour	0·05 per year
protection switching	$45{\cdot}6 \times 10^{-6}$ per hour	0·4 per year.

This leads to an outage rate due to equipment failures for an average modulation section comprising 6 radio hops with 1 go-and-return channel of 2·6 per year. On the $1+1$ telephony link Celaya—Ciudad Juarez with 132 radio equipments, 10 modems, and 12 protection-switching equipments, expected equipment outages per year will be 27·12. Actual outage time of an equipment, before repair can be effected, will be of the order of 4 to 6 hours including engineer's traveling time. Assuming half-a-failure per equipment per year (that is worse than the calculated figures), actual average outage time per equipment per year will be 3 hours, or less than 0·05 percent of a year.

With such an outage probability a system having 33 stations, 1 operating and 1 standby channel, and 6 switching sections has an overall outage probability of less than 10^{-4}, or less than 1 hour per year [5].

These figures apply for the link Celaya — Ciudad Juarez, 1430-kilometers (888-miles) long. Primary power-supply failures are expected to be negligible because the 48-volt battery supply has a storage capacity for about 8 hours operation after failure of the mains or a diesel.

For propagation the reliability of the system was calculated, for example, for the above-mentioned link Celaya — Ciudad Juarez, to be in terms of interruptions less than 150 seconds per month or less than 0·005 percent of the time, that is, less than 0·5 hour per year. All radio paths were tested by the antenna-height-variation method before site locations were finally determined.

Equipment and propagation reliability together result in an interruption time of less than 2 hours per year, or less than 0·03 percent of the time. This means improvement by a factor of nearly 10 compared with the earlier system operating with tubes. Even if this cannot be fully realized after the first six months of operation and the eliminating of initial troubles, a factor of 5 will very likely be achieved according to the experience obtained with 6-gigahertz equipments that have been in operation more than two years.

6. Performance

Equipment and system design are based on the specifications of the German Bundespost which in some respects requires a higher performance than recommended internationally by the CCITT and CCIR. The reference section comprises only 3 hops of 46·7 kilometers (29 miles) in length each, or an overall length of 140 kilometers (87 miles). Reference-path loss is 67 decibels, of which 62 decibels is free space and 5 decibels is fading allowance. The weighted noise in the 3·4-kilohertz channel at 0 reference level must not exceed the following values:

thermal noise for 5 decibels	
simultaneous fading	200 picowatts
intermodulation	190 picowatts
outside interference	30 picowatts
total noise	420 picowatts or 3 picowatts per kilometer.

CCIR Recommendation No 395-1 specifies for links with a length L of $50 \leqslant L \leqslant 840$ kilometers, $3L+200$ picowatts mean noise power in any hour.

This gives 620 picowatts for $L = 140$ kilometers (87 miles) or 4·4 picowatts per kilometer, and 1040 picowatts for $L = 280$ kilometers (174 miles) or 3·7 picowatts per kilometer.

Measurements with artificial standard-path attenuation resulted in

200 picowatts for 3 hops (140 kilometers or 87 miles) or 1·5 picowatts per kilometer, and

420 picowatts for 6 hops (280 kilometers or 174 miles) or 1·5 picowatts per kilometer.

The path-dependent thermal noise is about 40 picowatts for a 67-decibel loss. This corresponds to a system figure of merit of 141 decibels for the top one of 1800 telephone channels (with 960 channel loading, an improvement of 9 decibels would be obtained and this would mean a noise reduction to 1 picowatt per kilometer). Actual measurements on a section of 9 hops in Mexico (Chihuahua—Torreón, 447 kilometers or 278 miles) are in line with the estimates as shown in Table 2 for the rather long modulation section Chihuahua—Torreón that consists of 9 hops, total length 447 kilometers (278 miles).

Table 2 – Cumulative noise in the top channel of 1800 telephone channels, modulation section Chihuahua — Torreón

No of path	Length in kilometers (miles in brackets)	Thermal noise (picowatts)	Intermodulation noise (picowatts)
1	22·0 (13·6)	62	23
2	59·0 (36·6)	120	30
3	44·0 (27·3)	150	30
4	64·0 (39·7)	250	50
5	59·5 (37)	290	110
6	68·0 (42·2)	350	160
7	42·0 (26)	380	170
8	49·0 (30)	450	130
9	39·0 (24·2)	500	200
Total	446·5 (277)	500	200
		1·12 picowatts per kilometer	0·45 picowatt per kilometer

Total noise is 1·6 picowatts per kilometer (Figure 6). Path loss during the time of measurements only slightly exceeded the calculated free-space values. Similar results were obtained on other sections. Thermal noise is about 2/3 of the total noise, whereas in older systems intermodulation noise prevailed over thermal noise. With an improved receiver input stage it would be possible to reduce the noise figure from 10 to 8 decibels without using a tunnel-diode amplifier. With bigger antennas, for example 4-meter (13-foot) paraboloids, or horn paraboloids,

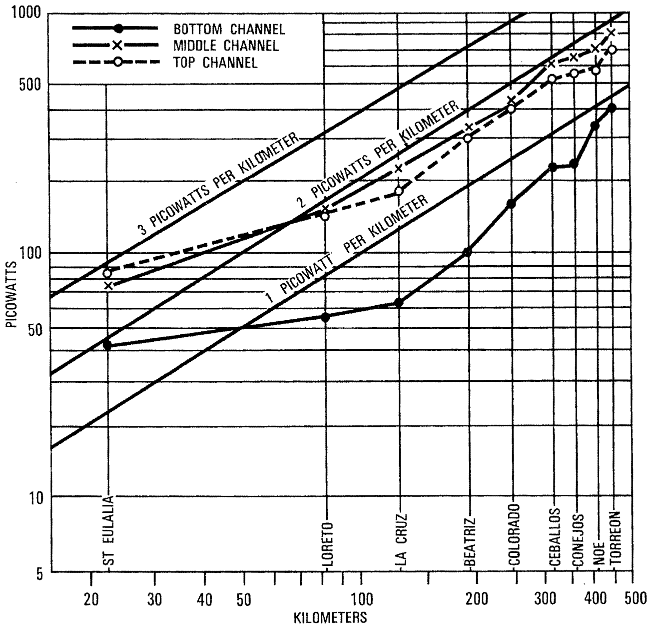

Figure 6 - Total noise, Chihuahua—Torreón, 446·5 kilometers (277 miles), 1800-channel loading.

at least another 2 or 3 decibels could be gained. This would bring the thermal noise down to about 0·5 picowatt per kilometer, or less, and result in about 1 picowatt per kilometer for the overall noise. This is the much discussed objective for worldwide long-distance circuits. Such an objective is nearly attainable now, even for 1800-channel systems, without undue technical effort where a commercially justified demand exists. Some improvement of the existing system could be directly achieved by increasing the output power of the transmitter to 15 watts, in particular on those sections where the path loss is above average.

The fading range on each path exceeds 30 decibels before the squelch is actuated. Details regarding the fading behavior of the new system are not yet fully known, but during the first months of operation of the completed sections no extreme deep fading has been noticed.

Of special interest is the intermodulation noise and the manner in which it adds from hop to hop. Figure 7 shows the distribution of the intermodulation noise for the section Chihuahua—Torreón. The slightly irregular behavior can be seen, though the deviation from a power addition is quite moderate. The irregularities start after the 3rd hop and indicate the increasing difficulties of equalization proportional with the number of hops involved. The adjustment, however, is stable enough over long periods of time.

Time-delay distortion is shown on Figure 8. The variations within a 24-megahertz band are less than 1·8 microseconds. Some of the irregularities are due to the antenna and feeder mismatch reflection factor, of the order of 5 percent, which at least partly prevents a systematic build-up of the equipment distortion characteristics.

Aside from the noise performance, rather high demands are made nowadays on the baseband response of a radio-link system. Without equalization the characteristics

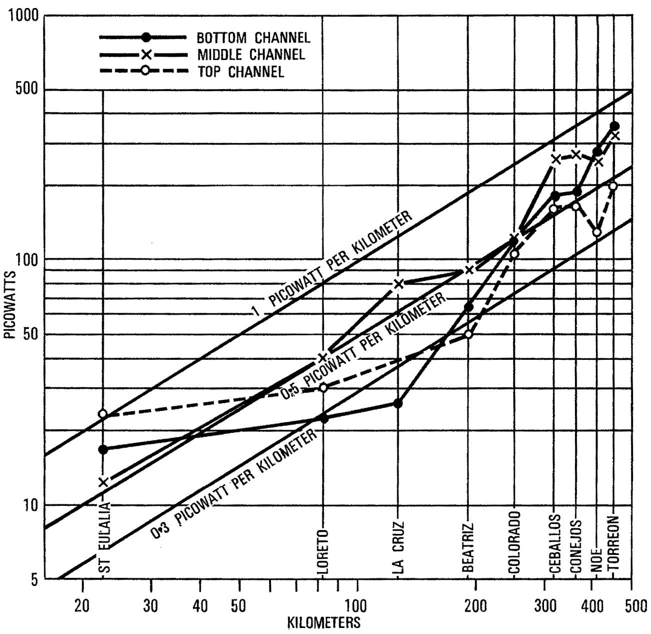

Figure 7 - Intermodulation noise, Chihuahua—Torreón, 446·5 kilometers (277 miles), 1800-channel loading.

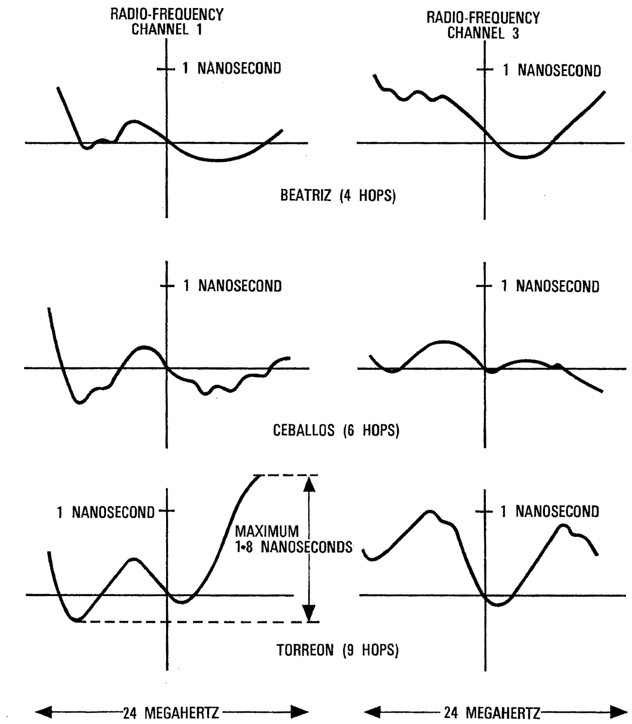

Figure 8 - Time-delay distortion, Chihuahua—Torreón.

of the radio equipment cause a baseband level drop of as much as 2 decibels at the top end above 8 megahertz, within a modulation section of 6 to 8 hops.

At 5 megahertz, the upper end of the television band, the drop in the response curve is about 0·5 decibel for about 6 hops in tandem. For a television modulation section with nominal 18 hops this becomes 1·5 decibels which is not always acceptable. Equalization of the base-band response for deviations of fractions of a decibel is achieved at intermediate frequency by slightly attenuating the carrier and consequently increasing the relative level of the outermost sidebands.

Otherwise television and sound channel performance depends very little on the characteristics of the radio equipment but on the properties of the modulator and demodulator equipment. Differential phase and differential gain of these are better than 1 degree and 1 percent, respectively, within the television band. All measurements have confirmed the well-proved experience that any system good for 960 telephone channels easily meets television requirements for 625- or 525-line systems and there are even fewer problems in this respect with a system designed for 1800 channels.

References

[1] H. Carl and G. Lupke: 400 Mc/s Long-Distance Microwave Radio Relay Network, Mexico City — USA, SEL-Nachrichten, volume 10, no 3, 1962, p 147—159.

[2] H. Carl: Extension of the Wideband Radio Relay Network of Teléfonos de México, SEL-Nachrichten, volume 13, no 1, 1965, p 53—56.

[3] 6-GHz Radio Relay System FM 1800/TV-6000, SEL-Nachrichten, volume 14, 1966, pp 45—107.

[4] A. Liekens and E. Reygaerts: Microwave Radio Relay System for Multi-channel Telephony and Television in the 6-GHz Frequency Band. Part V, Auxiliary Radio Relay System BFM 24/6000, Electrical Communication, volume 40, no 2, 1965, p 209.

[5] I. Welber, H. W. Evans and G. A. Pullis: Protection of Service in the TD-2 Radio Relay System by Automatic Channel Switching, Bell System Technical Journal, volume 34, 1955, p 473.

Helmut Carl was born in Danzig in 1916. He received a doctor of engineering degree from the Technical University of Danzig in 1943. He joined Standard Elektrik Lorenz in 1939, and carried out development on radar, frequency-modulation broadcast transmitters, and microwave radio systems. Later he became head of a planning group for telecommunications systems. During that time he was an active member of the CCIR. Since 1965 he has been product-line manager for transmission systems.

STAMP Automatic Mobile Public Telephone System

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1. Introduction

Many Administrations are now in the planning phase for automatic public mobile radio telephone systems. ITT contributes to the plan with its participation in the *IMTS* (Improved Mobile Telephone Service) or *MJ* system [1] developed for the Bell System by ITT Kellogg, Motorola and Secode, and with the *STAMP* or *AMPTS* (Automatic Mobile Public Telephone System) [2] developed by LMT for the Spanish Administration in Madrid (Figure 1) and Barcelona, and now being demonstrated in Paris to the French and other Administrations.

Both systems give the mobile telephone subscriber all the facilities of a fixed subscriber connected to the public telephone network: the mobile can dial a fixed subscriber and *vice versa*.

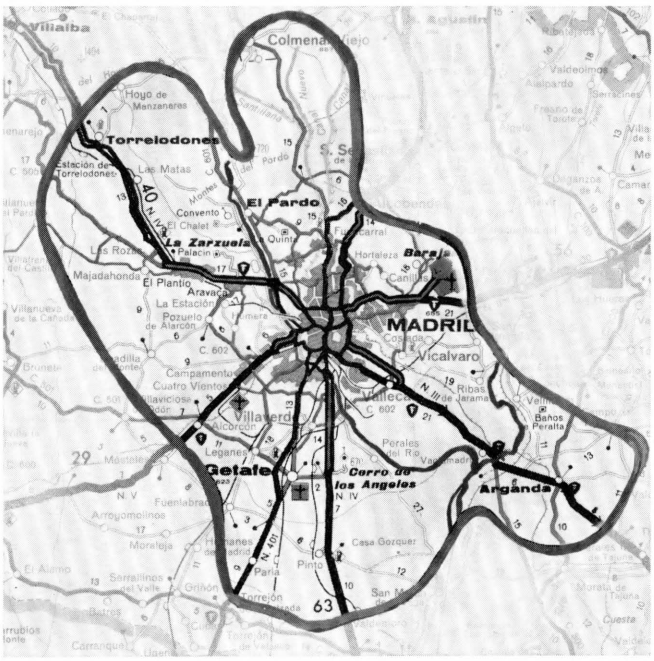

Figure 1 - The area covered by the *STAMP* system around Madrid.

2. Main Features

2.1 Principles

A fixed control terminal, performing the functions of switching, transmission, and signaling, automatically connects the mobile subscriber on the radio telephone network through to the radio equipment in the central office. There is 1 transmitter, and more than 1 receiver, per channel. The receivers work in space diversity to cover the network.

The mobile subscriber has a transmitter-receiver and a combined switching and signaling unit, to connect with the control terminal and central office.

2.2 Multichannnel Access

A major feature of *STAMP* is the multichannel access principle. Each mobile subscriber has access to all the radio channels in his network and his equipment automatically selects an idle channel.

Because the system connects N mobile subscribers to the inlets and outlets of a central office over n radio channels, the system can be considered as a concentrator (Figure 2). The control terminal marks as free, 1 of n radio channels by sending on that channel a characteristic idle tone of 1500 hertz. The mobiles, constantly hunting for this tone by cyclically switching their crystal oscillators, then lock on to it.

When an incoming or outgoing call is originated, it will occupy this free channel, which now becomes busy and is immediately replaced by another free channel. The remaining receivers lock themselves on this new channel in readiness for the next call to be made.

The advantage of this arrangement is illustrated in Figure 3 which shows the lower probability of finding all channels busy when 2, 4, 8, or 12 channels are shared against the higher probability when channels are used independently. These curves are based on well-known probability laws which apply when a given number of subscribers have full access to a given number of common trunks.

On a single channel with an individual traffic of 0·01 erlang, 11 subscribers have a 10-percent chance of finding their channel occupied during the busy hour.

If 4 channels are used independently, 44 subscribers can have the same grade of service. If 4 channels are shared on the multiaccess principle, 200 subscribers can be accommodated.

3. Radio-Frequency Coverage and System

One of the limiting design factors is the number of radio-frequency transmitters that can be colocated with their antennas on a single mast. Through antenna coupling, one transmitter radiates into the other and nonlinearities create $nf_1 - mf_2$ products which must be 60 decibels below carrier level. These methods will give this figure.

— Eliminate products by sufficient spacing between channels. It can be shown [3] that 8 channels with 20-kilohertz spacing must be scattered over a band of 700 kilohertz to avoid 3rd-order products. The mobile receivers are scanning all radio-frequency channels by switching their crystal oscillators at high speed, and so radio-frequency circuitry has to be wide band. In practice 1 megahertz has been found to be the limit.

— Use ferrite circulators giving 20 decibels attenuation to be added to the 40 decibels obtained by antenna decoupling.

— Radiate carrier at low level, for example, -50 decibels on those channels not in use.

The first two methods are used in Spain, where an automatic and a manual system with a total of 7 channels share the same antenna mast.

In *IMTS*, 8 channels have been accommodated using the second and third methods. A Japanese system is re-

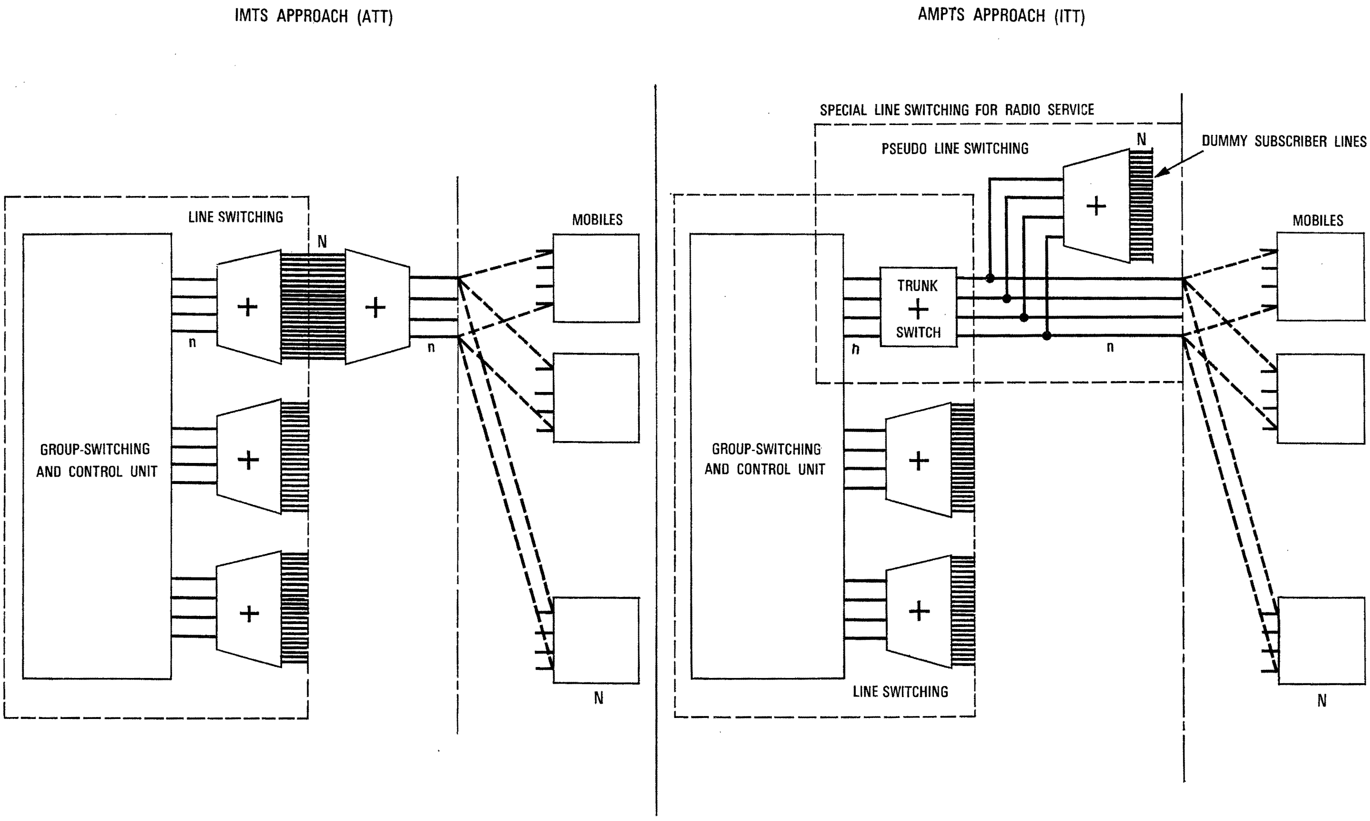

Figure 2 - Switching equipment, on the left the *IMTS* approach, and on the right, the *STAMP* approach.

ported to have 12 channels on an antenna system using a combination of all three methods.

For city coverage, 2 transmitter sites may be necessary, with 2 independent sets of frequencies. This solution is being considered by the German Administration in Hamburg and may be proposed for use in Paris.

For national coverage, 2 stations using the same group of frequencies could intersperse with 2 other stations using other groups of frequencies, so that a same frequency group is used every 3rd network. With this method, at least 7 groups of a minimum of 2 frequencies must be made available for coverage of rural areas [4]. These 7 groups can be used in the suburbs of large cities with many highways.

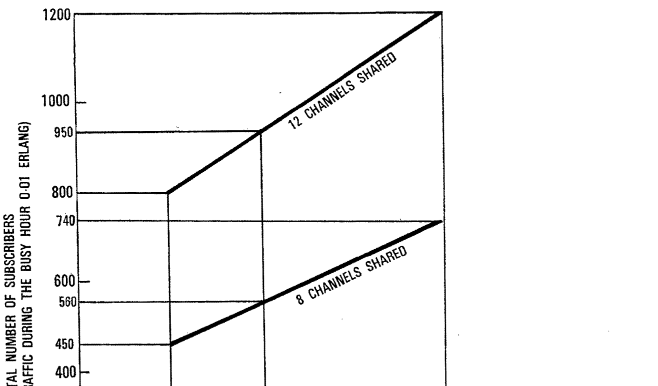

Figure 3 - Efficacy of channel sharing as opposed to independent channels.

Figure 4 shows an attempt to cover France by serving the large cities and a number of highways. If Paris, for example, uses 8 channels, there will be 4 channels for the outgoing highways to the north, south, and west. The distance between stations before the same frequency can be used again depends on the terrain and must be checked by a survey. With the assumption that the same frequency can be used every second network in a "linear" configuration along highways, it is found that 12 frequencies could cover 10 cities with 400 subscribers each, and 60 cities with 100 subscribers each, a total of 10 000 subscribers.

The total number of frequencies needed for national coverage could be $2 \times 8 = 16$ for large cities, and $2 \times 7 = 14$ for rural areas, or a total of 30. With 6 frequencies in reserve, a total of 36 channels is needed.

Justification for selecting 36 as a maximum can be explained as follows. It has been shown [4] that the optimum number of groups for repetition every 3rd network is 9 (Figure 5). For uniform coverage of an area of constant density, groups of 4 frequencies would mean $4 \times 9 = 36$ channels. If in Figure 5 the circled *1* is a high-density city area, and the shaded square represents suburbs, groups 2 to 9 could have 3 frequencies; the 8 frequencies thus released could be used in the center where the total could be $8 + 4 = 12$ channels.

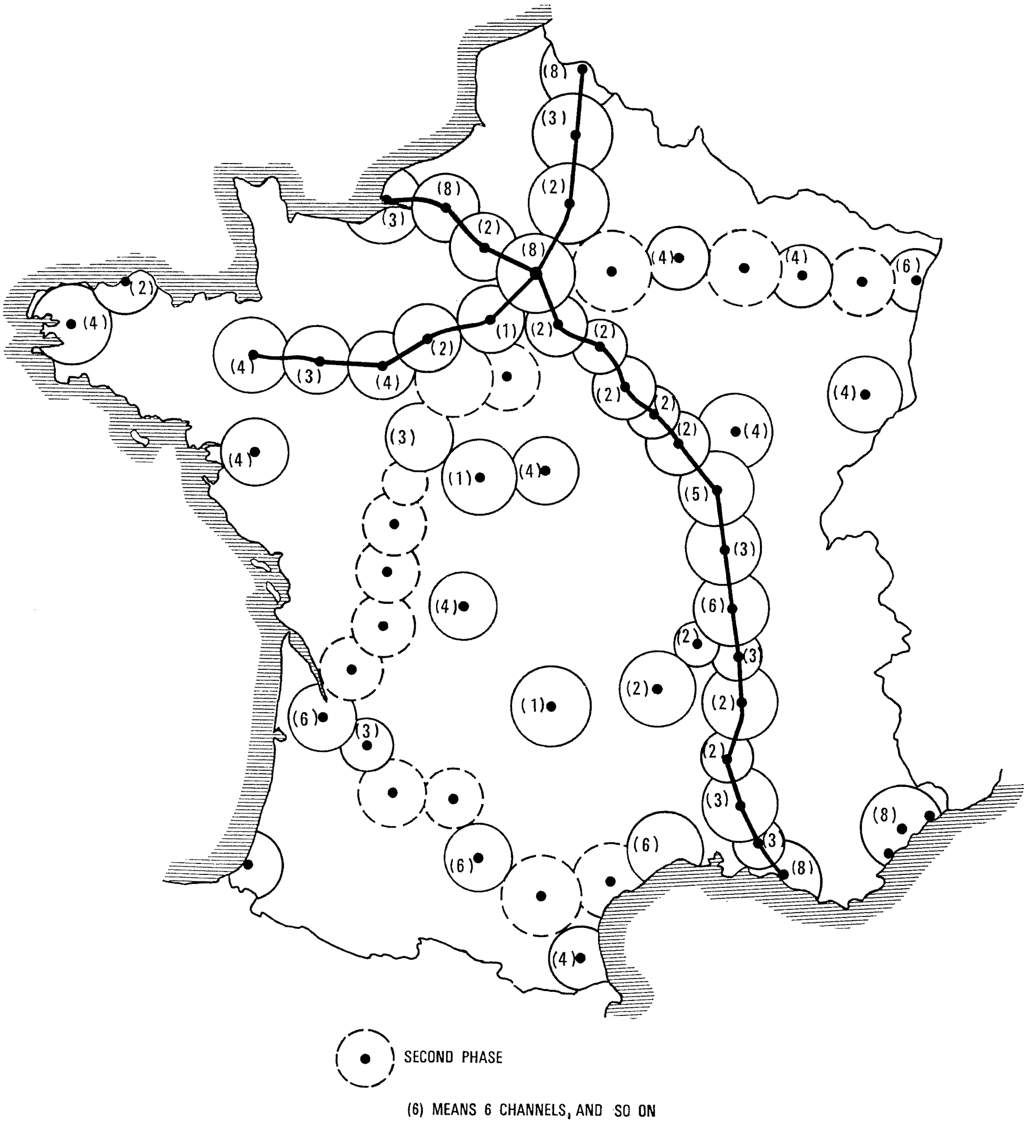

Figure 4 - Method of organizing the radio-frequency coverage for a national network of cities and rural areas.

Consequently, 2 types of radio sets could be considered, 12-channel sets for high-density areas and 36-channel sets for national coverage.

The number of channels for each mobile will depend on the subscriber's movements. A subscriber moving from one city to another wants to talk along the highway and in the next city, and so he must be fitted with all the frequencies used along the route.

The mobile set will have frequencies for its home network but will work other frequencies by operating a "roam switch" to make the set to scan the full set of frequencies (typically 6 or 12). When the switch is on *home* in overlap areas it prevents the mobile from locking on a neighboring network so allowing it to be called on its home network.

In some countries, the roaming mobile will want up to 36 channels, making the equipment more expensive. However, with digital-synthesis techniques this will be possible in the near future.

There are two conflicting considerations; the number of channels should be high to give a large number of subscribers and exploitation of overlapping networks, whereas the mobile should be cheap and have a mini-

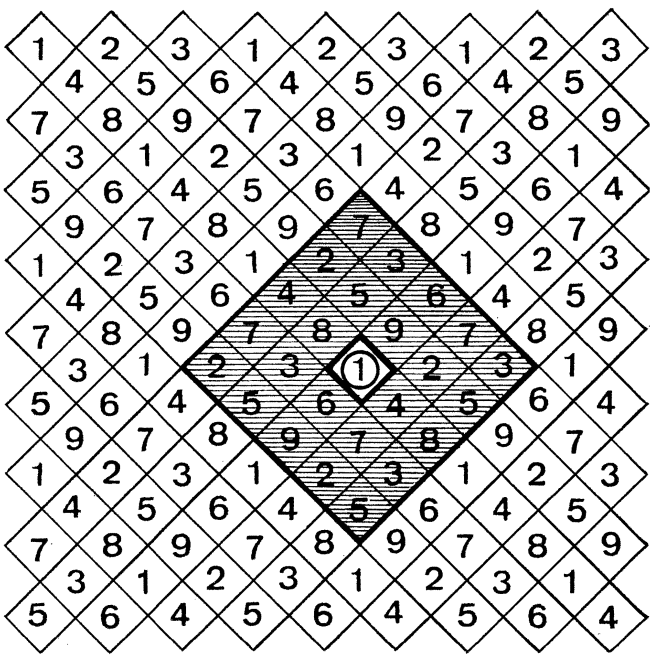

Figure 5 - Channel allocation in the *STAMP* system.

mum number of channels. The compromise will largely depend upon the country. The concept of the *STAMP* is compatible with any choice.

4. Switching Equipment

4.1 General

Among the specifications for *STAMP* the most important one is the service given to a mobile subscriber. It must, in all respects, be identical to the service given to a normal subscriber on a public telephone system. This service includes, in addition to local service,

— toll service,

— special service classes, such as absentee service, restriction, transfer, cancellation (this condition was one which deeply influenced the design), and

— possibility of offer.

The mobile system must also be capable of connection to crossbar, rotary, and step-by-step switching systems.

Numbering must be consistent with major European plans. Planning is based on 10 000 subscribers per country with possibility of extension to 110 000, in multiples of 10 000. In a country with 11 million cars, this assures 1 car in 1 000 equipped with a mobile telephone and a factor 10 in reserve for growth.

Metering must be compatible with European individual-subscriber metering and optionally with automatic message recording.

Roaming subscribers must be dealt with automatically without the help of an operator, provided the subscriber accepts a special contract specifying the cities or networks to which access is desired.

As an alternative, 2 groups of subscribers can be formed: national subscribers receiving a roamer service in all those cities where such service is available (automatic or manual, depending upon the city) and local subscribers who can only use their home network.

Ringing time from fixed subscribers to mobile subscribers must be limited to avoid unnecessary occupation of radio circuits in case of no answer.

On these calls, when no acknowledgment is received from the mobile (for example, because the mobile set is not in service), the calling subscriber must be put through to a terminal where a recorded message says the mobile cannot be reached. However, if the carrier disappears for less than 30 seconds because the mobile is in a screened area the call will continue.

To meet these requirements, there are two basic approaches. One is the *IMTS* approach shown on the left of Figure 2 which treats the mobile network as completely independent of the central office, like a concentrator-deconcentrator. The control terminal is connected to the main distributing frame of the central office, and behaves in respect to the central office like independent normal subscriber lines. The mobile subscriber station has a telephone number of the series allocated to the parent exchange.

The *STAMP* system, shown on the right of Figure 2, differs from the *IMTS* approach which has switching equipment connected at the main distributing frame where there is an unnecessary deconcentration in the parent exchange. In the *STAMP* system, the control-terminal switching equipment is connected directly to the group-switching element by a number of trunks equal to the number of radio channels. Thus, 4 radio channels are switched by a single multiselector, called the trunk switch, on 4 incoming and outgoing trunks.

This arrangement alone would not provide all the special services, nor would it be compatible with individual metering, nor would it provide information on the busy-line condition. Therefore, associated with the trunk switch is a pseudo line-switching element in which every subscriber line with its meter, its cut-off relay, and ancillary circuits is imitated by a dummy subscriber line terminated on a dummy load.

The radio terminal is allocated a prefix different from the parent exchange, and the subscriber numbers are not included in the numbering plan of the parent exchange.

STAMP hardware was originally designed for connection to Pentaconta switching centers. However, it can be connected to any type of system if the necessary changes for internal signaling are made. Designs for rotary and step-by-step are available.

4.2 Numbering Plan

The *STAMP* system was primarily based on the French and Spanish numbering plans. Both have an 8-digit nationwide plan with a special toll-access code:

	Toll	*Area*	*Office*	*Subscriber*
France	(16)	AB	PQ	$MCDU$
Spain	(9)	AB	PQ	$MCDU$

Paris = $1\text{-}PQR\text{-}MCDU$.

It is initially proposed to assign 10 000 discrete subscriber numbers to the mobile service. This can be done by a unique series of the last 4 digits $MCDU$. In each area, the mobile network is identified by a set of special PQ prefixes, corresponding to fictive offices superimposed on existing offices. In rotary and Pentaconta switching, such prefixes can be easily added and existing central offices can handle the additional prefix, provided traffic dimensioning is adequate. Since the $MCDU$ number is unique, the PQ number need not be outpulsed, nor at this stage the AB.

A subscriber wanting a nationwide roamer contract, will receive a dummy line and meter in each center An Bn Qn at the places he chooses and will be handled automatically by them in the same way as a local mobile subscriber. A fixed-to-mobile call will be placed by dialing $An\ Bn\ Pn\ Qn\ MCDU$.

The repetition of dummy lines and meters is a large part of the cost of an automatic nationwide service. To make it economical, a 1500-subscriber-line capacity per 8-channel network has been chosen.

4.2.1 Nationwide Call

As a unique number is nationally assigned to any mobile, it is possible to reach any subscriber in any place within the national networks, without knowing his actual position. He could be in his home network or outside it. This is possible by interrogating the radio networks from an originating toll center and sending them the wanted-subscriber number $MCDU$ directly. When the wanted mobile is reached, it acknowledges receipt of its identity, the local exchange receiving the acknowledgment identifies itself to the toll center, and the toll center then establishes a regular toll call to the mobile through the normal switching network. This procedure is shown in Figure 6 for a toll center in a large city, a highway, and a toll center and local center in the area being presently used by the mobile $MCDU$ [5].

Now assume a fixed subscriber in the city wants to contact the mobile subscriber $MCDU$.

The calling party first dials the national toll code *16* and a special 4-digit prefix $A_o\ B_o\ P_o\ Q_o$ which identifies radio service for that particular highway. It is sufficient for 5 such 4-digit combinations to identify 5 highways. This gives access to a specialized junctor J which in turn has access to a bus line connecting the toll center directly with all the radio terminals along the highway. In each of the terminals, the bus line is connected to a junctor which has access to the control terminal and can be accessed from the local center. When the calling party dials $MCDU$, the number of the mobile subscriber, the junctors J and $j_{1\,\ldots\,n}$ produce simultaneous outpulsing of $MCDU$ by all radio stations along the highway. Station n then receives acknowledgment from the mobile. Junctor j_n of station n sends back to the toll center the identity $A_n\,B_n\,P_n\,Q_n$ of center n. Junctor J in the toll center then establishes a regular toll call to station $A_n\,B_n\,P_n\,Q_n$ $MCDU$. The local center and radio station either place a new call to subscriber $MCDU$, or alternatively junctor j_n keeps the called radio channel busy and mobile ready

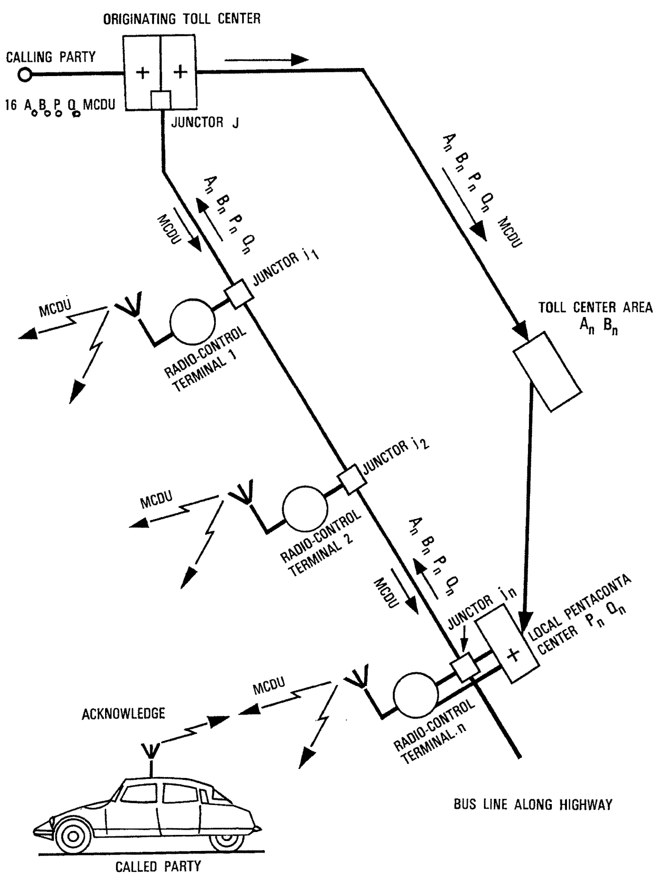

Figure 6 - Stages for a nation-wide call to a mobile.

to receive dial tone. In this case, junctor j_n will have sent its own identity $A_n\,B_n\,P_n\,Q_n\,\mu\,\gamma\,\delta\,v$ to the toll center which places a call to reach junctor j_n with the number $\mu\,\gamma\,\delta\,v$, which then establishes connection to the mobile.

Such a system has to be carefully weighed against the one-way calling systems of the *EUROCALL* type. Obvious advantages of the first system is an integration of the paging and communication functions within a single radio infrastructure.

The cost of such an arrangement is the bus line along the highway. But systems like *EUROCALL* also need a line to feed the call information to all the transmitters scattered over the country. In future the roamer service may use automatic message recording. Then information will be sent through data channels, and the call information will use the same channels.

Traffic load for such a call channel is not high. Known planning figures are 1 call per day per subscriber and 1 call per 10 subscribers in the busy hours.

Assuming 3600 subscribers using a highway, this gives 360 calls needing less than 1 second each, or 0·1-erlang total call traffic.

4.3 Extension of Capacity Above 10 000

The mobile systems are designed for 110 000 discrete subscriber numbers. Using the French numbering plan, a fully automatic national service can be given to 10 000 of them.

To identify the additional 100 000 subscribers on a national basis, use has to be made of 5 of the 8 digits of the national numbering plan.

One solution is to have a second set of $P'\,Q'$ prefixes allocated on a national basis to serve 100 000 additional subscribers, with fictive offices superimposed on existing offices. The AB prefixes in the toll-center translators are in 10 geographic groups corresponding to approximately equal numbers of potential subscribers. These 10 groups are identified by a digit a which, with $MCDU$, will represent a unique national mobile-subscriber number of the second category, $aMCDU$.

In each area a, the $MCDU$ number must be allocated by some central body to make sure that no two identical $MCDU$'s are allocated within an area. The subscriber is then identified by knowing the AB and $MCDU$ numbers. The prefix $P'\,Q'$ is used only to indicate that the subscriber has mobile service of the second category in a given local center.

The 100 000 subscribers in this category cannot receive an automatic fixed-to-mobile roamer service, because 5 digits are needed to identify 1 subscriber out of 100 000 ($AB\ MCDU$ equivalent to $aMCDU$) and 4 digits are needed to find the radio station, giving a total of 9 digits, whereas the numbering plan provides only 8 digits.

To reach a category 2 roaming mobile, an operator must be dialed in the city where the roamer is assumed to be. Given his number $AB\,(P'\,Q')\,MCDU$, the operator will translate AB into a with a 10-entry table valid for the whole country and dial $aMCDU$.

In the reverse direction, the roamer is identified by $aMCDU$ which the operator translates into $ABMCDU$ for ticketing purposes.

Translation of AB into a and *vice versa* can be done automatically for the operator.

A general call along highways, described in Section 4.2.1, is still possible through a toll operator having direct access to the bus line as shown in Figure 6 and fitted with a translator converting $ABMCDU$ into $aMCDU$. Junctor j_n having found the roaming subscriber will keep the radio channel busy and send its identity $A_n B_n P_n Q_n \mu\gamma\delta v$ to the originating toll center which will then place a regular call to reach the junctor using that name. In this case, precautions must be taken on the bus line to identify the 10 000 subscribers having access to the national automatic roamer service, for example, by adding to their $MCDU$ in the originating junctor J (Figure 6) an additional 2-digit code $\alpha\beta$ to enable junctors j_n to recognize a category *1* national subscriber from a local, or category *2*, subscriber.

Because of the French numbering plan with its 8 digits, and design of *STAMP* switching units accessed directly by the group selection of a switching center through a trunk switch, 110 000 subscribers can be served as follows:

— Category *1*, nationwide fully automatic roamer service to 10 000 subscribers identified as follows,

Any area	Radio 1	Subscriber identity.
AB	PQ	$MCDU$

— Category *2*, or manual roamer service, to 100 000 subscribers, identified as follows:

	Home area	Radio 2	
	AB	$P'Q'$	$MCDU$
Group → of areas	a		
	$aMCDU$		
	Subscriber identity.		

Call service along highways can be provided in principle to both categories.

It must be recognized that this scheme is only given as an example of an organization adapted to a particular numbering plan. The limitation of automatic roamer service to 10 000 subscribers would not exist with a 9-digit numbering plan, or with an open numbering system as used in step-by-step networks.

In any case, the limitation is not very serious. Whereas the number of subscribers wanting roamer service may be high (80 percent in Germany), it is likely that the manual roamer service will be acceptable in most cases, so that provision of automatic service to 10 percent of them would seem adequate.

The *STAMP* system is designed to meet various needs. For example, it is possible to have the following with no change in design.

— National service, automatic in certain selected cities, manual in others.

— National service restricted to 10 000 subscribers, the other 100 000 being limited to local service, with no access to networks other than their home network.

4.4 Metering

Metering arrangements in the *STAMP* system are for individual metering and optionally for automatic message recording.

In no case will the fixed subscriber calling a mobile pay extra, because this is not compatible with present metering methods. The simplest way for charging the mobile is a special flat rate. Another simple method is increased unit reading on the normal subscriber meter.

A more sophisticated method is to discriminate between incoming and outgoing calls and to measure their duration with the help of 2 additional meters.

Every subscriber line in the *STAMP* system can be equipped with up to 3 meters for this purpose.

4.5 Selecto-Call between Fixed and Mobile Subscribers

For up to 10 000 subscribers a 4-digit number only is outpulsed to identify a mobile. A code for exchanging this information will be some combination of tone pulses. Here, there are 3 relevant considerations.

— Send only 1 tone at a time, so as to use maximum power and selectivity for each signal and thus increase the range under threshold condition. One signal may be above noise level while 2 signals (with ¼ power each) may be below.

— Send long pulses rather than short pulses, to protect the selecto-call signal from rapid changes in received level due to the car moving from interference maxima to minima and also against interference from transients. Published information [6] shows that 25 milliseconds per pulse is too short, 100 milliseconds desirable, and 50 milliseconds an acceptable compromise at 150 megahertz (at 72 kilometers per hour (45 miles per hour) and 150 megahertz, the time between two minima is 50 milliseconds and ignition pulses are spaced by about 10 milliseconds).

— The time for placing a local call should not exceed a few seconds.

This indicates that the code should be as efficient as possible in terms of bits per digit. Considering the various codes for pulsing out a 4-digit number (start-stop not included) they can be classified in order of increasing merit (decreasing number of bits) as follows:

— decimal code (*IMTS*)	40
— 2 out of 5 [7]	20
— binary decimal (*STAMP*)	16
— pure binary	14
— decimal 10 tones (CCIR) [8]	4
— 3 tones out of 26 (Swiss)	3

For *STAMP*, the decision was made in favor of binary decimal for the following additional reasons.

— Pure-tone selection systems (CCIR and Swiss) rely on highly selective filters whereas binary codes use digital circuitry which can be microminiaturized.

— Decoding of pure binary is expensive.

— Binary decimal is more efficient than a *2-out-of-5* code, although the latter has the advantage of an inherent parity check.

Steps taken to increase the reliability of selecto-call system are as follows.

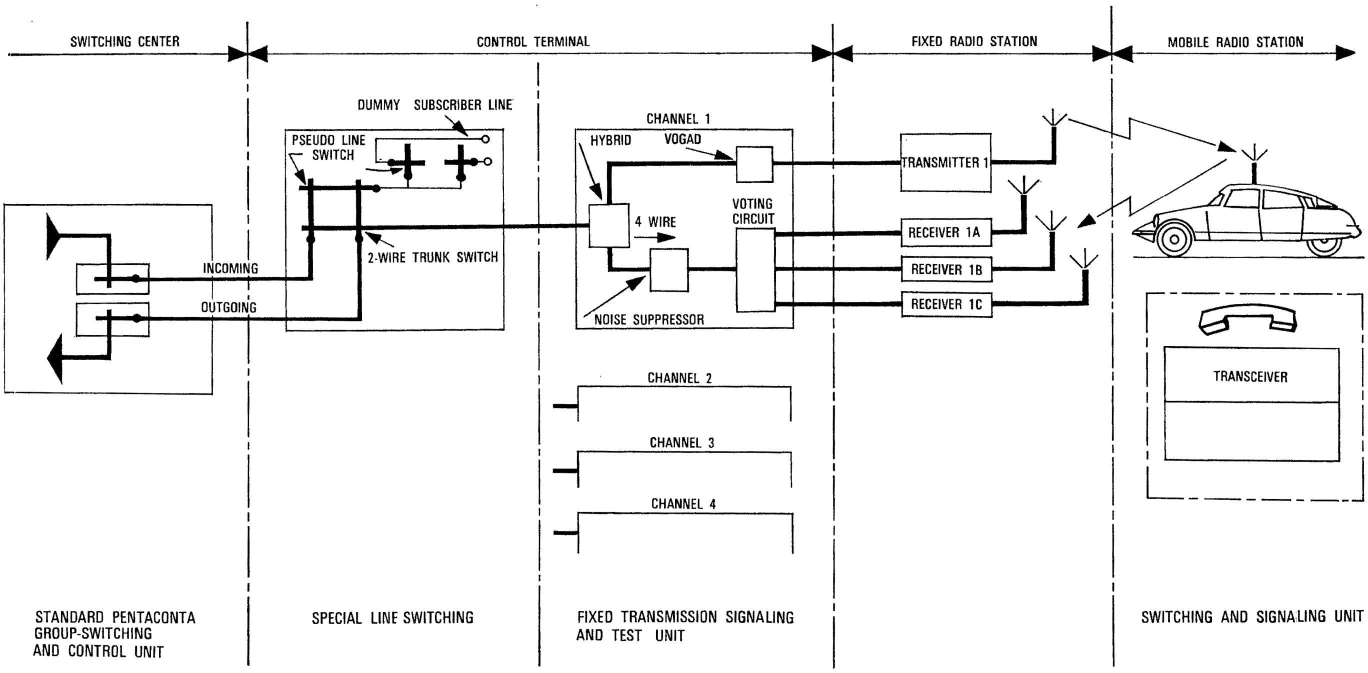

Figure 7 - The *STAMP* system.

— Received pulses are counted and the signal rejected if count is incorrect. This is similar to parity check of *2-out-5* code.
— On mobile to fixed calls, the subscriber identity received by the fixed station is recorded in the control terminal and sent back to the mobile receiver for check with the subscriber code. No dial tone will be given if mobile receiver finds check incorrect.

Thorough reliability tests on the percentage of calls lost, and the percentage of answers to false calls, have shown that calling is reliable as long as the radio circuit can be used for conversation.

For the extension to 5 digits needed for category 2 service, the *STAMP* system uses different signaling tones for carrying the pulses. The 10 000 national or category *1* subscribers are identified by 2 signaling tones f_s and f_c. Every group of 10 000 of the category *2* is identified by another pair tone, so 11 different pairs of tones are needed to call 110 000 subscribers. Each mobile set, however, will be fitted with only one of them, so that extension from 10 000 to 110 000 subscribers does not make the mobile more expensive.

For category 2 subscribers on their home network, terminals need only 2 signaling tones, national and local area a.

With these refinements, the *STAMP* code with 16 bits for 110 000 subscribers becomes more efficient than pure binary, which needs 17 bits.

5. Stamp System

The design is shown in block schematic form in Figure 7 for a particular case of 4 radio channels and 3 diversity receivers per channel.

On the left of Figure 7, there is a standard Pentaconta group-switching element and a control unit. On the right there is a mobile radio and the associated fixed radio station. In between, there is the fixed equipment required to connect the mobiles to the control terminal (or switching center). This terminal (Figure 8) consists of a special line-switching element with a trunk switch and a pseudo-line switch made of Pentaconta standard apparatus, and 4 fixed transmission signaling and test units (as many as there are radio channels) containing the specialized electronic signaling circuitry and ancillary circuits for the fixed radio transmitters and receivers.

Figure 7 shows the path followed by speech. The circuit is on 4 wires from the fixed radio station to the hybrid. The switching circuits are then on 2 wires. The arrows in the group switching unit show specialized 2-wire trunks for incoming and outgoing calls connecting group switching elements with the special line-switching element.

5.1 Radio Equipment

The mobile radio equipment is a 10-watt fully transistorized set operating from a 12-volt supply. Separation between transmit and receive frequencies is 4·6 megahertz, channel spacing 20 kilohertz, and frequency modulation is used. The crystal-controlled oscillator circuits are switched by semiconductors at a rate of 10 per second to hunt for the free channel.

The mobile switching and signaling unit contains a counter associated with a diode matrix for decoding the 16-bit selecto-call signal and creating the local code, and the logic circuitry required to communicate with the fixed transmission, signaling, and test unit to perform the signaling and supervisory functions. Also included are tone generators and detectors for signaling.

The fixed transmitters are transistorized, except for the final 250-watt amplifier. Permanent monitoring of the power transmitted is performed by a directional wattmeter indicating back to the control terminal.

Fixed receivers are fully transistorized, 8 of them in one bay having a total power consumption of 10 watts (Figure 9).

Fixed transmit antennas are on a common mast in a staggered arrangement to minimize intermodulation (Figure 10).

5.2 Fixed Transmission, Signaling, and Test Unit

Transmitters and receivers are connected to the control terminal by matched permanent telephone lines. The fixed transmission, signaling, and test unit has a transmitter control circuit that switches on those transmitters needed for conversation and the marking of the next free channel.

The modulation level of the transmitters is adjusted by a voice-operated gain device (*VOGAD*). A circuit compares noise-generated direct-current voltages from the receivers and when the quality of the signal from a receiver falls below a predetermined threshold it switches to a new receiver. Switching is rapid and cannot be heard.

A noise suppressor or sound-operated noise attenuation device (*SONAD*) prevents re-radiation of received noise through the hybrid during the periods when no modulation is received.

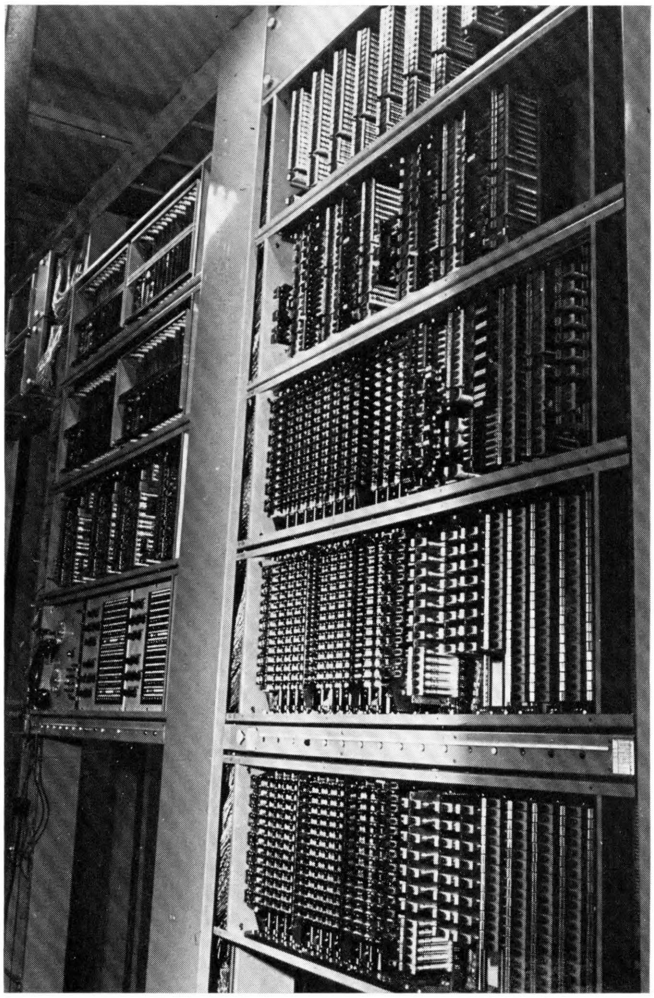

Figure 8 - A 2-channel terminal.

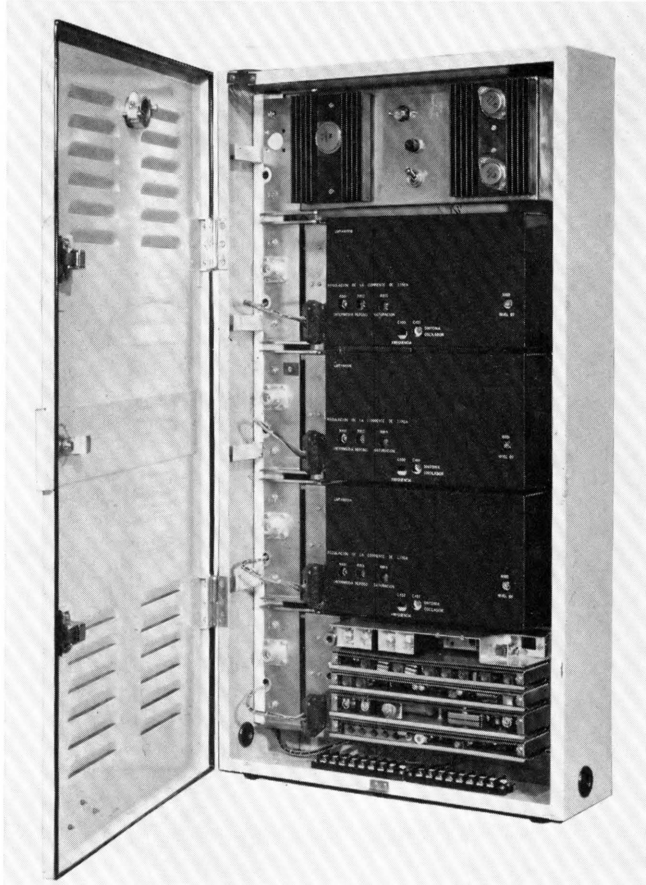

Figure 9 - Receiver cabinet in a 4-channel system.

The unit also has a shift register to record the calling mobile subscriber number in decimal binary code, a code generator identical to the mobile one, and the voice-frequency oscillators and filters for the exchange of selecto-call signals at f_s and 1500 hertz and of supervisory signals at 2100 hertz, f_c, and 3000 hertz. Up to 10 other tones can be added to the basic frequencies $f_s = 600$ hertz and $f_c = 1650$ hertz.

5.3 Control and Switching Equipment

Details of the control and switching equipment located on the left half of Figure 7 are given on Figure 11 which shows the arrangement of the special line-switching element connected to a standard Pentaconta group-switching element.

The special line-switching element contains a trunk switch which directly connects the incoming and outgoing trunks to the radio channels, and a pseudo line-switching element.

The associated control circuitry in the special line-switching element consists of a marker, (Figure 12) and idle-channel allotter, and the dummy subscriber line. In the group-switching element and control unit are the standard Pentaconta control circuits, such as register with junctor and finder, translator, couplers, and highway unit.

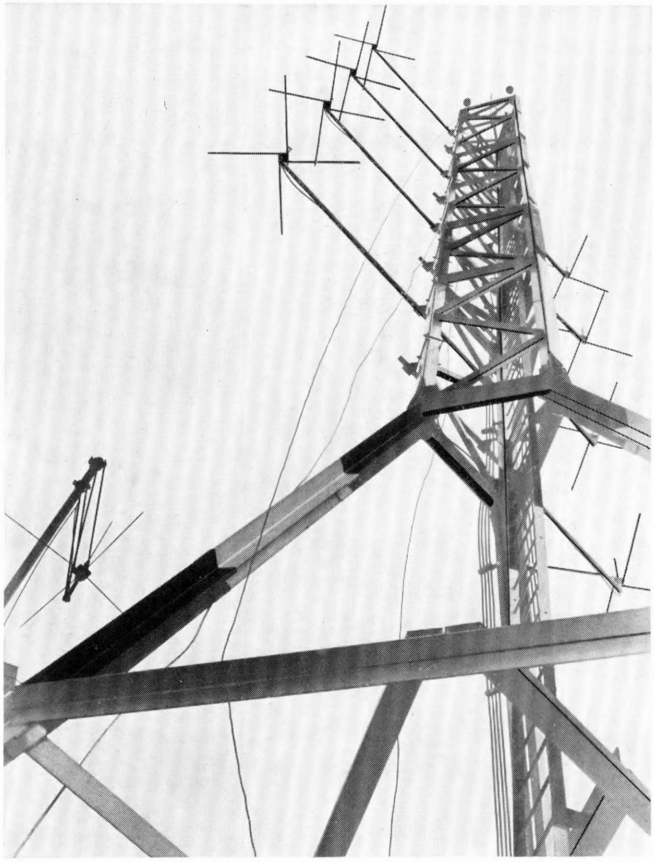

Figure 10 - A shared transmitting antenna.

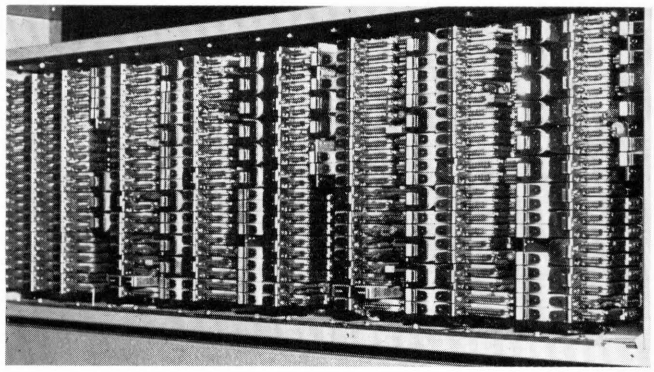

Figure 12 - Pentaconta marker frame with 2 markers.

The transmission, signaling, and test unit (Figure 7) exchanges information with the mobile on one side and with the markers and the idle channel allotter on the other side (Figure 11). The latter selects at any time the next free channel to be marked with the idle tone.

The markers exchange signals with the registers of the control unit. The two markers operate, one at a time, on a traffic-sharing basis.

The pseudo line-switching element connecting the dummy subscriber line to the trunks consists of primary selectors and terminal selectors (Figure 13) in sections of 104 subscribers.

The dummy subscriber line consists of a loading circuit, a hybrid, a pulse sender, a ringing-tone detector, a

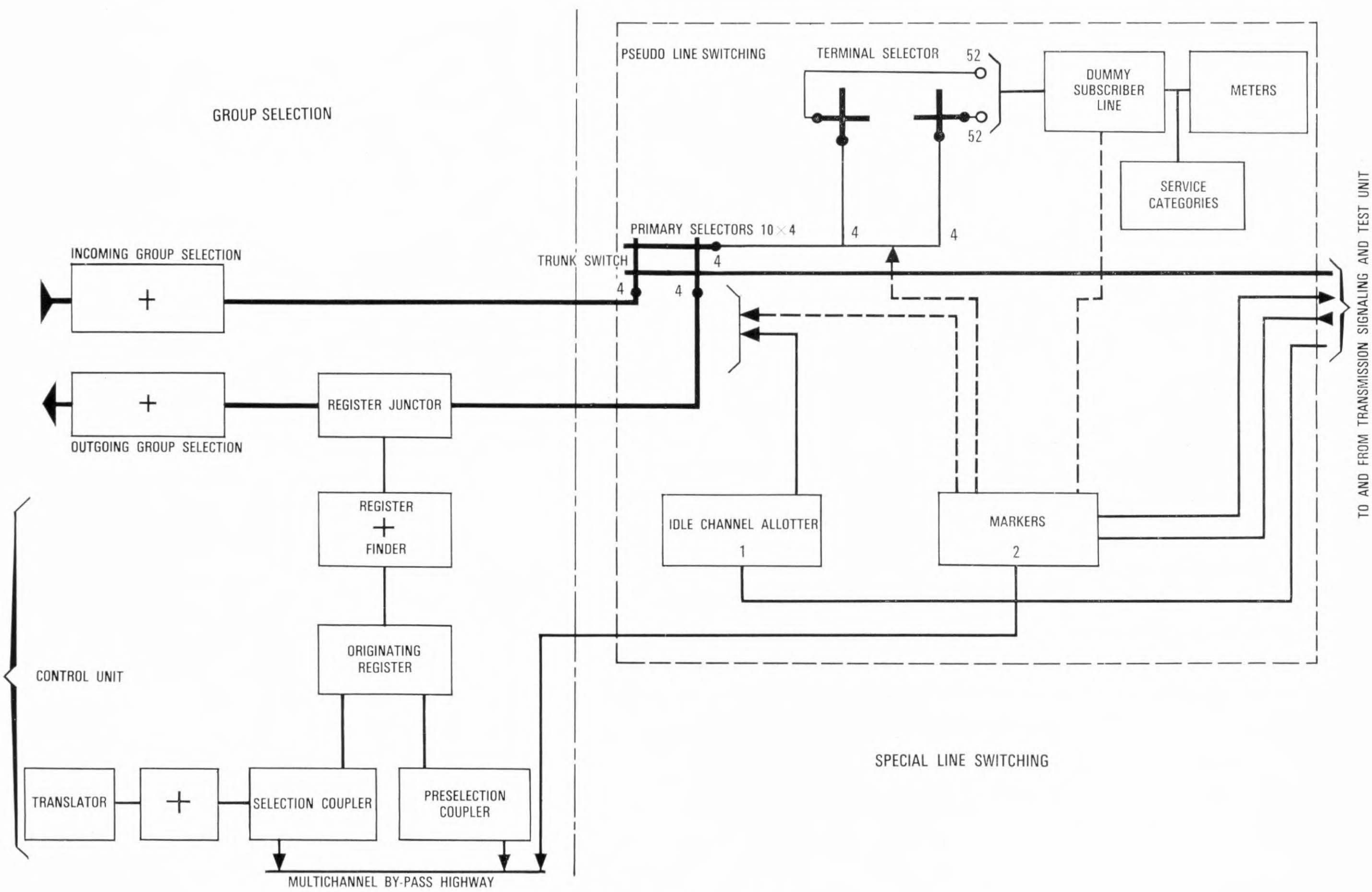

Figure 11 - Control and switching equipment.

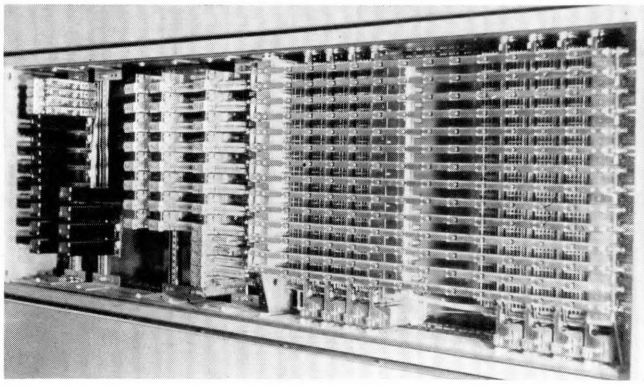

Figure 13 - Pentaconta terminal selector frame for 104 subscriber lines.

cut-off relay which identifies busy lines, and the circuitry to connect 1, 2, or 3 meters.

6. System Operation

The functions of the various units are best understood by examining the signals exchanged between the fixed station and a mobile, when an incoming or an outgoing call is established.

6.1 Incoming Call

The fixed subscriber dials the number of a mobile subscriber. In France this would be *16 AB PQ MCDU* (toll call, area prefix, mobile radio prefix, and the subscriber number), *PQ* being a special prefix for the mobile radio service.

This number is registered in the originating center which establishes a toll call to reach the dummy subscriber line assigned to the called party in the special line-selection element at the radio center. In this center, an incoming register is seized, which transmits to the marker in a *2-out-of-5* code the information relating to the wanted mobile subscriber. The marker finding the corresponding line free, transmits this information to the fixed transmission, signaling, and test unit, after translating it into decimal binary code (16 bits).

Then a sequence of signals is exchanged with the mobile as shown in Figure 14. The selecto-call code is sent out by the fixed station (alternating 600- and 1500-hertz tones). As soon as this selecto-call signal starts, a new channel is marked free by the idle-channel allotter.

Three things happen simultaneously:

— mobiles locked on the first channel cannot leave it until they have received the 16 bits and recognized that the call is not for them,

— mobiles hunting for a free channel cannot lock on this first channel, and

— mobiles locked on this channel cannot initiate a call.

One mobile receives its code and recognizes it. All others leave the channel. The called mobile acknowledges the call by sending out a 2100-hertz guard tone. When this acknowledgment is received at the terminal, the marker connects the radio channel to the incoming trunk and through the highway unit informs the register that ringing can be sent out.

When the mobile lifts its handset, a 1650-hertz connect tone is sent out by the mobile which, when received at the terminal, informs the register that connection is estab-

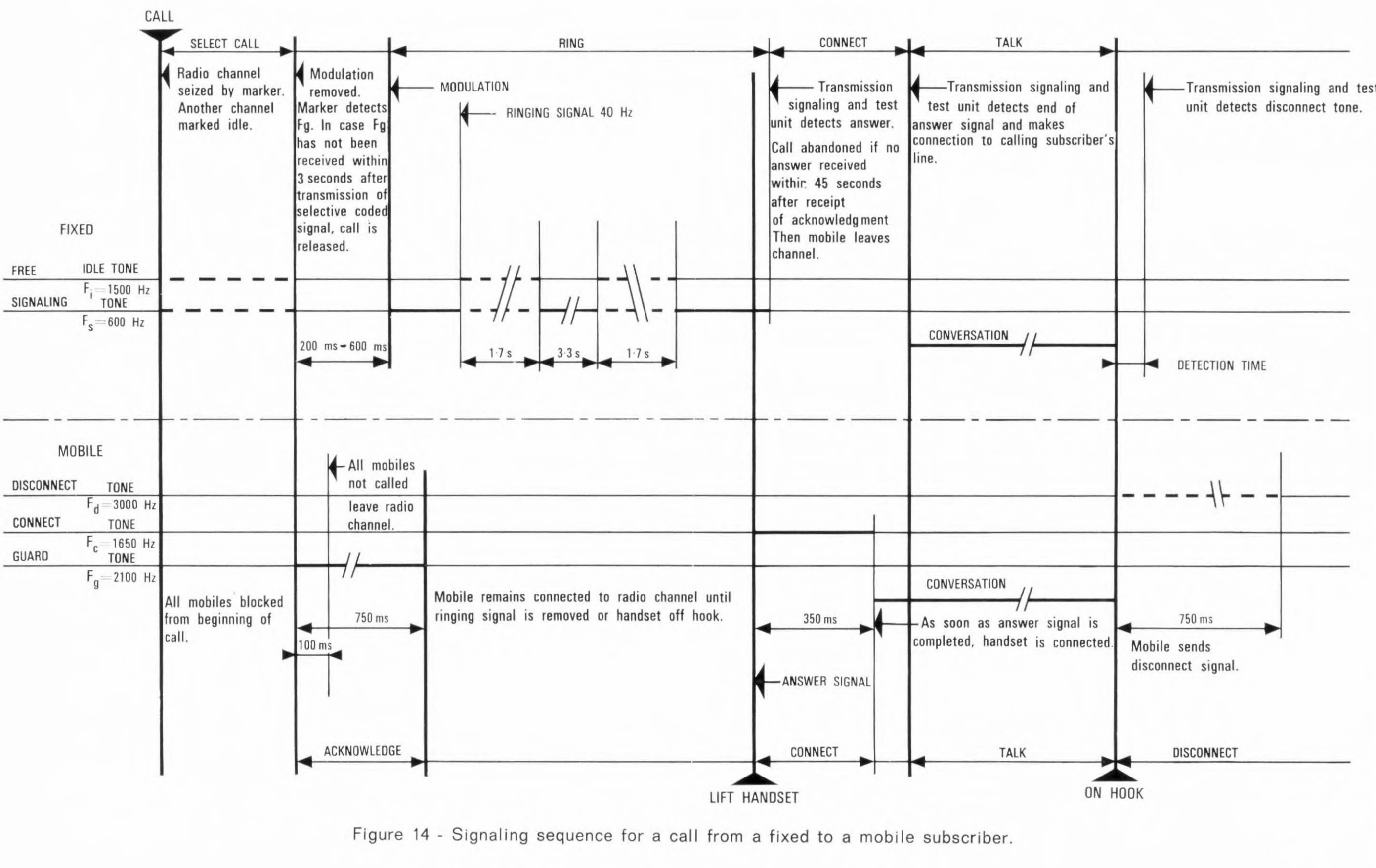

Figure 14 - Signaling sequence for a call from a fixed to a mobile subscriber.

lished. Conversation takes place. When the mobile finishes the call by replacing the handset a clear-down signal is sent out which releases the circuit.

6.2 Outgoing Call

The mobile lifts its handset. If no free channel is available, or no signal is received, a red lamp appears and the mobile must wait.

If a free channel is available the mobile locks on an idle marked channel as follows: it first sends out a guard tone of 2100 hertz (see Figure 15) which, received at the terminal, marks the radio channel as busy and prevents it from being seized by an incoming call. After 350 milliseconds, the mobile sends out a 1650-hertz connect tone which informs the fixed transmission, signaling, and test unit that the radio channel is connected. The idle-channel allotter now removes the idle tone from the first channel and sends it on the next free channel. After 20 milliseconds the mobile hearing this tone disappear recognizes that its own call has been received, and after a delay, sends out its identity in the 16-bit code. This is received, recorded, and fed to the marker which translates into *2-out-of-5* code and marks the dummy subscriber line. The 16-bit code is then sent back to the mobile which checks it and sends back the guard frequency as an acknowledgment. The fixed transmission, signaling, and test unit then informs the marker which now connects the radio channel and the dummy subscriber line to a free outgoing trunk. An outgoing register is seized which sends the dialing tone to the mobile. The mobile dials, the register sets up a connection in the usual way, and conversation takes place.

When the mobile finishes its call the disconnect signal is sent.

It will be noted that the exchange of supervisory and selecto-call information is such that only one tone is present at any time in each direction.

For extension to 110 000 subscribers, the 600-hertz signaling tone f_s and the 1650-hertz connect tone f_c are replaced by another set of two frequencies for every group of 10 000 subscribers (every value of digit a).

6.3 Roamers

On leaving his home network, a category *1* roamer with a national contract for automatic service, puts himself on the absentee service and switches his channel selector to *roam*. In other cities where he has advised he will be, he is treated like a local subscriber both for incoming and outgoing calls.

If a roamer has no national contract, the terminals of other networks will recognize that there is no dummy line allocated to him, or that his connect frequency is category *2*. The call (incoming or outgoing) will then be directed to an operator, or not be accepted.

6.4 Manual Compatibility

The system is so designed that automatic mobiles can also communicate with manual networks if these are fitted with compatible selecto-call and signaling.

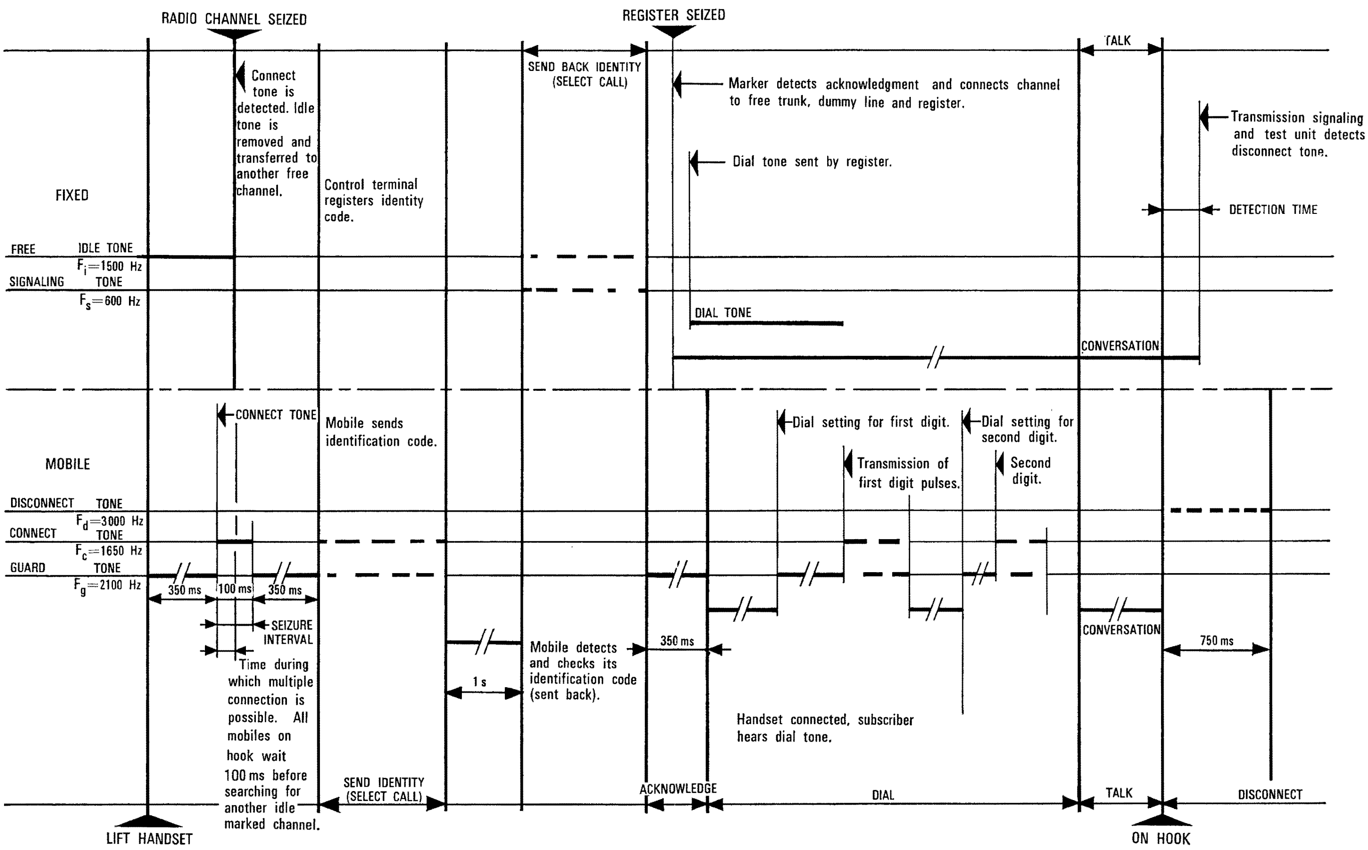

Figure 15 - Signaling sequence for a call from a mobile to a fixed subscriber.

7. Future Prospects

Potential users of fully automatic 2-way systems are numerous and it seems reasonably justified to expect that many countries will soon experience an expansion similar to the one presently seen in the USA. We believe our approach of a system capacity of 110 000 national automatic roamers gives sufficient margin for expansion, with the possibility of progressive implementation.

One can, for example, imagine initial installation of 12 frequencies and 10 000 subscribers, compatible with an ultimate plan for 110 000 subscribers and 36 frequencies. This extension potential does not raise the cost of an initial installation.

The *STAMP* system concept was set up, having in mind the future introduction of electronic switching equipment. In particular, the code translations and data transmissions involved will be natural functions of stored-program controlled switching centers.

8. Acknowledgments

The author is indebted to ITT Kellogg for many useful discussions and to Messrs Henquet and Bruley of LMT who were responsible for the development of the equipment.

Jean-Jacques Muller's biography appears on page 368.

References

[1] V. A. Douglas: The *MJ* Mobile Radio Telephone System, Bell Laboratory Record, December 1964, p 383.
[2] J. J. Muller: *STAMP*, Système Téléphonique Automatique Mobile Public, Commutation et Electronique, no 18, July 1967, p 66.
[3] Wallace C. Babcock: Intermodulation Interference in Radio Systems, Bell System Technical Journal, January 1953, p 72.
[4] C. Colavito, G. Pagni: Critere Informative per la Realisatione di un Servizio Radio Mobile Puboico, XIV International Convention, Geneva, 12—15 October 1966.
[5] Nationwide call — French Patent PV 105,371.
[6] Les parametres essentiels d'un systeme d'appel de vehicules. Contribution of the Swiss Administration to the Study Question R. 16 of CEPT.
[7] CCIR Document XIII/76, February 2, 1966 — Question 271 XIII.
[8] CCR Document XIII/33 (Rev. 1) — April 27, 1967.
[9] K. Bullington: Radio propagation fundamentals, Bell System Technical Journal, May 1957.
[10] D. Talley: Radio Engineering and Field Survey Transmission Methods for Mobile Telephone Systems, IEEE Transactions on Vehicular Communication, volume VC 14, no 1, March 1965, p 7.

Appointment

General Technical Director of International Telephone and Telegraph System

Albert E. Cookson, vice president of International Telephone and Telegraph Corporation, has been promoted to General Technical Director of the System. He assumes the post previously held by **Dr Henri G. Busignies,** who has been advanced to Chief Scientist.

Mr Cookson received a Bachelor's degree in electrical engineering in 1943 from Northeastern University. After serving as a navy radar officer during the second World War, he joined the Research Laboratory for Electronics of Massachusetts Institute of Technology. In 1951 he received a Master's degree in electrical engineering from that university.

He joined ITT Federal Laboratories in 1951 and became director of the Missile Guidance Laboratory, where he supervised the development of guidance, countermeasure, and telemetry systems for the Meteor, Lacrosse, and Talos missiles.

In 1959 he was made vice president and director of operations of the Data and Information Systems Division during implementation of the *465 L* program for the United States Air Force.

He became president and general manager of the newly formed ITT Intelcom in 1962 and was responsible for its contracts with the Department of Defense.

In 1965 he was transferred to the headquarters technical staff as deputy general technical director, where he now serves as General Technical Director.

Mr. Cookson is a member of *Tau Beta Pi* and *Sigma Xi* engineering and scientific honorary societies, Institute of Electrical and Electronics Engineers, American Institute of Aeronautics and Astronics, American Management Association, Armed Forces Communication and Electronics Association, National Space Club, and Electronics Industries Association.

Digital Telemetry Equipment in Space Craft

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D. PABST
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1. Introduction

The launching cost for a low-orbiting satellite is at present of the order of $ 2500 per kilogram weight of satellite. Hence it is necessary that the design and production of space equipment meet very stringent requirements with respect to weight and reliability. The same applies to the power consumption, which determines the size of chemical batteries and the area of solar batteries and therefore affects the weight of the satellite. The space equipment has to operate under adverse environmental conditions, such as vacuum, high acceleration and vibration during launch, wide variations of temperature, and sometimes nuclear radiation of high energy. For these reasons the design and production of telemetry units for space vehicles are determined to a far higher degree by non-telecommunication requirements and environmental conditions than similar equipment in ground stations. The solution of such difficult problems involves high cost so for commercial reasons, functionally identical satellite-borne and ground instruments are made using entirely different circuits, components, and techniques; the most expensive techniques are reserved for satellite-borne equipment.

In the following paragraphs we shall describe those features of the space-flight technique relating to data-processing instrumentation for telemetry systems. Units and systems will be described which we developed with the aid of grants made available from the national space program by the German Federal Ministry for Scientific Research.

2. System layout and Development

For space-flight applications a telemetry system employing pulse code modulation (*PCM*) offers a number of advantages when compared with other modulation techniques. From the results of measurements a sequence of coded signals can be derived, which are easily stored on the satellite, are simply transmitted, and without great effort can be evaluated by a computer. The coding into *Yes-No* data offers an effective protection against errors and can be carried out to a large extent, as with the time-division multiplex (*TDM*), using digital circuits. These digital circuits are easily produced in the form of integrated circuits (*IC*) and hence permit a small, light construction. Instructions for the identification of the data can be added to the format of a *PCM* telemeter system in a simple manner by giving each format a successive number. Thus it becomes possible to assign the data to a particular time and, provided the orbit of a space vehicle is known, to a location. Compression of data is feasible with comparatively simple methods and saves storage capacity on the satellite and hence reduces weight and volume as well as transmitter power. The straightforward evaluation of the telemeter data by a computer during integration and checkout of a space vehicle is also possible.

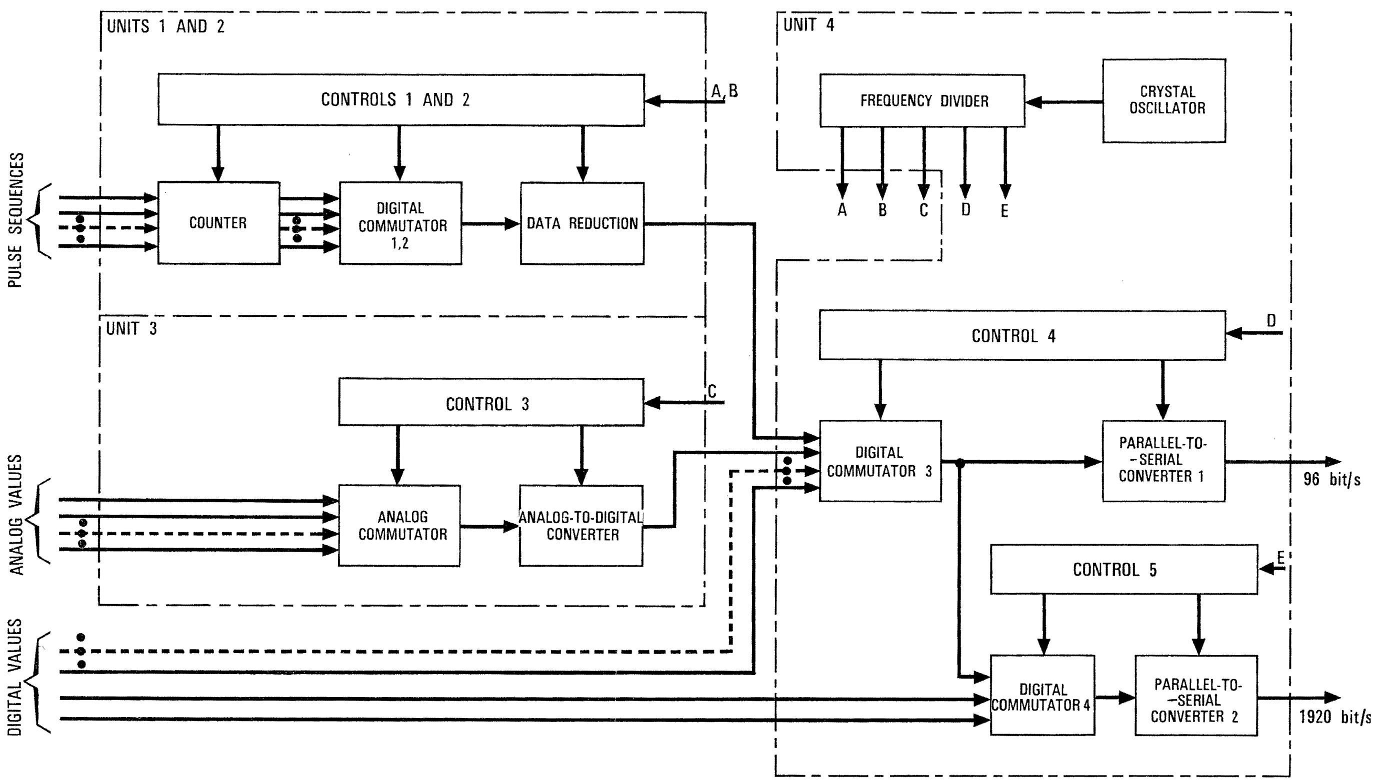


Figure 1 - Block diagram for *PCM* telemetry system *AZUR*.

Figure 1 shows the block diagram of the *PCM* telemeter system for the scientific satellite *AZUR*. This is an example of a data-processing system which handles analog and digital data as well as pulse sequences from scientific experiments and transmits them from two outputs with different bit-repetition frequencies by means of *TDM*. The data from the 96-bit/second output are meant to be recorded on tape. They are contained in the data of the 1920-bit/second output, which modulates the transmitter directly. Each word of the 96-bit/second format is additionally marked by a number and inserted into the 1920-bit/second format. (See Figures 2 and 3 for formats.)

Some design advantage is obtained by subdividing the total system into four units. A number of smaller boxes allows better mechanical stability because they may be used to counterbalance each other thus removing the need for additional weights to maintain balance in the satellite. These four units were designed so that the number of electrical interconnections was as small as possible. A large number of connections would increase the weight in the form of cables and plugs, would require additional circuit elements for the suppression of noise arising from interconnections, and would increase the time and effort needed for checkouts. A small number of connections is possible because each instrument uses *TDM* and needs only one working pulse and one synchronizing signal. These are generated in unit *4*. Hence four commutators with separate controls take part in the generation of the 96-bit/second format. (See Figures 1 and 3.)

Units *1*, *2*, and *3* each generate 6 bits in parallel which are taken over by unit *4* into the parallel-to-serial converters. Each time six digital data are interrogated simultaneously.

All the control signals are derived from a redundancy-technique crystal oscillator housed in unit *4*. If one oscillator should fail the second is automatically connected to the circuit. The frequency divider which follows is also duplicated and can be changed over by a command signal. The same holds for the parallel-to-serial converter *2*. Care has been taken that no individual component failure will cause both the outputs of the telemetry system to be simultaneously inactive. With these measures it is possible to considerably improve the reliability.

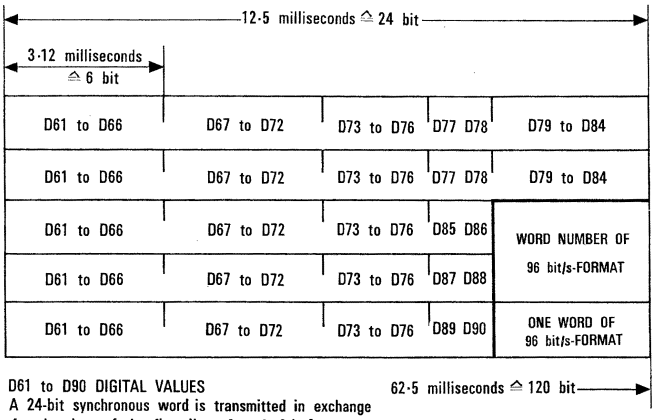


Figure 2 - 1920-bit/second format.

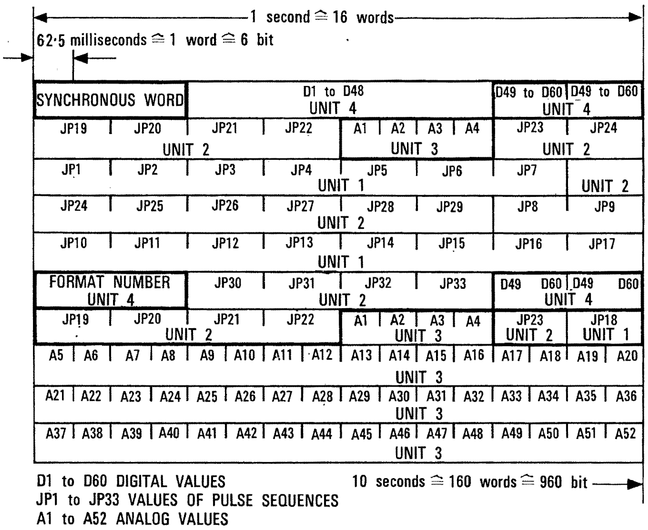


Figure 3 - 96-bit/second format.

The digital commutators *3* and *4* use integrated diode switches because of their low power consumption and small size.

To increase reliability, each of these digital commutators is built up of a number of smaller commutators, the outputs of which are combined in a further commutator.

The same principle has been applied to the analog commutator of unit *3*. It uses integrated choppers triggered by pulse transformers. The next-in-line analog-to-digital converter digitizes voltages between 0 and 2·5 volts in six cycles into 6-bit words. The principle showing how the highest-order bit is obtained is as follows (see Figure 4). With the control signal for the highest order (*S 5*) the flip-flop (*FF*) for the highest-order bit is switched to *1* where it will be held, whereas all other *FF's* are kept at *0*. The *FF's* feed a digital-to-analog converter, which then yields 1·25 volts at the output. A comparator compares this voltage with the measured voltage and, depending on whether the latter is less than, equal-to, or greater-than the measured voltage sends the information *0* or *1* back to the *FF's*. The flow of signals must be completed within the duration of the control signal.

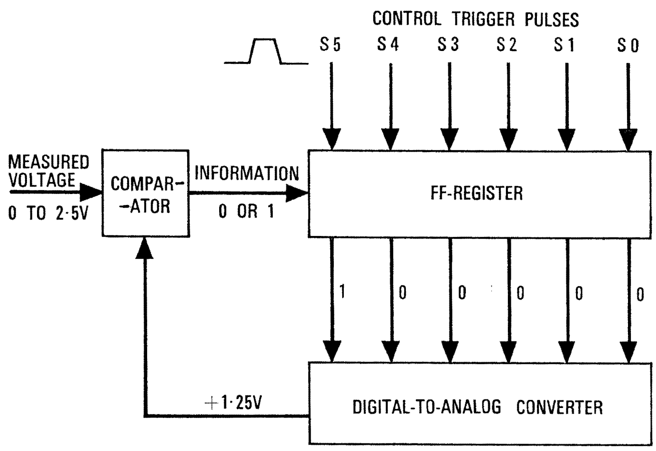


Figure 4 - Principle of analog-to-digital conversion.

At the end of the control signal *S* 5 the information is taken up by the *FF* for the highest-order bit. In the same way the lower-order bits are determined one after the other with a further five control signals.

To save power, integrated circuits of series *51* have been connected in an unusual way in control *3*. The emitter-follower output of one *NAND*-stage yields the supply voltage for several other *NAND*-stages (Figure 5). With this arrangement one obtains circuit-saving *NAND* configurations and a noticeable saving of power when several such groups are required. A further saving is possible if outputs *A* to *H* have to be positive for only a short time, which is the case for the triggering of the analog commutator.

Units *1* and *2* are supplied with pulse sequences from radiation detectors. For each of 33 independent pulse sequences these instruments determine the number of pulses per unit time in 22-digit binary counters. The numbers obtained are transferred by *TDM* into a data-reduction device. This transforms the binary numbers into floating-point representation by shifting and counting (mantissa 7 bits, exponent 4 bits) and passes them in parallel on to unit *4*. During the time of transmission of the numbers into the data-reduction device the counter inputs are shut for 125 milliseconds (see format, Figure 2).

The problem of transmitting 33×22 bits in *TDM* has been solved with fewer circuits. A backward-counting binary counter in the data-reduction device is fed by control signals that simultaneously drive forward the counter whose contents are going to be transferred. The overflow pulse, which is conducted via either digital commutator *1* or digital commutator *2*, stops the backward-counting counter, which then contains the transferred number. Since this method would require a maximum of 2^{22} cycles in 125 milliseconds (equal to 33 megahertz), 11 bits are transferred in a first step and another 11 bits in a second step. This requires only 2×2^{11} cycles (equal to 33 kilohertz).

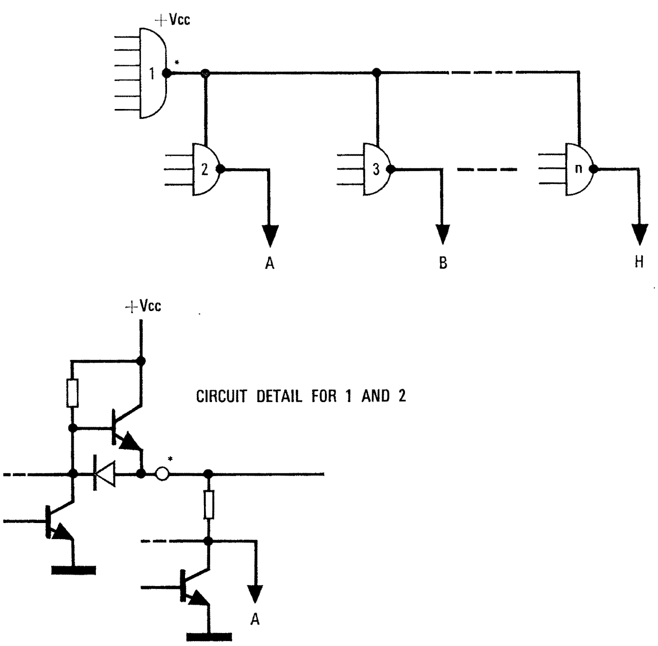


Figure 5 - *NAND*-configuration which reduces the number of integrated circuits.

825 *IC's* are required for the counters in units *1* and *2*. The entire system as shown in Figure 1 contains 1600 *IC's* and about 600 conventional components.

3. Construction and Technology

A well-established and versatile technique has been chosen for the construction of space equipment. Integrated circuits and conventional components are welded or soldered onto cards, which are printed on both sides. These cards are housed in a casing with as little distance between them as possible. Depending on the requirements they can be either soldered or plugged into a printed motherboard.

A careful analysis was made to determine the optimum card size and the required number of plug pins for the construction of the equipment. The following conditions have been met in this analysis.

- Connections to the card on one side only to allow them to be easily exchanged.
- Both sides of the cards printed. Multilayer construction is avoided for reasons of reliability, production time, and production costs.
- Use of *IC's* and if possible other semiconductors in flatpack construction.
- If possible, accommodation on one card of an entire functional unit, as for example, the shift register and counter with trigger unit, analog-to-digital converter, and so on. This eases the checking and finding of errors, increases the versatility, and reduces the number of connections.

As a result of this study a card with dimensions $57{\cdot}5 \times 60$ millimeters ($2{\cdot}25 \times 2{\cdot}36$ inches) was chosen which normally provides space for up to 24 *IC's*. If the wiring is very simple, as for instance in binary counters or shift registers, and using *IC's* with only 10 connections, a maximum of 28 *IC's* is possible.

Figure 6 shows the plug-in type of card with a 38-pin Cannon *MTA*—plug, which is replaced by the required number of connection strips in the solderable type of cards.

The printed layers are made of nickel, which guarantees good welds with the *IC's* and also reliable soldered connections with conventional components. The spacing between printed strips is $^1/_{40}$ inch (0·635 millimeter) whereas the spacing between the conduction leads of the *IC's* is $^1/_{20}$ inch (1·27 millimeters), so that a printed strip can be led between two adjacent conduction leads of the *IC's*. This arrangement requires 20-percent less area and it simplifies the outlay of the cards.

Figure 7 shows a unit constructed on these principles. It contains a telemetry encoder for 30 channels, a *PCM* command decoder, and a direct-current converter for the power supply. Previously a unit performing exactly the same functions was built using conventional techniques, so that a comparison could be made. By using the modern techniques a reduction of weight and volume of about $^1/_7$ was achieved and at the same time the mechanical stability was considerably improved.

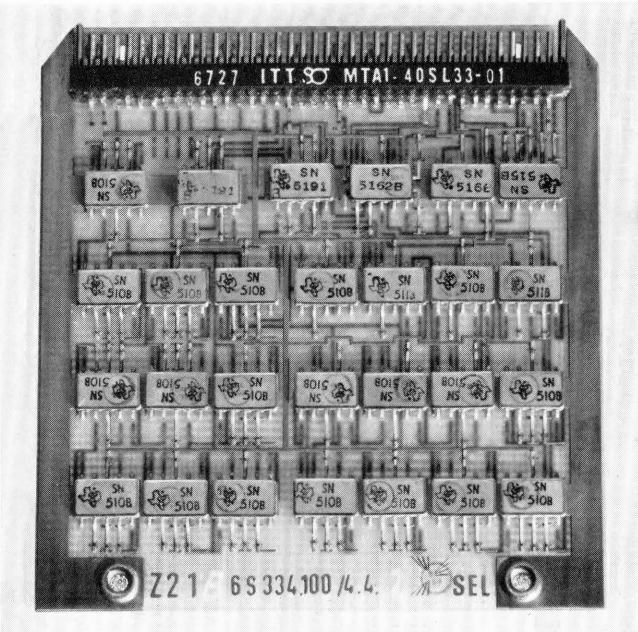


Figure 6 - Printed card of the plug-in type.

The cards are fixed in the casing on all four sides; on the upper side by the plug guides, on the underside by a metal strap with an elastic insert, shown in Figure 7 in front of the box, and on the other two sides by spring clamps. With this arrangement a mechanical stability is achieved which is sufficient in most cases. A number of units have been subjected to a maximum of 50 *g* in vibration tests and no failures occurred. If this is not sufficient for extreme requirements, the boxes can be filled with foam material. In this case, however, they can no longer be repaired.

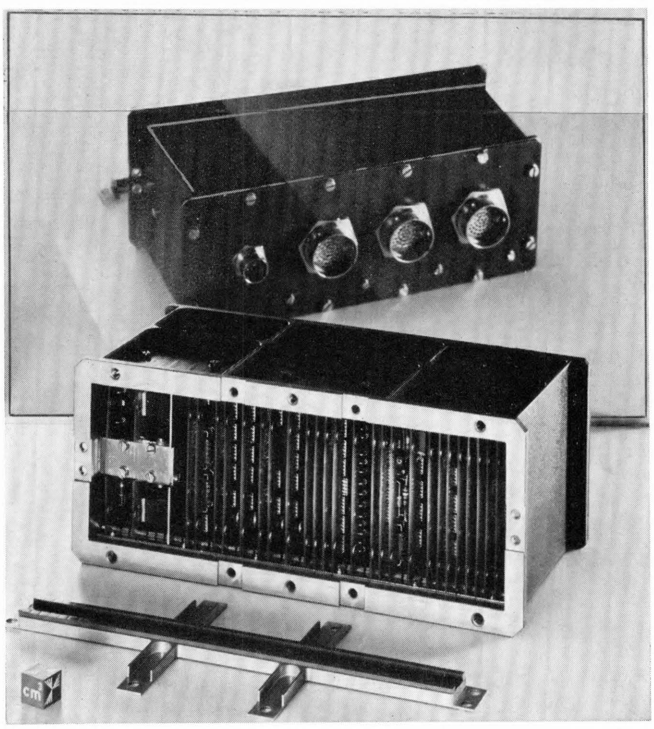


Figure 7 - *PCM* telemetry and command unit.

4. Components and Materials

The selection of components for satellite-borne equipment is a difficult problem. Usually one requires a reliability of the entire satellite of more than 0·5, that is, the probability that the mission is successful during the required period of time (for example, 1 year) is expected to be better than 0·5. If one deduces the required reliability of the telemetry equipment from this value one arrives at failure rates which are of the order of 10^{-7} to 10^{-9} per hour for the various components. At present such values can only be obtained if utmost care is taken in their production. In view of this, one would obviously tend to rely on lists of recommended components, for example, those issued by NASA, in the selection of components. Usually these lists contain only those components that have turned out to be reliable in practical trials over several years. This implies that some recommended components are not those most recently developed. Hence instruments using such components may already be out of date at the time of their completion. For this reason recommended components are not exclusively used, but new or improved ones whenever they offer advantages with respect to weight or power consumption. In these cases extensive and expensive tests are made to obtain sufficient knowledge of their reliability.

In the equipment developed so far, extensive use of circuits of the series *SN 51* has been made. They are recommended by NASA and tested in a large number of satellites and even today they can compete with newest developments in this field.

All the other materials for casings and cards were chosen for having low weight and yet giving sufficient stability and durability in the environmental conditions to which they will be subjected.

In special cases like project *AZUR* an additional difficulty is that magnetic materials have to be avoided as far as possible so as not to interfere with measurements of the earth's magnetic field.

5. Production and Checkout

The assembly of space equipment and the required facilities for assembly must take account of the following:

— very small parts have to be handled and processed which means a large number of operations must be done under a microscope and,

— many controls and intermediate checks are made during the precise operations to achieve the highest possible reliability of end product.

For welds and soldering joints a failure rate of 10^{-9} per hour was assumed in the project *AZUR*. Although this value is very difficult to achieve in production it is necessary if one takes into account that the total satellite comprises about 40 000 to 50 000 electrical connections. The actual production and assembly of most of the satellite-borne instruments and devices are therefore performed in clean rooms by carefully selected and trained personnel. Figure 8 shows such a clean room, in which equipment of this type is assembled.

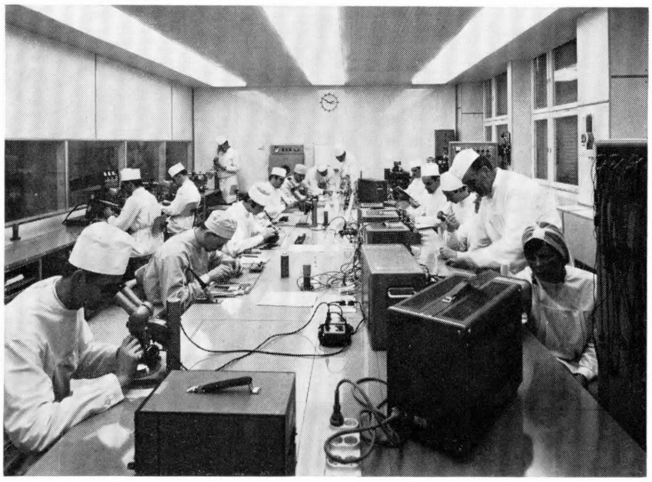


Figure 8 - Clean room for space equipment at SEL factory.

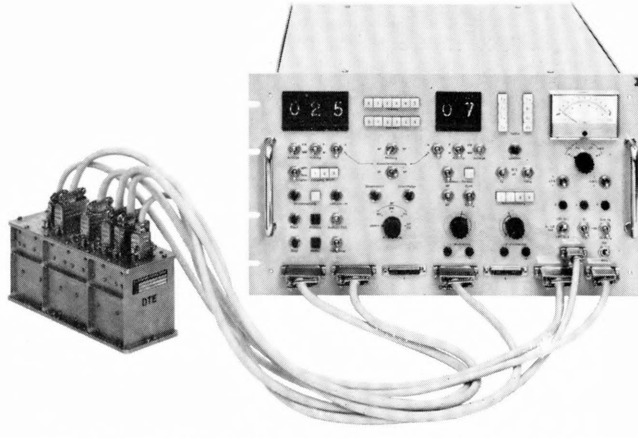


Figure 9 - Automatic test device connected to a telemetry unit.

The functional test of the cards and the final checks at the end of the production process are also performed in this room, but the extensive qualification and acceptance tests (vibration, shock, vacuum, temperature, electrical, and magnetic effects) are mainly done by IABG, a German central authority for environmental tests. Before, or after, each individual environmental test and at various preset values of, for example, temperature or supply voltage, functional tests designed to detect any possible defect of the equipment are made. For one single qualification test an estimated 30 such functional tests are required. For a satellite project involving five sets of equipment about 150 are needed. Some functions take several hours or even days to complete (longer measuring programs, orbit counter, emergency program) so that purely manual tests with conventional test instruments are no longer feasible. Hence test devices have been developed for the various satellite-borne units. These enable complete and automatic functional tests to be made, which may, if required, be accelerated, without using further auxiliary equipment. Figure 9 shows such a test device connected to a telemetry unit from Project *AZUR*.

Hermann Endres, born 1922 at Pfaffenhofen, Ilm, received his engineering education at the Technical University, Munich, majoring in communication engineering. After qualifying in 1949 as Diplomingenieur he entered Standard Elektrik Lorenz AG. He was engaged on the development of electronic switching equipment, carrier frequency and time-division-multiplex systems, and computer systems. Since 1963 he has been chief of development of air traffic control and telemetry systems.

Dietrich Pabst, born 1931 at Sorga, Hessen, received his engineering education at the Technical University, Darmstadt, majoring in communication engineering. After qualifying in 1958 as Diplomingenieur he entered Standard Elektrik Lorenz AG, and was engaged in computer development. Since 1966 he has been head of a laboratory for development of space equipment.

Radar Performance Improved by Digital Processing

J. M. COLIN
Laboratoire Central de Télécommunications, Paris

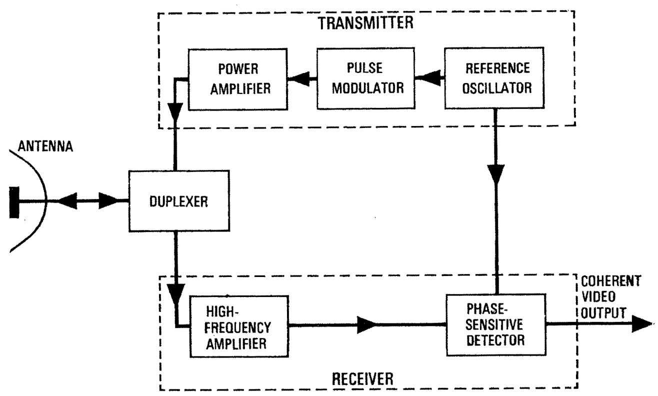


Figure 1 - Basic block diagram of a coherent pulsed radar.

1. Introduction

For many years research and development have been applied to the use of the Doppler effect for ground-surveillance radar systems [1]. In these systems a coherent pulsed transmitter and a receiver with range gates and Doppler filters are used to give a 40-decibel discrimination between a moving-target echo and the clutter from fixed-targets echoes at a range up to 30 kilometers (18·6 miles). Such equipment could mean the use of 100 range gates, each with 10 Doppler filters, giving a total of 1000 filters.

To avoid this large number of filters, a technique employing 5 sliding gates, each with 2 Doppler filters, has been in general use. This technique, however, gives a worsened radar performance.

We now have a technique, suggested by S. Albagli, for processing Doppler-radar signals using a digital technique which reduces the number of filters required, gives a matched-filter concept, and so improves the radar performance.

In the process each range-gate output is stored in a memory and examined sequentially through one series of filters and their associated threshold detectors.

Compared with the sliding-gate technique this new process has the following advantages:

— increased receiver sensitivity,
— increased scanning speed,
— opportunity to measure the radial velocity of an echo, and
— greater protection against jamming.

These improvements make the technique suitable for the next generation of Doppler-radar equipments.

2. Doppler Coherent Pulsed Radar

In a coherent pulsed radar the phase of the transmitted signal is maintained for comparison with the received-echo phase by a reference oscillator that controls the phase-sensitive detector. The basic diagram is shown in Figure 1.

If A is the amplitude of the received signal and φ its phase difference with respect to the master oscillator, the output voltage V of the phase discriminator will be

$$V = A \sin \varphi.$$

The fixed-target echo has a constant phase difference with respect to the transmitted pulse and the phase-difference signal is constant from one pulse to the next. For a moving target, this phase difference will vary with successive pulses and the phase-difference-signal envelope constitutes a Doppler signal.

The whole process, from the antenna to the video-frequency signal, is linear and the moving-target information contained in the received pulse is preserved without distortion through to the video-frequency stages. The coherent receiver changes a spectrum of received signals around the carrier-wave frequency into a spectrum around zero frequency.

The high-frequency amplifier, shown in the receiver in Figure 1, can be replaced by a heterodyne receiver, provided the received signal and the reference signal are mixed with the same stabilized local oscillator. Thus high-frequency amplification can be replaced by intermediate-frequency amplification which is easier to arrange; however the principle of operation remains the same.

2.1 *Frequency Spectrum of Received Signal*

The spectrum of an echo reflected by a fixed target consists of lines spaced out at the repetition frequency f_r.

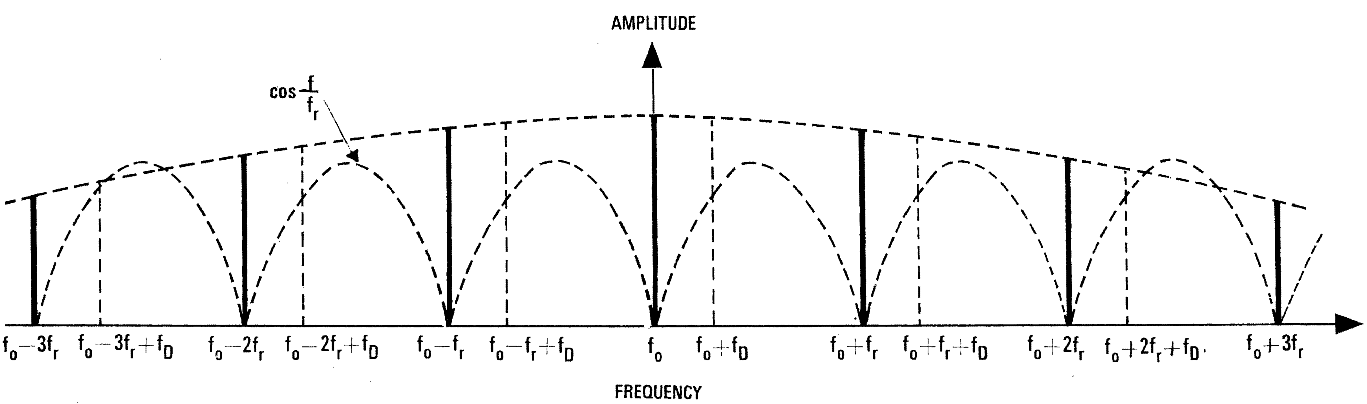


Figure 2 - Echo spectra for a fixed antenna.
The solid lines are echoes from a fixed target and the vertical dotted lines are from a moving target.

A portion of this spectrum, set around the carrier frequency f_o, is shown in solid lines in Figure 2.

But the spectrum of an echo reflected off a moving target is shifted by the Doppler frequency f_D and produces the dotted lines whose frequency is given by

$$f_o + f_D \pm nf_r$$

where n is an integer.

The aim is to suppress fixed echoes and this was first achieved by a delay line whose frequency response is in the form of

$$\cos \frac{f}{f_r}.$$

This response curve appears in Figure 2.

This only applies if the radar antenna has a fixed direction. If the antenna rotates, as in surveillance radar, the spectrum lines become wider and their spectral width is approximately equal to the inverse of the time the beam stays on target. Figure 3 shows the echo spectrum for this condition. In the figure the spectrum is taken at the video stage with the spectrum folded over due to the shift in reference frequency from the carrier to zero. Looking at this spectrum it is obvious that filtering with a delay line cannot completely suppress fixed echoes. Greater suppression can be achieved by a band-pass filter, as shown in Figure 3, with cut-off frequencies f_{min} and $f_r/2$. A moving target producing a Doppler frequency between $nf_r + f_{min}$ and $(n+1)\ F_r - f_{min}$ will be passed through the filter, and fixed echoes suppressed. However, this only applies to a single echo, so each echo must be selected by a range gate before the filtering process.

There are two possible methods of selecting echoes throughout the range scale of the radar.

— The use of a large number of range gates in succession (usually about 100), up to the maximum range of the radar. Each gate is followed by a Doppler filter as shown in Figure 4.

— The use of a smaller number of range gates (5 for instance) which are slowly shifted throughout the radar range scale.

The former avoids any reduction in information output rate but requires a large number of Doppler filters and range gates.

The latter implies a simpler radar but a reduction in the information output rate since the beam must remain on the target for as long as it takes the range gates to scan the range scale. Nevertheless, this method is widely used in ground-surveillance radar systems where targets are slow moving.

2.2 Estimate of Noise

Since the receiver of a coherent radar like the one shown in Figure 1 is linear from the antenna to the video-frequency output, its noise pass band is that of the Doppler filter.

In the example of Figure 3, the noise pass band is $\frac{fr}{2} - f_{min}$, whereas the bandwidth of the signal is much narrower and can be calculated in the following manner. The antenna-rotation speed must allow the beam to be on target for a time at least equal to one cycle at the lower Doppler frequency to be detected, that is, $1/f_{min}$. Thus, the bandwidth of the received signal f_i is approximately equal to f_{min}. Usually, the ratio of the noise bandwidth $\frac{fr}{2} - f_{min}$ to the signal bandwidth f_i is between 10 and 50 and this leads to reduced sensitivity in the same ratio. Information theory shows that the optimum signal-to-noise ratio is obtained when the receiver pass band is equal to the spectral width of the received signal. To design the necessary filter presupposes knowledge of the Doppler frequency and this is impossible. However, a number of narrow filters each with a pass band of approximately f_i can be used with a threshold detector at each output to detect the presence of an echo. Such an arrangement provides for a near perfect radar as regards sensitivity and information output rate, but it will have too many components, for example, double the multiplicity of Doppler filters.

In a conventional Doppler radar with n range gates, each gate having m Doppler filters, n should be about 100 and m at least 10. This means 1000 Doppler filters.

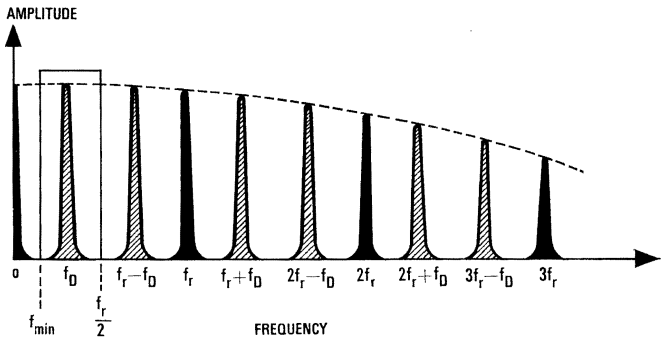


Figure 3 - Echo spectrum for a rotating antenna.

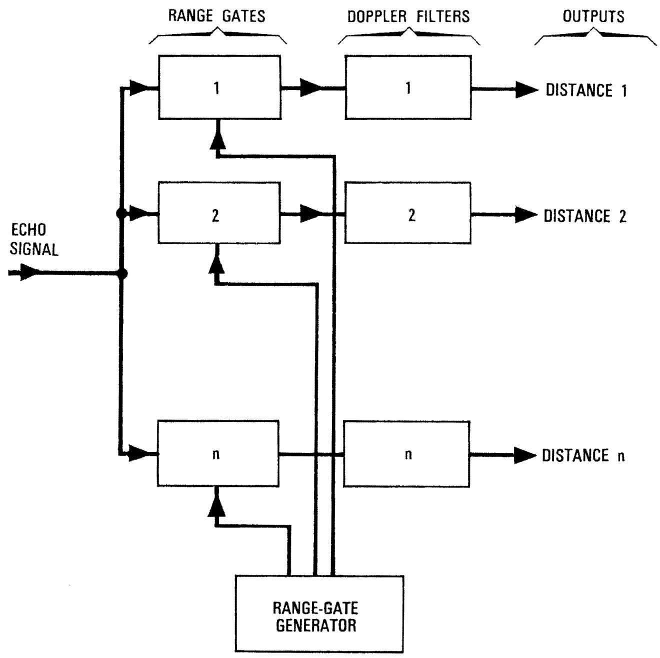


Figure 4 - Principle of echo detection with fixed range gates.

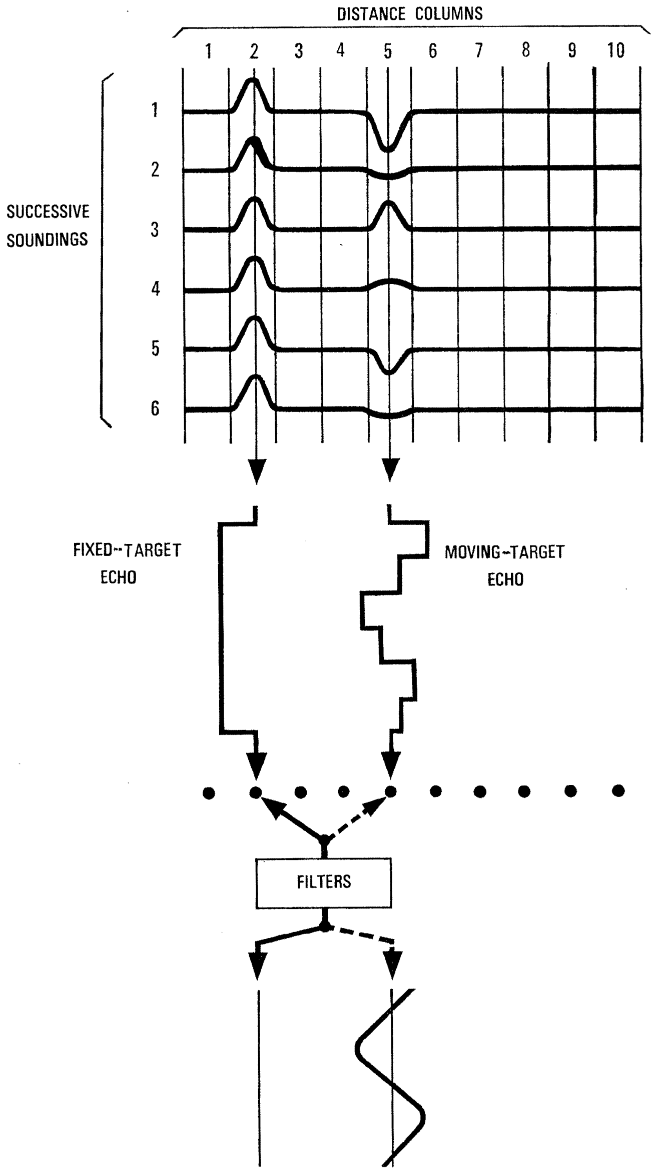


Figure 5 - Principle of the new system.

In the system described below, this large number of filters will be avoided whilst the sensitivity and information output rate of the radar system is maintained.

3. Doppler Radar with Digital Processing

Video-frequency signals coming from successive radar soundings are recorded line by line in a memory, as shown in Figure 5. Six soundings are represented, each for two echoes, a fixed echo in range slot 2, and a moving echo in range slot 5.

Once this recording has been completed, the columns are read in succession. Each read-out provides the history of a particular echo and successive read-outs can be directed in sequence to a series of Doppler filters.

Only one set of filters and threshold detectors need be used; and each echo is analysed in succession. The parallel operation of a large number of range gates is now replaced by a series operation.

The number of distance columns is decided by the radar resolution and the number of soundings p to be recorded must be such that at least one cycle of the lowest Doppler frequency to be detected f_{min} is recorded. If f_r is the repetition frequency, the minimum number of soundings p_{min} recorded is given by

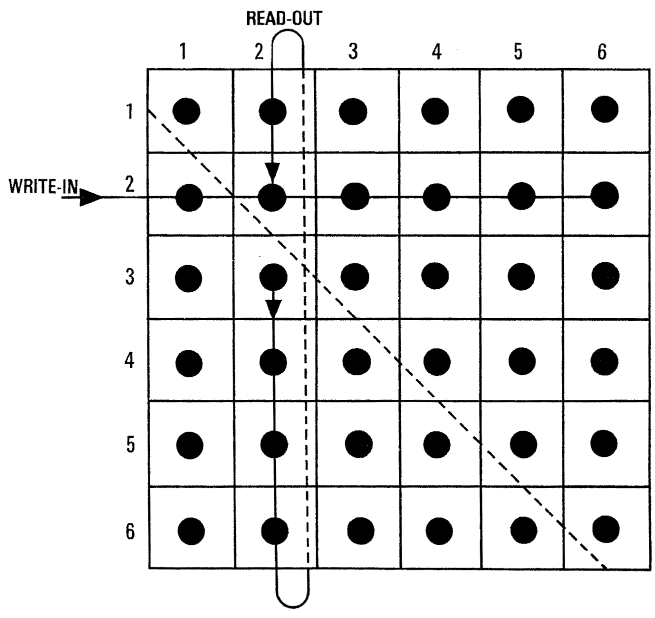
$$p_{min} = \frac{f_{min}}{fr}.$$

The read-out time of a column is completely independent of the recording time. It is thus possible to choose the read-out speed and in many cases a column can be read out in the interval between two soundings. Read-out time can then be equal to, or less than, the recording time.

Two memories can be used; one being written whilst the other is being read, or alternatively, write-in and read-out operations can be arranged in sequence, allowing for a continuous flow of data with a single memory, as shown in Figure 6.

If the technique is to be efficient in suppressing fixed echoes, it is important to avoid spectrum broadening due to a transient in a Doppler filter (see Figure 5).

If at the beginning and at the end of read-outs the signal from the memory is multiplied by a Gaussian time function, as shown in Figure 7, the beginning and end



TIME number	WRITE-IN ON LINE number	READ-OUT ON COLUMN number	READ-OUT FROM LINE number
1	1		
2		1	2
3	2		
4		2	3
5	3		
6		3	4
7	4		
8		4	5
9	5		
10		5	6
11	6		
12		6	1

Figure 6 - Write-in and read-out sequence in the case of a single memory.

of each column read-out is smoothed and shock excitation of the Doppler filters is avoided; however approximately half the information is lost.

To overcome this, each piece of information must be read twice. This is done by recording twice the number of lines that would be theoretically sufficient and carrying out the read-out operation as in Figure 7.

4. Practical Implementation

Modern surveillance-radar systems which operate in the vicinity of large fixed targets need a dynamic scale greater than 40 decibels. This dynamic scale must be maintained in the system right up to the last detector. Existing analog memories have dynamic scales of approximately 30 decibels and consequently are inadequate. Therefore the data has to be recorded in digital form.

To achieve this, the output signal of the coherent detector is sampled for each unit distance and then coded. To avoid loss of data, the coder must have 512 levels (9 bits), which theoretically implies a dynamic scale of 56 decibels, and it must, moreover, effect a coding during the duration of a distance-unit interval whose typical value is 1 microsecond.

The signal obtained in digital form can be recorded in a magnetic memory and retrieved using conventional means. The memory is read as indicated in Figure 6 and the result is applied to the decoder. Gaussian weighting can be applied in various ways, one of the simplest being to feed the decoder with a signal in the form of a Gaussian curve.

The analog signal delivered by the decoder is directed to the series of Doppler filters, each one of which is followed by a threshold detector.

The overall block diagram of the system is indicated in Figure 8.

Because threshold detectors are used the output signals can be added to give a common output without the mean noise voltages from the various Doppler filters being included.

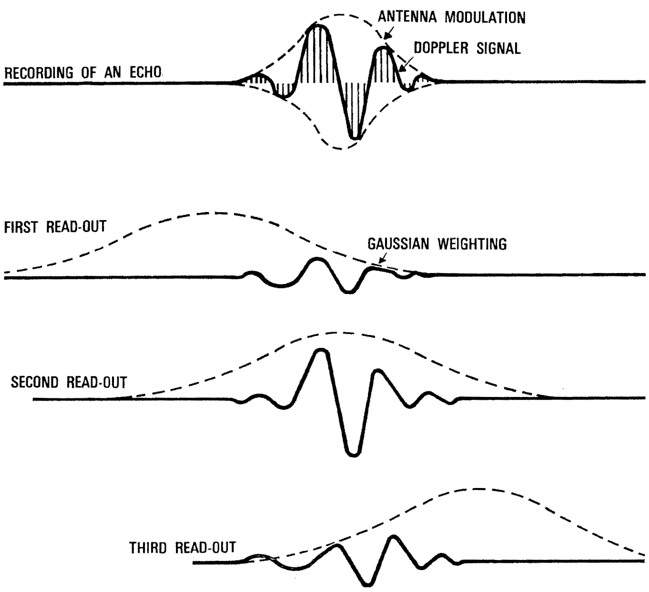


Figure 7 - Signal smoothing using multiplication by a Gaussian function.

When a signal appears at the system output the range is given by the number of the column which has just been read indicated by the memory-sequence circuit. Output signals can thus be displayed on an oscilloscope.

Each channel includes radial-velocity data and the output of each filter can be used to energize a velocity indicator.

The echoes' azimuth, range, and radial velocity data can also be sent to a central computer.

5. Applications

5.1 General

In the technique described, a coherent integration of echoes received from a given target is obtained with the help of several Doppler filters matched to the signal. The pass band of these filters is directly dependent on the time the antenna stays on the target; the longer the time the narrower the bandwidth of the signal. In other words, the slower the azimuth scan, the greater the sensitivity of the receiver.

The improvement of the signal-to-noise ratio may be accompanied by an increase in clutter cancellation for fixed echoes. In fact, the limit to the degree of cancellation is mainly the stability of the reference oscillator.

In most cases, phase variations are due to modulation by white noise. The use of Doppler filters with a narrower pass band reduces the phase noise in the same proportion as the amplitude noise of the receiver. The degree

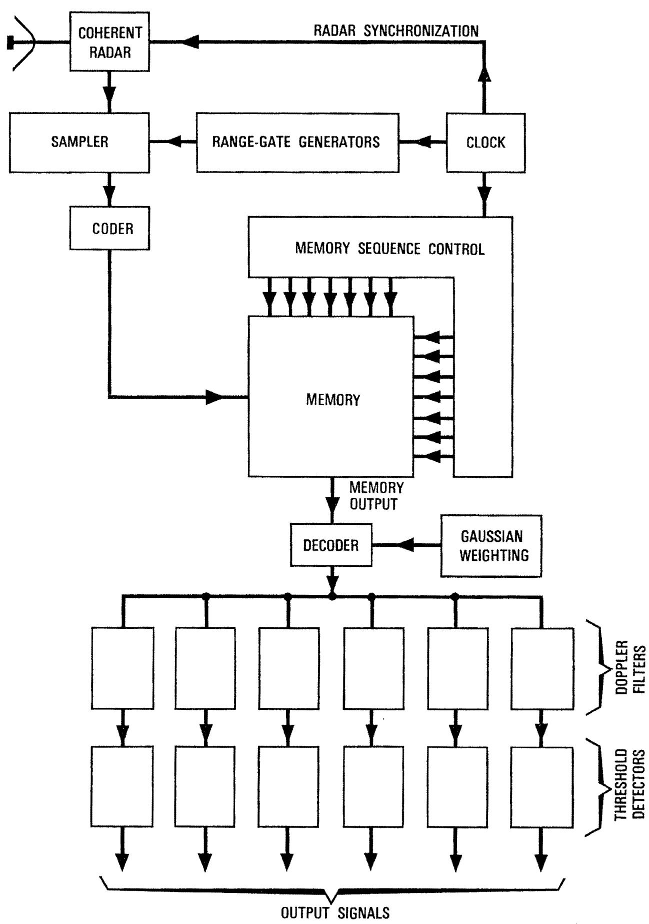


Figure 8 - General block diagram of the system.

of cancellation for fixed echoes should therefore be increased in the same ratio as the sensitivity.

For air-traffic observation, high-speed antenna rotation with a small number of Doppler filters and a high minimum Doppler frequency are the best combination.

On the other hand, for slow-moving targets, pedestrians for instance, slow scanning means a high sensitivity.

The technique gives the maximum information-output-rate-sensitivity product.

5.2 Performance

The laboratory model [2] has been intentionally simplified, the object being to illustrate the validity of the principle rather than to achieve maximum performance. Thus the memory capacity has been limited to 8000 words of 9 bits each, whereas 48 000 words would be necessary to achieve maximum sensitivity.

Nevertheless, gains in information output rate and sensitivity are significant in ground-observation radar [1] compared with the sliding-gate analysis technique in general use.

The use of 20 Doppler filters allows a sensitivity gain of 13 decibels and the display of radial velocity of moving echoes.

The use of 64 gates, each having a range of 160 meters (525 feet) ensures the observation of a zone 10 kilometers (6·5 miles) deep. An antenna with a beam width at 3 decibels of 1·4 degrees needs 4 seconds to scan 180 degrees compared to 22 seconds necessary in the case of five sliding gates [1].

6. Conclusions

The digital processing technique is developed from an idea by S. Albagli, Chief Engineer of the Genie Maritime, suggesting a relatively simple implementation of a matched filter in Doppler radar. It is hoped it will lead to a marked improvement in ground-observation radar systems.

Measurements made on a laboratory model confirmed the theoretical results. Field tests will soon be made using ground-surveillance radar to make a full assessment of the advantages of the technique.

It is important to note that the use of this device is not confined to ground-surveillance radar but also applies to modern Doppler radars designed for air-control operations in which sensitivity and information output rate are at a premium.

7. Acknowledgments

Research has been helped by the cooperation of the Direction des Recherches et Moyens d'Essais and the Section d'Etudes et de Fabrication des Télécommunications.

References

[1] G. Van den Broek, SDS radar, Surveillance radar designed to detect mobile ground targets, L'Onde Electrique, October 1964, pp 1032—1036.

[2] Recent Achievement Notes, Electrical Communication, volume 42, no 3, 1967, pp 440—441.

Patents

French patent 1 384 552, filed on 28 August 1958 in the name of S. Albagli, Chief Engineer of the Genie Maritime: Improvements to coherent radars.

French patent 1 438 257, filed on 14 December 1964 in the name of LCT (inventors: H. J. Bosc, G. M. E. van den Broek d'Obrenan, J. M. H. Colin, J. M. Villemagne): Improvements to pulsed Doppler radars.

French patent 1 448 794, filed on 17 February 1965 in the name of LCT (inventors: H. J. Bosc, J. M. Colin, J. M. Villemagne, R. Visocekas): Pulsed coherent Doppler radar memory.

J. M. Colin was born in Nancy, France, in 1936. In 1958, he received an Engineering degree in Electronics at the École Supérieure d'Electricité and then his Doctor's degree at the University of Paris, Science section.

He entered the Laboratoire Central de Télécommunications in 1962 and is now in the Radar Department as the head of the Advanced-Studies Section devoted to research and development of new processes and devices for improved coherent radars.

Initial Experience with the 10 C Switching System

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1. Introduction

At the end of 1964 attention was focused on space-switching systems, using mechanical contacts, which could be easily introduced into existing telephone networks. A new project was started early in 1965 to develop a reliable system characterized by reduced maintenance and floorspace and by increased flexibility and standardization. A *10 CX* semi-electronic system [1] was designed which became commercially available at the end of 1967 as the *10 C* switching system [2].

Development for this system was based on these requirements:

— use of Herkon* miniature dry-reed sealed contacts,
— a stored-program control for increased flexibility and computer-aided maintenance, and
— modular construction for on-site extensibility.

The modular concept implies that each module is a self-contained standard switching unit serving a group of 1024 lines (Figure 1). One set of signaling units and one set of peripheral circuits for testing, marking, and driving are shared by 2 line-group modules.

Peripheral registers access the central-processor system to the peripheral packages. Common control is duplicated, operating on a load-sharing basis. Peripheral circuits are partly duplicated so that a single fault in a non-duplicated circuit never affects more than 64 subscribers.

* Registered trademark of International Telephone and Telegraph System

2. Wilrijk 10 C Trial Exchange

The Wilrijk (suburb of Antwerp, Belgium) trial exchange comprises one 1000-line module of a *10C* terminal exchange installed in a building containing an existing 10000-line *7EN* rotary exchange. The traffic-handling capacity is 0·1 erlang bothway per subscriber. Interoffice signaling is performed exclusively by compelled multifrequency-code signaling.

An overall view of the exchange equipment, built in accordance with ITT standard equipment practice *(ISEP)* [3],

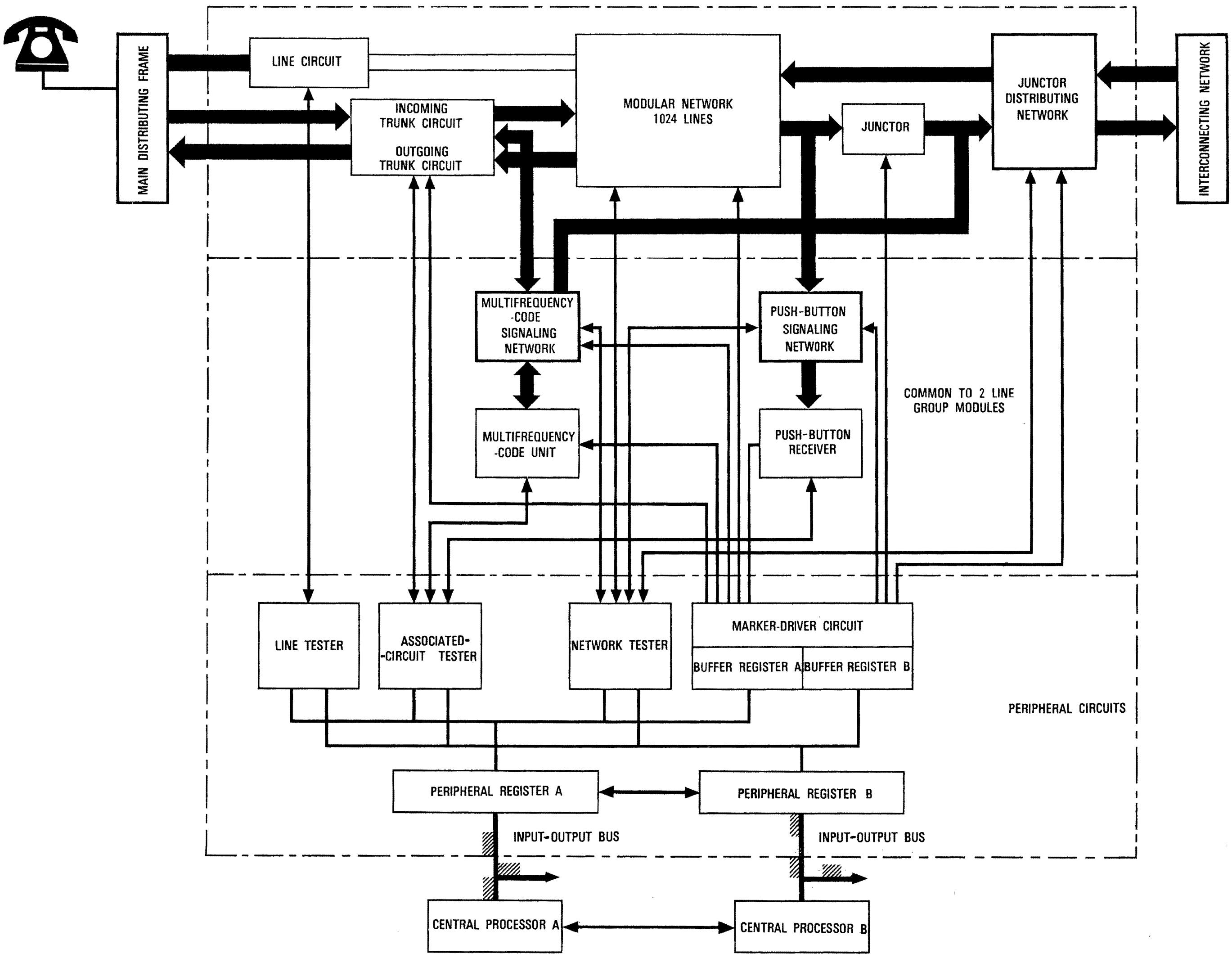

Figure 1 - The *10C* peripheral package.

is shown in Figure 2. The front row has 5 racks of common control-and-monitoring equipment able to serve up to 10 000 lines. The duplicated central processor system, including memory, is housed in 2 racks. A third rack is equipped with converters and stabilizers, to provide derived power for the central-control unit. The monitoring and test equipment, high-speed tape reader, and input-output punch are in the other 2 racks.

The line-module equipment consists of 10 racks, of which 5 are network racks including the line-circuits and feed junctors. The peripheral circuits, common to 2000 lines, are in 2 racks and trunk circuits in 2 racks, one for incoming and the other for outgoing traffic. The last rack of the line-module is equipped with signaling equipment, which includes the multifrequency-code sender-receiver units and push-button receivers, common to 2000 lines.

The exchange equipment is completed by a teleprinter with low-speed reader and punch, and a supervision desk. Space is allocated for a second teleprinter for remote monitoring when the exchange is unattended.

In exchanges of 2000 lines, or more, equipment which is common to 2 line modules will be spread over both modules so that a large exchange will have alternate rows of 9 and 8 racks, corresponding to odd and even line modules. The speech network of a 1000 line modules has 4 standard submodules of 256 lines, each in a single bay. Such a submodule is considered as the smallest extension unit; one is shown in Figure 3.

After 3 months of overall functional testing in the factory, the trial exchange was installed in Wilrijk. The installation time, excluding the main distributing frame and main power supply available at the premises, was 1·8 man-hours per line.

After hand-over to the Belgian Telephone Administration on September 25th of 1967, the exchange was tested. At this time the traffic was limited to lines owned by the Administration. Acceptance tests related to transmission performance and overall rate of fault occurrence, for a specified upper limit of 0·5 percent for all types of calls. The test period ended in February 1968, and in March of that year 600 external subscribers were connected to the exchange. Since the end of May 1968 the installed capacity of 1000 lines has been used.

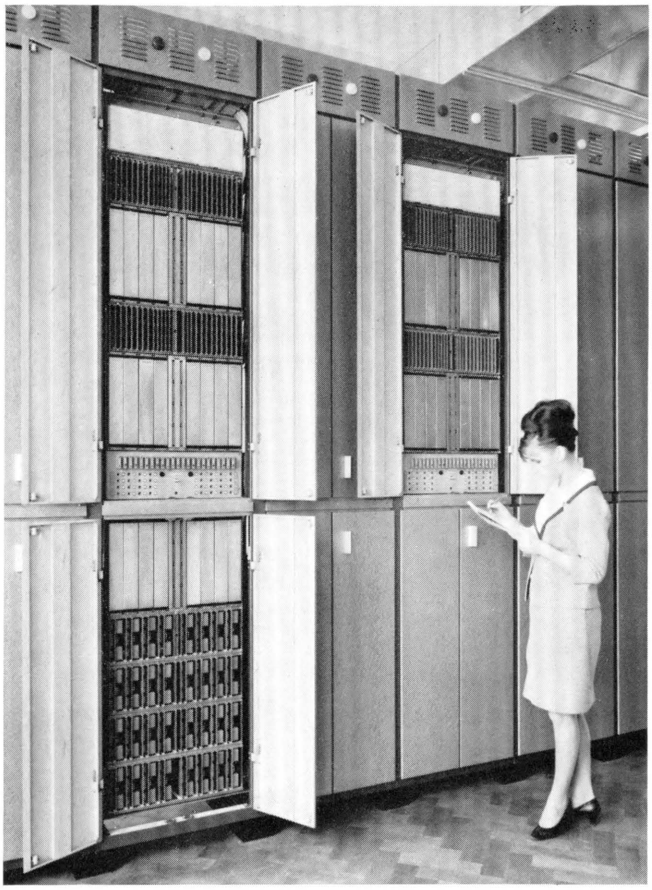

Figure 3 - A submodule of 256 lines.

Figure 2 - The *10C* exchange. On the left, a line-group module of 1000 lines. On the right, the central-control unit.

3. Reliability

3.1 General

Special attention was given to both hardware and software reliability. Reliability has been built in at all levels of system design and construction. A summary of the measures and safeguards in the *10CX* system has already been given [1]. This section comments on some of the more important points and provides quantitative data.

3.2 Relays

Assuming an exchange life of 30 years, all relays are used below their maximum number-of-operations rating. Miniature 50-millimeter (1·97-inch) Herkon reed relays are used for the speech and signaling networks [4, 5]. These relays do not switch current. For higher operational rates or when currents have to be switched, 80-millimeter (3·14-inch) reeds are used with make-contacts only. All reeds have gold-plated diffused contacts [6]. For even higher operating rates, or when larger currents have to be switched, mercury-wetted relays are used.

3.3 Circuit Design

Worst-case circuit design has been applied incorporating special safeguards to avoid propagation of failures. Independent supply-voltage tolerances of ±10 percent are allowed and circuits are specified to be operational within the temperature range −10 to +70 degrees Celsius. All components are substantially derated both as regards end-of-life tolerances and power dissipation, maximum voltage, current, et cetera. Logic circuits were designed for a minimum noise immunity of 0·5 volt on inputs, outputs, earth, and power leads.

3.4 Reliability Target

The duplicated part of a *10C* exchange is shown in Figure 4. Each set of peripheral circuits comprising the line, associated-circuits and network testers, the marker driver, and the peripheral register, serves a peripheral package of 2 line-group modules for 2048 lines. The central processor unit controls N such peripheral packages corresponding to a $N \times$ 2048-line exchange.

Based on previous experience with electronic equipment the following figures have been assessed for *10C* reliability [7, 8, 9].

A conservative estimate for the mean-time-between-failures figure for a given peripheral package is 3900 hours or 5·3 months. The figure for a central processor unit, including memory, is estimated at 2900 hours or 4 months. Assuming a repair time of 5 hours per failure, including traveling time, fault tracing, and repair, a given peripheral package of 2048 lines would go out of service on an average every 173 years, whereas a total breakdown of the exchange would occur once every 95 years.

The memory increases with an increasing number of lines, and so the mean time between total breakdowns decreases with increasing exchange size. However, for small- and medium-size exchanges, say up to 10 000 lines, the major part of the memory space is reserved for the operational program package whose volume does not depend on exchange size, so the reliability figures given are representative for the range of exchanges considered.

The estimated mean time between failures for a central processor unit, excluding memory, but including interfaces, is 14·7 months. This favorable result is achieved by using silicon integrated semiconductor circuits exclusively. A plug-in unit of the central processor unit is shown in Figure 5.

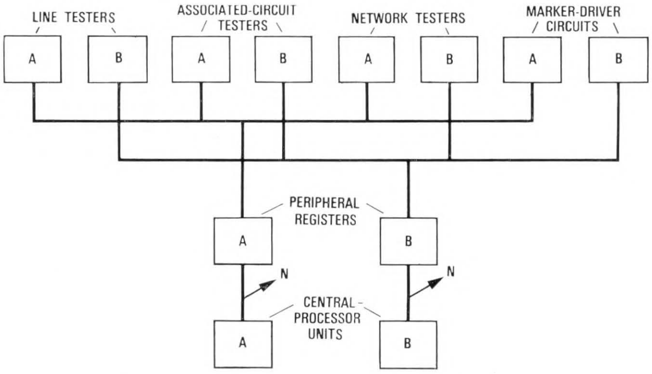

Figure 4 - The duplicated part of a *10C* exchange.

Component-failure rates giving these results are partly based on previous experience with electronic equipment and partly on manufacturers' data. Experience has shown that component performance in conservatively designed equipments is much better than indicated by manufacturers. Also, many components, when failing, do not cause a total breakdown of the system but only slightly degrade performance.

4. Programming

Stored-program controlled systems require hardware that is functionally simple, and the system complexity is in the program; therefore, during system checkout most of the faults show up in the software. Experience has shown it is essential to proceed gradually to avoid undue complexity during program checkout. As a processor system with adequate input and output devices was available, efficient use was made of extensible utility software.

The first steps were unit-program debugging and program-package debugging to clean up coding errors in programs. The utility software used at this stage was limited to memory-dump programs.

As a third step, simulation was used. Simulation programs can create any concurrence of circumstances and, more important, reproduce it as often as the programmer likes.

Since the system can keep a record in detail, a detailed analysis of the switching-system behavior can be made which has no precedent in conventional system-testing practice.

Several months before assembly and completion of peripheral-hardware wiring, the programmers were able to use this technique to test *10C*-system programs under field conditions including the most intricate and improbable situations which the program might have to face.

The simulation system is shown in Figure 6. The inputs were call-event specification forms, on which telephone engineers can specify test calls, with or without details, using plain telephone language. The form contains boxes for specification of any number of simultaneous calls, start time, calling and called subscribers' numbers, predialing delay, interdigital pauses, pulse and interpulse duration, sneak pulses, premature release, et cetera, including different incorrect dialing procedures. If one of these specifications is not included in the simulation, the box is left blank and the missing details are automatically

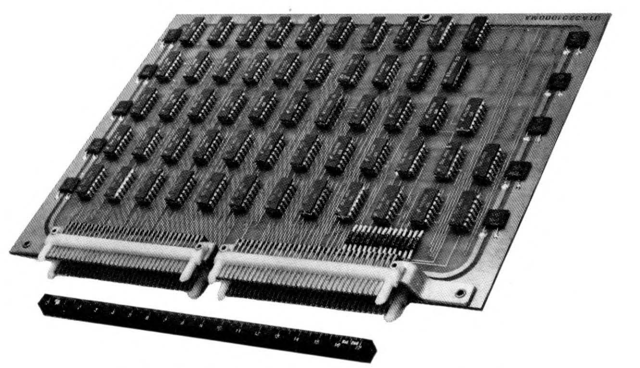

Figure 5 - Plug-in unit of the central processor.

filled in during assembly using Monte-Carlo methods with constraints. This input, transcribed on punched tape, is fed to the simulation processor which has an event-compiler program. The output is the event tape written in machine language and containing a sequence of elementary actions derived from the input analysis.

The simulation processor is then used on-line to simulate the telephone network. Its memory reflects the topology of the network and its associated circuits. The simulation processor further contains housekeeping programs to up-date its data maps according to information fed in by the event tape and the switching orders given by the processor systems under test. Using this system first on the simplex and then on the duplex processor system, it was possible to locate and correct about 400 errors in the program before the processors were connected to the real telephone network for final system checkout. During that final phase about 17 remaining faults were found which were harder to trace, as their occurrence was dependent on highly improbable coincidences.

4.1 Program Size

Careful attention has been paid to minimizing the number of instructions in call-handling programs. Call-processing programs comprise about 13200 instruction words, including call-processing and general-purpose subroutines. On-line test programs and man-machine communication programs require 2100 and 3900 instruction words, respectively, whereas about 1100 words are used for *start up* and automatic recovery. Finally, a field of about 750 words is reserved for the introduction of *on-demand* on-line programs which may be used for routine tests, statistics, service-quality observation, or any other special purpose.

5. Field Experience

5.1 Acceptance Test

The *10C* automatic call sender was used to set up about 100000 local calls. The rate of occurrence of faulty connections was less than 0·1 percent average. An analogous test for incoming and outgoing calls from and to distant exchanges (urban and toll) revealed a higher rate of faulty connections, but it could be shown that most of these failures were due to the distant exchanges. The fault-tracing programs used for this purpose cleared some faults in distant exchanges thus convincing administration engineers of the efficiency of program-controlled systems for maintenance and fault tracing. Tests by concentration boxes originating 10 simultaneous calls gave almost the same results as automatic call senders.

5.1.1 Transmission Features

The following results were obtained in the speech-band, 300 to 3400 hertz, between 600-ohm terminations at the main distributing frame:

— insertion loss at 800 hertz: 0·4 decibel of which 0·15 decibel is due to the cable connection between switching equipment and the main distributing frame,

— attenuation distortion: less than 0·6 decibel,

— crosstalk attenuation: higher than 95 decibels, typically 105 decibels,

— broad-band crosstalk attenuation (buzzer): higher than 85 decibels,

— unbalance: less than 0·8 percent, typically 0·5 percent at 300 hertz, 0·6 percent at 800 hertz, and 0·7 percent at 3400 hertz,

— total harmonic distortion at 0 dBm0: less than −40 decibels, and

— noise: peak noise voltage less than 10 millivolts, psophometric voltage less than 0·1 millivolt,
psophometric voltage integrated over 100 seconds less than 0·2 millivolts;
noise measurements taken during concentration tests using 2 concentration boxes each originating 10 simultaneous calls.

It is of interest to note that the insertion loss, measured at the switch terminals, is less than 3 decibels at 200 kilohertz, and crosstalk attenuation is more than 70 decibels at the same frequency.

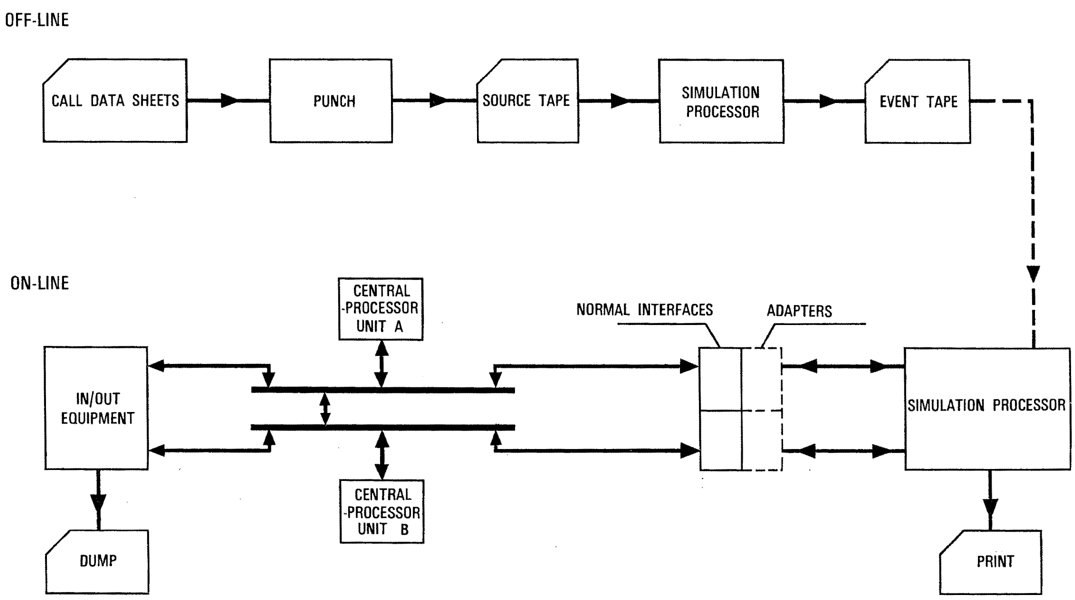

Figure 6 - Simplex and duplex simulation.

5.2 Maintenance

Corrective maintenance is based mainly on on-line test programs. These are low-priority programs executed during slack hours. On-line tests are related to hardware and software. In this way all peripheral circuits are checked for adequate decoding and execution of the orders received from the central-processor system. There are consistency checks on hardware busy-idle states and the memory contents. There is another set of programs for mutual checks between central processors to test the inter-processor communication system and the operating condition of each processor.

The test results are analyzed by the on-line test programs and adequate action is taken in case of failure. A detected fault produces a teleprinted error report giving the type of error and the identity of the affected circuit. A persistent fault causes non-urgent or urgent alarms according to its nature. For example, a faulty processor is put off-line and an urgent alarm is given. In that case the on-line processor starts an automatic recovery procedure and the faulty processor is consecutively tested, reloaded with the operational program, updated, and put on-line again.

The call-handling programs include holding-wire continuity check for any established path. In the case of failure, an error report is printed identifying the faulty path. As the fault report does not in general identify a faulty printed-circuit board, a single report may not be sufficient for fault location. However, such a fault is bound to appear again. From the coincidence of information derived from two or more reports the fault can then be located. This form of automatic trouble indication has proved to be economical and effective.

A fault is usually remedied by replacing the faulty plug-in unit. The repair can be carried out afterwards by qualified technicians in a central repair center.

5.3 Failures, Corrections, and Modifications

5.3.1 Hardware Failures

From November 1967 to June 1968, the following failures were noted,

— 1 cracked 50-millimeter reed due to transport,
— 1 cracked 80-millimeter reed due to transport,
— 1 sticking 80-millimeter reed caused by needle and crater formation,
— 1 shorted mercury-wetted contact due to excessive contact current,
— 10 badly soldered joints,
— 1 failing transistor,
— 4 damaged diodes due to maintenance procedures,
— 2 failing semiconductor integrated circuits,
— 2 shorts on printed-circuit boards,
— 3 non-identified failures, and
— 8 memory failures.

In the processors, the memory developed intermittent failures causing parity errors. In turn these errors caused a large number of automatic-processor reloads.

Persistent memory failures took about half an hour to trace and repair whereas intermittent failures took up to 4 week's observation before the faults could be traced and repaired.

5.3.2 Hardware Corrections and Modifications

In 3 instances diodes were replaced by another type to correct overrating. For design reasons a capacitor was replaced in the periphery and 2 resistors added in the central processors. One logic-design and one circuit-design modification was carried out in the central processors, and the urgent-alarm indicator in the system console was modified. The total number of changes in the hardware was considered to be smaller than expected.

5.3.3 Software Corrections and Adaptations

Adaptations are changes in programs caused by corrections in other programs.

— Call-handling programs: 6 corrections and 11 adaptations.
— On-line test programs: 3 corrections, 1 additional program, and 2 adaptations.
— Start-up and automatic recovery: 6 corrections.
— Man-machine communication programs: 24 modifications and 1 adaptation.

Finally 4 special on-demand test programs were written for tracing faulty test calls.

5.3.4 Processor Reloads

Memory parity errors caused 33 processor reloads before the faulty card was replaced. Another 32 reloads were caused by marker-driver intermittent circuit failures. The history of processor reloads caused by initial program faults is shown in Figure 7. Most of the reloads were eliminated by repair of the peripheral bus receiver at the end of November. The increase of reloads during January was due to reloads purposely created to trace causes of sporadic reloads. At the end of January a

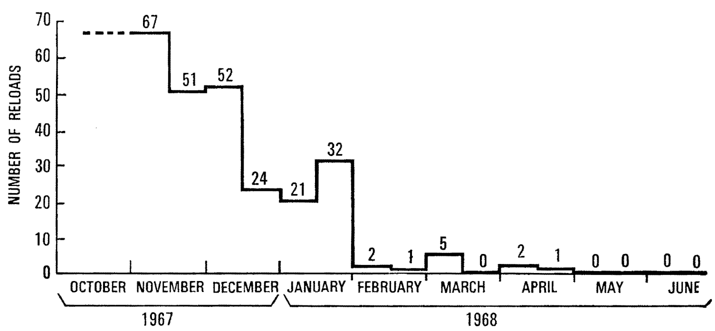

Figure 7 - Processor reloads caused by initial program faults.

correction of logic design in the processors and 3 corrections on operational programs were carried out. From the beginning of May no reloads were observed. It must be stressed that, owing to the load-sharing processor arrangement in conjunction with the automatic reload procedure, none of these faults have, at any time, put the exchange out of action. To trace a memory fault, a memory dump was started by a sense switch before each reload.

5.3.5 *Total Breakdowns*

As expected a few breakdowns were caused by human intervention. A few others were caused by rectifier failures when the main voltage supply rose from 48 to 60 volts and outside the specified limits of 48 ± 5 volts.

Besides these minor breakdowns two special cases could be mentioned. In the first case one processor was down and the other was running in a loop so that it did not take charge of the off-line processor as normally happens. The future possibility of this type of breakdown has been eliminated by program modification.

In the second case a breakdown was caused by a hardware failure in the input receiver of one processor. From interprocessor checks the faulty processor erroneously concluded that the other processor was faulty and put it off-line and then put itself out of service after detecting its own failure. Again the future possibility of this occurring has also been eliminated by program modification.

6. Conclusions

Field experience has proved the intrinsic value of the *10 C* system both from the points of view of hardware and software. Simulation methods are very effective in program debugging. The system satisfies the most stringent transmission requirements and reliability standards. Computer-aided maintenance of the Wilrijk exchange is reduced to regular adjustments of input-output devices.

As a result of the overall flexibility of stored program systems, the *10 C* exchange is remarkably versatile. New subscriber facilities such as push-button dialing, abbreviated selection, and call transfer are already provided and other services can easily be introduced. Remote control by teleprinter can be applied for all the usual changes in operation, especially for updating of variable data such as line classes and routing data, traffic measurements, service observation, statistics, and routine testing. Furthermore, as the exchange restores itself in case of transient faults, it can be left unattended.

References

[1] H. H. Adelaar and J. L. Masure: Semielectronic Reed Crosspoint Telephone Switching System 10 CX, Electrical Communication, volume 42, no 1, pp 33—46, 1967.

[2] H. H. Adelaar: The 10-C System, a Store-Program Controlled Reed Switching System, lecture at the IEEE International Conference on Communication (Philadelphia), June 14, 1968.

[3] F. Beerbaum, J. Evans and F. Leyssens: Standard Equipment Practise for ITT Europe, Electrical Communication, volume 39, no 2, 1964, pp 199—211.

[4] H. Rensch: Crosspoint Elements and Relays with Miniaturized Reed Contacts, Electrical Communication, volume 42, no 1, pp 22—32; 1967.

[5] H. Rensch: Requirements on Crosspoint Elements in Space-division Multiplex Switching Systems, NTZ Communications Journal, volume 5, no 1, pp 1—4; 1966.

[6] H. Rensch: Characteristics and Applications of Reed Contacts, Electrical Communication, volume 40, no 3; 1965.

[7] W. Rauscher: Experience with Trial Office HE-60 L Stuttgart-Blumenstrasse, Electrical Communication, volume 43, no 1, pp 14—18; 1968.

[8] H. Oden: Experience Gained with Quasi-Electronic Switching Equipment for Local and Long-Distance Traffic, Proceedings Colloque International de Commutation Electronique (Paris 1966), pp 690—703.

[9] H. Willrett: Field Experience with Quasi-Electronic Telephone Switching Systems, IEEE Transactions on Communication Technology, volume COM-15, number 6, pp 730—735; December 1967.

[10] H. Ebenberger: Vienna-Zollergasse Trial Telephone Exchange, Electrical Communication, volume 43, no 3, 1968, pp 243-249.

Joseph A. Broux was born in Munsterbilzen, Belgium, in 1931. He obtained the degree of civil engineer in electronics at Liège University in 1957 and joined Bell Telephone Manufacturing Company in that year as a development engineer in the electronic switching department. He helped in the development of a TDM-PAM switching system and contributed to a military pulse-code-modulation switching project. He also contributed to the 10C project as the engineer responsible for system design.

11 B Telephone Switching System

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1. Introduction

The *11B* switching system is designed for public exchanges covering the lower capacity range. It is part of the family of ITT electronic switching systems [1]. It uses wired-logic common control and has all the features of a modern electronic system. The system uses new ITT miniaturized components, and a large amount of electronics in the control equipment, to achieve:

- superior performance,
- high-speed operation,
- smaller volume, and
- easy installation.

It is designed for a capacity range of 16 to 12 288 lines in 2 steps, 16 to 512 lines as a 2-stage exchange, and 96 to 12 288 lines as a 4-stage exchange.

Both integrated and discrete electronic components are used in the control equipment. Miniature relays, shown in Figure 1, appear in the line circuits, local junctors, and trunks.

The switch matrix provides a 4-wire path and operates with mechanically latched switches (Figure 2).

2. Design Objectives

A standardized 4-stage switching network is used in the 96- to 12 288-line range. Portions of this network are employed to form the 2-stage exchanges. This standardization of plug-in units and equipment practice facilitates the conversion of a 2-stage to a 4-stage exchange.

Both exchange configurations may be operated as independent units in a network or, alternatively, as dependent exchanges. The 4-stage exchange may also be used for the extension of step-by-step exchanges with minor additions to the interface relay sets for incoming traffic.

The following aspects have been specifically considered in the design.

- Reduced time for installation and testing by the extensive use of plug-in printed-circuit boards.
- Clear and simple maintenance procedures achieved by sophisticated fault indication and alarm transfer to a remote maintenance center.
- Flexibility of number of subscribers, junctions, traffic, and facilities.
- Easy conversion from single- to multi-stage or from 2-stage to 4-stage switching by the addition of standard cards to pre-wired shelves.
- Unattended operation.

3. System Outline

3.1 General Capabilities

The *11B* system handles local, incoming, outgoing, and transit traffic. A separate class of service information is available for originating and terminating traffic. Equipment number and directory number translators are provided to give complete freedom for directory number allocation. Centralized route analyzers with number translators common to all registers are used. Line and register signaling can comply with any specification, for example direct current or multifrequency alternating current.

3.2 Switching Configurations

The 4-stage switching network comprises 2 main units; the line-switching unit and the trunk-switching unit. Each of these contains two switching stages *A* and *B*, hence the switching network consists of the line unit *A*, line unit *B*, trunk unit *A*, and trunk unit *B*. The 2-stage network is constructed using these basic switching modules. The trunking arrangements of the two exchange configurations are shown in Figure 3 and Figure 4.

3.2.1 2-Stage Version

For the 2-stage version the standard primary stage (line unit *A*) and a secondary stage (line unit *B*) are interconnected by links. A 512-line exchange is organized as outlined in Figure 3. All subscribers are connected

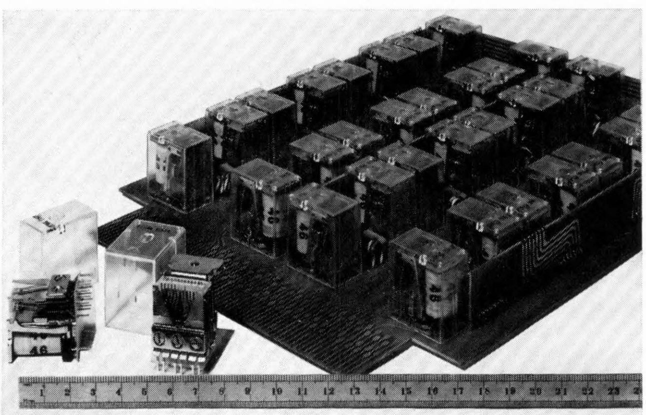

Figure 1 - Miniature relays.

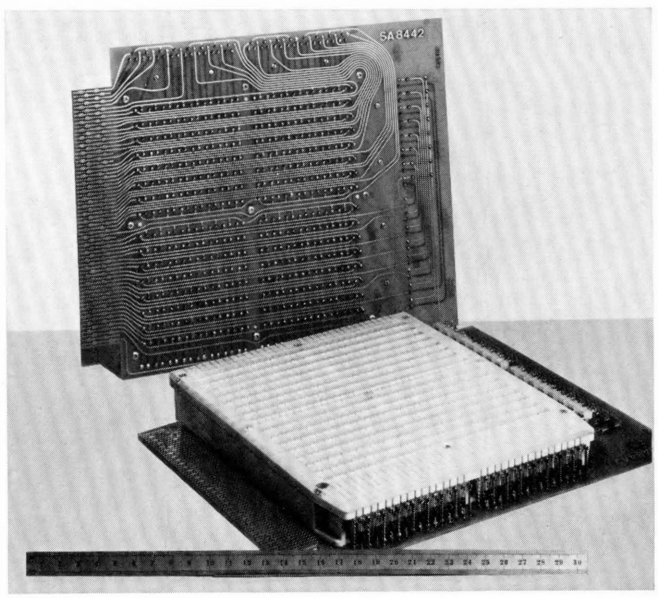

Figure 2 - The switch unit.

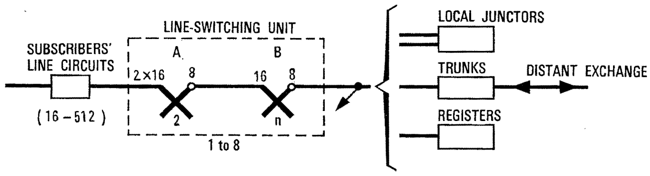

Figure 3 - A 2-stage exchange: 16 to 512 subscribers' lines.

to the primary stage, which is extensible in steps of 16 lines. The local junctors, trunks, and registers are connected to the secondary stage. Four wires are switched through in every crosspoint.

3.2.2 4-Stage Version

In the 4-stage version either 256 or 512 subscribers' lines can be connected to 1 line-switching unit dependent upon traffic loading (Figure 4). A maximum of 24 line-switching units and 8 trunk-switching units is required when the system reaches its design maximum.

In this case, 8 links from each line-switching unit are connected to every trunk-switching unit. If fewer trunk-switching units are required then more links from each line-switching unit are connected to each trunk-switching unit.

Trunk links are provided both within and between trunk-switching units and are used both for ordinary (for example, trunk to register) and overflow traffic.

3.3 Traffic Capacity

Extensive traffic simulation has been done to check the design principle and determine switch-dimensioning rules. The system is flexible in its traffic-handling capacity, the only rigidity being in the 4-stage version where a choice is required between a 256-line line-switching unit, carrying an average of 0·16 erlang bothway traffic per line, or a 512-line line-switching unit carrying an average of 0·08 erlang bothway traffic per line. For all versions and for all traffic cases, resetting is employed to obtain a minimum internal loss. The trunk-switching units, local junctors, registers, and trunks are provided according to traffic.

3.4 Marking Philosophy

Figure 5 shows line-switching units, a trunk-switching unit, and a central marker. Each line-switching unit and trunk-switching unit has its own marker, line marker, and trunk marker, respectively, which may be duplicated for security in the 4-stage exchange. The line and trunk markers monitor the operation of their local switches and are clock controlled. The central marker is only engaged for short intervals during test or release operations, and interworks with the line and trunk markers to:

— identify calling and called lines,
— investigate the state of switches, trunks, registers, local junctors, et cetera.

Conditional testing on a guide-wire network is used throughout to determine free paths through the 4-wire switching network of the exchange.

The marking principle of the 2-stage exchange is shown in Figure 6.

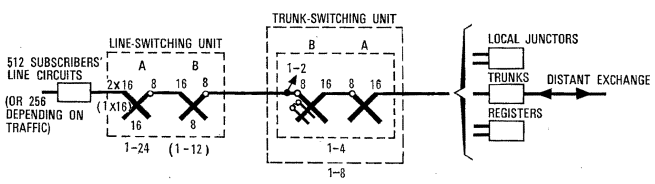

Figure 4 - A 4-stage exchange: 96 to 12 288 subscribers' lines.

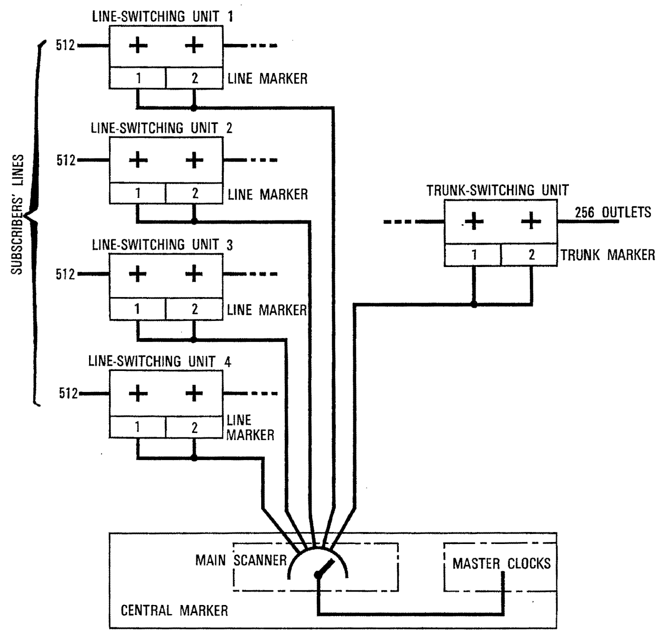

Figure 5 - Marking principle for a 4-stage exchange.

3.5 Call Supervision

The various devices for supervising connections are all connected to the outlets of the trunk-switching units. For a basic switch these consist of local junctors, trunks, and registers.

The local junctor is the supervisory element for local calls, it provides feed, loop supervision, ringing current, and tone to the subscribers.

The trunk circuit provides the same facilities for the local subscriber (calling or called as appropriate), and the signaling conversion for the junction or trunk signaling.

The registers — combined registers and senders — provide the necessary subscriber supervision during

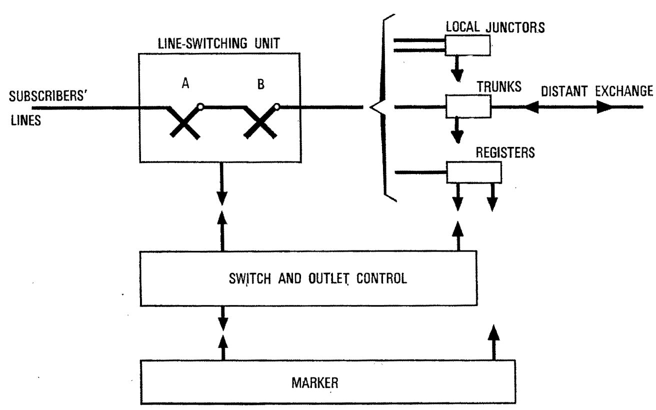

Figure 6 - The marking principle for a 2-stage exchange.

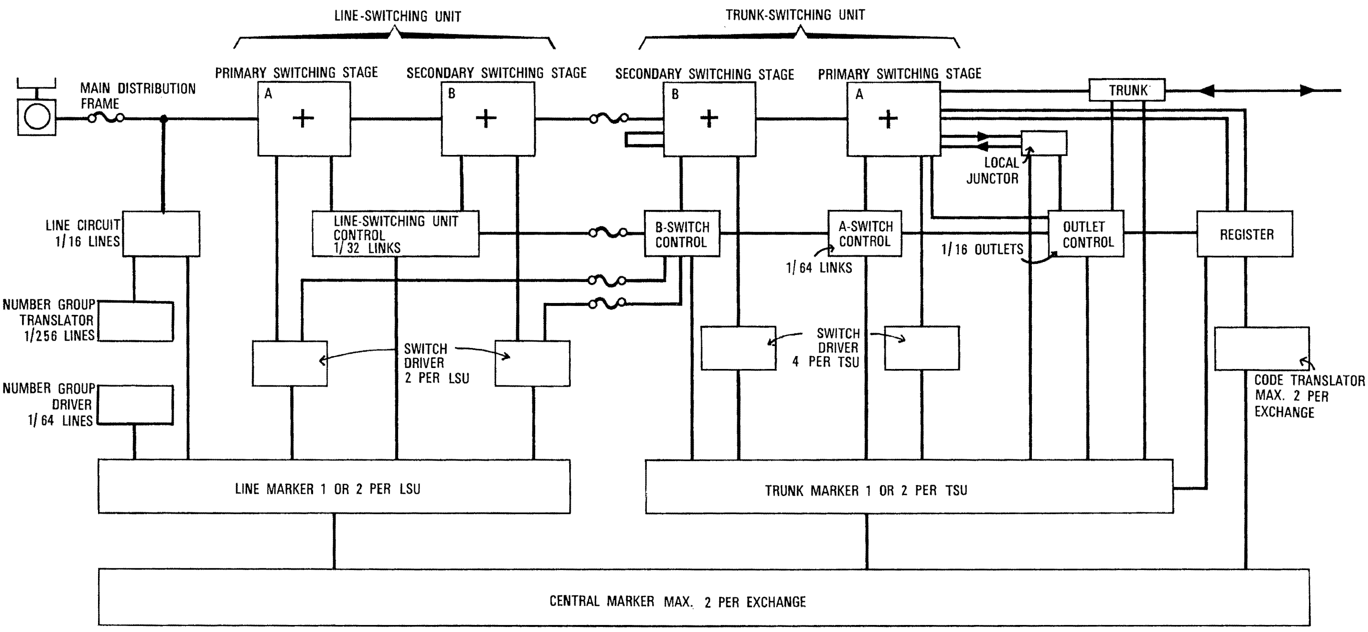

Figure 7 - Block diagram for a 4-stage exchange.

dialing and control outpulsing (if required) to a junction or trunk circuit.

4. System Operation

Figure 7 shows in block form a complete 4-stage exchange. All operations are controlled by the central marker by a clock-controlled program and a continuously stepping scanner which enable instructions to be given to, and information to be returned by, the line and trunk markers and code translators. The central marker can order the line and trunk markers to perform these basic functions:

— scanning for a calling line or incoming trunk,
— selection and connection of a path from a subscriber or trunk to a specified type of outlet, for example, register, local junctor, or trunk, and
— release.

Detection of a calling line is made by the line marker and of an incoming trunk by the trunk marker. The path search and subsequent connection of a new call to a register is performed using a guide-wire network as shown in Figure 8. A signal is injected into the guide-wire at the line-unit-A switch corresponding to the subscriber requiring connection. This signal propagates through the guide-wire on all paths corresponding to free-switch paths. Under instructions from the central marker, the

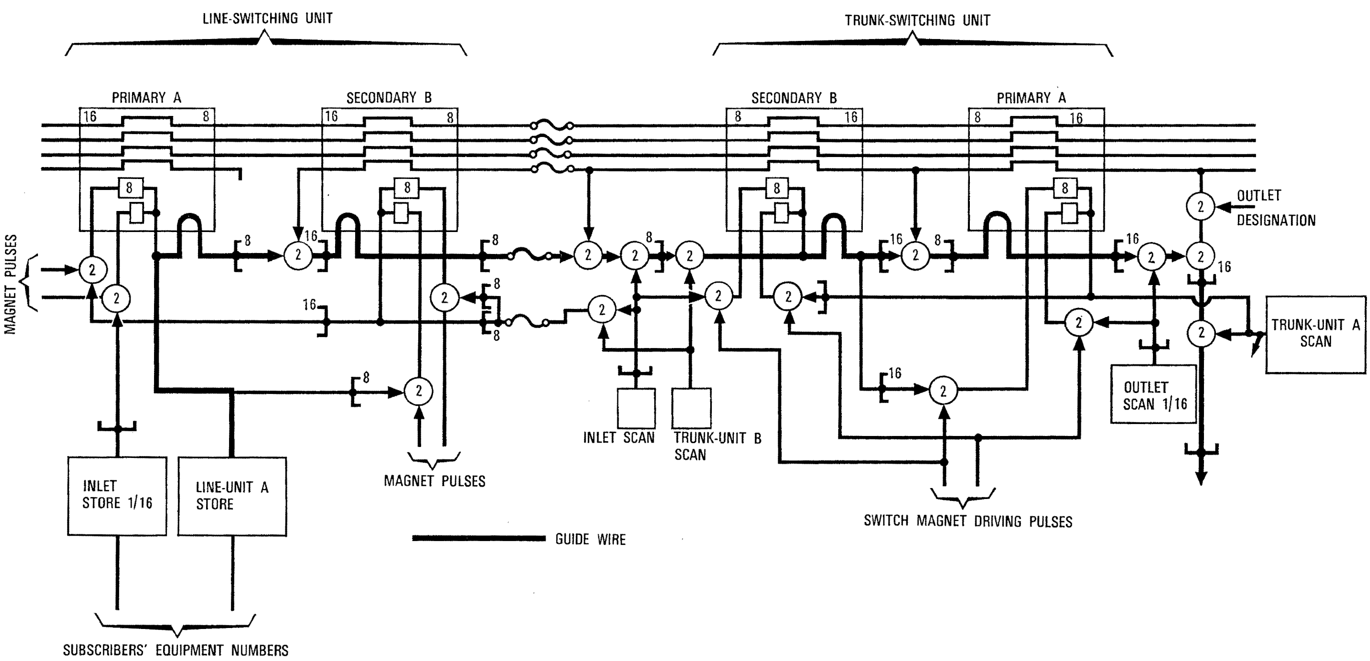

Figure 8 - The path-search and connection equipment.

trunk markers mark the appropriate outlets of the trunk-unit-*A* switches corresponding to the connection required. By using, in this order, the outlet scanner, the trunk-unit-*B* switch scanner, and the inlet scanner, it is possible to determine which one of the free paths is available, and the scanners define, in conjunction with the subscriber's equipment number, that path. By applying switch-magnet control pulses to this marked path, the connection is set up.

The routing information received by a register is translated by the code translator to determine the route required. The code translator is continuously scanning the registers and stops if a register requiring service is found. The output information from the code translator, junction-route code or called-subscriber's directory number, call-metering information, et cetera, is passed to the central marker, and the final connection is established.

Once a path through the switches is set, it is marked busy to further calls. When the calling-subscriber-clear condition is detected, this busy condition is removed, and the path may be re-selected, but the crosspoints remain operated due to their mechanical latch until a release instruction is generated by the central marker at the completion of the call.

Typical connections through the switch network are as follows.

— Subscriber to local junctor, register, or trunk.
— Incoming trunk to register or register to outgoing trunk using a trunk link.
— Use of a trunk link for overflow traffic when a direct connection is not possible.

5. Mechanical Design

ISEP equipment practice [2] is used to house the equipment; a rack is 2640-millimeters (8-feet 8-inches) high, 900-millimeters (35·5-inches) wide and 355-millimeters (14-inches) deep (Figure 9).

All the switches, relays, discrete components, and integrated circuits are mounted on printed-circuit boards, 282 millimeters (11·1 inches) by 221 millimeters (8·7 inches), and 15 are housed on a shelf. There are 4 shelves in a sub-rack and 2 sub-racks, with a miscellaneous shelf mounted between them, form a complete rack. The center shelf may be used to mount either miscellaneous facilities for maintenance purposes, et cetera, or for heat-deflecting shields when required.

6. Power Supply

The basic power supply is -48 ± 4 volts and is used for the operation of the switches and relays. The following additional supplies are also required.

$+48 \pm 4$ volts for metering,
$+18 \pm 0{\cdot}5$ volts and $+12 \pm 0{\cdot}5$ volts for discrete-component electronics, and
$+5 \pm 0{\cdot}25$ volts for discrete-component and integrated-circuit electronics.

7. Installation and Testing

The use of plug-in techniques throughout the system makes it possible to have an installation and test time of approximately one hour per line, the time being dependent upon exchange size and skill of personnel.

Typical layouts for exchanges up to 4000 lines are shown in Figure 10.

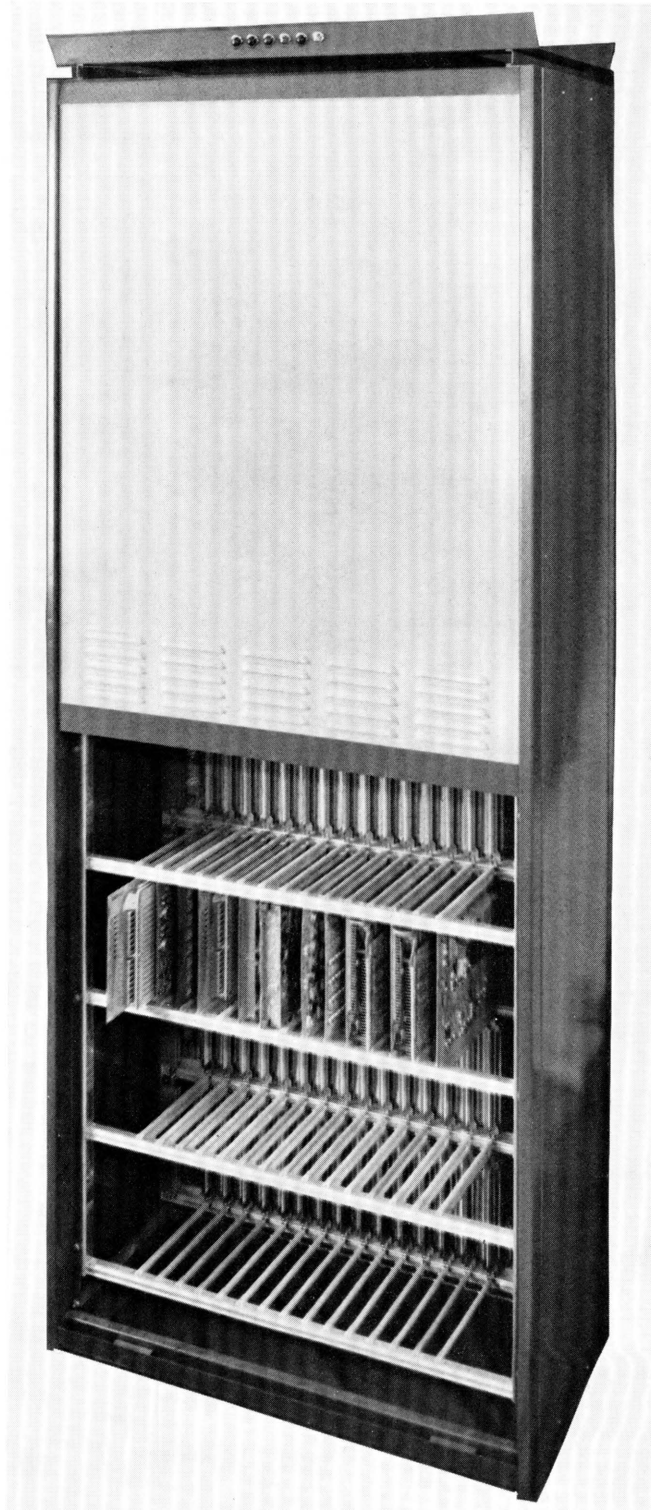

Figure 9 - A complete *11B* rack constructed in accordance with ISEP standards.

8. Conclusions

The *11B* system is the first public switching system employing the ITT miniaturized crossbar switch. It has been

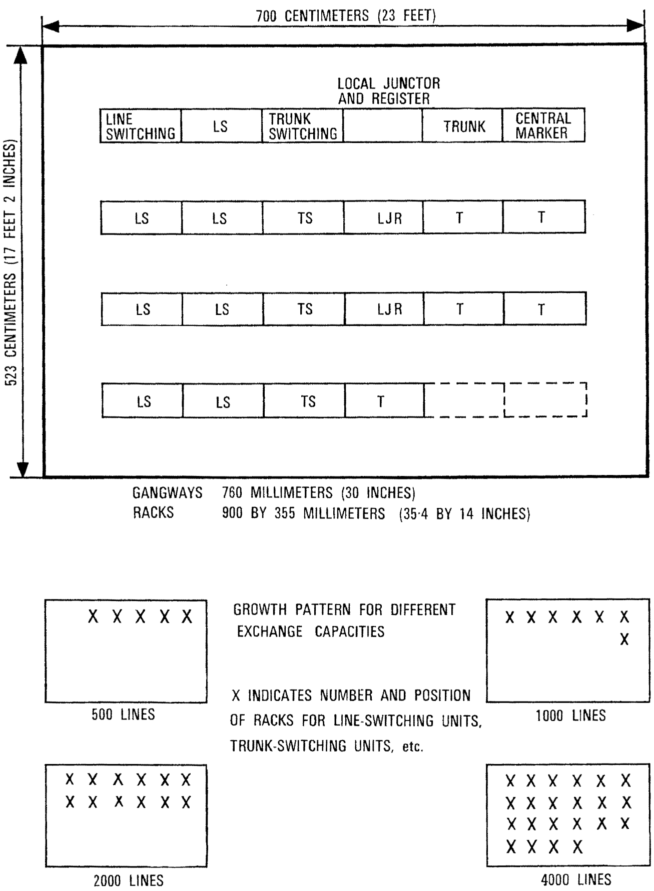

Figure 10 - Floor layouts up to 4000 lines.

possible to take advantage of inexpensive electromechanical crosspoints for the switching network combined with a fast-operating common control to obtain a highly standardized switching system suitable for a wide range of exchange sizes and traffic capacities. Other features making the system competitive are its modular construction giving easy on-site expansion, reduced space requirements, and reduced installation and test times in comparison with existing conventional electromechanical systems. On-site maintenance is reduced to supervision, fault location, and replacement of faulty plug-in units.

References

[1] H. H. Adelaar, and J. L. Masure: Semi-electronic Reed Crosspoint Telephone Switching System 10CX, Electrical Communication, volume 42 (1967), no 1, pp 33—46.

[2] F. Beerbaum, J. Evans, and F. Leyssens: Standard Equipment Practice for ITT Europe, Electrical Communication, volume 39 (1964), no 2, pp 199—211.

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After 8 years' administrative work, system evaluation, planning, and traffic analyzing with the Telecommunication Administration, he joined the engineering staff of Standard Radio & Telefon in 1956 as assistant chief switching engineer. He became chief switching engineer in 1961 and was later responsible for design and export of public telephone systems. He joined the Standard Telephones and Cables Crossbar Division in 1966 as chief engineer. He is now with ITT Europe in Brussels as a product-line manager.

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Transferred-Electron Bulk Effects in Gallium Arsenide

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1. Introduction

The transferred-electron or Gunn-effect microwave oscillator is the latest incursion of solid-state techniques into the microwave region where its impact could be comparable to the transistor at lower frequencies. Experimental observation of coherent microwave current oscillations occurring in n-type gallium arsenide when the applied electric field is sufficiently high was first made by J. B. Gunn [1] in 1963. Although it was not appreciated at the time, the essentials of a theoretical explanation of the phenomenon had already been given in published work by Ridley and Watkins [2] and Hilsum [3]. The theoretical and experimental studies in the intervening period now give a detailed understanding of the physical principles underlying the Gunn effect.

A transferred-electron oscillator is radically different from established devices such as the transistor, varactor, and tunnel diode. Its operating mechanism comes from a bulk property of gallium arsenide and so there are no pn junctions. The active device consists of an electrically-uniform and geometrically regular semiconductor with two ohmic contacts for the application of a bias voltage. The Gunn effect's most widely used and easily observed mode of operation involves a space-charge packet, called an electric domain, which traverses the sample from cathode to anode during each current cycle. The effect is transit-time dependent and the higher the operating frequency the thinner the sample. In consequence, the power output for a given device impedance decreases as f^{-2}. At a fixed frequency an increase in the output power means a *pro rata* reduction in the device impedance. The Gunn-effect oscillator operating in the transit-time mode is therefore similar to existing solid-state devices although its power-*versus*-frequency characteristic is improved. A different mode of operation identified by Copeland [4], and referred to as the limited-space-charge accumulation or *LSA* mode, avoids this transit-time limitation. Although the circuit and bias conditions for the *LSA* mode are critical, the technique opens up the possibility of high pulsed powers over the whole microwave spectrum.

In Gunn effect the magnitude of the electric fields, material conductivity, and the low conversion efficiency, causes a high energy dissipation throughout the device which requires efficient heat sinking. For continuous-wave operation this heat sinking is only possible for devices with small linear dimensions. In practice this limitation restricts the lowest operating frequency to about 4 gigahertz and the total active-volume limitation restricts the output power to a few hundred milliwatts. Under pulsed conditions, where the mean dissipation can be lowered by reducing the duty cycle, the low-frequency restriction is removed and pulsed output power can be increased by enlarging the device cross-sectional area for a transit-time device, or the cross-section area and/or sample thickness for an *LSA* device. There will, of course, be a limit to the maximum permissible pulse width to avoid overheating during the pulse. The existing pulse widths, power outputs, and duty cycles for systems such as mobile radars, aircraft direction- and height-finding equipment, and aircraft identification systems, are within these limits.

The advantages of the Gunn-effect microwave oscillator can be summarized as follows:

— it is a solid-state device which can be designed to operate in any part of the microwave spectrum,

— output powers of a few hundred milliwatts continuous wave, or pulsed powers of the order of a kilowatt are feasible,

— the active sample is small, simple, potentially cheap, and is compatible with hybrid-integrated-circuit technology, and

— the oscillator is more compatible with the use of solid-state bias circuits than are high-voltage microwave tube oscillators.

It seems likely that the bulk-effect device will, in future, find applications not directly related to microwave generation. The domain-originated functional integrated circuit (*DOFIC*) is discussed later when describing the use of high-field domains for generating complex functions and its application to digital and high-speed data-processing systems is considered.

2. Gunn-Effect Mechanism

The Gunn effect derives from an electron-transport property in gallium arsenide (and certain other compound semiconductors) which is not found at normal temperatures and pressures in elemental semiconductors such as silicon and germanium. Gallium arsenide is a direct-gap semiconductor and the electrons at the bottom of the conduction band exhibit a low effective mass and a high mobility. At electric fields of the order of 3 kilovolts per centimeter, the energy supplied to the electrons by the

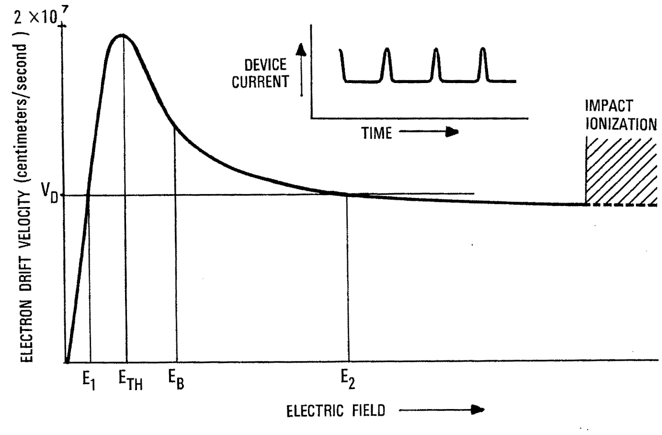


Figure 1 - Transferred-electron characteristic for gallium arsenide illustrating domain field distribution and, inset, the device current.

field cannot be dissipated in the crystal lattice and the average electron energy (that is, electron temperature) rises above the lattice energy. As the electric-field intensity increases these "hot" electrons make a rapid and almost complete transfer into the more numerous higher-energy states in the conduction band where their effective mass is higher and their mobility lower. The net effect is to produce a characteristic with a region of differential negative mobility as shown in Figure 1. When biased in the negative-slope region, the condition is unstable and any space-charge disturbance arising from material inhomogeneity, or noise, will tend to grow. This instability was predicted by Ridley [5] who suggested that the final form of the space-charge distribution would be a narrow region of high field intensity, which he called

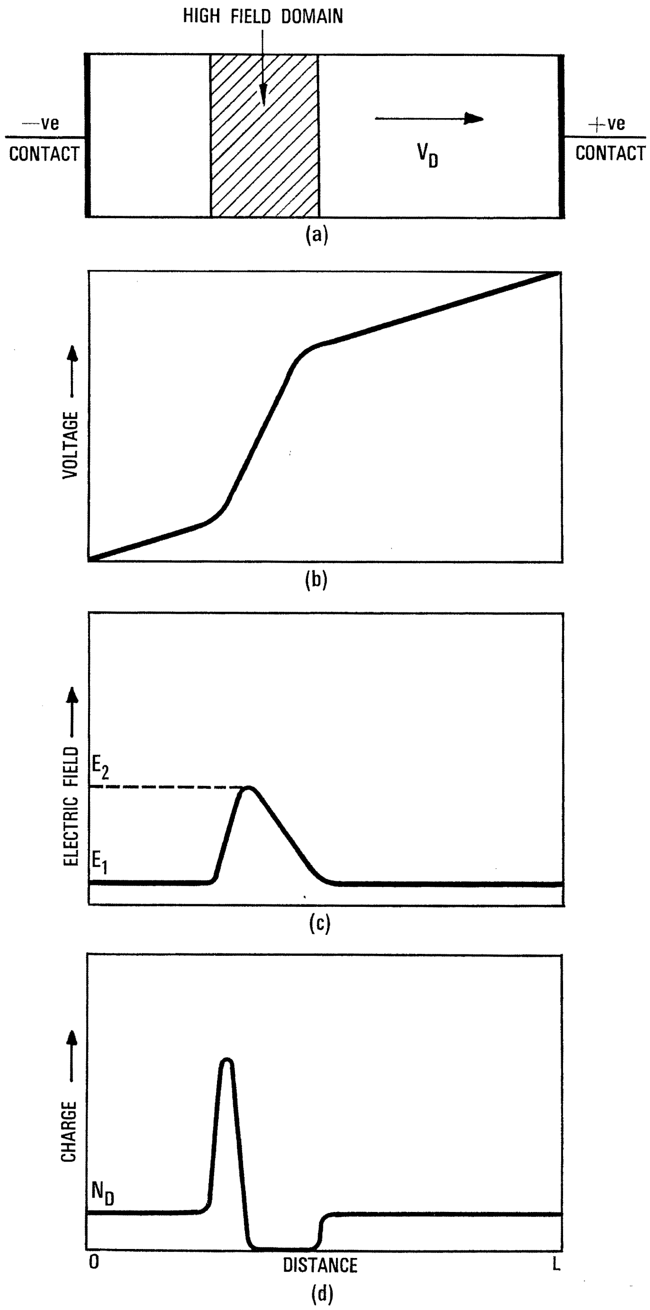


Figure 2 - (a) Representation of Gunn-effect oscillator,
(b) Voltage distribution through the device,
(c) Electric-field distribution,
(d) Charge distribution.

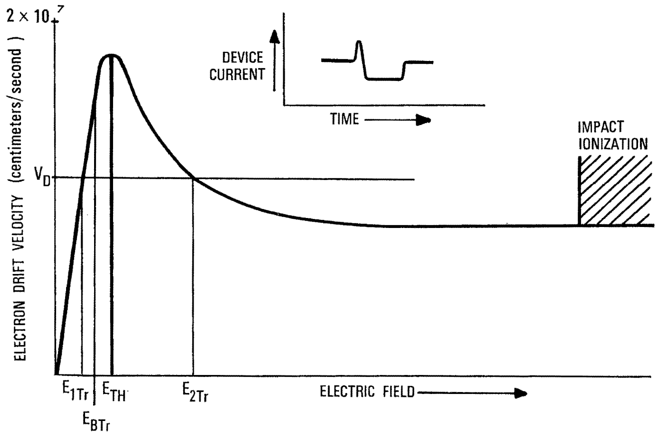


Figure 3 - The triggered-mode operation. Field distribution and one cycle of current waveform are shown in the inset.

a "domain", formed within the low field intensity of the remainder of the sample. This distribution prevents the negative conductivity from being directly accessible at the sample terminals. The formation of a domain is schematically represented in Figure 1 where a typical value for the peak domain field E_2 is 100 kilovolts per centimeter and the field in the remainder of the sample E_1 is 1·5 kilovolts per centimeter. The field and space-charge distributions within the domain, shown in Figure 2, are analogous to those occurring in an abrupt *pn* junction. One consequence of the complete carrier depletion on the positively charged side of the domain is that, for current continuity, the domain must move with the same velocity as the drifting carriers outside the domain. The domain now initiated at the negative cathode contact, moves to the positive anode with a uniform velocity of about 10^7 centimeters per second. During this transit-time the current magnitude is constant at about half the threshold current. On reaching the anode the domain collapses, the current increases to the threshold value and the cycle will begin again with the creation of a new domain at the cathode. The current waveform is illustrated in the insert of Figure 1.

The flattened form of the transferred-electron characteristic at high field intensities shows the current in the presence of a domain to be relatively independent of the applied bias voltage, the domain absorbing any changes in the terminal voltage. This process is limited by 2 conditions: the first occurs when the bias voltage is high enough to precipitate impact ionization [6], and the second when the bias voltage is too low to maintain the domain.

Figure 3 shows the conditions for triggering the launching of a single domain [7] without a second being initiated when the first reaches the anode. If the bias field at E_{BTr} is below the threshold E_{TH}, the application of a trigger pulse will increase the cathode field above E_{TH} and a domain will form. The domain now continues to propagate stably even though the disappearance of the trigger pulse reduces the cathode field below E_{TH}. The electric fields E_{1Tr} and E_{2Tr} occur outside and inside the domain, respectively. When the domain reaches the anode the field returns to E_{BTr} which, being below E_{TH}, is insufficient to launch another domain. Should the bias field be reduced even further, then E_{1Tr} and E_{BTr} will approach each other and there will come a time when there is insufficient voltage across the domain for it to propagate stably. Under these circumstances it is impossible to propagate a domain with a trigger pulse. Further, if the field is reduced after the domain is launched so that there is insufficient voltage across it, then it will instantly collapse or be quenched. The exact value of this lower bias limit is dependent on the material resistivity and sample length, but is typically close to one half the threshold voltage.

If excessive impact ionization is avoided, this behavior can be used in conjunction with a suitable resonant circuit to create a basic Gunn-effect microwave oscillator. A number of usable circuits are discussed in this paper and particular emphasis is placed on the microstrip-based structure.

3. Operation in Resonant Circuits

The bulk negative resistance from the transferred-electron characteristic does not appear at the device terminals because of the rapid space-charge build up in the high-field domain. The movement of this domain from cathode to anode produces the transit-time current oscillation observed in a purely resistive circuit. When devices are operated in resonant cavities, the resulting voltage swing across the sample defines the operating frequency by controlling the domain formation and possibly its extinction. If the radio-frequency voltage initiates a domain at the instant when the total applied voltage passes above the threshold level and does not quench it during transit, the oscillator can be tuned down to about one half the transit-time frequency. If on the other hand the circuit tuning and loading are such that the domain is quenched during the transit, the tuning range can extend to higher frequencies. These two modes of operation do not make the best use of the Gunn effect. Operating below the transit-time frequency, the device remains passive for part of the cycle, while operating above the transit-time frequency restricts the domain movement to only a part of the sample; the remaining portion acting as a loss resistance. Further, by allowing the domain to fully form, the oscillator performance is degraded in two ways. First the fast changes of current produced at the formation and extinction of the domain cause power to be wasted in harmonic frequencies. Second, because of the concentration of voltage across the domain, the breakdown field of the material [6] is reached at relatively low degrees of overdrive. So that the voltage excursion can include a large proportion of the negative resistance characteristic and produce maximum output power and efficiency, bias voltages much higher than the E_{TH} threshold are required.

An important factor is the influence of material resistivity. For a given domain voltage the domain capacitance varies as the square root of the carrier density, the series resistance inversely with carrier density, and hence the resistance-capacitance time constant inversely as the square root of the carrier density.

With increasing material resistivity the domain growth and decay times are increased and peak domain field for a given domain voltage is reduced. Thus the current waveform tends to become more sinusoidal and higher drive voltages can be applied before material breakdown occurs. Both these effects give an improvement in device performance. According to Kroemer [8], for a given sample length there is an upper limit to the resistivity (more strictly a lower limit to the free-carrier concentration) above which any domain build up is inhibited because there are too few electrons in the whole sample to form a domain. Copeland [9] has analyzed the performance of a Gunn diode in a parallel resonant circuit and defines optimum-performance limits to a product of *carrier concentration* $\times$ *sample length* of between 1 and 2×10^{12} per centimeter^2. In a 1 gigahertz transit-time oscillator using high-mobility gallium arsenide this criterion would correspond to a material resistivity between 5 and 10 ohm-centimeters and proportionally lower resistivities at higher frequencies. Amongst the other predictions of Copeland's theory are maximum efficiency of 8 percent, effective radio-frequency impedance from 30 to 50 times the direct-current impedance, and a *output power (watts)* $\times$ *device impedance (ohms)* $\times$ *frequency*^{2} *(gigahertz)* of 240. This latter parameter is a convenient way of expressing the performance of a transit-time oscillator. Recognizing that there is a lower tolerable limit to the effective device impedance for low-loss operation in practical circuits, the product enables a prediction of the maximum output power possible at any particular frequency. For example, at 1 gigahertz, a sample with a low-field resistance of 1 ohm should give 240 watts pulsed output power and at 10 gigahertz a sample of the same impedance would give 2·4 watts output.

It is clear that the space-charge build up tends to complicate the Gunn effect and to prevent full use of the inherent negative resistance. Under static bias conditions it is impossible to obtain the negative resistance at the device terminals, as with the tunnel diode for example. Even if domains are inhibited with a reduced carrier concentration, above the Gunn-effect threshold the magnitude of the static space charge at the cathode causes the resistance at the device terminals to remain positive, although small-signal amplification at the transit-time frequency is possible in these conditions. Practical utilization of bulk negative resistance has recently been made possible by the concept of the limited space-charge accumulation or *LSA* mode [4]. In this mode the bias field, circuit frequency, radio-frequency loading, and sample resistivity are arranged to give only a small build up of space charge, in the form of a negatively charged accumulation layer, when the voltage excursion is above the threshold value E_{TH}. This space charge decays away completely in the relatively short part of the radio-frequency cycle during which the voltage is below the threshold as shown schematically in Figure 4. By inhibiting the growth of large space-charge disturbances the bias field remains in the negative-resistance regime over the greater part of the sample. Thus samples are no longer limited to the transit-time length and power output can be increased by using longer and, for the same cross-section, higher-

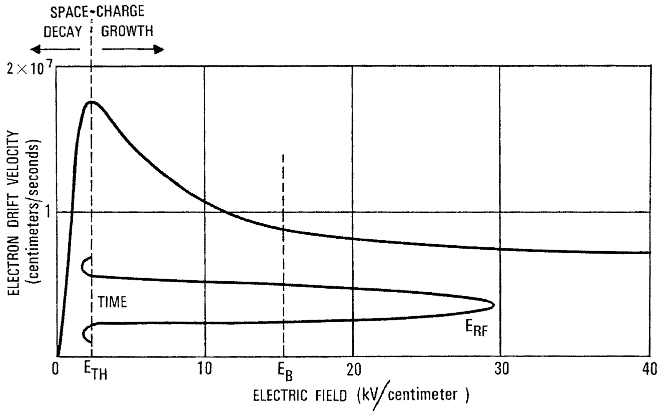


Figure 4 - Primary transferred-electron characteristic for gallium arsenide showing applied bias and radio-frequency amplitude for *LSA* operation.

impedance devices. The essential requirement for *LSA* is that the ratio of doping level to operating frequency should be between 2×10^4 and 2×10^5 seconds per centimeter^3. For a 1-gigahertz oscillator this means that the resistivity should lie in the range 5 to 50 ohm-centimeters with proportionally lower resistivities at higher frequencies. Theory predicts that the optimum bias field and the radio-frequency loading vary with the doping/frequency ratio in a complex manner but in general the bias fields are higher and the radio-frequency load impedance lower than for the transit-time mode. The theoretical efficiency can be as high as 21·5 percent and the power output for a given resistance and frequency increases as the square of the ratio of the physical length to the transit-time length of the sample.

An *LSA* mode is identified experimentally by the oscillation frequency's lack of dependence on transit-time and the relatively high product of power, impedance, and frequency. It has been suggested by Bott and Fawcett [10] that a similar operation results from a hybrid mode in which a dipole domain, although existing for part of the transit, it is not fully formed and so the major part of the negative resistance appears at the terminals. On the circuit side an extra requirement for the *LSA* and hybrid modes is that the correct starting conditions are provided so that they can build up from the lower-frequency transit-time mode. This point will be discussed more fully in Section 6.

4. Gallium Arsenide Material

Gallium arsenide for Gunn-effect oscillators must be high-mobility n-type material with a high degree of crystalline perfection and a low density of deep donors. Three methods are currently in use.

4.1 Melt Grown (Bulk Gallium Arsenide)

This is produced by the horizontal static-gradient freeze process during which gallium arsenide is melted in a boat of quartz or Spectrosil and is controllably cooled until crystallization is complete. Temperatures as high as 1270 degrees Celsius are involved in the process and under these conditions the material tends to take in impurities (mainly silicon) from the containing vessel. The maximum value of the mobility is about 6500 centimeter^2 per volt-second.

4.2 Vapor-Phase Epitaxy

The material is grown as a layer on a gallium-arsenide single-crystal substrate material which may be either semiconducting or semi-insulating. This method of producing material was first described by Knight [11] and temperatures up to 760 degrees Celsius are used. The growth reaction is

$$6\, GaCl + As_4 \rightleftharpoons 4\, GaAs + 2\, GaCl_3$$

and room temperature mobilities for the grown layer of over 8000 centimeter^2 per volt-second have been obtained by Bolger [12].

4.3 Liquid-Phase Epitaxy

In this process the gallium-arsenide single-crystal substrate slice is immersed into a melt of gallium and gallium arsenide. As the temperature of the system is reduced, epitaxial growth occurs on the substrate. The technique produces relatively thick layers with a purity similar to the vapor-phase method. This process was first described by Nelson [13] and temperatures of about 850 degrees Celsius are involved. Some of the purest crystals ever produced were made using this method. Room temperature and liquid-nitrogen mobilities of 8450 and 118 000 centimeter^2 per volt-second, respectively, have been obtained by Hicks [14] at this laboratory.

4.4 Material Assessment

Initial assessment of the crystals is made using conventional Hall mobility and resistivity data. The purest material produced by each of the three processes tends to have a resistivity of only about 1 to 2 ohm-centimeters although the measured mobilities indicate that the epitaxial gallium arsenide has in fact the lowest total impurity content. Because the transferred-electron mechanism is a high-field effect, the normal low-field evaluation of the material is insufficient to confirm its suitability for oscillator applications. Some of the more important features of the crystal behavior, such as the peak-to-valley ratio of the current waveform, have been discussed previously [15].

Material produced by the melt-grown method forms a large ingot which can be sliced on the correct orientation for use as substrates in the epitaxial processes. It can also be used as active Gunn-oscillator material and the appropriate resistivity achieved by compensation doping (usually with oxygen). While it is possible to obtain the whole range of resistivities needed for Gunn oscillators it is difficult in practice to fabricate a device from a crystal die less than about 30 microns thick. Optimum performance in the transit-time mode at frequencies from L band to Q band would require material of approximately 100 microns thick and 7 ohm-centimeters for L band and 3 microns thick and 0·25 ohm-centimeter for Q band.

The practical problems of handling the thinner layers for high-frequency oscillators are largely resolved by using epitaxial layers on highly doped substrates. There is, however, a fundamental difference between the "bulk"

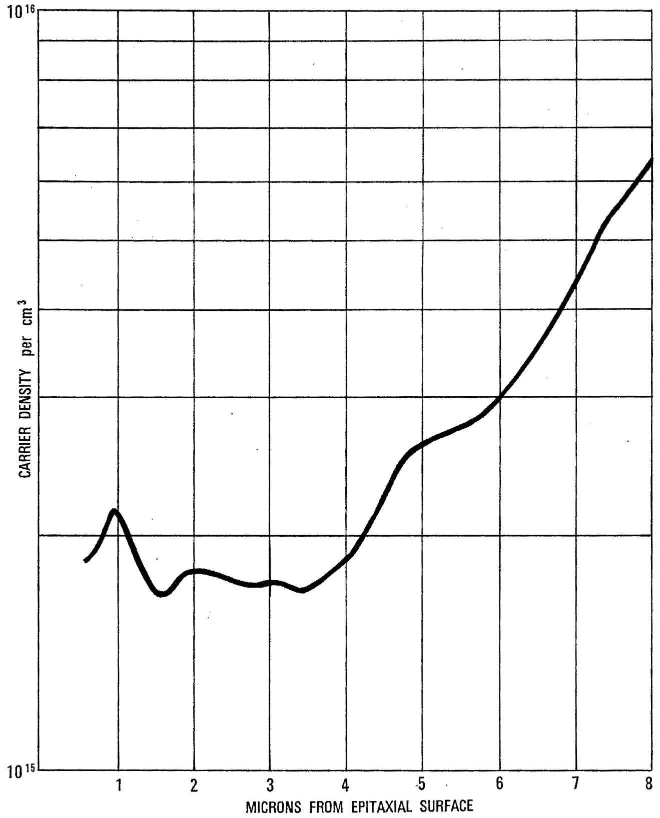


Figure 5 - Carrier-density profile through thickness of epitaxial gallium arsenide layer as derived from a Schottky barrier diode measurement.

and the "epitaxial" crystal in terms of electrical properties as a function of temperature. At resistivities above 1 ohm-centimeter, bulk material is invariably compensated and is found, with certain rare exceptions, to have a donor ionization level at about 0·2 electron-volt below the conduction band. This results in a very high negative temperature coefficient of resistivity causing a marked sensitivity to environmental conditions and a tendency to current runaway if sample heating occurs. In addition, since the sample temperature is unlikely to be uniform, it will cause non-uniformity of carrier density throughout the crystal. These features of the bulk material make it unsuitable for commercial applications. It is, however, convenient to use such material under laboratory conditions when large crystals of high resistivity are required for low-frequency, or for LSA operation. Experimente can then be conducted which give useful data on device behavior, valuable in establishing design criteria.

Epitaxial gallium-arsenide material produced by the vapor-phase or the liquid-phase techniques exhibits a positive temperature coefficient of resistance with T^x where x is somewhere in the range 1 to 1·5. This is primarily caused by a reduction of mobility with increasing temperature, and a comparative absence of partially ionized deep donors, and has the effect of inhibiting thermal runaway of current and consequent destruction of the device. A less desirable feature of the epitaxial material is the resistivity gradient observed in many layers. This usually manifests itself as an increase in carrier density toward the substrate. A good example of this tendency in poor material is shown in Figure 5. This carrier-density profile can be easily measured using Schottky barrier-diode capacitance-versus-voltage plots. The technique can be understood by applying Poisson's equations to the depletion region of the diode and obtaining,

$$n_x = \frac{C^3}{e A^2 \varepsilon \varepsilon_0} \cdot \frac{dV}{dC}$$

where C is junction capacitance
n_x is carrier density at x
A is area of depletion region normal to electric field
$\frac{dV}{dC}$ is obtained from measurement of C as a function of junction voltage
ε is relative dielectric constant
ε_0 is dielectric constant of vacuum
e is electronic charge

The carrier-density gradient, usually present in epitaxial material, causes the domain-transit distance, and hence oscillation frequency, to be dependent on bias voltage. This is analogous to a mechanism discussed later in Section 7. In the presence of this type of non-uniformity the less-well-defined reduction in average sample current above the threshold bias gives a lower efficiency. This point is illustrated by a comparison of the current-voltage plots for typical bulk and epitaxial oscillations (Figure 6). The curve for a selected bulk-material sample is representative of material having uniform conductivity. However, only epitaxial material has a sufficiently low density of deep donor levels to make it acceptable for commercial devices and the remaining problem is to improve the electrical uniformity.

5. Device Fabrication

The Gunn-effect device can be designed for either low-power continuous operation, or as a high-power pulsed oscillator and the detailed structure will depend on the particular application. Essentially the device comprises the active gallium-arsenide layer, with or without a substrate, and two ohmic contacts. The ohmic contact on the active layer is an evaporated film of silver tin which is alloyed in at 600 degrees Celsius. The thickness of the crystal needed for the specified frequency and the resistivity of the material determine the operating voltage and current density, respectively. The power output will obviously be dependent on the cross-section area and conversion efficiency, and they both control the amount of heat to be removed from the semiconductor chip. An array of continuous-wave samples on an n^+ substrate with evaporated top contacts is shown in Figure 7(a). The samples are cut out in groups of three mesas and these are connected in parallel to increase the output power.

In the case of an epitaxial device it is desirable to have the active gallium-arsenide layer bonded directly to the heat sink as the thermal conductivity of the substrate is much lower than that of copper. With a device made from bulk gallium arsenide it is best to make a good thermal connection to both sides of the semiconductor.

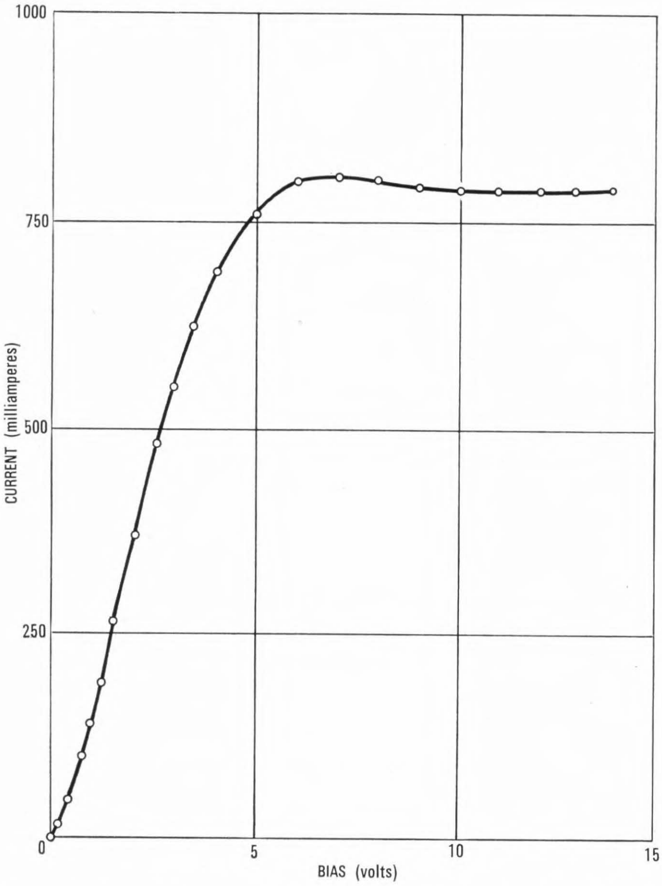
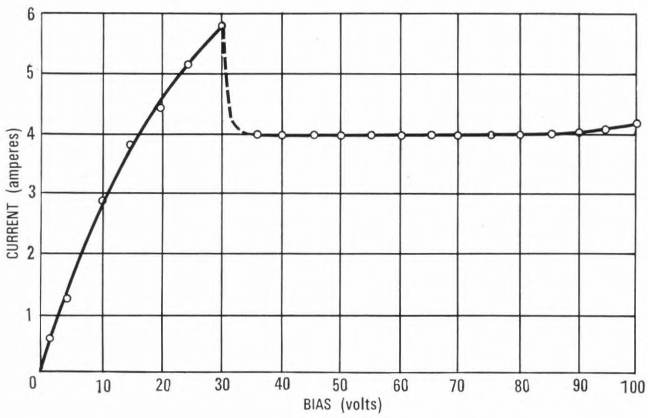


Figure 6 - Typical bias current *versus* voltage characteristic for a Gunn-effect oscillator.
(a) Epitaxial device (X band).



(b) Bulk gallium-arsenide device (L band).

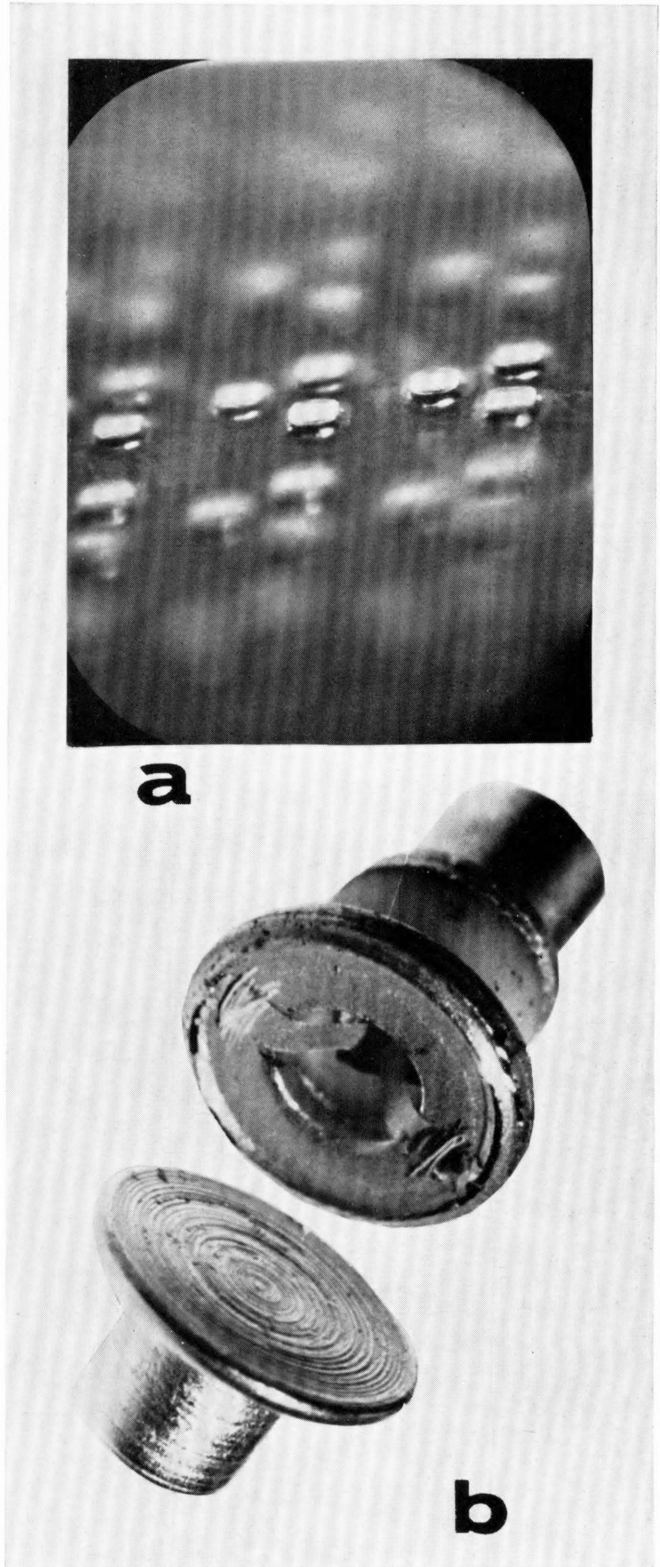


Figure 7 - (a) Continuous-wave epitaxial mesa devices with 0·004-inch (0·1 millimeter) diameter silver-tin evaporated contacts in groups of three on an n^+ gallium-arsenide substrate.
(b) Epitaxial devices in *SO 86* capsule.

An alternative configuration for the device is offered by the use of epitaxial layers on semi-insulating substrates. In this transverse structure [16] both contacts are on the epitaxial face (see Figure 8(c)) and heat conduction is normal to the direction of current flow. This arrangement is entirely compatible with monolithic integrated circuits and enables the direction of heat flow to be separated from the current flow. It is particularly suitable where long epitaxial samples are required for operation at the lower microwave frequencies or in the *LSA* mode.

Another satisfactory method of making contacts involves growing a very thin layer of highly doped n^+ gallium arsenide onto the active material and then making metal-to-semiconductor ohmic contact to this layer. The chip is in the form of an $n^+ n\, n^+$ sandwich. The contacts are

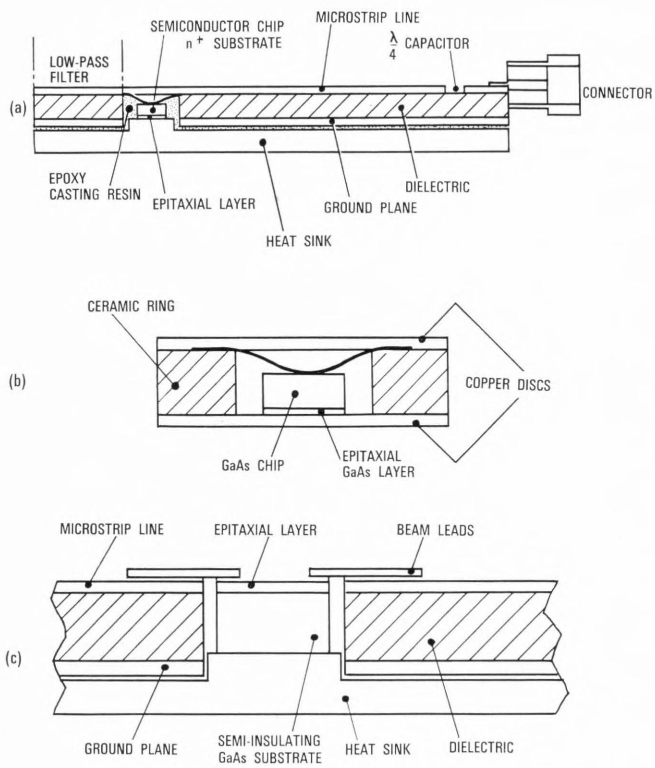


Figure 8 - Sectional drawings of devices mounted in microstrip circuit.
(a) The diode bonded into the dielectric,
(b) Diode encapsulated in miniature flat pill,
(c) The transverse diode structures on semi-insulating substrate.

grown in a similar clean environment to that used for the active crystal growth, thus minimizing the risk of subsequent contamination. High-temperature working would not affect these contacts, neither would the process of attaching leads during encapsulation. The life of such a device is expected to be good because a high-field domain never exists in the region of the metal contact. The disadvantage of this arrangement is that the extra gallium-arsenide contact layer reduces the thermal conductance between the active layer and the heat sink.

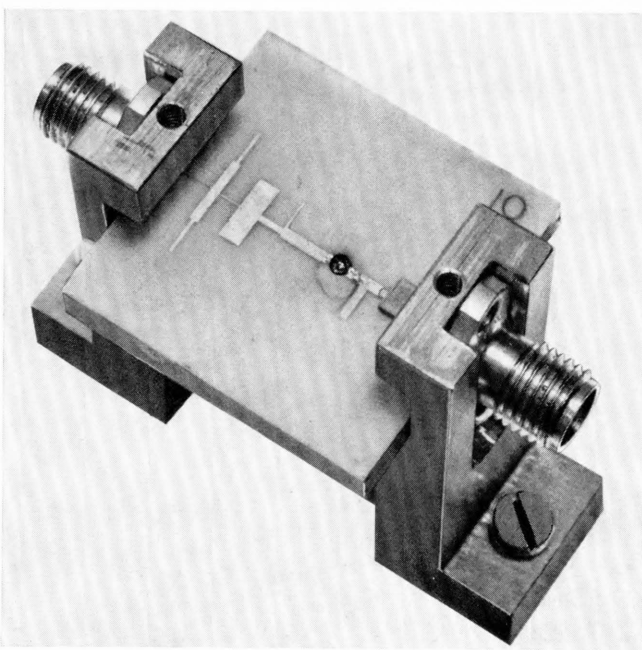


Figure 9 - Photograph of *X*-band microstrip oscillator circuit mounted in bench test jig.

The type of package chosen and the method of encapsulation can be varied to suit the particular application. In the case of the small continuous-wave device, already available commercially, a standard ceramic-metal pill is used (see Figure 7(b)). For a device mounted in the microstrip circuit no separate package is used, instead the chip with its ohmic contacts is potted directly into the thickness of the alumina dielectric (Figure 8(a)). Not only does this reduce the cost but it also permits the die to be bonded directly to the ground plane of the line which acts as an efficient heat sink. The contact material on devices used in this way is usually masked off from the edge of the die to reduce the risk of short-circuiting around the edge of the thin active layer. For a microstrip circuit in which the diode can be replaced instead of the whole circuit, a small flat pill (Figure 8(b)) is available which screws into the ground-plane heat sink.

6. Circuit Design and Microwave Performance

While the device operation is complex the circuit requirement is conceptually straightforward once an equivalent circuit has been agreed. Experiments have shown that radio-frequency power is relatively independent of the impedance at harmonic frequencies and therefore linear operation can be assumed. Measurements of the sample equivalent circuit under conditions of optimum performance show that it can be represented as a frequency-dependent negative resistance (that is, at the transit-time frequency) about 10 to 20 times the sample low-field resistance, and a parallel capacitance about equal to that of the "cold" device. The optimum circuit is required to present a conjugate match to this impedance and can consist in the most general case of two independent (that is, series and parallel) reactive elements. Such circuits have been realized in microstrip (Figure 9), and in coaxial line, waveguide, and lumped elements (Figure 10). Comparable microwave performance is obtained for each of these circuits.

The particular type of resonant circuit adopted will depend on the application. A calibrated signal-source circuit is likely to be a sophisticated and expensive piece of hardware with a precision-engineered mechanical tuning facility. The cavity would have a relatively high Q factor to achieve adequate frequency stability and mechanical tuning ranges of one octave are possible. Conversely, for some radar warning beacon equipments a less sophisticated fixed-tuning cavity might be used and would be correspondingly inexpensive. Another application for the Gunn device which will certainly be considered at some future date is the backward-wave-oscillator replacement. Gunn oscillators with varactor and Yttrium-iron-garnet tuning elements have been studied but to date the frequency-sweep range has been short of an octave.

If the device is used in a high-stability system then the practice, already in common use, of having a master reference, or injection-locking signal, would probably be

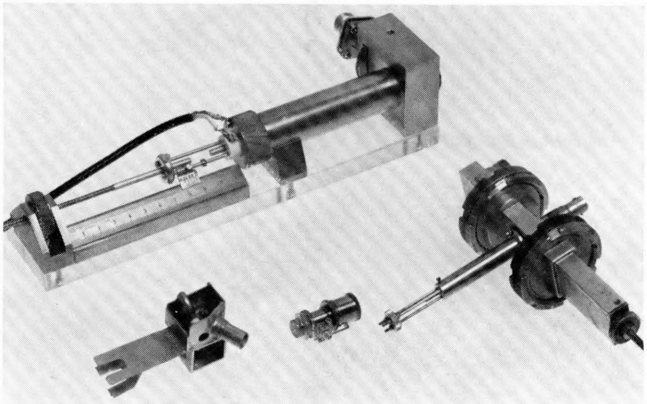


Figure 10 - Top - Wide range 3-to-12-gigahertz coaxial cavity with vernier tuning and adjustable output coupling.
Bottom left - L-band circuit with lumped elements.
Bottom center - miniature tunable coaxial cavity for X band.
Bottom right - tunable X-band waveguide cavity with coaxial matching stub.

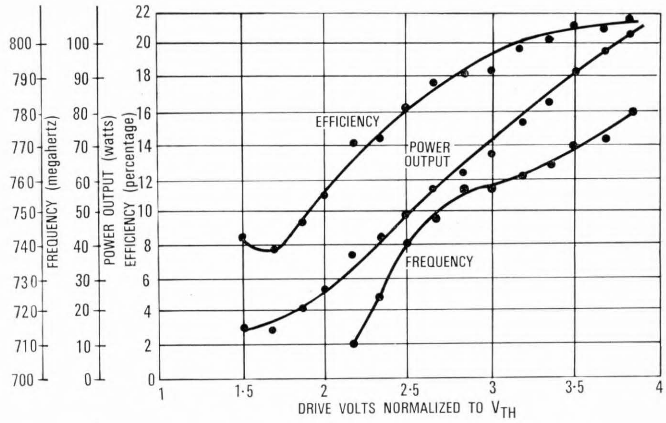


Figure 11 - Power, efficiency, and frequency for bulk device in lumped-element circuit.

used and a low-Q circuit would then be appropriate. Presently, an important factor influencing the choice of circuit would be the compatibility with existing systems.

A microstrip circuit on alumina substrate provides what is probably the simplest, most compact, and cheapest form for a fixed-frequency oscillator. Such a unit has been developed for X band [17] and is shown in Figure 9. The input bias is applied through a low-pass filter and the resonant circuit comprises the length of line between the diode and the filter, and the diode and side stub. The microstrip circuit cannot conveniently be tuned mechanically but the use of varactor elements for electronic tuning is being studied. If the line impedance is made equal to the effective negative resistance of the device at the center frequency of operation, the resonant cavity consists of the length of line between the diode and the input filter. This provides the inductive element to resonate with the diode equivalent capacitance. The varactor can be mounted in series with the cavity line and bias applied through a second low-pass filter. This type of minimum-size circuit will give the widest electronic tuning and ranges approaching 20 percent have been obtained in an S-band unit by Pearson [18].

In the *LSA* mode of operation there is a complication because the sample can present a negative resistance over the range from the intended *LSA* frequency down to the transit-time frequency. Transit-time oscillations can occur in a purely resistive circuit and even under short-circuit loading conditions. In practice, *LSA* oscillators start up in the transit-time mode but that if the cavity presents a short-circuit at this frequency, that is, no power is extracted, then the oscillations will build up at the *LSA* frequency. The most successful circuits for *LSA* have used waveguide.

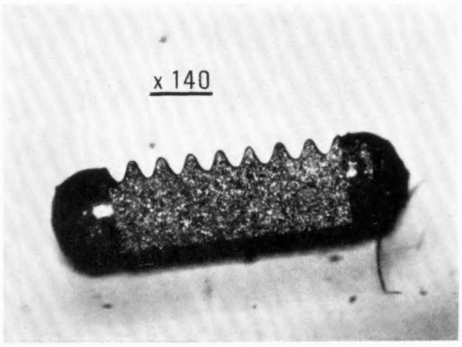
In conclusion some performance data, available at the time of preparing this paper, will be given for devices made at these laboratories. At X band, continuous-wave power is typically in the range of a few tens of milliwatts, the best single devices giving more than 50 milliwatts at 3-percent efficiency. A mechanical tuning range of one octave is normally obtained using a coaxial cavity. In addition a small electronic tuning range is usually found, particularly in epitaxial devices, with a doping gradient as discussed in Section 4. A linear frequency-modulation characteristic over a 40-megahertz range has been observed [19] in these epitaxial devices. Continuous-wave epitaxial diodes now being life tested have to date reached 6000 hours of operation with only marginal changes in performance. Some larger epitaxial samples have been operated in the pulsed mode and output powers of 14 watts at 3·4 gigahertz [20], 20 watts at 2 gigahertz, and 100 watts at 1 gigahertz have been obtained. Higher pulsed powers have been obtained from large devices made from bulk-grown gallium arsenide. A number of samples have given about 200 watts peak power with 12-percent conversion efficiency and in one case a lumped-circuit oscillator operated at 21-percent efficiency with 100 watts output at 0·8 gigahertz [21]. Detailed performance curves for the oscillator are shown in Figure 11. The highest powers of all have been realized in the *LSA* mode with samples up to 40-times longer than the transit length. At 2 and 3 gigahertz, output powers of 1 kilowatt and 300 watts, respectively, have been obtained with efficiencies up to 5 percent [21].

The apparently superior performance of diodes made from bulk gallium arsenide is due in part to the better uniformity of material resistivity along the drift path in some selected devices and also in smaller degree to the fact that the operation is at the low duty cycles needed to ensure negligible heating.

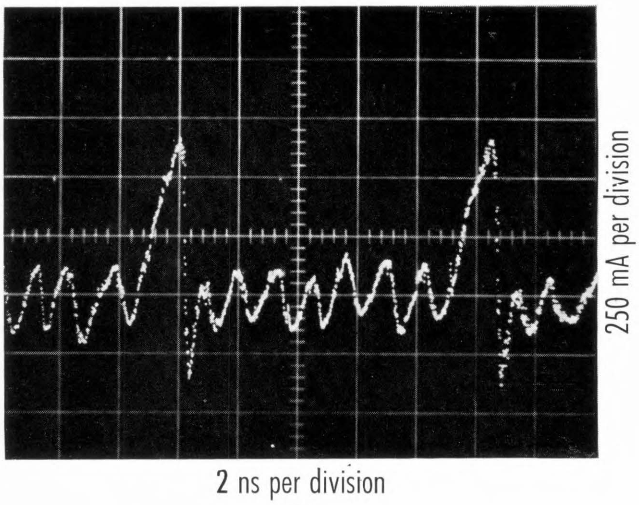
The value of these results is that they illustrate the potential performance which can be expected for commercial units when epitaxial techniques are more fully controlled. The work on bulk material samples obviously provides useful design data for the research and development activities.

7. Other Applications of Domains

An important domain property, arising from the form of the electron-drift velocity *versus* electric-field characteristic of bulk gallium arsenide, is that although the domain peak field is dependent on applied bias, the domain velocity is relatively constant over a wide range of bias. This property can be inferred from Figure 1. It can be



(a)



(b)

Figure 12 - (a) Long gallium-arsenide device with cyclic changes of cross-section area along the sample.
(b) Current waveform from the device.

shown [22] that current flowing in the presence of a domain is therefore almost constant in a uniform device, irrespective of applied bias, and is given by,

$I = nAve$,

where

I is the current

n the carrier concentration in the immediate vicinity of the domain

A the effective drift-path cross-section area in the immediate vicinity of the domain

v the drift velocity, and

e the electronic charge.

Variation in conductance along the domain drift path will result in changes in current which are proportional to the product of n and A. The high velocity of the domain coupled with its short response time suggest potential applications in the field of high-speed circuitry. An example of the domain response to changes in cross-section area along the drift path is shown in Figure 12 where one cycle of the current variation occurs during a time interval of about 1 nanosecond. Some of the ways in which the nA product, the "conductor-path profile", can be varied are:

— localized alloying or diffusion of a donor element along the drift path,
— changes of cross-section area of the drift path,
— white-light illumination of portions of the drift path, or
— localized impact ionization of deep donors at very high domain fields.

Since changes in domain current have associated changes in domain voltage, it is also possible to monitor the domain voltage, using point-contact or capacitive probes, along the non-uniform sample. Thus multiterminal devices have been constructed using a pattern of capacitively coupled electrodes which sense the domain voltage as it passes each terminal. It is also possible to interact with the domain by biasing either dielectric [23], or junction isolated, electrodes.

If the conduction-path profile is changed by localized alloying or diffusion, or by modifying the cross-section area along the drift path, the information content is a permanent feature built into the device during manufacture to perform a specific function. Suitable applications would be in waveform generation of such functions as sawtooth or staircase waveforms. On the other hand, the properties of the domain in a non-uniform sample under triggered-mode conditions enable it to be used in analog-conversion and coding functions. Consider the tapered sample shown in Figure 13(a) in which the bias polarity is such that the domain is initiated at the smaller electrode. As the domain moves along the sample the current increases progressively, the necessary additional voltage across the ohmic bulk of the material being drawn from the domain itself. The domain will eventually collapse at a point in the sample where its voltage will have fallen below the critical value necessary for stability. At a higher bias level the domain will traverse a greater distance before it runs out of voltage. Current waveforms for three different drive levels are illustrated schematically in Figure 13(b). A uniformly tapered sample will thus provide an analog conversion between voltage level and time interval. In addition the output can be quantized if a geometrical ripple, such as that shown in Figure 13, is superimposed on the taper. Current waveforms for a simple 5-level version of this type of coder are shown in Figure 14, and for a 16-level version in Figure 15. Compact coders with many levels for high-speed operation can be constructed by photoetching a suitable edge profile on a thin epitaxial ribbon of gallium arsenide (Figure 16) supported on a semi-insulating substrate, but of course the demands on material quality become progressively more severe.

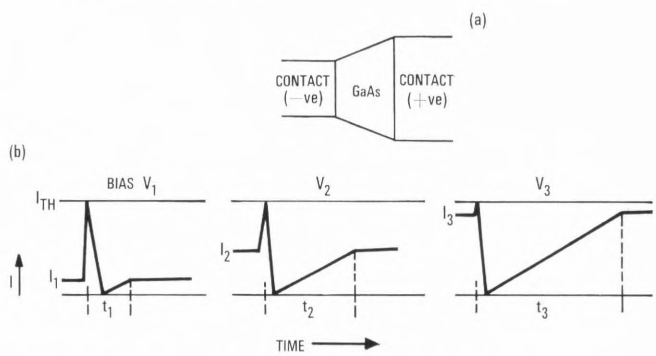


Figure 13 - The principle of analog conversion (that is, bias voltage to domain transit time) in a "wedge" shaped device in triggered mode.
(a) Device geometry,
(b) Current waveform.

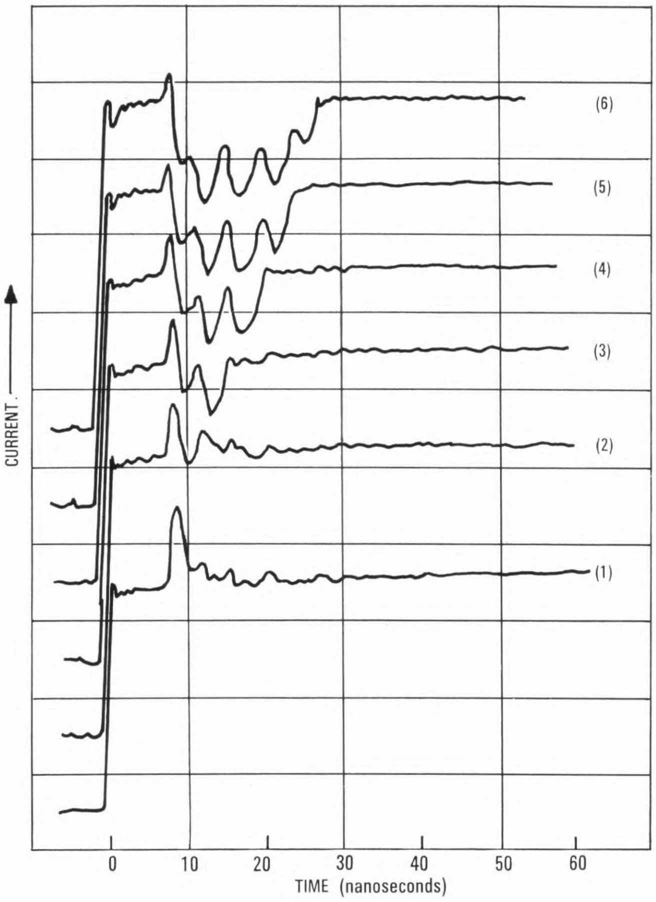


Figure 14 - Current waveforms for analog-to-digital convertor with bias voltage increasing from traces *1* to *6*.

Other ways of modifying the conduction path profile start with a uniform device and modulate the carrier concentration by external means. In principle, a differential level of illumination along the sample will produce localized variations in carrier concentration which will be monitored on the current waveform during each cycle of the domain. Thus it is feasible to consider using a ribbon-shaped device as a compact high-speed optical scanner. In the final technique a localized increase in free-electron concentration is obtained by momentarily increasing the applied bias above the level where impact ionization occurs within the domain. In the presence of a certain deep impurity level, almost always found in gallium arsenide, the holes produced during this impact ionization are rapidly trapped while the surplus electrons remain free for times of the order of one microsecond. Information can then be written in along the sample, stored for short periods of time, and nondestructively read out on the current waveform.

Devices of the type described above have been termed *DOFIC* (Domain Originated Functional Integrated Circuits). These ideas, all of which are presently being studied, by no means exhaust the possible applications for the moving high-field domain. One could, for example, consider the use of what is essentially a moving *pn* junction as a parametric element. Or again, the domain could be used in a scanning display with a moving mirror to perform a frequency-changing function using the Doppler effect, or modulating radiation with wavelength in excess of about 1 micrometer.

All these devices from oscillators to a *DOFIC* have a relatively simple geometry compared to equivalent conventional junction components.

Because bulk-effect devices derive their characteristics from a complex interaction between the electron and the crystal lattice, the key to successful commercial exploitation lies in the complete control of the properties of the starting material.

8. Conclusions

Presently, the status of the Gunn-effect oscillator rests mainly on its performance under laboratory conditions, where continuous-wave powers approaching a 0·5 watt [24] and pulsed powers near 1 kilowatt have been obtained. It has also been demonstrated that the Gunn diode will give continuous-wave and high-pulsed-power devices covering the whole of the microwave spectrum. Some manufacturers are already offering continuous-wave X-band diodes on a commercial scale but the output powers and efficiencies are significantly less than the best obtained in the laboratory. Clearly, the full commercial impact of the Gunn diode will not be realized until cheaper and more repeatable techniques for producing high-quality epitaxial gallium arsenide have been developed. In this respect the Impatt (Impact avalanche transit time) device which uses silicon offers some advantages, but present indications are that the transferred-electron oscillator will remain superior from the

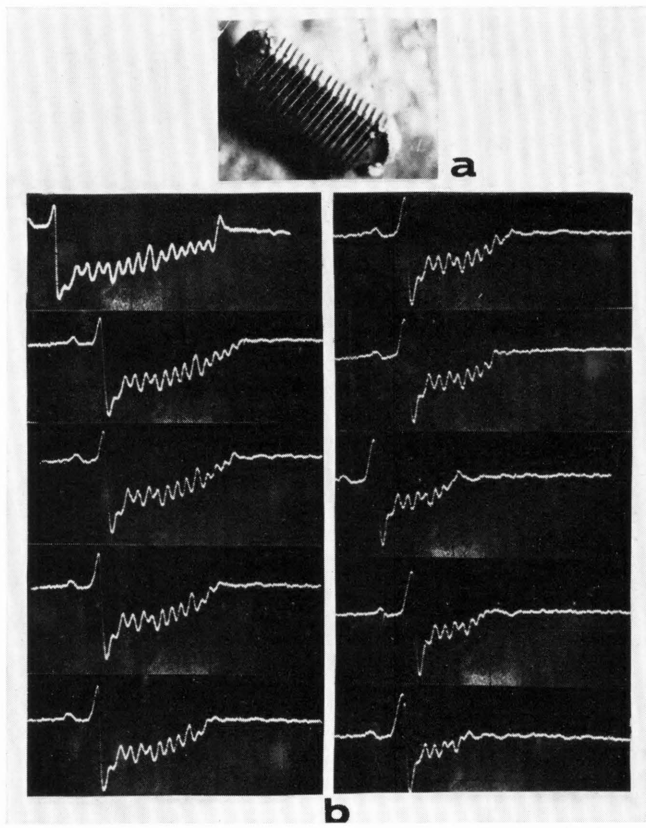


Figure 15 - (a) Geometrically coded device with 16 levels,
(b) Current waveforms as a function of time for different domain transit distances.

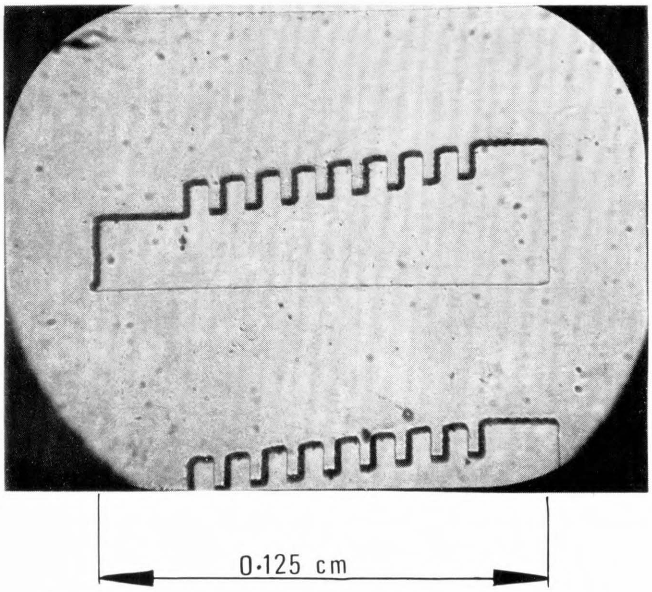


Figure 16 - A *DOFIC* fabricated in epitaxial gallium arsenide on a semi-insulating substrate.

standpoint of noise performance, tuning range, and peak power.

The potential field of application is wide, including local oscillators, microwave links, laboratory test equipment, phased-array and conventional radars, and direction and height-finding aircraft equipment. One can expect that the compact microstrip oscillator with provision for electronic tuning and injection phase locking will be particularly suitable in many of these fields. It is inevitable with such a new device that the first uses will be as a replacement component for equipments in the established microwave field. However, the potential cheapness and simplicity of the Gunn-effect oscillator could open up a large consumer market for more mundane applications such as collision-avoidance radar on cars and trains, hopper-level indicators, and general velocity-measurement equipments.

The *LSA* and hybrid modes have made very high pulsed power possible, whilst still retaining a measure of control over the device impedance. The fundamental limit to maximum power obtainable from a single device in this truly bulk-effect mode of operation is set only by the need to restrict the sample dimension to avoid skin-effect losses and standing waves within the sample. It can be shown that in practically realizable circuits these considerations are not serious below output power levels of the order of 1 megawatt at the lower microwave frequencies. However, except in the case of extremely low duty cycles, the problems arising from heat dissipation in such a sample would favor the alternative approach whereby very high output power is derived from many smaller power units, as, for example, in phased-array radar.

The family of devices we have discussed which rely on the properties of the high-field domain in extended samples, are as yet only in the research stage of development. They illustrate the exciting possibilities of a phenomenon that is unique in solid-state physics. The *DOFIC* represents a new way of realizing complex electronic functions which is completely divorced from the established concept of an interconnected assembly of passive and active elements using *pn* junctions. It is particularly encouraging that the optimum operation speeds of the device are in the region where conventional techniques are near their upper limit of operation.

9. Acknowledgments

The authors wish to express their thanks to many colleagues at STL who have contributed to the work reviewed in this paper. In particular thanks are due to J. Froom, M. P. Wasse, and R. E. Cooke.

References

[1] J. B. Gunn: Microwave Oscillations of Current in III—V Semiconductors, Solid State Communications, volume 1, p 88—91, September 1963.
Instabilities of Current in III—V Semiconductors, IBM Journal of Research and Development, volume 8, p 141—159, April 1964.
[2] B. K. Ridley and T. B. Watkins: The Possibility of Negative Resistance Effects in Semiconductors, Proceedings of the Physical Society, volume 78, p 293, 1961.
[3] C. Hilsum: Transferred Electron Amplifiers and Oscillators, Proceedings IRE, p 185, February 1962.
[4] J. A. Copeland: *LSA* Oscillator — Diode Theory, Journal of Applied Physics, volume 38, p 3096—3101, July 1967.
[5] B. K. Ridley: Specific Negative Resistance in Solids, Proceedings of the Physical Society, volume 82, p 954—966, 1963.
[6] J. S. Heeks: Some Properties of the Moving High Field Domain in Gunn Effect Devices, Transactions IEEE Group on Electron Devices, volume ED 13, p 68—79, January 1966.
[7] J. S. Heeks, A. D. Woode, and C. P. Sandbank: Coherent High Field Oscillations in Long Samples of GaAs, Proceedings IEEE (Correspondence), volume 53, p 554—555, May 1965.
[8] H. Kroemer: Theory of the Gunn Effect, Proceedings IEEE, volume 52, p 1736, December 1964.
[9] J. A. Copeland: Theoretical Study of a Gunn Diode in a Resonant Circuit, Transactions IEEE Group on Electron Devices, volume ED 14, p 55—58, February 1967.
[10] I. B. Bott and W. Fawcett: Theoretical Study of Effect of Temperature on X-band Gunn Oscillators, IEE Electronic Letters, volume 4, no 10, p 207—209, May 1968.
[11] J. R. Knight, D. Effer, and P. R. Evans: The Preparation of High Purity GaAs by Vapour Phase Epitaxial Growth, Solid State Electronics, volume 8, p 178—180, 1965.
[12] D. E. Bolger, J. Franks, J. Gordon, and J. Whitaker: Preparation and Characteristics of Gallium Arsenide, Proceedings of International Symposium on Gallium Arsenide, Institute Physics and The Physical Society, Conference Series No 3, 1966.
[13] A. Nelson: Epitaxial Growth from the Liquid State and Its Application to the Fabrication of Tunnel and Laser Diodes, RCA Review, volume 24, p 603, 1963.
[14] H. G. B. Hicks: Private communication to authors.
[15] G. King, M. P. Wasse, and C. P. Sandbank: An Assessment of Epitaxial Gallium Arsenide for use in Gunn Effect Devices, Proceedings of International Symposium on Gallium Arsenide, Reading 1966, Institute of Physics and The Physical Society, Conference Series No 3.
[16] C. P. Sandbank, G. King, and J. S. Heeks: Consideration of Materials and Configurations for Gunn Effect Devices, IEE Conference on Microwave Properties of Ferrimagnetics and Plasmas, September 1965.
[17] M. P. Wasse, A. Pearson, and G. King: A Microstrip Circuit Module for the Gunn Oscillator, To be published.
[18] A. Pearson: Private communication to authors.
[19] G. King and M. P. Wasse: Frequency Modulation of Gunn Effect Oscillators, Transactions IEEE Group on Electron Devices, volume ED 14, p 717—718, October 1967.
[20] G. King and M. P. Wasse: High Power Gunn Effect Oscillators using Epitaxial GaAs, IEE Electronic Letters, volume 2, no 8, August 1966.
[21] J. S. Heeks, H. K. Au, and A. D. Woode: An Experimental Study of High Peak Power Gunn Effect Oscillators, To be published.
[22] C. P. Sandbank: Synthesis of Complex Electronic Functions by Solid State Bulk Effects, Solid State Electronics, volume 10, p 367—380, 1967.
[23] M. Shoji: Current Pulse Generators, Proceedings IEEE, p 710, May 1967.
[24] T. Okoshi: Gunn Devices are on Target, Electronics p 125—130, December 11th 1967.

C. P. Sandbank was born in Vienna in 1931. He obtained an Honours Degree in Physics from London University in 1953 and joined Standard Telephones and Cables the same year. In 1956 he was awarded the Diploma of Imperial College, London, in Electrical Engineering, and in 1960 moved to the STC Transistor

Division, where he was responsible for special device and semiconductor integrated-circuit development. He is now head of solid-state bulk effects and microelectronics techniques research at Standard Telecommunication Laboratories.

J. S. Heeks was born in Stoke-on-Trent, England, in 1934. He received the BSc degree in physics and the PhD degree for work on microwave spectroscopy from the University of Birmingham, England, in 1955 and 1958, respectively. He joined Standard Telecommunication Laboratories in 1960 since which time he has studied a variety of problems mainly connected with the operation of mixer, modulator, and parametric diodes at millimeter wavelengths. He is currently working on the Gunn effect.

G. King was born in London in 1925. After training at the Royal Technical College in Glasgow, he served in the Royal Air Force where he worked on experimental and operational radar systems.

In 1947 he joined the engineering staff of Standard Telecommunication Laboratories and worked on problems associated with thermionic emitters and microwave tubes. More recent work has included fundamental studies of velocity modulation in high-power high-efficiency klystrons. He is currently engaged on studying instabilities in bulk semiconductor materials and their application to solid-state microwave devices.

Mr. King is the holder of the City and Guilds of London Institute final grouped certificate in telecommunications engineering.

Awards for Engineering Creativity

Forty-four employees of affiliated companies were named by International Telephone and Telegraph Corporation as recipients of cash awards totaling 56 000 dollars.

The employees, from ten ITT companies, are being honored under the ITT-awards program, established in 1966 to recognize outstanding contributions of ITT System personnel in developing inventions and new products or services.

The winners will receive commemorative medallions and certificates in addition to their cash awards. Their Companies will receive trophies for display.

The awards were announced by Harold S. Geneen, Chairman and President of ITT, who said: "Our awards program is ITT's way of recognizing those employees who have contributed materially to strengthening and broadening ITT's product mix. The program stimulates creativity both in our traditional fields and in our new and diversified organization to aid increased corporate profiability. On behalf of our more-than-210 000 ITT System employes, I am happy to express to the current winners, ITT's appreciation through these awards."

The achievements for which the awards are given are in two categories: inventions and products/services.

In the products/services category, two joint first awards totaling 20 000 dollars were granted.

E. H. Ings, R. Tatman, W. G. Cook, R. Y. Gill, and B. E. Ash, of ITT's British affiliate, Standard Telephones and Cables, London, will share 10 000 dollars. The award recognizes their development of a widely used type-*174* coaxial cable, which is a substantial improvement on previous wideband communication cables.

In the second joint award, G. K. Duddridge, H. A. Moore, C. F. G. Smith, A. Hynd, and D. A. Hibbs, also of Standard Telephones and Cables, share 10 000 dollars for the development of the STC 1-inch submarine cable. This cable is for use on very-long-distance submarine telephone systems, up to 640 channels.

In the field of inventions, a first award of 10 000 dollars will be shared by C. Vazquez, and his associates, G. C. Dufresnoy, S. M. Y. Maelstaf, and M. C. J. Barbaut. These engineers of Compagnie Générale de Constructions Téléphoniques, Paris, developed a miniature crossbar multiswitch. This "miniswitch" is a very small high-speed low-cost switch suitable for all semielectronic and electromechanical telephone and telegraph switching systems.

In the field of new products, additional awards totaling 20 000 dollars were bestowed. They included:

5 000 dollars – shared among C. S. Nevin, O. A. Drake, H. W. Baker, and K. R. Crowe of ITT Industrial Laboratories Division, Fort Wayne, Indiana, and E. A. Ziemer, A. W. Hoover, and J. E. Barlow of ITT Electron Tube Division, Easton, Pennsylvania, for contributions to the development of night-vision devices.

5 000 dollars – shared among Dr. H. Carl, Dr. O. Laaff, K. Schmid, G. Gebhard, and H. Kuhn of Standard Elektrik Lorenz, Stuttgart, Germany, for the development of the 6-gigahertz radio-relay system which is a long-range microwave system for the transmission of large groups of telephone channels as well as television.

5 000 dollars – shared among H. A. French, L. T. Gannon, M. W. Green, C. Greenwald, and J. G. Gulack, of ITT Defense Communications, Nutley, New Jersey, for the development of the *660*-series microwave equipment, used by the US military in a variety of applications.

5 000 dollars – shared among 8 engineers of ITT Gilfillan, Inc., Van Nuys, California, for the development of a long-range shipboard radar. The recipients are: G. B. Crane, I. W. Hammer, S. L. Howard, N. T. Keyes, T. Kinaga, A. W. Meyer, R. E. Stein, and E. E. Thomas.

In the field of inventions, four additional awards totaling 6 000 dollars were announced.

2000 dollars – to G. Gassmann of Standard Elektrik Lorenz, Stuttgart, Germany, for a synchronizing circuit for television receivers.

2000 dollars – shared by H. Adelaar and J. Masure of Bell Telephone Manufacturing Company, Antwerp, Belgium, for a channel-alignment principle for time-division-multiplex switching exchanges.

1000 dollars – to J. Keyes, of ITT Bell and Gossett Hydronics, Morton Grove, Illinois, for an anti-squeal pump impeller, which assures quiet circulation of heating fluids in homes and industry.

1000 dollars – to W. D. Hessler, ITT Marlow, Midland Park, New Jersey, for a Trash Hog centrifugal pump, which can easily be cleaned if jammed by solids in the fluid it pumps.

Subscriber Stages in Pentaconta PC 1000 C Exchanges*

R. BERNARD
Laboratoire Central de Télécommunications, Paris
M. GRUSZECKI
Bell Telephone Manufacturing Company, Antwerp
J. R. DE LOS MOZOS
International Telephone and Telegraph Laboratorios de España, Madrid

1. Introduction

Pentaconta line-selection and group-selection elements use the interaid principle within the link system [1]. *Interaid* means mutual aid between sections of the same selection element to permit a call on one section to use, if necessary, the links of the other sections. Extensive traffic simulations were made for the line-selection speech network using the Kosten "roulette" model and for its control circuitry using a time-true model. The simulation of the speech network and control circuits allowed investigation of several arrangements of speech-network geometry with various values of traffic and investigation of control-circuit behavior.

2. Network Geometry

A typical junction diagram, Figure 1, shows the position of a line-selection element in a Pentaconta exchange. The element is shown in more detail in Figure 2. It has primary and secondary sections and is controlled by its own control circuit, thus making a conjugated-selection element fairly independent of other exchange elements. The interaid network used here permits a call on a given primary section, needing a particular secondary section, to use not only f links between the sections but, if these links are not free, the links of the other sections. This reciprocal aid between primary sections is one of the characteristic features of the Pentaconta system. The majority of calls can be completed through the 2 main stages and only a small number will use 3-stage selection. Thus the interaid principle gives the equivalent of 3-stage conjugate selection with 2 principal stages and 1 interaid stage with reduced dimensions.

Figure 2 shows a line-selection element with K primary and M secondary (or terminal) sections. Each primary section has S penultimate selectors for terminating traffic, C call finders for originating traffic, Z interaid selectors, D outlets towards secondary sections, and E interaid outlets for connection with K–1 primary sections. The average number of interaid links f' between any 2 primary sections is defined as,

$$f' = \text{minimum}\ (Z, E/K\text{–}1).$$

* This paper was not published until 25 October 1968.

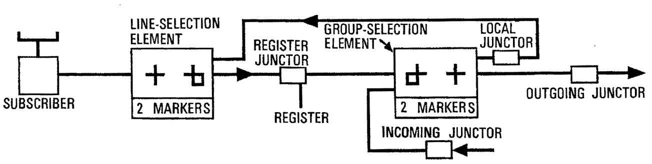


Figure 1 - Crossbar Pentaconta local office.

Each of the M secondary sections has T secondary selectors, used for bothway traffic, and n outlets. Furthermore,

$$T = 2K \text{ and } 3MT = 2KD,$$

that is, $T/2$ links can be connected to 2 primary sections (common links) and $T/2$ to 1 primary section (individual links). The network is completely symmetric.

When a subscriber call is originated, the control circuit scans the links and call finders towards all registers. Individual links are first tested and then if they are busy, the common links. As a last choice the interaid network is available but is seldom used in preselection. The terminating calls appear at random on the penultimate selectors of all primary sections; a call from a particular primary section to a particular terminal section first tests the individual link and then, if busy, the common links. As a third choice, all individual and common links of the other K–1 sections are explored through the interaid network (Figure 3). If all these tests fail to find a free path towards the wanted subscriber, a completely new attempt is made with $K\text{–}1/K$ chances that the call will appear on another primary section.

In this new attempt, referred to as reselection, again 3 choices are available, individual, common, and interaid links.

3. Calculation of Congestion

3.1 *Originating-Traffic Congestion*

The probability P_p that a subscriber will meet congestion in preselection (excluding register congestion) can be calculated by the straight addition of the individual congestions (provided they are small) on 1 secondary section and all call finders,

$$P_p = F_T^{n-1}(a) + E_{KC}(A_o), \tag{1}$$

where $F_T^{n-1}(a)$ is the Engset call-congestion term for n sources, each offering traffic a and having access to T channels. It is expressed as the conditional probability that T channels are busy when a call is offered and may be written as,

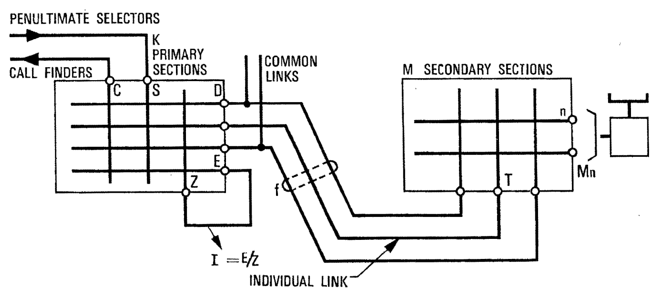


Figure 2 - Outline of a line-selection element.

$$F = F_T^{n-1}(a) = \binom{n-1}{T}\left(\frac{a}{1-a(1-F)}\right)^T \times \frac{1}{\sum_{j=0}^{T}\binom{n-1}{j}\left(\frac{a}{1-a(1-F)}\right)^j}.$$

The second term in Equation (1) $E_{KC}(A_o)$ is the Erlang loss function for KC call finders and a total originating traffic A_o, and can be expressed as,

$$E_{KC}(A_o) = \left(\frac{A_0^{KC}}{(KC)!}\right)\left(\frac{1}{\sum_{j=0}^{KC}\frac{A_0^j}{j!}}\right).$$

Internal blocking in preselection is negligible and the use of the interaid network for originating traffic, although possible, is not taken into account here.

3.2 Terminating-Traffic Congestion

To produce formulas for computer use the following simplifications have been introduced.

- Lee-Le Gall's method [2, 3] is used which implies stochastic independence between stages.
- The probability of choosing the same primary section in the first and the second attempt is $1/K$. This hypothesis is equivalent to saying that when a terminating call makes a second attempt to complete, every primary section has at least one penultimate selector free.

  The line-selection loss probability P_s can then be expressed in the following terms,

  $$P_s = \frac{P_o + (K-1)P_1}{K}, \tag{2}$$

  where P_o is the conditional probability that a terminating call is lost assuming that the same primary section is used in both the first and second attempts, and P_1 is the conditional probability that the terminating call is lost assuming that 2 different primary sections are used in the first and second attempts.
- Erlang and Engset traffic are assumed on the interaid and secondary selectors, respectively.

The deduction of P_o is made using the general Lee-Le Gall's method. A graph is prepared representing all possible paths between the calling primary section and the called secondary section. To simplify the formulas and to write them in a general form independently of K, it is assumed that all primary sections are interconnected by f' the same average number of interaid links.

The graph is then drawn in the series-parallel canonical form and formulas obtained assuming a Bernoulli distribution for all stages. The formulas will be reduced according to the following multiplication rule,

$(xy)(uv) = (xy)$ if and only if $x = u$ and $y = v$,

where (xy) denotes the common link connecting primary sections x and y.

The formula is then simplified by assuming all individual and common links are equally loaded; this hypothesis implies

$(xy) = (q) = p$

for every common link (xy) and every individual link (q)

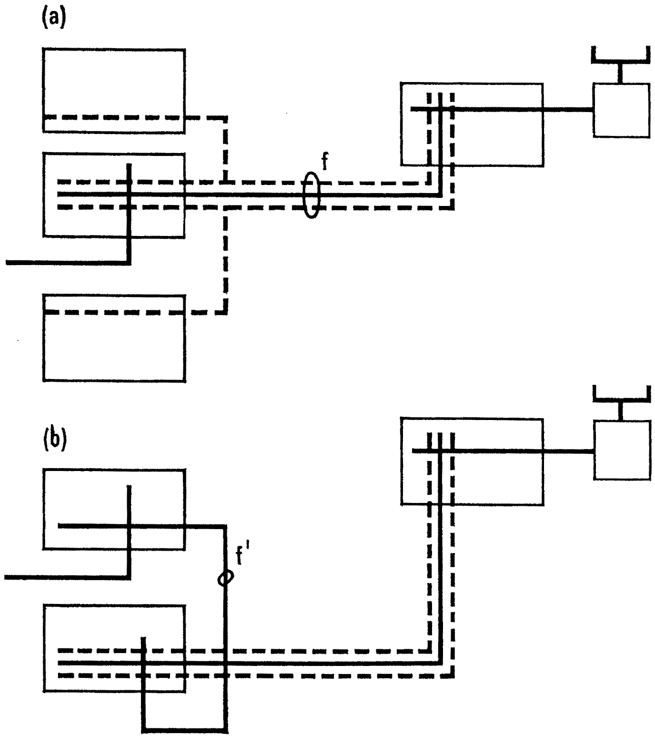


Figure 3 - Line selection through
(a) 2 stages, and
(b) 3 stages using interaid.

(q denotes the primary section to which the link is connected and p is the average load per secondary selector). Next the Bernoulli distribution is substituted by the actual one in the corresponding stage and the interaid traffic A_E calculated. The formula obtained by this substitution will have the following form:

$$P_o = \sum_{i=0}^{K-1} Q_{oi} P_{oi+1}, \tag{3}$$

where Q_{oi} represents the probability that only i-determined primary sections are available through the interaid network from the primary section in which the terminating call appears.

P_{oi+1} represents the addition of blocking probabilities between any combination of $i+1$ primary sections and the secondary section of the called subscriber. (The terminating call appears in one of the $i+1$ primary sections whilst i primary sections are accessed through the interaid network). Depending on the relative location of the $i+1$ primary sections the probability of blocking will be different. To give formulas which can be translated into symbolic computer language, the average number of links α_i connecting i primary sections and the called secondary section have been calculated,

$$\alpha_i = 3 + (i-1)\left(3 - \frac{i}{K-1}\right). \tag{4}$$

We can now repeat the final formula for P_o,

$$P_o = \sum_{i=0}^{K-1} Q_{oi} P_{oi+1}, \tag{5}$$

where

$$Q_{oi} \mathrel{\overline{\wedge}} df'^{(K-1-i)}(1-df')^i = \sum_{j=0}^{i}(-1)^j\binom{i}{j} df'^{(K-1-i+j)}, \tag{6}$$

and

$$P_{oi+1} \overline{\overline{\wedge}} \binom{K-1}{i} P^{\alpha_{i+1}}, \tag{7}$$

d is the interaid-selector load,
f' the average number of interaid links between any pair of primary sections,
and
$\wedge$ denotes the use of Le Gall's symbolic rule.

The corresponding formula for P_1 also has the form:

$$P_1 = \sum_{i=0}^{K-2} Q_{1i} P_{1i+2}, \tag{8}$$

where

$$Q_{1i} \overline{\overline{\wedge}}\ d^{f'(K-2-i)}(1-d^{f''})^i = \sum_{j=0}^{i} (-1)^j \binom{i}{j} d^{f''(K-2-i+j)}. \tag{9}$$

and

$$P_{1i+2} \overline{\overline{\wedge}} \binom{K-2}{i} P^{\beta_{i+2}} \tag{10}$$

where

$$\beta_{i+2} = \alpha_{i+2}, \tag{11}$$

and f'' is the average number of interaid links between any pair of primary sections and one of the other $K-2$ sections.

Substituting each term d^x and p^y by the corresponding value obtained with Erlang and Engset distributions, respectively, we obtain:

$$d^x = \frac{E_{KZ}(A_E)}{E_{KZ-x}(A_E)}, \tag{12}$$

$$p^y = \frac{F_T^{n-1}(a)}{F'^{\,n-1-y}_{T-y}(a)},$$

where

$$F'^{\,n-1-y}_{T-y}(a) = \frac{\binom{n-1-y}{T-y}\left(\frac{a}{1-a(1-F)}\right)^{T-y}}{\sum_{i=0}^{T-y}\binom{n-1-y}{i}\left(\frac{a}{1-a(1-F)}\right)^i},$$

with $F = F_T^{n-1}(a)$.

When y is not an integer a generalization of Engset formula is used.

The interaid traffic A_E in Equation (12) is calculated as follows. If π is the proportion of traffic using interaid (interaid rate) and A_T is the total terminating traffic, then

$$A_E = \pi \cdot A_T, \tag{13}$$

which assumes that the contribution of the originating traffic to the interaid traffic does not need to be taken into account as explained in Section 3.1. In Section 2 we explained that between each primary and secondary section there are one individual and two common links, the first choice and the second choice links, respectively. The traffic offered between one primary and one secondary section is $b = A/KM$. The proportion of traffic rejected by the individual link is $\pi_1 = E_1(b)$. For one or two channels and a practical range of loads, the character of this traffic is near random. The traffic offered to the common links is then approximately,

$$bE_1(b) + \frac{1}{2}bE_1(b) + \frac{1}{2}bE_1(b) = 2bE_1(b) = A_c$$

since the common links receive the traffic from the individual link connected to the section considered and half of the traffic rejected by individual links of the two adjacent sections. The proportion of traffic rejected by the common links is $\pi_2 = E_2(A_c)$. The interaid rate π is then $\pi = \pi_1 \cdot \pi_2$

$$\pi = E_1(b) \cdot E_2(A_c)$$

or

$$\pi = \frac{2b^5}{(1+b)\{2b^4 + 2b^2(1+b) + (1+b)^2\}}. \tag{14}$$

Later in Section 4.1 we show that these formulas agree with the experimental results.

4. Simulation Results

4.1 Speech-Network Simulation

By using the Kosten "roulette" model, Markoff chain experiments were simulated which correspond here to the successive changes of the state of the network, that is, the call attempts and call releases.

The geometry of the network and the hunting rules mentioned in Section 2 were fully included in the descriptive part of the program. Busy subscribers do not originate calls and calls directed to busy subscribers do not create any occupancy on the line-selection links.

The assumptions made agree with the Engset distribution on secondary selectors. The unbalance of sources in actual exchanges has a favorable influence on loss when the distribution of sources on the secondary sections is good. Hence the results obtained have a safe margin. Furthermore, the existence of PBX groups has been neglected in the simulations. In practice, a call to a PBX group marks all the lines of the groups in different sections and a preference is given to a line accessible without interaid. Due to the influence of the PBX traffic, the congestion in the line-selection element, as well as the amount of interaid traffic, will be much lower in actual exchanges.

The pseudo-random numbers needed for the simulations were generated using the power-residue method. Each simulation run was started from an empty network state and the transitory call period was disregarded before starting the counting and lost-calls statistics.

The confidence interval ΔP was estimated using the Student t test.

$$\Delta P = t_{c,m} \sqrt{\frac{1}{m(m-1)} \sum_{i=1}^{m} (P_i - P_o)^2}, \tag{15}$$

and

$$P_o = \frac{B}{N} = \frac{1}{N} \sum_{i=1}^{m} B_i, \tag{16}$$

where B is the total number of calls lost, N the total number of generated calls during the stationary period, m the number of samples, B_i the number of lost calls in sample i, P_i the proportion of lost calls in sample i, and $t_{c,m}$ is the Student coefficient. The true value of loss probability P is then contained in the interval $P_o \pm \Delta P$ with a confidence level $c = 95$ percent,

$$\text{probability}\ \{P_o - \Delta P < P < P_o + \Delta P\} = 0{\cdot}95. \tag{17}$$

In practice the line-selection elements comprise $K = 4 \div 11$ primary sections each with $D = 42$ outlets for links and $E = 10$ interaid outlets; $M = 14$ secondary sections, each with 74 subscribers, and $T = 8 \div 22$ selectors. The results selected here illustrate two trends. Table 2 gives several simulation results for one particular geometry and only the total traffic values are changed to permit the investigation of the blocking and the interaid traffic over a normal range of loads. The originating and terminating traffic are kept equal to eliminate the influence of additional parameters. Tables 1 and 3 give results of simulations for several geometric arrangements including an experiment with a different number of outlets for the direct and interaid links.

We observe the following tendencies from Table 2. The measured preselection loss is well approximated by $P_p = F_T^{n-1}\ (a) + E_{KC}(A_o)$ but in some cases the measured value $\overline{P}_p$ is lower than calculated, which may be due to the dependence between the stages.

The measured value for selection loss $\overline{P}_s$ is also rather close to the value P_s calculated on a computer using Equations (2) through (14). We see also that the calculated value of P_s is only slightly higher than $F_T^{n-1}\ (a)$, that is, the internal blocking is low because the Pentaconta line-selection element has several selection alternatives if direct links are not free; for example, the common links, the interaid network, and reselection. In calculating P_s the congestion on the penultimate selectors is disregarded because it is part of the blocking on the group-selector-element outlets.

The interaid traffic is always low and constitutes only a few percent of the total traffic. This is a consequence of having common links for traffic to reach a given secondary section from two primary sections and to facilitate an efficient interaid. The calculated values of interaid traffic A_E agree with the measurements for a wide range of loads. The same is true for the simulated and calculated interaid rates. For high loads the measured interaid traffic is higher than calculated. In practice, the interaid traffic in line-selection elements will be lower than in simulation because of the many PBX groups.

Tables 1 and 3 show that with the changing number of primary sections and secondary selectors these tendencies are confirmed. From the simulations marked with an asterisk in Table 3, we see that the increase of interaid outlets per primary section from 10 to 12 does not reduce the blocking $\overline{P}_s$. This would suggest that the practical arrangement with 10 interaid outlets per primary section and the complete symmetry of the direct links is better than an improved accessibility for the interaid selectors with a less-regular direct-link layout.

In cases of overload the blocking values increase slowly as would be expected and there is no spreading congestion. With the increase of the total traffic the interaid traffic increases almost linearly as can be seen from Figure 4.

A dimensioning chart for line-selection elements derived from the simulation results is given in Figure 5.

4.2 Control-Circuit Simulation

The control circuit of the line-selection element was considered separately. Several configurations were simulated and the results presented in graphical form in Figures 6 through 9, and in tabulated form in Table 4,

Table 1 – Simulation results for a line-selection element with $K = 4 \div 6$ primary sections each with $Z = 2$ interaid selectors 10 K call finders and 10 K penultimate selectors. $M = 14$ secondary sections each with 74 outlets, and $T = 8 \div 12$ selectors, $nM = 1036$ subscribers per element. $A_o = A_T = 0{\cdot}5\,A$

Number of primary sections Number of secondary selectors	$K = 4$ $T = 8$			$K = 5$ $T = 10$			$K = 6$ $T = 12$		
Data									
Total traffic per 1036 subscribers in erlangs	33·0	39·0	44·0	48·0	56·0	63·0	66·0	75·0	86·0
Simulation results									
Number of calls simulated	360 000	240 000	180 000	360 000	240 000	180 000	360 000	240 000	180 000
Preselection loss $\overline{P}_p$	0·00169	0·00479	0·00832	0·00136	0·00420	0·00866	0·00137	0·00398	0·01133
± confidence interval I_p	±0·00019	±0·00050	±0·00059	±0·00023	±0·00046	±0·00081	±0·00018	±0·00052	±0·00097
Selection loss $\overline{P}_s$	0·00176	0·00492	0·00860	0·00140	0·00382	0·00817	0·00148	0·00425	0·01174
± confidence interval I_s	±0·00026	±0·00047	±0·00080	±0·00023	±0·00037	±0·00071	±0·00025	±0·00043	±0·00109
Interaid rate $= \overline{A}_{ET}/0{\cdot}5\,A$	0·019	0·035	0·048	0·032	0·053	0·074	0·049	0·075	0·0106
Interaid traffic in erlangs $\overline{A}_E$	0·31	0·68	1·05	0·77	1·49	2·35	1·62	2·83	4·66
Interaid traffic produced by originating calls $\overline{A}_{EO}$	0·00	0·00	0·00	0·00	0·01	0·02	0·00	0·01	0·09
Idem terminating calls $\overline{A}_{ET}$	0·31	0·68	1·05	0·77	1·48	2·33	1·62	2·82	4·57
Calculations									
Preselection loss P_p	0·00174	0·00448	0·00849	0·00143	0·00405	0·00883	0·00149	0·00406	0·01258
Selection loss P_s	0·00174	0·00452	0·00867	0·00144	0·00410	0·00878	0·00152	0·00414	0·01178
$F_T^{n-1}\ (a)$	0·00174	0·00450	0·00866	0·00143	0·00400	0·00827	0·00148	0·00389	0·00998
Interaid rate π	0·023	0·039	0·049	0·037	0·057	0·078	0·054	0·076	0·105
Interaid traffic in erlangs A_E	0·38	0·75	1·07	0·89	1·60	2·44	1·79	2·85	4·53

Table 2 – Simulation results for a line-selection element with $K = 7$ primary sections, $KC = 70$ call finders, $KS = 70$ penultimate selectors, $Z = 2$ interaid selectors per primary section, $M = 14$ secondary sections, $n = 74$ outlets per secondary section, $T = 14$ selectors per secondary section, $nM = 1036$ subscribers per element. $A_o = A_T = 0{\cdot}5\ A$

Data								
Total traffic per 1036 subscribers in erlangs	84·0	92·0	98·0	102·6	106·8	110·4	114·6	117·6
Simulation results								
Number of calls simulated	360 000	120 000	120 000	100 000	80 000	60 000	40 000	20 000
Preselection loss $\overline{P}_p$	0·00145	0·00309	0·00653	0·00863	0·01374	0·01734	0·02612	0·03546
± confidence interval I_p	±0·00026	±0·00059	±0·00080	±0·00173	±0·00214	±0·00326	±0·00559	±0·00289
Selection loss $\overline{P}_s$	0·00167	0·00374	0·00680	0·01005	0·01225	0·01925	0·02632	0·03372
± confidence interval I_s	±0·00028	±0·00048	±0·00116	±0·00159	±0·00226	±0·00163	±0·00509	± 0·00342
Interaid rate $= \overline{A}_{ET}/0{\cdot}5\ A$	0·061	0·084	0·101	0·115	0·119	0·135	0·143	0·148
Interaid traffic in erlangs $\overline{A}_E$	2·57	3·89	4·98	6·00	6·55	7·71	8·65	9·35
Interaid traffic produced by originating calls $\overline{A}_{EO}$	0·00	0·01	0·05	0·12	0·20	0·27	0·45	0·64
Idem terminating calls $\overline{A}_{ET}$	2·57	3·88	4·93	5·88	6·35	7·44	8·20	8·71
Calculations								
Preselection loss P_p	0·00135	0·00312	0·00573	0·00912	0·01384	0·01952	0·02848	0·03657
Selection loss P_s	0·00141	0 00322	0·00569	0·00864	0·01253	0·01710	0·02426	0·03078
$F_T^{n\text{-}1}\ (a)$	0·00134	0·00290	0·00483	0·00686	0·00923	0·01168	0·01508	0·01788
Interaid rate π	0·069	0·086	0·100	0·111	0·121	0·130	0·140	0·148
Interaid traffic in erlangs A_E	2·88	3·96	4·90	5·69	6·42	7·17	8·03	8·68

Table 3 – Simulation results for a line-selection element with $K = 8 \div 11$ primary sections, $Z = 3$ interaid selectors, $M = 14$ secondary sections each with 74 outlets and $T = 16 \div 22$ selectors, $nM = 1036$ subscribers per element. * marks a case where $D = 40$ and $E = 12$. In all the other cases the number of levels allowed for direct links $D = 42$ and interaid $E = 10$

Number of primary sections / Number of secondary selectors	$K = 8$, $T = 16$		$K = 9$, $T = 18$		$K = 10$, $T = 20$			$K = 11$, $T = 22$		
Number of call finders	$KC = 80$	$KC = 72$	$KC = 90$	$KC = 81$	$KC = 90$	$KC = 100$	$KC = 100$	$KC = 99$	$KC = 110$	$KC = 110$
Number of penultimate selectors	$KS = 72$	$KS = 80$	$KS = 81$	$KS = 90$	$KS = 100$	$KS = 90$	$KS = 90$*	$KS = 110$	$KS = 99$	$KS = 99$*
Data										
Total traffic per 1036 subscribers in erlangs	113·7	129·7	131.0	134·1	150·1	168·7	150·2	166·6	173·3	162·1
Originating traffic in erlangs A_o	57·1	64·6	68·5	67·1	69·9	86·7	75·1	76·9	87·2	81·1
Terminating traffic in erlangs A_T	56·6	65·1	62·5	67·0	80·2	82·0	75·1	89·7	86·1	81·4
Simulation results										
Number of calls simulated	280 000	200 000	340 000	320 000	340 000	300 000	320 000	320 000	320 000	320 000
Preselection loss $\overline{P}_p$	0·00354	0·04164	0·00371	0·01272	0·00403	0·01873	0·00243	0·00306	0·00333	0·00106
± confidence interval I_p	±0·00060	±0·00320	±0·00551	±0·00153	±0·00079	±0·00193	±0·00042	±0·00070	±0·00066	±0·00027
Selection loss $\overline{P}_s$	0·00348	0·01081	0·00266	0·00316	0·00222	0·00985	0·00295	0·00148	0·00264	0·00141
± confidence interval I_s	±0·00031	±0·00012	±0·00033	±0·00033	±0·00028	±0·00078	±0·00039	±0·00028	±0·00044	±0·00024
Interaid rate $= \overline{A}_{ET}/A_T$	0·103	0·156	0·111	0·134	0·128	0·177	0·155	0·131	0·140	0·144
Interaid traffic in erlangs $\overline{A}_E$	5·85	11·13	6·97	9·00	10·24	14·59	11·69	11·84	12·15	11·73
Interaid traffic produced by originating calls $\overline{A}_{EO}$	0·04	0·98	0·02	0·03	0·01	0·07	0·07	0·10	0·13	0·00
Idem terminating calls A_{ET}	5·81	10·15	6·95	8·97	10·23	14·52	11·62	11·74	12·02	11·73
Calculations										
Preselection loss P_p	0·00385	0·04664	0·00418	0·01479	0·00478	0·02222		0·00123	0·02248	
Selection loss P_s	0·00327	0·01069	0·00240	0·00309	0·00209	0·00765		0·00144	0·00232	
$F_T^{n\text{-}1}\ (a)$	0·00309	0·00937	0·00221	0·00279	0·00178	0·00596		0·00116	0·00186	
Interaid rate π	0·103	0·137	0·109	0·115	0·117	0·149		0·119	0·129	
Interaid traffic in erlangs A_E	5·85	8·94	6·82	7·70	9·36	12·20		10·68	11·15	

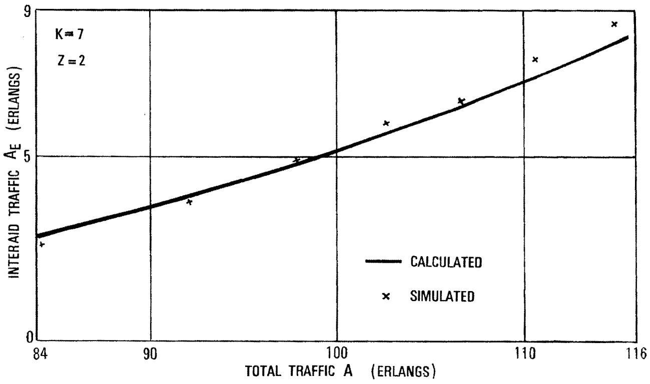


Figure 4 - Comparison of calculated and simulated interaid traffic.

correspond to simulations made on a control-circuit model used in a line-selection element equipped for high traffic. This model with 11 primary sections, 2 markers, 2 sets of marking relays, and points where queues can form, is shown in Figure 10.

The model neglects the influence on the circuits of the waiting time for the information path, as the average waiting time is low compared with the holding time of the circuits. (10 milliseconds as opposed to 100 and 400 milliseconds for the information path and marker, respectively). The preselection calls originate from 1036 subscribers and so it is assumed that Poissonian traffic is offered to all primary sections from a common queue with a random order of service. The selection calls are originated by a large group of registers and therefore the selection traffic is also assumed to be Poissonian and offered to each section from an individual queue with a random order of service. Every call has to seize one of two possible sets of marking relays through the primary sections and markers. The set of marking relays to be seized is determined for each call by its origin; from the point of view of the control circuits, the choice can also be considered random.

A call first seizes a primary section during a constant time S_1, then asks for a marker which it occupies during a constant time S_2 and finally asks for the marking relay which it occupies during a constant time S_3. At the end of this time S_3 it releases quasi-simultaneously the three units: the primary section, the marker, and the relay.

The model operates in a slightly different way depending whether the calls are selection or preselection calls. These differences concern,

— the value of the holding times S_1, S_2, and S_3,
— the priorities in front of the primary sections; the selection calls having the higher level of priority, and
— the method of seizing the primary sections,
— a selection call waits in front of a predetermined primary section. A preselection call can seize any section but only 2 preselection calls can simultaneously seize the section, 1 call asking for 1 set of marking relays, and the other call asking for the other set of marking relays.

The program was written in *GPSS3* general-purpose simulation language well adapted to waiting problems; realtime models can be described easily and exact hunting rules and queuing priorities can also be included without difficulty.

Several traffic values (number of calls per hour) were simulated. In each simulation run 100 000 calls were simulated, preceded by a transient sample of 5000 calls. The measurements were performed separately for preselection and selection calls, which follow different queuing disciplines. For each category of calls the simulation gave histograms and averages for total waiting times.

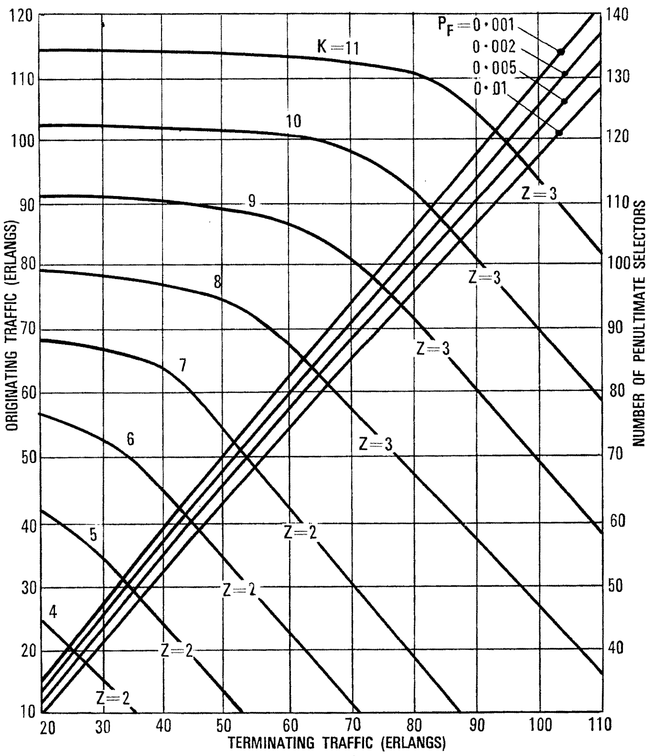


Figure 5 - Dimensioning of line-selection elements for loss probabilities in line selection and in preselection of 0·01
K = number of primary sections
Z = number of interaid selectors
P_F = Erlang-loss probability on penultimate selectors.

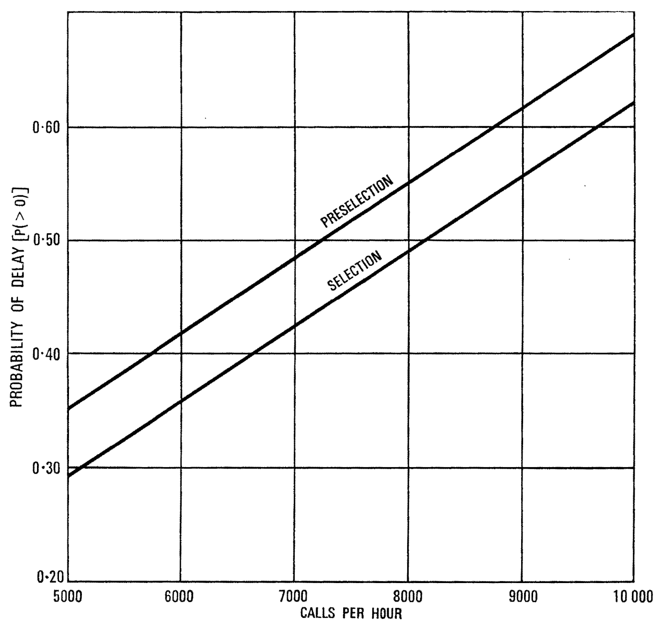


Figure 6 - Probability of delay.

Table 4 – Control circuits: results of simulations

	Selection $S_1 = 80$ ms, $S_2 = 110$ ms, $S_3 = 300$ ms					Preselection $S_1 = 305$ ms, $S_2 = 600$ ms, $S_3 = 300$ ms				
Traffic (number of calls per hour)	5000	6000	7000	8000	10 000	5000	6000	7000	8000	10 000
Mean waiting time (milliseconds)	69·8	89	114	141	225	142·8	191·6	250	323·8	578·3
Probability (%) that the waiting time in milliseconds is equal to, or less than,										
0	70·7	64·4	58	51·8	38·3	65	57·5	50·8	44	29·5
300	92·8	90·6	87·7	84·5	74·7	82·6	77·3	72·5	67·1	52·6
600	98·3	97·4	96·2	94·6	89·5	92·6	89·7	86·1	82	69·9
900	99·7	99·4	98·9	98·3	95·4	97·1	95·3	92·9	90	80·2
1200	99·9	99·9	99·6	99·3	97·8	98·4	97·3	95·6	93·6	86
1500	100	100	99·8	99·7	98·8	99·3	98·6	97·4	96	89·8
1800			99·9	99·9	99·3	99·5	99·2	98·3	97·3	92·3
2100			100	100	99·6	99·8	99·5	99	98·1	94·1
2400					99·8	99·8	99·7	99·3	98·6	95·4
2700					99·8	99·9	99·8	99·5	99	96·4
3000					99·8	100	99·9	99·7	99·3	97·1

The results were printed out after each 10 000 calls so that confidence intervals could be estimated using the Student test; their order of magnitude is 1 to 2 percent of the waiting time. In cases where only a few calls wait more than a certain time, the accuracy of the results is lower.

The performance criteria are:

— preselection: the total probability of waiting for the dial tone more than 3 seconds is lower than, or equal to, $1{\cdot}5 \times 10^{-2}$, and

— selection: the probability of waiting more than 2 seconds is lower than, or equal to, 10^{-3}.

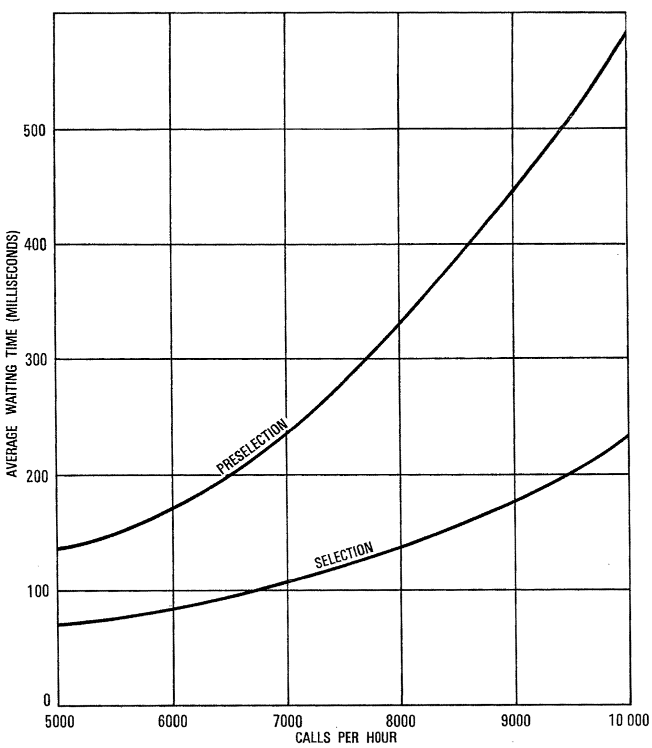


Figure 7 - Average waiting time.

The latter criterion has been chosen, taking into account a register timing-out with the double aim of good traffic performance and efficient use of control circuits.

The simulation results show that the above criteria are fulfilled for practical traffic of 5000 to 7000 calls per hour. For a higher number, the performance does not decrease rapidly and some overload can still be handled with an acceptable grade of service.

Although a theoretical study has not been made, some comments can be made to improve the understanding of the operation and to facilitate interpolations or extrapolations of the results. Let us consider, separately, selection calls and preselection calls.

4.2.1 Selection Calls

The presence of primary sections has little effect on the delay probability and the mean waiting time.

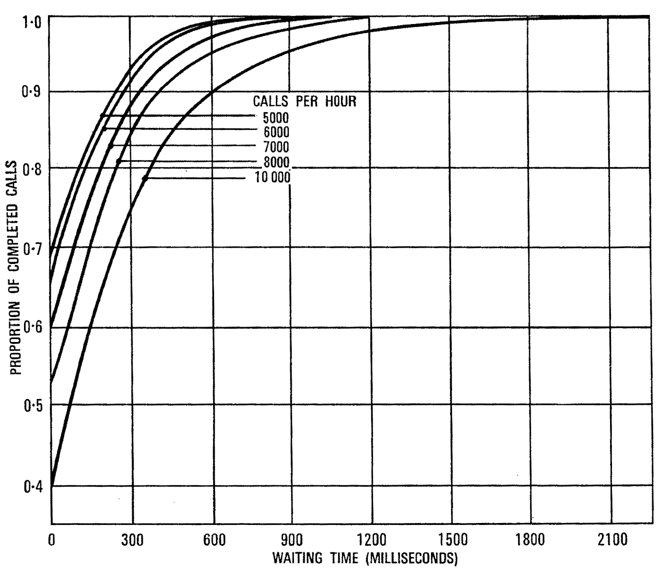


Figure 8 - Waiting time during selection.

It has been verified by simulations that results do not vary much with the number of primary sections. Only in special conditions will the number of primary sections affect the system: a selection call must be immediately preceded by another call using the same section, or separated from this call by a very small number of calls. Even in these cases, the effect may be small. A third call, arriving later, may seize the marker and the relay instead of the selection call delayed by the primary sections. As a general rule, the existence of the primary sections does not increase the total call delay in the system. If a call waits for a period of time in front of the section, it will wait a shorter time in front of the other stages.

As a first approximation, the primary sections are not considered so only the markers and relays remain. The estimation of the line-selection delay probability in this simplified model can then be stated as follows.

$$P'_s = \frac{S_2 + 2S_3}{3v} \tag{18}$$

where v is the mean interarrival time of calls.

Taking into account the total traffic this formula agrees with the results of simulation.

It will be noticed that the formula giving the mean waiting time for a single server agrees with the results,

$$t_w = \left(\frac{S_2}{2}\right)\left(\frac{P'_s}{1-P'_s}\right). \tag{19}$$

But for the time being, this formula is empirical and has to be used with caution.

4.2.2 Preselection Calls

While the existence of the primary sections has little effect on the processing of selection calls, the presence of the sections has some effect on preselection calls, but their exact number has very little effect because only two preselection calls can be handled simultaneously by the sections.

As a first approximation, let us neglect the selection calls. The model can then be compared to 2 independent chains each made up of a primary section, a marker, and a marking relay. The well-known waiting formulas for a single server with constant holding time $S_1+S_2+S_3$, handling a quarter of the traffic, can then be used.
The delay probability P'_p is then,

$$P'_p = \frac{S_1 + S_2 + S_3}{4v} \tag{20}$$

and the mean waiting time is,

$$t_{Wp} = \left(\frac{S_1 + S_2 + S_3}{2}\right)\left(\frac{P'_p}{1-P'_p}\right). \tag{21}$$

These formulas give only lower limits for the simulated model but results give a fairly good approximation for the delay probability.

5. Conclusions

The simulations of the speech-network and the control circuits of a Pentaconta line-selection element give experimental verification of the presently used dimensioning methods.

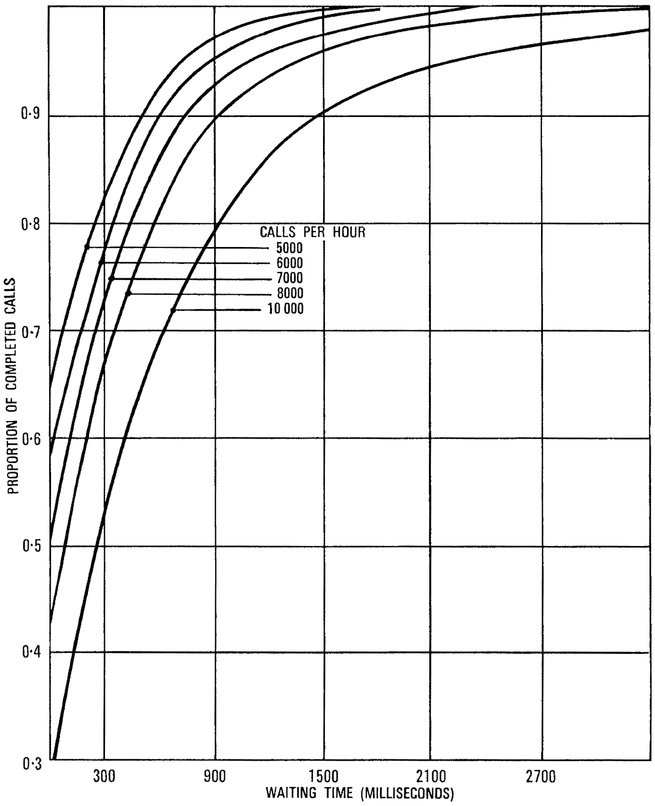


Figure 9 - Waiting time during preselection.

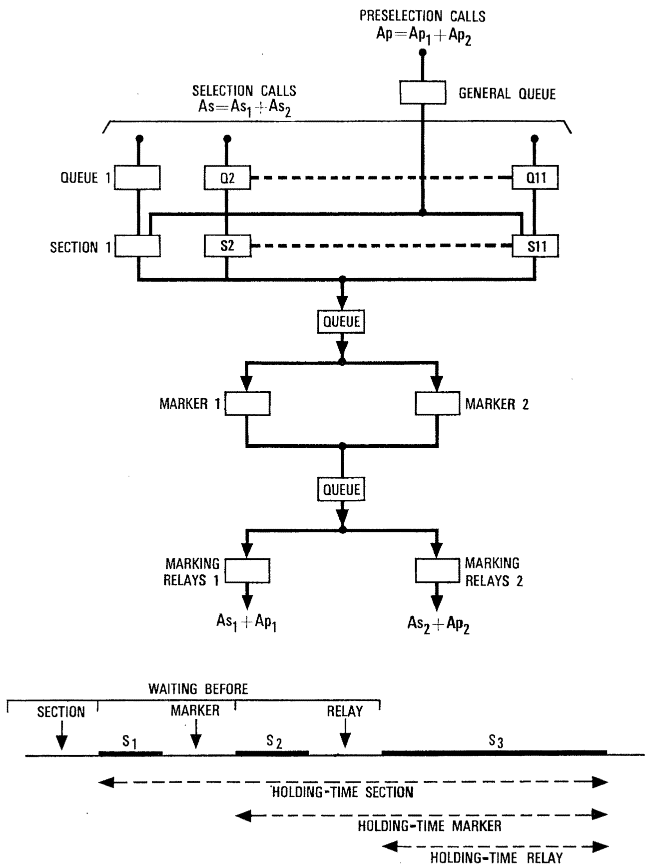


Figure 10 - Model of the control circuit.

The calculations of blocking for the speech path have proved to be fairly accurate for normal congestion. The different errors which may result from approximations and the assumed independence between the stages do not impair the calculations which are sufficient for engineering purposes.

For the control circuit, the simulations confirmed that the design of a complex waiting system can be aided by the approximate calculation of average waiting times and the delay probability, but it is impossible to calculate the waiting-time distribution and so it is preferable to simulate such systems.

6. Acknowledgments

The authors express their gratitude to Mr Canceill for his help and many stimulating discussions, and to Mr Guerrero of ITTLS who prepared the program for the simulation of the speech path.

References

[1] B. Canceill, Gutierrez, D.: Entraide Networks Combined with Link Systems, Electrical Communication, volume 42, no 3, 1967.
[2] P. Le Gall: Les calculs d'organes dans les centraux téléphoniques automatiques modernes, Edition Revue d'Optique, Paris, 1959.
[3] C. Y. Lee: Analysis of switching networks, Bell System Technical Journal, volume 34, no 6, 1956.

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The GH 210 Data Communication System

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1. Introduction

For a data communication system to be efficient some method of correcting transmission errors is necessary [1]. The degree of error control will depend upon the class of transmission system and the type of data to be transmitted. In designing a system this aspect must assume a major importance and so it was one of our first considerations in the development of the *GH 210* medium-speed data communication system.

2. Design Philosophy

A program began in 1959 to find the nature of errors on switched and leased telephone circuits operating at speeds up to 1200 bits per second.

A significant factor to emerge from the tests was that error distribution was more important than error rate. Random errors, even at high rates, require a relatively simple technique to give adequate protection. However, it was found that errors occur in "bursts" and so it was necessary to find a more-sophisticated protection against this particular type of error pattern. Information theory led us to the conclusion that the most suitable method of applying error control to bulk-data transfers is on a block basis.

For any given method of error control there has to be a compromise between a high degree of error protection and a large amount of redundant information on the one hand, and a low degree of error protection but high data-transmission efficiency on the other [2, 3]. It was necessary, therefore, to formulate a method which used the principles of block transmission combined with an adequate method of error control.

The possibility of using forward-correcting codes on telephone circuits was rejected due to the high redundancy required and the tendency for a system without a large storage capacity to saturate in the presence of considerable noise. Consequently, the now widely accepted idea of error correction by block retransmission was evolved.

Important considerations for determining system parameters were the type of protective code to be used, the method of identifying blocks, the block length, and the method of calling for retransmission.

2.1 Protective Code

Early results showed that the use of a simple character-parity bit was insufficient as it would detect only 80 percent of all line errors. The addition of a parity character at the end of each block of data gave some improvement. Although this method of error detection further improved with increased block length, yet it did not provide an optimum solution in terms of information-transfer efficiency.

A more powerful type of iterative code, found in the cyclic codes, was now considered. Based on the theory of polynomials it can be constructed to give an almost 100-percent protection with a minimum of redundant information. This type of code can also be designed to cater for different types of noise pattern and can generally be optimized for the type of transmission system used. If necessary, the amount of protection can be raised by a small increase in redundancy. We found that a 12-bit polynomial gives the necessary protection over a large range of block sizes up to a maximum of approximately 1000 bits.

2.2 Block Identification Method

The problem of losing data because of line interference in either the forward or backward transmission paths was next considered. To avoid this loss it is necessary to employ block numbering. Examination showed that there should always be at least one more block number in a cyclic-numbering system than there are blocks in a repetition cycle.

Since a three-block repetition cycle has been adopted, 4-block (or sequence) numbers are used. To achieve maximum security on these identification (or service) bits, they were included in the overall protective code and given a maximum Hamming distance by using *2-out-of-4* coding. In addition to the 4 sequence numbers used for information-block identification, an extra sequence number is used to identify synchronizing blocks.

2.3 Block Length

The choice of the most suitable block length for transmission purposes was influenced by the protective-code security, information-transfer efficiency, and the maximum transmission-path-loop delay of the system. The 12-bit protective code will cope with blocks of up to 1000 bits without serious deterioration in protection but there is a conflict of requirement between maximum information-transfer efficiency and the transmission of short bursts of data. In addition, the behavior of the system in the presence of noise must not result in a severe drop in efficiency.

This drop in efficiency could occur if error bursts occupied time intervals similar to the block length. A suitable compromise answer for the majority of these cases is a 240-bit information block which, with the addition of 4 service bits and 12 protective bits, forms a convenient block length of 256 bits.

When operating at 1200 bits per second, the 256-bit block gives a permissible loop delay of 213 milliseconds. This is adequate for all national and most international circuits, including transatlantic-cable circuits. In instances where single- or double-hop synchronous-satellite circuits are employed, the need to increase the block length to 976 bits has been recognized.

2.4 Method of Calling for Retransmission

Any reliable error-correction technique requires a retransmission facility. The concept of using a backward-channel technique at 75 bauds for this purpose has long

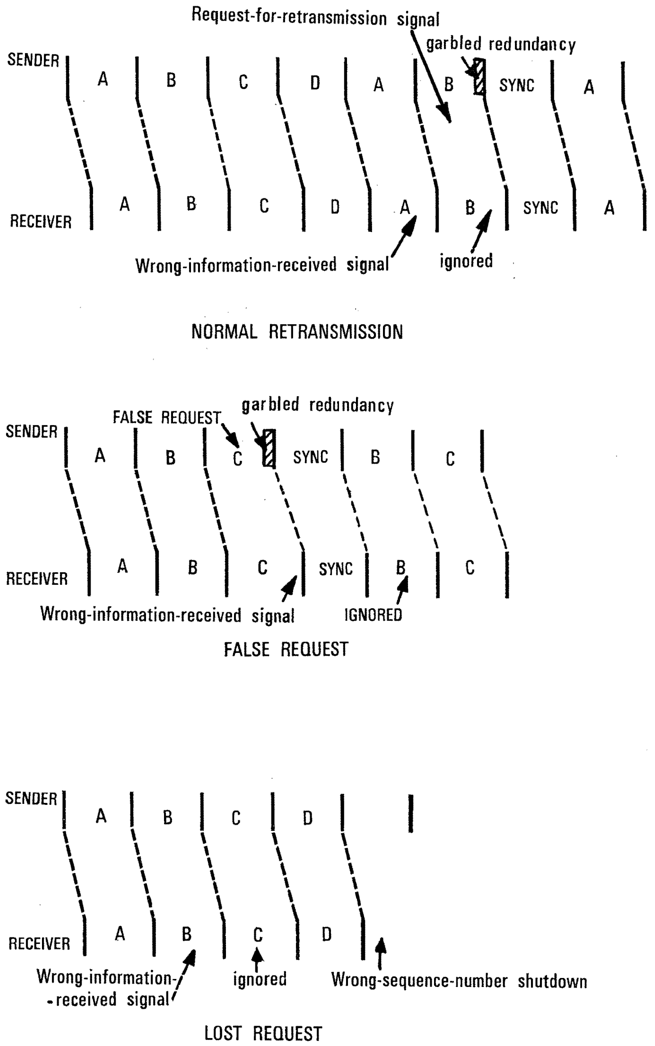

Figure 1 - Three simple cases of error control.

been considered the most suitable method of achieving a high information-transfer rate. It requires three effective conditions: *proceed, repeat,* and *wait.*

It is possible to achieve all three conditions with a very simple procedure on a 2-state channel and the *GH 210* system is designed to use a steady binary *0* as the *proceed* signal. The *repeat* signal is a 60-millisecond pulse of binary *1*, whilst the *wait* condition consists of successive *repeat* signals. Any interruption of the steady *0* condition is interpreted as a request to stop transmission, bearing in mind that the modem rest condition recognized by the CCITT is a steady *1*. The three most straightforward cases of error control are shown in Figure 1. They are:

— *Normal retransmission.* The second block, *A*, is received in error. A request for retransmission is sent on the 75-baud channel arriving at the sender while block *B* is being transmitted. The redundancy pattern of block *B* is deliberately garbled, and this block is ignored by the receiver. A synchronizing block is then transmitted followed by the expected block whose sequence number is *A*.

— *False request.* Certain types of line interference cause a false request for transmission as shown occurring during block *C* in Figure 1. The redundancy pattern is again deliberately garbled and rejected by the receiver. The sender terminal completes its normal retransmission cycle which results in block *B* being correctly received for a second time. If the receiver is expecting block sequence number n but correctly receives a block whose sequence is $n-1$ it ignores this block, knowing it has already been received and sent on to the peripheral equipment.

— *Lost request.* This is an extremely rare condition, and is detected, as shown in Figure 1, by the receiver detecting a correctly received block whose sequence number is $n+1$ or $n+2$ where n is the expected sequence number.

3. Parameters

Using the fundamental design parameters now defined, the earlier *GH 205* equipment [4] was built and widely installed. Line trials over loop circuits with a high line attenuation confirmed the ability of the system to perform satisfactorily over circuits which, in some instances, were not even acceptable for speech. The results of these tests on the public telephone network revealed an undetected-error rate of less than one character in 50 million.

Tests have also been performed on satellite circuits to demonstrate the ability of longer block lengths to cater for increased loop delays.

With the advent of micrologic and the resultant size-and-cost reductions, the *GH 210* system was designed using the basic philosophy outlined and expanded to provide greater flexibility.

The equipment has the following broad design parameters:

— compatibility with existing *GH 205* installations,
— basically a send/receive terminal,
— use of integrated circuits wherever possible,
— small physical size, and
— extended facilities such as long-loop delay working, automatic answering, and operation in conjunction with synchronous and nonsynchronous modems at speeds up to 4800 bits per second.

The *GH 210* logic is divided into three parts: *Error Detection* and *Correction, Store,* and *Peripheral.* To permit greater flexibility and ease for future adaptations an electrical and mechanical interface exists between each of these parts as illustrated in Figure 2.

In the input mode, characters which may comprise 5, 6, 7, and 8 bits are fed in parallel to a buffer register. The information is then transferred serially across the peripheral store interface at the rate of 38 000 bits per second.

In the output mode, information is transferred serially from the store at 38 000 bits per second to the buffer service which outputs 5-, 6-, 7-, or 8-bit parallel characters to the peripheral device, but only when the peripheral equipment is ready to accept the information.

4. Equipment

4.1 *Error Detection and Correction*

In the error-detection-and-correction section, there are two main paths: *information* and *control.*

In the sending mode, information to be transmitted is received at the interface to the store section and then fed to the data combiner, the transmission control, and the redundancy generator which adds the redundancy bits to the end of each block. Blocks are preceded by a sequence number from a sequence-number generator and the sequence is timed by three units, the block-control circuit, an oscillator, and the synchronizing generator. At the same time information from the transmission control is fed to the transmitted-data modem interface and the modem interface control operates in response to signals from the manual controls and alarms.

In the receiving mode, the information from the modem is fed to the reception control and from there to the store interface, the redundancy checker, and the sequence-number checker. All data are stored and their validity signaled across the interface to the store section.

4.1.1 Automatic Answering

This facility is not essential but an adjunct to the error-detection-and-correction section. Two logic boards provide the facility and can be replaced by dummy boards if it is not required. Automatic answering operates when a terminal is switched to *auto*. It will always answer in the receive mode and will expect one of the following signals:

— *Synchronizing blocks.* In this case the paper-punch equipment will be switched on and reception of data will proceed as in the manual case.

— *A reversal instruction.* In this case the auto terminal will disconnect the receive modem, connect the send modem, and then feed in a block of data and send synchronizing blocks to the calling station.

It follows that in both cases the calling terminal must first connect the send modem to the line to transmit either synchronizing blocks (mode select switch at *send*) or the reversal instruction (mode select switch at *receive*). In the latter case the auto-answer logic detects that the auto station has switched over its modems and so it disconnects the send modem and connects the receive modem to the calling station. These "handshake" procedures are all performed automatically.

Having dialed the call, the operator need only fix the required setting on the mode-select switch and operate the action key from *speech* to *data*. There is no operational difference between calling a manual station and an auto station.

At the end of a transmission, the auto station will revert to the receive mode for 20 seconds. In this state it can receive a further message, or, if the tape reader has been reloaded, send another message. Thus a *GH 210* outstation may be left in the auto mode, loaded with

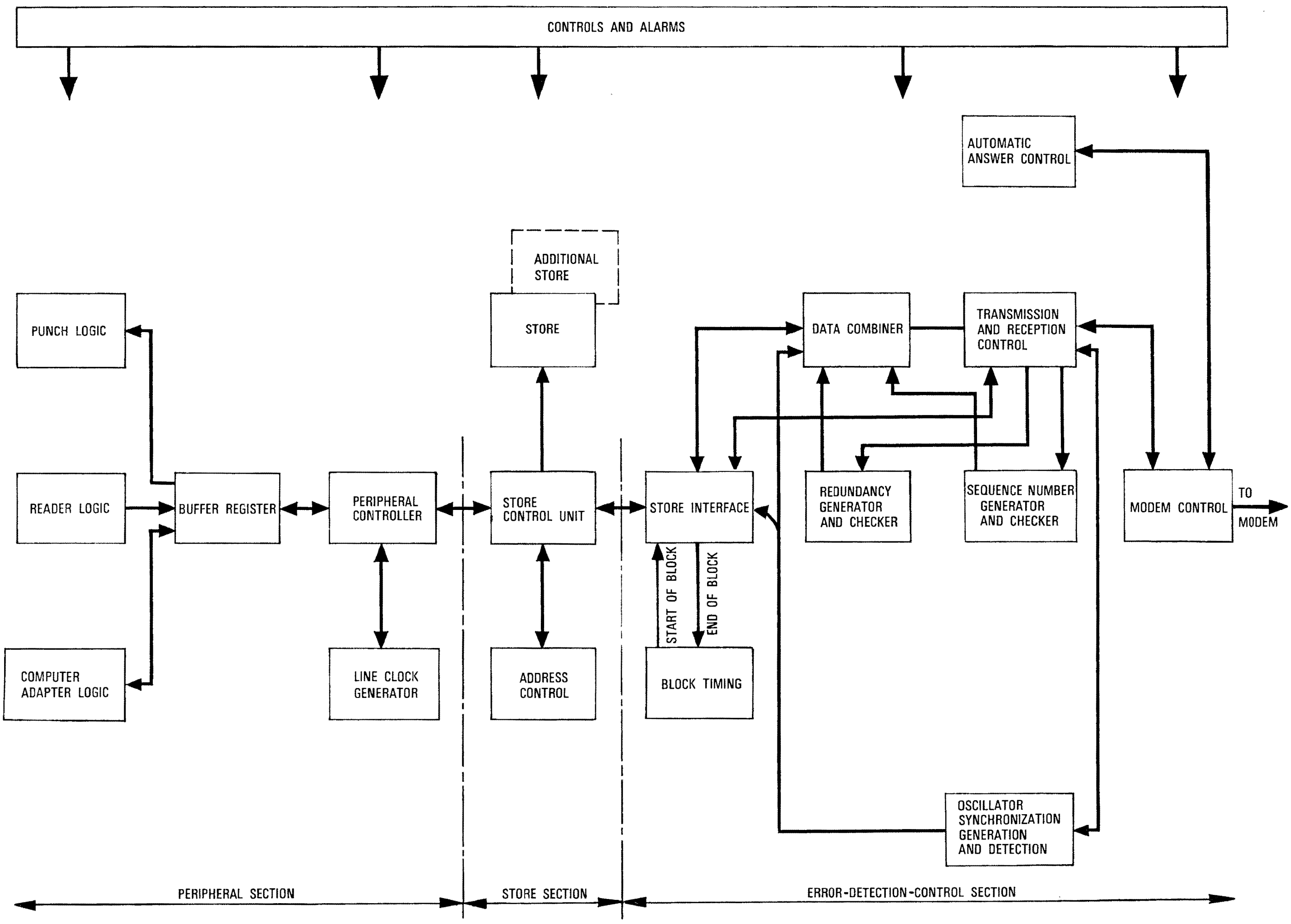

Figure 2 - The *GH 210* system block diagram.

input data, without the outstation operator needing to answer the telephone at all.

4.2 Store

A store section consists of a 16 × 32 ferrite-core matrix, pulse generators, and switches. There are two 240-bit counters one of which controls the high-speed data transfers to and from the peripheral buffer register, while the other controls the data transfers to and from the error-detection-and-correction section at the medium-speed line bit-rate. The line counter always has priority for access to the store.

One store unit permits transmission over circuits with loop delays up to 426 milliseconds at 600 bits per second. The further addition of up-to-three identical store units will allow a maximum loop delay of 1628 milliseconds at 600 bits per second. This latter figure is adequate for double-hop synchronous-satellite working.

4.3 Peripheral Section

The peripheral section controls the input and output of data to and from the peripheral devices. These devices can be varied to suit a customer's requirements. The standard equipment is able, by changing plug-in boards, to accept different combinations of reader or paper-punch equipment. Add-on features permit the connection of a 40-character-per-second printer or a 300-line-per-minute printer.

This latter facility includes horizontal-format control, which permits any character in the printer's repertoire (including space) to be repeated up to 196 times by means of a 5-character-format control code so saving line time especially on open-print formants.

5. Main Control Panel

5.1 Mode-Select Switch

The mode-select switch allows four modes of operation to be selected. They are as follows:

— *Auto* (automatic answering only). The switch must be set to this position if the terminal is to answer calls automatically. No other control is active when the terminal is in the auto mode. The speed of transmission in this mode is set to 600 bauds but can be altered to 800 bauds if required.

— *Receive*. There are two speeds of operation, normal (600 bauds) and fast (800 bauds). When working to a manual terminal the transmission rate must be agreed with the distant operator. This will normally be on *fast* but poor line conditions could mean a reversion to *slow*. When working to an automatic unattended answering terminal the switch must be set to *slow*. When the character-length selection switch is set to positions 5 or 6, the speed setting of the mode-select switch is immaterial since data are always transmitted at 600 bauds.

— *Send*. The remarks made for the receive mode also apply to this mode.

— *Copy*. Information is copied from the paper-tape reader on to the punch at an average speed of 71 characters per second.

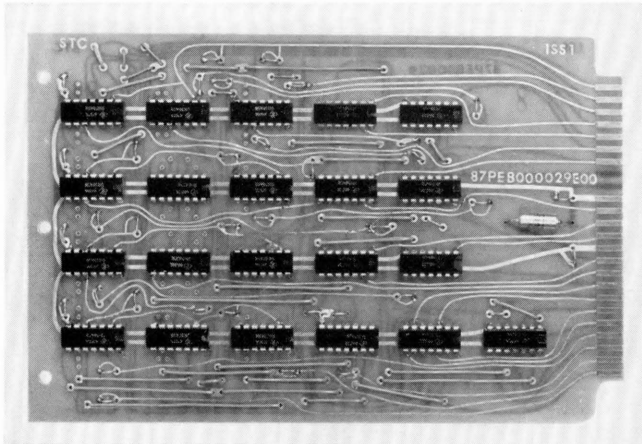

Figure 3 - A typical double-sided, plug-in, printed-circuit board.

The act of switching from one mode to the other with the power switched on generates an automatic reset condition to the logic.

5.2 Action Key

Having set the mode-select switch the action key is used to control the passage of data and manual modes. It has three locking positions:

— *Speech*. With the key in this position the terminal is always off-line and will not be connected to the external lines and will not transmit, receive, or copy data.

— *Data*. The terminal will transmit, receive, or copy data when the key is set from *speech* to *data*. Thus, if the power is switched on with the key in the data position, the terminal can be activated only by resetting the key to *speech* and then to *data*.

— *Wait*. The terminal will remain on-line, but will hold up transmission or copying if the key is moved from the data position to the wait position. If the power is switched on with the key at *wait* the terminal will remain off-line.

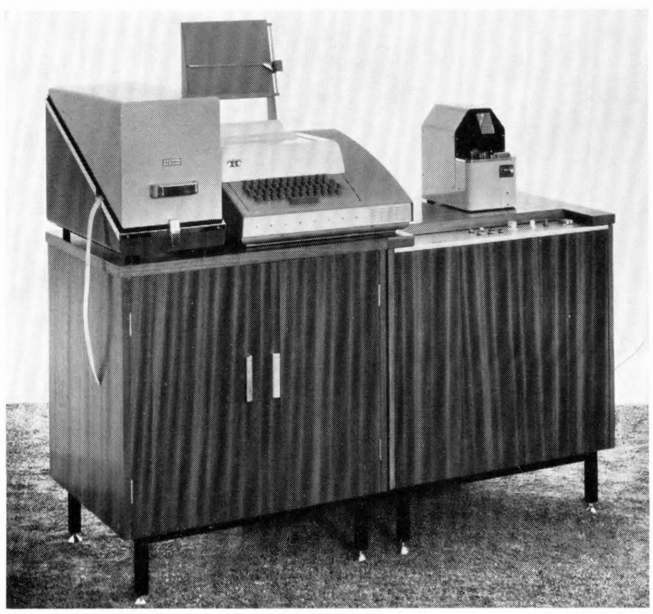

Figure 4 - The *GH 210* data communication terminal equipment.

5.3 Runout Key

This non-locking key has two purposes:

— With the action key set to *speech* or *wait*, it will cause the paper-punch to start up and to output blank tape.

— With the action key at *data* or *auto* it will reset the audible alarm.

5.4 Lamps

Six lamps are provided to enable operators to monitor the progress of a transmission.

— *Data set ready (green).* This lamp lights when the terminal is connected to the external telephone line. It will light when the action key is switched from *speech* to *data*, and will remain alight for the entire duration of the connection.

— *Carrier fail (red).* It is extinguished as soon as a remote terminal goes on-line, but it does not indicate that the two terminals have synchronized.

— *Wait (white).* This lamp is lit continuously when either terminal goes to *wait*. At a send terminal it is also lit when the distant (receive) terminal is unsynchronized.

— *Tape low (amber).* This lamp is lit when the low-tape contacts in the paper-punch are operated, indicating that only about 100 feet (30 meters) of tape remains. The audible alarm is also sounded. Transmission of data is unaffected, as this alarm is intended only as a warning.

— *Parity alarm (red).* This lamp is lit only when a parity error has been discovered on the input tape, and is activated only with the parity key set to *odd* or *even*. Transmission ceases and the audible alarm sounds.

— *Wrong-sequence number (red).* This lamp is lit only when the terminal in the receive mode discovers that one or more blocks have been lost in transmission. Transmission ceases and the audible alarm sounds. This condition only occurs if a request for retransmission is lost due to extremely poor line conditions.

6. Auxiliary Control Panel

6.1 Parity Key

This has three locking positions.

— *Odd parity.* Data from the reader are examined to ensure that all characters have an odd number of bits. The logic can be strapped to ignore parity on blank or another single even-parity code tape, so a mixed tape (for example, odd parity interspersed with blanks) can be transmitted.

— *No parity.* No input data are checked.

— *Even parity.* Data from the reader are examined to ensure that all characters have an even number of bits.

6.2 Character-Length Selection Switch

This switch selects the number of channels read from the paper-tape reader. It is essential that the settings of both send and receive terminals are identical.

6.3 Audible Alarm

This will sound if the operator's attention is required, when the action key is in the data position. The alarm may be cut off by restoring the data key to *speech* or *wait* or by momentarily operating the runout key. The intensity of the alarm may be adjusted.

7. Mechanical Design

The *GH 210* mechanical design places emphasis on the following points.

— *Cabinet design.* It has been designed as a free-standing plinth unit, complete with drop-over polished wood cabinet that has a removable front and top panels for easy access. It measures 19·5-inches (50-centimeters) deep, 26·75-inches (68-centimeters) wide, 29·5-inches (75-centimeters) high and has adjustable legs.

— *Internal layout.* The logic is mounted in two subracks hung between side plates which are themselves attached to the plinth unit. The power supply is located beneath the logic. The control panel and interface panel connections for incoming and outgoing cords are fixed to the top of the side plates. The whole equipment is built, wired, and tested before the cabinet is fitted.

— *Equipment boards.* The ferrite store, all micrologic, and discrete components are mounted on double-sided fiber-glass printed-circuit boards measuring 7 inches (17·8 centimeters) by 4·7 inches (12 centimeters) on 0·6 inch (1·5-centimeter) pitch, with 48-way edge connections.

Up to 24 dual-in-line micrologic packages can be mounted on a board giving, typically, 50 logic functions.

— *Back wiring.* The majority of the wiring between board connectors has been achieved by $^{1}/_{32}$-inch (0·8-millimeter) double-sided fiber-glass printed-circuit boards. This feature provides economy of construction and ease of maintenance.

8. Applications

The *GH 210* data communication system is expected to find a market in large areas of industrial communications where the fast, accurate, and unattended transmission of data is required. These areas will include electricity-generating authorities, chemical-refining plants, airlines, and general intercomputer communications. This modestly-priced equipment, whilst performing a complex technical function, can be installed as part of an office-suite furnishing.

References

[1] Stuttard, E. B.: Data Communication 1967, Industrial Electronics, August 1967.
[2] Peterson, W. W.: Error Correcting Codes, MIT Press and John Wiley & Sons.
[3] Wright, E. P. G.: Error Rates and Error Distribution on Data Transmitted Telephone Connections, IERE Symposium on Data Transmission, London, 1960.
[4] Bloch, C.: GH 205 and GH 206 Medium-Speed Data Systems, Electrical Communication, volume 42, number 3, pp 350—356, 1967.

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Portable Single-Sideband High-Frequency Transceiver with Military Applications

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1. Introduction

The *TR-TM 4* radio-communication transceiver is a low-power (10 to 15 watts) fully transistorized single-sideband high-frequency set, designed to replace conventional amplitude-modulated high-frequency sets in military applications.

It provides tactical communication over short and medium distances, 20 to 50 kilometers (12·4 to 31 miles), where the terrain would interrupt very-high-frequency frequency-modulated communication. Furthermore, the particular properties of short-wave propagation permit long-distance communication under favorable conditions over ranges of 1000 to 2000 kilometers (621 to 1242 miles).

We selected the single-sideband mode of transmission *A3J* because of its advantages over double-sideband modulation *A3*.

These are:

- economy of bandwidth (bandwidth halved),
- low-power consumption (the average power transmitted for the same range is one-sixth of that needed with *A3* modulation),
- better immunity against jamming and distortion from indirect propagation,
- better signal-to-noise ratio, and
- increased radio silence (zero emission in the absence of modulation and reduced carrier-level fluctuations with modulation level).

On the other hand, carrier-suppressed single-sideband modulation requires the transmitter and receiver oscillators to be extremely stable, since it is essential that the equipment be simple to operate and for an operator to be able to establish communication immediately, even in a net of several parties. This requirement is met with a frequency synthesizer producing, for each of the 10 000 channels, a signal with a frequency drift one order less than the 20 to 30 hertz generally tolerated for single-sideband radio-telephone communication.

The smallness of this drift means that direct voice-frequency telegraphy (Coquelet system) can be used without manual adjustment.

Summarizing, the features we gave this set for use by non-specialized personnel are:

- ease of operation,
- mechanical ruggedness, reliability, and capability of withstanding environmental extremes,
- high-frequency stability and accuracy,
- light weight and small volume,
- easy maintenance,
- multi-purpose operational facilities with good electrical performance, and
- compatibility with earlier-generation equipment.

Development, which started in 1955, made use of experience gained in the field of single-sideband communication and applied the latest technology, using components such as power transistors, ferrite cores, printed circuits and high-stability glass-encapsulated oscillator crystals.

The first prototype contract, awarded in 1960, was followed by seven years' of experimentation on 36 prototypes, of which 8 were delivered to the US Army Signal Corps, and 23 (of which 7 were of an airborne type) to the French Military Forces. This set is now in quantity production for the latter.

The rapid technological progress made during these seven years provoked many technical modifications during development. The inclusion of these modifications was made easier by the modular construction of the transceiver.

2. General Characteristics

2.1 Equipment Types

2.1.1 Portable Set

The portable set consists of,

- a portable *ER-94* transceiver in a single man-pack to be carried on the back of a soldier,
- a power supply (a 12-ampere-hour battery or a crank generator with a 3-ampere-hour buffer battery), and
- normal operating accessories (a handset, a portable 5-meter antenna, a keyer unit, et cetera).

The power supply and the accessories form a second man-pack.

The complete portable equipment, with generator and buffer battery, is illustrated in Figure 1.

2.1.2 Vehicle-Mounted Set

The vehicle-mounted set consists of,

- an *ER-94* transceiver,
- a shockproof mounting,
- a vehicle-mounted junction box, and

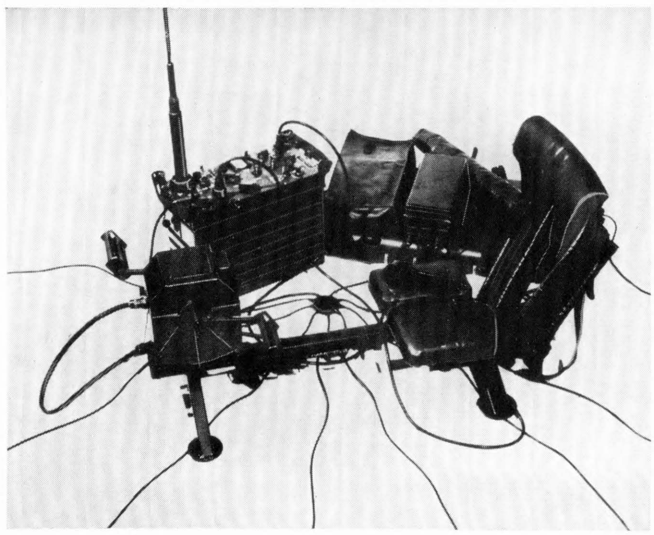

Figure 1 - Portable equipment with generator and buffer battery.

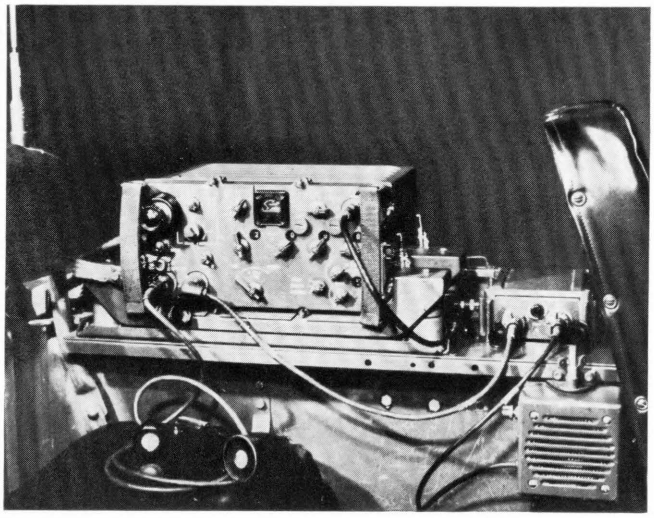

Figure 2 - Vehicular version.

— antenna accessories (antenna and feeder), and operating accessories (keyer, handset, headset, loudspeaker, et cetera).

The complete vehicle-mounted version is shown in Figure 2 and the front panel of the transceiver in Figure 3.

2.1.3 *Other Versions*

Prototypes of other versions have been developed, as follows,

— a special Navy version, operating from a 115-volt alternating-current supply, and

— a remote-controlled version, with a 100-watt power amplifier, for helicopter installation in accordance with specifications for airborne equipment.

This version of the transceiver makes use of all the units of the *ER-94* equipment, but the front panel is replaced by a special sub-assembly containing the remote-control unit. The 100-watt amplifier contains a vacuum tube and is connected to a remote-controlled, adjustable-inductance, antenna-coupling unit.

2.2 *Main Technical Characteristics*

The guaranteed main performance characteristics of the equipment are as follows.

Frequency range:	2 to 12 megahertz, 10 000 channels with 1-kilohertz separation.
Operating modes:	**A 3 J** (upper sideband), **A 3 H** (single-sideband transmission with restored carrier), **A 3** (reception), **A 1** (wideband and narrow band), **F 1** (with an adaptor). The narrow-band **A 1** mode has an automatic break-in facility.
Frequency stability:	short-term $\pm 5 \times 10^{-7}$, from —40 to +55 degrees Celsius and for supply voltages varying from 20 to 30 volts.
Power output:	10 to 15 watts peak envelope power, or continuous wave into 50 ohms; intermodulation better than — 25 decibels (CCIR test with two modulating signals); carrier suppresion in **A 3 J** mode, 40 decibels down.
Voice bandwidth:	400 to 3000 hertz in the **A 3 J** mode (upper sideband and suppressed carrier).
Voice output level:	50 milliwatts (portable version); 500 milliwatts (vehicle-mounted version).
Receiver sensitivity:	in the **A 3 J** mode, 1 microvolt for $\frac{S+N}{N} > 10$ decibels, and in the narrow-band **A 1** mode, 1 microvolt for $\frac{S+N}{N} > 20$ decibels.
Receiver selectivity:	image-frequency attenuation, 70 decibels; desensitization less than 3 decibels for an interfering signal of 3 volts at 8 percent ± 30 kilohertz from the carrier frequency; cross-modulation less than 10 percent distortion produced by an interfering signal of 3 volts at 4 percent ± 20 kilohertz from the carrier frequency.
Dimensions and weight:	transceiver volume, 15 liters; transceiver weight, 13·5 kilograms (29 pounds).
Operating duration:	20 hours for the portable version, assuming 10 percent transmission and 90 percent reception (with the 12-ampere-hour battery).
Environmental conditions:	temperature, —40 to +55 degrees Celsius; humidity, 95 percent at 55 degrees Celsius (unit open); vibration, 6 *g* at 55 hertz without shock-absorbers; drop test, six drops from a height of 1·2 meters (4 feet) on the six sides without affecting performance; water-tightness, 2 hours under 1 meter (3·3 feet) of water; proof against sand and salt spray.

3. Circuit Description

3.1 *Radio-frequency Circuit Tuning*

The highest-to-lowest frequency ratio was one of the first difficulties met in development. Whatever the tuning principle chosen (adjustable inductors or capacitors, or adjustable-capacitance diodes), it was necessary to switch 5 or 6 subranges as tuned elements cannot cover a frequency ratio of 6 in a single band.

It is not always possible to do band switching with diode gates, especially for receiver input circuits, where they would cause excessive cross-modulation in the presence of high-level jamming at frequencies close to the wanted signal.

For these reasons, the band switching uses selectors operated by the manual megahertz control. The subranges then correspond to integer numbers of megahertz, as shown in Table 1.

The oscillator frequency is offset by 1 megahertz from the selected frequency. This offset corresponds to the 1-megahertz intermediate frequency used in the set.

The frequency ratio, which never exceeds 1·5 for any band, is obtained by variometers with adjustable-core coils. The latter, because of their small size and weight, were preferred to adjustable capacitors.

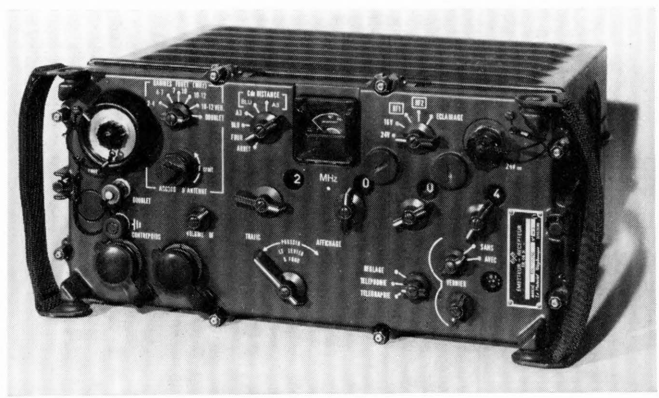

Figure 3 - Front panel.

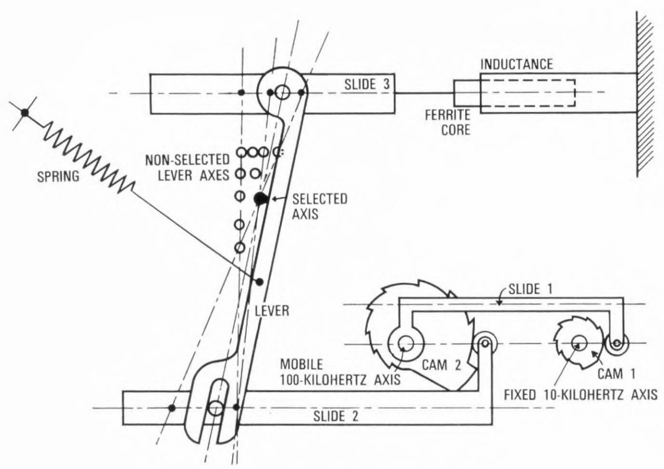

Figure 4 - Digital/analog mechanical principle.

Tuning within a given band could have been done with adjustable-capacitance diodes (varactors). Although, this solution seemed attractive because of their small size, it was not used because varactors are not suited to transmitter circuits with high-level radio-frequency signals, and electronic tuning of the oscillator over a wide frequency range would have reduced the signal-to-noise ratio (by increasing the oscillator noise) thus making telephony more difficult.

For these reasons, all circuits are mechanically tuned by adjusting the positions of ferrite cores inside coils wound with a varying pitch to give a linear relationship between core position and frequency [1].

It should be emphasized that, because of the narrow band of the preselector filter, the circuit in the receiver must be tuned with an overall accuracy of 0·7 percent of the selected frequency, this tolerance including any frequency-drift due to temperature changes.

This degree of accuracy is achieved by making the adjustments to the tuning coils linear to within 0·1 percent and allowing a frequency tolerance of approximately 0·26 percent for mechanical-position errors of the cores which have a total excursion of 19 millimeters (0·75 inch).

To ensure that the set has good operational performance in practice, even when used by inexperienced operators, the operating procedures were simplified as much as possible. To avoid any manual tuning of precision circuits, such as the oscillator or the receiver, the selection of the operating frequency automatically effects all other tuning operations.

Table 1 – Subrange frequencies and ratios

Megahertz control position	Transmitter and receiver		Oscillator	
	Subrange frequency in megahertz	Ratio	Subrange frequency in megahertz	Ratio
2	2 to 3	1·5	3 to 4	1·33
3	3 to 4	1·33	4 to 6	1·5
4	4 to 6	1·5	4 to 6	1·5
5	4 to 6	1·5	6 to 9	1·5
6	6 to 8	1·33	6 to 9	1·5
7	6 to 8	1·33	6 to 9	1·5
8, 9, 10, 11	8 to 12	1·5	9 to 13	1·44

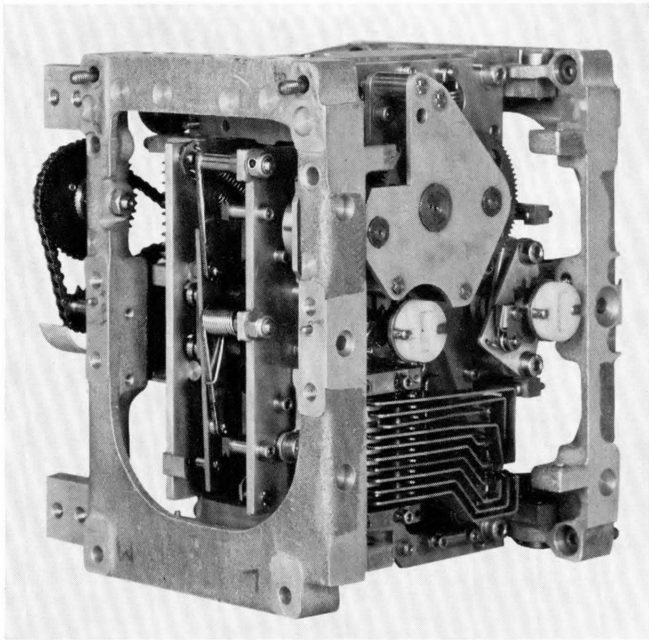

Figure 5 - Tuning mechanism.

Rather than use a servomechanism, which would have been complicated, bulky, and slow in operation, the selector controls were directly connected to the moving cores by a special mechanism which behaves as a digital-to-analog converter.

3.2 Tuning Mechanism

The mechanism is shown in Figure 4. The 100- and 10-kilohertz stepped cams have their radii added in slide 2 which causes the lever to move the transmitter- and receiver-coil cores to give a total change of 1 megahertz. In band *1* this means the whole of the core excursion of 19 millimeters (0·75 inch).

In bands *3*, *4*, and *5* the total core excursion must change the frequency by 2, 2, and 4 megahertz, respectively. The cams must then move the core by only the appropriate amount. In the case of band 5 this will be a quarter of the total distance, 4·75 millimeters (0·19 inch). The controlled movement of the cores over each megahertz step, and the displacement of the core to begin each step, is determined by the movement and displacement of the lever, respectively.

How much the lever moves and the sector over which it moves, is determined by the choice of 10 lever axes. When selecting a frequency, a special device, delayed by a mechanical damper, disengages the lever from the axes and the rollers from the cams to enable the controls to be moved freely. When the set is operating, the frequency selection controls are declutched to avoid accidental damage to the mechanism.

The assembly shown in Figure 5 comprises two sets of 10 selectable axes, 2 slides *3*, and 1 slide *2*, common to both sets of axes (refer again to Figure 4).

The 3 sub-assemblies controlled by the mechanism are directly mounted on it; in each sub-assembly, 2 or 3 circuits are simultaneously tuned by 2 common-control linkages.

3.3 Local Oscillator and Control-Loop

The 3- to 13-megahertz self-excited *LC* master oscillator is phase locked to a reference signal from the frequency synthesizer as shown in Figure 6.

The oscillator signal is analyzed by successive mixing and filtering with the harmonics and subharmonics of a frequency-divided signal from a 5-megahertz reference oscillator.

After the third stage of analysis, a 70- to 80-kilohertz signal is modulated by the 375- to 384-kilohertz output of an oscillator with 10 switchable crystals. This produces the first of two 455-kilohertz signals to be fed to the phase discriminator. The second 455-kilohertz comparison signal is obtained by modulating a 1-kilohertz-spaced 70- to 80-kilohertz spectrum from the last divider stage with 375- to 384-kilohertz output from the same switchable oscillator.

It would have been possible to do this phase comparison at a lower frequency say, 1 kilohertz, but this idea was rejected because of the bulk of low-frequency components, the difficulty in removing a 1-kilohertz residual signal from the phase discriminator, and the inability of the control loop, due to its low cut-off frequency, to correct for phase jitter caused by mechanical vibration.

The chosen method eliminates drift inherent to the auxiliary crystal oscillator and the kilohertz information is introduced by electronic switching of its 10 crystals. It is not necessary to interpolate between successive integer numbers of kilohertz when working two *TR-TM 4* equipments together, but for the purpose of providing compatibility with older single-sideband transceivers having poor frequency stability and requiring vernier adjustment, it can be arranged as follows.

The synthesized 455-kilohertz signal is replaced by a 455 ± 0·5-kilohertz signal produced by beating the output of a 5123-kilohertz crystal oscillator with the output of a 5578-kilohertz oscillator of the same design. The oscillator's frequencies can be varied in opposite directions with a varactor. The absolute drift of this beat signal is small if the individual drifts, due to temperature, of their AT-cut crystals are similar. This drift, however, is apparent in the output signal, as is the 375- to 384-kilohertz 10-crystal-oscillator drift, which is no longer corrected. Thus with interpolation, the output signal frequency may vary a few tens' of hertz some time after adjustment. This is still quite acceptable, since the set will be operating in net with sets of mediocre stability.

Under normal operating conditions, that is without interpolation, the frequency drift of the output signal, now phase controlled, is held within a few hertz of the selected frequency. The maximum error is 6 hertz at 12 megahertz under all conditions.

3.4 Phase Control

Phase-control lock-on and subsequent hold is effected by frequency sweep, frequency discrimination, and phase discrimination.

In spite of the accurate setting of the coil cores in the 3- to 13-megahertz oscillator, the frequency error can be 120 kilohertz at the top end of the frequency band in the absence of phase-control. In this extreme case, the frequency-analyzer circuit would be unable to feed any signal to the discriminators because of the intervening narrow-band filters. It is therefore necessary to sweep the oscillator frequency over a range corresponding to the maximum natural frequency error, positive or negative, so that the frequency is made to pass through the selected frequency. This frequency sweep is obtained by the relaxation of the direct-current amplifier which follows the frequency discriminator. Once phase-control has been established, the heavy negative feedback of the control

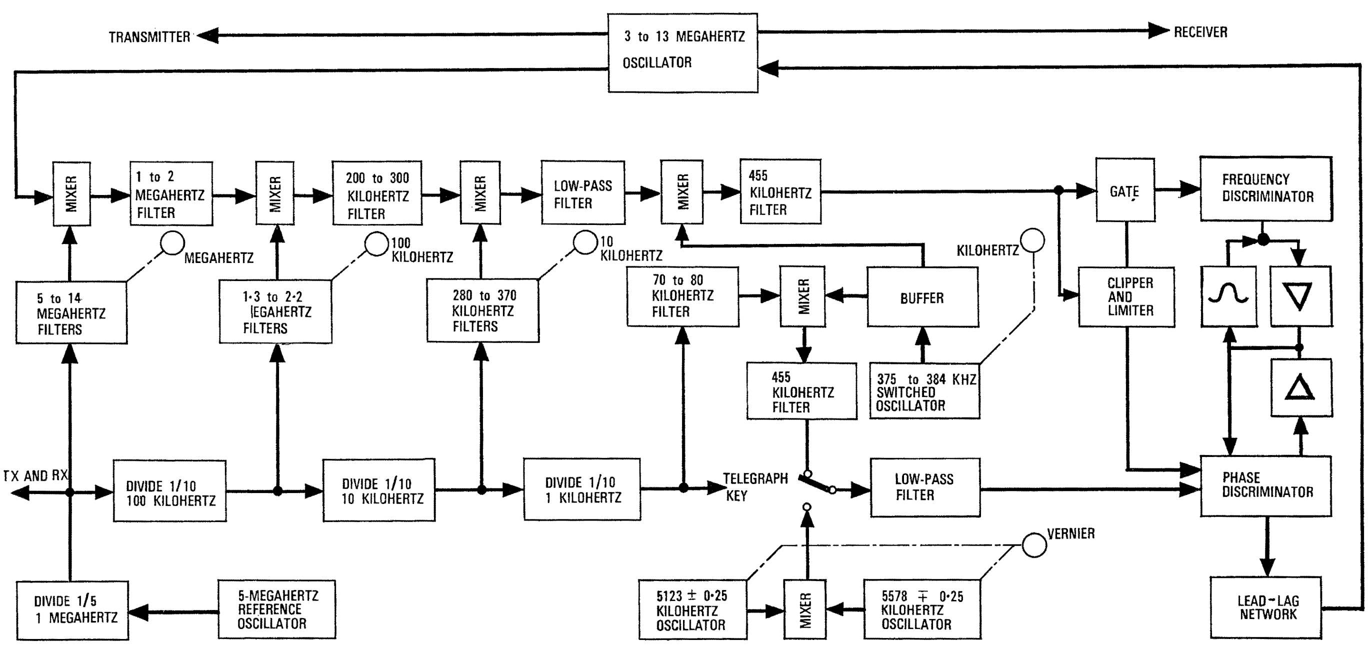

Figure 6 - Decadic master oscillator.

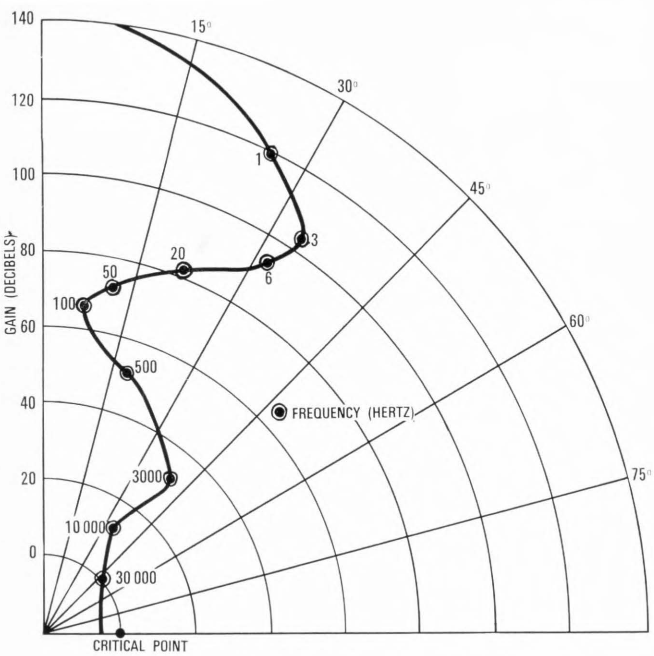

Figure 7 - Nyquist diagram for control loop.

loop quenches the relaxation and suppresses the frequency sweep.

The frequency discriminator is permanently connected and aids the phase discriminator by widening the frequency band over which effective control is maintained.

The phase discriminator produces two error signals. One is amplified in a high-gain long-time-constant direct-current amplifier. The amplified signal corrects the large, long-term frequency drift of the oscillator.

The second error signal is not amplified and corrects the small, short-term drifts of the oscillator frequency.

The final phase-control signal applied to the oscillator is the sum of the amplified error-signal from the frequency discriminator, the amplified, long-time-constant phase-error signal, and the unamplified, short-time-constant phase-error signal.

The phase-control signal is applied to the oscillator by a correcting network, which changes the amplitudes and phases of the individual signals as functions of the working frequency to achieve a stable control loop.

The frequency-response curve of the control loop is the Nyquist plot reproduced in Figure 7, showing that the cut-off frequency, corresponding to unity gain, is 35 kilohertz.

The frequency-discriminator error signal under normal locked-on operation is theoretically zero. In practice it is very small resulting only from the drift of its own circuits. On the other hand when the 3- to 13-megahertz oscillator is way off frequency, a large error-signal voltage pulls the oscillator frequency rapidly into the band where the phase discriminator can lock on. The frequency discriminator operates in the same way if a physical shock to the equipment causes the frequency to ride out of the band over which the phase discriminator can hold lock. In this case, the oscillator is rapidly brought back under phase-control before the slow frequency sweep is able to start and the interruption appears to the operator simply as a slight transient noise. This system is particularly efficient where the equipment is subject to heavy mechanical shocks.

The oscillator block diagram in Figure 6 shows a gate and clipping-and-limiting amplifier preceding the discriminators. Their purpose is to avoid locking onto low-level spurious signals produced by the modulators.

The image frequencies are attenuated by the band-pass filters of the analyzer circuits and prevented from disturbing the control loop.

The control loop enables an oscillator signal to be obtained with less than 0·012 radian (0·7 degree) of phase jitter over the whole frequency range.

3.5 Frequency Reference

The master oscillator is placed in a thermostatically controlled oven employing proportional control, and thermally insulated in a Dewar-flask enclosure. The crystal is of the *AT*-cut type and oscillates at 5 megahertz in the 3rd partial mode with a Q factor of more than 10^6 (see Figure 8).

The short-term frequency stability is better than 10^{-7}. The long-term frequency stability, which is a function of aging, has been measured and found to be of the order of 3×10^{-7} per year.

The equipment contains a simple device which enables the master oscillator to be recalibrated once a year by tuning into the international 2·5, 5, or 10-megahertz frequency-standard transmissions.

3.6 Transmitter and Receiver Circuits

To simplify the transceiver, which operates in the simplex mode only, some of its circuits are used in both transmission and reception. The common circuits are the oscillator, intermediate-frequency amplifier, crystal filter, preselector radio-frequency filter, demodulator, and low-frequency amplifier used for telegraph automatic break in.

The block diagram showing the interconnections between the various units is given in Figure 9.

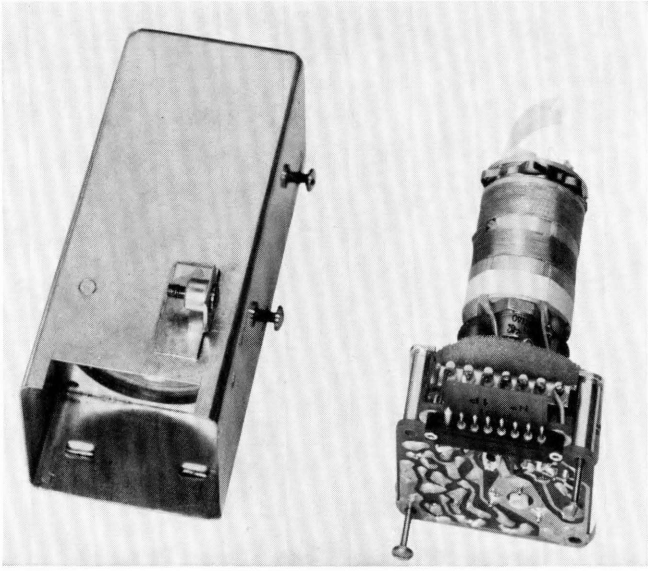

Figure 8 - Master oscillator.

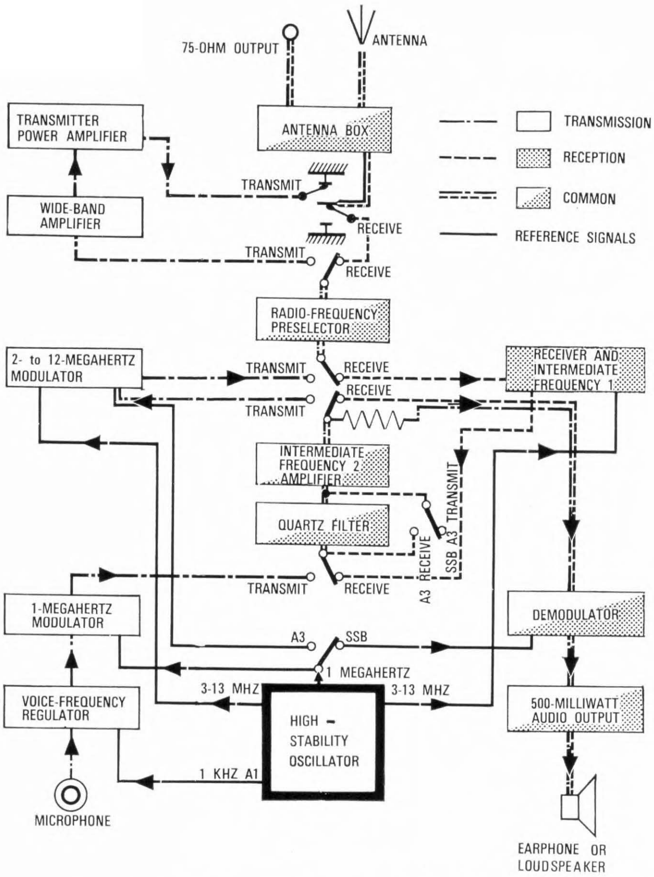

Figure 9 - TR-TM 4 block diagram. The oven for the high-stability oscillator and the transmitter power amplifier operate from a 24-volt source while all other units are fed 16 volts through a regulator.

Figure 10 shows the packaging of the subassemblies inside the set, seen from underneath with the cover off.

The receiver and transmitter face one another. They are connected to the remainder of the set by plug-in connectors.

The other circuits are mounted on plug-in, printed-circuit cards (labelled *A* to *T*) protected by insulating fiber-glass covers, as shown in Figure 11. After inspection and adjustment these cards are coated with a special varnish which firmly locks the components in place and protects the circuit from humidity.

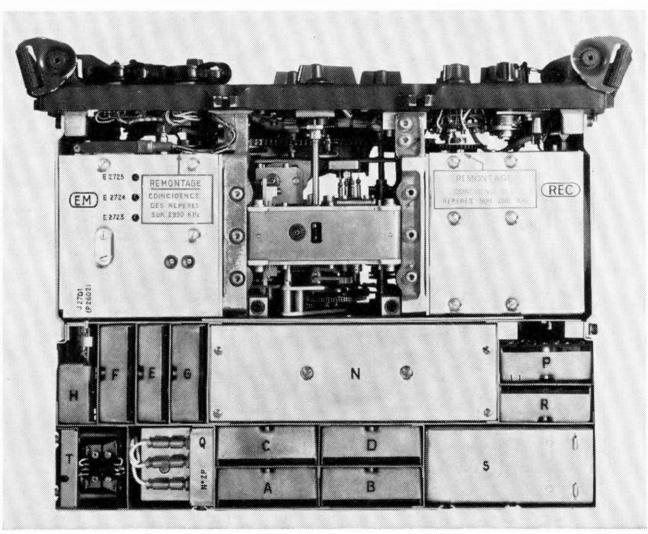

Figure 10 - Bottom view of set with cover off.

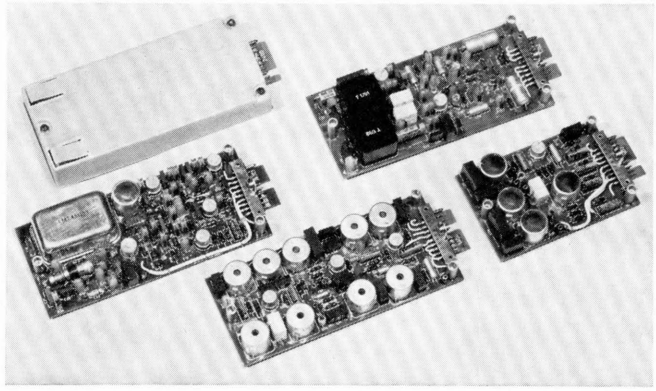

Figure 11 - Five printed-circuit cards with four of the covers removed.

The cards are provided with test points and have markings as an aid to maintenance.

The printed-circuit cards are housed in rectangular cells in the main frame, which provide screening.

The modular construction of the equipment is illustrated by Figure 12 which shows the equipment exploded into its subassemblies.

3.7 Receiver

The receiver is preceded by a preselector stage of 2 coupled tuned circuits, which form a highly selective filter protecting the input stage against cross-modulation caused by high-power jamming close to the operating frequency, and also against image-frequency interference (more than 70 decibels of attenuation).

This preselector is also used in transmission and the switchover is made by miniature relays to avoid cross-modulation.

When receiving at the top end of the frequency range, 11·999 megahertz, a 1-volt jamming signal, 200 kilohertz away from the working frequency, and connected to the

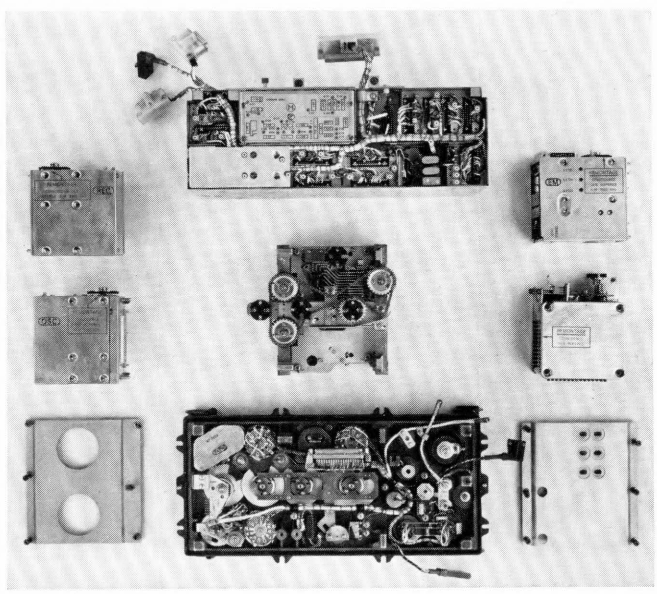

Figure 12 - Set exploded to show main units.

receiver input terminal, only slightly cross-modulates the useful signal. If the jamming signal level is 10 millivolts, the frequency offset can be reduced to 10 kilohertz. The receiver desensitizing and cross-modulation characteristics are given in Figures 13 and 14.

The receiver input stage, which uses a low-noise transistor, comprises a 3rd tuned circuit and is followed by a frequency-conversion stage, tuned to 1 megahertz by a filter consisting of 2 coupled circuits, and then by 2 stages of amplification. The latter stages also supply the automatic-gain-control voltage to the input stage.

This first intermediate-frequency amplifier is used as a filter in the compatible radio-telephone mode of operation. In the case of single-sideband radio telephony, or telegraphy, it is followed by a crystal filter of 2 Jaumann elements, each containing 4 crystals. Appropriate electronic switching for selecting the different operating modes (transmission, reception, *A3*, *SSB*, *A1*) is associated with this filter.

Because of the high gain concentrated in the single 1-megahertz intermediate frequency, it was necessary to split the intermediate-frequency amplifier into two sections separated by the crystal filter.

The automatic gain control of the first section of the intermediate-frequency amplifier (located in the receiver unit) is shared with the radio-frequency input stage. It is obtained by bias voltages applied to the transistors.

The second section of the intermediate-frequency amplifier has its own automatic-gain-control signal obtained from its output stage and acting on a diode attenuator connected to its input.

These automatic gain controls ensure satisfactory reception of input signals ranging from 1 microvolt to 100 millivolts.

The total gain of the receiver from the radio-frequency front end to the audio output is approximately 170 decibels of which 50 decibels compensate for filter and demodulation losses, leaving a useful overall gain of 120 decibels.

3.8 Transmitter Stages

The input to the transmitter is fed with a filtered 5-millivolt signal from the second modulator stage. A wide-band amplifier, mounted on a single printed-circuit card, raises the level of the signal to approximately 1 volt across 100 ohms. This output signal is fed directly to the transmitter unit, which consists of 2 tuned power-output stages producing 24 to 32 volts across a 50-ohm load (12 to 20 watts).

The power-output stage was initially designed to operate with a *2N1899* transistor, which has proved lasting qualities, but has certain limitations: it is nonlinear at high operating levels and has high collector capacitance varying considerably with I_c, low F_T, et cetera. With the progress which is continuously made in this area, it will be possible to replace this transistor with another type having higher performance as soon as reliability has been proved. Figure 15 shows typical intermodulation levels as a function of output power for transistor types *2N1899* and *BLY 40*.

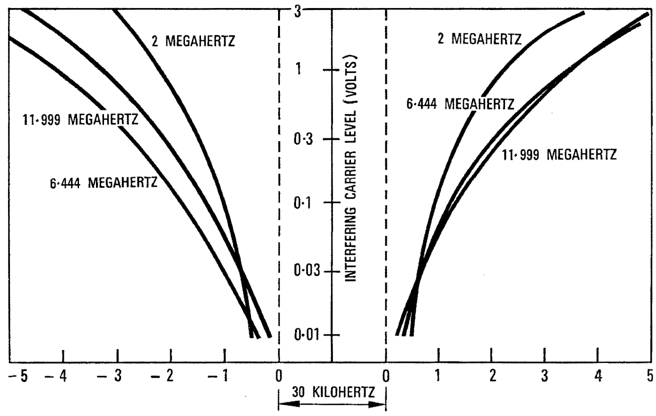

Figure 13 - Receiver desensitization limits.

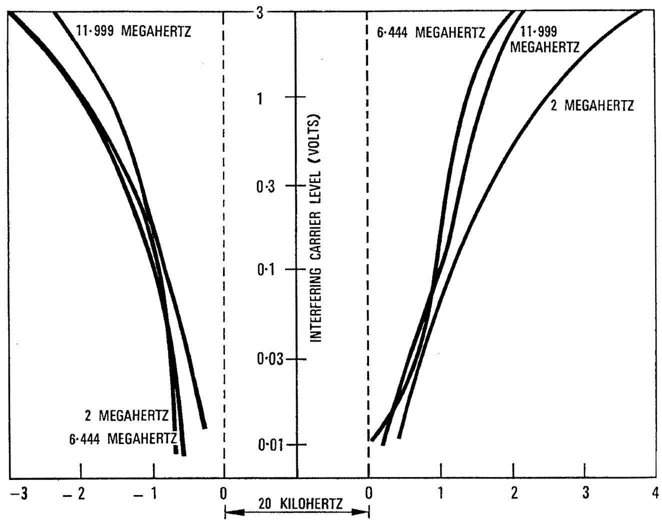

Figure 14 - Receiver cross-modulation limits.

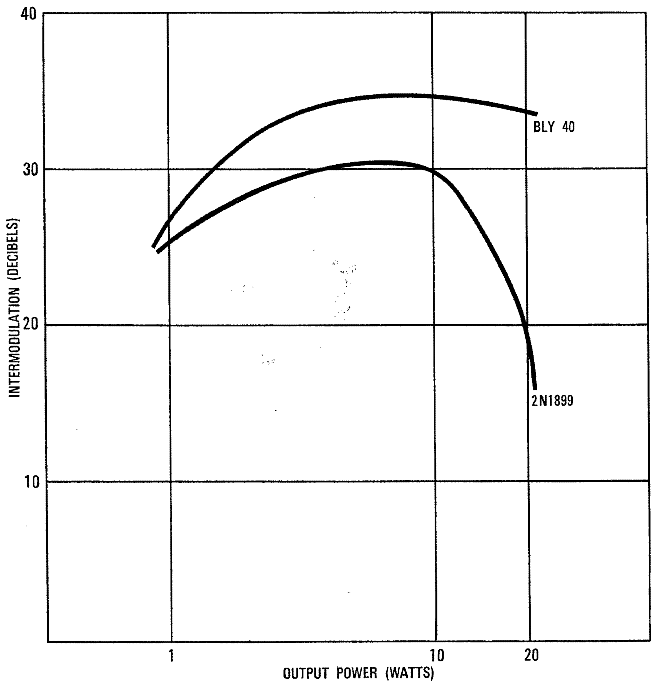

Figure 15 - Typical intermodulation curves plotted against output power for two transistors used in equipment. The CCIR 2-tone test was applied.

3.9 Antenna-Coupling Circuits

Both the portable and the vehicle-mounted versions use 3- to 5-meter whip antennas whose coupling circuits are in a subassembly that also contains the radio-frequency receive-transmit relay. Tuning may be adjusted by a control knob and the appropriate test meter.

The antennas, which are always capacitive in the 2- to 12-megahertz range, are matched by an *L*-shaped circuit, consisting of a shunt capacitor across the 50-ohm output of the transmitter, and an adjustable inductor in series with the antenna, both elements being switched for each band. Depending on the frequency, the efficiency of this circuit varies between 25 and 95 percent.

The restricted effective height of the antenna for the lower end of the frequency range requires the use of large matching inductors with losses. In addition, the high-frequency voltages after impedance matching reach 1200 volts at the output terminal. Referring to the figures given in Section 3.8, it is seen that at 2 megahertz, the total voltage gain between the wide-band amplifier input and the whip antenna terminal is a high as 240 000. For this reason, special precautions have been taken to ensure earth continuity and to avoid high-frequency re-injection by the accessory equipment, such as the handset, keyer, et cetera, when placed in the direct field of the antenna.

Long-wire and dipole antennas for sky-wave transmission are connected to the set via the 50-ohm outlet through a special antenna-coupling unit, which is used only for semi-permanent installations.

3.10 Filtering and Switching

The wide-band filters of the frequency analyzer circuits (see Section 3.3) are of the *LC* type, with the exception of the 455-kilohertz crystal filter.

Selection of the harmonics and subharmonics of the master frequency is by narrow-band ladder filters using 2 or 3 crystals. None of these filters requires special adjustment; they are stable in time and with temperature changes.

Separation of the required sideband at 1 megahertz is done with an 8-crystal Jaumann filter.

The various operating modes (*A3*, *A3H*, narrow-band *A1* and *A3J*) provided for compatibility with earlier-generation sets, require additional switching of various circuits. Diode-gates are used in all cases of low-level switching where cross-modulation is not a problem. In the preselector stage, and for receive-transmit switching, relays are used.

4. Technology

The equipment has approximately 2000 electrical components. Based on their individually assessed performance the overall calculated mean time between failures lies between 760 and 1700 hours, depending on environmental changes and the number of switching operations per hour. The guaranteed reliability corresponds to a minimum nominal mean time between failures of 400 hours.

The frequency-selection mechanism was subjected to 50 000 operations without noticeable deterioration of its accuracy.

The fully equipped printed-circuit cards are subjected to aging cycles before adjustment and final test to reduce the incidence of early failures. After adjustment and test, all subassemblies are subjected to the full individual temperature tests.

All these precautions, taken to ensure the required reliability from an equipment in which volume and weight preclude much circuit redundancy, have often led to outright rejection of solutions which would have been attractive, but are still too recent to be safe.

5. Accessory Equipment

The set uses conventional accessories, such as microphone, headset, whip antenna, et cetera, already in service with the various arms. Special cadmium-nickel batteries, capable of rapid charging have been developed (3 and 12 ampere-hour, 24 volts), together with automatic charging equipment. The operating duration with a 12-ampere-hour battery is approximately one day.

In the vehicle-mounted version, the set is powered from the 24-volt vehicle battery via a junction box, which protects the set against voltage surges and contains a 0·5-watt low-frequency amplifier to drive a loudspeaker.

A crank generator, with a 3-ampere-hour buffer battery, can also be used to obtain practically unlimited operating time, both on transmit and receive, when away from a maintenance base where batteries would be recharged.

6. Conclusions

The *TR-TM 4* transceiver suitable for either vehicle-mounting or man-pack, has as its major requirement simplicity of operation which led to the reduction of manual adjustment to an absolute minimum and the use of a mechanical method of tuning that has proved itself capable of achieving and holding the required accuracy in the high-frequency band.

The frequency stability guarantees simple operation when working in a communications net and provides for special telegraph operations.

The 50-kilometer ground-wave range, which exceeds that of portable or mobile very-high-frequency equipments, may be increased in the vehicle-mounted version by the addition of a 100-watt amplifier to cover areas inaccessible to very-high-frequency communications.

7. Acknowledgments

The authors wish to thank all those who have contributed to this development, in the Technical Branches of the French Army, the US Army Signal Corps, and also in the engineering and manufacturing departments of LMT, coordinated by Mr C. Loeffler.

References

[1] Kloepfer, W. et al: A Mobile Radio Equipment SEM 25, Electrical Communication, volume 42, N° 1, p. 62, 1967.

Jean-Jacques Muller was born in 1910 in Basel, Switzerland. He graduated in 1934 at Ecole Centrale des Arts et Manufactures in Paris, France. In 1936, he received the degree of Doctor in Technical Science from the Polytechnicum, Zurich, Switzerland, where he was engaged in research on magnetrons and development of early closed-circuit television systems.

He joined Le Matériel Téléphonique in 1940, became Chief Radio Engineer in 1947, and Technical Director in 1957. After working on the theory of klystron behavior and transmission-line distortion, he became responsible for the design of single-sideband high-power transmitters, radio links, military tactical radio, and various telecommunication systems.

He is a member of the Société Française des Électroniciens et Radio Électriciens and a Senior Member of IEEE.

J. Lisimaque was born in Paris in 1921. He obtained the diploma of physicist in 1942 from École Supérieure de Physique et de Chimie.

From 1943 to 1945 he was at C. Lorenz. He joined Laboratoire Central de Télécommunications in 1945 in the Transmitting Department and later transferred to Le Matériel Téléphonique, where he specialized in the manufacture of single-sideband transmitters and their associated receivers.

In 1955 he started work on synthesizers and mobile single-sideband equipments in the high-frequency band, and he is now project manager for the development of single-sideband portable and airborne equipment.

Mr Lisimaque is a member of the Société Française des Électroniciens et Radio-Électriciens.

Clamping Connector for Printed-Circuit Boards

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1. Introduction

Modern trends in electronic equipment design and maintenance impose increasingly severe requirements on connectors. The increase in component reliability and system sophistication demands a corresponding increase in connector reliability. At the same time for maintenance purposes there is a move towards large functional plug-in units. Such units have a large number of outlets which must be easy to disconnect.

In conventional connectors with a large number of pins easy disconnection implies a low contact pressure. Low contact pressure makes it necessary to use noble metals to obtain good contact.

By separating the functions of card insertion and contact pressure, and avoiding unnecessary miniaturization, high contact pressure can be used to give good contact without noble metals whilst at the same time making connector withdrawal and insertion easier.

Connectors of the type described in this paper are being applied to switching systems. A connector following similar principles is being manufactured by ITT Cannon Electric in the USA.

2. Principles of Contact Springs

The problem of designing springs for connector contacts can be examined generally as follows.

Suppose F_0 (Figure 1) to be the force sufficient for good contact. An infinite number of springs with different characteristics can provide this force; for example, there are the alternatives of a rigid spring with a small deflection d_1 or a more flexible spring with a relatively large deflection d_2.

To establish a criterion for the selection of springs, the following additional data are needed;

— the tolerances on nominal deflection value attainable with practical configurations, and

— the permissible variation of contact pressure.

Suppose Δd to be the spread resulting from the manufacturing process and ΔF the permissible spread of the contact force.

As shown in Figure 2, the spread Δd, acting in conjunction with the nominal deflection d_1 of the rigid spring, produces a large variation of force ΔF_1. The same spread applied to the nominal deflection of the more flexible spring produces a relatively small variation of force ΔF_2. Thus the best compromise between manufacturing tolerances and variations of contact pressure is provided by weak springs with large deflections.

Physically, the two springs, having the characteristics shown in Figure 2, differ from one another in the amount of mechanical energy stored in them to produce a force F_0. This energy is proportional to the area of the triangles contained between the response curve of each spring and the horizontal axis (Figure 3).

Thus, stored mechanical energy = mean force × displacement, or

$$W = \frac{1}{2} F_0 \, d. \tag{1}$$

Since $d = \frac{\Delta d}{\Delta F} F_0$ this value can be substituted for d in (1) to obtain,

$$W = \frac{1}{2} F_0^2 \frac{\Delta d}{\Delta F}. \tag{2}$$

From (2) the following conclusions may be drawn:

— the energy stored is inversely proportional to contact-force stability. Other things being equal the smaller the desired spread of force the greater the energy to be stored, and

— for a constant spread, the energy varies as the square of the nominal contact force.

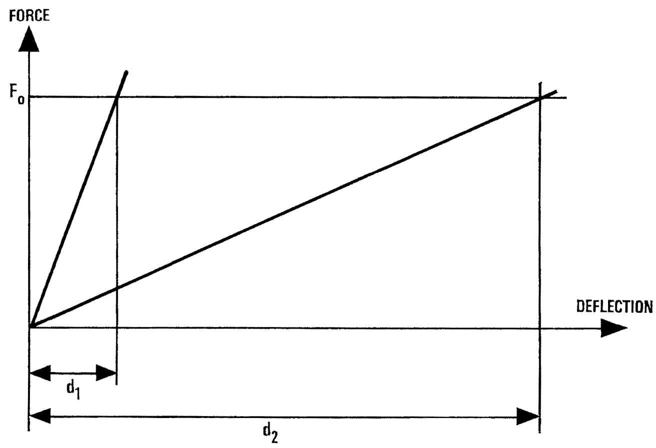


Figure 1 - Force *versus* deflection relationship for various types of springs.

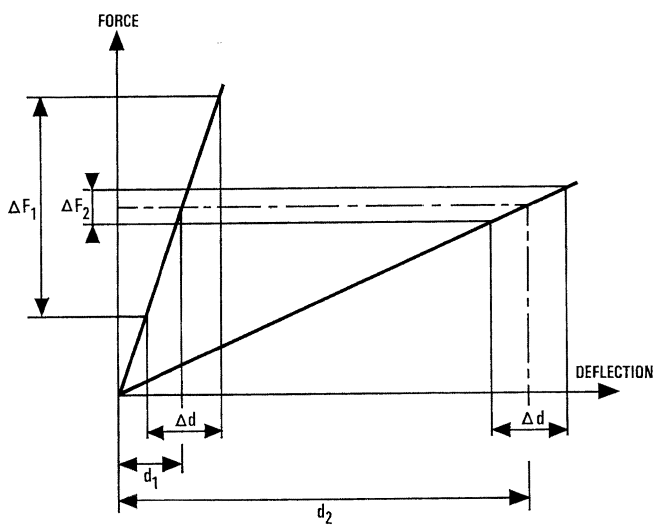


Figure 2 - Force spread *versus* deflection spread for various types of springs.

— large number of contacts. Four models are available, 50 and 66 terminals for single-sided printed-circuit boards and 100 and 132 terminals for double-sided printed-circuit boards. The 66- and 132-terminal types are shown in Figure 5,

— practically no plug-in force. After the card has been inserted the connector is clamped onto it by two cams, and

— a good compromise between quality and cost, since higher reliability is obtained without an increase in costs.

3.2 Description

Figure 6 shows the construction of the connector for double-sided boards. It consists of a female part only, the male part being provided by the printed-circuit board.

The essential elements are: two movable bars A carrying insulating members B: contacts C mounted on the insulating member at 2·54-millimeter (0·1 inch) pitch; springs D mounted between B and C. The two bars A can be moved towards or away from each other by screwdriver-operated cams at each end of the bars (these controls can be seen on Figure 5).

To insert a card, the cams are operated so that the two bars A are at their maximum distance apart. This leaves space between the two sets of contacts so that the card can be inserted with negligible pressure. After insertion, the cams are operated so that the bars A are at a minimum distance apart and this causes the contacts to be clamped onto the card.

To withdraw a card, the operations are reversed.

The connector has the following main features.

— Each connection is made by two independent contact points ($X\,X'$ on Figure 6).

— The helical springs D are pre-stressed as part of the connector assembly operation. Thus, even in the released condition, the springs are attempting to force the contacts C away from the insulator B but movement is prevented by the ledges E. In the clamped condition the contacts $X\,X'$ rest on the board and gaps appear at the ledges E. Thus in the clamped condition the springs have, in effect, a large deflection although the travel caused by operating the cams is small. Figure 7 shows how this provides with a small travel d a large force F relatively insensitive (small ΔF) to travel variations Δd within the limits of tolerance.

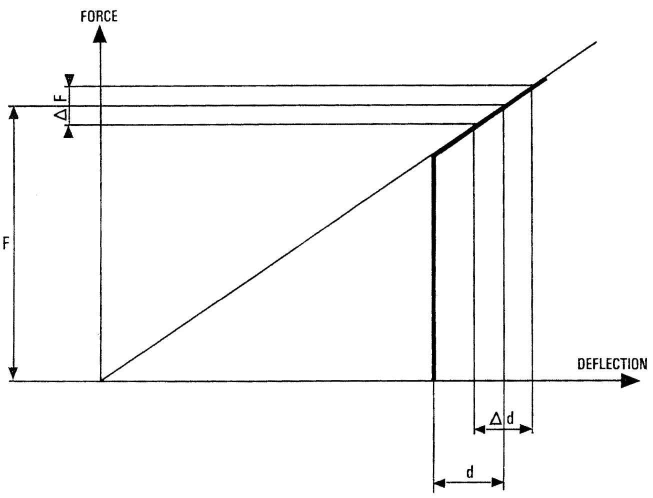


Figure 7 - Effects of pre-stressing.

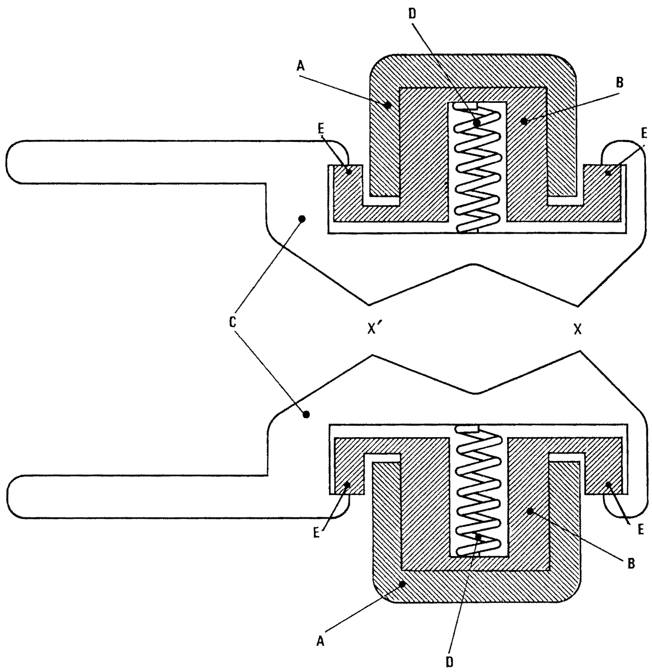


Figure 6 - Construction of the dual-face-type connector (transverse cross section).

— Since the plugging-in of the printed-circuit cards is dissociated from the application of pressure by the contact springs, there is no risk of separation of the copper layer from its base.

— Because the contacts do not scrape the printed circuit the contact area can be made very small, thus producing a high pressure per unit area (2·5 kilograms per square millimeter) which is an important contribution to reliability.

— The connector has successfully undergone ITT standard tests: contact resistance, insulation resistance, arc resistance, vibration, accelerated damp-heat test (4 days at 50 degrees Celsius and 95 percent relative humidity), long-term humidity test (150 days at 30 degrees Celsius and 90 percent relative humidity) and life tests (1000 operations).

4. Conclusions

The connector described provides a highly reliable contact in an economical and practical manner by taking full advantage of the space available between plug-in units, particularly in switching equipment.

The design demonstrates the practicability of providing very high contact pressure without incurring the penalties which this carries with conventional connectors.

Charles Vazquez was born in Bilbao, Spain, in 1919. He entered Compagnie Industrielle des Téléphones in 1948, where he was Head of the Apparatus Development Division from 1950 to 1957.

He then joined Compagnie Générale de Constructions Téléphoniques where he is now Head of the Engineering Department. He is responsible for numerous inventions covered by thirty-five patents, twenty-five of which are in the name of Compagnie Générale de Constructions Téléphoniques.

In 1967, C. Vazquez shared an ITT award for his work on a new miniaturized crossbar multiswitch.

Guy Claude Dufresnoy was born in Paris in 1927. He joined Compagnie Générale de Constructions Téléphoniques in 1949 and, since then, has been working within the Electromechanical Apparatus Development Division where he has been concerned with the development of Pentaconta telephone switching equipment. In 1967, he shared an ITT award for his work on a new miniaturized crossbar multiswitch.

G. C. Dufresnoy is now head of the Apparatus Division of the Engineering Department of Compagnie Générale de Constructions Téléphoniques in Paris.

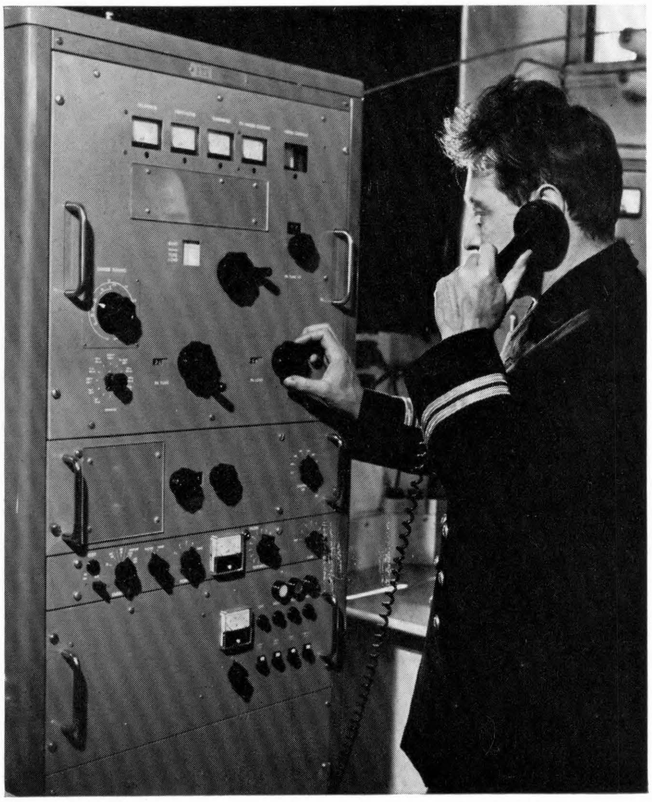
Recent Achievements

Queen Elizabeth 2 Radio Equipment · Amongst the radio equipment being supplied to the new Cunard liner, *Queen Elizabeth 2*, are communication transmitters, supervisory equipment, navigational aids, and survival equipment.

Three *ST 1430 A* transmitters will each provide 1-kilowatt peak envelope power. Their power amplifiers and associated notch antennas will be situated in the transmitting room near the funnel. The exciters and remote tuning facilities will be in the receiving room near the bridge.

Frequency selection at low power is by rotary switching to 1 of 11 bands between 1·5 and 25 megahertz. A second switch then selects 1 of 15 channels in the selected band. On switching to high power in the receiving room, the power amplifiers are remotely tuned by a servo.

The remaining five transmitters include an *ST 1400** and four very-high-frequency transmitter-receivers; two *STR 20's* covering 16 channels with a power output of 10 watts and two *STR 60's* covering 41 channels with a power output of 20 watts. These latter four equipments† operate from the receiving room and are for harbor communications and public correspondence.



A radio officer operates a 1·5-kilowatt *ST 1400* transmitter similar to the one to be installed on the *Queen Elizabeth 2*.

The receiving room seats four radio officers sharing common facilities mounted on two swivelling consoles. On each console are the *ST 1430 A* remote control and exciter units, receiver muting equipment, a receiver, Vogad (voice-operated gain-adjusting device), and Lincompex* (linked compressor and expander) remote-control equipment.

Push-button control will allow a radio officer to monitor radiotelephone channels, either of two receivers, or the 500-kilohertz distress channel. He can also contact the ship's private automatic branch telephone exchange. Operators will be able to monitor the audio content of radio-telephone channels in sequence, listening to seven seconds of conversation on each channel.

A display in the receiving rooms shows the band and channel setting of each transmitter. Numerical-indicator tubes show which receiving antennas are in use. If any receiving antenna accidentally has a high voltage induced on it, the antenna is automatically disconnected.

An emergency station is fitted with an *IMR 113* reserve transmitter, and *SR 401* reserve receiver, and an *AKU* automatic keying unit.

Navigational aids include *4202 B* loran operating on systems *A* and *C*. The longer-wavelength *C* signals may be crossed with the *A* signals to obtain a fix under most conditions. Cycle matching provides delay measurements of approximately one tenth of a microsecond, giving a good resolution.

Two portable Solas* II lifeboat equipments complete the equipment supplied by us.

International Marine Radio Company, United Kingdom

Telephone Exchanges in Indonesia · As part of a long-term contract to install over 40 000 lines in the public telephone networks of the Borneo, Celebes, and Moluccas Islands of Indonesia, a 1600-line exchange has been cut over in Ambon, the capital of the Moluccas Islands. A second expansion, also of 3000 lines of new equipment, will further modernize the Makassar public network.

This automatic switching equipment is of the *HKS* system, which is based on 100-outlet crossbar switches.

Standard Elektrik Lorenz, West Germany

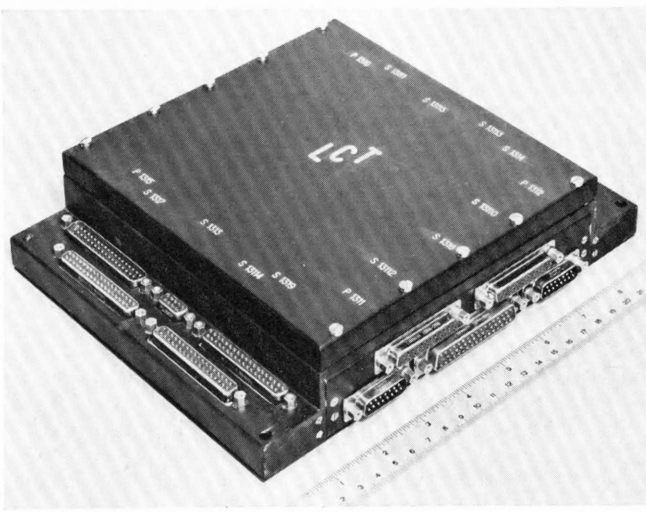
ESRO 1 Scientific Satellite Checkout Consoles · Two different types of checkout consoles for the *ESRO 1* scientific satellite have been made within the framework of the housekeeping system of the satellite.

The first type of console was made in duplicate. Connected through the umbilical cord, it provides for monitoring and controlling the satellite. It also permits complete and detailed testing of the housekeeping system of the satellite.

The second type of console, of simpler design, is mainly intended for use on the range before firing the launch missile of the Scout type. The function of this console is mainly to supply electric power to the satellite and control its operation. It also permits the telecontrol system of the satellite to be simulated during certain special tests.

Both types of consoles were used during the testing of prototype satellites and flight units.

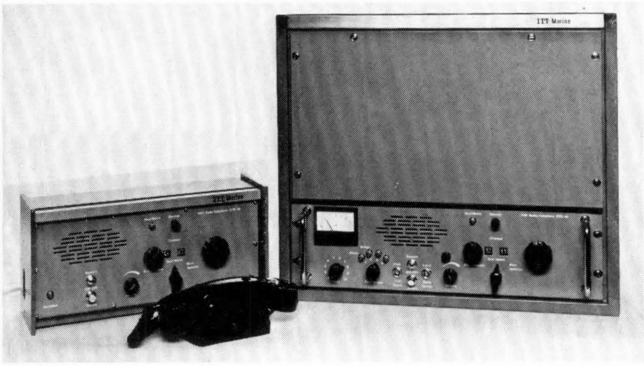
Laboratoire Central de Télécommunications, France



Checkout console (first type) of the housekeeping system of the ESRO 1 satellite.

* - manufactured by Standard Radio and Telephone, Sweden.
† - manufactured by Standard Electric, Copenhagen.

* Registered trademark
* Registered trademark of Standard Telephones and Cables International Marine Radio Company



The *STR-60* marine radio set with remote control.

Marine Radio Equipment for Brazil · Petroleo Brasileiro, Petrobras has selected for its fleet of tankers, floating derricks, and other vessels, marine radio equipment manufactured by Standard Electric (Denmark), which is called for in a contract placed through our associate company in Brazil, Standard Eléctrica.

There will be delivered 28 of the 41-channel *STR-60* and 70 of the 16-channel *STR-20* equipments complete with remote controls. The *STR-60* was developed in Denmark. It is in modular construction and is based on the techniques used for Ministac* equipment. It is fully adapted to the planned changes in the marine service including doubling of its frequency band.

Standard Electric, Denmark

Telegraph Centers *D53* and *D54* · A *D53* automatic telegraph switching center was put in service early in 1968 for the French Land Forces. This is a computer-controlled message-retransmission system operating under a stored program. It serves about 30 duplex lines having modulation rates of 50, 75, and 200 bauds.

For maximum reliability, duplicate processors are connected to the incoming lines. Both process the messages independently of each other but only one is connected to the outgoing lines. If trouble occurs on the fully operating processor, the stand-by unit is switched in automatically without loss or distortion of any characters being processed.

Provision is made for supervising lines, revising messages that do not conform with prescribed procedures, display on a screen of trouble reports, storage of messages awaiting transmission, and recording of both received and transmitted messages.

The first *D53* installation in France has been serving Air-France since 1966. Another installation in the Air Navigation Department processes 24 000 messages per day.

The Turkish army has chosen the *D54* equipment for its telegraph center at Ankara. This is a new-generation design of reduced size. It operates both message processors simultaneously.

Compagnie Générale de Constructions Téléphoniques, France

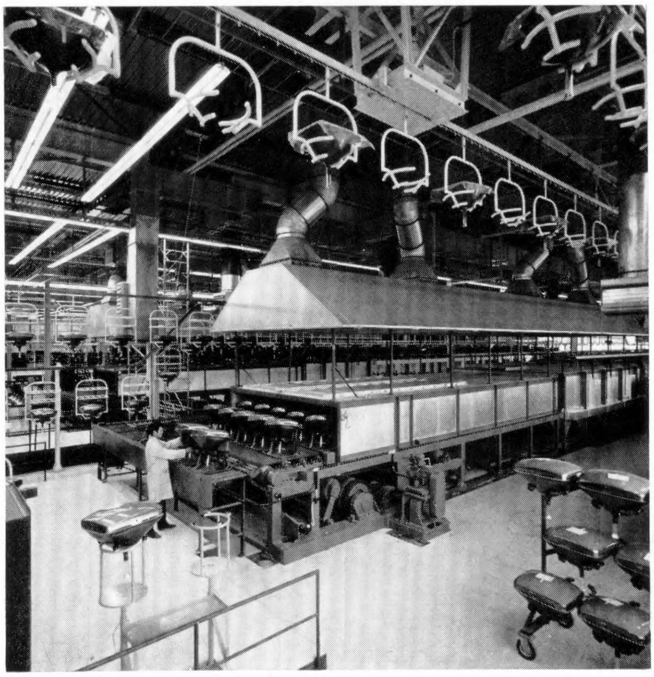
Vibrating Sample Magnetometer · A vibrating sample magnetometer has been developed to measure and record the hysteresis characteristics of ferromagnetic materials. Measurements can be made on samples up to 0·75-inch (19-millimeters) long by 0·25-inch (6·4-millimeters) diameter in fields up to 1500 oersteds.

The magnetometer vibrates the sample axially in a long solenoid to induce an electromotive force in sensing coils which give an output proportional to the induced magnetization. This output, together with a signal proportional to the applied field, is amplified and rectified to drive an X–Y recorder, which traces out the hysteresis loop of the sample as the field is varied.

Both eddy currents and switching-time effects are minimized with this technique since the sample is in a substantially constant field during the measurements. These features are particularly important when measuring properties of metals or electrodeposited platings on conducting substrates.

Standard Telecommunication Laboratories, United Kingdom

Color-Picture Tube Plant Operational · A completely new factory for television color-picture tubes has started production in Esslingen, Germany, in modern buildings providing some 80 000 cubic meters of working space. Extensive automatization of production processes and elaborate control methods guarantee a consistently high quality for these complicated cathode-ray tubes.



Sintering furnace in the Esslingen color-picture tube factory.

A sintering furnace, 35 meters (115 feet) in length, joins the faceplate with the inserted shadow mask and the cone of the tubes together at a temperature of about 450 degrees Celsius. The Permachrome method of shadow-mask suspension is used to ensure very high color fidelity immediately on switching on the television receiver.

The SEL PERMACOLOR* picture tubes can also be supplied. They avoid the need for a separate protective glass screen and the tube may project beyond the front of the cabinet as has become popular in black-and-white sets.

Standard Elektrik Lorenz, West Germany

Loran Airborne Set *AN/APN-181* · A family of automatic receivers for the loran C navigation system has been developed from the *AN/APN-181* set that operates on both loran C and D signals.

The high-density modular packages make up an airborne installation. The related master and slave signals are automatically acquired and tracked and the difference in their times of arrival to within 0·1 microsecond is continually displayed on 6 decimal nixie tubes. Higher precision is available for computer input.

ITT Avionics Division, United States of America

* Registered trademark of Standard Telecommunication Laboratories

* Registered trademark of Standard Elektrik Lorenz

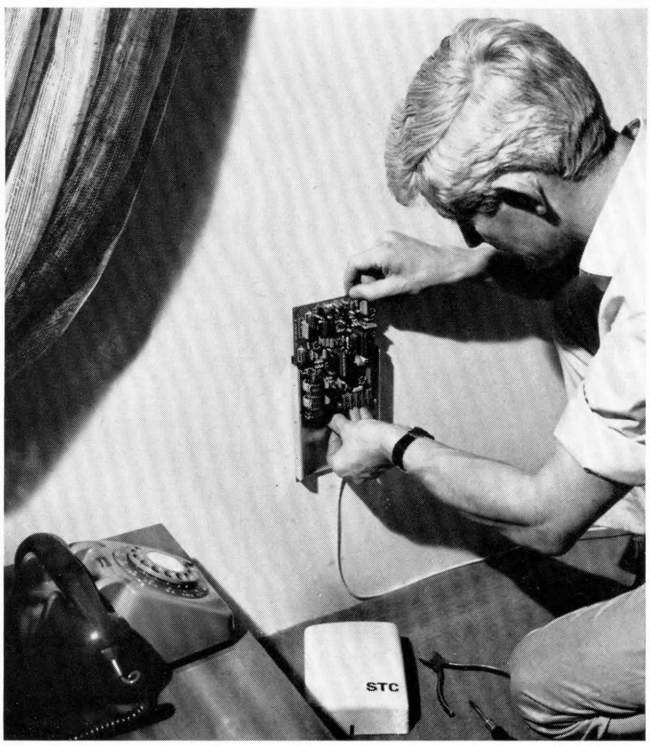
Airborne automatic loran receiver.

Subscriber Carrier Equipment · In the *SUB-1A* subscriber-carrier system the existing voice-frequency instrument has a low-pass filter placed in the cable pair between it and the exchange to isolate it from a high-frequency carrier system for a second instrument.

A spur cable from the exchange side of the low-pass filter connects through a carrier band-pass filter to the second subset so that its carrier, modulation, and demodulation equipment is isolated from the first subset's voice-frequency signal.

Thus the two instruments can operate simultaneously, independently, and with complete privacy.

An outgoing 28-kilohertz carrier is used for transmission from subscriber to exchange and an incoming 64-kilohertz carrier for exchange to subscriber. Dialing interrupts the outgoing carrier to the exchange and the exchange- to subscriber-ringing voltage is sent by pulsing the incoming carrier.



The *SUB-1A* subscriber carrier system compared with a standard telephones set.

The system can tolerate a 43-decibel cable attenuation at 64-kilohertz corresponding to about 3 miles (4·8 kilometers) of normal cable.

The low-pass filter on the first subscriber's premises is in a plastic box, 3 × 1·5 × 1·25 inches (76 × 38 × 31 millimeters), and the high-frequency equipment on the second subscriber's premises, is also in a plastic box 7 × 5·5 × 2·25 inches (180 × 140 × 58 millimeters). The equipment is powered by a rechargeable nickel-cadmium cell boosted by the exchange control battery during non-operating periods.

Standard Telephones and Cables, United Kingdom

Computer Control of Express Subway in Paris · The Régie Autonome des Transports Parisiens will put in service next year a 46-kilometer (28·6 mile) express subway line connecting the northwest and southeast suburbs of Paris.

A *CT 21* duplex computer programmed for automatic control of the system is in the control center and is connected over 2400-baud transmission equipment to the train stations and to safety stations. These safety stations keep check of the rail switches and signals in their areas and employ logic circuits that prevent any unsafe action.

Control is based on the identification and location of each train. The position of each rail switch, the aspect of each signal, and the information displayed on luminous panels on the station platforms are controlled by and reported back to the control center. The computer processes this information for display or for transfer to the control system. It checks and directs to the proper places all orders from the automatic control or from an operator. The transmission system reports any loss or alteration of a message to the computer. A telephone network is part of the system.

This regional express line will handle 600 trains per day with 50 trains running simultaneously at peak traffic hours.

Compagnie Générale de Constructions Téléphoniques, France

ITT Officially Recognized in France as Semiconductor Manufacturers · The Intermetall Département Semiconducteurs de la Société des Produits Industriels ITT, the French sister company of Intermetall, Freiburg, Germany, has been accepted as semiconductor manufacturer within the French association of electron tubes and semiconductor manufacturers (SITELESC, or "Syndicat des Industries de Tubes Électroniques et Semiconducteurs").

ITT semiconductor houses comprising Intermetall (Freiburg and Nuremberg, Germany), STC Semiconductors, (Footscray, Kent, UK), and ITT Semiconductors (Lawrence, Massachusetts, West Palm Beach, Florida, and Palo Alto, California) have been known for years by French users.

Plans made in 1965 to install a semiconductor plant in France were implemented by the foundation of the Colmar factory; its first products were silicon rectifiers in *DO-7* casings, and silicon capacitance diodes. This line was enlarged in March 1968 by the addition of high-speed silicon switching diodes in miniaturized double-plug casings. The Colmar plant which, meantime, had reached about 100 employees, has presently a production capacity of approximately 3 million diodes per month. A part of this output is for export. A further increase in the production program and capacity will be achieved in 1969 with an extension of the factory in the North of Colmar.

Intermetall, West Germany

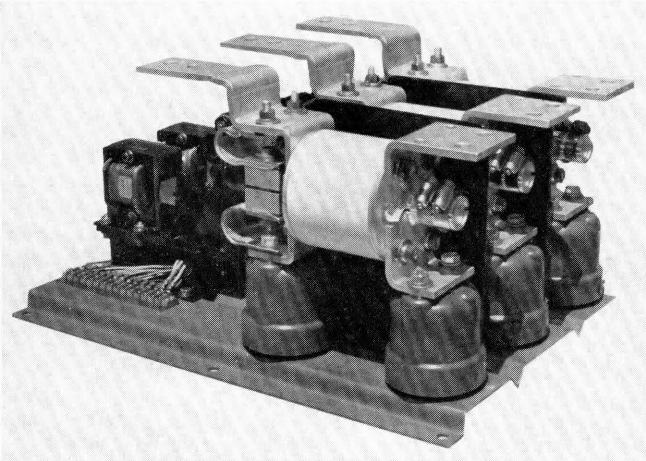
Switch for Printed Circuits · This miniature make-or-break *ITP 7750-A* switch fits on 0·1-inch (2·54-millimeter)-grid circuit boards by direct soldering. The phosphor-bronze contact-and-terminal material is gold plated to a depth of 0·2 micron and then silver plated to a depth of 10 microns. The insulating support material is reinforced polystyrene. Maximum switched current is 1·5 amperes at 50 volts.

The switch has overall dimensions of 21 by 11 by 4 millimeters (0·8 × 0·4 × 0·16 inch) and is available in 1-, 2-, 3-, or 4-unit combinations.

Standard Telephones and Cables, United Kingdom

Large-Power Vacuum Contactors · The *900* series is the lightest and fastest contactor to meet the *Size-6* switching requirements of the US National Electrical Manufacturers Association. It exceeds standard ratings and is available for 1500, 2300, and 5000 volts at 800 amperes. It has an interrupting rating of 12 000 amperes at 2300 volts.

The 3-pole normally-open contacts are vacuum sealed. They have been life tested for over 250 000 operations. The actuating coils can be wound for various voltages and currents, either alternating or direct.



This 3-pole normally-open vacuum contactor will interrupt 12 000 amperes at 2300 volts.

The contactors are intended for primary-circuit control of power supplies for high-power radio transmitters, heating equipment, industrial controls, and motor controls. They can be used with current-limiting fuses in circuits with high-fault currents. Interrupt time is 3 hertz. Weight is about 90 pounds (40 kilograms).

ITT Jennings, United States of America

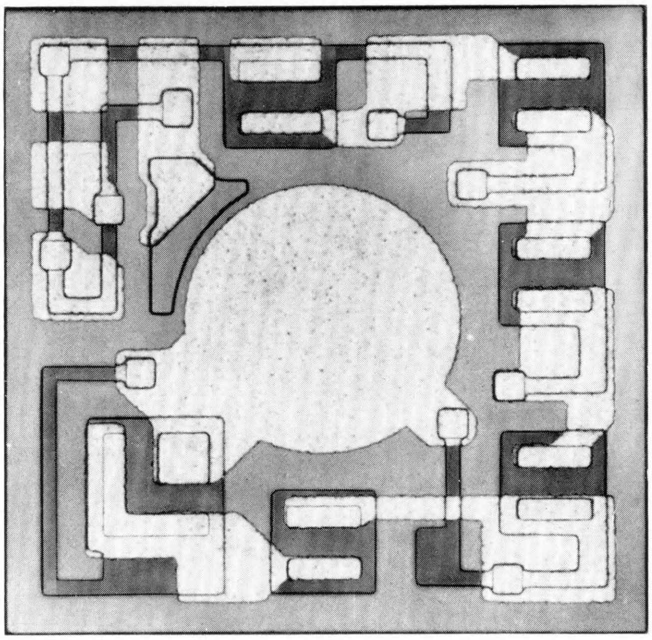
Zener Diode *ZTK 33* Is Temperature Compensated · The *ZTK 33* was designed to stabilize the supply voltage for the electronic tuning of television and radio receivers. Its improved characteristics over ordinary zener diodes simplifies the design and construction of these tuners particularly with regard to temperature compensation of the reference voltage.

The *ZTK 33* is not a simple diode but a linear integrated circuit in silicon planar construction. A 2-terminal network in a *TO-18* case, it can be used as if it were an ordinary zener diode.

For a current of 5 milliamperes producing a zener output of 33 volts, comparing the conventional zener diode *ZF 33* with the *ZTK 33* gives for temperature coefficient of zener voltage 10^{-3} against 2×10^{-5} per degree Celsius and for dynamic resistances 40 and 12 ohms, respectively. Thus the temperature coefficient is 50 times better and the dynamic resistance about 5 times better for the *ZTK 33*.

The *ZTK 33* comprises several ordinary diodes and zener diodes that have temperature coefficients of voltage that are positive for some and negative for others. The monolithic silicon design gives such good thermal coupling that no temperature gradient is observed. The surface is protected by silica to ensure long-term stability and long life.

Intermetall, West Germany

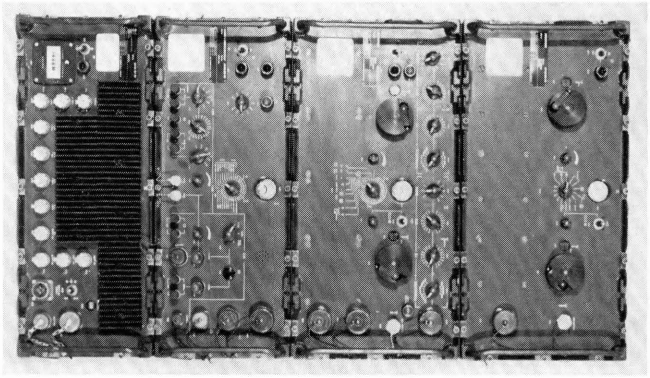


Geometry of the *ZTK 33* zener diode that is well compensated for temperature coefficient of zener voltage output. The actual size is 0·5 by 0·5 millimeter (0·02 by 0·02 inch).

Tactical Military Radio Relay Equipment · Prototypes of a tactical military radio relay equipment have been field tested over three different routes during May and June 1968.

This equipment covers the ranges 225 to 400 megahertz and 610 to 960 megahertz with output power up to 15 watts in the lower frequency range and 10 watts in the higher range. Its capacity is 24 frequency-division-multiplex or pulse-code-modulation telephone channels.

Bell Telephone Manufacturing Company, Belgium

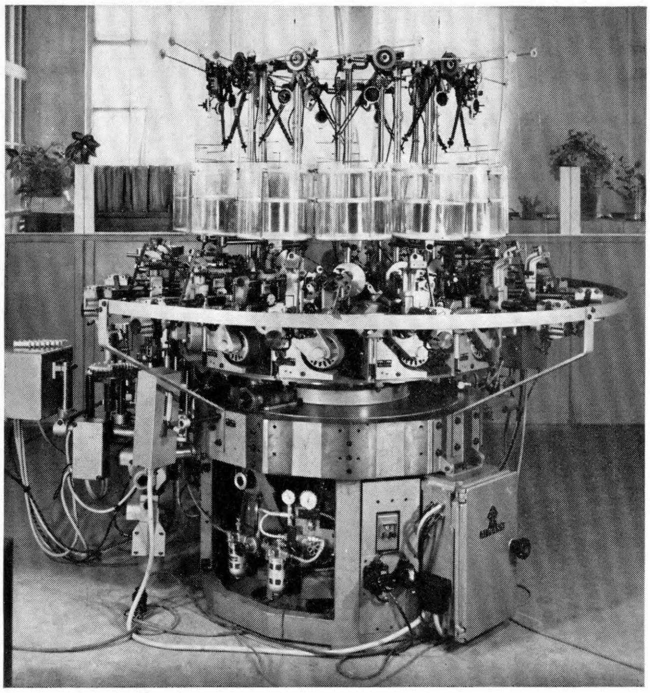


Tactical military radio relay equipment.

Coil Winding Machine · The machine has been developed in close cooperation with the manufacturer for the automatic production of relay coils. Part of the cooperation included redesign of existing coils to adapt them to machine manufacture.

A turret supports 12 interchangeable winding heads that may operate up to 1200 revolutions per minute. Automatic operations include loading the coil form, winding a prescribed number of turns, soldering of connecting leads, wrapping the coil with adhesive tape bearing identification marks, loosening the leads to avoid breakage, and ejection of the coil. Production is 4 coils per minute.

Le Matériel Téléphonique, France



Automatic winding of relay coils.

Indexing Machine for Belgium Postal Cheque Office · The envelopes in which credit and debit advices and account statements are sent to those using the Belgian Postal Cheque system bear address labels on which the postal code is printed in *OCR-A* type face.

The first of several new machines has been installed that optically reads the postal code, translates it into a 2-out-of-5 code, and prints this in fluorescent ink as a row of bars in the lower right corner of the envelope. These bars are read for checking purposes and the envelopes are then presorted into 10 classes.

The machine handles 6 letters per second. Its modular construction provides for a maximum of 16 sorting classes.

Bell Telephone Manufacturing Company, Belgium

Automatic indexing machine used for presorting envelopes in postal cheque office.

Doppler VOR for Frankfurt Airport · Following extensive testing at two experimental installations, near Munich and near Rüdesheim, a Doppler very-high-frequency omnidirectional range was placed in service at the busiest German airport, Frankfurt on the Main, on 21 May 1968. The equipment is mounted on a 39-meter (128-foot) high tower in a wooded area near the airport.

The application of the Doppler principle to the existing omnidirectional range greatly reduces errors due to reflections of the transmitted waves and permits smooth approaches of aircraft even over irregular terrain. Operating in the conventional range band, the Doppler transmissions are fully compatible with existing airborne receiving equipment. Aircraft suitably equipped for Doppler signals will be able to use automatic flight control.

The installation was made for the Bundesanstalt für Flugsicherung (Federal Agency for Air-Traffic Control).

Standard Elektrik Lorenz, West Germany

British Broadcasting Corporation to Use Message Switching · The British Broadcasting Corporation (BBC), London, will install an *ADX** message-switching system at its London headquarters to connect with 100 terminals, including some teleprinters, throughout the United Kingdom. In this automatic store-and-forward equipment, addressed messages are sent under computer control to terminals as they come free to give a more efficient distribution of internal memoranda.

Also at headquarters an existing uniselector equipment controlled from Caversham Park, where foreign broadcasts are monitored on a 24-hour basis, is being replaced by 4 multioutput selection units each with a capacity of 10 out-stations. Information on foreign news broadcasts will be distributed to BBC news and government departments using a 3-letter heading code similar to the *ADX* system. The equipment is of modular design with remote changeover facilities if a module fails in service.

Standard Telephones and Cables, United Kingdom

Radio Supervisory System for Power Network · A radio supervisory system has been developed for the Valencia power network of Hidroeléctrica Española.

The control supervisory station uses a 50-watt transmitter in the 80-megahertz band, frequency modulated with a deviation of ± 6 kilohertz. Each controlled distribution center is assigned 2 out of 10 frequencies between 300 and 600 hertz, thus providing for a maximum of 45 centers. Both frequencies are transmitted simultaneously and reed filters in the receivers at the distribution centers accept a call only if the 2 frequencies are those assigned to the specific station. The 10-watt transmitters at these stations all use the same frequency as only one operates at a time.

The control station calls all distribution centers, 20 of which are presently in service, every 2 minutes. As each call is received, the transmitter in that center reports on the status of the center. If there is any abnormal condition, an alarm identifying the center is given in the control station. The control operator can confirm the report by a manual operation that queries the center again.

Standard Electrica, Spain

Censor 900 Data System · A new integrated real-time data system is based on the concept of the Censor* computer successfully used in air-defense and air-traffic control systems. This Censor 900 data system includes graphic, alphanumeric, and special display terminals and two types of processors. One

* Registered trademark of Standard Radio and Telefon

* Registered trademark of International Telephone and Telegraph Corporation

processor is for computation work (Censor 932) and the other is for satellite data administration and processing (Censor 908).

The new system has been applied in various areas such as satellites, patient-data display systems for hospitals, on-line information retrieval systems of various kinds, automatic display of meteorological maps, management information systems (for instance in ITT companies), synthetic radar display (Eurocontrol), and complex air-defense computation systems.

Standard Radio and Telefon, Sweden

Voice-Frequency Telegraph System *RTT 8* · A voice-frequency telegraph system suitable for high-frequency radio transmission has been derived from the recently developed *MTT* system. With respect to this latter, the new channel modems provide increased adjacent-channel rejection. Channel spacing is 170 hertz. The radio system can be operated in space and frequency diversity. A diversity combiner of a new type provides rapid and continuous transfer from the weaker to the stronger channel.

Equipments can be provided with up to 16 transmitters, 16 receivers, or a combination of transmitters and receivers to constitute 16 channels. Supervisory and test facilities are comprehensive: no external test gear is required for system maintenance and alignment.

The output stages producing up to ± 80 volts at 40 milliamperes are proof against short circuits. They are not damaged by the wrong application of a telegraph battery or of 70-volts, 25-hertz ringing sources.

Bell Telephone Manufacturing Company, Belgium

Navaids for Dublin Airport · A solid-state *STAN 38* glide path and two *STAN 39* marker beacons will be installed at Dublin Airport. The glide-path equipment will have a sideband-reference antenna to suit the terrain configuration.

Airport direction-finding equipment will be the automatic very-high-frequency *DDF 1-B*. This 3-channel/8-frequency system provides air-traffic control, general navigation, and distress service. It has a rotating antenna, and receivers for unattended operation.

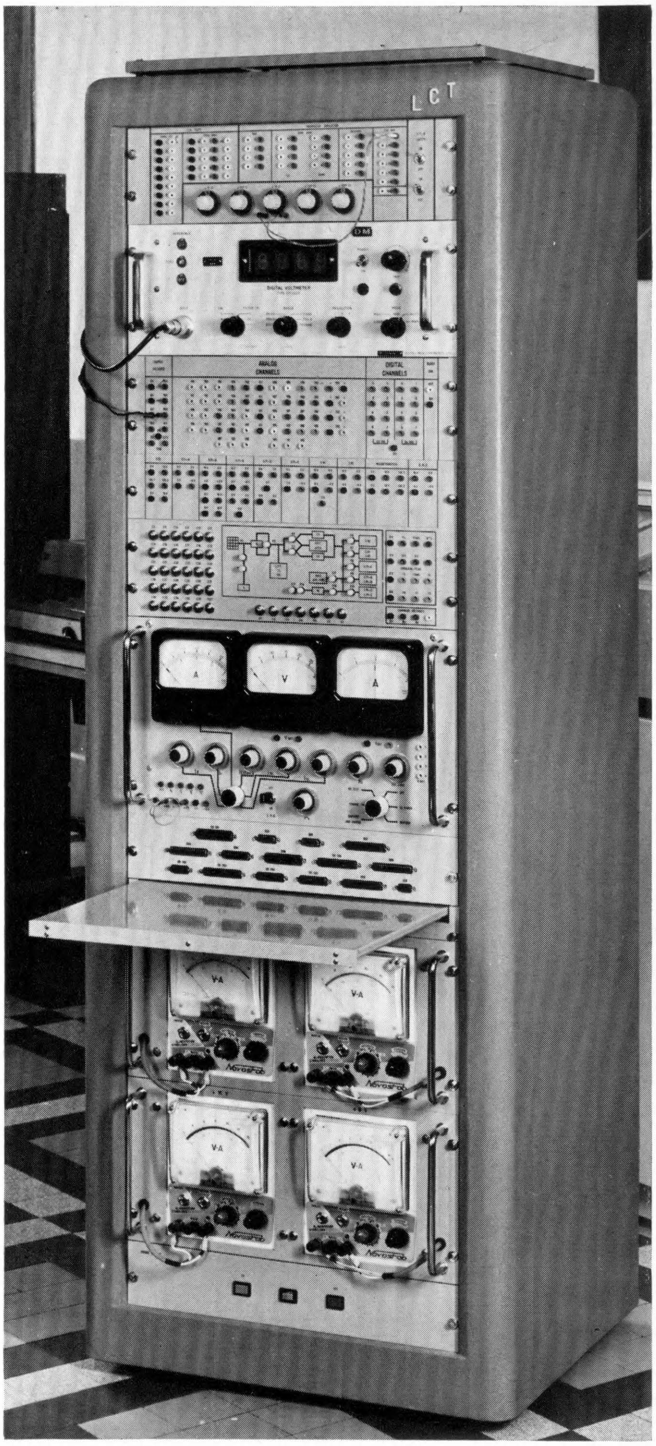
Standard Telephones and Cables, United Kingdom

Spanish Radio Relay Network Expanded · A new radio relay network installed in Spain connects Madrid to Irun at the French border on the Atlantic coast, and to Barcelona and Los Limites at the same border on the Mediterranean side, covering distances of 500 and 700 kilometers (310 and 435 miles), with 10 and 12 hops, respectively.

The equipment is of the *FM 60-900* type working in the band from 890 to 960 megahertz with frequency diversity. Transmitter output is 3 watts. Active standby equipment is provided. All repeaters are unattended.

This system is intended for telegraph transmission with an ultimate capacity of 48 systems of 24 telegraph channels each.

Bell Telephone Manufacturing Company, Belgium



Flight equipment of the housekeeping system for the ESRO I satellite.

ESRO 1 Scientific Satellite Housekeeping System · ESRO, the European Space Research Organization, also known as CERS, the Centre Européen de Recherches Spatiales, has placed among our prime contractor's responsibilities the definition, design, and construction of the surveillance or housekeeping system. This basic support equipment in the satellite ensures three principal functions.

The necessary power supplies are connected to the various satellite equipments over numerous bistable relays controlled from the ground.

Sensors that provide 6 current, 11 voltage, and 24 temperature measurements are connected to telemetering equipment for transmission to ground. The sensor circuits have outputs between 0 and 5 volts that are proportional to their inputs. Accuracy is ± 2 percent for voltage and current values and ± 3 degrees for temperatures between -30 and $+60$ degrees Celsius.

By comparing 9 significant measurements with predetermined threshold values, automatic switching of 5 relays will protect the satellite against the effects of temporary or permanent failures.

Two prototype and three flight units were manufactured in 1966 and 1967 and the particularly severe qualification and acceptance tests were undergone successfully. Special attention was paid to the mechanical design so the equipment would withstand the launching vibrations.

The electronic circuits are built in small modules of a few cubic centimeters using electrical welding for fastening the components together. The modules are similarly welded to double-faced printed-circuit boards.

The wiring and relays are completely potted in polyurethane foam, the thin sheet-iron package casing serving as the mold. The assembly thus achieved is extremely rigid, without any wall-resonance frequencies.

Reliability is obtained at the equipment level by redundancy in the wiring and in some circuits. Each component has been selected with the greatest care and has been submitted to pre-aging tests before utilization in the flight equipments. As an example, the contact resistance of each relay was measured before and after about five thousand operations at the load to be carried and only relays showing negligible variations in performance were utilized. These tests were carried out by Le Matériel Téléphonique.

The photo shows a flight equipment. Worth noting is the large number of connectors necessary to its functioning.

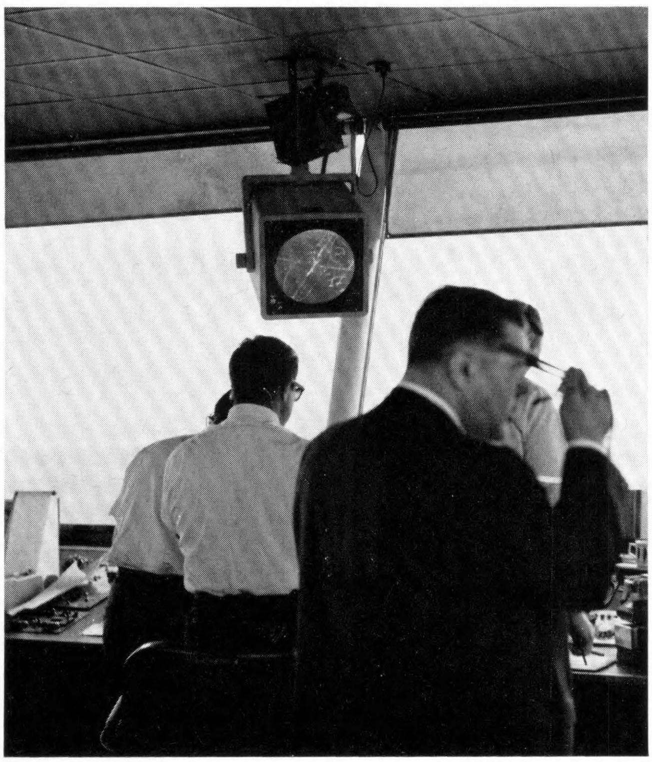
Laboratoire Central de Télécommunications, France

Air Traffic Control Towers Get Bright Displays · The photo shows one of the recently installed Bright Radar-Indicator Tower Equipments (*BRITE*) that can operate against the normal daylight ambient in an airport control tower. Conventional radar 'scopes require hoods to reduce the ambient light.

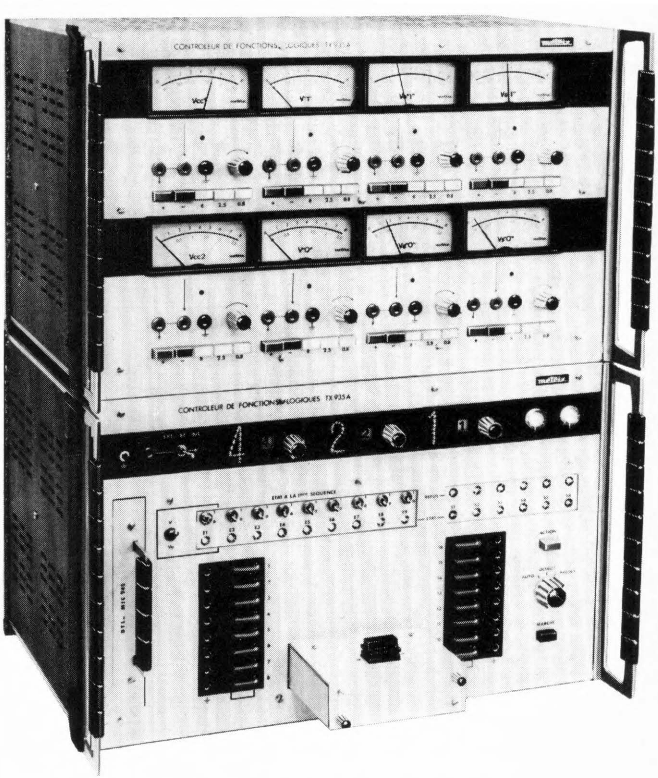
ITT Industrial Laboratories, United States of America

Integrated Circuit Test Equipment *TX 935 A* · This test set will check the logic functions of digital integrated circuits having up to 9 inputs and 6 outputs. It may be used as an automatic programmed system for the rapid testing to prescribed tolerance limits of many units with recording of results. This permits the sorting of units into classes. A second use is as a programmed checker that will stop when a faulty parameter is found. This is of the nature of a *go, no-go* test. Third, it may be used as a semi-automatic programmed instrument to analyze sequences of operations.

Parameter testing is by comparison of the unit under test with a standard unit subjected to the same test conditions. Separate power supplies are provided for the test and standard units. About 0·5 second is required per test for a 9-input package.



BRITE radar display in an airport control tower can be viewed without the conventional hood or other means of reducing the high ambient light.



TX 935 A set for testing logic integrated circuits.

The test program is established by a printed-circuit board that includes the standard and the fan-out loads for testing. It is plugged-in on the front panel. The device to be checked is connected directly to the test set or via a cable that permits it to be subjected to the required test environment, such as an extreme temperature.

Input voltages corresponding to logic *1* or *0* may be applied to any input of the circuit under test. Two additional input voltages may be used as clock or expander inputs. The output levels of the standard circuit are defined by two more voltages corresponding also to a *1* or *0*. All these voltages are stable to 10^{-4} and may be adjusted from 0 to ± 8 volts within an accuracy of 1·5 percent with built-in voltmeters. This accuracy can be improved by using suitable external voltmeters. The instrument is self-checking.

Compagnie Générale de Métrologic, France

Telecommunication Control of Gas Pipeline · A pipeline installed by Gaz de France to transport gas from the Belgian border to the Paris, Lille, and Lorraine areas of France will be controlled by a telecommunication system. The gas originates in The Netherlands.

Dispatching centers at Paris, Lille, and Metz will be connected to pipeline stations via Digital 1000*[1] equipment for information on flow or pressure and to control valves and compressors. A logic unit in Paris will provide optimum supervision and minimize the effects of local trouble on general operation by isolating a faulty element.

Transmission will be over a highly reliable telephone system that is part of the installation. It will be possible for the dispatching centers to reach any pipeline station via the public telephone network.

Compagnie Générale de Constructions Téléphoniques, France
Bell Telephone Manufacturing Company, Belgium

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1 J. M. Lauriks, "Digital 1000 Remote-Control System", Electrical Communication, volume 43, number 1, pages 50—56; 1968.

Austria Gets High-Capacity Telephone Cable System · An *LG 12 A* solid-state 12-megahertz 2700-circuit telephone cable system has been installed between Salzburg and Bischofshofen, a distance of 37 miles (60 kilometers). It uses two coaxial cables of 9·5-millimeter (0·375 inch) diameter and 12 repeaters at 2·8-mile (4·5-kilometer) intervals.

The repeater gain is 37 decibels and the noise figure of 1 picowatt per kilometer is lower than the CCITT figure of 3 picowatts per kilometer. Each line amplifier has 3 silicon-planar-transistor stages with local and overall bridge feedback. Power consumption is 0·64 watt per amplifier. Line equalization was carried out by telexing measured parameters to the Computer-Aided Design Unit at Cockfosters in the United Kingdom. The results were then telexed back to the installation team in Austria.

The link will carry national traffic and international through traffic from Western Germany to Italy and Yugoslavia.

Standard Telephones and Cables, United Kingdom

Data Transmission Modems for Defense Project · Modems will carry speech, data, and telegraph traffic over communication channels at speeds up to 2400 bauds for the British *Skynet* defense communications system.

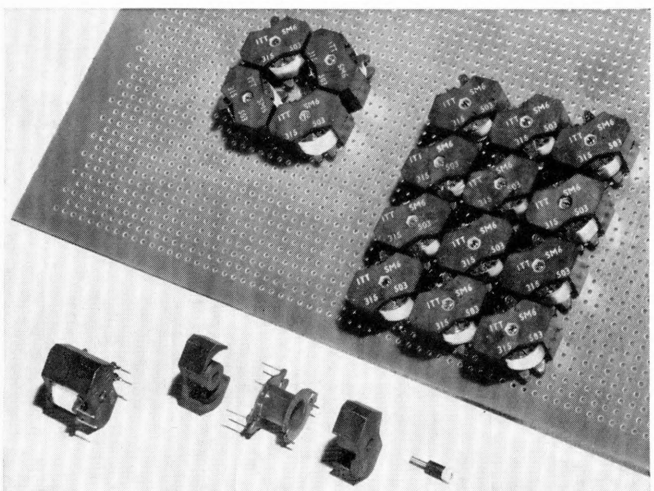
The equipment is basically the same as the British Post Office *Datel Modem 7* system but includes higher timing accuracy and more-comprehensive failure-indication techniques.

The modems will connect strategic communication centers to the earth stations terminating *Skynet* satellite links.

Standard Telephones and Cables, United Kingdom

Ferrite Pot Cores With Higher Packing Densities · The new *SM 6* modular ferrite pot fits directly into printed-circuit boards without additional hardware. It provides a performance approaching that of an 18- by 11-millimeter pot core having dimensions standardized by the International Electrotechnical Commission but offers a much higher packing density. The assembly consists of two core halves, a bobbin with molded-in terminal pins, and an adjuster if required.

Windings can be terminated while the bobbin is still on the winding machine, giving a robust component ready for preassembly testing. The terminal pins are 4·7-millimeters (0·19-inch) long, to suit 1·59-millimeter (0·06-inch) printed-circuit boards. When using 0·79-millimeter (0·03-inch) boards, the pins require cropping. The bobbins are available with four or six pins, as required. The pins fit the standard printed-circuit matrix of 2·54 millimeters (0·1 inch) the pin spacing being equal to the diagonal of a 2·54-millimeter square in all cases. The maximum core height of 12·5 millimeters (0·5 inch) enables standard board spacing to be used.



The new ferrite pot cores plug into printed-circuit boards and give a high packaging density.

The new cores are available in four grades of ferrite material: *SA 502*, *SA 503*, *SA 601*, and *SA 611*. The first two are intended for inductor applications, the latter two for transformer use. For inductor use, the center bosses of the core halves are ground and lapped to produce gapped cores. An adjuster is fitted that ensures a smooth adjustment characteristic. By virtue of its design, the adjuster concentricity is maintained and a self-locking action provided thus offering improved setting accuracy compared to other systems.

ITT Components Group Europe, Belgium

Tactical Radar with Digital Output · The *AN/TPS-32* developed for the United States Marine Corps is a fully automatic primary sensor for large tactical command systems. It provides target range, azimuth, and altitude, together with any relevant *IFF* (Interrogation, Friend or Foe) data, in a digital format to the Marine Tactical Data System. Various manual and automatic back-up modes are available.

Extensive flight tests were included in several thousand hours of operation to demonstrate its target-determination accuracy, data-output rate, and countermeasure capabilities.

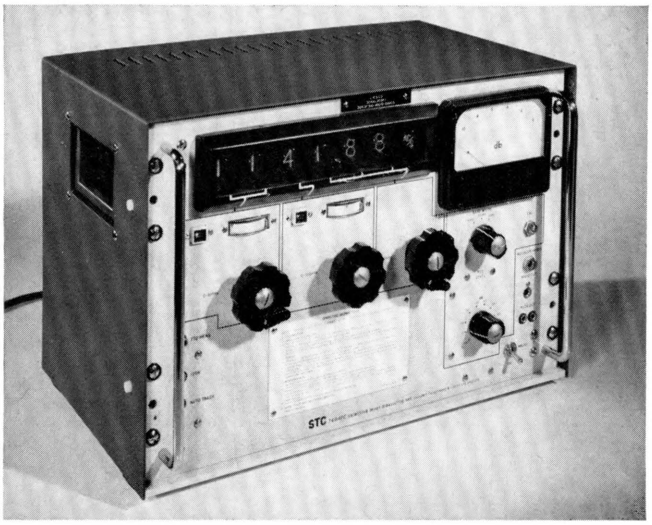
The complete radar system is transportable by helicopter in 6 sections and can be set up for operation in a few hours. Modular design allows mechanical reshaping without electrical redesign. A smaller version is available in 3 sections.

ITT Gilfillan, United States of America

Level-Measuring Equipment for Coaxial Systems · The *74313* oscillator and *74314* frequency-selective level-measuring set make in-traffic measurements in or between channels, and without interference, from 50 kilohertz through 6·1 megahertz.

The *74314* has 6 cold-cathode indicator tubes to show frequency in kilohertz with a fixed decimal point before the last two digits. A counter samples the frequency at 0·2-second intervals and resets the display. The *74313* provides a meter-monitored autotracking signal for the *74314* whose tuning circuits have 3 bandwidths, ±2 kilohertz, ±200 hertz, and ±25 hertz.

AN/TPS-32 provides target information in data form directly to a tactical data system.



The *74314* frequency-selective level-measuring set has a digital readout of frequency updated at 0·2-second intervals.

The latter band will select a tone from an in-traffic channel. Using the *74313* autotracking facility a steady level reading can be obtained in the ±25-hertz band. An external recorder will operate from the meter circuit of the *74314* which also provides a jack point for aural detection of low-level input tones.

The *74313* output may be set from +10 to −99 decibels reference 1 milliwatt and the *74314* measures +11 to −91 decibels reference 1 milliwatt.

Both instruments can be housed in portable metal cases or mounted in 19-inch (48-centimeter) racks. The case dimensions are 19·4 inches wide by 13·75 inches high by 12 inches deep (492 × 337 × 305 millimeters). Each instrument weighs 63 pounds (28·6 kilograms) and will operate from 100 to 125 or from 200 to 250 volts at 45 to 66 hertz. For field operation a 19- to 21-volt 4-ampere direct-current source may be used.

Standard Telephones and Cables, United Kingdom

Private Automatic Exchange for Power Station · A type *4120* automatic telephone exchange of 300 lines and ancillary communications equipment will be installed at the Pembroke Power Station for the Central Electricity Generating Board. It will have subscriber dialling for internal calls but direct-wire links for selected subsets around the control room area. Maintenance personnel will use 12 portable subsets and have access to 24 jack points throughout the system.

Fire alarm will be given by dialling a predetermined number and 5 simultaneous alarm calls can be received on the control engineer's alarm set. The alarms will also appear on a zone indicator in the control room.

The ancillary equipment also includes a radio address system for 2-way speech between control-room mobile staff, a very-high-frequency staff-location system using 50 pocket receivers, and an emergency very-high-frequency radio-telephone system.

Standard Telephones and Cables, United Kingdom

Fire Brigades Get Private Alarms · Many civilian fire brigades use audible alarms in the homes of brigade members to avoid loud sirens or horns in public places. Each fireman then goes to a specified meeting point for information on the call.

To improve the effectiveness of the brigade, a very-high-frequency radiotelephone transmitter may be installed in the fire station. Each fireman has a portable receiver that can be carried with him. A 20-second tone will alert him and is followed by information on the emergency. Thus only those needed respond and proceed to the emergency.

An initial installation using 40 alarm receivers was placed in service in Kehl late in 1967.

Standard Elektrik Lorenz, West Germany

Gallium-Arsenide Laser Operating at Room Temperature · For applications where high power and efficiency are not vital requirements it has been found possible to fabricate a laser which operates at room temperatures and so dispense with the elaborate coolant (liquid nitrogen, et cetera) apparatus.

The gallium-arsenide laser described is an efficient source of radiation in the near infra-red, at some 9000 angstrom units. This radiation is emitted into a solid angle of some 60 millisteradians (approximately a 15-degree cone of radiation), and it can conveniently be focused by a simple lens system. The laser is operated under pulsed conditions with up to 0·5-microsecond pulses and repetition rates of the order of 1 kilohertz.

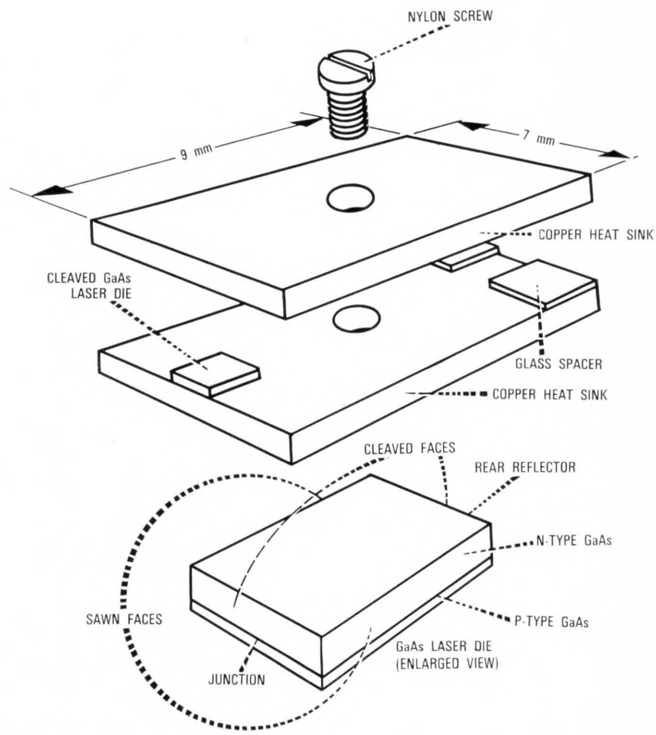
Such lasers are fabricated either by diffusing zinc into selenium-doped n-type GaAs to form a pn junction, or by growing an epitaxial layer of p-type material on an n-type substrate, which itself may be either bulk grown or epitaxial material.

Having formed a pn junction, low-resistance ohmic contacts are made to each side of the wafer. The wafer is then cleaved along cleavage planes to form mirror surfaces that, because of the original orientation of the wafer, are perpendicular to the pn junction. The cleaved strips are now sawed into rectangular dice, which require only a reflector to be deposited on one cleaved face before mounting on copper heat sinks.

When a small current is passed in the forward direction through the device, light is emitted by radiative recombination of electrons and holes in the junction region. As the current is increased, the probability of a photon stimulating a recombination increases until a condition is reached such that the losses due to absorption and to transmission at the front face in the plane of the junction are just compensated for by the gain due to stimulated emission. Above this threshold the light emission from the device increases rapidly with current and becomes directional and coherent within lasing filaments.

Room-temperature GaAs lasers are generally operated at between 2 and 5 times their threshold currents.

Standard Telecommunication Laboratories, United Kingdom



The gallium-arsenide laser junction at the bottom is clamped between the heat-sink plates at the top.

Antennas for New Jet Plane · An airborne operator on the Royal Air Force vertical-take-off plane *Harrier* selects the working frequency for the *AN 13* antenna system using the *0* to *9* buttons on an equipment-control unit which sends digital information to the frequency-selector unit. This latter unit accurately sets the mechanical tuning units of the notch antenna for high-frequency operation and of the blade antenna for very-high-frequency operation. Notch antennas fit flush to the skin of the aircraft to reduce drag and static caused by rain.

Similar systems have been developed for the *Concorde*, *Trident*, *HS 125*, and *Buccaneer* aircraft.

Standard Telephones and Cables, United Kingdom

Speed Control of Direct-Current Motors · A foot-operated control unit uses a thyristor to chop the current from the battery to the motor on a battery-traction vehicle. This technique means less waste power and, when the foot-operated control is used as an accelerator pedal, continuous speed control from vehicle standstill.

Smooth acceleration is achieved using a ramp control which is inoperative during deceleration to increase braking.

The control unit has no moving parts or relays and maintenance is minimal. Each unit comprises a solid-state control circuit, thyristor/diode stack, commutating capacitor and choke, and current-sensing resistor.

Units weigh between 32 and 34 pounds (14·5 to 15·4 kilograms) and occupy 0·65 to 0·9 cubic feet (0·018 to 0·025 cubic meter) depending upon electrical rating.

Standard Telephones and Cables, United Kingdom

Meteorological Satellite Ground Station · A ground station has been developed and is now operational at the Brussels Royal Meteorological Institute for receiving all pictures from the Environmental Science Services Administration satellites (ESSA) as well as the high-quality pictures from the geostationary experimental Applications Technology Satellite (ATS-3), which collects worldwide data from satellites in polar orbit for retransmission to ground stations.

The ground station provides for tracking of satellites and for receiving and reproducing cloud-cover pictures taken by the spacecraft for transmission in real time or after storage.

The techniques and instrumentation are identical to those used in large spacecraft tracking stations, such as the one delivered to the European Launcher Development Organization (ELDO) for the real-time guidance of launcher vehicles.

Bell Telephone Manufacturing Company, Belgium

Other Papers from International Telephone and Telegraph System Authors

This list includes papers published in other periodicals, and lectures presented at meetings. Some of these latter are also available in a written form, either printed in proceedings or edited internally. Where the publication is indicated, requests for reprints should be made directly to its editor, not to Electrical Communication. In the other cases, such requests should be made to the nearest editor of Electrical Communication or its associated language versions, as it may happen that a limited number of copies could be made available.

Standard Elektrik Lorenz

Articles

Bernutz, J., Entwicklungsmerkmale elektromagnetischer Verbindungselemente der Fernsprechvermittlungstechnik, Feinwerktechnik, volume 72, no 6, 1968, pp 265—277.

Crone, W., and Popp, H., Principes et avantages du radiophare omnidirectionnel V.H.F. Doppler, Navigation, volume XVI, no 61, January 1968, pp 40—50.

Dombrowski, E., and Wilde, H., Erfassung und Darstellung der Zuverlässigkeitsdaten von Bauelementen, Nachrichtentechnische Zeitschrift, volume 21, no 3, 1968, pp 136—140.

Schmitz, W., SEL-Beiträge zur Fortentwicklung der Eisenbahnsignaltechnik, Jubiläumsausgabe Signal und Draht, volume 60, nos 1—2, 1968, pp 35—38.

Schwant, J., Vergleich der Realisierungsverfahren aktiver RC-Netzwerke, Nachrichtentechnische Zeitschrift, volume 21, no 5, 1968, pp 250—254.

Schwant, J., Ein Syntheseverfahren für aktive RC-Netzwerke unter Verwendung der Struktur von Yanagisawa, Archiv der Elektrischen Übertragung, volume 22, no 7, 1968, pp 349—354.

Stammelbach, J., Ein Präzisions-Amplitudenmodulator für den Frequenzbereich 108 MHz bis 118 MHz, Internationale Elektronische Rundschau, volume 22, no 7, 1968, pp 179—180.

Lectures

Behne, R., Moderne Qualitätssicherung (Erfahrungen mit einem Qualitätssicherungssystem in einer Unternehmensgruppe), Österreichisches Produktivitätszentrum, Vienna, 21 May 1968.

Behne, R., Erfahrungen mit einem Qualitätssicherungssystem in einer Unternehmensgruppe, Ausschuss für wirtschaftliche Fertigung, Berlin, 14 May 1968.

Bernutz, J., Entwicklungsmerkmale elektromagnetischer Verbindungselemente der Fernsprech-Vermittlungstechnik, VDE Düsseldorf, "Feinwerktechnik" meeting, 15 May 1968.

Giese, W., Funksprechgeräte für den öffentlichen und zivilen Bedarf, Verband Deutscher Elektrotechniker Wilhelmshaven, 6 June 1968.

Handel, S., Was ist Wertanalyse? Österreichisches Produktivitätszentrum, Vienna, 21 May 1968.

Siebel, H. D., Digitale Schaltungstechnik, Technische Akademie, Essling, 10 and 11 June 1968.

Wilde, H., Stand und Probleme der Postautomation, Allrussische wissenschaft 1, Popov-Gesellschaft Meeting, Moscow, 14 to 16 May 1968.

Widl, E., Der Schutz von ferngespeisten Zwischenverstärkern für Kleinkoaxialpaare gegen Blitzbeeinflussung, Technisches Komitee für Beeinflussungsfragen, Krems, Austria, 14 to 16 May, 1968.

Intermetall

Articles

Adam, G., Halbleiterbauelemente für Höhere Spannungen, Tagungsbroschüre, VDE-Fachtagung Elektronik 1968, May 1968.

Mićić, L., Kapazitätsdioden, Tagungsbroschüre, VDE-Fachtagung Elektronik 1968, May 1968.

Mićić, L., and Uhlmann, S., Temperaturkompensierte Z-Diode, Funkschau, no 9, May 1968.

Mićić, L., Diodenabgestimmter Resonanzkreis, Internationale Elektronische Rundschau, no 6, June 1968.

Pruin, W., Kapazitätsdioden-Abstimmung der Mittelwelle, Funkschau, no 11, June 1968.

Lectures

Mićić, L., Preselection Circuit with Tuner Diodes, IEEE Chicago Spring Conference 17 June 1968, Chicago, USA.

Mićić, L., Kapazitätsdioden, VDE-Fachtagung Electronica, 2 May 1968, Hanover, West Germany.

Bell Telephone Manufacturing Company

Lecture

Adelaar, H. H., De toepassing van Computers in de Communicatietechnik (Application of Computers in the Communication Techniques), Holiday Course on Use of the Computers in Industry and Organisation, IEEE, Technical High School of Gwent, Holland.

Laboratoire Central de Télécommunications

Lectures

Desauty, J., La fiabilité d'un ensemble non réparable dans les techniques spatiales, Conservatoire National des Arts et Métiers, 24 April, 1968.

Desauty, J., Notions de fiabilité, Le Matériel Téléphonique, 3 May 1968 and Compagnie Générale de Métrologie, Annecy, 27 June 1968.

Desauty, J., La fiabilité dans le domaine spatial, École Polytechnique de l'Université de Lausanne, 30 May 1968 and Contravès, Zurich, 26 June 1968.

Gaugain, E., Crossbar System Number 5, 5th High Level Pentaconta Engineer Seminar, 28 March 1968.

Le Materiel Telephonique

Articles

Audic, B., Montcouquiol, J. (LMT): Rouzier, M. and Puech, S. (CNET); La commande du réseau de connexion de l'autocommutateur Périclès-Michelet, Commutation et Électronique, no 21, April 1968.

Robert, F., Exemple de définition automatique des dossiers de fabrication et d'installation des centraux téléphoniques, Onde Électrique, no 494, May 1968.

Lecture

Borel, G., The New Frontier in Quality Improvement, Congress of the American Association for Quality Control, Philadelphia, May, 1968.

Compagnie Générale de Constructions Téléphoniques

Article

Girinsky, A., Gillon, L. and Tat, N., Structure et modularité du système de commutation des messages DS4, Commutation et Electronique, no 21, April 1968.

Lecture

Goudet, G. and Benmussa, H., Exposé sur le système électronique de commutation de messages DS 4 de la CGCT, 10th International Communications Conference IEEE, Philadelphia, 12, 13 and 14 June 1968.

Standard Eléctrica ITT Laboratorios de España

Lectures

de los Rios, F. J., Dimensioning of Telephone Exchanges and Networks, ITT Worldwide Programming Seminar, ITTE, Brussels, 3 April 1968.

de los Rios, F. J., Optimización de Redes, Telecommunication Engineers High School, Madrid, 17 April 1968.

de Miguel, J. A., Aplicación de los Ordenadores al Control de Centrales Telefónicas, Telecommunication Engineers High School, Madrid, 19 April 1968.

Ott, K. W., Engineering Information System and CADEM Hardware-Software Standards, ITT Worldwide Programming Seminar, ITTE, Brussels, 3 April 1968.

Ott, K. W., ITTLS CADEM Activities Presentation to British Post Office, STC, Cockfosters, near London, 7 June 1968.

Ott, K. W., ITTLS Telephone Network Planning Activities, ITT-Iskra Symposium for Yugoslavian Administration, Belgrade, 11 June 1968.

Rodriguez, A., Simulación de Tráfico Telefónico Mediante, Telecommunication Engineers High School, Madrid, 17 April 1968.

Rodriguez, A., ITTLS Traffic Activities Presentation to British Post Office, STC, Cockfosters, near London, June 1968.

Vidondo, F., Areas de Aplicación de los Ordenadores, Telecommunication Engineers High School, Madrid, 16 April 1968.

Standard Telephones and Cables

Articles

Davies, L. M., Communications, Factory Management, April 1968, pp 6, 10 and 13.

Hughes, M., Planning Communication Systems for Business Organisations, Management Decision Journal, Spring 1968, pp 44—47.

Lectures

Boswell, D., Thick-Film Technology in Europe, IEE/IERE/ISHM Conference on Thick-Film Technology at Imperial College, London, 8 to 9 April, 1968.

Boswell, D., Microelectronics in the Component Equipment Interface, NEDC Conference on Microelectronics Management, London, 30 May 1968.

Blay, A. G., Computers as an aid to Productivity in Development and Engineering Design, SIRA Conference, Eastbourne, 6 to 8 May, 1968.

Davidson, D., All Solid-State 960 Channel CCIR Microwave System, IEEE International Communications Conference, Philadelphia, USA, 12 June 1968.

Kliber, L. J., and Salisbury, L. D., The Effects of Process Conditions on the Reliability of Solder to Thick Film, IEE/IERE/ISHM Conference on Thick-Film Technology at Imperial College, London, 8 to 9 April 1968.

Standard Telecommunication Laboratories

Articles

Lewin, L., Amplifying Properties of Bulk Negative-Resistance Material, Electronic Letters, April 1968, pp 145—147.

Lewin, L., The Solution of Singular Integral Equations Over a Multiple Interval and Applications to Multiple Diaphragms in Rectangular Waveguide, SIAM Journal of Applied Mathematics, March 1968, pp 417—438.

Lewin, L., Rational Fraction Approximations and Asymptotic Series, IEE Control and Science Record, June 1968, p 548.

Lewin, L., Generation and Effect of Surface Waves at a Waveguide-Ferrite Boundary, Proceedings IEE, July 1968, pp 895—897.

Lomax, R., and Simmons, J. C., A Thin-Film, Cold-Cathode, Alpha-Numeric Display Panel, Radio and Electronic Engineer, volume 35, section 5, May 1968, pp 265—272.

Lytollis, J., Infrared Optical Communication Systems, Infrared Physics, volume 8, March 1968, pp 123—129.

Rawlings, I. R., Optical Absorption in Silicon Monoxide, British Journal of Applied Physics, series 2, volume 1, June 1968.

Reeves, A. H., PCM; Past, Present and Future, Franklin Institute Journal, volume 285, no 4, April 1968, pp 243—250.

Reeves, A. H., The Communications Revolution, International Science and Technology, April 1968, pp 106—109.

Reeves, A. H., More Calls, Bit-by-Bit, The Times, May 1968, p 27.

Lectures

Butler, M. B. N., Future Electronic Systems, Colloquium on Modern Electronic Devices, West Ham Technical College, London, 30 June 1968.

Flemming, G. P., (1) An Electron Beam Potential Probe, (2) Display of Data from Scanned Measuring System, Scanning Electron Microscopy Conference, Cambridge, 9 June 1968.

Goodman, C. H. L., Materials at High Pressures, Conference on Materials Under Extreme Conditions, Imperial College, London, 9 to 10 April 1968.

Goodman, C. H. L., Radio Variability, Conference on the Chemical Bond in Inorganic Solids, University of Bath, 16—17 May 1968.

Hall, R. A., Non-Linear Compensation, IEEE International Conference on Communications, Philadelphia, 13 June 1968.

Haywood, G. C., RC Active Filters, Surrey University, 6 February 1968.

Hockham, G. H., A Periodically Modulated Surface Reactance Aerial, IEE, London, 16 May 1968.

Hockham, G. H., A Periodically Modulated Surface Reactance Aerial, URSI Conference, Stresa, Italy, 28 June 1968.

Marsh, D. H., Semiconductor Light Emitters and Detectors Microwave Summer School, Leeds, 16 July 1968.

Pion, M., Measurements on Junctions, Sectioning and Probes, Edinburgh University, 29 February 1968.

Pitt, G. D., High Pressure Single Crystal Hall Effect Apparatus to 70 kb, 6th Annual European High Pressure Conference, Cadarache, Aix-en-Provence, 9 April 1968.

Sandbank, C. P., Solid-State Bulk Effects, IERE, East Anglian Section, 8 May 1968.

Smyth, K. J., Design and Limitations of Practical Gyrators, IEE Colloquium, London, 9 April 1968.

Sterling, H. F., Chittick, R. C., and Alexander, J. H., The Properties of Amorphous Silicon, Spring Meeting of Electrochemical Society, Boston, Mass. USA, 5 to 9 May 1968.

ITT Telecommunications — Transmission Department

Articles

Flack, M. M., and Whittaker, A., Microwave Communications, Telephone Engineer and Management,
Part 1, 1 April 1968
Part 2, 1 May
Part 3, 15 June
Part 4, 1 July.
Further parts will be published in later editions during 1968.

ITT Avionics Division

Lectures

Dodington, H., Aircraft CNI Systems, ASME Aviation and Space Convention, Los Angeles, California, 19 June 1968.

Ellis, B. T., Navigation Set Loran AN/ARN-92, National Aerospace Electronics Conference (NAECON), Dayton, Ohio, 6 to 8 May 1968.

ITT Defense Communications Division

Lectures

Wasylkiwskyj, W. (ITTDCD) and Kahn, W. K. (Polytechnic Institute of Brooklyn), Mutual Coupling and Element Efficiency for Infinite Linear Arrays, Symposium held by Union Radio Scientific International (URSI), Stresa, Italy, 24 June 1968.

ITT Gilfillan

Articles

Newdorf, A. S., Technical Writers and Technical Manuals Logistics Spectrum, volume 2, no 2, pp 23—24, summer 1968.

Lectures

Newdorf, A. S., Logistics Considerations in the Management of Technical Publications, San Fernando Valley Chapter of the Society of Logistics Engineers, California, 26 June 1968.

ITT Industrial Laboratories Division

Articles

Branchflower, G. A. and Koening, E. W., The Image Dissector Camera, A New Approach to Spacecraft Sensors, Information Display, volume 5, no 2, pp 55—60, March-April 1968.

Lectures

Davis, J. A., Faeth, P. A. and Sisneros, T. E., Superlinear Cathodoluminescent Phosphors, Electrochemical Society Spring Meeting, Boston, Massachussetts, 5 to 9 May 1968.

Sisneros, T. E., Cathodoluminescence of Eu^{+13} in $LiInO_2$, Electrochemical Society Spring Meeting, Boston, Massachussetts, 5 to 9 May, 1968.

International Telephone and Telegraph Corporation

Lecture

Westfall, T. B., International Communications, the Problems of Progress, International Communications Association, Philadelphia, Pennsylvania, 6 May 1968.

International Telephone and Telegraph System Principal Divisions and Subsidiaries

NORTH AMERICA:

Manufacturing — Sales — Service

Canada

ITT Canada Ltd, Montreal, Quebec (1946)
Branches: Edmonton, Alberta; Regina, Saskatchewan; Winnipeg, Manitoba
Barton Instruments Ltd (Canada), Calgary, Alberta (1962)
Cannon Electric Canada Ltd, Toronto, Ontario (1951)
ITT Industries of Canada Ltd, Guelph, Ontario (1953)
Lustra Lighting (Canada) Ltd, Toronto, Ontario (1959)
Royal Electric Company (Quebec) Ltd, Pointe Claire, Quebec (1958)
Wakefield Lighting Ltd (Canada), London, Ontario (1953)

Jamaica

ITT Standard Electric of Jamaica Ltd, Yallahs (1953)

Mexico

ITT de México, SA de CV, Mexico City (1966)
Industria de Telecomunicacion, SA de CV, Mexico City, Naucaipan de Juarez, Toluca (1957)
Standard Eléctrica de México SA, Mexico City (1953)

Panama

ITT Standard Electric of Panama SA, Panama City (1963)

Puerto Rico

ITT Caribbean Mfg Inc, Rio Piedras (1962)
ITT Caribbean Sales and Service Inc, Rio Piedras (1961)
ITT World Directories — Western Hemisphere Inc, Hato Rey (1966)

United States

Federal Electric Corporation, Paramus, New Jersey (1945)
Intelex Systems Inc, Paramus, New Jersey (1947)
International Standard Engineering Inc, Paramus, New Jersey (1958)
ITT Technical Services Inc, Paramus, New Jersey (1958)
International Standard Electric Corporation, New York, New York (1918)
International Telephone and Telegraph Corporation, Sud America, New York, New York (1929)
ITT Abrasive Products Company, Tiffin, Ohio and Detroit, Michigan (1889)
ITT Advanced Mechanization Laboratories, Chatsworth, California (1967)
ITT Arkansas Division, Camden, Arkansas (1962)
ITT Avionics Division, Nutley, New Jersey (1967)
ITT Cannon Electric Division, Los Angeles, California (1915)
ITT Controls and Instruments Division, Glendale, California (1966)
Barton Instruments, Monterey Park, California (1925)
ITT Snyder, Houston, Texas (1948)
General Controls, Glendale, California (1930)
Hammel-Dahl, Warwick, Rhode Island (1940)
Henze Valve Service, Hoboken, New Jersey (1939)
ITT Data Services Division, Paramus, New Jersey (1965)
ITT Electron Tube Division, Easton, Pennsylvania and Roanoke, Virginia (1962)
ITT Defense Communications Division, Nutley, New Jersey (1967)
ITT Electro-Physics Laboratories Inc, Hyattsville, Maryland (1966)
ITT Environmental Products Division, Philadelphia, Pennsylvania (1966)
Nesbitt, Philadelphia, Pennsylvania (1917)
Hayes, Torrance, California (1941)
Reznor, Mercer, Pennsylvania (1888)
ITT Export Corporation, New York, New York (1962)
ITT Farnsworth Research Corporation, Fort Wayne, Indiana (1947)
ITT Federal Laboratories, San Fernando, California, and Fort Wayne, Indiana (1960; pred co 1909)
ITT Federal Support Services Inc, Richland, Washington (1965)
ITT Fluid Handling Division, Morton Grove, Illinois (1966)
Bell & Gossett Hydronics, Morton Grove, Illinois (1916)
ITT Jabsco, Costa Mesa, California (1941)
Marlow, Midland Park, New Jersey, and Longview, Texas (1924)
Stover, Freeport, Illinois (1907)
ITT Gilfillan Inc, Los Angeles, California (1912)
ITT Lamp Division, Lynn, Massachusetts (1968)
Amplex/Lustra, Carle Place, New York (1934)
Champion Lamp, Lynn, Massachusetts (1900)
Wakefield Lighting, Vermilion and Cleveland, Ohio (1882)
ITT Industrial Laboratories Division, Fort Wayne, Indiana (1962)
ITT Industrial Products Division, San Fernando, California (1957)
ITT Industries Inc, New York, New York (1963)
ITT Jennings Division, San Jose, California (1942)
ITT Mackay Marine Division, Clark, New Jersey (1909)
ITT Microwave Inc, Mountain View, California (1964)
ITT Semiconductors Division, West Palm Beach, Florida; Lawrence, Massachusetts; Palo Alto, California (1962)
ITT Telecommunications Division, Memphis, Tennessee; New York, New York; Corinth, Mississippi; Milan, Tennessee; Raleigh, North Carolina (1952)
ITT Terryphone Corporation, Harrisburg, Pennsylvania (1946)
ITT Wire and Cable Division, Pawtucket, Rhode Island (1964)
Royal, Pawtucket, and Woonsocket, Rhode Island (1921)
Surprenant, Clinton, Massachusetts (1946)
US Telephone and Telegraph Corporation, New York, New York (1965)

Puerto Rico

Puerto Rico Telephone Company, San Juan (1914)

Virgin Islands

Virgin Islands Telephone Corporation, Charlotte Amalie (1959)

SOUTH AMERICA:

Manufacturing — Sales — Service

Argentina

Compañia Standard Electric Argentina SAIC, Buenos Aires (1919)
ITT Latin America Inc, (Area HQ), Buenos Aires (1967)

Brazil

Standard Eléctrica SA, Rio de Janeiro (1937)
Eletrônica Industrial SA, São Paulo (1960)

Chile

Compañia Standard Electric SAC, Santiago (1942)

Colombia

ITT Standard Electric de Colombia SA, Bogotá (1963)

Ecuador

International Standard Electric of New York Ltd (Branch), Quito (1962)

El Salvador

International Standard Electric of New York Ltd (Branch), San Salvador (1962)

Surinam

ITT Standard Electric Surinam NV, Paramaribo (1965)

Venezuela

ITT de Venezuela CA, Caracas (1957)

Chile

Compañia de Teléfonos de Chile, Santiago (1930)

Peru

Compañia Peruana de Teléfonos SA, Lima (1920)

EUROPE:

Manufacturing — Sales — Service

Austria

Standard Telephon und Telegraphen AG, Czeija, Nissl & Company, Vienna (1884)

Belgium

Bell Telephone Manufacturing Company, Antwerp (1882)
ITT Europe Inc (Area HQ), Brussels (1960)
ITT Standard SA (Branch), Brussels (1961)

Denmark

Standard Electric Aktieselskab, Copenhagen (1931)

Finland

Standard Electric Puhelinteollisuus Oy, Helsinki (1940)

France
Cannon Electric France SA, Toulouse and Paris (1962)
Centre Français de Recherche Operationelle (CFRO), Paris (1954)
Claude/Paz et Visseaux, Paris (1930)
Compagnie Générale de Constructions Téléphoniques, Paris (1892)
Compagnie Générale de Métrologie, Annecy (1942)
Graetz-France, Boulogne-Billancourt (1962)
Laboratoire Central de Télécommunications, Paris (1945)
Le Matériel Technique Industriel, Paris (1940)
Le Matériel Téléphonique, Paris (1889)
Océanic-Radio, Paris and Chartres (1946)
Société des Produits Industriels ITT, Paris (1964)
Société Industrielle de Composants pour l'Electronique, Levallois-Perret (1963)

Germany
Deutsche ITT Industries GmbH, Freiburg (1952)
Dräger GC Regelungstechnik GmbH, Essen (1958)
Intermetall GmbH, Freiburg (1952)
Standard Elektrik Lorenz AG, Stuttgart (1879)
Graetz KG, Altena (1947), and other subsidiaries
Alfred Teves GmbH, Frankfurt (1906)

Greece
ITT Hellas AE, Athens (1965)

Italy
Fabbrica Apparecchiature per Communicazioni Elettriche Standard SpA, Milan (1909)
Societá Impianti Elettrici Telefonici Telegrafici e Construzioni Edili SpA, Florence (1931)

Netherlands
Nederlandsche Standard Electric Mij NV, The Hague (1911) and affiliated companies

Norway
Standard Telefon og Kabelfabrik AS, Oslo (1915)

Portugal
Fabricação de Conjuntios Electrónicos SARL, Cascais (1967)
Standard Eléctrica SARL, Lisbon (1932)

Spain
Compañia Internacional de Telecomunicación y Electrónica SA, Madrid (1931)
Marconi Española SA, Madrid (1935)
Compañia Radio Aérea Maritima Española SA, Madrid (1931)
Standard Eléctrica SA, Madrid (1926)

Sweden
Standard Radio & Telefon AB, Barkarby (1938)

Switzerland
Intel SA, Basle (1961)
ITT Standard SA, Basle (1964) (branches in several countries)
Standard Téléphone et Radio SA, Zurich (1935)
Müller-Barbieri AG, Wettswil (1959)
Steiner SA, Berne (1927)

United Kingdom
Cannon Electric (Great Britain) Ltd, Basingstoke (1952)
Creed and Co Ltd, Brighton (1912)
ITT Fluid Handling Ltd, London (1967)
ITT Industries Ltd, London (1964)
Maclaren Controls Ltd, Glasgow (1844) and other subsidiaries
Standard Telephones & Cables Ltd, London (1883)
Standard Telecommunication Laboratories Ltd, London (1945) and other subsidiaries

AFRICA AND THE MIDDLE EAST:

Manufacturing — Sales — Service

ITT Africa and the Middle East
(a division of ITT Europe Inc), (Area HQ) London (1966)

Algeria
Societe Algérienne de Constructions Téléphoniques, Algiers (1947)

Congo
Bell-Congo, Kinshasa (1967)

Iran
ITT Battery Company of Iran, Tehran (1966)
Standard Electric Iran AG, Tehran (1955)

Morocco
ITT Maroc SA, Casablanca (1967)

Nigeria
ITT Nigeria Ltd, Lagos (1957)

Republic of South Africa
Standard Telephones and Cables (SA) (Pty) Ltd, Boksburg East (1956)
ITT Supersonic South Africa (Pty) Ltd, Boksburg (1951)

Rhodesia
Supersonic Radio Mfg Co (Pvt) Ltd, Bulawayo (1950)

Tunisia
ITT Hotel Corporation of Tunisia, Tunis (1967)

Turkey
Standard Elektrik ve Telekomünikasyon Ltd, Sirketi, Ankara (1956)

Zambia
ITT (Zambia) Ltd, Ndola
ITT Supersonic Radio Zambia Ltd, Livingstone (1965)
Regional offices of ITT Africa and the Middle East: Luanda, Angola; Nairobi, Kenya; Beirut, Lebanon; Dakar, Senegal; Tunis, Tunisia

FAR EAST AND PACIFIC:

Manufacturing — Sales — Service — Operations

Australia
Cannon Electric (Australia) Pty Ltd, (50 % interest) Melbourne (1955)
ITT Oceania Pty Ltd, Sydney (1966)
Standard Telephones and Cables Pty Ltd, Sydney (1912)
ITT Australia Pty Ltd, Brisbane and other cities (1930)
STC Finance Ltd, Sydney (1966)

Hong Kong
ITT Far East and Pacific Inc, (Area HQ) Hong Kong (1961)
ITT Far East Ltd, Hong Kong (1961)
Transelectronics Ltd, Hong Kong (1965)

India
ITT Far East and Pacific Inc, (Branch) New Delhi (1965)

Indonesia
ITT Far East and Pacific Inc, (Branch) Djakarta (1967)

Japan
ITT Far East and Pacific Inc, (Branch) Tokyo (1961)

Malaysia
ITT Far East and Pacific Inc, (Branch) Kuala Lumpur (1967)

New Zealand
Standard Telephones and Cables Pty Ltd, (Branch) Upper Hutt, Wellington (1914)

Pakistan
ITT Far East and Pacific Inc, (Branch) Karachi (1967)

Philippines
Globe-Mackay Cable and Radio Corporation, Manila (1935)
ITT Philippines Inc, Makati, Rizal (1960)
Philippine Press Wireless Inc. Manila (1937)

Thailand
ITT Far East and Pacific Inc, (Branch) Bangkok (1966)

BUSINESS AND CONSUMER SERVICES

Abbey Life Assurance Co Ltd, (50 % interest) London (1961)
Hamilton Management Corporation, Denver, Colorado (1931)
Intel Finance SA, Lausanne (1965)
Internationale Levensverzekering Mij NV, (50 % interest) Amsterdam (1966)
ISE Finance Holdings SA, Luxembourg (1966)
ITT Avis Inc, Garden City, New York (1956)
ITT Consumer Services Corporation, New York, New York (1966)
Airport Parking Co of America, Cleveland, Ohio (1954)
ITT Aetna Finance Company, Clayton, Missouri (1918)
Bergon Corporation/Island Finance, Santurce, Puerto Rico (1959)
ITT Financial Services Inc, New York, New York (1964)
Great International Life Insurance Company, (50 % interest) Atlanta, Georgia (1964)
International Telephone and Telegraph Credit Corporation, New York, New York (1961)
Kellogg Credit Corporation, New York, New York (1953)
ITT Hamilton Life Insurance Company, Clayton, Missouri and Denver, Colorado (1955)
Howard W. Sams & Co Inc, Indianapolis, Indiana (1946) and subsidiaries

INTERNATIONAL COMMUNICATIONS OPERATIONS

American Cable & Radio Corporation, New York (1939)
- All America Cables and Radio Inc (1878)
- The Commercial Cable Company (1883)
- Globe-Mackay Cable and Radio Corporation (1935)
- ITT Central America Cables and Radio Inc (1963)
- ITT Cable and Radio Inc, Puerto Rico (1922)

ITT Communications Inc, Virgin Islands (1963)

ITT World Communications Inc (1926)

Press Wireless Inc (1929)
- Philippine Press Wireless Inc (1937)
- Press Wireless Uruguaya (1942)
- Teleradio Brasiloira Limitada (1938)
- ITT Comunicacoes Mundiais SA, Rio de Janeiro (1930)
- ITT Comunicacoes Mundiales SA, Buenos Aires (1928)
- ITT Comunicacoes Mundiales SA, Santiago (1928)

Radio Corporation of Cuba, Havana (1922)

NOTE: International telegraph offices are operated in the following countries: Argentina, Bolivia, Brazil, Canada, Canal Zone, Chile, Dominican Republic, Ecuador, Guatemala, Haiti, Netherlands Antilles, Nicaragua, Panama, Peru, Philippines, United Kingdom, United States (including Puerto Rico and the Virgin Islands), Uruguay, Venezuela.

INTERESTS AND ASSOCIATE LICENSEES
(minority and other)

Australia
- Austral Standard Cables Pty Ltd, Melbourne (1948)

France
- Lignes Télégraphiques et Téléphoniques, Paris (1920)

Italy
- Società Italiana Reti Telefoniche Interurbane, Milan (1921)

Japan
- Nippon Electric Co Ltd, Tokyo (1899)
- Sumitomo Electric Industries Ltd, Osaka (1920)

Figures in parentheses refer to founding date of unit or of predecessor.

Book Review

Uncertainty in Nature and Communications

H. B. Rantzen of Standard Telecommunication Laboratories is the author of a recently published book on Uncertainty in Nature and Communications. It is divided into four parts and 8 chapters as follows.

Part 1, Uncertainty per se
1. Law and disorder
2. The normalized Neogaussian solution
3. Statistical interpretations

Part 2, Uncertainty in nature
4. In the lower atmosphere
5. In gravity

Part 3, Uncertainty in communication
6. In speech
7. In radio propagation at microwave frequencies

Part 4, Matters of opinion
8. The proper study of mankind is man.

The book is 5·25 by 8·25 inches (13·5 by 21 centimeters) and contains 151 pages. It is published by Hutchinson Scientific and Technical Publications, 178—202 Grand Portland Street, London, W1, England, at 50 shillings per copy.

ITT Appointments

Manuel Marquez Balin, managing director of SESA, Madrid, has been appointed a member of the technical advisory board of the Spanish Institute of Electricity and Automation, and of the Spanish Center for Physics Research. Both organizations are part of the National Scientific Research Center, a key governmental body.

Ervin M. Bradburd was recently appointed director of Engineering for ITT Defense Communications Division. Mr. Bradburd, who came to ITT from RCA Communications Systems Division, will be responsible for engineering and product development. The ITT division develops and manufactures communications switching and transmission systems, including satellite subsystems and earth terminals for satellite communications.

Gisto Canestrari was recently elected a vice president of ITT World Communications Inc. Mr. Canestrari will serve as director of rates, tariffs and agreements. A retired colonel in the US Air Force, he joined ITT Worldcom as deputy director, rates and tariffs, in 1965.

Roy N. Colin has been named director of business planning and development of ITT Data Services. In the newly-created position, Mr. Colin will be responsible for the overall direction of the division's short- and long-range business planning activities, market research, marketing strategies and related activities.

Roger Desoille was recently elected by the board of directors of the Compagnie Generale de Metrologie as managing director. Mr. Desoille succeeds David A. Lush who was recently appointed managing director of the Societe Claude in Paris, a new affiliated company of the ITT System.

Don L. Eddy was recently appointed data processing and systems manager for ITT Jabsco, Fluid Handling Division, International Telephone and Telegraph Corporation. Prior to joining ITT, Mr. Eddy acted as a consultant in the installation of computers for various organizations in the Los Angeles area.

J. Evans has been appointed assistant director of Research, Materials and Components, at Standard Telecommunication Laboratories, Harlow, Essex.

Georges Goudet has been elected chairman of the board of Compagnie Generale de Constructions Telephoniques. Mr. Goudet replaces Paul Queffeleant. The board of directors confirmed on Mr. Queffeleant the title of honorary chairman of CGCT.

Manuel S. Krupsaw has been appointed chief industrial engineer by ITT World Communications Inc. Before joining the ITT System, Mr Krupsaw was employed as an industrial engineering supervisor at Jamesbury Corporation in Worcester, Mass., and has held key managerial positions with several other companies in the East and Midwest.

Bruce M. Prevost has been named manager-Programming for ITT Defense Communications Division, Nutley, N. J. He is responsible for all programming in the Engineering department and will advise the Marketing department of new business opportunities in the software area. He comes to ITT from Western Union Telegraph Company, where he was manager-message switching applications.

Gene P. Ross has been appointed general sales manager of ITT Aerospace Controls. In his new post, Mr. Ross will be responsible for all sales and product management functions.

Ronald W. Satzke has joined ITT Bell & Gossett, Fluid Handling Division, as industrial sales manager. Before joining ITT Bell & Gossett, Mr. Satzke was product manager for the A. J. Gerrard Company in Des Plaines, Illinois.

G. James Saveriano has been appointed director of Operations Control for ITT Defense Communications Division, Nutley, N. J. He is responsible for managing programs in satellite communications, store and forward message switching systems, automatic communications circuit switching systems, military antennas and tropospheric-scatter and line-of-sight radio terminals.

Hermann Scheiffele, a director of Standard Elektrik Lorenz, A. G., and manager of that company's West division with headquarters at Dusseldorf, retired on June 28. Director Scheiffele has been with SEL for eleven years.

Gordon F. Scott has been appointed comptroller for ITT Jabsco, a unit of ITT's Fluid Handling Division. Mr. Scott joined ITT in 1960 as a financial analyst at ITT Headquarters. He subsequently held posts in various ITT units as audit manager, manager of budgets and forecasts, and assistant comptroller.

A. B. Sparzani recently was appointed special representative in Venezuela and Colombia for ITT World Communications, Inc., with headquarters in Caracas, Venezuela. In this capacity Mr. Sparzani will have direct responsibility for all activities related to the promotion, growth and solicitation of telex and lease business and the maintenance and improvement of ITT ICO's relationship with the respective governments and connecting carriers.

Stanley B. Tupper was recently appointed product line manager Bell & Gossett ITT, Fluid Handling Division, International Telephone and Telegraph Corporation. In this position, Mr. Tupper will be responsible for overall product management of the hydronic specialities, centrifugal pumps, heat transfer equipment and plumbing product lines.

Ralph E. van Hoorn, director-Marketing, North America, has been re-elected a director and vice president of the Electronic Industries Association, and J. A. Milling, senior vice president of Howard W. Sams has been re-elected treasurer.

F. A. Weaving was recently appointed administrative manager at Standard Telephones and Cables (SA) (Pty) Ltd. Mr. Weaving was previously marketing services manager.

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