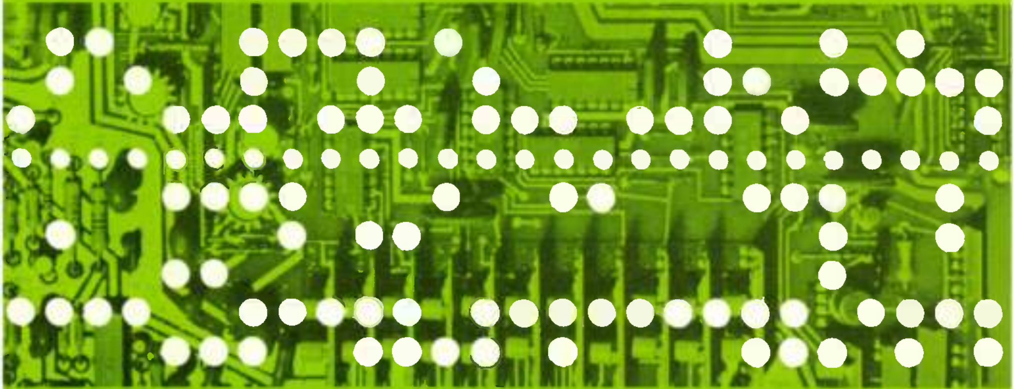
GTE LENKURT

DEMODULATOR

APRIL 1972

NEW MAINTENANCE AND TESTING TRENDS



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Troubleshooting and testing methods are undergoing notable changes in the telecommunications industry. The increasing use of integrated circuitry in modern equipment has supplied the impetus for modification of traditional field repair and testing methods.

The decreasing cost of telecommunications equipment over the past few years has been largely due to the use of integrated circuits in system design. While use of this circuitry provides a high degree of equipment reliability, it also makes isolation of malfunctions by use of conventional field-test methods more difficult to carry out. This is true in the case of modern FDM (frequency division multiplex) subassemblies, and especially true of subassemblies used on digital transmission equipment. Figure 1 shows the prolific use of integrated circuits in a GTE Lenkurt PCM (pulse code modulation) common equipment unit.

Traditionally, when a user of telecommunications equipment purchased a system, he was supplied with system diagrams, schematics, and other instructional material which his technicians could use to troubleshoot and maintain the equipment. Today, with equipment utilizing complex integrated circuits and thin- and thick-film hybrid circuits, this concept of field repair is beginning to lose its practicality.

Integrated Circuits

The branch of electronics that has to do with integration of components is known as *microelectronics*, and supplies the basic impetus for the new trend in field maintenance techniques.

The function of an integrated circuit is essentially the same as that of a circuit made up of discrete components – it is designed to perform a particular signal processing function. The difference lies in that the components of an integrated circuit – transistors, diodes, capacitors, resistors, etc. – have been inseparably formed, on a single semiconductor substrate. It is this "inseparable formation" which makes the integrated circuit potentially non-repairable.

Hybrid Film Circuits

Although GTE Lenkurt uses commercially available integrated circuits, it also manufactures hybrid film circuits for use in its equipment. This type of circuit is used when a particular custom design is necessary.

In hybrid film circuits, passive elements such as conductors, capacitors, and resistors, are formed by applying specially formulated layers of conductive, dielectric, and resistive inks to a ceramic substrate. The active elements – such as diodes and transistors – are connected to the integrated passive formation as discrete components. Therefore, hybrid film circuit construction incorporates aspects of both monolithic integrated circuits and discrete component circuits. Figure 2 shows the general appearance of the hybrid film circuits produced by GTE Lenkurt.

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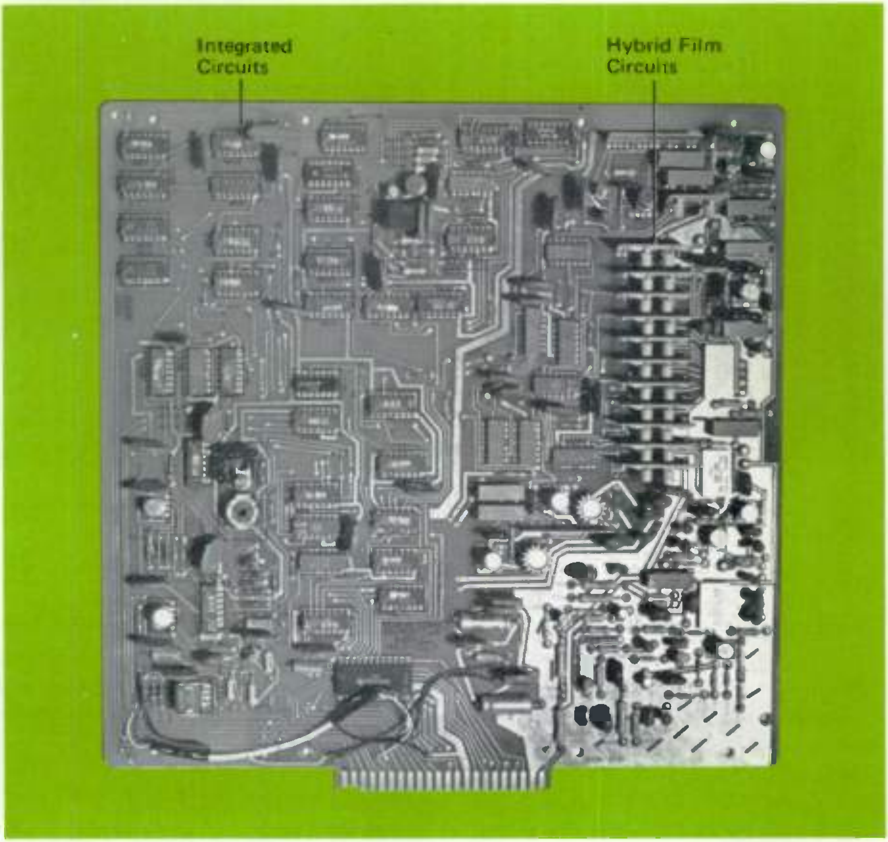

Figure 1. Modern telecommunications equipment subassemblies widely employ the use of integrated and hybrid film circuits.

The Problem of Integrated Circuitry

Although equipment which does not utilize microelectronics is still being manufactured and will be operational for years to come, a look into the future reveals ever increasing applications of integrated circuitry. This stems from the need to provide more reliable, lower priced, and more compact telecommunications equipment. The price to be paid for these advantages is the growing impracticality of traditional field repair methods. Such problems as defective resistive or capacitive elements in a hybrid film circuit cannot be solved in the field; neither is it conceivable that a polylithic crystal filter which, like the hybrid film circuit, is constructed under clean-room conditions, could be repaired in the field (see Figure 3). Even if a malfunction is traced to a particular hybrid film circuit, its removal is a delicate process because of the closeness of associated components and because of the uniformity of heat required on the leads. A misapplied soldering iron could not only destroy nearby components, but could

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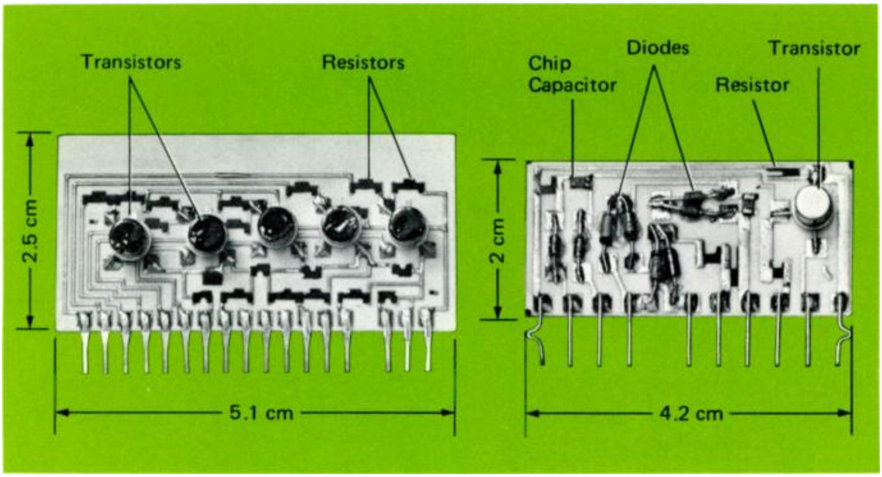

Figure 2. General appearance of GTE Lenkurt hybrid thick-film circuits before encapsulation.

also damage the printed circuit board.

In addition to these problems, the complex nature of integrated circuits makes it difficult to discern whether a particular substrate is indeed the problem, and not some other aspect of the surrounding circuitry. To successfully test an integrated circuit, the technician now needs more sophisticated test equipment such as higher frequency oscilloscopes and higher impedance, high frequency voltmeters with probes that bridge the circuitry to assure that suitable measurements are being made. Usually, the technician cannot rely on simple dc measurements to determine whether an integrated circuit is functioning correctly.

In many cases, the integrated circuitry inherent in modern equipment is custom designed to perform a particular function within a subassembly; a customized circuit of this type is seldom available from distributors and can be obtained only from the equipment manufacturer in most cases. The difficulty of tracing a problem to a particular circuit, the risk involved in replacing that circuit, and the high cost of the test equipment necessary for the whole process hint at the need for changes in the field maintenance approach.

New Concept for Field Maintenance

The new trend for field maintenance procedures is to isolate system malfunctions to the level of a plug-in subassembly by a sequence of steps using block diagrams. Once the technician traces a problem to a defective plug-in unit, that unit should be replaced and the defective one returned to the manufacturer. The manufacturer may then take the responsibility of replacing the complex parts which cannot be repaired in the field. Although this new concept seems to make the field technician's job easier, it also requires of him an expanded awareness of the overall system so that he may be able to isolate the defective subassembly quickly and accurately. His transition will be from an acute awareness of the function of individual

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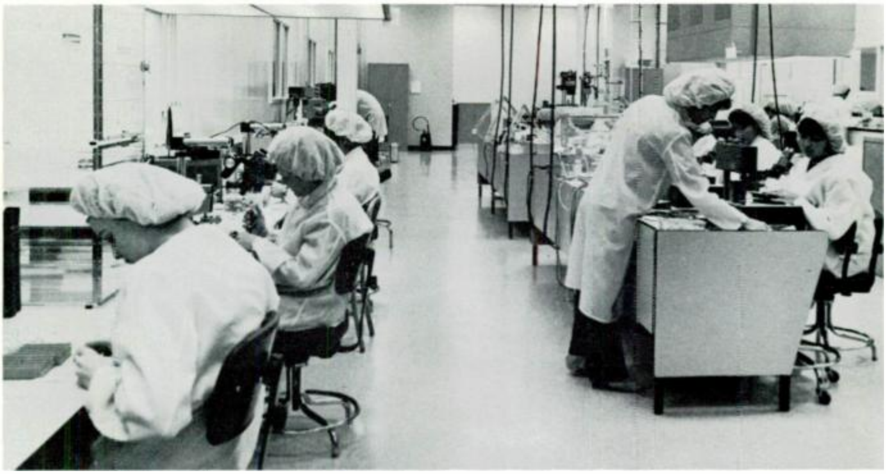

Figure 3. Integrated circuits, hybrid film circuits, and polylithic crystal filters are constructed in a clean-room environment.

circuits, to a working knowledge of total systems.

Modern telecommunications equipment is not totally made up of microelectronics. There *are* discrete components which can be replaced, although certain guidelines should be carefully considered in the process. Replacing of selected or tuned parts and their related components should be left to the responsibility of the manufacturer. Parts which are difficult to remove without physically damaging nearby parts, or the printed circuit board, should also be left to the manufacturer. Units with defective integrated and hybrid film circuits, should definitely be returned to the factory for service.

Automatic Testing Devices

The problems of modern subassembly test and repair require increasing consideration from the manufacturer. Today's manufacturer of telecommunications equipment is faced with a greater need to provide faster and more efficient test and repair service of new units, and defective units returned from the field. Part of the answer to this predicament is the use of automatic testing devices.

An automatic testing device – whether at the quality control or at the repair station level – is an invaluable tool in detecting problems in subassemblies. Such devices provide fast, efficient test and repair of subassemblies, and at the same time keep field repair costs at a minimum.

Although automatic testing devices have been used by manufacturers for some years, these have been mainly hard-wired, semi-automatic units. Now, a new generation of computer-controlled test systems is being used to meet the demand for efficient testing and trouble shooting of subassemblies with a variety of options. While a hard-wired automatic testing device might only serve to test one particular subassembly, the computerized test system has the flexibility to test a variety of units which perform different functions. This flexibility is limited only by the capacity of the

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Figure 4. The GTE Lenkurt System 250 computerized test set in operation.

programmable computer memory, and allows for the expansion of testing procedures as new subassemblies are designed and manufactured. Two such systems have been developed by GTE Lenkurt and are presently being used to test and troubleshoot PCM channel units and common equipment subassemblies.

Testing PCM Subassemblies

The GTE Lenkurt System 250, shown in Figure 4, uses commercially available test equipment and a minicomputer to test and troubleshoot PCM channel units. It has the capacity to perform 100 different tests without having to exchange core memory information. The function of the computer in this automatic system is to monitor test equipment inputs to the unit under test and to evaluate whether the unit is operating properly. The evaluation is accomplished in the computer memory by comparing the correct values with the actual values of the unit under test. All failures are indicated by a print-out on a tag printer. At the end of the complete test, a go, no-go light indicates the channel-unit condition. If a no-go condition is indicated, the print-out tag accompanies the unit to a repair station.

The entire test sequence takes approximately one minute, thus several hundred channels can be tested during an eight-hour period. The relationship of equipment for the System 250 is shown in Figure 5. Unlike hard-wired test systems, this automatic test system remains uncommitted to any particular type of telephone equipment up to the interface connector (unit

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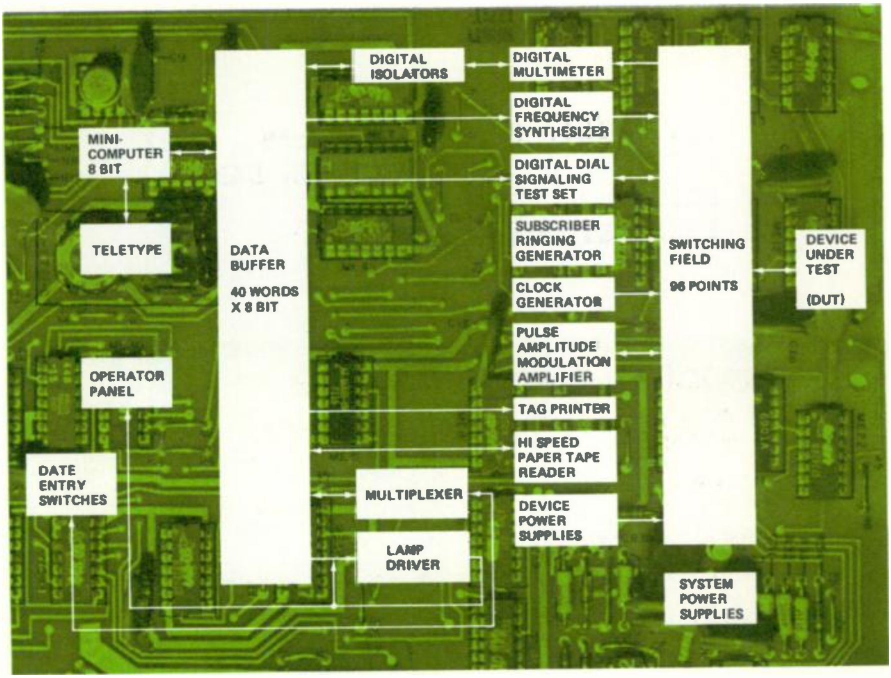

Figure 5. The relationship between equipment in the System 250.

plug-in location). By changing the channel unit holding fixture and a portion of the core storage, any other unit can be tested within the capabilities of the test instruments.

Testing Common Equipment Subassemblies

The GTE Lenkurt System 300, commonly known as the "FIXIT," is used to test PCM common equipment subassemblies. Although this system does not use a computer to control the test equipment, it *does* contain a programmable memory which allows it to compare the correct values for a subassembly with the actual values of the unit under test. The System 300 has the capacity to check the value of each component on a common equipment printed circuit board (such as shown in Figure 1) without having to remove any component from the subassembly.

Automatic test systems such as the Lenkurt 250 and 300 provide quick and efficient testing of new or field-returned subassemblies. The use of such systems frees the technician and engineer to concentrate his knowledge on more complex problems which are not readily solved by computers.

The forthcoming changes in equipment will require the modification of traditional maintenance and testing techniques to meet the demands of an expanding world of telecommunications. Speed and efficiency, both in the field and in manufacturing, are the prerequisites for attaining this goal.

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VIDEO, VOICE & DATA
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The GTE Lenkurt Demodulator is circulated monthly to technicians, engineers and managers employed by companies or government agencies who use and operate communications systems, and to educational institutions. Permission to reprint granted on request.

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GTE LENKURT

DEMODULATOR

MARCH 1972

TWENTIETH ANNIVERSARY

Yesterday and Today

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The Demodulator has kept pace with innovations in electronics for 20 years, serving its readership as an informative, educational vehicle, covering some of the most complex advances in the telecommunications industry. The need for this publication arose early in Lenkurt's history as transmission technology became increasingly complex.

Man's progress in the communications field has been significant since Alexander Graham Bell's invention in 1876. The first practical telephone circuits employed a single wire with a ground return and a telephone connected at each end. Under these conditions, each telephone could be connected only with the telephone at the opposite end of the circuit – and not to any others. From this early arrangement there developed the idea of establishing a practical means of interconnecting all the telephones in a local area through an exchange office. Because of excessive electrical disturbances, the single-wire line was replaced with the two-wire line which utilized two closely paralleled wires. One of the wires provided the current return path instead of returning the current through the earth. This arrangement was known as an open-wire line since bare wire was attached to insulators on crossarms that were mounted near the tops of poles.

As the demand for more telephone circuits increased, and the number of wires stretching between cities began to reach its limit (see Figure 1), a method of increasing the number of telephone circuits without adding more wire became imperative. Research in this area led to the development of multiplexing – the combination of several individual voice circuits for simultaneous transmission over a common transmission line. This development existed in a primitive state shortly before 1900. The advent of the vacuum tube and its further refinement by addition of the control grid cleared the way for the rapid advancement of multiplex telephony.

Early Systems

In 1918, the Bell System placed the first carrier system into operation between Baltimore, Maryland and Pittsburgh, Pennsylvania. This system, designated as Type A, provided four two-way channels for use over a single open-wire line, with the same carrier frequencies used for each direction of transmission. The Type B system was put into use by Bell in 1920. In this system, three two-way channels were provided using different frequencies for each direction of transmission. The technique of using different frequencies for each direction provided what is known as an equivalent *4-wire system*. Both the Type A and B systems used amplitude modulation to superimpose the voice signals onto the carrier frequency. In the Type A system, the carrier and one sideband were suppressed with only the remaining sideband being transmitted. In the Type B system, one sideband was suppressed while the other sideband and the carrier were transmitted.

The Type C system, introduced in 1925, incorporated the best features of the two earlier systems. This system

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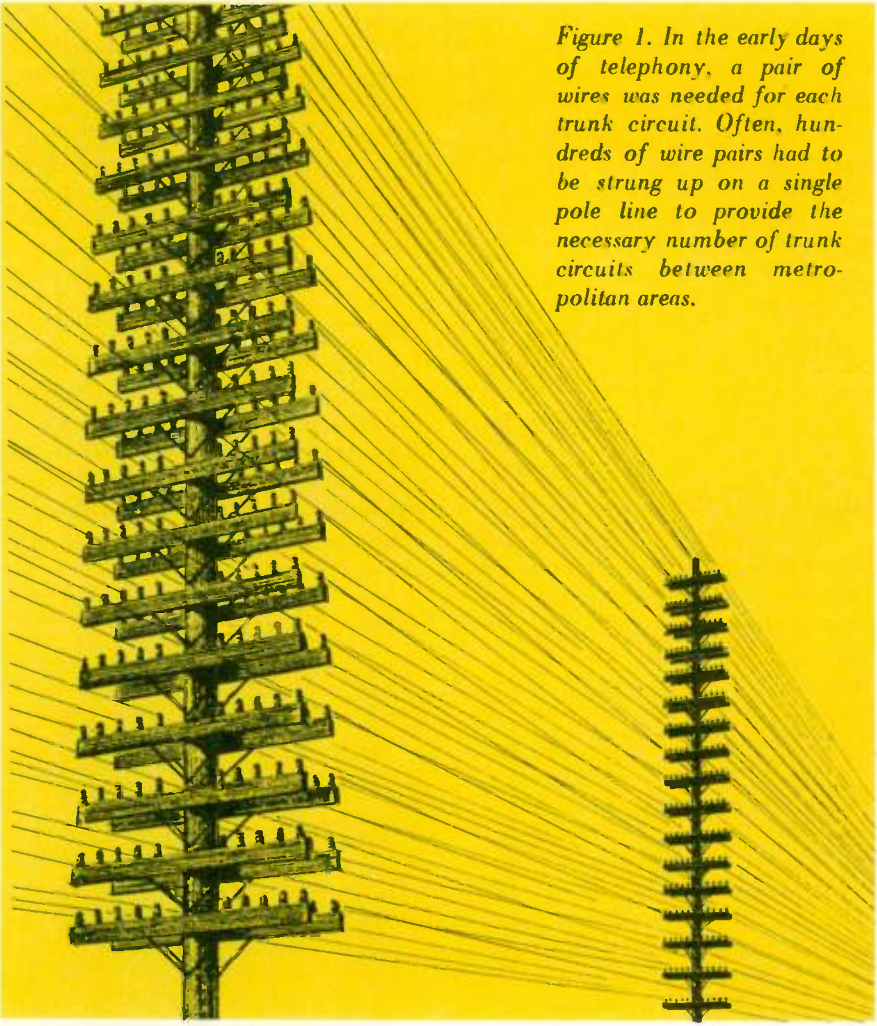

Figure 1. In the early days of telephony, a pair of wires was needed for each trunk circuit. Often, hundreds of wire pairs had to be strung up on a single pole line to provide the necessary number of trunk circuits between metropolitan areas.

provided three channels using different frequencies for each direction of transmission, and transmitted only one sideband. The Type C system became extensively used throughout the Bell System's long distance toll routes and by 1928, several transcontinental 3-channel routes were in operation in addition to many shorter systems between such points as Chicago and Pittsburgh, and San Francisco and Los Angeles.

12-Channel Systems

Technological advances soon proceeded far enough to permit the development of 12-channel carrier systems designed to operate over cables and open-wire lines. A 12-channel system was used on a transcontinental cable route in 1938. The frequency band for this system was from 12 to 60 kHz for transmission in both directions. This was done by using a different wire pair for each direction, thus establishing a

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physical 4-wire system. The lower line frequency was achieved by using a new technique called *group modulation*. In the earlier systems, the carrier line frequencies were accomplished by a single direct modulation step. Group modulation, however, used two or more steps of modulation to establish the line frequencies. One of the most significant advantages of group modulation was that it provided a simplified means of interconnecting standard sub-groups of channels at line frequencies, a technique that was to be employed extensively in later carrier systems.

Advances in Communications

As World War II became a reality for the United States, the telecommunications industry, along with most other industries, curtailed its peacetime endeavors and concentrated its resources on the war effort. During World War II great advances were made in the field of military communications. These advances were later to have a significant influence upon commercial communications such as microwave, video and higher-density carrier systems.

In 1944, with the end of the war somewhat in sight and with the relaxing of commercial development restrictions, men with foresight realized that there would soon be a demand for expanded communications facilities. Two such men were Len Erickson and Kurt Appert – founders of the company whose name still bears the combination of their first names. Founded in 1944, Lenkurt Electric was destined to make significant contributions to the telecommunications field. With their experience in military communications, Erickson and Appert began to design carrier equipment that would be suitable for commercial purposes, and in 1945 introduced the Type 12 and 17 carrier systems. Both systems were single-channel systems and collectively utilized a frequency range from 12 to 20 kHz, with signaling above the voice channel. These systems were designed for use on open-wire lines, and repeaters were available to permit use on short, medium, or long-haul circuits. The typcial appearance of these early units is shown in Figure 2.

The Demodulator

By 1952, the field of telecommunications had achieved a high degree of sophistication. Innovations such as transistors, silicone diodes, and printed circuits began to be seen as practical applications. As equipment became more specialized, so did the men who

Figure 2. Typical appearance of early Lenkurt Type 12and Type 17 terminals.

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designed it. In many cases specialists in one field were only vaguely aware of what was taking place in other fields of communications. Clearly, a method was necessary for acquainting engineers, managers, technicians, installers, and other individuals who worked in the communications industry, with the various advances being made. It was in this light that the Demodulator came into existence, and its first issue was published in March, 1952.

The early years found the Demodulator staff busy with explanation of basic telecommunications concepts and their applications. Even as these concepts were coming to light, new ones were being introduced, and throughout its 20-year existence, the Demodulator was to print information on such topics as open-wire carrier, signaling, cable carrier, microwave radio, data transmission, and many other related products and applications.

In a sense, the Demodulator has been both witness and recorder to many of the developments in the telecommunications field. In the past 20 years, the Demodulator has endeavored to report not only on GTE Lenkurt developments but also on advances which have taken place in the telecommunications industry as a whole.

Plug-In Components

A significant contribution was made to the telecommunications industry in the early 1950's with the introduction of the "universal carrier" concept. In this Lenkurt development program, carrier systems for all the different transmission mediums were developed by using the same basic parameters for all systems. This eliminated the necessity of demodulating the line signals to voice level at the interconnect point (between cable, open-wire, or radio systems), with only the line and common equipment required at this interface. The result was a substantial cost savings to the user and significantly better transmission quality, since two steps of modulation were saved at each interface. Variations between systems were made only when required in order to obtain the necessary characteristics peculiar to a particular system.

The basic chassis for the universal carriers was the same throughout all systems regardless of channel assignment or particular system, while the frequency-determining components, such as filters and oscillators, plugged into specified pregroup arrangements. An example of the plug-in concept is shown in Figure 3.

Miniaturization

One of the developments which the Demodulator has watched with keen interest has been in the field of miniaturization.

The electronics industry has undergone a progressive miniaturization of equipment component parts as well as entire electronic circuits. From the early vacuum tube hand-wired circuits, the progression has been to transistorized printed circuits, to thick and thin-film integrated circuits.

As reported in the November and December 1971 issues of the Demodulator, the miniaturization of filters has been dramatic. From the early large and bulky filters, technology in this field has improved greatly with the introduction of the polylithic filter developed by GTE Lenkurt. The relative size-reduction of filters over the years is shown in Figure 4. Crystal filters have not only increased the efficiency of equipment, but have also allowed engineers to decrease the size of telecommunications equipment and at the same time increase its performance and capacity.

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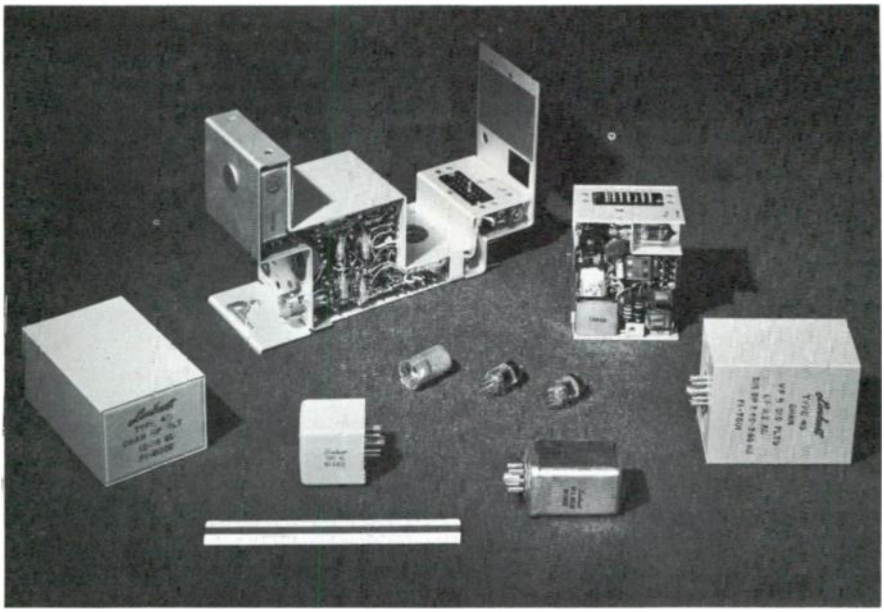

Figure 3. Plug-in components were essential to the universal carrier concept as shown by this Lenkurt Class 45 channel unit.

The major impetus to miniaturization of electronics equipment has been the development of devices and circuits which operate using principles of applied solid-state physics. Because of the importance of solid-state development to the telecommunications field, this subject has been the topic of several Demodulator articles. These articles have progressed in their description from basic transistor analysis to principles of integrated circuitry.

Multiplex Technology

The advances in multiplex technology are as impressive as those made in other fields of communications. In 1946, Lenkurt was producing 3- and 4-channel systems suitable for open-wire lines. These systems required that all channels, common equipment and repeaters be installed in order to function properly. A major development of the late 1940's was the introduction of fully "frequency-stackable" equipment. This type of equipment allowed all channels to operate independently with the exception of the power supply and line filters. Also, the repeaters for the equipment were stackable in that any channel and its corresponding repeater could operate independently without requiring the installation of repeaters for the other channels.

From these early beginnings, the Demodulator has observed and reported the great parade of technological advances in the multiplex field. Developments in solid-state circuitry and filter design have dramatically reduced the size of equipment and expanded channel capacity to such a degree that the space required for a 1260-channel system is not much more than that required for an early 48-channel system (see Figure 5).

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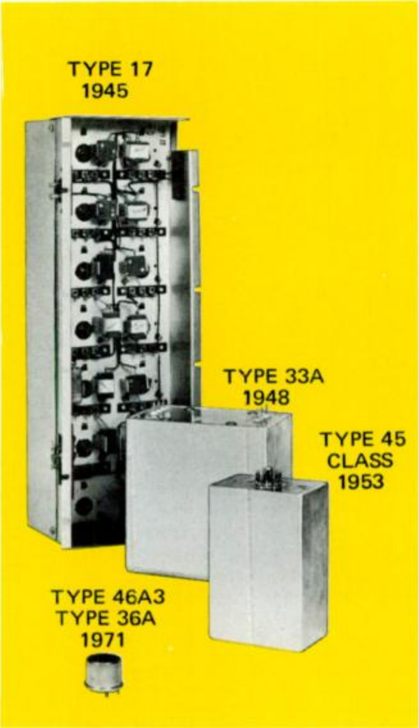

Figure 4. Filter size in GTE Lenkurt equipment has changed dramatically over the years.

Data and PCM

With the advent of the computer age, the Demodulator witnessed and recorded some of the great advances in digital technology. One of these advances was the duobinary coding technique of data transmission which was developed by GTE Lenkurt, and which proved to be a breakthrough in the world of digital transmission. Using this coding technique, which in effect doubled the capacity of the binary system, data transmission systems such as the Lenkurt 26C, could transmit digital signals over conventional voice channels by wire, land or submarine cable, or microwave radio, at fixed speeds of 2400 bits of information per second. The duobinary method, explained in the February, 1963 issue of the Demodulator, allows higher data speeds to be achieved with simple frequency modulation techniques rather than the complex methods previously required.

PCM (pulse code modulation) was first discussed in the Demodulator in January, 1959. The telecommunications industry was long since aware of the advantageous properties of PCM – relative freedom from noise and interference, and regeneration of signals without significant distortion. However, it was not until solid-state technology had made significant advances that PCM became a practical means of transmission.

Unique in its concept, PCM differed greatly from conventional FDM (frequency-division multiplex) techniques. Like FDM, PCM channels share the same transmission medium. Unlike FDM, all PCM channels are not transmitted simultaneously, but "take turns," each being connected to the line very briefly, then replaced by the next. Since PCM is a relatively new form of information transmission, and since the future of PCM as an established transmission technique is apparent, the Demodulator has devoted several articles in recent years to the theory of PCM and its applications.

Microwave

As early as May, 1952, the Demodulator became involved in the explanation of microwave transmission. Using the Lenkurt 72A microwave system as an example, the Demodulator confronted the problems of transmission losses in radio links. In these days, the microwave frequency range was around 900 MHz with a transmission capacity of only up to 36 toll-quality, carrier-derived voice channels, with repeater spacing of 25 to 35 miles.

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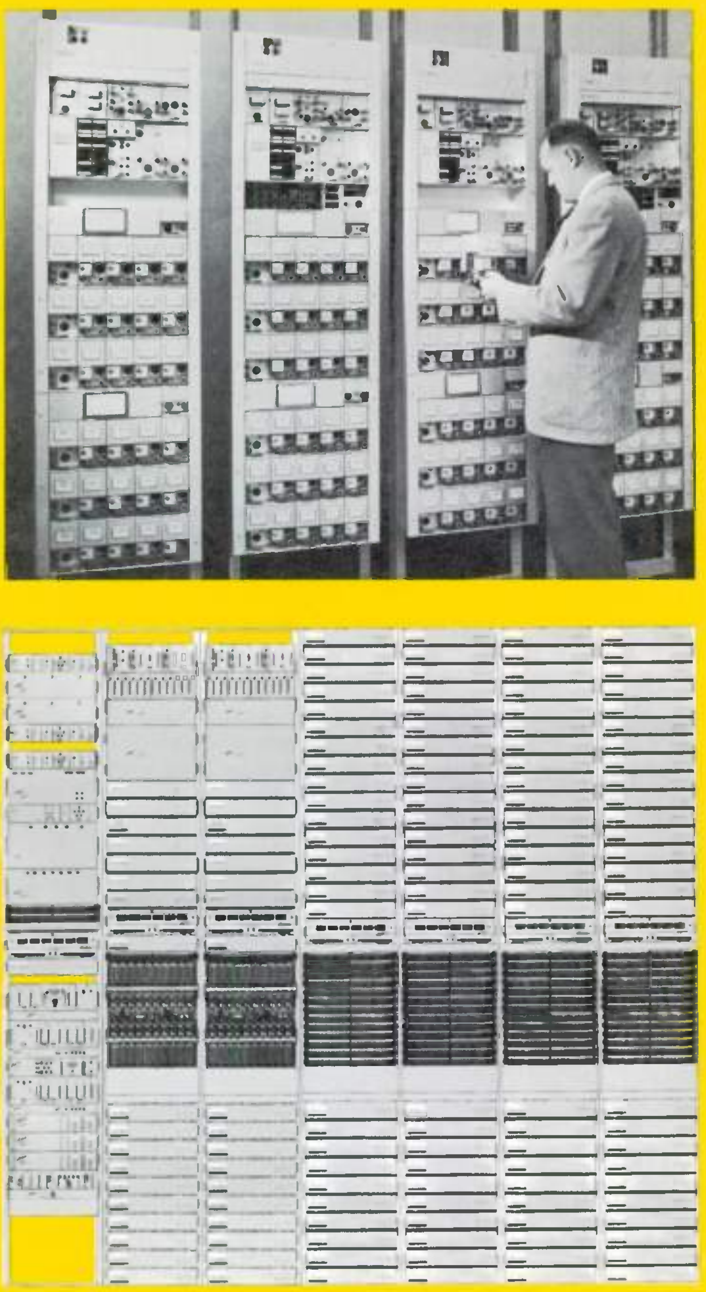

Figure 5. The 45 BX multiplex terminals were large compared to modern 1260-channel systems such as Lenkurt's 46A3.

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Methods of establishing microwave paths have varied over the years. One method, employed by the colorful "Captain Eddy," utilized an airplane equipped with low-altitude radar altimeters. Captain Eddy's low-flying aircraft could often be seen skimming the ground in order to establish ground clearance for microwave transmission paths.

Although line-of-sight radar mapping is still in use today, the most widely used method is path layout using topographic maps, confirmed by ground surveying. Verification of the ground survey includes the use of strobe lights, altimeters, mirrors, and/or metallic reflectors. Another method utilizes a helium-filled balloon with a light source or reflector attached to it. A *simplified* example of this procedure goes something like this: During calm weather, an individual at point A allows the balloon to ascend, controlling the ascent by means of a line attached to the balloon. An individual at point B watches with binoculars in the direction of point A. When point B observes the light source or reflector, he notifies point A. Point A then takes an altitude reading which will indicate the obstruction height of this particular microwave link.

As microwave technology advanced, telephone companies began to find that microwave systems had a definite place in their outside plants since numerous installations had demonstrated that microwave systems could be engineered to be equally, or more reliable than conventional open-wire lines or cables. Subsequent Demodulator articles considered such topics as microwave propagation techniques, waveguide, and antenna applications.

Continual improvements in design and performance – especially solid-state advances – greatly increased the popularity of microwave systems so that by the early 1960's, there existed some high-quality systems capable of handling more than 1200 voice channels or one video channel. Today 1200-1800 channel systems are a matter of course, and their 36-channel predecessors seem to be almost forgotten in the mass of telecommunications history. However, these first systems, their problems and applications, are periodically recorded in the 20-year span of Demodulator issues.

Coaxial Cable Systems

Several Demodulator articles over the years have offered coaxial cable systems as a logical alternative in areas where microwave frequency bands are becoming increasingly congested.

Although coaxial cable has been used for communications since 1936, installation costs have limited its application. Some advantages of a coaxial cable system are high reliability, low maintenance costs, and low-cost expansion. The increasing demand for instant communication between individuals or computers, and the corresponding bandwidths necessary (high-speed data, video, video telephone), often justify the installation of coaxial cable. One coaxial cable link may handle as much traffic as several microwave links since each microwave channel has definite bandwidth limitations.

With the rapid growth of big cities, which is where most high-density communications links terminate, coaxial cable systems are becoming increasingly attractive as so-called "entrance links." This implies that a microwave system does not extend to the downtown area, but the baseband signal is brought there from a point on the perimeter of the city by coaxial cable. This prevents having to re-engineer a system every time a new high-rise

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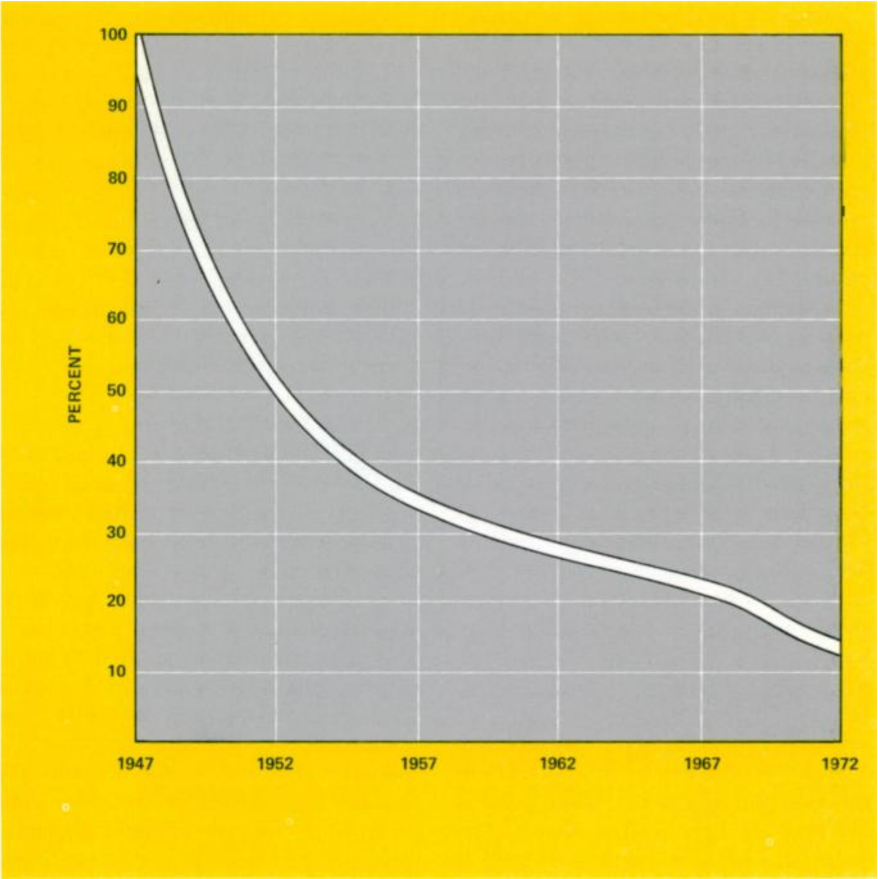

Figure 6. The decreasing price trend of GTE Lenkurt carrier and multiplex equipment reflects the general trend of the telecommunications industry.

building is erected in a microwave path. Also, this method avoids the very real problem of not being able to obtain a microwave frequency in the desired band.

Exchange Carrier

The October, 1960 issue of the Demodulator presented the difficult problem of exchange carrier and offered a solution. Long distance systems required great care in regulating and reducing distortion. For this reason, carrier equipment designed for toll or long haul service was quite elaborate and costly. For shorter distances, the same complex terminal equipment proved too expensive, especially since shorter systems didn't require the same features found in a long system.

Using the Lenkurt 81A exchange trunk carrier as an example, the Demodulator described the advantages of this type of system. The main overall advantage of exchange carrier is its flexibility in expanding plant facilities to meet new demands. As cable cir-

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cuits become fully utilized, exchange carrier channels can be added one at a time. This provides a means for orderly expansion even in areas where demand becomes much greater than had been expected.

Prior to the introduction of exchange carrier, the cost of carrier equipment was such that it could only prove-in on long distance routes. Exchange carrier provided exchange and toll-connecting trunk carrier service for routes of up to 30 miles.

Subscriber Carrier

A particularly successful endeavor for GTE Lenkurt was the development of the subscriber carrier in 1967. Carrier transmission over open wire or cable between the central office and a subscriber is the function of subscriber or station carrier. An ordinary cable pair carries one voice or data channel. This same pair, using a subscriber carrier system, can carry from one to six frequency-derived circuits which can be used for voice or data.

As pointed out in the March, 1970 issue of the Demodulator, subscriber carrier transmission can be an economical alternative to cable when the annual circuit requirements are small or where the circuit length is quite long. If future requirements are uncertain, subscriber carrier provides interim relief, allowing time to gather reliable data before making a major cable addition. Subscriber carrier systems are also advantageous where new cable additions would provide a great many extra pairs that would be idle for several years.

Cost Reduction

In the last two decades, manufacturers of telecommunications equipment have marketed many different types of voice carrier systems ranging from relatively simple single-channel products to highly complex 1260-channel systems.

While the complexity of each carrier product has greatly increased, the average price per channel has decreased steadily over the years and current products are priced substantially less than their representative predecessors of twenty years ago. The main factors which have been responsible for price reductions during the past two decades have been the technological developments in the state of the electronics art and improved design and manufacturing techniques. Using 1947 as an index, figure 6 shows the average declining price trends of GTE Lenkurt carrier and multiplex equipment.

The Future

In the telecommunications industry, a backward glance at the past is permitted only occasionally (*such as on anniversaries or birthdates*). The usual point of attention is to the unlimited possibilities and applications that lie in the future. Challenges are being met daily to keep products ahead of technological changes, and at the same time new demands are being met with more sophisticated communications systems.

As new developments take place, the Demodulator will record and report on these events, for the success of the Demodulator can only be measured by its ability to bring to its readers available information on current developments in a concise and readable form.

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D1/T1	9001B/9101B
D2/T1	9002A/9101B
Radio Multiplex:	
L	46A
Microwave Radio:	
TD2, TD3	75G
TH3	75A
TM, TL	78A, D
FM-3A/4A	759A Modem
Data Transmission:	
43A, 43B	25C/25D
108	25B/108
T1WB-1, T1WB-2, T1WM-1	9003A, 9005A
Auxiliary Equipment:	
LWM-1, N2WM-1 Wideband Modulator	970A
N2WM-2 Wideband Modulator	973A
3A Echo Suppressor	931C
E Type Signaling	927A
E and F Type Signaling	11A

For detailed information and specifications on any of GTE Lenkurt's Bell-compatible equipment, write: GTE Lenkurt Incorporated, Dept. C720, 1105 County Road, San Carlos, California 94070.

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