Bell Laboratories **RECORD**

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Cover *Harold Schonhorn of the Chemical Research Laboratory deposits a monolayer of stearic acid on water surface, prior to bonding thermoplastic to metal (See page 24).*

The ability of the Data Set 202 to transmit information over the regular telephone network makes it one of the most flexible and economical instruments of modern communications.

An FM Data Set for Voiceband Data Transmission

S. T. Meyers

IN THIS AGE of automation, computing machines are performing more and more of our routine business and scientific chores with unmatched speed and accuracy. Data-handling and data-processing have become large, complex fields and are daily becoming ever larger and still more complex. The increasing use of digital equipment requires communications techniques which enable machines to "talk" to machines in a variety of ways and at any distance apart. This, in turn, creates an area of vital interest to the telephone system where there exists an extensive nationwide communication network ready to serve a wide variety of new data needs.

The FM data set developed at the Laboratories is one of several data sets designed to transmit information over the voice-band telephone network. In its role as coupling unit between the business machine and the telephone line, it operates on binary sequential data; the output at the receiver appears as a recovered copy of the data input at the transmitter. The bit (*bi*nary digi*t*) speed, within broad limits, is entirely under the control of the business machine.

Frequency moduation is used because it allows signals to be correctly recovered despite sudden amplitude changes of the carrier during wire-line transmission. Any signal-to-noise advantage resulting from the use of frequency modulation in this application is usually small because of the character of wire-line noise and because of the small deviation ratio usually used to obtain the utmost in transmission speed.

The frequency deviation itself, however, is relatively large—nearly two to one—with the modulated signal swinging between so-called "mark" and "space" frequencies of 1200 and 2200 cycles respectively. Furthermore, with a modulating rate exceeding 1200 bits per second, a mark bit contains less than one cycle of the mark frequency. This generates a carrier interference problem in the lower sideband requiring special design consideration in the data set.

Operational requirements such as these are necessary to insure high efficiency in the use of voice-frequency telephone circuits for data transmission. The most economical design of a set to meet such requrements involves the use of relatively simple circuits. Accordingly, in desiging the FM data set, Laboratories engineers made extensive use of digital techniques to attain the necessary accuracy. They designed the set so that no adjustments would be needed even in manufacture.

The data set is extraordinarily versatile. It may be installed for two-wire or four-wire operation with or without a telephone and with manual or automatic answering of data calls. The data set can be tested from a central test location in the telephone plant. Customers have a choice of two transmitting levels (0 and —6 dbm), two line impedances (600 and 900 ohms), and they have the option of having the set operate with or without delay or amplitude compromise equalizers.

There are two types of FM data sets: one—with the telephone as an integral part of the set—is known as the Data Set 202A and operates on a two-wire basis; the other—where the telephone is separated from the data set—is known as the Data Set 202B and operates in either a two-wire or four-wire arrangement. In two-wire operation, both types generally work on voice channels in the switched telephone network with data speeds presently limited to 1200 bits per second. However, on private lines—where the communication link is fixed and the amplitude is equalized by using special delay circuits — a maximum speed of 1600 bits per second is expected to be offered.

The data set is made up of three basic circuits: the transmitter, the receiver, and the control circuitry. These circuits are shown on page 5. The transmitter and receiver are transistorized and use simple modulation and demodulation techniques; that is, voltage control of a multivibrator frequency at the transmitter and zero crossing detection at the receiver. The control circuitry is composed mostly of relays, which, when used with suitable strapping arrangements

E. R. Bay and Miss G. B. Newmier demonstrate how the Data Set 202 A is used to transmit information between two data points. Both parties are about to press the DATA *button which permits the transfer of information. At the end of transmission, the data set is automatically turned off.*

or with pushbuttons associated with the telephone, allows for changing the modes of terminal operation. The data set operates within close tolerances on plus and minus dc voltages derived from a simple unregulated 115-volt 60-cycle power supply.

Data sets with telephones have four pushbuttons which control the modes of operation. When a customer presses the TALK button, the telephone can be used in the usual way for dialing and talking. When he presses the DATA button, the set changes to the data mode. With the telephone on hook, interlocking safeguards prevent the accidental operation of any of the buttons from interrupting a data call. Only by lifting the telephone and pushing the TALK button can a data call be interrupted.

An AUTO button switches the data set from a manual to an automatic mode for answering data calls. It too, has interlocking safeguards which insure that the terminal and data-processing equipment are in operational readiness. A TEST button switches the set to a mode which permits testing from a central test location in the telephone plant. There are two extra buttons which permit the telephone to be used for talking on other telephone lines at the data-set location. These buttons may be operated without interrupting data transfer.

The block drawing on page 5 shows the data set in the two-wire configuration. The four-wire configuration is obtained by rearranging certain connections in the control circuit and splitting the line connections between the transmitter and receiver to allow independent transmit and receive paths. A four-wire telephone may also be used in this configuration.

The transmitter circuitry is shown in block form at the top of the drawing on the next page. Transmitting starts when a business machine initiates a request-to-send signal by switching from —3 volts to +3 volts on the interchange lead assigned to this function. The request-to-send control in the data set is a transistor switch which closes and starts the multivibrator and the clear-to-send circuit. The clear-to-send circuit consists of a two-stage transistor amplifier and a resistor-capacitor timing network. About 200 milliseconds after the request-to-send operates, the timing network switches the clear-to-send output from —8 volts to +8 volts, at which time the business machine may start sending data on the data-in lead. During this time, the communication channel is prepared for data transmission.

The multivibrator uses two transistors and precision resistor-capacitor cross-coupling networks. Its frequency depends on the voltage applied at the junction of the two network resistors leading to the transistor bases. A typical range of frequency variation versus voltage input is shown on page 6. The characteristic is substantially linear.

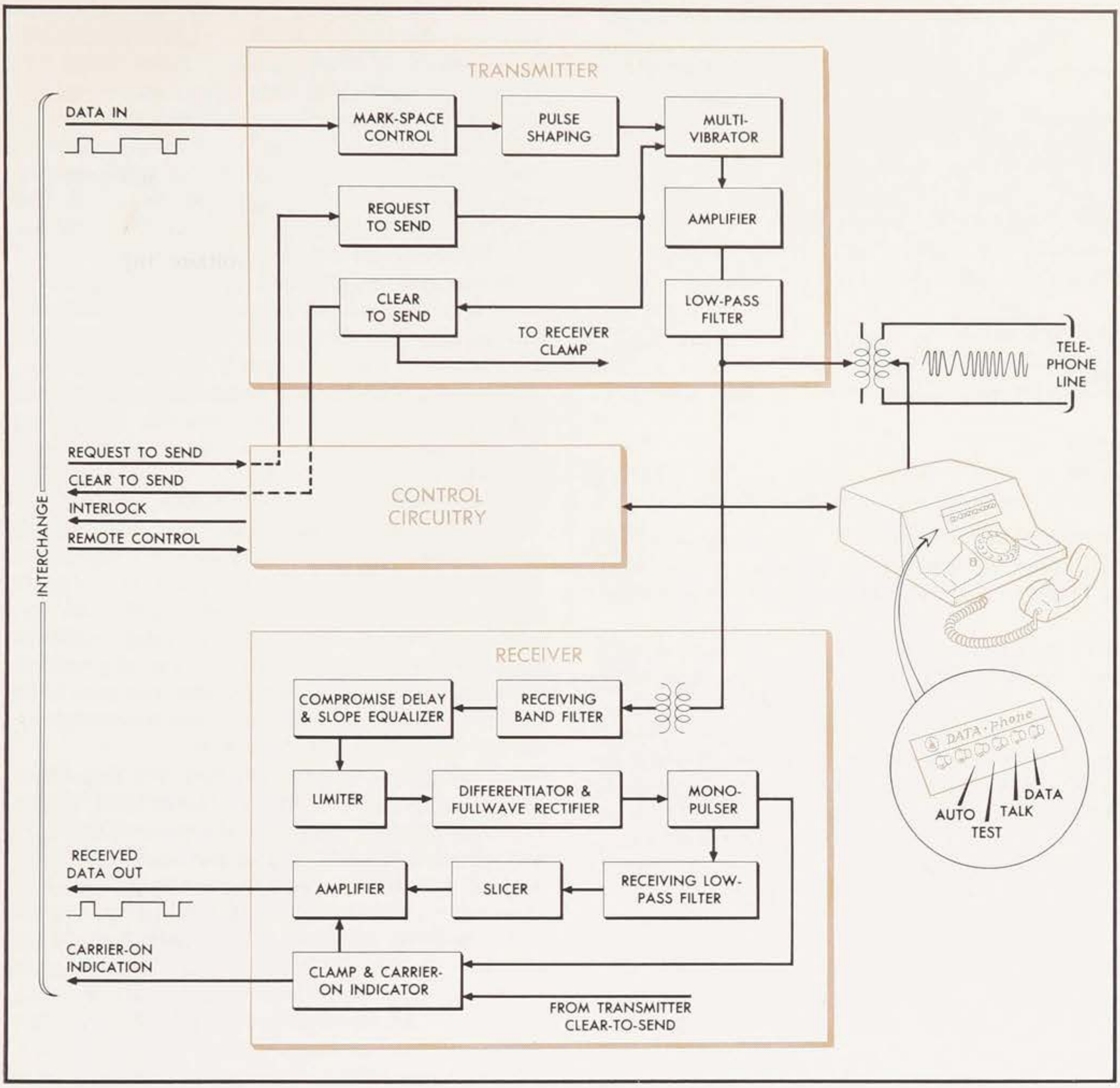
To shift the frequency of the multivibrator precisely between mark and space frequencies, a mark-to-space control is interposed between the send-data input and the voltage input to the multivibrator. This control circuit consists of a two-stage transistor gate in which a send-data input voltage of at least —3 volts and +3 volts (representing respectively mark and space inputs) causes the gate output to go from a low to a high-impedance condition. This causes precise changes in output voltage of a resistance-divider network at the input to the multivibrator.

To make frequency control independent of supply voltage changes, the divider network is placed across ground and the power supply to the multivibrator. A resistance-capacitor pulse-shaping network is interposed between the divider and the multivibrator. This network limits higher data-pulse frequency components thereby reducing certain disturbing effects of the corresponding lower sideband frequency components appearing in the carrier band.

The multivibrator output is isolated from the transmission line by a single transistor amplifier. The amplifier is followed by a low-pass filter having only sufficient attenuation to suppress harmonics of the carrier to tolerable levels on the telephone line. The filter output circuit is high impedance so that it may, in two-wire applications, be bridged across the receiver input without serious loss of receiver sensitivity. The sending level may be wired for 0 dbm or —6 dbm output.

The receiving circuit is shown in block form in the lower part of the drawing opposite. The FM signal received from the line passes through a repeating coil and a constant-resistance receiving band filter with a pass-band characteristic centered around the mean of the 1200- and 2200-cycle mark-and-space frequencies. The signal then passes through a constant-resistance line-delay equalizer and slope equalizer circuit to the input of the limiter. All of this circuitry terminates the repeating coil in a fixed resistance. Taps on the repeating coil allow the line to be terminated in 600 or 900 ohms.

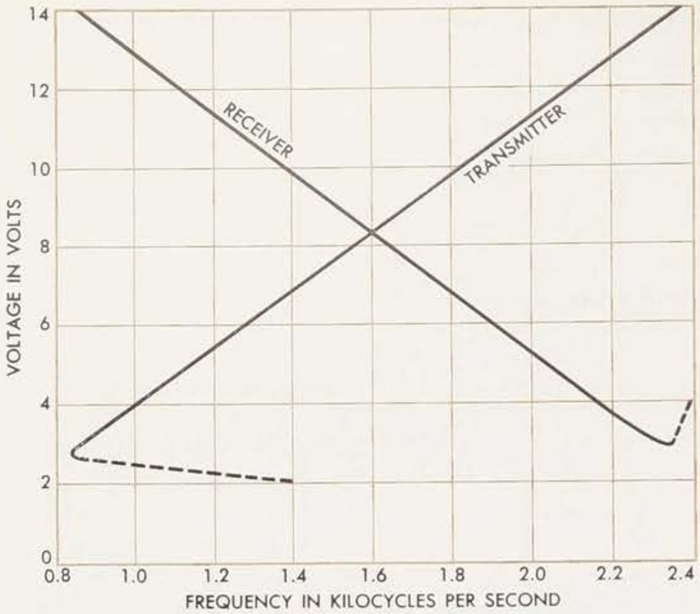
The remainder of the receiving circuit consists of the following components: a limiter, which converts the received sinusoidal input to a corresponding square-wave output; a differentiator,



Over-all block diagram of the Data Set 202 A and B. The set can transmit information over the regular switched telephone network or over private lines. It is readily adaptable and economical for both commercial and industrial applications involving data transfer over any distance.

which provides a voltage output only at the transitions of the square wave; a monopulser, which measures out a fixed amount of energy for every transition of the square wave developed by the differentiator; a low pass filter, which clears away all unwanted frequency components leaving an average voltage output which varies in proportion to the received frequency input; an output slicer-amplifier which makes a decision at a specific value of the average filter ouput voltage to indicate mark or space and then saturates correspondingly to give, at the received-data output, —8 volts for mark and +8 volts for space.

The received data output is a copy of signal input to the transmitter. It is applied to an interchange lead assigned for the purpose and passed on to the business machine. To prevent troublesome outputs caused by sporadic noise hits while the receiver is on line and no received carrier is present, a "clamping" or inhibiting circuit holds the data output in the —8 volt marking condition. When steady carrier has been received for 40 milliseconds, the holding condition is removed. The clamp stays off until carrier is removed for 15



Curves show linearity of the modulation and demodulation processes in terms of voltage input at modulator and voltage output at demodulator.

milliseconds or more. The 15 millisecond holdover prevents clamping on occasional short interruptions of the carrier tranmission.

On two-wire circuits without echo suppressors or where echo suppressors have been disabled for data transmission, some form of echo suppression must be provided in the data terminal. This is required when a customer has just finished transmiting from a two-wire terminal and wishes, for example, to receive some sort of confirming signal from the distant terminal. Upon termination of a transmission cycle, the request to send is operated from a positive to a negative voltage causing the transmitter to go off and the clear-to-send output to go immediately from +8 to —8 volts. This initiates a "squelch", or blanking action in the receiver data output and echo voltages from the transmission cycle appearing at the receiver input are prevented from giving a received data output for about 80 milliseconds. The time is long enough to insure echo suppression over the longest round-trip echo path in the switched telephone network.

The control circuit is a complex of relays and pushbuttons interconnected to provide the means for controlling the terminal. As described previously, the circuit performs several more or less unrelated functions.

There are two ways of answering a data call at the receiver. Attended answering is manual; a person first has to answer the telephone and then, upon verbal arrangement with the calling party, switch from the talk-mode to the data-mode by pressing the DATA button on the phone. In the data-mode, the data set is normally in the receiving condition. The transmitting condition is established when the data-processing circuitry, after receiving a positive interlock voltage from the data set, places +3 volts or more on the request-to-send input. Data transmission may then proceed after a minimum delay for line conditioning. Thereafter, transmission in either direction may take place automatically in accordance with instruction codes in the message and the states of the interchange control leads set by the data-processing equipment and the data set.

Unattended answering is an automatic receiving function which is established by the operation of the AUTO button or by a permanently wired-in automatic condition. When a call is received in this mode, the received ringing current pumps a resistance-capacitor tank circuit until enough current is available to operate a ringing relay. The pumping is required to insure against operation of this relay on unwanted interference. The operation of this relay provides, among other things, a closure on the ring-indicator leads to the data-processing equipment so that this equipment may be set in motion in anticipation of the data to follow.

To indicate a ready condition, the data-processing equipment provides a closure between the three leads called ready, remote-control-common, and remote-release. Under these conditions, after ringing has been received, a 1200-cycle tone is then sent to the transmitting terminal at the far end signifying to the attendant there that the receiver is ready to receive data. Transmission may then take place in the usual manner with alternate transmission and reception controlled by the data-processing equipment. Upon completion of a call, a code word can cause the receiving data-processing equipment to open the remote release lead and drop the receiver off the line, or the carrier may be removed for the same purpose. If either should fail, an automatic feature in most central offices causes a disconnect about 30 seconds after the transmitting terminal has gone off line.

Another feature of the data set is remote testing. When trouble is suspected, remote techniques can be used to check out the equipment for any gross malfunction before a telephone craftsman is dispatched to the site. The testing is done at a control testing location in the telephone plant by means of tones sent over the telephone line. To check the Data Set 202, the attendant at the test center first makes telephone contact with someone at the data terminal. He then places a 1200-cycle test tone on the line which is the cue to push the test button and place the terminal in the test mode. In this mode, all important interchange leads to the data-processing equipment are disconnected from the data set with all output leads given negative or idle mode potentials. At the same time, suitable interconnections are made between receiver output, transmitter input and certain control functions. The connections are made so that the largest number of data-set functions are tested. Maximum load is placed on all output leads and minimum input is applied to all input leads.

When the test button is pressed and the associated lamp remains lighted (indicating test in progress), the attendant hangs up and waits for a call from the test center informing him of the test results. The tester may now proceed with the testing. The 1200-cycle tone from the test center (the mark frequency) is derived from a calibrated oscillator. The tester listens for the transmitted tone as well as for the tone coming back from the data terminal. To ascertain whether there are any defects in most of the interface inputs and outputs as well as to determine the receiver slicing and the accuracy of the mark and space frequencies coming from the data set, the tester slides the oscillator frequency up and down in prescribed sequences between mark and space frequencies. The tester may also estimate transmitter send level and receiver sensitivity if he knows the line loss. By suitable filtering and test tone offset, he may select the specific tone from the data set and measure its level. Similarly, he may measure the oscillator level at which the data set drops off the line (it is held on line through the "carrier-on" indicator).

During the testing, the tones from the data set are interrupted internally by means of a "flasher" or timer circuit which switches the tones "on" and "off" at about one second intervals. This prevents the data set from locking itself into one state during testing.

The Data Sets 202A and 202B are designed for use in the medium speed range of approximately 200 to 1600 bits per second. An effort has been made to incorporate as much flexibility as possible for coupling business machines together through a voice-frequency channel. The unattended, receiving mode is part of the step required for machines to "talk" to machines without human intervention. The development and widespread use of these and related sets brings closer the day when communication facilities may handle more data than voice calls and "conversations" between machines may exceed in bulk those between people.

Telstar II to be Launched in Spring

A second Telstar will be launched in the spring of 1963, according to a recent announcement by the A.T.&T. Co. An important objective of Telstar II is to learn how to extend satellite life by avoiding or overcoming radiation damage. It was radiation which disabled Telstar I's command circuit after four months of successful operation (see story on page 22).

Telstar II will be launched for A.T.&T. by the National Aeronautics and Space Administration, with the company paying all costs for launching as it did for Telstar I.

Bell Laboratories, creator of Telstar, has been studying various means of reducing the radiation damage from the time its intensity became apparent. Among the possibilities are additional shielding for the satellite, and placing it in an orbit more suitable than the orbit of Telstar I.

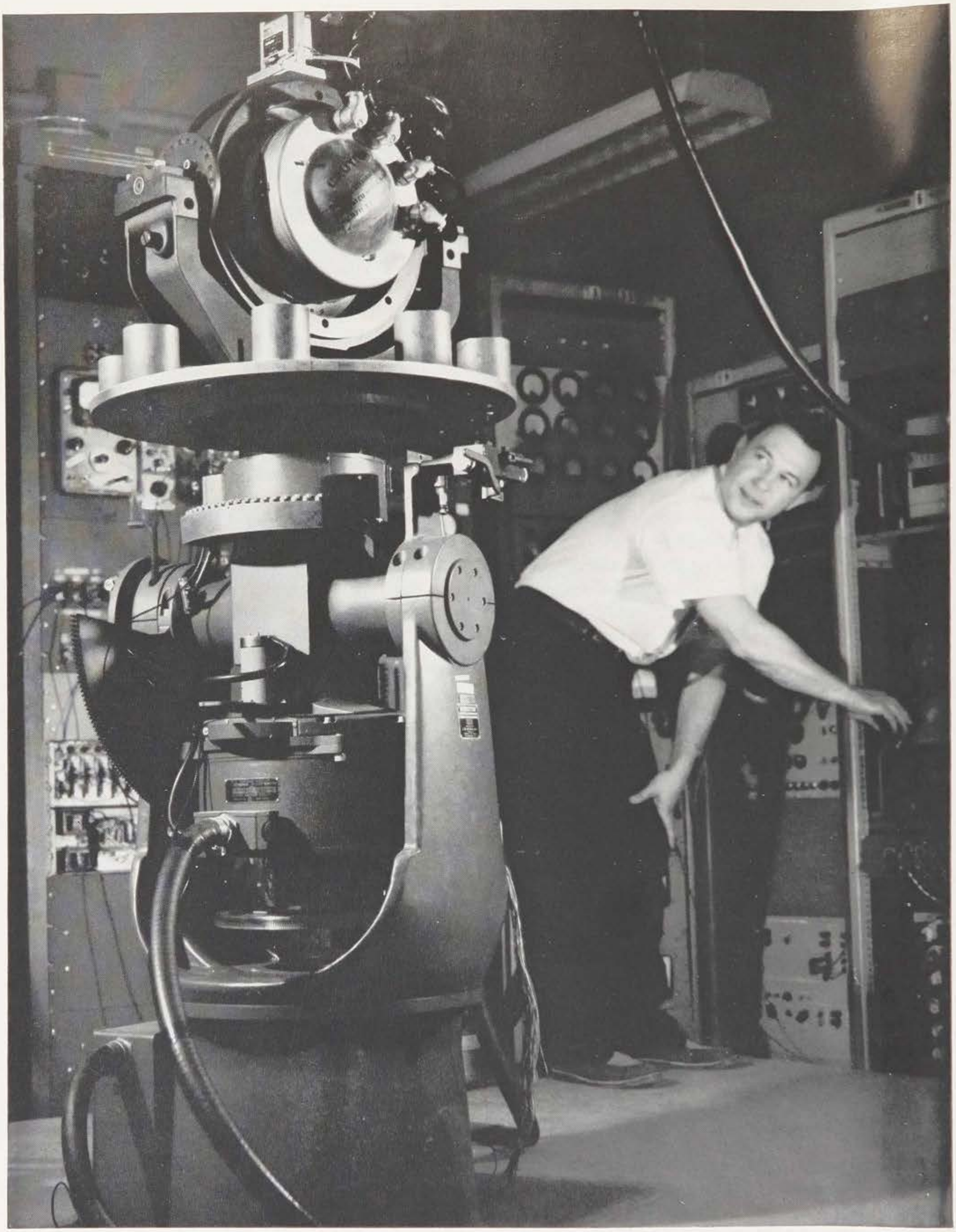
In providing additional shielding, special attention will be given to insuring greater protection for the command circuit. This circuit receives a series of coded signals from the ground stations and "readies" the satellite for communications — the last signal, in effect, turns on the receiver and transmitter. Radiation damage to this command circuit was the reason that no communications functions were carried on via Telstar I for six weeks.

The availability of a modified Thor Delta Rocket, more powerful than that used for Telstar I, makes possible a higher and more suitable orbit. The altered orbit could be meaningful, Bell Laboratories believes, if Telstar II could be exposed to less of the high energy levels of the electron radiation in the inner Van Allen Belt.

Also, a modification will be made in the radiation package to be used in Telstar II, and this should give additional information on radiation in space.

Under terms of the launch agreement, A.T.&T. will provide NASA with complete scientific data, much of which may be valuable in planning communications satellites programs. Also, all experimental data and progress reports will be made available to the general scientific community by Bell Laboratories.

Telstar I was launched July 10, 1962. Since that date, it has been furnishing telemetry information on its own condition as well as measurements on radiation and the space environment. Such information is important to the planning of any operable satellite system.



Technician initiates test of a stabilized platform on high performance servo table; controls are in background.

C. W. Spencer

Instrument Evaluation for Missile Application

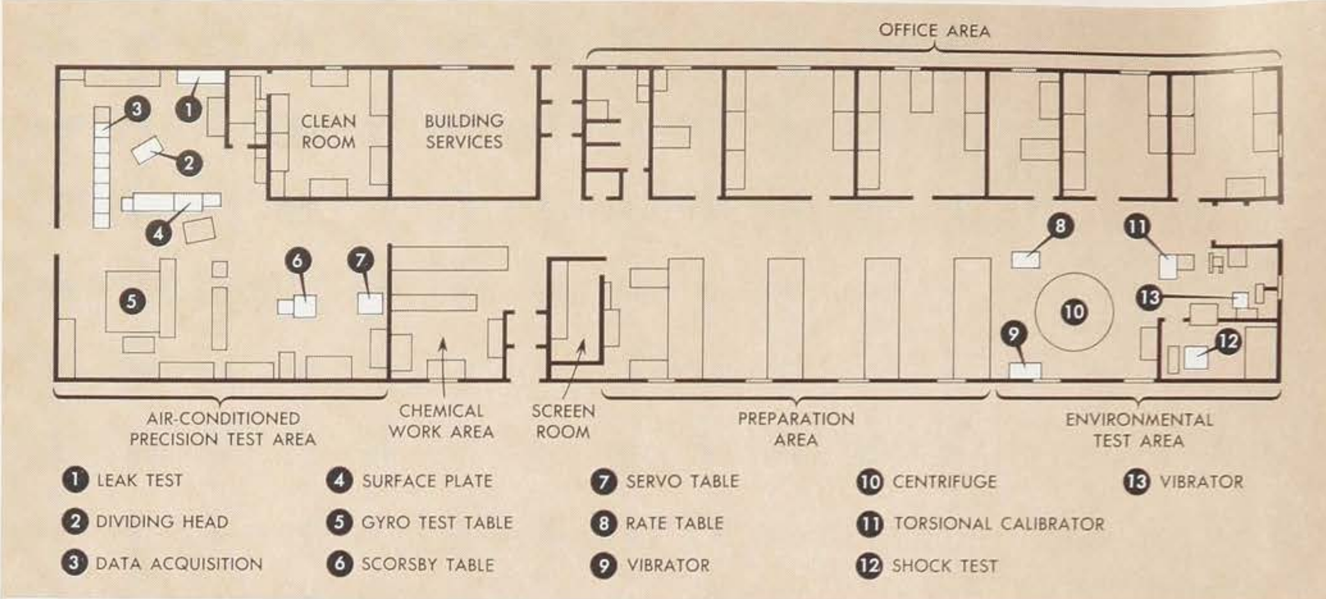
During the middle 1940's Bell Telephone Laboratories became involved with a number of missile guidance system projects requiring flight control instruments such as gyroscopes, accelerometers, and pressure transducers. It quickly became apparent that the instruments then available would not withstand the temperature, shock, vibration or acceleration environment of a missile, nor the rough handling which could be expected under tactical conditions. This situation was probably natural, since prior to that time, these instruments had been used in manned aircraft, where environments were comparatively mild. Also, they were normally maintained and checked out under favorable conditions in a repair depot.

An additional weakness of the available instruments lay in their low degree of reliability. For missile application, these instruments are required to possess a reliability level never before achieved, since compensation for gross errors in instrument performance or for catastrophic instrument failures would not be practical when a missile was in flight.

At that time, test facilities were not adequate to evaluate the probability of successful operation of these units in this new application, and there were no accepted standards by which the operation or quality of these instruments could be measured. In view of this situation, Bell Laboratories organized a group to specialize in flight instrumentation; its function was to formulate requirements and test procedures and to assure a quality of instruments completely acceptable in vital missile applications under investigation.

To supplement this engineering effort, a laboratory was established to confirm that the requirements and test procedures specified were appropriate, and that the instrument designs being considered were adequate for the application. It was planned that most instruments would be manufactured by any of several established instrument companies to designs approved and controlled by the Laboratories. This required a laboratory with highly flexible facilities to test properly the large variety of instruments involved. Because of the ever-increasing precision and complexity of flight control systems, this laboratory has since been expanded materially and now occupies a 40 by 160 foot building at Whippany, N. J.

The building was erected especially for instrument work and is arranged as shown on page 10. It houses over half of the 44 Laboratories people now engaged in instrument and allied work, as well as the wide variety of equipment which is required. About one-quarter of the building area is air conditioned to provide the constant temperature conditions required for precise measurements. Included in the air-conditioned area is a 16-foot square room specially equipped with entrance and air filtering arrangements to provide a superclean area where instruments may be opened for examination, or assembled and sealed without excessive dirt contamination. Even here, a special booth is provided for jobs where the ultimate in cleanliness is necessary, since even the



Floor plan of Inertial Instrument Laboratory at Whippany, N. J. shows functional arrangement.

most elaborate "white" rooms cannot completely eliminate airborne contaminants.

Both the mechanical and the electrical facilities required for instrument work are unusual. In general, the inputs to instruments are mechanical in nature, and are difficult to measure, but must be precisely known and carefully controlled. Because of the extreme sensitivity and precision of many of these instruments, electrical measurements of performance must be very accurate to be meaningful. Since we are often interested in the dynamic characteristics, measurements during a transient condition are essential.

Among the special facilities to provide the required mechanical inputs are a 36-foot diameter centrifuge, a torsional vibrator, an optical dividing head, a gyro servo test table, a Scorsby test table, a 5-foot diameter centrifuge which is being replaced in the near future with a more flexible unit, a precision rate-of-turn table, and shock and vibration machines, as well as a variety of holding and positioning fixtures. The large centrifuge, located in the Environmental Test Laboratory in another building at Whippany, has a precision contrarotating table to be used in high acceleration tests of precision instruments sensitive to rotation. The torsional vibrator provides a rotational sinusoidal input to instruments at controlled amplitudes in the frequency range of 5 to 1200 cps. It has an electromagnetic pickoff (output signal device) so that the input to an instrument can be compared to its output, to determine dynamic response characteristics. The gyro test table is a high performance servo table. The Scorsby table supplies a sinusoidal oscillation simultaneously about three orthogonal axes during free gyro drift tests.

Measuring the performance of an instrument during its testing requires a wide variety of electronic testing equipment, including precision power supplies, oscilloscopes, precision a-c or d-c voltmeters, recorders, wave analyzers, oscillators, amplifiers, counters and bridges. On instruments such as precision accelerometers, voltage measurements down to 0.000,000,1 volt are necessary in order to obtain meaningful data on instrument performance near the null or zero point. Similarly, precision integrating gyros may be required to have drift rates of only 0.01 degree/hour or even 0.001 degree/hour. Measuring the actual capabilities of an instrument to such precision requires extreme mechanical stability and control and the ultimate in electrical measurements.

Since these instruments are seldom used under ideal conditions, their capabilities can only be determined by simulating operating environments. Testing such devices as four-gimbal stable platforms requires many simultaneous precise measurements. Such tests may require up to a half-dozen bays of electronic testing equipment.

The wide variety of the tests and measurements made during instrument evaluation requires extremely complicated data recording equipment. The most complex recording equipment used in the instrument laboratory is an analog-to-digital data system which is used to acquire and record data taken on instruments operating in various environments and under dynamic conditions. This facility can measure voltages to an accuracy of 0.15 per cent on each of ten input channels, at a measurement rate of 625 times per second. It then converts these measurements to digital form and records them on magnetic tape for subsequent processing by a high-speed computer. At the completion of a recording, the tape can be played back and monitored on an oscilloscope as a "quick look" confirmation that the test was valid.

In addition to the 10 analog inputs, this device accepts a 24-bit code word which can be used to record information such as date, specific test conditions or other coded information. Precision amplifiers have been provided at the inputs so that the scale factors can be set, and so that the full input voltage range can be used to achieve maximum recording accuracy. Special computer programs have been written to permit the information on the tapes to be fed directly into the IBM 7090 computer at Whippany.

Another analog-to-digital facility used in the instrument laboratory consists of three single-channel recorders equipped to convert voltages to digital form and to control an IBM cardpunch. The recording rate is limited by the ¼ second full scale response time of the recorders. This system also permits the accumulation of data in a form convenient for computer processing. Other recorder facilities include X-Y recorders for plotting calibration curves or making error plots, and a variety of variable-speed strip chart recorders for plotting events against time.

When a need arises for instruments for a new application, the instrument group with the cooperation of the over-all systems project engineer determines and defines the performance characteristics required of the individual instruments. The market is surveyed for available instruments of such characteristics. If a commercial instrument which essentially meets the requirements is in production, it is usually more economical to design around such an instrument incorporating the necessary minor modification. If an instrument is not available, then the choice of developing internally or subcontracting the development must be made. In either case, a thorough evaluation of representative models of the final instrument is made by Bell Laboratories.

Thirty-six foot centrifuge, located in Environmental Test Laboratory, is used in high-acceleration tests of instruments and other rotation-sensitive devices. Here it is shown before a Telstar test.

On many of our past instrument applications, the Western Electric Company has acted as a second production source. This has permitted us to have direct control of manufacture and introduction of changes, and to enable us to arrive at a proven, high quality, reliable instrument design.

Since flight control instruments are usually very expensive components, test programs must be planned to give a maximum amount of information while destroying a minimum number of instruments. This concept must not be pushed too far—judging a design on the basis of a "sample of one" is almost sure to lead to unpleasant surprises. If an instrument has adequate capability margins in the design, a sample of four test units is usually sufficient to prove in a design. When a new instrument design is involved, the manufacturing group usually goes through a learning period before instruments free of serious production problems are produced and a true evaluation of design capability can be made. If, after all of the testing problems are solved, instrument troubles are encountered, an investigation to pinpoint the weakness is required, and new instruments with corrections introduced as required must be produced and reevaluated. Even after an instrument is in production, sensitivity to manufacturing imperfections requires a continuing extensive test program by the manufacturer, confirmed by the customer, to achieve needed reliability for missile use.

The facilities and program outlined above have made it possible for the Bell Laboratories development work on missile systems to push forward at a fast pace, confident that these critical components will withstand the stresses of a missile environment without being hampered by obscure instrument problems.

Over 140,000 inertial instruments have been produced for use in missile systems delivered by Western Electric during the past ten years. The painstaking effort to obtain reliable instruments has "paid off"—very few missiles have failed in test firings because of instrument malfunction.

S. B. Weinberg

New Range Charts For PBX Operation

EVERY DAY, more than one quarter of all telephone calls placed in the Bell System originate from or terminate at a private branch exchange, or PBX. The nearly 200,000 Bell System PBX installations throughout the country vary in size from single position switchboards serving a few extensions to large multiple switchboards, assocated with dial equipment, serving several thousand extensions. With this size of plant, it is essential that each installation be engineered to provide the best possible service to the customer in the most economical manner.

Because of the many variations in PBXs in service, and since each PBX must be able to operate into every type of central office, the engineering problems presented by any given PBX installation can be many and varied. One of the primary considerations is that the PBX, when installed, will have adequate signaling ranges. Without this capability, the PBX equipment would not function in the best manner.

Signaling, as applied to PBX ranges, includes the functions of supervision, ringing and dialing. *Supervision* includes the ability to respond to off or on-hook conditions of the PBX extension, and the operation of line relays, cord circuit supervisory relays and ring-trip relays. *Ringing* signals in some cases operate a ringer by ringing current for an audible signal; in other cases they operate a relay which controls a lamp to signal an attendant at a PBX visually. *Dialing* refers to response to a dialing operation by both dial equipment at the PBX or central office and circuits such as a PBX dial trunk.

Signaling range, which is measured in ohms, represents allowable electrical length of the conductor loop between a PBX extension and a PBX, or between a PBX and a central office.

The engineer laying out a PBX installation must know the limitations imposed upon the particular job by the signaling ranges. He must make sure that the individual and combined conductor loops do not exceed the permissible range for the PBX and central office. He must know the maximum conductor loop resistances that may be used and still permit a connection through the PBX to another extension. He must also know the maximum allowable trunk conductor loop between the PBX and the central office. Also, he must be aware of the limitation placed on the combined station and trunk conductor loops. If any of the required conductor loops exceed the signaling range limit, the engineer must know what can be done to increase the limit or how he can use the longer conductor loop and still achieve proper signaling.

At one time the only range information available to the engineer appeared as notes on the drawing for each circuit associated with the PBX. This information was limited and defined for specific conditions. For instance, one of the requirements imposed on the circuit designer was the resistance of the loop over which the circuit would have to operate. The designer would check a circuit for proper operation over the required loop and enter that range on the drawing as the working limit for the circuit. The telephone company engineer, having only this limited information available, would have to install long-line or long-trunk equipment for all loops that were to exceed the listed range information, or select plant facilities having lower resistance values. In many instances, the circuits were actually capable of operation over loops exceeding that on the drawings.

To provide the operating telephone company engineer with more exact and complete range information, PBX range charts were prepared prior to World War II. These charts showed permissible trunk and station conductor loop resistances for the many combinations of PBXs and central offices then in general use. Each chart listed the pertinent information for a particular central office and gave a maximum conductor loop range for each PBX that would operate into that central office. In addition, information as to how additional ranges could be obtained was given with the range information for each PBX.

The continuing development of means for extending the central office customer-loop ranges, especially between 500-type telephone sets and No. 5 crossbar and long range step-by-step offices, has out-dated these early range charts. As part of the process of catching up, a new, uniform and practical set of principles was developed at Bell Laboratories, whereby signaling ranges could be engineered to be as great as possible, while still providing satisfactory service.

The original range charts had been calculated on the basis of "all worst circuit conditions". In these calculations, the resistive elements in the circuit are assumed to be at a value to reflect resistance variations due to heating, aging, and manufacturing tolerances. Also, voltages were calculated at the minimum tolerable values, and current requirements were increased to compensate for stiff relays and increased resistances. Ranges based on a combination of the "worst" conditions, although sure to permit satisfactory operation, were necessarily shorter than they needed to be.

To avoid, as far as possible, the extra expense of installing long line circuits, which function to extend the signaling range of station line or central office circuits, and to keep pace with the long

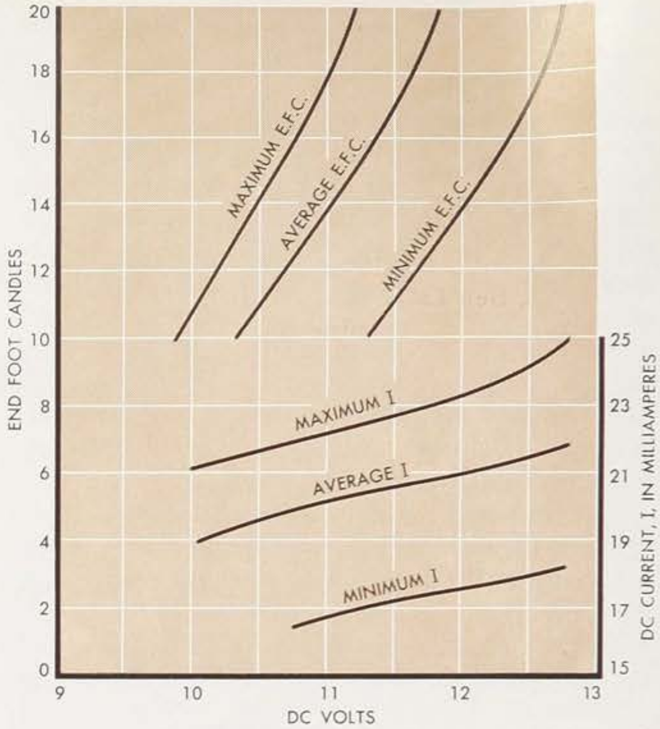
Author S. B. Weinberg checks data on a PBX cord circuit drawing. The book held by L. Mark (foreground) contains data gathered from new calculations and information.

customer loops being installed from the newer central offices, a more liberal approach to range calculations was worked out. The new approach recognized that there are many variable components such as lamps, relays, transmitters and voltage variations. Also, the new approach assumed that it was highly improbable that all "worst circuit conditions" would exist in a circuit at one time. Therefore, if average, or nominal, values were given to the variable components, longer calculated ranges would result for most of the circuits, while giving reasonable assurance of proper equipment operation. The telephone companies could thereby realize substantial savings by avoiding the use of unneeded long line circuits or by providing larger gauge conductors than actually required.

In the treatment of the circuit parameters and components to obtain longer ranges, a dual approach has been taken—updating some of the existing information, and taking a more practical and realistic approach to the use of other data. For example, switchboard lamps are limiting factors in many cases in determining PBX station conductor loop ranges. Considering that the only purpose of a switchboard lamp is to attract the attention of the switchboard attendant, its effectiveness is dependent on the general level of background illumination around the PBX. After various tests, Laboratories engineers recommended that the acceptable level of switchboard lamp illumination should be a minimum of 20 end foot candles (a measure of the amount of illumination delivered at the end of the lamp), provided that the background illumination at the PBX was 7.5 foot candles or less.

The parameters for these lamps used in previous range calculations were taken from data obtained 20 years ago. Also, these parameters were for a high illumination level; information for the lower illuminations required by PBXs was not too detailed or exact. New tests were made for the lamps at the proper illumination levels and the resulting data were incorporated into the present range calculations.

Another important factor in range calculations is the proper operation of the relays in the PBX and central-office circuits. The resistance of the windings of each of the relays is generally accepted to be the nominal value stated by the manufacturer for the relay at 68 degrees F. However, the resistance of the winding will increase by about 1 per cent for each 8 degree rise as its temperature goes up because of ambient temperature changes or heating caused by previous



Graph shows variations in end-foot-candles and current af attendant alerting lights, one of the variable factors in PBX installation engineering.

operation of the relay. The "test-operate" current values used in the range values are shown on the circuit requirement tables on the circuit drawings. Test-operate current values are obtained for each relay by taking 105 per cent of the re-adjust value for single relay operation and 110 per cent for relays which must operate in multiple. These currents do not take into account the heating of the winding as previously discussed.

The increased resistance of the winding due to heating will increase the total resistance of the circuit in which it appears. With the circuit voltage supply remaining constant, the increased circuit resistance will cause a corresponding decrease in the current through the circuit. The current may, therefore, drop below the test-operate value for the relay, and the relay will not operate. To compensate for this condition, a "worst circuit current" allowance of 5 per cent is added to the test-operate current for range calculations. This rule applies to most relays.

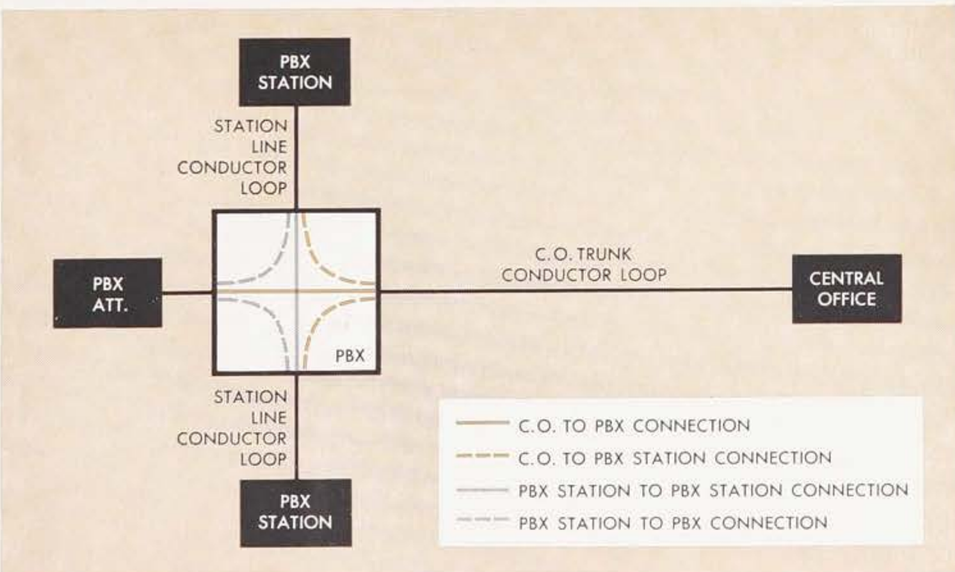
Another factor that must be considered in range calculations is the resistance presented to the circuits by the telephone set, most of which occurs in the transmitter. In order to function as a transmitter, the resistance of this component must necessarily be variable. The variations in transmitter resistance due to speech occur at voice frequencies and do not, therefore, affect dc signaling ranges. Other transmitter characteristics, however, do result in a wide variation of resistance which does affect the signaling ranges. For instance, the resistance of the carbon telephone transmitter will vary from one instrument to another due to differences in the packing of the carbon granules. The resistance will also vary depending on the position in which the transmitter is held. In connection with the extension of central-office ranges and the introduction of 500-type sets, Bell Laboratories engineers made tests and studies to determine the average resistance of a transmitter used by a central-office customer. An average resistance was thus determined for a transmitter with an average current flowing through it. Since the resistance of the carbon transmitter varies inversely with the amount of current through it, and since PBX currents are variable, a table showing transmitter resistance for various current levels was prepared for use in PBX range calculations.

To complete the picture of the factors that are involved in PBX signaling range calculations, the voltage variations of the power plants for the PBXs and central offices involved must be considered. This is because the operating range of a relay or a lamp is related directly to the available voltage. In most central offices today, a battery is "floated" on a regulated charger and prolonged power failures are rare. Because of this, there is little probability of circuit failures due to a combination of high-resistance apparatus together with a stiff relay during infrequent short intervals when the voltage is below the value of the minimum floating voltage. Therefore, it has become customary to engineer ranges on the basis of the central-office floating voltage. When the central-office battery is not floated, the voltage is subject to wide fluctuations during normal conditions. In these cases, range calculations are based on a minimum non-floating voltage.

Local battery power for the PBX may be obtained from several different types of power plants. Small PBXs are sometimes supplied with rectifiers and batteries containing from eight to twelve cells. When this type of power plant is used, the voltage is considered to be two volts per cell. For larger PBXs, 48-volt battery power plants are used. Several rectifier-type power plants, without batteries, operating from commercial power are also available to provide power for PBXs. These rectifiers range in capacity from 16 to 48 volts and the output specified by the manufacturer is the value used in range calculations.

Another source of power for the PBX is that obtained from the central office or from a building battery and brought to the PBX by cable pair feeders. Voltage provided by this method depends upon the central office or building battery voltage, resistance of the cable pair feeders, and the total instantaneous current drain. Voltage data is based on the nonfloat or power failure minimum voltage at the central office. However, since PBX ranges are based on central office floating voltage values, which are a few volts higher than the nonfloat values, it is assumed that the voltage is two volts higher than the engineered value for PBXs supplied by cable pair feeders.

In view of the number of different types of power plants and the voltage variations of each of them, it is essential that the engineer be aware of the exact type of power plant in the central office and in the PBX, so that he can best calculate the effects of the voltage fluctuations on the signaling ranges.



PBX range information and calculations are needed for engineering typical PBX installations, such as the one shown.

One factor which may limit signaling ranges is the voltage of ringing current supply at the central office and the type of ring-up circuit and relay at the PBX. When the central office seizes the PBX trunk, it sends ringing current over the trunk conductor loop to the PBX to operate a ring-up relay. The operation of the relay lights a lamp at the switchboard.

The central-office ringing current supply provides direct current with ac superimposed. The minimum ac component of this ringing current is used in range calculations. The existing data on the operation of ring-up relays was based on the "worst circuit" conditions under which the ring-up relays would be expected to operate.

Ringing ranges, however, cannot be calculated simply, because of the combinations of electrical factors and mechanical variations presented by the ring-up circuit. To determine these ranges, laboratory tests were made and the results were made available for use in range calculations.

Station ringing in most manual PBXs is achieved by the operation of a ringing key at the switchboard. In the 608A, 607A, and 756A PBXs, automatic machine ringing is used to ring a station. In automatic machine ringing, a relay operates to trip the ringing when the station answers. If a station answers during the ringing cycle, the ac voltage super-imposed on the dc component of the ringing current is sufficiently high to allow tripping over an extremely long, nonlimiting, station loop. However, if the station answers during a silent interval, only the PBX battery voltage is present and the station conductor loop may be limiting.

The new data that have been compiled for the circuit components, and the new, liberal approach to range calculations, equations and other circuit factors have now been made available to operating telephone company engineers in the Bell System. This information provides the engineer with a technique that will enable him to establish working limits for circuit combinations which are not specified in existing range charts. All the necessary information, including assumptions, circuit parameters, equations and circuit arrangements for commonly used PBXs and central offices, to allow range calculations is included. Also, a new set of range charts has been prepared for most of the important central-office and PBX combinations using the new information and methods.

Through the use of the new range charts and the other published information, much engineering effort and expense will be eliminated, while supplying improved service potential to the PBX customer.

Range Charts–How They're Used

A typical range chart is shown opposite. Range data for each PBX situation is shown in a double column of figures. The left column ("Trk") contains trunk conductor loop ranges; the corresponding permissible station conductor loop ranges are shown at right ("Sta"). Tables consisting of a varying number of double columns under each PBX listed allow for all possible PBX power supply arrangements and circuit options. Footnotes cover deviations from the basic range data where required.

A check mark shown on the tables refers the chart user to a note explaining, in effect, that the sum of the trunk conductor loop resistance and the station conductor loop resistance, for all trunks and stations falling between the values above and below the check mark, may be equal to the subscriber conductor loop range of the central office less the resistance value of all series relays.

The asterisk refers the chart user to a note explaining the use of an intermediate table to find conductor loop values for all trunks and stations falling between the values above and below the asterisk, and reflects the limitation placed on the conductor loop range by PBX supervision.

In a typical example, suppose that a 555 PBX was to be installed at a distance of 270 ohms from a No. 5 Crossbar central office with a subscriber conductor loop range of 1360 ohms. The engineer in charge of the installation would know the type of power supply to be used and the various circuit options in the PBX. Assume that this PBX will have an 11-cell local battery and that the line circuits will be equipped with UA 97 line relays. Also, assume that the cord circuits will contain a 150 ohm cord bridge without a series pad resistor.

To determine the maximum allowable station conductor loop resistance for the installation, the engineer would refer to the table between line number 21 and 26 (the line numbers are located at the extreme left side of the page), and read the double column under "11-cell battery." For all trunk conductor loop ranges over 50 ohms and below 1325 ohms, the engineer is referred to the intermediate table. He would check the intermediate table and locate 270 ohms under the "Trk" column, which is the given trunk conductor loop for this problem. The maximum station conductor loop resistance associated with the 270 ohm trunk loop will be found in the adjacent column headed "Sta," and reads 520 ohms. This value would be the maximum station conductor loop resistance that may be used with a trunk conductor loop resistance of 270 ohms.

PBX CONDUCTOR LOOP RANGES FOR 1360-OHM NO. 5 CROSSBAR OFFICES

555 PBX (Cont)

STATION LINES EQUIPPED WITH UA97 LINE RELAYS

Direct Feeders From Central Office or Building Battery Engineered for a Minimum PBX Voltage of: (with a 150-ohm cord bridge only)

16 VOLTS		18 VOLTS		20 VOLTS		22 VOLTS AND UP	
Trk	Sta	Trk	Sta	Trk	Sta	Trk	Sta
0	475	0	660	0	855	0	965
315	475	160	660	50	855	*	*
*	*	*	*	*	*	1325	0
1325	0	1325	0	1325	0		

Direct Feeders From Central Office or Building Battery Engineered for a Minimum PBX Voltage of: (with a pad resistor added in series to the 150-ohm cord bridge) #

16 VOLTS		18 VOLTS		20 VOLTS		22 VOLTS		24 VOLTS		26 VOLTS AND UP	
Trk	Sta	Trk	Sta	Trk	Sta	Trk	Sta	Trk	Sta	Trk	Sta
0	475	0	660	0	855	0	1040	0	1235	0	1325
850	475	665	660	470	855	285	1040	90	1235	√	√
√	√	√	√	√	√	√	√	√	√	1310	15
1310	15	1310	15	1310	15	1310	15	1310	15	1310	0
1310	0	1310	0	1310	0	1310	0	1310	0		

Powered by Local PBX Power Plant (with a 150-ohm cord bridge only)

9-CELL BATTERY		10-CELL BATTERY		11-CELL BATTERY		101G RECTIFIER		KS-15668 RECTIFIER	
Trk	Sta	Trk	Sta	Trk	Sta	Trk	Sta	Trk	Sta
0	475	0	660	0	855	0	475	0	965
315	475	160	660	50	855	315	475	*	*
*	*	*	*	*	*	*	*	1325	0
1325	0	1325	0	1325	0	1325	0		

Powered by Local PBX Power Plant (with a pad resistor added in series to the 150-ohm cord bridge) #

9-CELL BATTERY		10-CELL BATTERY		11-CELL BATTERY		101G RECTIFIER		KS-15668 RECTIFIER	
Trk	Sta	Trk	Sta	Trk	Sta	Trk	Sta	Trk	Sta
0	475	0	660	0	855	0	475	0	1325
850	475	665	660	470	855	850	475	√	√
√	√	√	√	√	√	√	√	1310	15
1310	15	1310	15	1310	15	1310	15	1310	0
1310	0	1310	0	1310	0	1310	0		

#These columns show how the station range may be increased for a given trunk by connecting a pad resistor in series with the 150-ohm cord bridge. Provide a 100-ohm pad for trunks greater than 1100 ohms, or a 200-ohm pad for trunks smaller than 1100 ohms.

√Deduct the known trunk conductor loop resistance from 1325 ohms to obtain the permissible station conductor loop resistance. Where the station conductor loop resistance is known, deduct this value from 1325 ohms to obtain the permissible trunk conductor loop resistance.

*Find the trunk value nearest the known trunk conductor loop resistance in the Intermediate Table and read the corresponding station value. Or, if the station conductor loop resistance is known, find the nearest station value and read the corresponding trunk value.

*INTERMEDIATE TABLE

Trk	Sta	Trk	Sta	Trk	Sta	Trk	Sta	Trk	Sta	Trk	Sta	Trk	Sta	Trk	Sta
0	965	100	760	200	610	300	490	405	390	550	290	740	190	1010	90
10	940	110	745	210	595	310	480	420	380	565	280	760	180	1040	80
20	920	120	730	220	580	320	470	430	370	580	270	785	170	1080	70
30	900	130	710	230	565	330	460	445	360	600	260	810	160	1120	60
40	880	140	695	240	555	340	450	460	350	615	250	835	150	1160	50
50	860	150	680	250	545	350	440	470	340	635	240	860	140	1200	40
60	840	160	665	260	535	360	430	485	330	655	230	890	130	1240	30
70	820	170	650	270	520	370	420	500	320	675	220	920	120	1285	20
80	800	180	635	280	510	380	410	515	310	695	210	950	110	1315	10
90	780	190	620	290	500	390	400	530	300	720	200	980	100	1325	0

Strain Waves in Crystal Rotated By Magnetic Field

Scientists at Bell Telephone Laboratories have rotated the direction of polarization of a transverse ultrasonic wave traveling in a crystal by causing the wave to interact with a magnetic field. Their work is significant because the rotation is nonreciprocal, that is, when the wave is reflected at the end of the crystal and travels back to the input it does not rotate back to its original direction of polarization.

A new family of ultrasonic devices, such as circulators and isolators, now appears possible. An ultrasonic isolator, for example, might be used in ultrasonic delay lines to suppress reflections which occur when a wave encounters a discontinuity in a system. The isolator would work this way: An ultrasonic wave leaves the input of a system and travels through the isolator, which rotates the direction of polarization of the wave 45 degrees. When the wave is reflected back to the isolator it is rotated an additional 45 degrees. A device in the isolator absorbs the energy of waves polarized at 90 degrees; thus the reflected wave is prevented from reaching the input.

Herbert Matthews and R. Conway LeCraw of The Solid State Device Laboratory recently described their experiment in Physical Review Letters, a Journal of the American Physical Society.

They bonded a quartz disk to one end of a cylinder of single crystal yttrium iron garnet and applied a dc magnetic field parallel to the axis of the cylinder. The magnetic moments of the iron atoms in the garnet then lined up parallel to the field.

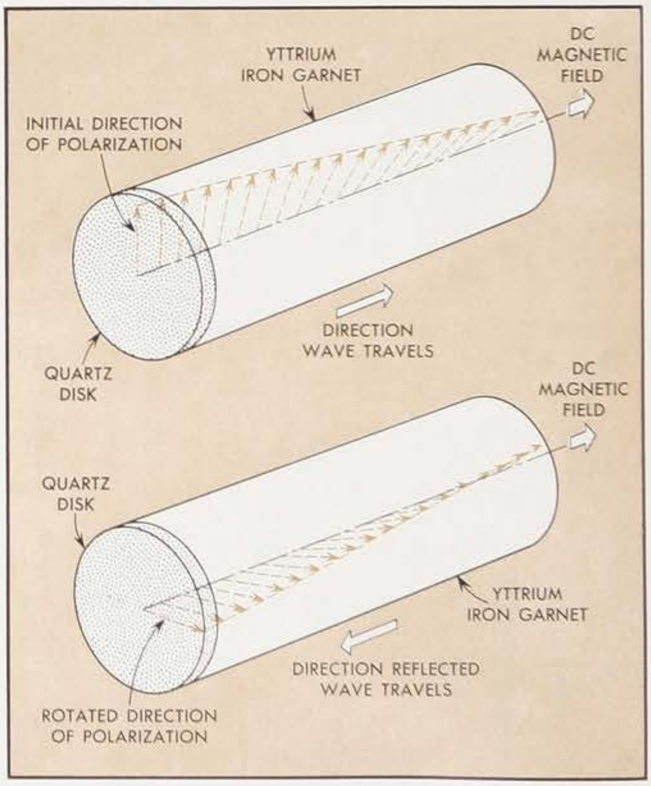
Next, they applied a pulsed radio frequency electrical field to the quartz disk generating (by the piezoelectric effect) an ultrasonic wave pulse. This 500 megacycles per second pulse was polarized parallel to the (100) quartz axis.

The ultrasonic pulse traveling down the garnet cylinder strained the crystal lattice so that the iron atoms were alternately pulled apart from each other and squeezed together in a direction perpendicular to the magnetic field.

Straining the atoms created a second magnetic field, called an rf field because it varied with the frequency of the 500 megacycle (rf) pulse. The rf field was perpendicular to the applied (dc) magnetic field. A component of the rf field interacted with the lined-up iron atoms and changed the direction of their magnetization. (This process is the inverse of magnetostriction whereby ferromagnetic materials such as iron elongate in the direction of a dc magnetic field and contract in a direction perpendicular to the field.)

The change in the direction of the magnetic moments of the iron atoms affected the direction in which they moved as the pulse strained the YIG lattice. (The motion of the iron atoms was linearly polarized in a plane perpendicular to the wave's direction of travel.) The initial group of iron atoms moved up and down in this plane. The next group of atoms moved at an angle to the previous group in the perpendicular plane. This rotation was caused by interaction of the rf field and the lined up iron atoms and is analogous to the Faraday rotation of electromagnetic waves in ferrites. Each group of atoms was strained at an angle to the previous atomic strain and thus the direction of motion was rotated continuously.

When the wave was reflected at the end of the YIG cylinder, rotation of the strain polarization continued in the original direction since the interaction between strain and the lined up iron atoms was independent of the direction in which the wave traveled. The amount of rotation depended upon the distance the wave traveled and the strength of the dc field.



As a strain wave travels down the crystal, it is rotated 45 degrees by a magnetic field. Below, the reflected wave receives additional rotation.

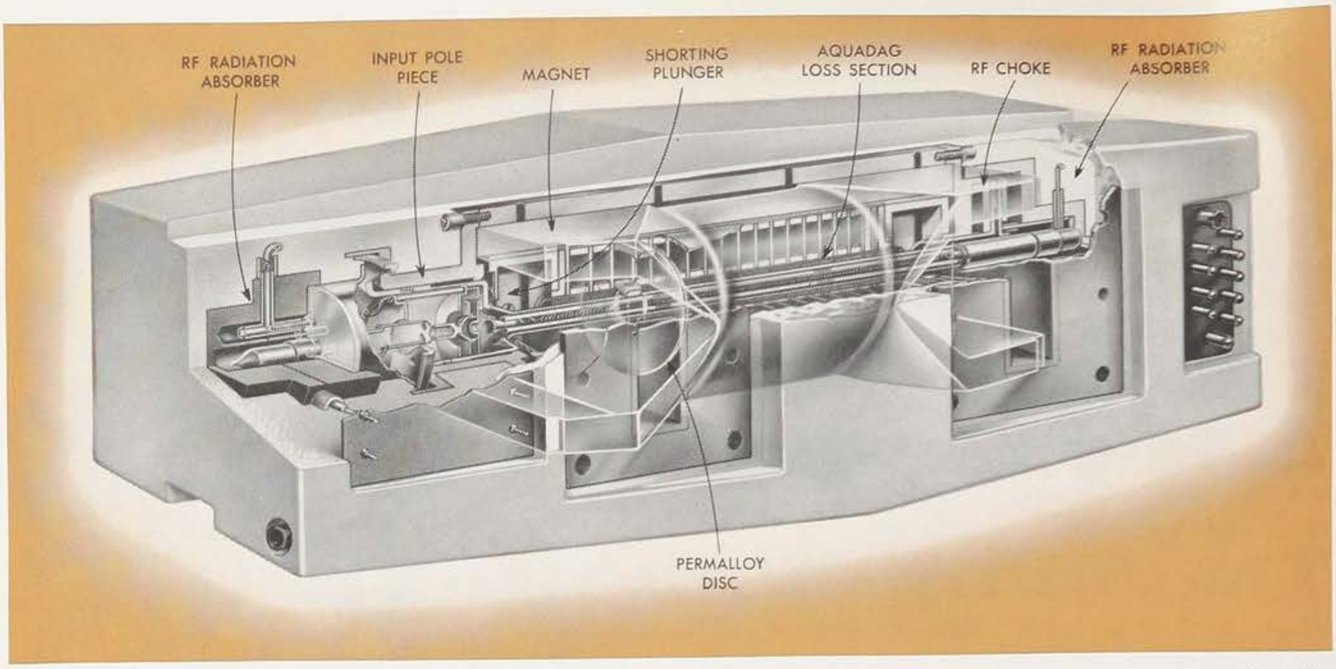
In the past few years, the traveling-wave tube has performed with outstanding success in military systems. Recently, Bell Laboratories developed a rugged, lightweight tube to help in the vital task of guiding a missile.

A Missile-Borne Traveling-Wave Tube

W. D. Apgar and C. E. Bradford

THE Bell Laboratories Command Guidance System, developed for the United States Air Force, has successfully guided over 100 flights of missiles and space vehicles. One of the major components in the receiver of that system is a traveling-wave tube that can amplify a guidance signal over twenty thousand times. As the success of the system attests, the tube functions with high reliability under the extreme acceleration strains, shock amplitudes, and temperatures of missile guidance and flight. Recently the Laboratories has developed an advanced version of that tube for the lightweight missile-borne guidance equipment now being put into the Delta space vehicle.

The unique quality of a traveling-wave tube is its ability to greatly amplify microwave signals over a wide band of frequencies. Its superiority over other types of amplifiers in this respect stems from its principle of operation which can be called "traveling-wave interaction." A signal wave and an electron beam traveling at nearly the same velocity continuously interact over a comparatively long distance. In other microwave amplifiers, such as the klystron, the interaction region may be only a hundredth that of the traveling-wave tube at the same voltage and frequency. To obtain appreciable amplification the klystron's electric field must be very high. This can be obtained only in a resonant cavity which, in turn, limits the tube's bandwidth to a few per cent of the center frequency. The traveling-wave tube does not have this limitation. The tube described in this article, for example, provides a gain at midband of 37 db, and has a 3 db bandwidth equal to more than 24 per cent of the midband frequency. Its gain can be controlled by varying the



A cross-section of the traveling-wave tube package showing the tube and its helix and gun structures, the focusing magnet, and other details. The outer casing is a low-density foamed plastic.

voltage at the first grid, or beam-forming electrode. Also, the control action of this electrode can be used for automatic gain control by arranging to sample the output of the detector following the traveling-wave tube, amplifying it, and feeding it back to the grid to maintain a constant output. Gains from 37 db to —35 db can be obtained.

Design for Ruggedness

To withstand the hazardous environment of missile launching and flight, the new device has been made extremely rugged. One thing that has been done to achieve this is the joining of the tube and its focusing magnet in an inflexible unit. The magnet itself is a rigid support, a sort of backbone for the package; the tube and many other parts are cemented to it with a low-density epoxy adhesive that forms a bond with a shear strength approaching that of aluminum. Cementing the parts together eliminates many screws and bolts and helps to achieve a lightweight structure—one of the requirements of this device. The entire assembly is encased in low-density foam plastic which prevents contact between the magnet and other magnetic materials that would disturb its field and keeps out dirt and magnetic particles. The outer surface is plastic and has openings for input and output waveguides. The whole structure weighs only a little over two pounds and is less than eight inches long.

The heart of the tube itself consists of an electron gun and a wire helix which serves as a slow-wave circuit. The electron beam developed by the gun passes coaxially down the center of the helix which intercepts less than two per cent of the beam current. An rf signal is coupled to the helix through an input waveguide near the gun. The signal and beam interact in such a way that the signal is amplified at the expense of the kinetic energy of the electrons. The amplified signal is coupled to an output waveguide at the end of the helix opposite the electron gun.

In line with the requirements for extreme ruggedness, the components of the tube are also joined in a tightly-knit assembly. Three ceramic rods are glazed to the helix as a support. This assembly fits snugly into a glass bulb. The cathode and other electrodes of the electron gun are also supported by ceramic rods. These rods are held by two metal discs which, in turn, are brazed to the inside of the metal part of the tube.

An Alnico magnet surrounds the tube. It provides a nearly uniform axial magnetic field of 500 oersteds over the length of the helix. This field prevents the electron beam from spreading and striking the helix. Actually, the diameter of the beam is 0.031 inch, and the inside diameter of the 3 inch long helix is 0.035 inch. The beam cannot be focused properly unless the force on the electrons from the radial component of the magnetic field is very small at any given point. A "field straightener" minimizes the radial component of the magnetic field at the axis of the tube. It consists of a number of permalloy discs with center holes through which the tube passes. The discs, separated by aluminum spacers and mounted perpendicular to the axis of the tube, act as "equipotential planes" in the long longitudinal field and help keep the transverse field small.

Another important design consideration was the prevention of feedback of rf output power to the input. This may cause oscillations which, though they are sometimes far removed from signal frequencies, may reduce the power of the amplified signal. Freedom from oscillation is difficult to achieve in a high-gain, broad-band device. The input and output waveguides each contain a shorting plunger to help establish rf coupling between the waveguide and the helix. To help prevent oscillations, these plungers contain rf chokes. There is also rf absorbing material around the glass envelope of the tube inside the field straightener, and rf absorbing material and chokes around the dc leads to the electrodes.

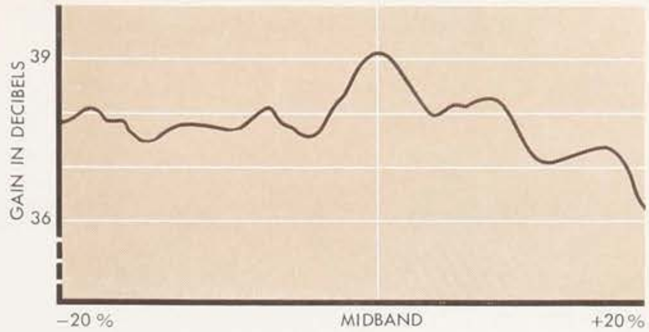
Design for Low Weight

Because very low weight was a basic requirement for the new device, all components were made as small as possible without jeopardizing their ruggedness. In this respect, the magnet is the greatest concern. It comprises more than half the weight of the device—weight largely determined by the length of the helix and the axial magnetic field requirements. In a traveling-wave tube, a short section of the helix near its center is coated with "lossy" material to prevent feedback from output to input. In the new tube, this section (called the helix loss section) is divided into two parts, each only 0.15-inch long—much shorter than in other traveling-wave tubes. The divided loss results in better match performance, but each part can provide enough loss to prevent oscillation.

Because the helix loss section is shorter, the helix itself can be shorter, and the weight of the magnet can be reduced. Furthermore, the helix can be made still shorter if a low-voltage electron beam is used, as this yields higher gain per unit length of the helix. However, the magnetic field must be increased as the beam voltage decreases, and this tends to increase the weight of the magnet. Accordingly, the beam voltage and the axial magnetic field were calculated to allow minimum weight for the magnet. Among the possible magnet materials that were considered, Alinco V was found to offer the required field with the least weight.

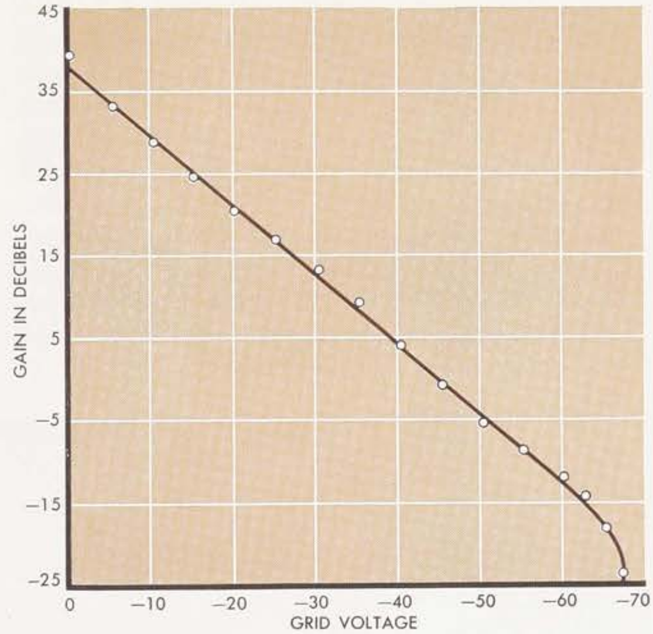
A rigorous test program was carried out at the Laboratories to make sure that the device would withstand the vibrations it will be subject to in missile launching and flight. Each device was tested for one hour under constant vibrational acceleration of 20 g at frequencies varying from 50 to 2000 cycles per second. Samples have survived accelerations up to 60 g and shock amplitudes up to 40 g.

The full useful life of this tube is only a few minutes during missile flight, but it must be ready for those few minutes and it must function when it is called on. All the design effort was directed toward those few minutes to make sure that the tube will deliver perfect performance during its paradoxically short life.



A plot of gain versus frequency. This figure shows a part of the bandwidth of the new tube.

Gain of the traveling-wave tube versus the voltage applied to the first grid. For this plot output power of the tube was kept at —20 dbm. Gain for the tube can be obtained over a range that is dependant on output power and beam current.



Telstar Transmits Transatlantic Pictures Again

Telstar transmitted television pictures on January 4 after being out of operation for six weeks. During the intervening period, engineers at Bell Laboratories diagnosed the difficulty and found a way to restore normal operation.

Transatlantic pictures were seen in New York at a press briefing and were made available to television networks for broadcast.

The day before, test patterns were received and transmitted by Telstar, the first signals relayed by the Bell System's experimental satellite since November when its command circuit stopped working and its communications equipment could not be turned on.

Scientists and engineers at the Laboratories explained that studies and experiments had pinpointed the malfunction to one particular transistor in one of Telstar's command decoders and to a few possible transistors in the second decoder.

The difficulty in the transistors was diagnosed as a *surface* effect of radiation, discovered by Walter M. Gibson of Bell Laboratories and G. Lorimer Miller of Brookhaven National Laboratory in October 1961. (These surface effects can apparently occur at lower levels of radiation than the better-known internal effects.)

In these studies it was found that transistors sometimes recover when the radiation intensity is reduced. During December, Telstar had been at its highest point, where the Van Allen radiation is weaker, while over the southern hemisphere. Therefore, an attempt to command Telstar was made earlier from the NASA Minitrack station at Johannesburg, South Africa. These tests were unsuccessful.

Meanwhile other engineers looked for some way to reduce the bias on the decoder transistors. This appeared at first glance to be virtually impossible, since the only means known to do this—disconnecting the satellite batteries or by circuit operation—called for an ability to command the satellite, at least in some small degree. The search was therefore started to find a way to trigger the command decoder circuits into operation despite the inoperative transistors.

In the laboratories a command decoder similar to that used in Telstar, with its normal voltage applied, was placed in a radiation environment. The decoder developed symptoms similar to those of Telstar's decoders. Detailed testing then revealed which portions of the circuit were most sensitive. Particularly sensitive was a transistor in the "zero gate", a circuit that recognizes the "zeroes" in the one-and-zero code used to command the satellite.

Deducing also from circuit behavior that this transistor was affected in at least one of the two command decoders, the engineers then applied themselves to finding some way to by-pass the ailing transistor, by using a special form of command signal. Spearheading this effort were Robert H. Shennum, Head of the Satellite Design Department; Henry Mann, of the Exchange Transmission Laboratory; and John S. Mayo, Head of the Pulse Code Modulation Terminal Department.

In the code used by the satellite, a "one" is a long pulse; a "zero" is a short pulse. The problem the men faced was to send some sort of signal that would register as a zero. The solution hit upon was to send as a "zero" a long pulse with a dip, or notch, in the middle. This was successful in registering a "zero", in the laboratory.

Two racks of equipment were put together for sending "notched pulse" commands, capable of sending only two of the fifteen commands to the satellite during a single pass, but sufficient for a trial of the method. On the first attempt, on pass 1492 at noon December 20, the command worked. It turned a switch, and indication of this was received from the satellite by telemetry.

The engineers planned to prepare a complete program of all 15 commands on tape. Eventually and with due caution they would send a command to Telstar to disconnect its storage batteries. During eclipses power would then be off the satellite. This would remove the bias from the transistors, allowing the surface effect to dissipate and restore the regular command function.

But the "trick" commands in use at Andover were on two occasions misinterpreted and Telstar disconnected its batteries ahead of time. After the eclipses that followed, it was found that *normal* command performance was partially restored. The treatment was purposely repeated on January 2 and 3 with complete restoration of the normal command function.

The radiation effects are believed to have been produced when high energy radiation penetrated the enclosure of a semiconductor device and ionized gases and other substances within the enclosure. The ions thus created can collect on the surface and cause detrimental electrical changes. Under reverse bias (or voltage), these effects are greatly accelerated.

Semiconductors are known to recover toward their original operating condition when the radiation levels are decreased or when the reverse bias is decreased or removed, although they remain more sensitive to a subsequent exposure.

The semiconductors in Telstar were selected to perform satisfactorily at the radiation levels expected in its orbit from data available at that time. However, it is now known that Telstar encountered a very high density of electrons having much higher energies than expected, resulting in the radiation intensity inside the satellite 100 times greater than that anticipated.

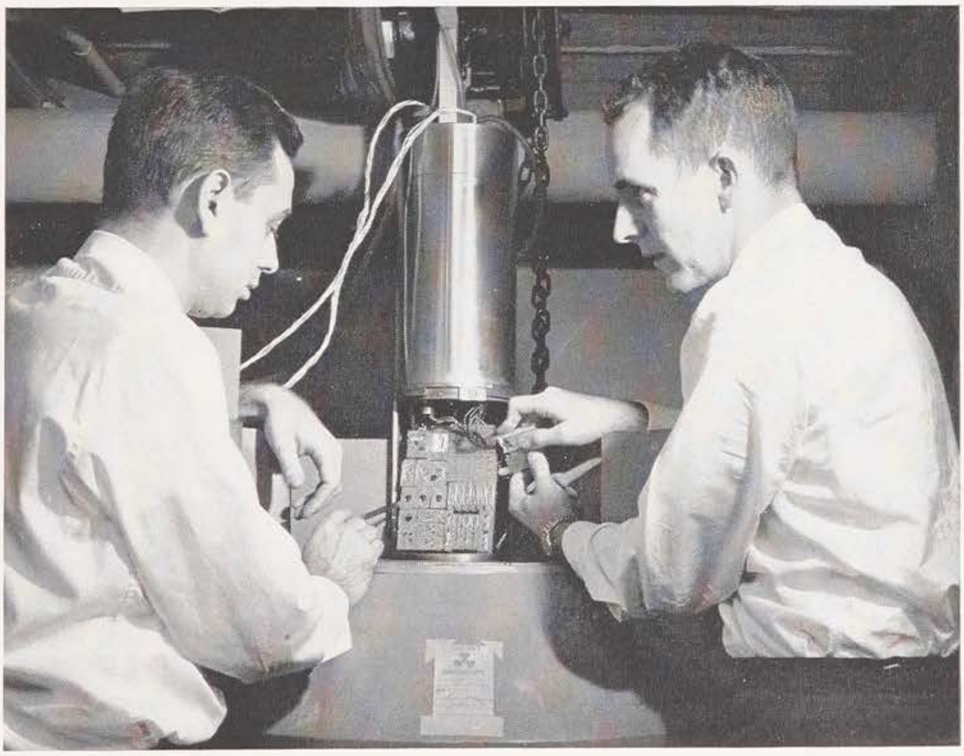
Transistors in the command decoders are receiving radiation more intense than those in the telemetry circuits and the receiver because of less metal shielding—and many of them are normally under continuous reverse bias. This combination of conditions is believed to be the reason for the failure of the decoders.

During the days in November when the command circuit began to operate intermittently, the satellite was in view of Andover, Me., during a series of four successive passes and then out of view during five.

The command function would fail to operate during the first pass or two in the series. Apparently the continuing command signals sent from ground helped to restore the response. This was consistent with the belief that the difficulty was caused by the surface effects or radiation, since processing of commands greatly decreases the reverse bias on many of the transistors and allows for partial recovery of degraded units.

Bell Laboratories will publish a scientific paper on the subject in the January, 1963 issue of the *Bell System Technical Journal.* It is written by D. Stewart Peck, Head of Semiconductor Reliability Department; Royer R. Blair, of the Military Data Systems Department; Walter L. Brown, Head of Semiconductor Physics Research Department; and Friedolf M. Smits, now with the Sandia Corporation.

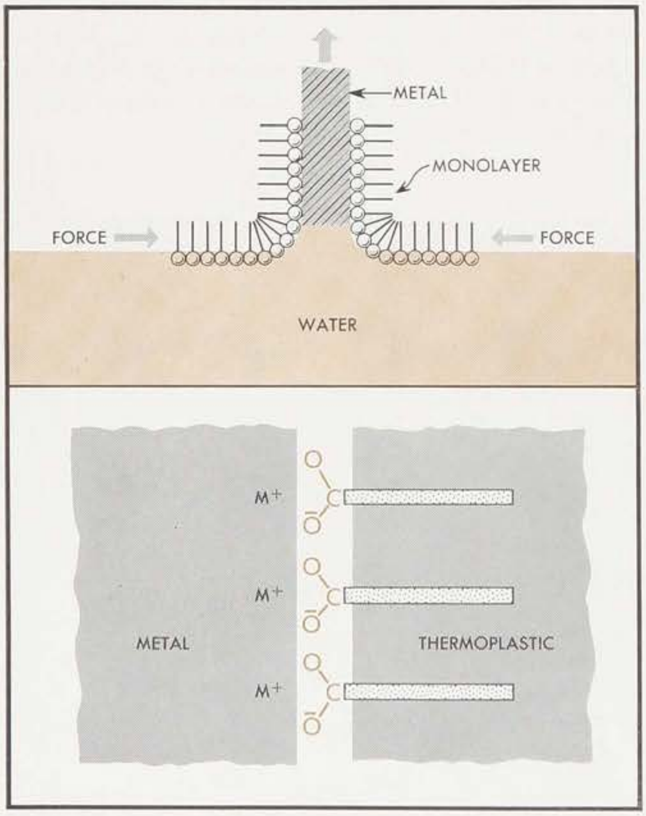
A Telstar command decoder unit, containing 37 transistors and 191 diodes, is prepared for a gamma radiation test at Bell Laboratories by William Gianopulos, left, and Frank J. Witt.



Metals Joined to Thermoplastics With Single Layer of Molecules

A new method of bonding metals to thermoplastics with a single layer of molecules as an adhesive has been developed at Bell Laboratories. A bond so formed between aluminum and polyethylene is more permanent than any previously achieved and more resistant to tearing and pulling than the plastic itself.

Previously it had not been possible to form a direct bond between metals and polyethylene that would withstand mechanical stress when humidity and temperature were high. Dr. Harold Schonhorn of the Chemical Research Laboratory now reports that an aluminum-polyethylene-aluminum bond, prepared by the new method, has held up for months under 600 pounds per square inch of tensile-shear stress at 100 per cent relative humidity and 80-120 degrees F. Dr. Schonhorn bonded these materials together with a monolayer of stearic acid ($CH_3(CH_2)_{16}COOH$). A paper describing his work is to be published in *The Journal of Polymer Science*.



Acid molecules, hydrocarbon part outward, adhere to a metal plate as it is drawn through the monolayer. Below, diagram shows chemical bond to the metal and physical bond to the thermoplastic.

His method could find a number of applications in the electronics industry. For example, a permanent bond between polyethylene insulators and copper conductors could improve the mechanical properties of telephone cables or increase the reliability of a printed circuit.

Dr. Schonhorn applied a technique developed in 1935 by Irving Langmuir and Katherine Blodgett and used since by chemists to study the structure of single molecules. The technique, which enables scientists to deposit a single layer of molecules ("monolayer") of a substance on a water surface, had never been applied before to adhesion.

If certain long chain hydrocarbon acids are used as the monolayer, Dr. Schonhorn demonstrated in his experiment, the acid end of the molecule will form a chemical bond with the metal and the hydrocarbon part will form a physical bond with the thermoplastic. One end of the stearic acid formed aluminum stearate with the metal plate; the other end became immersed in the polyethylene. These reactions account for the permanence of the bond.

To prepare the monolayer, Dr. Schonhorn dissolved the stearic acid in benzene and spread the solution on water contained in a long trough. The volatile benzene evaporated and left a monolayer of stearic acid on the surface. The hydrocarbon portion of the stearic acid is insoluble in water and tends to stand up straight when the film is compressed. The acid portion dissolves and lies just below the surface of the water.

Next, Dr. Schonhorn lowered an aluminum plate through the monolayer into a rectangular well. When he raised the plate it contacted the acid portion of the molecules at the underside of the layer, forming a chemical bond. The molecules adhered to the sides of the plate with the hydrocarbon part facing out.

Once coated with such a monolayer, metals cannot absorb appreciable amounts of water or gases from the atmosphere and can be stored for months before they are bonded to thermoplastics. Unprotected metals become contaminated by the atmosphere in a short time and must be specially treated before they are suitable for bonding.

In the final stage of his experiment, Dr. Schonhorn melted polyethylene onto the monolayer. The hydrocarbon portion of the stearic acid molecule became immersed in the polyethylene, itself a long chain hydrocarbon. This completed the bond.

Dr. Schonhorn has also bonded aluminum, stainless steel and copper to polypropylene and polystyrene using octadecylamine and octadecylphosphonate. By varying the adhesive, he can in principle bond other thermoplastics and metals together.

PATENTS

Following is a list of the inventors, titles and patent numbers of patents recently issued to members of the Laboratories.

Bouton, G. M.—*Soldering of Aluminum*—3,063,145.

Bullock, D. B., Cocker, J. T., and Rack, A. J.—*Variable Frequency Pulse Generator*—3,064,208.

Butler, T. T.—*Parallel Input Fast Carry Binary Counter with Feedback Resetting Means*—3,064,890.

Chegwidden, T. H.—*Magnetic Amplifier*—3,064,181.

Cirone, F. P.—*Transistor Scanner Network*—3,061,682.

Cocker, J. T., see Bullock, D. B.

Coleman, S. B.—*Selective Signaling Systems*—3,064,236.

Cook, J. S.—*Traveling Wave Tube*—3,060,341.

Crater, T. V.—*Error Detection in Pseudo-Ternary Pulse Trains*—3,061,814.

Crawford, R. V.—*Adjustable Motor Speed Control*—3,065,397.

Dacey, G. C., and Wallace, R. L., Jr.—*Modulated Oscillator and Low Impedance Diode Construction Therefor*—3,063,023.

Ellis, B. C., Jr.—*Connection of Insulated Wire*—3,066,274.

Farrow, C. W.—*Oscillator Synchronizing System*—3,063,021.

Ferguson, J. G.—*Magnetic Gradiometer System*—3,064,185.

Ferguson, J. G.—*Magnetic Gradiometer System*—3,065,413

Graff, H. J., Kleinfelder, W. C., and Schwartz, P. C.—*Connector for Insulated Conductors*—3,064,072.

Hamori, A.—*Pulse Repeater Testing Arrangement*—3,062,927.

Hersey, R. E.—*Line Testing Circuit*—3,064,090.

Howard, B. T.—*Vapor-Solid Diffusion of Semiconductive Material*—3,066,052.

Hussey, L. W., and Saal, F. A.—*High Current Transistor Pulser*—3,060,324.

Jackson, H. M.—*Automatic Magnetron Control Circuits*—3,063,012.

Kleinfelder, W. C., see Graff, H. J.

Mason, W. P.—*Electromechanical Wave Transmission Systems*—3,064,213.

Mann, H., and Mayo, J. S.—*Synchronization of Pulse Communication Systems*—3,057,962.

Mann, H.—*Testing the Performance of PCM Receivers*—3,057,972.

Mayo, J. S., see Mann, H.

Meacham, L. A.—*Telephone Substation Apparatus*—3,064,084.

Miller, S. E.—*Microwave Ferrite Switch*—3,064,214.

Montgomery, H. C.—*Torpedo Control Circuit*—3,064,610.

Muller, G. G., and O'Brien, W. D.—*Semi-Automatic Relay Test Circuit*—3,058,055.

Newby, N. D., and Sturiale, P. J.—*Magnetic Core Arithmetic Unit*—3,061,193.

O'Brien, W. D., see Muller, G. G.

Peek, R. L., Jr.—*Electrical Switching Device*—3,059,075.

Peek, R. L., Jr.—*Switching Device*—3,061,696.

Pfann, W. G.—*Pressure Transducers*—3,065,636.

Rack, A. J., see Bullock, D. B.

Rea, W. T., and Roberts, A. W.—*Transmission System-Selection by Permutation of Parity Checks*—3,064,080.

Remika, J. P.—*Boron Oxide-Lead Oxide Etchant and Etching Process*—3,063,886.

Roberts, A. W., see Rea, W. T.

Robertson, S. D.—*High Frequency Apparatus of the Traveling Wave Type*—3,065,373.

Saal, F. A., see Hussey, L. W.

Schwartz, P. C., see Graff, H. J.

Schneider, H. A.—*Data Storage System*—3,064,241.

Sherwood, R. C., and Williams, H. J.—*Magneto-Optical Information Storage Unit*—3,059,538.

Smith, A. R.—*Compensating Arrangements*—3,060,583.

Smith, J. L.—*Magnetic Memory Circuits*—3,060,411.

Sturiale, P. J., see Newby, N. D.

Wallace, R. L., Jr., see Dacey, G.

Wallace, R. L., Jr.—*Negative Resistance Diode Building Block for Logic Circuitry*—3,062,971.

Warner, R. M., Jr., see Spector, C. J.

Weiss, M. T.—*Enhanced Gyromagnetic Effect in Nonreciprocal Wave Transmission*—3,063,028.

Wernick, J. H.—*Ferromagnetic Material*—3,065,071.

White, S. D.—*Preset Call Transmitter*—3,062,921.

Wilcox, A. S.—*Test Socket*—3,065,443.

Williams, H. J., see Sherwood, R.

Williford, O. H.—*Automatic Call Recording System*—3,062,918.

Wrathall, L. R.—*Regenerative Pulse Repeater*—3,065,297.

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TALKS

Following is a list of speakers, titles and places of presentation for recent talks presented by members of Bell Laboratories.

Abrahams, S. C., *Magnetic and Crystal Structure of Titanium Sesquioxide Between 1.5K and 700K*, Polytech. Inst. Brooklyn, New York City.

Anderson, E. W., see McCall, D. W.

Anderson, P. W., *L Not-Equal-To Zero Pairing in Superconductors*, Am. Phys. Soc., Seattle.

Anderson, P. W., *Impurity Scattering in Superconductors*, Brookhaven Natl. Lab., Upton, L. I., N. Y.

Andreatch, P., see Sikorski, M. E.

Atalla, M. M. and Kahng, D., *A New "Hot Electron" Triode Structure With Semiconductor-Metal Emitter*, Solid State Devices Research Conf., Durham, N. H.

Baraff, G. A., *Growth Rate of Microwave and dc Avalanche Breakdown in Hydrogen*, Gaseous Electronics Conf., Boulder, Colo.

Bateman, T., see Mason, W. P.

Becker, F. K., *Joint Use of Telephone Lines for Voice and Data Transmission*, Audio Engrg. Soc., New York City.

Bescherer, E. A., *Project Telstar*, 1. Kiwanis Club, Winston-Salem, N. C. 2. Independent Telephone Companies Conv., Pinehurst, N. C.

Bird, C. M., see Flanagan, J. L.

Black, H. S., *New Developments in Communications Research*, Western Electric Grad. Engrg. Training Prog., New York City.

Black, H. S., *Satellite Communications*, Workshop for Teachers of Sci. and Math., Kingston, N. Y.

Black, H. S., *The Basic Philosophy of Communications and New Developments in These Fields*, Western Electric Co. Conf., Cedar Grove, N. J.

TALKS (CONTINUED)

Blecher, F. H., *Applications of Transistors in the Telephone Industry,* Northeast Electronics Res. and Engrg. Mtg., Boston.

Bomberger, D. C., *Exotic Power Sources,* AIEE, Washington Sect., Washington, D. C.

Bonfeld, M. D., *Superconducting Magnet for a Traveling-Wave Maser,* IRE, Prof. Group on Electron Devices, Washington, D. C.

Bovey, F. A., *The Development of Polymer Science-A Brief View,* Am. Chem. Soc., Minnesota Sect., Minneapolis.

Brown, H., see Wagner, R. S.

Buchsbaum, S. J., *Solid-State Plasmas,* MIT, Plasma Dynamics Seminar, Cambridge, Mass.

Calbick, C. J., and Schwartz, N., *Tantalum Crystal Chemistry in the Electron Microscope,* Am. Vacuum Soc., Los Angeles.

Chang, J. J., Forster, J. H., and Ryder, R. M., *Semiconductor Junction Varactors with High Voltage Sensitivity,* Electron Devices Mtg., Washington, D. C.

Chynoweth, A. G., *Avalanche Multiplication Processes in Semiconductors,* IRE Electron Device Mtg., Washington, D. C.

Clogston, A. M., *Orbital Paramagnetism and Knight Shift of D-Band Superconductors,* Univ. of Chicago.

Cohen, B. G., Goordman, R. V., Snow, W. B., and Tretola, A. R., *Gallium Arsenide Diodes as Cryogenic Thermometers,* Electron Devices Mtg., Washington, D. C.

Coker, C. H., see Flanagan, J. L.

Compton, K. G., *Criteria for Cathodic Protection,* Nat'l. Assoc. Corrosion Engrs., San Diego.

Cottingham, W. B., and Buchsbaum, S. J., *Electron Ionization Frequencies in Hydrogen,* 15th Gaseous Electronics Conf., Boulder, Colo.

Courtney-Pratt, J. S., *A Fiber Optics Camera,* 6th Intern. Cong. on High Speed Phot., The Hague.

Coyne, J. C., *Percussive Welding —A New Form of Capacitor Discharge Arc Welding,* ASME Discussion Group, Ohio State Univ., Columbus.

Crowell, C. R., and Spitzer, W. G., *Attentuation Length Measurements of Hot Carriers in Metal Films,* Solid State Device Research Conf., Durham, N. H.

Darling, D. W., *Automatic Calling for Switched Data Communication Services,* AIEE, Chicago.

Darnell, P. S., *The Nature of Effective Specifications,* Am. Soc. Qual. Control, Univ. of Michigan, Ann Arbor.

Darnell, P. S., *Electronic System Reliability—An American Viewpoint,* 2nd Symp. on Electronic Equipment Reliability, London.

Davis, C. G., *Pulse Code Modulation,* Assoc. Am. Railroads, Chicago.

Davis, R. L., *Radio Interference in Carrier Telephone Systems,* AIEE, Chicago.

Deininger, R. L., *Human Factors in Telephone Systems Engineering,* ASME, Bergen-Passaic Group, Fairleigh Dickinson Univ., Teaneck, N. J.

Delchamps, T. B., *Simulation of the Space Environment in Development of the Telstar Communications Satellite,* 1. ASME, North Jersey Sect. Mtg., Newark, N. J. 2. Inst. Environmental Sciences, Manhasset, L. I., N. Y.

Deutsch, M., *Cooperation and Trust — Interpersonal and International,* Univ. of Pittsburgh, Psych. Dept. Symp.

Dillon, J. F., Kamimura, H., and Remeika, J. P., *Magneto-Optical Studies of Chromium Tribromide,* Conf. on Magnetism and Magnetic Materials, Pittsburgh.

Douglass, D. C., see McCall, D. W.

Draper, R. D., *Communication as Leadership,* Red Cross Leadership Inst., Madison, N. J.

Dunn, H. K., Flanagan, J. L., and Gestrin, P. J., *Complex Zeros of a Triangular Approximation to the Glottal Wave,* Acoust. Soc. Am., Seattle.

Edwards, R., see Sikorski, M. E.

Eggers, F. G., and Strauss, W., *A UHF Delay-Line Using Single Crystal Yttrium Iron Garnet,* Conf. on Magnetism and Magnetic Materials, Pittsburgh.

Favin, D. L., and Fennick, J. H., *The 6-A Impulse Noise Counter and Its Use,* AIEE, Chicago.

Felch, E. P., *Radio Command Guidance of Scientific Satellites,* 4th Intern. Symp. on Space Technol. and Sci., Tokyo.

Fennick, J. H., see Favin, D. L.

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Flanagan, J. L., Bird, C. M., and Hause, A. D., *Digital Simulation of Basilar Membrane Motion,* Acoust. Soc. Am., Seattle.

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Forster, J. H., see Chang, J. J.

Frosch, C. J., and Thurmond, C. D., *Vapor Growth of Single Crystals of Gallium Phosphide and Gallium Arsenide by a Gallium Oxide Vapor Transport*

Mechanism, Electrochem. Soc., Boston.

Frosch, C. J., see Thurmond, C. D.

Frost, H. B., *Some Experiments on Water Introduced into Electron Tubes,* 1. MIT Phys. Electronics Conf., Cambridge, Mass., 2. ASTM Symp. Cleaning and Materials Processing, Los Angeles.

Gallagher, P. K., *Ultraviolet Absorption Spectra of o-, m-, and p-Phenylenediamines and Their Mono and Dihydrochlorides in Aqueous Solution,* Am. Chem. Soc., Atlantic City, N. J.

Garn, P. D., *Analysis of Gaseous Thermal Decomposition Products,* Eastern Analytical Symp., New York City.

Garrett, C. G. B., *Optical Masers and Their Application in Welding, Cutting and Communications,* Am. Welding Soc., Milwaukee, Wis.

Garrett, C. G. B., *Optical Masers,* 1. IRE, North Carolina Sect., Greensboro, N. C., 2. Esso Research Club, Linden, N. J., 3. ASME Symp., Albuquerque, N. M., 4. Am. Chem. Soc., Washington, D. C. Chapt.

Gause, G. R., *The Quality Survey as an Administrative Control,* Midwest Qual. Control Conf., Denver.

Germond, P. J., and Mayer, K. L., *An Automatic Calling Unit for Switched Data Communication Service,* AIEE, Chicago.

Geschwind, S., *Optical Detection of Paramagnetic Resonance in Crystals,* Brandeis Univ., Waltham, Mass.

Gestrin, P. J., see Dunn, H. K.

Gewartowski, J. W., *The Telstar Experiment,* Summit Chapt. Illinois Inst. Tech. Alumni Assoc., Summit, N. J.

Gianola, U. F., *Magnetic Switching Circuits and Memory Techniques,* North New Jersey IRE Fall Lecture Series, Montclair, N. J.

Gianola, U. F., *Disturb Thresholds in Cylindrical Film Memory Wire,* Conf. on Magnetism and Magnetic Materials, Pittsburgh.

Ginsberg, A. P., *Hydride Complexes of Rhenium and Technetium,* Mellon Inst., Pittsburgh.

Giordmaine, J. A., *Non-Linear Optical Effects in Crystals,* Univ. of Rochester, Phys. Colloq., Rochester, N. Y.

Goddard, C. T., *Telstar,* Dixie Cup Corp., Easton, Pa.

Goddard, C. T., *Telstar,* Engrs. Club, Lehigh Valley, Pa.

Goordman, R. V., see Cohen, B. G.

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Haines, A. B., *Telstar,* N. C. Chapt. Telephone Pioneers Am., Winston-Salem, N. C.

Hamming, R. W., *Computer Operation in an Open-Shop Situation,* Argonne Natl. Lab., Chicago.

Hamming, R. W., *Information Theory and Numerical Analysis,* 1. Midcontinent Computer Club, Chicago, 2. Univ. of Nebraska, Lincoln.

Hannay, N. B., *Viewpoints on Materials Science and Engineering,* Natl. Metals Cong., New York City.

Harris, G. G., see Flanagan, J. L.

Hatch, R. W., *Telstar Satellite Communications Experiment — Objectives, Description, and Preliminary Results,* 1. IRE, Texas Assoc. Broadcast. Executives, Dallas, 2. IRE, Dallas Sect. Engrs., 3. Southwestern Bell Tel. Co., Dallas, 4. IRE, Monmouth Subsect., Little Silver, N. J.

Haugk, G., *The Morris Electronic Switching System,* 1. Essex County Soc. Prof. Engrs., East Orange, N. J., 2. IRE, North Carolina Sect., Burlington, N. C.

Hause, A. D., see Flanagan, J. L.

Hauser, J. J., *Magnetization of Thin Superconducting Films of Hard Superconductors,* Am. Phys. Soc., Cleveland.

Herriott, D. R., *Optical Masers,* Brooklyn Polytech. Inst., Elec. Engrg. Dept. Colloq., New York City.

Holbrook, B. D., *Bell-Telephone-Laboratories Computer Operating Systems,* British Computer Soc., London.

Holt, H. O., *The Uses of Teaching Machines in Employee Training,* Univ. of Florida, Tampa.

Hutson, A. R., *Ultrasonic Traveling-Wave Interactions in Solids,* G. E. Research Lab., Schenectady, N. Y.

Hutson, A. R., *Ultrasonic Traveling-Wave Amplification in Piezoelectric Semiconductors,* Northeast Electronics Res. and Engrg. Mtg., Boston.

Irvin, J. C., *Diffused Gallium Arsenide Varactors — Epitaxial and Nonepitaxial,* Electron Devices Mtg., Washington, D. C.

Iwama, M., *Telstar Antenna Steering System,* IRE, Prof. Gr. on Automatic Control, New Jersey Chapt., Little Falls, N. J.

Jaccarino, V., *The Nucleus as a Probe of the Solid-State,* 1. Fordham Univ., New York City, 2. MIT, Cambridge, Mass.

Jaccarino, V., *Physical Properties of Intermetallic Compounds,* AIME, New York City.

Jaccarino, V., *Conduction Electron Polarization and Possible Superconductivity in Rare-Earth Metals,* Brookhaven Natl. Lab., Upton, L. I., N. Y.

Joy, H. W., see Saturno, A. F.

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Kahng, D., see Atalla, M. M.

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Kamimura, H., see Dillon, J. F.

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Kane, E. O., *Photoelectric Emission from Semiconductors,* Westinghouse Res. Lab., Pittsburgh.

Kane, J. V., *The Reaction Oxygen-16 (Alpha, Two-Alpha) Carbon-12 (G.S.),* Johns Hopkins Univ., Baltimore.

Kane, J. V., *The Stored Program Computer as a Nuclear Radiation Analyzer,* Conf. on Multiparameter Radiation Analysis, Grossingers, N. Y.

Kersta, L. G., *Voiceprint Identification,* 1. Am. Assoc. Univ. Women, Bound Brook, N. J., 2. Cleveland Crime Commission, Cleveland, O., 3. Audio Detection Engrg. Soc., Los Angeles, 4. Audio Engrg. Soc. and Soc. of Motion Picture and Television Engrs., Joint Mtg., Los Angeles, 5. IRE, Princeton Sect., Princeton, N. J., 6. Acoust. Soc. Am., Seattle, 7. Inst. Elec. and Electron. Engrs., Princeton, N. J.

Ketchledge, R. W., *The Morris Electronic Central Office,* Western Electric Co., Columbus, O.

Klauder, J. R., *Relativity Theory and Space Missions,* Bellcomm, Inc., Washington, D. C.

Klauder, J. R., *On the Covariant Quantization of the Gravitational Field,* Princeton Univ. Relativity Seminar, Princeton, N. J.

Lax, M., *Influence of Time-Reversal on Selection Rules Connecting Different Points in the Brillouin Zone,* Intern. Conf. on Physics of Semiconductors, Univ. of Exeter, England.

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Leenov, D., *The Silicon Pin Diode as a Microwave Radar Protector at Megawatt Levels — Theory,* Electron Devices Mtg., Washington, D. C.

Lozier, J. C., *Computer Controlled Feedback Systems,* Rensselaer Polytech. Inst., Troy, N. Y.

MacChesney, J. B., *Processing Variables Affecting the Positive Temperature Coefficient of Resistivity in Doped Barium Titanate,* Am. Ceramic Soc., Basic Sci. Div., Columbus, O.

MacLean, D. J., *A Personal Voice Amplifier,* Audio Engrg. Soc. Conv., New York City.

MacNair, D., *Hydrogen Conversion of Thermionic Emitters Containing Alkaline-Earth-Carbonates,* 6th Nat'l. Conf. Tube Techniques, New York City.

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Matthews, H., *Acoustic Wave Rotation by Magnon-Phonon Interaction,* Pennsylvania State Univ., Elec. Engrg. Dept. Seminar, University Park.

Mayer, K. L., see Germond, P. J.

McCall, D. W., *Nuclear Magnetic Relaxation in Polymers by Pulse Methods,* NMR Symp., New York City.

McCall, D. W., Douglass, D. C., and Anderson, E. W., *Self-Diffusion Studies by Means of Nuclear Magnetic Resonance Spin-Echo Techniques,* Deutsche Bunsengesellschaft fur Physik. Chem., Munster, Germany.

McLean, D. A., *Thin Film Components and Circuits,* 1. IRE, Chicago Sect., 2. IRE, New York City Sect.

Miller, S. E., *Circular Electric Waveguides for Communication,* Northeast Electronics Research and Engrg. Mtg., Boston.

Mumford, W. W., *Noise Performance Factors in Communication Systems,* Seminar on Noise, Rochester, N. Y.

Nelson, D. F., *Recent Developments in Molecular Amplifiers,* Gordon Conf. on Instrumentation, Colby Junior College, New London, N. H.

Nelson, D. F., *The Optical Maser,* Georgia Inst. Tech., Atlanta.

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Peterson, A. E., *The Development of the Mercury Communications Network,* Western Electric Co. Engrg. Conf., 1. Newark, 2. New York City.

Pfann, W. G., and Wagner, R. S., *Principles of Field Freezing,* AIME, New York City.

Pierce, J. R., *What Compters Are Good For,* Advanced Res. Projects Agency Lecture Series, Washington, D. C.

Pollak, H. O., *On the Nature of Essentially Time- and Band-Limited Signals,* Univ. of California, Berkeley.

Pollak, H. O., *On the Nature of Applied Mathematics,* Franklin Inst., Philadelphia.

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Zone of New York State, Buffalo.

Pollak, H. O., *Mathematics Applied to Communications*, Princeton Univ., Math. Studies in Engrg. Mtg., Princeton N. J.

Pollak, H. O., *On the Nature of Mathematical Research in Industry*, Natl. Youth Conf. on the Atom, Chicago.

Pollak, H. O., *School Mathematics Study Group, Ninth Grade*, Rockford College, Rockford, Ill.

Remeika, J. P., see Dillon, J. F.

Richards, P. L., *Magnetic Resonance in the Far-Infrared*, U. S. Naval Research Lab., Washington, D. C.

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Riordan, J., *Generating Functions*, Univ. of Calif., Lectures at Palo Alto, Los Angeles, Corona and San Diego.

Rosenberg, S., *A Psychological Model for Two-Person Interactions in the Laboratory*, Columbia Univ., New York City.

Rothkopf, E. Z., *The Sentence as Stimulus in Human Learning*, 1. Univ. of Connecticut, Psych. Colloq., Storrs. 2. Center for Programmed Instruction, New York City.

Ryder, R. M., *Transistors*, IRE, North N. J. Sect., Montclair.

Ryder, R. M., see Chang, J. J.

Saal, F. A., *TASI, A Band Compression System*, Audio Engrg. Soc. Conv., New York City.

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Slepian, D., *The Threshold Effect in Modulation Systems That Expand Bandwidth*, Intern. Symp. Inform. Theory, Brussels.

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Slichter, W. P., *Some Nuclear Magnetic Resonance Studies of Polymers*, Celanese Labs, Summit, N. J.

Smith, G. E., *Hybrid Resonance in Bismuth and Bismuth Antimony Alloys*, Univ. of Pennsylvania, Philadelphia.

Smith, J. L., *The Waffle Iron—A New Memory Structure*, Conf. on Magnetism and Magnetic Materials, Pittsburgh.

Smolinsky, G., *The Chemistry of Nitrenes*, Cornell Univ., Ithaca, N. Y.

Snow, W. B., see Cohen, B. G.

Snyder, L. C., see Saturno, A. F.

Sokoler, R., see O'Neill, J. F.

Spitzer, W. G., see Crowell, C. R.

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Strauss, W., see Eggers, F. G.

Stuart, J. C., *Magnetic Memory Devices*, AIEE-IRE Joint Student Branch, North Carolina State College, Raleigh.

Sylwestrowicz, W. D., *Fracture Mechanism of Single Crystals of Silicon*, Intern. Conf. on Fracture, Maple Valley, Wash.

Tanabe, Y., see Kamimura, H.

Tanenbaum, M., *Materials, Magnets, and Masers*, Maryland Sect. Am. Chem. Soc., Baltimore.

Thomas, D. G., *Excitons and the Band Structure of Cadmium Sulfide*, New York Univ., Univ. Heights Campus, New York City.

Thompson, R. H., *The Challenge of Modern Industry to Education*, Upper Montclair, N. J.

Tretola, A. R., see Cohen, B. G.

Turner, D. R., *Electrochemistry of Some Semiconductor Materials*, Electrochem. Soc., Washington, D. C., Sect.

Thurmond, C. D., and Frosch, C. J., *Thermodynamic Properties of Gallium Phosphide and Gallium Arsenide*, Electrochem. Soc., Boston.

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Van Uitert, L. G., *Maser Materials*, Electrochem. Soc., Boston Sect.

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Wagner, R. S., see Pfann, W. G.

Walker, P. P., see Mathews, M. V.

Warner, A. W., see Stockbridge, C. D.

Watson, B. J., see Flanagan, J. L.

Werthamer, N. R., *Bound Electron Pairs and the Superconducting State*, Fordham Univ., New York City.

Wertheim, G. K., *The Mossbauer Effect and Its Applications*, Am. Soc. Met. and Metallurgical Soc., New York City.

Wertheim, G. K., *The Mossbauer Effect Isomer Shift*, California Inst. Tech., Pasadena.

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