Bell Laboratories

RECORD

May 1962

Contents

Cover   *Quad-helix antenna outside control building at Andover, Me., will be used in tracking the Telstar satellite from 136-Mc beacon signal (see story on page 166).*
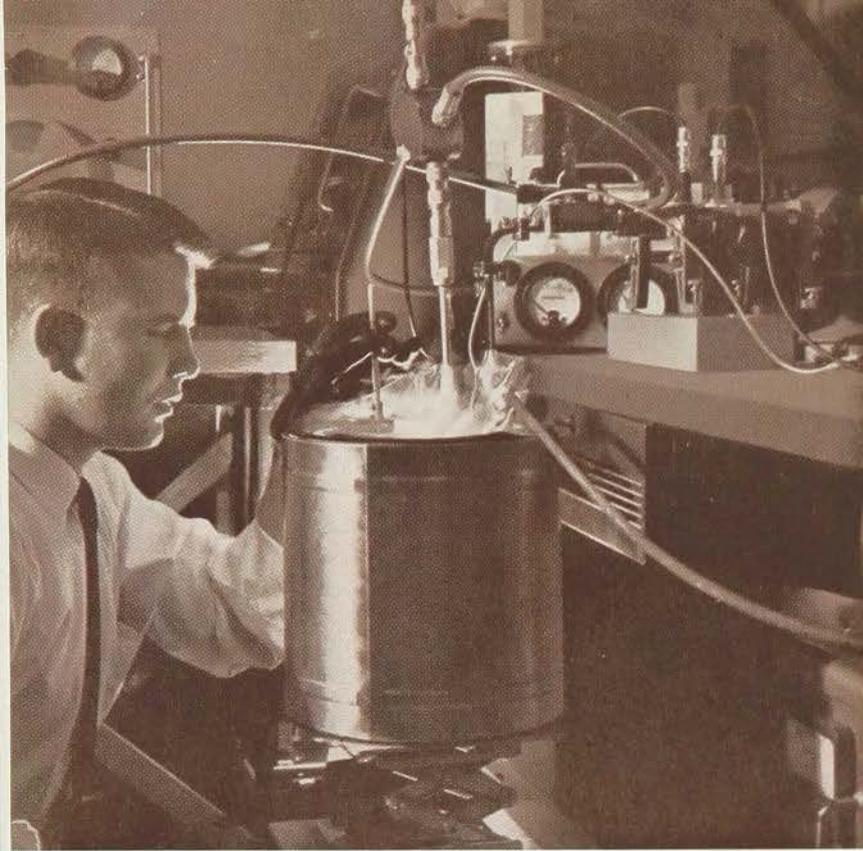
D. C. Hanson tests a parametric amplifier immersed in liquid nitrogen. The fluid's temperature, about 77 degrees K, is highly effective in reducing the noise temperature of the amplifier and it is much simpler to use than liquid helium.

Low-Noise Mi

Microwave signals that travel a long path to the receiver may arrive as faint echoes from a noisy sky. Signal and noise pass through the receiver together and are amplified together; at the output the signal may be barely distinguishable in the noise. Compounding the problem, conventional amplifiers generate even more noise than the sky, and this is also added to the input signal. The cumulative effect is that the signal often is drowned out by the noise.

The development of quiet amplifiers has been a major concern of researchers and designers for many years. Their efforts have begun to bear fruit in both solid state devices and low noise electron tubes. Some of these—notably the solid state maser—have already demonstrated exceptional capability for low noise performance. Others appear to have the potential to do so.

Bell Laboratories has developed a number of low-noise amplifiers. Among the solid-state devices the Laboratories is particularly interested in the maser, the semiconductor parametric amplifier, and the Esaki diode. Promising electron-tube devices include the low-noise traveling-wave tube and the cyclotron wave amplifier. Some of these devices already have been operated in experimental systems. This article will discuss their operation, compare their noise performance, and will try to predict how they may be used in

microwave communications in the future.

In order to compare noise performance, we must be able to measure noise quantitatively. Noise arises from the random motion of charged particles, such as electrons, which exist in a free state or are bound in atoms or molecules. At high temperatures these particles move rapidly and emit much electromagnetic radiation; at low temperatures they slow down and emit less radiation. An index of the amount of radiation emitted is "effective temperature" or "noise temperature" which is given in degrees Kelvin with 0 degrees K (absolute zero) equivalent to no noise at all. These terms are used to express the noise power that enters the amplifier; hence, they are measures of the degradation of system performance produced by sky noise and by self-generated amplifier noise.

Effective temperature is not uniform in all parts of the sky and it varies with frequency. One way to reduce system noise is to turn an antenna to a part of the sky where the effective temperature is low. Another is to transmit at frequencies where it is low. In the 0.7 to 10 kilomegacycle frequency band, for example, the effective temperature may be as low as 2 or 3 degrees K. Therefore, ultrasensitive radars, satellite and tropospheric scatter communications systems, radio astronomy and radiometry systems operate in this
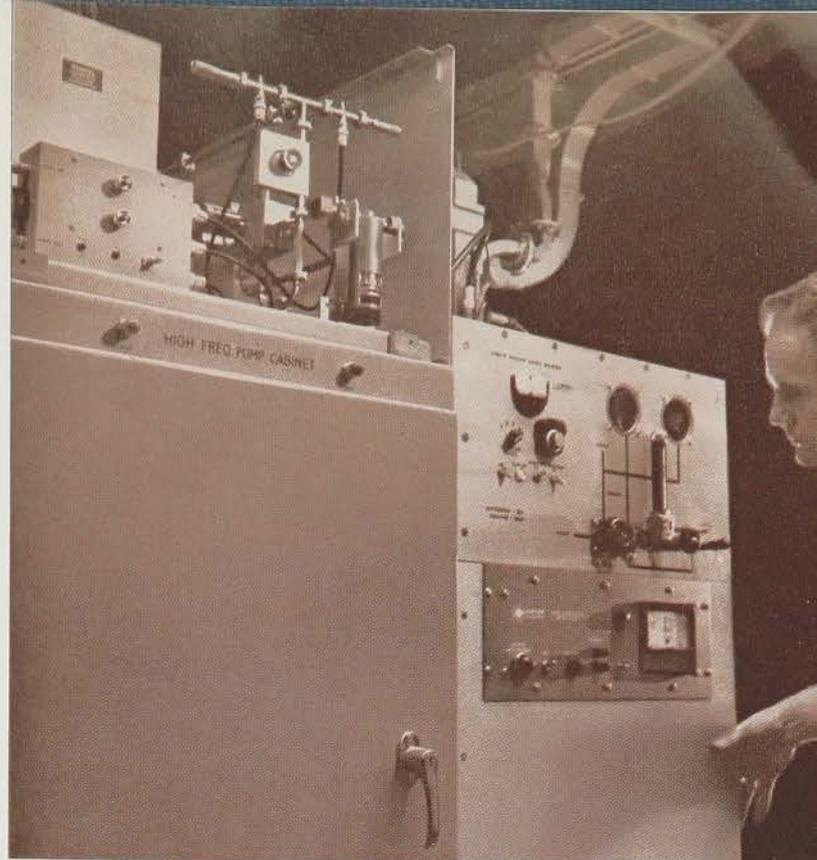
ve Amplifiers

H. Seidel

G. E. Storck studies the control panel of maser used at the communications satellite ground tracking station in Maine. Cabinet at right houses the maser, larger rack at left contains the microwave pump supply needed to power the maser.

band. Nature's challenge to the communications engineer is that he design an amplifier whose effective temperature will match the effective temperature of the sky in this quiet frequency band. Only the solid-state maser fully meets the requirements. Immersed in liquid helium it has been operated at a noise temperature of 4 degrees K.

To describe the operation of the maser (RECORD, *May* 1960) we must turn to the quantum picture of matter. In this view, electrons exist in different states, each corresponding to a specific quantity of energy. For maser action to take place, more electrons must be maintained in the higher energy states than would normally exist there. To do this, microwave energy is used to "pump" electrons from the lower to the higher states. The signal to be amplified stimulates the electrons to drop back to their original states and in doing so they give up coherent microwave energy which is added to the signal. This, of course, is the energy of amplification. Occasionally, an electron drops back to the lower state spontaneously and produces incoherent energy. This is noise. From the point of view of the system designer, the maser is a negative resistance device; that is, an increase in voltage accompanies any decrease in current. A positive resistance absorbs the power of signal waves; a negative resistance adds to it.

The Esaki diode (RECORD, *March* 1960) also has

the property of negative resistance. Like conventional diodes it develops its conduction properties when certain impurities are added to a very pure semiconductor material. Increased concentrations of impurities give rise to a range of forward bias voltages in which forward conduction decreases as the bias voltage increases. In that range the diode develops a region of negative ac conductance which serves as an amplifying mechanism. The internal noise temperature of the diode depends on the ratio of forward current to conductance. Esaki diodes with germanium crystals have operated at a noise temperature of 350 degrees K at frequencies below 1 kmc; with gallium antimonide crystals, noise temperature is as low as 300 degrees K at the same frequencies. The unabated noise arises from the random character of the forward current and from unavoidable resistance in the diode.

Another category of solid-state amplifiers is the variable reactance device (RECORD, *July* 1958). Semiconductor and ferrite amplifiers are in this class. They are actually an extension of modulation techniques which use variable resistance instead of reactance elements. (A circuit element that stores energy, for example, a capacitor, is said to have reactance.)

Engineers have known for some time that semiconductors can be used as variable reactances.

S. E. Plauski adjusts an experimental model of a low-noise parametric amplifier. This device is undergoing intense development and is being tested with different types of diodes. Encouragingly low noise temperatures have been attained.

The semiconductor diode is essentially an open circuit to dc in the reverse direction; it is also a voltage sensitive capacitor. Because the capacitance of a p-n junction depends on the voltage applied across it, a rapidly variable capacitance can be obtained through a high-frequency voltage drive. This drive is the microwave pump signal, or in the terminology of the modulation art, the carrier. When a carrier wave is amplitude modulated it sets up an upper and lower sideband with frequencies equal to the sum and difference, respectively, of the carrier frequency and the modulating frequency. The sidebands in variable *resistance* modulators do not contain as much energy as the modulating signal. In variable *reactance* amplifiers they contain more. Each sideband characterizes a distinct mode of operation: Modulating power is absorbed and amplified by the variable reactance elements in the upper sideband mode; power is regenerated by the reactance elements in the lower sideband mode.

Theoretically, variable reactance elements are as noiseless as the best maser. However, other parts of the system add noise. Noise temperature for a perfect variable reactance amplifier depends on the ratio of the signal to the pump frequency. In upper sideband operation the noise temperature is approximately the product of this ratio and the noise temperature of the amplifier

which follows the reactance elements. When the system is operated at room temperature the noise temperature of the second amplifier may be as high as 2000 degrees K. Noise temperature in lower sideband operation is (if the pump frequency is much greater than the signal frequency) approximately the product of the same signal-pump frequency ratio and the lowest "available" temperature in the system—usually the bath temperature of the diode which is about 290 degrees K at room temperature operation. Hence, lower sideband operation has the greatest promise for low noise amplification.

Additional noise may arise in a diode amplifier from the small series resistance of the diode. Refrigeration may be a way around this problem. A gallium arsenide point contact diode operating at 6 kmc may have a noise temperature of 60 degrees K above that for ideal variable reactance lower sideband amplifiers. If the diode were refrigerated with liquid nitrogen this excess noise might be reduced to only 20 degrees K. The excess noise is added to other noise and the total noise temperature may be quite high. For example, a parametric amplifier using a gallium arsenide diode and operating with a pump frequency of 24 kmc and a signal frequency of 6 kmc has a noise temperature of 160 degrees K when it is maintained at room temperature. When the diode is refrigerated with liquid nitrogen, the noise temperature is reduced to 50 degrees K.

Although refrigeration to liquid nitrogen temperature adds some complications, it is much simpler than refrigeration to the liquid helium temperature required for the maser, and it may be worth accepting higher noise to gain system simplicity. Another, more compact, means of reducing noise is through thermoelectric cooling. This method can reduce the diode temperature by about 100 degrees K, thus reducing excess noise to 40 degrees K and total noise temperature to 110 degrees K.

Diode performance tends to deteriorate at very high frequencies. Ferrite amplifiers eventually may be useful at these frequencies. They operate on the principle of a varying permeability which is established through the very complex motion of spinning electrons in the microwave pump fields. So far, however, ferrite amplifiers have had excess noise temperatures of over 4000 degrees K at about 4.5 kmc. Moreover, they require fairly high pumping power.

Turning to electron tube amplifiers, we find some new ways of controlling the energy of the electron beam used to amplify a signal. Both the traveling-wave tube and the cyclotron wave ampli-

fier operate on principles very different from those of earlier electron tubes.

In the traveling-wave tube a radio-frequency wave and the electron beam, traveling at nearly the same velocity, continuously interact over a comparatively long distance. The electrons lose part of their kinetic energy in the interaction and the lost energy is transformed into more radio frequency energy.

At one time it seemed that the traveling-wave tube would never be capable of low noise performance. The nature of the process that reduces noise in the device was so poorly understood that designers thought its lowest possible noise temperature was about 1000 degrees K. The process is still imperfectly understood, but we now know it is related to the large number of electrons that accumulate in the region immediately in front of the cathode. This electron cloud tends to correlate the normal random motion of electrons leaving the cathode, thus reducing noise in the tube. The noise problem has been attacked by using novel geometries for the electron gun in this device. In this way its noise temperature has already been reduced to about 450 degrees K at 6 kmc. Experiments now being performed in the Laboratories should lead to a better understanding of the noise reduction process and thus, hope-

fully, to even lower noise temperatures.

The principle of the cyclotron wave amplifier—a beam type parametric amplifier—also departs from that of earlier electron tubes. A charged particle under the influence of a magnetic field tends to drift in the direction of that field. If an electric field is superimposed perpendicular to the magnetic field the electron will rotate about the magnetic field axis. The rate of rotation is called the "cyclotron frequency". If the electric field of the signal to be amplified varies at approximately the cyclotron frequency, the beam gains rotational energy from the microwave field. It can also be made to give this energy back. However, before it is given back to the microwave field, the rotational energy is increased. Thus the signal is amplified.

The cyclotron wave amplifier (see the drawing below) consists of two identical transducers—microwave structures that produce the electric field across the electron beam. One transmutes microwave to rotational energy, the other returns the rotational energy to microwave energy. Between these transducers is a quadrupole array of alternately charged plates. Because of the alternate changes an electric field is not produced at the center of the array. Hence, if an electron beam is shot along the axis it will not be attracted
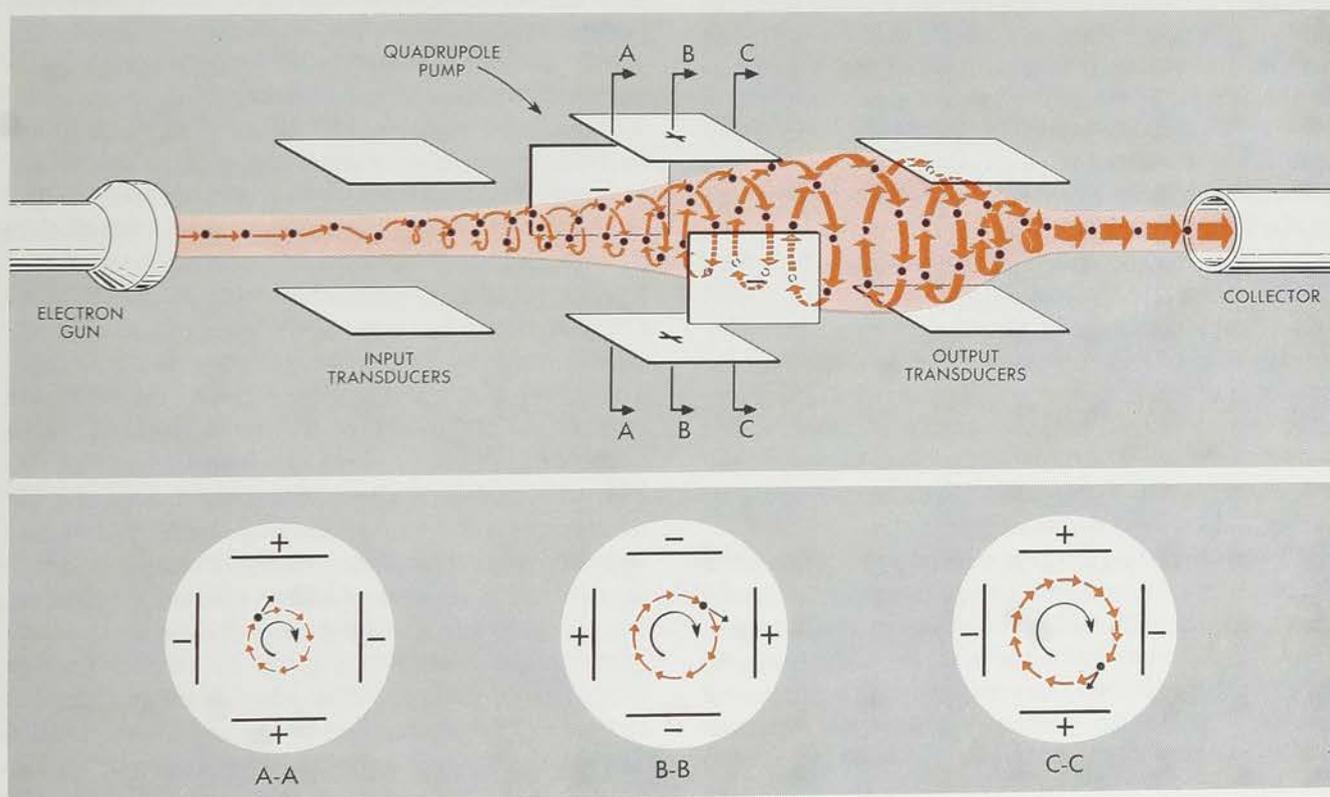
Highly simplified drawing shows operation of cyclotron wave amplifier. Lower view, along axis of electron beam, shows how orbital energy of electron increases as the beam, attracted to the plates in quadrupole field by alternately changed polarities, whips around in the quadrupole pump.

E. J. Zimany sets up apparatus in which Laboratories engineers are studying the noise process in traveling-wave tubes. Studies indicate that a lower noise figure than previously thought possible is likely for these wideband amplifiers.

to any of the plates. However, if the beam is deflected by signal energy toward a plate momentarily charged to attract it, it will be whipped around the quadrupole field toward the next plate in the array. If the polarity of the second plate is again changed, the beam will be attracted to it and it will whip toward the succeeding plate. As this process continues the beam will move around the array in ever widening orbits.

A microwave pump signal causes the plate charge to alternate. During pumping, the electron beam stores orbital energy which it ultimately surrenders to the second microwave transducer, thus amplifying the signal. Amplifiers of this type operated experimentally in the 0.5 to 4 kmc band have had an excess noise temperature of only about 50 degrees K. Their main source of noise is loss in the waveguide.

The major determining point in predicting the future of these new microwave amplifiers is the character of different microwave systems. In a satellite communications system for example, amplification of the exceedingly weak incoming signal is uncompromisingly important. Its antenna-receiver system is designed without regard for any other problem. For example, Andover, Maine was chosen as the site of the A.T.&T. Company's imminent Project Telstar experiment (RECORD, *November* 1961) partly because the

weather there is accommodating to the maser. Severe rainstorms, for example, may increase the effective temperature of the sky by as much as 30 degrees K for an antenna pointed straight up and tuned to a frequency of 4 kmc. The Andover area has a comparatively low probability of intense rainfall and thus, the very low noise receiver-antenna system can be used to its best advantage. The horn antenna Bell Laboratories designed for the satellite system and the maser give superlative noise performance as a unit. In measurements made at the Andover site the two produced an entire system noise temperature of 26 degrees K at 4 kmc with the antenna turned toward the sky.

Its excellent noise performance made the maser the first choice for this experimental satellite system. The weight of its cryogenic system and its magnet, and the maintenance they require, were minor concerns in view of the size, complexity, and cost of the other terminal equipment, including the antenna itself. However, there was one practical problem that had to be solved for a commercial satellite system.

Present plans for satellite communications anticipate the use of FM feedback which requires large bandwidth in the receiver. The maser can be tuned in a way that will increase its bandwidth, but at the expense of gain. Therefore, the latest designs have increased the maser's efficiency so that the required gain is achieved together with the needed bandwidth.

These new masers will be excellent amplifiers in future satellite systems. Nevertheless, when commercial satellite systems are developed the choice of amplifiers for them will be competitive, as it is for other communications systems. Thus, a light traffic system that can sacrifice some channel capacity may gain more from system simplicity than from the ultimate in noise performance. In this case, the parametric amplifier may be a better choice than the maser.

Radar systems present other problems. The design of a radar receiver must be related strongly to its specific use; a receiver used for target acquisition and tracking does not have the same requirements as one used for airport traffic control or weather observations. A single weapons system may use several types of receivers, each fitted to a different function. Moreover, radar systems differ from pure communication systems in that there are inevitable degradations in radar data before it is received. Losses in the transmit-receive switch and losses in phase comparators used in interferometer systems are inescapable. Total noise temperature in the most carefully de-

signed systems may mount to well over 100 degrees K. This does not include sky noise which significantly adds to the noise level at frequencies below 1 kmc. Finally, considerations of range, bandwidth and complexity make the choice of the lowest noise receiver—the maser—debatable.

At 2 kmc the noise temperature of the maser is typically between 5 and 10 degrees K. At the same frequency the noise temperature of a variable reactance diode amplifier cooled with liquid nitrogen is 45 degrees K. Calculations of radar range for each amplifier show that range is reduced less than 5 per cent when the diode is used instead of the maser. The slightly reduced range may be worth the savings in cost and size that the diode offers.

In terms of gain-bandwidth the diode is again the better choice for radar systems. The maser cannot produce adequate gain over the noise of later amplifier stages unless the bandwidth is limited. Systems requiring frequency agility, that is, systems in which the transmitter frequency continually shifts, make difficult demands for rapid magnetic tuning. The diode amplifier is very rapidly tunable. It is quite capable of operating over a 10 per cent bandwidth with quite small noise degradation and with fast tuning.

A final point of comparison between diode parametric amplifiers and masers in radar systems is reliability. Here, refrigeration is a determining factor. The diode can be cooled either thermoelectrically or in a large vessel containing liquid nitrogen which is merely refilled periodically. The maser, on the other hand, requires a liquid helium environment. This will be attained through a closed cycle helium refrigerator now being developed—a complex piece of equipment that will need periodic maintenance.

There are further reasons for the maser to yield to other amplifiers in radar systems. Thermoelectrically cooled diodes, for example, have great advantages in size over the maser. Also, the Esaki diode, despite its present high noise temperature, has the advantages of small size and the fact that it does not require an expensive pump source. In choosing a receiver for a radar system a designer must carefully consider the range he can achieve with each amplifier and relate these to the demands of the system. Only then can he make the best choice.

Terrestrial radio relay systems offer a final example of the considerations involved in choosing an amplifier to fit a system. There are four major sources of signal degradation in these systems: cross talk produced by system non-linearities, noise from various forms of interference, noise generated by the earth's surface and atmosphere, and the familiar self-generated systems noise. The maser is free of crosstalk and would be effective against systems noise, but that is only one part of the problem; the other major sources of noise would still affect these systems. Thus the maser would be of small benefit to them. Where transmitter power is limited and external interference is low the variable reactance diodes operating at room temperature, and the traveling-wave tube, can be and have been used to good advantage. These two devices give linear amplification even at high power levels—over 10 microwatts, significantly higher than can be handled by either the maser or the Esaki diode. This is particularly important in radio relay systems, where the input signal level to the receiver must be unusually high.

### The Future of Low-Noise Amplifiers

However, both the maser and the parametric amplifier have assured places in the microwave field. Masers will be used in systems that require the ultimate in low noise performance despite cost and complexity. Parametric amplifiers are excellent for systems which can accept somewhat higher noise and will benefit from economies in size, initial cost, and maintenance. Developments are under way with both devices which in the long run may change their relative merits.

The Esaki diode also may eventually gain an important place, possibly in systems that require a very large number of receivers and can accept somewhat higher noise temperatures.

The ferrite amplifier is the least predictable, but if the ferrite interactions can be harnessed we can anticipate low noise amplification over the entire microwave to millimeterwave range.

The cyclotron wave amplifier competes with the diode amplifier in radar systems at lower microwave frequencies. It does not permit the system range that the diode amplifier does, but it will not burn out and can protect the microwave receiver from high-level pulses.

The low-noise traveling-wave tube is now being used as an excellent second stage to a maser. Its future depends on cathode life and ultimate noise reduction but it is so simple to use that it is being intensively studied. Just as at the lower frequencies the advantage of transistors and electron tubes are constantly compared for particular tasks, so at microwave frequencies electron tube amplifiers are continuously examined as rivals of solid state devices. Between the two classes of amplifiers, a strong future is being built for microwave communications.
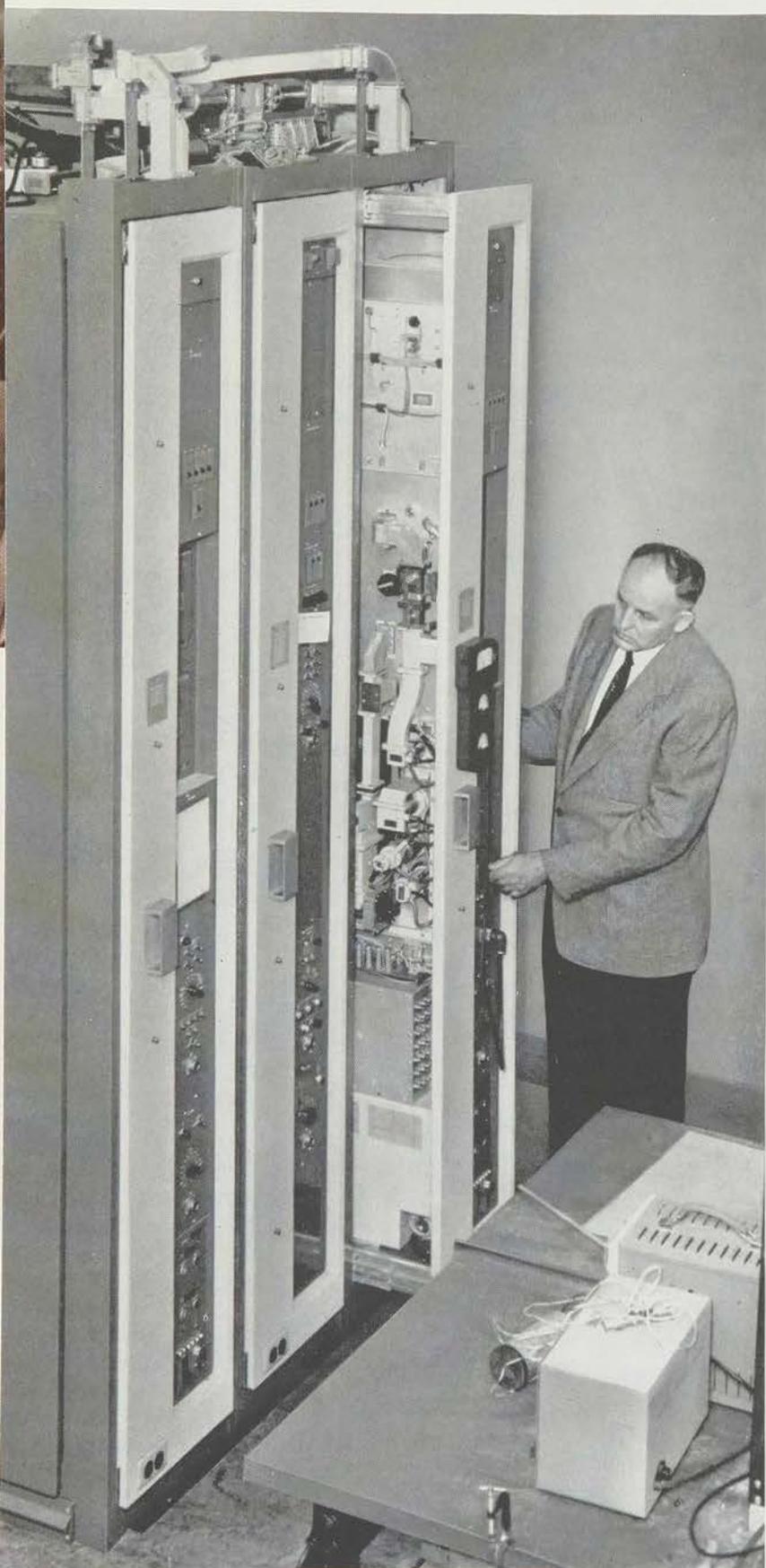
A. J. Uminowicz makes final current checks of the high-frequency-generator of the MCS in the temperature-controlled room at the Laboratories.

The carrier frequencies for the TH Radio System are derived from a single crystal. The method of obtaining these frequencies and safeguarding the system's transmission of information represents a new step in the advance of telephone technology.

TH Microwa

The TH microwave system is a long-haul radio-relay facility that can handle television, telephone, or other wideband communications (RECORD, *February*, 1961). This system will complement the TD-2 system which presently spans the continental United States. The heart of the TH system is its microwave carrier supply (MCS) which generates the frequencies necessary to derive the carriers of the TH communication channels. This source of carrier supply is common to all transmitters and receivers at each TH repeater station. It contrasts markedly with the TD-2 system where each transmitter and each receiver has its own microwave frequency generator. Another departure from the TD-2 design is the use of new devices, such as the traveling-wave-tube amplifier, and microwave ferrite isolators and switches.

The TH system operates in the 6-kmc common-carrier band, and incorporates 20 radio channels (eight two-way broadband communication channels and two two-way narrow-band auxiliary channels). The four basic TH carrier supply frequencies, 29.7, 59.3, 6049, and 6301 mc, are derived from a single 14.8-mc crystal. The 6049- and 6301-mc frequencies are used alone or in combination with one of the shift frequencies (29.7 or 59.3 mc) to provide either the beating oscillator or carrier frequencies required at the receivers or transmitters. Where a desired carrier

A. E. Earp and A. F. Perks

arrier Supply

frequency is the sum of, or the difference between two of the frequencies, a shift modulator on the transmitter or receiver combines the two.

There are two primary reasons which make it advantageous to have a common generator for the carrier frequencies: (1) when all the carriers are derived from a single frequency source, any change in the basic frequency shifts each of the carrier frequencies by the same amount and in the same direction, and (2) the proper choice of the basic oscillator frequency places unwanted modulation products between the microwave radio channels so that the possibility of tone interference is minimized.

Because the MCS supplies the carriers for all the channels in the system, reliability and frequency stability were the prime objectives in its design. Thus, because more than 10,000 conversations may pass through a repeater station simultaneously, a failure of the MCS would be very serious. A high degree of reliability is achieved by providing a standby carrier supply identical to the regular supply. Detectors continuously monitor the condition of each supply. If any one of the four frequencies from the regular generator drops below a predetermined level, a built-in switching system automatically transfers the output of the carrier supply to the standby generator. Such a transfer takes less than 5 milliseconds and simultaneously registers a failure

alarm. A similar alarm goes off if any portion of the standby equipment fails.

Reliability is further achieved by using low-level drives to prolong electron-tube life wherever possible. This is exemplified by various harmonic generators in the low-frequency generator units (operated as class-C amplifiers) which draw less than 100-microamps grid current. A crystal-controlled, thermistor-compensated oscillator is used as the basic frequency source. It exhibits a long-term stability of better than 10 parts per million over the entire operating temperature range of the system.

The microwave carrier supply is mounted in three bays: two frequency generation bays (regular and standby), and one common control. The bays are nine feet high, composed of cabinets with the equipment mounted on sliding racks. The microwave switching equipment is mounted on top of the bays. Flexible rectangular waveguide and hinged bay local cables are used between the racks and cabinets. This arrangement expedites all maintenance and repair procedures. To gain access to any of the components of the MCS, a maintenance man pulls the sliding rack out of its cabinet and into the aisle. Control panels and a metering test unit are conveniently located on the front of the bays for routine maintenance. The traveling wave tube and the high-frequency multipliers are air-cooled through flexible hoses.

The MCS consists of six major units: (1) the 14.8-mc supply unit, (2) the low-frequency generators, (3) the high-frequency generators, (4) the dc amplifier and switching control unit, (5) the low-frequency switching unit, and (6) the high-frequency switching equipment. A block diagram of the MCS is shown on page 162.

The 14.8-mc supply unit furnishes the basic frequency. It consists of two identical oscillators (regular and standby) and a frequency comparator. Each oscillator, composed of a crystal-controlled oscillator stage plus a buffer amplifier, has two outputs—one high level, and one low-level. The high-level output of the "active" oscillator feeds both low-frequency generators. The high-level output of the inactive oscillator is terminated in the low-frequency switching unit. The low-level outputs of both oscillators pass into the frequency comparator which is mid-way between the two oscillators in both the electrical and the physical sense. The comparator, as its name implies, compares these outputs with each other and can also compare each frequency to a secondary frequency standard. If the difference in frequency between the two oscillators exceeds 150 cps, the comparator sounds an alarm.

The low-frequency generator supplies the second (29.7-mc), the fourth (59.3-mc), and the seventeenth (252-mc) harmonics of the basic oscillator frequency. The input signal to the low-frequency generator diverges into two paths. One path consists of a chain of three doubler stages and two amplifier stages; a second path consists of two tripler stages. The outputs of the first and second doublers are followed by power amplifiers that amplify the 29.7 and 59.3-mc outputs to a level of approximately +29 dbm. Diode limiter networks in the grid circuits of each power amplifier stabilize the amplitude of the signal and compensate for any variation in the input signal. The outputs of the third doubler stage and the second tripler stage (the eighth and ninth harmonics) are coupled to a balanced modulator to produce the seventeenth harmonic. The modulator is followed by a buffer amplifier and a grounded grid power amplifier. The power amplifier provides the third output of the low-frequency generator.

The 29.7- and 59.3-mc signals from both the regular and the standby generators are fed to the low-frequency switching unit. The two 252-mc outputs from each low-frequency generator are fed to their respective high-frequency generators.

The high-frequency generator, in effect, multiplies the 252-mc input frequency from the low-frequency generator by 24 and 25 to produce the 408th (6049-mc) and the 425th (6301-mc) harmonics of the basic 14.8-mc oscillator frequency. The output of the last multiplier is coupled to a traveling-wave-tube amplifier (RECORD, *June*, 1960) which provides between 30 and 35 db of gain and delivers an output power level of +38 dbm to the high-frequency switching equipment. A small part of the 6049-mc traveling-wave-tube output is coupled to a high-frequency modulator, where it is combined with the signal from the second 252-mc output of the low-frequency generator to obtain the 425th (6301-mc) harmonic. The output of the modulator is coupled to another traveling-wave-tube amplifier where it is amplified to a power level of +38 dbm.

Each of the microwave outputs from the regular and standby generators is channeled to the
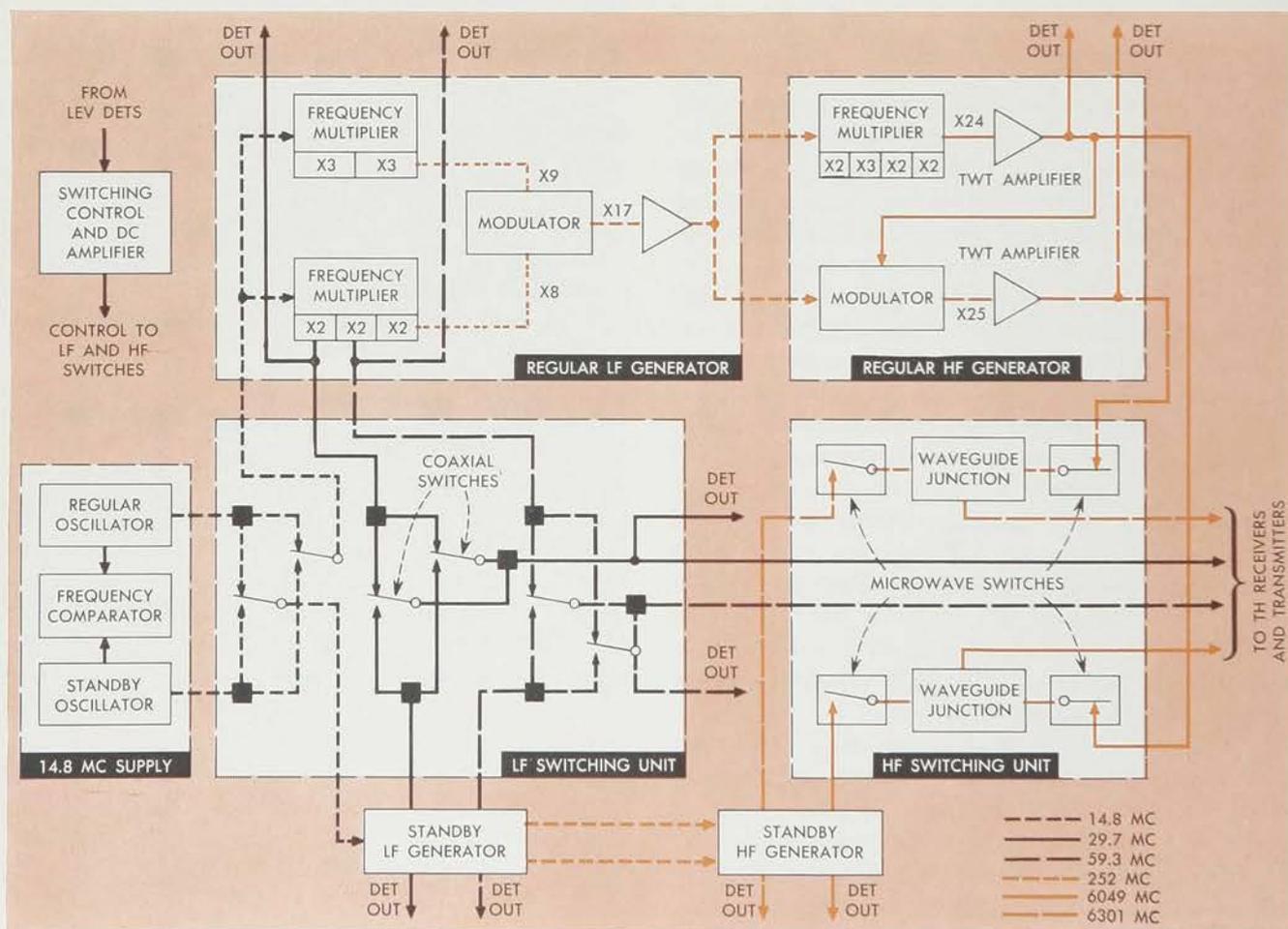
Block diagram of the MCS shows how the four basic carrier supply frequencies are generated from a single frequency source. High reliability is achieved by providing a standby supply.

high-frequency switching equipment through a low-pass filter which suppresses any harmonics generated by the traveling-wave-tube amplifier. An isolator in the inactive path absorbs the energy of the generator which is reflected from the high-frequency switching equipment.

Because of the nonlinearity of the input-output characteristics of the various generator stages, it is possible for one of the lower frequency outputs to degrade slowly to an unsatisfactory level without causing a corresponding drop in the 6301-mc frequency. To preclude this, level sensing detectors are provided not only in the 6301-mc output, but also in the 29.7, 59.3 and 6049 lines.

The switching control unit contains relay equipment which automatically substitutes the standby supply for the regular supply when any one of the four output levels from the regular generators or the regular 14.8-mc oscillator level falls to an unsatisfactory value. Thus, if either a fast- or slow-type failure occurs, a switch will take place regardless of the condition of the standby equipment, and the supply will remain on "standby" until manually reset. If the supply is reset manually, a switch back to "regular" will occur only if all output levels of the regular generators are satisfactory. Degeneration of the standby outputs never causes an automatic switch, but an alarm is registered to alert attendants.

Manual Controls for Maintenance

Manual controls on the MCS can be used to substitute one supply for the other for maintenance purposes. Such a transfer can be made only if the outputs of the selected supply are satisfactory. In the event that an automatic transfer to a "failed" supply has occurred, or difficulty arises in the logic circuitry, a "forced" switch can be made to either supply. This switching operation overrides the built-in logic of the system.

The switching control unit also controls the "in-service" alarms. A light and buzzer mounted on top of the frequency generator bay go on whenever the "in-service" bay is pulled out. A guard lamp on the active oscillator also lights if the oscillator-and-control bay is pulled out for servicing. These features guard against accidental interruption of the working circuits.

The low-frequency switching unit is composed of hybrid-type transformers and coaxial switches. The three frequencies supplied to the low-frequency switching unit feed into hybrids. The outputs from each hybrid feed into a pair of coaxial switches. Except for the 14.8-mc signal, the coaxial switch outputs are re-combined to furnish single outputs for each frequency. This switching

arrangement permits in-service maintenance and increased reliability in the event of a switch failure. The circuitry of the switching unit connects the active 14.8-mc oscillator to the input of both the regular and the standby low-frequency generators.

The high-frequency switching equipment on top of the bays is built around ferrite switches. Basically, these switches consist of a circular waveguide assembly with a ferrite insert. The waveguide is surrounded by a solenoid. When energized, the solenoid magnetizes the ferrite rod which rotates the plane of polarization of the wave as it progresses through the switch and produces an effective rotation of 90 degrees. Thus, by appropriate orientation of the input and output waveguides, the input energy can pass through the switch with little attenuation or can be almost 100 percent reflected.

A switch in each microwave path connects the regular output and the standby output to the 6049- and 6301-mc waveguide junctions. The solenoids of the pair of switches associated with a particular frequency are connected in series and normally carry current. The input-output waveguides are oriented to accept the microwave energy from the regular high-frequency generator and to reflect the energy from the standby generator. The energy from the standby generator is dissipated in an isolator. A switch to "standby" de-energizes the solenoids and allows the "standby" switch to transmit the useful energy through the waveguide junction. Waveguide shutters placed between the microwave switches and the junctions permit in-service maintenance on the switches.

Six separate power supplies furnish the various voltages required for the microwave carrier supply. Three of these supplies feed the active chain, and three feed the standby chain. These power supplies are mounted on the bays. Primary power is derived from two separate 230-volt, single-phase, 60-cps sources. Even if one of these primary sources fails, the MCS still continues to function satisfactorily.

Bell Laboratories engineers tested two preproduction models of the MCS. These tests included temperature studies, tube-life tests, and switching reliability tests. The field trial of the MCS, conducted on the TH route betwen Denver, Colorado and Salt Lake City, Utah, was highly satisfactory. This equipment has now been turned over to the Long Lines Department of the A.T.&T. Co., and the MCS functions as a vital part of the Bell System's highest capacity transmission system.

New Information on Nuclear Fission Fragments

Recent experiments have revealed that atomic nuclei which undergo fission as a result of slow neutron bombardment almost always split into two unequal fragments whose mass ratio tends to assume one of three values. These "preferred" mass ratios depend upon the total energy released by a fissioning nucleus, Walter M. Gibson of Bell Laboratories Semiconductor Research Laboratory reported at a recent meeting of the American Physical Society.

Dr. Gibson displayed a three-dimensional model of the data resulting from an experiment on the fission of uranium nuclei. Made of clear acrylic plastic, the model illustrates the energies of the two fission fragments from over a million and a half fission events. Such an experiment can be performed in a single day.

While performing the experiments, Dr. Gibson cooperated with three other physicists: Dr. T. Darrah Thomas, Princeton University; Dr. George J. Safford, Columbia University; and Dr. G. L. Miller, Brookhaven National Laboratory.

Two silicon particle detectors, p-n junction diodes, were especially designed for this experiment. With these new detectors, the physicists were able to measure the fission events with the accuracy and statistical significance required for a detailed examination of the fragment masses,

impossible with any other measuring techniques.

The physicists have studied thermal neutron fission of Uranium 233, Uranium 235 and Plutonium 239. They placed a thin film of one of these isotopes between the two detectors, and covered these with a clear plastic container. The container and the necessary electronic amplifiers were housed in an evacuated aluminum can and lowered into the thermal column of the research reactor at the Brookhaven National Laboratory.

As the nuclei undergo fission, two fragments fly apart in opposite directions. The particle detectors were arranged so that one fragment would strike one of the two detectors, in a large fraction of the fission events, and the other fragment would strike the opposite detector. Electronic "coincidence circuitry" rejected those cases in which only one of the two fragments was measured, since only by measuring both fragments was it possible to determine the fragment masses.

The data showed that when the total energy of fission is high, the masses of the fragments are always unequal and tend toward a preferred mass ratio. At lower energies another preferred mass ratio occurs. Under these conditions, the most probable fragment masses are more unequal than at high energy levels; i.e., the preferred mass ratio is higher. Occasionally, however, fragments of equal mass appear. At still lower energies there is a third preferred mass ratio, with the masses of the fragments even more unequal. Simultaneously, however, the probability of fragments having equal masses is greatest at this low energy.
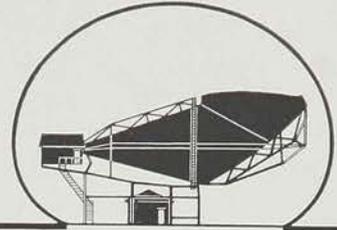
◀ *Walter M. Gibson demonstrates plastic model of data from fission experiments on uranium nuclei.*

TELSTAR
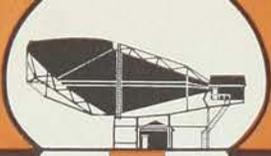## The Andover
Ground Station

The principal station for Bell Telephone Laboratories engineers in carrying out their experiments with Telstar communications satellite is on a 1000 acre hilltop tract owned by the Long Lines Department of A.T.&T. Co. in Andover, Me. The site is in a shallow bowl, ringed by mountains which help protect it from interference by other radio transmissions. Another station that will assist in the experiments is the Bell Laboratories installation on Crawford Hill, Holmdel, N. J., built in 1959-60 for the Project Echo experiments.

The Andover station will include means for tracking the satellite, computing its orbit, sending commands, receiving telemetry information, and carrying out the principal purpose of the Telstar project, experiments in broadband transmission by way of the satellite.

The power of the signal radiated at the satellite is about $2\frac{1}{4}$ watts, spreading out uniformly in almost all directions. To scoop up as much as possible of this radiation, very much weakened by its 3000-mile trip through space, Bell Laboratories and McKiernan-Terry Corp. engineers have designed the largest horn antenna yet built. Its 3600-square-foot opening will receive about a billionth watt of the broadband signal; its sides will keep out unwanted ground radiation.

The mammoth horn at Andover has imposed requirements more exacting than any other structure of its size ever built, for it must track its tiny target smoothly and continuously, to an accuracy of better than a twentieth of a degree. Design engineers had to consider that the weight of the antenna itself would introduce bending, and a different amount of bending for every position it takes. It is, therefore, built as rigidly as possible and—for its size—more accurately than a fine watch. A 70-foot diameter rotating ring gear, for example, is machined to a tolerance of less than one thirty-second inch. To remove the factors of wind stress, icing and rapid temperature changes, the entire horn is covered with an inflated radome, 210 feet in diameter and 161 feet high, made of Dacron and synthetic rubber.

On the next pages are shown pictures of various stages in the construction of the steel and aluminum rotating structure. Other pictures show contractor personnel and Laboratories engineers installing and checking typical consoles and equipment at Andover. Similar work is proceeding simultaneously at Holmdel, while van-loads of tracking and telemetry equipment are being set up outside Bell Laboratories Ground Guidance station at Cape Canaveral, Fla.

The horn antenna at Andover carries two fair-sized houses as it rotates. In the upper cab are contained the maser amplifier used in receiving the weak signals from space, and the transmitter equipment which sends a continuous FM signal to the satellite at a power level of about two kw. The lower antenna house contains the antenna control and power amplifier equipment, plus a separate transmitter supplied by NASA for Project Relay. The entire antenna and its associated equipment is protected by an air-supported radome.

Ray Cave works on a wooden up of the ring gear for the antenna and the cranes neede it into place, before actual
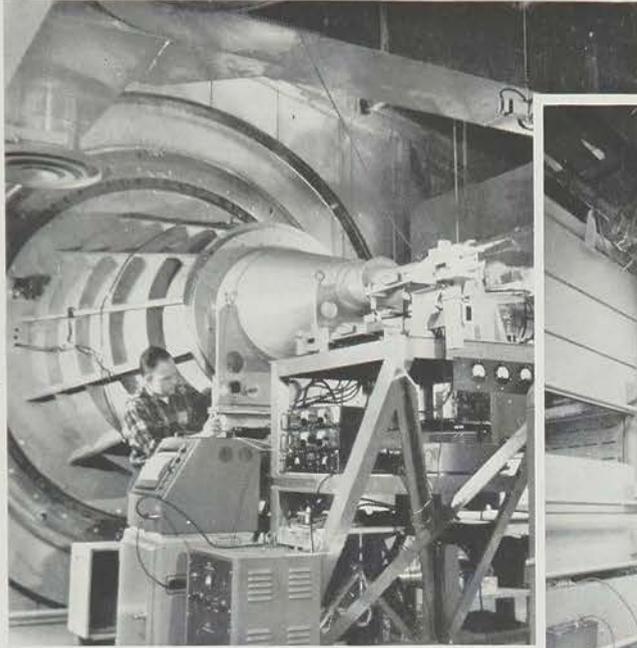

The completed antenna, weighing about 340 tons and 177 feet long over-all, dwarfs workman on steelwork.

Unusual view of horn in "dumped" position gives some feeling for the tremendous mass of the structure.

Glenn Storck checks equipment at the "receiving end" of the horn. The signals come through the waveguide assembly and are directed to the maser amplifier.

...ng of the 70-foot diameter ring gear ...s, with model in evidence in fore-...nd. This was one of the touchiest ...ations in the construction program.

Here, Dick Klahn checks out the beam rectifier control cabinet in the lower antenna house.

These two photos show final stages in erection of the 50-ton gear, which rotates the antenna for changes in elevation while tracking the satellite.

Steel work completed between ring gear and upper cab, the antenna looked like a giant spider web.

169
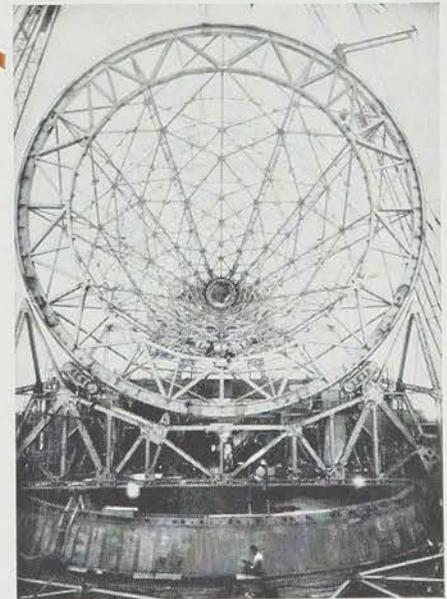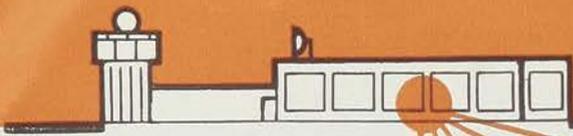
A quarter mile from the horn antenna, a one-story control building houses the antenna tracking and computer equipment, as well as the communications equipment necessary for tieing the satellite into the nationwide telephone network. Auxiliary power supplies and air-conditioning equipment are also located here, as is the main computer room, which will serve as the main monitoring post during the satellite communications experiments. Photos show typical equipment during installation and calibration operations.

J. V. Anders is shown here checking out the precision tracker console in the control building, while the next photo shows B. O. Larson at the command track transmitter.

Emergency power is supplied by two 550-kw diesel alternators. The control panel for the supply is shown here shortly after installation.

Typical of the equipment in the main computer room are the tape units shown in the background and the tracking consoles in the foreground. Television monitors are also installed in the computer room to check the received signals during TV transmission.
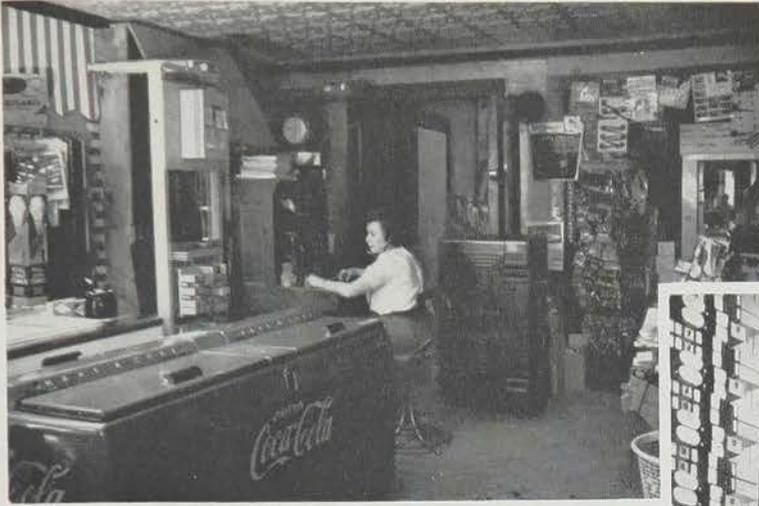
To tie the satellite into the nationwide telephone network, a New England Telephone Company installer (at right) works on central office equipment in the control building, which will handle the test calls anticipated during the experiments. The contrast between the new station being installed on "Space Hill" and the central office of the Andover Telephone Company (above), less than five miles away, is startling, and perhaps indicative of the rapid strides being taken in telephone communications today. The fact that two such diverse communication centers can exist side by side, working together efficiently, is an example of how many of the problems of compatibility in the telephone plant have been resolved.
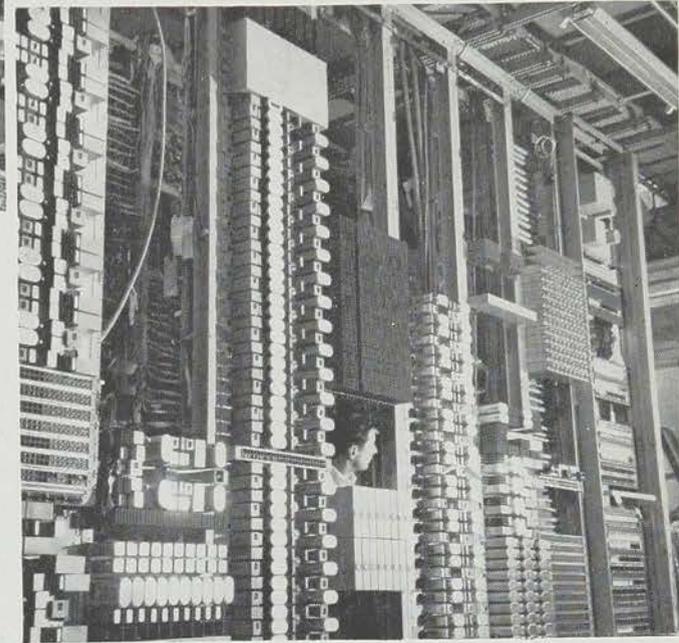
B. O. Larson makes adjustments on the ground telemetry control panel. At the right of the panel is the command encoder equipment.
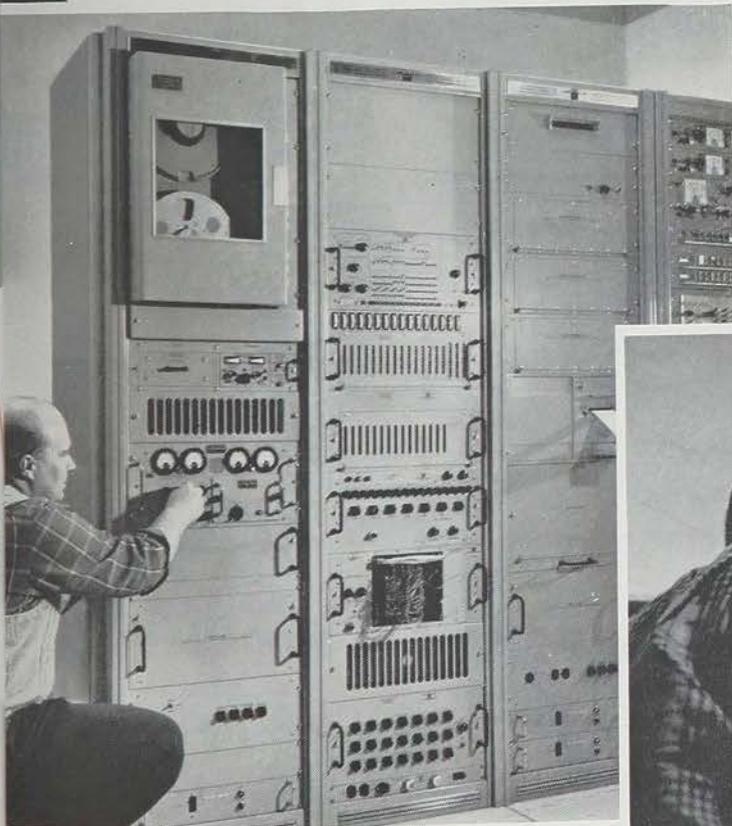
T. Thompsen, below, works on the station clock, the timing equipment to which all measurements at the control building are related.
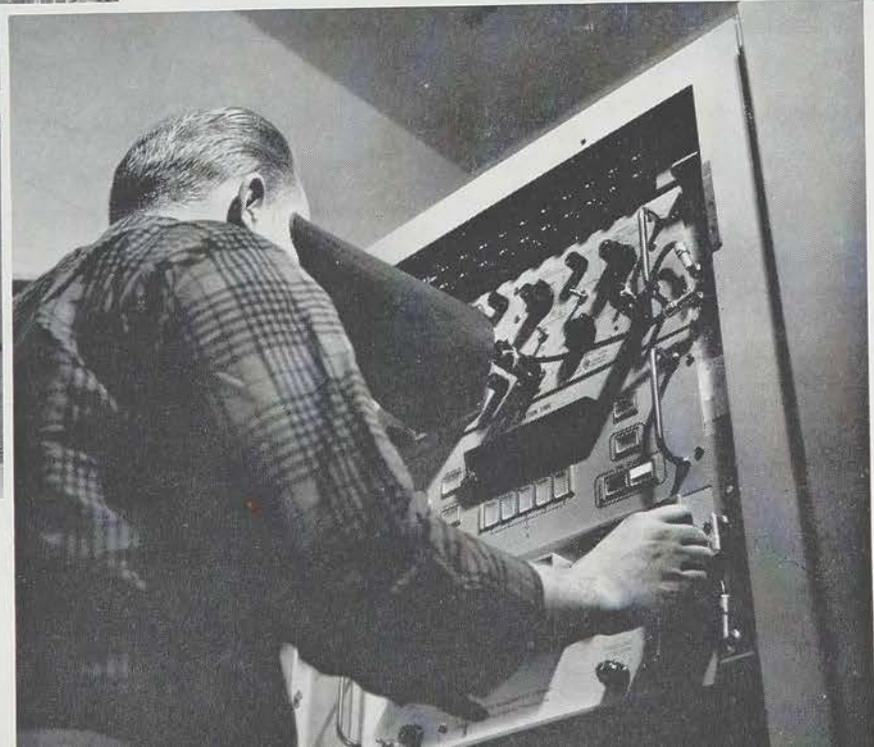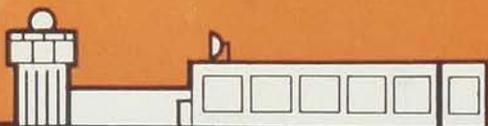
Just outside the control building are two tracking antennas. The quad-helix antenna at the right will pick up the satellite's 136 Mc beacon and telemetry information, and will transmit commands to the satellite on about 120 Mc. Once the satellite has begun to transmit its broad band communications signal and associated 4080 Mc precision beacon, the precision tracking antenna on the pedestal at left will track on this signal to a much greater precision. The small dish on the building roof is a microwave antenna which carries telephone, TV and data signals to and from the Andover station, connecting it with the nationwide telephone network.

Antenna tower on Black Mountain, 5 miles away from the Andover site, receives the microwave signals and sends them on to Portland and Boston. It is also used to radiate signals to tracking antennas at site, simulating a satellite for calibration purposes.

Laboratories engineers developed a highly reliable method of protecting transmission channels for the TH Radio System. It involves the use of two channels that automatically handle calls if there is an equipment failure or a deep fade.

R. H. Higgins, L. M. Klenk and
W. R. McClelland

Automatic Protection Switching For The TH System

As the demand for more long-distance telephone and television circuits increases, new and more complex transmission systems must be developed. The primary requisites of these new systems are higher transmission capacity and reduction in the cost per transmission channel. However, the consequence of a failure in the case of such high-capacity systems is so serious that a highly reliable protection switching system must be provided to insure continuous service. This requirement led to the development of the automatic protection switching system for the TH radio-relay system.

The TH system is one of the newest and largest Bell System transmission systems. It provides eight two-way broad-band radio channels each of which can carry 1800 telephone circuits or one television signal. Two of these eight channels are protection channels which do not normally carry messages but substitute for any of the regular channels if there is an interruption in the service.

It also provides two narrow-band auxiliary channels (in addition to the eight broad-band channels) which operate in parallel. These channels are used for the transmission of voice, protection switching, and alarm signals. The TH protection switching system determines when a protection channel is needed, and it incorporates the automatically operated switches that facilitate such substitutions.

Since it is not feasible to protect each radio repeater with an individual switching system, the TH system is divided into switching sections consisting of a maximum of 10 repeaters. Each switching section, in turn, contains two independent switching systems, one for each direction of transmission. A channel in trouble within a switching section is replaced by a protection channel for the entire length of the section. The series of repeaters is protected by a set of switches at intermediate frequencies. This arrangement, shown on page 174 is known as IF-IF switching.

TH BROADBAND TRANSMISSION FACILITY

RECEIVING SWITCH — REGULAR CHANNELS

A
B
C
D
E
F

MAXIMUM OF 8 BROADBAND CHANNELS

TRANS-MITTING SWITCH

X
Y

PROTECTION CHANNELS

MONITORS MONITORS MONITORS

PROTECTION CHANNELS

X
Y

OVERRIDE CONTROL

— VERIFICATIONS
— ORDERS

VERIFICATIONS —
ORDERS —

OVERRIDE CONTROL

MANUAL CONTROL

TRANS-MITTING LOGIC

TONE RECEIVER

STATUS CIRCUIT

TONE TRANS.

RECEIVING LOGIC

TONE TRANS.

ORDER CIRCUIT

TONE RECEIVER

AUXILIARY CHANNEL

ALARM AND INDICATION LAMPS

ALARM AND INDICATION LAMPS

Block diagram of a switching system for one direction of transmission in a switching section. If any of the six regular channels fail, protection channels X and Y are automatically substituted.

Since a switching section must stop at every message-dropping point, the average switching section will usually consist of less than eight repeaters.

FM terminals at a message-dropping point are protected separately from the radio repeaters. In this case, both ends of a switching system are in the same building. Switching takes place at baseband frequencies (BSB) and at intermediate frequencies (IF). This is BSB-IF switching.

System Operation

The automatic protection switching system insures against service interruptions caused by either equipment failures or radio fading. Some equipment failures are relatively slow in causing degradation in service; others may interrupt service almost instantaneously. Routine maintenance usually minimizes equipment failures. In microwave radio transmission, however, the path loss between stations varies, and, under certain atmospheric conditions, a deep fade will make a radio channel unusable.

Since the TH radio channels are more closely spaced than those in previous microwave systems, a deep fade can affect more than one radio channel. A statistical analysis of this situation indicated that two protection channels were needed.

There is a small possibility of simultaneous radio fades in more than two channels, but it is not economically sound to provide a third protection channel for this contingency. After extensive testing, Laboratories engineers found that this system keeps the outage time of any channel of a 4000-mile circuit below 0.01 percent per year and below 0.05 percent in the worst fading month.

Vital components of the automatic protection switching system are the switches, or gates, that control the transfer of the signal from a regular to a protection channel. It is essential that this switching action be accomplished without disturbing the received signal. To prevent such disturbances, the switching action must be carried out in sequence. First, the regular and the protection channel must be bridged together at the transmitting end of the switching section. Then, and only then, a fast transfer of the signal from the regular to a protection channel must occur at the receiving end.

The switching action may be accomplished by either a diode gate or a wire-spring relay switch. The diode gates are arranged in a T formation as shown on page 175. In the signal transmitting condition—when diodes D1 and D2 are conducting and D3 is nonconducting—the gate behaves as a low-loss pad. In the off, or non-

transmitting condition, diodes D1 and D2 are non-conducting and D3 is conducting. The gate then behaves as a high-impedance termination with a through loss of approximately 90 db. Diode gates are used at the transmitting end of switching sections for either IF or baseband frequencies. The IF gate is a single-sided 75-ohm circuit. At baseband, a 124-ohm balanced circuit is used.

At the receiving end of a switching section, a diode gate is used as an IF switch and a wire-spring relay circuit is used as a baseband switch. A simplified diagram of the baseband receiving switch on page 176 shows two generators, V1 and V2 (equal in magnitude and phase with the same internal impedances Rg), working into equal loads RL1 and RL2, respectively. Since the voltages at A and B are equal, switches (S2) and (S3) may be closed without disturbing the voltages across the loads. If switches (S1) and (S4) are now opened, the connections between the generator and the loads have been interchanged without an interruption of the received signal.

Another important group of elements in the switching system are the common-control circuits. These include a transmitting logic circuit at one end of a switching section, a receiving logic at the other end of the section, and signaling circuits which transmit information between the two logics. A simplified block diagram of a switching section is shown on page 174.

The transmitting logic is a transistorized computer which contains most of the memory and decision-making circuitry. It also sends orders directly to the transmitting switches and, via the signaling system, to the logic which controls the receiving switches. Information concerning the status of the broadband channels and terminals comes from monitor circuits in the repeaters and in the terminals.

Two types of signaling systems are used to transmit information: (1) dc reporting and (2) tone reporting. The first type is used with FM terminal switching sections where both ends of the switching section are in the same building. It uses direct wiring connections to carry information between the two logics. For the radio switching sections, where the transmitting and receiving ends of the system may be as much as 300 miles apart, tones are used for signaling. These tones are transmitted over the auxiliary radio channels.

There are two sets of common-control circuits in the TH automatic protection switching system: primary or automatic control circuits, and secondary control circuits. The primary-control circuits include the transmitting and the receiving logic

circuits. The secondary-control circuits provide for either manual or emergency override operation of the system.

Logic Controls

The primary control circuits perform the logic operations required to assign any one of six regular broadband channels to either of two broadband protection channels. They order the operation of the transmitting and receiving switches and perform various control functions based on the channel status, manual control, and switch verification signal information sent to the logic.

The transmitting logic, the brain of the system, is a sequential logic circuit which establishes the sequence of events which take place when a regular channel fails or "becomes good" after having failed. It also operates alarms whenever there is difficulty in establishing or releasing a switch. Thus, the logic accomplishes three main steps: transfer to a protection channel when a regular channel fails, release of a transfer to a
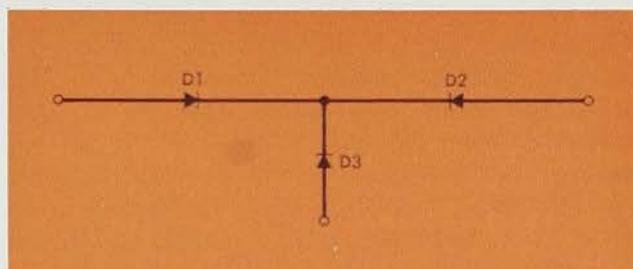
Simplified schematic of the type of diode gate used at the transmitting end of switching sections.

protection channel when the regular channel becomes good, and transfer of service to the second protection channel if the first protection channel fails.

A receiving logic controls the operation of the switches at the receiving end. In this case, the receiving logic acts as a decoder which continually checks whether or not a valid code is being received. Whenever a switch request from the transmitting logic occurs, the receiving logic decodes the order and checks the validity of the switch request. If the order is valid, the receiving logic orders the receiving switches to replace the output signal of a poor regular channel with the output signal of a good protection channel. If the switch request is incorrect, the order is not processed further.

Tone signaling consists of a maximum of 16 tones, eight of which are used to transmit status information, and eight for switch orders. These tones are generated by transistor oscillators.

Each of the eight status tones associated with a broadband transmission channel is inserted at the receiving end of a switching section. The order tones, which are inserted at the transmitting end, are controlled by the transmitting logic. They are arranged in two groups of four tones, and each group is associated with a protection channel. Switch orders are transmitted in a two-out-of-four code. At the ends of the switching section, the tones are detected in a tone receiver which converts the information into dc levels for presentation to the logic circuitry. This code arrangement permits the transfer, at the receiving end, of up to six regular channels to a protection channel.

Switching Channels

The monitoring devices associated with the broadband transmission channels control the status tones normally present in the tone receiver. In case of trouble on a channel, a monitor suppresses the status tone associated with that channel, the tone receiver detects the absence of this tone, and the switching action begins. At the transmitting end of the switching section, the carrier resupply monitor associated with the broadband radio transmitter operates directly on its assigned status-tone detector. At the receiving end, the automatic-gain-control monitor operates directly on its assigned status-tone oscillator. At the intermediate stations, the automatic-gain-control and carrier resupply monitors operate on the tone reporter, which in turn, reduces the level of the status tone being transmitted over the auxiliary channels. Whenever a deep fade occurs, the automatic-gain-control circuit causes the gain of the IF amplifier in the repeater to increase and to compensate for the decrease in signal power. This information is used to actuate the tone reporter, which suppresses the corresponding status tone.

If there is a sudden equipment failure in the transmission circuit, service is interrupted for approximately 30 milliseconds. This is because of the finite transmission times of the signals used to indicate the failure and to switch to a protection channel. If a deep fade occurs, there is essentially no loss in transmission because of the rapid reaction time of the protection switching system compared to the low speed of the fade.

How is a switch from a regular to a protection channel accomplished when a tone signaling system is used? Under trouble-free conditions, all the tones in the signaling system are present and no switching action occurs. Suppose, however, that trouble develops at an intermediate

repeater because of either a fade or an equipment failure. A monitor in the failed channel actuates the corresponding tone-elimination filter, thus suppressing a status tone. Then, the tone receiver at the transmitting end of the switching section translates the loss of the status tone into dc information for the transmitting logic. The transmitting logic recognizes the loss of the tone as a channel in trouble and selects a protection channel to which service is to be transferred.

At the transmitting end of the switching section, the regular channel signal is bridged to the protection channel and a verification signal (indicating that the bridge has taken place) is sent back into the transmitting logic. Simultaneously, a check is made as to whether or not the failure occurred in the previous switching section. This is done by the monitors associated with the broadband transmitter carrier resupplies in the regular and protection channels. If both of these monitors indicate failures within a given time interval, the failure is recognized by the transmitting logic as being in the previous section. If this happens, the regular channel is locked from the protection channel, the protection channel is released for further service, and the switch orders in this section are processed no further. If the failure has not occurred in the previous section, the transmitting logic then encodes the switching order by eliminating two of the four order tones, and sends it (via the auxiliary channels) to the receiving end where it is decoded in the receiving logic.

The decoded signal from the receiving logic operates the proper switch control circuit which, in turn, operates the receiving switch. The transmission signal (which is bridged on both the regular and protection channel) is now received from the protection channel. If more or less than two of the four order tones are eliminated, the trouble is detected by the receiving logic and the switch order is not processed further, a status
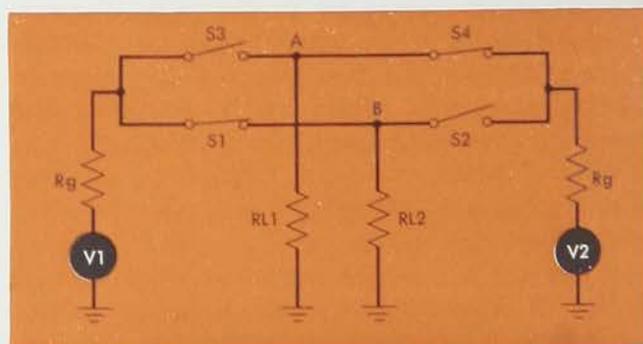
Schematic diagram of the relay switch used as a baseband receiving switch at receiving end.

quo is maintained and an invalid code alarm is issued. After the receiving switch has operated, a verification signal (a short interruption of the selected protection channel status tone) is sent back to the transmitting logic to indicate completion of the cycle and to release the transmitting logic for further orders. If the verification signal from the receiving end is not received within the prescribed time interval, the logic will signal for a transfer to the other protection channel.

A manual switch control circuit is provided to release the broadband channels for maintenance. The manual control, which is located at the transmitting end of the switching section, is a relay circuit which allows switching operations to be carried out on a manual basis via the transmitting logic. It permits the switching of any one of six regular channels to either of two protection channels by marking a regular channel "bad." The selection of a particular protection channel is decided in the logic.

This circuit also performs a lockout function which permits a broadband channel to be removed from control of the automatic switching system. The lock-out operation is accomplished by marking a regular channel permanently good or a protection channel bad.

The switching system also has an override switch control circuit, which is used only for emergency manual switching. Whenever the override switch control is used at either end of the system, it completely disables the logic circuits and prevents any further automatic switching. The override switch control operates directly into the switch control circuits, thus by-passing the remainder of the automatic protection switching circuits.

A regular channel may be switched to either one of the two protection channels. A switched regular channel may also be released from the control of the logic circuit, thus dropping a previously made switch. After an override switch release is made, the status quo of the system is automatically maintained. A separately operated status quo feature permits complete removal of all channels from control of the logic circuit while at the same time maintaining any switches previously set up through automatic switching or by the manual switch control circuit.

The development of automatic protection features for the TH Radio System represents an extraordinarily high degree of reliability. Its monitoring arrangements, verification circuits, and switching system immediately detect equipment failures and radio fading, and automatically substitute "good" channels for "bad" ones.

Laboratories Appraises Programmed Learning

Telephone technicians who learned basic electricity from teaching machines or programmed books did significantly better than a similar group who were taught the same material by conventional means, a Bell Telephone Laboratories study reveals. The research study, conducted by H. O. Holt, Director, Communications Social Science Research Laboratory and C. G. Valentine of the Michigan Bell Telephone Company, was set up to appraise the effectiveness of programmed self-instruction by telephone company employees.

Widespread interest in teaching machines began about 1958, largely as a result of the work of Prof. B. F. Skinner of Harvard. While several studies have been done since then, most involved very short programs and small numbers of experimental students; almost none are of the scope of the study reported by Mr. Holt. The Bell Laboratories research involved a self-instruction program roughly equivalent in length to a three-hour, one-semester course in college. Each student made 3500 responses as he worked through the program.

Sixty-four New Jersey Bell Telephone Company trainees were divided into two groups. Each group had approximately the same average I.Q., number of years with the company, and background in mathematics and electricity. One group was taught by an instructor in a course that met for a total of 44 hours. The other group taught itself from programmed books or machines.

Immediately after completing the course, each group took two final examinations. One examination dealt with the facts taught in the course, the other tested ability to manipulate electrical concepts. On both examinations the self-instruction group did significantly better than the other group. Six months later, when both groups took the final examinations again, some basic electricity had ben forgotten. However, the self-instruction group still did significantly better than the lecture group on both tests. In fact, the average score of the self-instruction group after six months was higher than the average score of the lecture group had been immediately after training.

This experimental study is one of a number of current Bell Telephone Laboratories research projects which are relevant to problems of programmed self-instruction. The teaching machines and programs were designed specifically for the study and are not available commercially.

SIMULATION TESTS CONDUCTED ON TELSTAR ANTENNA

frequency and then carried to Mr. Sageman's telephone in the radome. The whole process, which is instantaneous, was repeated each time one of the men spoke.

The pictures sent via the satellite were taken on the spot, fed into a high-speed facsimile machine, beamed at the satellite, and returned to the earth station. The quality of the pictures was good.

The changing of the temporary for the permanent radome was a precisely controlled operation. The temporary radome was partially collapsed and the new one inflated over it; the old structure was then deflated and removed from inside its fully inflated replacement.

The permanent radome, like the one it replaced, is 210-feet wide and 161-feet high; has an overall thickness of 0.07 inches; and its tensile strength is rated at 1000 pounds per square inch. Air pressure, which varies from about one-twentieth to one-tenth pound per square inch and can be adjusted for wind velocities, supports the structure.

The new radome is made of Dacron fibre coated with Hypalon synthetic rubber, materials practically transparent to radio waves. Segments of the material were bonded together to form a single piece some 120,000 square feet in size. The permanent and temporary domes are the largest inflatable structures ever made. They were put together and erected by BirdAir Structures of Buffalo, New York.

The National Aeronautics and Space Administration will launch the Telstar satellite from Cape Canaveral. The orbit is expected to range in altitude between 600 and 3500 miles. When the satellite is "visible" to the ground station, experimental communications will follow the process demonstrated in the simulation test. The giant antenna will track the satellite smoothly and continuously to an accuracy of better than one-twentieth of a degree. The radome removes some of the factors that would reduce this accuracy, like wind stress, icing and rapid temperature changes.

The satellite will also be able to relay signals to other ground stations in the United States and other countries.

Two developments last month marked significant progress toward the completion of the Bell System's satellite communication station in Andover, Maine. (See Telstar: The Ground Station, in this issue.) On April 3, the first simulation test for the Telstar experiment was conducted successfully. Later in the month a 13-story-high radome was inflated over the horn antenna. The new radome is a permanent replacement for the temporary one erected last October.

During the simulation test telephone voice signals were transmitted by the antenna to an engineering model of the satellite five miles away. The model amplified the signals and relayed them back to the antenna. In this way, a telephone conversation was carried out between Eugene F. O'Neill, Telstar project manager for the Laboratories and Robert E. Sageman, coordinating engineer for the A.T.&T. Company. In another phase of the test still photographs were sent successfully via the "satellite."

The 340-ton antenna responded accurately to electronic commands and "locked-in" on the satellite which was mounted on a 250-foot-high tower that has been erected on Black Mountain, south of Andover. When the antenna came into position the telephone conversation began.

Mr. O'Neill spoke first. His voice went from the radome to the station control building several hundred yards away over conventional telephone lines. There the signal underwent frequency changes and was piped back to the antenna where it was amplified and sent to the satellite by microwave radio. The satellite received the signal, amplified it billions of times, and relayed it back to the horn antenna. The antenna then sent the signal to the control building where it was changed back to telephone voice band

Silicon Solar Cells
Measure High Intensity Radiation

A study of silicon solar cells under various kinds of radiation has shown that the cells are the simplest and among the most useful devices available for measuring high intensity radiation. These results are reported by W. Rosenzweig of the Semiconductor Device Laboratory in a forthcoming issue of the *Review of Scientific Instruments*, a publication of the American Institute of Physics. The cells are not useful for measuring very low levels of radiation such as that resulting from fallout.

The cells are made by forming a thick layer of n-type semiconductor on a base of p-type semiconductor. In this form they are 10 to 15 times less subject to damage from radiation than are solar cells which follow the original Bell Laboratories form of the device—a p-type surface layer on an n-type base. The decrease in sensitivity to radiation damage makes the new solar cell potentially attractive for many radiation monitoring applications.

The major advantages of the solar cell over other types of radiation detectors are simplicity and economy. For most applications, all that is necessary is to solder wires to a solar cell and connect them to a relatively inexpensive, commercially available ammeter. A million rads per hour of X or gamma radiation, for example, would produce a current from the cell of 37 microamperes, easily measurable on a moderately sensitive meter. Intensities as low as 100 rads per hour can be measured with more elaborate instrumentation. Radiation as intense as 10^9 rads per hour can be measured if it is not too energetic. Since the sensitive layer of a silicon solar cell is extremely thin, it is especially useful in making precise measurements of the penetration depth of radiation.

Mr. Rosenzweig pointed out that the cells were not appreciably damaged by X rays or electrons produced by generators rated at up to about 300,000 volts. The cells can also be used to measure heavy-particle radiation such as alpha particles and protons, but with these the cell is damaged more quickly. The damaging effect can be useful in measuring cumulative exposure and

in obtaining permanent beam-intensity profiles. In the latter application, large area cells are exposed. Then, to determine the intensity of the beam of radiation at various locations on the solar cell, scientists need only measure the degradation of the cell at these locations.

W. Rosenzweig inserts silicon solar cell in test chamber of a Van de Graaff generator. The new configuration in solar cells provides the simplest and one of the most versatile devices available for measuring high-intensity radiation.
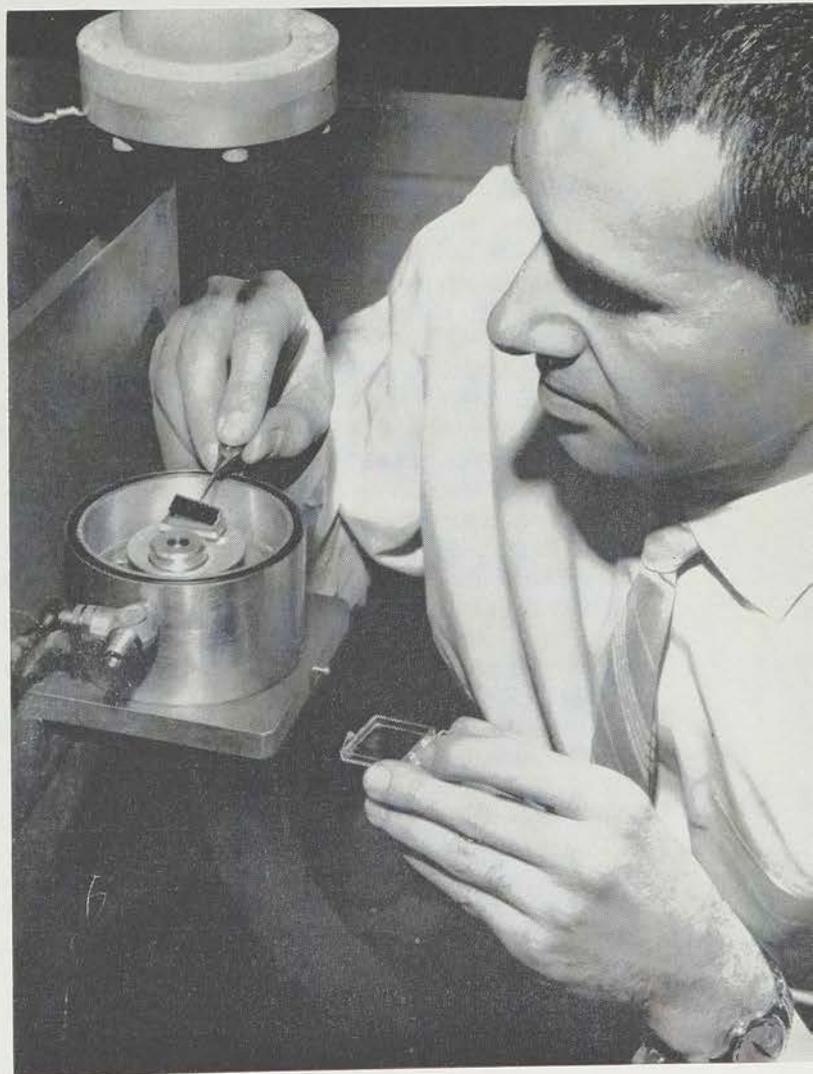
LABORATORIES SCIENTISTS DISCOVER NEW SUPERCONDUCTING ELEMENTS

Bell Telephone Laboratories' scientists have discovered that pure molybdenum is a superconducting element and have participated along with scientists at the U. S. Naval Research Laboratory in a similar discovery in pure iridium. These discoveries are far reaching because they suggest that many other metallic elements previously found not to be superconducting may become so if they are just made pure enough.

The discovery of the superconductivity of molybdenum — the first such discovery in an element since 1953—was announced in the April 15 issue of *Physical Review Letters*, a publication of the American Physical Society, by T. H. Geballe, B. T. Matthias, E. Corenzwit and G. W. Hull, Jr. of the Physical Research Laboratory. The discovery of the superconductivity of iridium was announced in the May 15 issue of *Physical Review Letters* by R. A. Hein and J. W. Gibson of the U. S. Naval Research Laboratory together with B. T. Matthias, T. H. Geballe and E. Corenzwit.

Superconductivity is a property of certain materials, which, when cooled to a few degrees above absolute zero, lose all electrical resistance. Twenty-three elements had been found previously to be superconducting. Samples of pure molybdenum, from different sources and prepared in different ways, were all found to become superconducting at about 1° Centigrade above absolute zero. Previous investigators had failed to find this property in molybdenum because it had not been believed that impurities of the order of parts per million could interfere with superconductivity. However, careful spectroscopic analyses by E. K. Jaycox of the Chemical Research Laboratory has now furnished evidence that iron present in such low concentrations suppresses the superconductivity. The superconducting samples of molybdenum were obtained by two methods: (1) molten pellets of molybdenum were heated for long times in an arc furnace, until the iron was simply "boiled off," and (2) a single crystal of molybdenum was grown by Ernest Buehler of the Metallurgical Research Laboratory and purified by electron-beam melting and floating-zone refining.

The samples of superconducting iridium were prepared by heating molten pellets in the arc furnace for long times, again giving impurities such as iron a chance to "boil off." The transition temperature of just 0.14°C above the absolute zero of temperature is lower than that of any other known superconducting element.

The discovery of the importance of purity on superconductivity will have an influence on theories about the nature and occurrence of superconductivity. It suggests that metals previously thought to be non-superconductors should be looked at again in a very pure state. Messrs. Geballe and Matthias said that there will be many implications from this unexpected discovery, but that it is still too early to predict them. Because the transition temperature (the temperature at which a material changes from a normal to a superconducting state) of pure molybdenum and iridium are so low it is unlikely that these elements will be used directly for superconducting magnets.

Low Cost, High Quality Quartz Grown By New Lithium-Doping Process

Synthetic quartz with virtually the same acoustic quality as natural Brazilian quartz can now be grown quickly and economically by a new method developed at Bell Telephone Laboratories. The method was developed by J. C. King, head of the Ultrasonic and Thin-Film Device Department, A. A. Ballman of the Crystal Chemistry Research Department and R. A. Laudise, head of that department. The three scientists conducted experiments, described in a letter to appear in the *Journal of Physics and Chemistry of Solids*, in which they grew quartz crystals at a rapid rate from solutions doped with small amounts of lithium. These crystals are relatively free of those defects that have made rapidly-grown quartz inferior to electronic-grade Brazilian quartz.

Large pieces of high-quality natural quartz (quartz with the ability to vibrate at its resonant frequency with very little energy loss) are comparatively rare and therefore expensive. Up to now, high-quality quartz could be grown only by relatively costly methods. This new Bell Laboratories method could mean substantial savings for the Western Electric Company and other crystal producers.

The technique of hydrothermal crystallization, developed by Bell Telephone Laboratories (RECORD, *January* 1959), utilizes waste or low-grade pieces of quartz. These pieces are dissolved in an alkali solution at temperatures approaching 400 degrees C and under pressures up to 25,000 psi. The pieces dissolve at the hot end of a specially designed, high tensile-strength, steel autoclave. Crystallization takes place on single crystal "seeds" located at the cool end of the vessel.

Large pieces of quartz can be grown rapidly this way, are cheaper than natural quartz, and are adequate for the majority of oscillator and filter crystal units manufactured for the communications industry. However, they cannot be used in frequency control resonators and other crystal units that require high acoustic quality. For these, synthetic quartz must either be grown slowly, or electrolyzed in a d.c. field. Both processes increase costs and nearly offset the savings synthetic quartz offers over natural quartz.

Until now, high quality quartz has been grown at the rate of 12 to 15 mils a day. In the new Bell Laboratories method, lithium salts are added to the hydrothermal solution, and high quality quartz can be grown at the rate of at least 40 to 50 mils a day.

news in brief

F. R. Kappel Speech At A.T.&T. Annual Meeting Covers Many Subjects

A record construction program of more than $2.8 billion is planned for 1962, Frederick R. Kappel, Chairman of the Board of A.T.&T., told the company's annual meeting in New York last month. This program is planned to take care of substantial growth and build improvements that make possible new and better services and more efficient operation of all services.

Mr. Kappel discussed as "matters of current concern," tax legislation, procurement methods used in the Nike missile systems, and satellite communications.

Calling the business situation "good" and developments in the business "encouraging," Mr. Kappel said that so far this year the rates of growth in telephones and in long distance conversations have shown healthy increases over the corresponding months in 1961.

He noted that during 1961, "a difficult year for most business," the system continued to build wider markets and was able to maintain earnings per share despite the fact that the average number of shares increased more than 13 million.

Improved earnings have been "absolutely essential" to enable us to manage a construction program that is now getting fairly close to $3 billion annually." He noted that a "vigorous construction program provides employment for many thousands of people outside our business as well as inside it, and opens the way to new and improved communication services that in turn enable all industry to function with greater vigor and efficiency."

Discussing the pending tax bill, Mr. Kappel said "the need for risk capital is greater than ever before. To grow and provide jobs, business in the years ahead must attract and employ many billions of dollars," he said. "What is urgent is to offer more incentive to savers, not less . . . a return to complete double taxation would discourage risk-taking investment, could cause serious damage to the economy."

As prime contractor for the development and production of Nike missile systems, Western Electric has saved the Government more than $350 million through cost reduction programs, "nearly five times the total profit Western has earned on Nike in 17 years of work," Mr. Kappel said. "This is precisely the kind of result that this government has been paying Western to accomplish," he said. We feel strongly that the conduct of the Nike program has been to the country's advantage, not only in performance but also in cost."

A great deal of progress has been made in satellite communications, Mr. Kappel pointed out. He told the share owners that we are in the final stages of preparing for the launching and testing of Telstar. This satellite is "strictly experimental," and we hope the tests "will produce the technical know-how to place a satellite communication system in operation by 1965." He pointed out that while many of Telstar's parts will be used for communications, more will be used to measure radiation and the effect of meteorite dust.

Ownership and operation of a worldwide system should be shared among all participating countries. "We are convinced the best results would flow from the international communications common carriers doing the job under public regulation."

While government research in rocketry makes it possible to put a communication satellite in orbit, it is the research and development work of private industry that makes the communication possible, he said.

A.T.&T. Testifies On Satellite Legislation

James E. Dingman, A.T.&T. Executive Vice President, has told the Senate Commerce Committee that it is imperative that satellite communications legislation be enacted by this session of Congress. Postponement of the legislation could "deprive the United States of the initiative in this field in which it now holds the lead," Mr. Dingman said.

Mr. Dingman pointed out that the lead which the United States now has in satellite communications is principally in the vital communications components — such as transistors, masers and solar batteries—"all of which are products of privately financed research done by our communications industry."

He described as "nonsense" the claims that communications companies might retard development of satellites because they would make obsolete the companies' present overseas facilities. He told the committee that a satellite system would supplement the existing world-wide communications network and would "provide added security and reliability."

Mr. Dingman advocated the ownership and operation of ground stations by the communications companies since they "are responsible for the operation" of the current network. He said that divided responsibility for operation of ground stations "will prove impractical and will degrade service to the public." He disavowed any "motive or intent" by A.T.&T. to dominate the new corporation. He said that "no carriers should be allowed to control the Board of Directors" and that "there should be appropriate governmental regulation" to prevent any company from gaining any competitive advantage from its investment in satellites."

Mr. Dingman told the senators that the "establishment of an operable communications satellite program at the earliest practicable time . . . is of paramount importance and transcends all other considerations."

K. G. McKay Named Executive Vice President

K. G. McKay, vice president of Systems Engineering, has been named an executive vice president of Bell Laboratories effective May 1, 1962, with responsibility for all systems engineering and related activities of the Laboratories. Mr. McKay has been associated with electronic, semiconductor and solid state research and development programs at Bell Laboratories since 1946.

K. G. McKay

Upon joining the Laboratories he undertook fundamental research studies of the physics of solids, including studies of secondary electron emission and electron bombardment conductivity in insulators and semiconductors. Later his work related to the electrical and optical characteristics of electrical breakdown in germanium and silicon. He was named director of development of solid state devices in 1957, director of development of components and solid state devices in 1958, and elected a vice president in 1959.

Mr. McKay has been granted nine patents. He is a Fellow of the American Physical Society and served on the Board of Editors of *The Physical Review* from 1955 to 1957. He is a senior member of the Institute of Radio Engineers and a member of the Research Society of America.

Labs System Guides International Satellite

The first international satellite —a joint United Kingdom-United States ionosphere experiment— was injected into orbit last month by a National Aeronautics and Space Administration Thor-Delta launch vehicle guided by the Bell Laboratories Radio Command Guidance system. The launch from Cape Canaveral was the eighth consecutive success for the highly reliable Douglas-built, Laboratories-guided Delta vehicle. The same combination of guidance and vehicle will be used early this summer to orbit the Bell System's Telstar satellite.

The new satellite, a 23-inch cylindrical payload which supports solar-cell paddles, antennas and booms for sensors, contains experiments for acquiring increased knowledge of the ionosphere and how it is affected by solar radiations and for obtaining data on primary cosmic radiations. All of the experiments were designed and tested by university research groups in Britain under the direction of the Office of U.K. Minister for Science. All launch operations were directed by NASA. Data from the experiments will be processed by NASA's Goddard Space Flight Center and then sent to the United Kingdom for further processing and analysis.

The intended elliptical orbit of the satellite, inclined about 55 degrees to the equator, has an apogee of about 600 miles and a perigee of about 200 miles.

Books Published By Labs Members

Four books, written by members of the Laboratories, have been published over the past year.

J. R. Pierce, executive director of the Research—Communications Principles and Communications Systems Division, is the author of *Symbols, Signals and Noise*, which was published by

Harper and Brothers in 1961.

F. Knox of the Crystal Chemistry Department is co-author with F. Y. Tyree, Jr. of the University of North Carolina of a *Textbook of Organic Chemistry*, published by the MacMillan Company in 1961.

A. D. Hall, head of the Broadband System Studies Department, is the author of *A Methodology for Systems Engineering*, published by D. Van Nostrand and Company, Inc. this year.

F. F. Kuo of the Digital Systems Research Department is the author of *Network Analysis and Synthesis*, published by John Wiley & Sons, Inc. this year.

SAC Accepts Operational Titan

The Air Force's first operational complex of Titan I ICBM's was accepted by the Strategic Air Command last month. Acceptance of this complex by SAC is significant as another increment to the nation's ever-increasing deterrent capability. These represent the first of a generation of missiles which can absorb the first blow and still strike back with crushing force against any aggressor.

This brain of the mighty Titan I is the Radio Command Guidance system developed by Bell Telephone Laboratories and manufactured by Western Electric. In the operational Titan I launch complex, both the guidance radar and the computer are underground with the other elements of the missile system. Just prior to launch, the huge Titan I missile and the guidance radar are elevated from their concrete silos. After the missile is fired, a guidance radar tracks it far out into space to get continuous, precise information on the missile's position and speed. By comparing this information with a predetermined trajectory stored in its memory, the Command Guidance system generates steering orders designed to keep the missile on its planned course. These orders are sent to

small, fairly simple guidance units in the missile via a radio link in the guidance radar. The missile-borne guidance units (a radar receiver, a decoder and a radar beacon) then transfer the steering orders to the missile's control elements (an autopilot and the engines) for execution.

The Air Force's Command Guidance system for Titan I has been successfully tested in more than 80 missile launchings. These include the first Titan flights in 1960 and the orbiting of Echo I and the Tiros weather satellites. This versatile system has also been used to guide boost vehicles in the Air Force's space-research program, the National Aeronautics and Space Administration's Thor-Delta satellite and space probe program and the Navy's transit navigation satellite program.

Research and development versions of the Command Guidance system, operated by Bell Laboratories-Western Electric crews, have been installed at both Cape Canaveral and Vandenberg Air Force Base to guide developmental Titan I missiles.

Air-Ground Service To Be Extended

The Bell System announced last month that it is building facilities to extend its developmental air-ground telephone service throughout the entire northeast quadrant of the United States. The project calls for construction of five new ground antenna stations—at Elmira, N. Y., Beckley, W. Va., Dayton, O., Vincennes, Ind., and Boston. Together with existing stations the new facilities will provide blanket air-ground coverage east of the Mississippi and north of the Virginias by early summer.

The new construction has been approved by the Federal Communications Commission on a developmental basis for collecting additional operating data. Still pending before the FCC is a request by the American Telephone

and Telegraph Company to provide the service on a regular basis nationally.

The service makes possible telephone conversations between airplane passengers and ground telephones. At present, only some corporate planes are equipped to use the new service. The Bell System expects, however, that the service would be popular with both commercial and private aircraft if it is provided throughout the country.

An air-to-ground call is made through an "aviation" switchboard operator who makes the connection between the air-borne telephones and the ground phones. Air-borne customers are able to talk with any telephone in the nationwide network. Ground-to-air calls are made by dialing the telephone company and asking for the "aviation" operator in the area where the plane is known to be flying.

Air-ground service was inaugurated on a trial basis in 1957 in the Chicago and Detroit areas. Three airlines—Capital, Northwest-Orient and United—participated in the tests. The Bell System proposal to make this new dimension in communications a regular service is largely a result of favorable response from persons who used it during the trial.

J. R. Pierce Appointed To Scientific Committee

J. R. Pierce, executive director of the Research—Communications Principles and Communications Systems Division, was recently appointed to a scientific advisory committee by the American Newspaper Publishers Association. The committee will make a year-long study to assess newspaper applications of scientific and technological developments.

Other members of the committee will be D. A. F. Spilhaus, Dean of the University of Minnesota's Institute of Technology, and T. Gardner, a former Assistant Secretary of the Air Force.

W. O. Baker Honored

W. O. Baker, vice-president, Research and Patents, was awarded the Honor Scroll of the New Jersey Chapter of the American Institute of Chemists. The award was made at the Honor Scroll and Awards Dinner of the Institute which was held in Newark, N. J.

Mr. Baker has been engaged in research in physical chemistry at the Laboratories since 1939. He was responsible for the discovery of a new kind of polymer called microgel, and conducted other studies which revealed new ways to apply purely synthetic materials to telephone and communications systems and thus improve their performance. He has been granted more than 10 patents on subjects of high polymers.

Mr. Baker is a member of the National Science Board of the National Science Foundation; a consultant to the Department of Defense; a member of the National Research Council and of the National Academy of Sciences and a member of the Municipal Manpower Commission. He is a consultant to several other government agencies and is a member of a number of professional and industrial societies.

Artificial Larynx Available World-Wide

The electronic artificial larynx is now available on a world-wide basis through the World Health Organization (WHO), the Bell System announced this month. Previously the electronic larynx had been available only in the United States and Canada. It was developed by the Laboratories and is manufactured on a non-profit basis by Western Electric for use by persons whose larynxes have been removed surgically or whose vocal cords are paralyzed. Now, any resident of a member nation of WHO may order the larynx through the ministry of health in his own country. The ministry will place the order through one of WHO's six regional offices.

TALKS

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

Ahearn, A. J., *The Application of Vacuum Spark Mass Spectroscopy of Solids to Special Problems*, Am. Chem. Soc., Washington, D. C.

Allen, F. G., *Field Emission: A Tool for Studying Semiconductor Surfaces*, Am. Chem. Soc., Washington, D. C.

Arthur, J. R., Jr., *The Adsorption and Surface Reactions of Hydrocarbons on Clean Iridium*, New York Acad. of Sci., N.Y.C.

Bak, T. A., see Frisch, H. L.

Baker, R. G., *The Use of Electroplated Metals in Static Contacts*, Delaware Valley Study Group, Philadelphia, Pa.

Ballentine, W. E., Saari, V. R., and Willey, L. F., *Recent Advances in Wideband FM Receiver Design*, Internat. Solid-Circuits Conf., Philadelphia, Pa.

Bartelink, D. L., see Moll, J. L.

Basseches, H., Manz, R. C., Thomas, C. O., and Tung, S. K., *Factors Affecting the Resistivity of Epitaxial Silicon Layers*, A.I.M.E., Los Angeles, Calif.

Benes, V. E., *Markov Processes Representing Traffic in Connecting Networks*, Cornell Univ., Ithaca, N. Y.

Bennett, W. R., Jr., *Recent Progress in Experiments with He-Ne Optical Masers*, Am. Phys. Soc., N.Y.C.

Black, H. S., *Exotic Communications*, A.I.E.E., Polytec. Insti., Brooklyn, N. Y.; High School Sci. & Math. Teachers, Buffalo, N. Y.

Black, H. S., *Global Communications Via Artificial Earth Satellites*, Western Electric Company, Buffalo, N. Y.; East Coast V.H.F. Soc., Ramsey, N. J.

Black, H. S., *New Developments in Communications Research*, Western Electric Grad. Engg. Training Prog., Chicago Ill., N. Y. C., Winston-Salem, N. C.

Black, H. S., *Satellite Communications*, Methodist Church, Westfield, N. J.

Blount, E. J., *Block Elections in a Magnetic Field*, Am. Phys. Soc., Baltimore, Md.

Boyd, G. D., Collins, R. J., Porto, S. P., Yariv, A. and W. A. Hargreaves, *Continuous Optical Maser Action at 2.56μ in Trivalent Uranium Doped Calcium Fluoride*, Am. Phys. Soc., N.Y.C.

Boyd, G. D., *Recent Advances in Solid State Optical Masers*, Brooklyn Poly Elec. Engg. Sem., Brooklyn, N. Y.

Brattain, W. H., *The Nobel Ceremonies*, Univ. of Nevada, Reno, Nevada.

Brattain, W. H., *Semiconductor Surfaces*, Univ. of Nevada, Reno, Nevada; Naval Ord. Test Station, China Lake, Calif.; New Mexico Insti. of Mining and Technol., Socorro, New Mexico.

Buchsbaum, S. J., *Electron and Ion Resonance in Plasma*, Plasma Phys. Lab. Colloq., Princeton Univ., Princeton, N. J.

Collins, R. J., see Boyd, G. D.

Connell, J. B., *Logic Circuit Synethesis and Simplification*, A.I.E.E., N.Y.C.

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

David, E. E., Jr., *Some Basic Processes in Human Communication*, California Insti. of Techn., Pasadena, Calif.

David, E. E., Jr., see Flanagan, J. L.

Davis, C. G., *Satellite Communications*, Molloy College for Women, Long Island, N. Y.; Cincinnati and Suburban Telephone Company, Cincinnati, Ohio

De Benedictis, T., see Hansen, R. H.

Fawcett, E., *Magnetoresistance of Transition Metals*, Franklin Insti., Philadelphia and Westinghouse Research Labs., Pittsburgh, Pa.

Feldman, D., *Storage Battery Requirements for Communications Satellites*, A.I.E.E., N.Y.C.

Fitzwilliam, J. W., *TWTs and Their Applications*, P.G.M.T.T., N.Y.C.

Fitzwilliam, J. W., *Satellite Communications*, San Diego State College, California Western Univ., San Diego, Calif.; California Polytechnic College, San Luis Obispo, Calif.; San Francisco Electric Club, San Francisco, Calif.; Lawrence Radiation Laboratory, Livermore, Calif.; Univ. of Calif., Berkeley, Calif.

Fitzwilliam, J. W., *Satellite Communications*, Student A.I.E.E.-IRE, Portland, Ore.; Kiwanis Club, Portland, Ore.; Portland Sec. A.I.E.E.-I.R.E., Portland, Ore.

Flanagan, J. L., David, E. E. Jr., and Watson, B J., *Effects of Masking upon the Binaural Lateralization of Cophasic and Antiphasic Clicks*, Biophys. Soc., Washington, D. C.

Fleckenstein, W. O., *Communication Aspects of Data Processing Systems*, Elec. Engg. Sem., Lehigh Univ., Bethlehem, Pa.

Frisch, H. L., *Corresponding State Treatment of Chemical Kinetic Data-Solvent Effects*, State Univ. College of Forestry, Syracuse Univ., Syracuse, N. Y.

Frisch, H. L., Bak, T. A., and Webster, Miss Eleanor R., *Corresponding State Treatment of Chemical Kinetic Data—Solvent Effects*, Harvard—M.I.T. Phys. Chem. Colloq., Cambridge, Mass.

Frishkopf, L. S., and Goldstein, M. H., *Effect of Auditory Stimulation on Responses from Single Units in the Eighth Nerve of the Bullfrog*, Biophys. Soc., Washington, D. C.

Fuchs, E. O., see Olsen, K. M.

Garrett, C. G. B., *Optical Masers*, Internat. Solid State Conf., Philadelphia, Pa.; E. E. Colloq., Princeton Univ., Princeton, N. J.

Geils, J. W., *Engineering as a Profession*, Howard Univ., Washington, D. C.

Gerard, H. B., *Inconsistency of Beliefs and Their Implications*, Syracuse Univ., Syracuse, N. Y.

Gerard, H. B., *Self-Evaluation and Social Comparison*, Syracuse Univ., Syracuse, N. Y.

Ginsberg, A. P., *Hydride Complexes of the Transition Metals*, Bryn Mawr College, Bryn Mawr, Pa.

Giordmaine, J. A., *Experiments with Optical Masers*, Univ. of Calif., Berkeley, Calif.

Giordmaine, J. A., *Mixing of Light Beams in Crystals*, Am. Phys. Soc., Baltimore, Md.

Glasor, J. L., *TELSTAR, the Bell System's Experimental Communication Satellite*, Armed Forces Communication and Electron. Assoc., Winston-Salem, N. C.

Goldstein, M. H., see Frishkopf, L. A.

Grunwald, E., *Rates and Mechanism of some 'Instantaneous' Proton Transfer Reactions*, Am. Chem. Soc., Texas and New Mexico.

Hagstrum, H. D., *Auger Electronic Transitions Involving Atoms Near Solid Surfaces*, N.Y. Acad. Sci., N.Y.C.

Hagstrum, H. D., *Electronic Transitions Involving Atoms Near Solid Surfaces*, Sandia Corp., Albuquerque, New Mexico

Hamming, R. W., *Information Theory and Numerical Analysis*, Boeing Aircraft Corp., Seattle, Wash.

Hamming, R. W., *The Role of Computers in the University*, Washington State Univ., Pullman, Wash.

Hamming, R. W., *The Role of Computing in Modern Society*, IBM Systems Research Insti., N.Y.C.

Hammock, J., *Teaching Machines*, P.T.A., Morris Township, N. J.

Hannay, N. B., *Semiconductor Chemistry*, Swarthmore College, Swarthmore, Pa.

Hansen, R. H., and DeBenedictis, T., *Studies of the Decomposition of Blowing Agents II. Azodicarbonamide and Other Compounds*, Am. Chem. Soc., N.Y.C.

Hargreaves, W. A., see Boyd, G. D.

Harmon, L. D., *Neural Analogs*, A.I.E.E., Princeton, N. J.

Hawkins, W. L., *Evaluation of the Stability of Polymers*, Polytec. Inst. of Brooklyn, Brooklyn, N. Y.

Helfand, E., *Diagrams for the Potential of Mean Force*, Am. Phys. Soc., Baltimore, Md.

Hemmendinger, B. G., *Semiconductors and Logic*, Phys. Club, Lewis College, Lockport, Ill.

Herbst, R. T., *Machine Aids to Design for Manufacture*, A.I.E.E. and S.A.M., Winston-Salem, N. C.

Holt, H. O., and Valentine, C. G., *An Exploratory Study of the Use of a Self-Instruction Program in Basic Electricity Instruction*, IBM, N.Y.C.

Hsu, F. S. L., see Olsen, K. M.

Jack, R. F., see Olsen, K. M.

Ketchledge, R. W., *The Morris Electronic Central Office*, A.I.E.E., N.Y.C.

Kisliuk, P., *Optical Masers*, Am. Chem. Soc., Woodbury, N. J.

Kuebler, N. A., see Nelson, L. S.

Kunzler, J. E., *Superconductivity at High Magnetic Fields and Superconducting Magnets*, Ohio State Univ., Columbus, Ohio.

Liu, B., *Network Synethsis in the Time Domain*, I.R.E., Univ. Pennsylvania, Philadelphia, Pa.

MacLean, D. J., see Prestigiacomo, A. J.

MacRae, A. U., *Low-Energy Electron Diffraction Studies of Clean Nickel Surfaces*, IBM, Yorktown Heights, N. Y.

McFarlane, R. A., *Microwave and Optical Masers*, A.I.E.E., N.Y.C.

Manz, R. C., see Basseches, H.

Matthias, B. T., *Metallurgy and Superconductivity*, A.I.M.E., N.Y.C.

Meacham, L. A., *Touch-Tone Calling—Space Age Dialing for the Bell System*, Univ. Wash. A.I.E.E.-IRE, Seattle, Wash.; Univ. of Idaho A.I.E.E.-IRE, Moscow, Idaho; Wash. State Univ., A.I.E.E.-IRE, Pullman, Wash.

Moll, J. L., and Bartelink, D. L., *P-N Junction Emitters*, A.I.E.E., N.Y.C.

Nelson, L. S., and Kuebler, N. A., *Flash Spectra of Thermally Produced Free Radicals*, Am. Chem. Soc., Philadelphia, Pa.

Olsen, K. M., Jack, R. F., Fuchs, E. O., and Hsu, F. S. L., *Preparation and Properties of Ultra Fine Niobium-Zirconium Superconducting Wire*, A.I.M.E., N.Y.C.

Peterson, A. E., *Project Mercury*, Rotary Club, West Milford, N. J.

Pollak, H. O., *The Nature of Essentially Time-Limited and Band-Limited Signals*, Harvard Univ., Cambridge, Mass.

Pollak, H. O., *How Abstract Should Secondary School Mathematics Be?*, Annual Meeting Indep. Sch. Ed. Board, N.Y.C.

Pollak, H. O., *On The Nature of Mathematical Research in Industry*, Regis High School, N.Y.C.; Piscataway Township High School, New Market, N. J.; Stevens Insti. Tech., Hoboken, N. J.; Univ. Michigan, Ann Arbor, Mich.

Pollak, H. O., *Applied Mathematics and Its Implications for Secondary School Curriculum*, Conf. Academic Year Insti. Math., Univ. Notre Dame, South Bend, Ind.

Porto, S. P., see Boyd, G. D.

Prestigiacomo, A. J., and MacLean, D. J., *A Frequency Shifter for Improving Acoustic Feedback Stability*, Audio Engg. Soc., N.Y.C.

Riesz, R. R., *Human Factors Research Activities at Bell Laboratories*, Human Factors Soc., N.Y.C.

TALKS (CONTINUED)

Rigterink, M. D., *Some Challenging Problems in Ceramic Engineering*, Rutgers Univ., New Brunswick, N. J.

Riordan, J., *Enumeration of Linear Graphs Associated with Random Mappings*, UCLA Colloq., Los Angeles, Calif.

Rosenberg, S., *Experimental Analysis of Two-Person Interactions*, N.Y.U., N. Y. C.

Rosenthal, C. W., *Automating the Design of Digital Systems*, Assoc. Computing Machinery, Atlantic City, N. J.

Saari, V. R., see Ballentine, W. E.

Scaff, J. H., *Metallurgy's Role in Electronics*, A.S.M., N.Y.C.

Schroeder, M. R., *Novel Uses of Digital Computers in Room Acoustics*, 62nd Meeting Acoust. Soc. of Am., Cincinnati 2, Ohio.

Smolinsky, G., *The Chemistry of Azenes*, Penn. State Univ., University Park, Pa.

Spitzer, W. G., and Crowell, C. R., *Electron Attenuation Length in Metals*, Philco Research Symp., Philadelphia, Pa.

Thomas, C. O., see Basseches, H.

Trambarulo, R. F., *A Low-Noise X-Band Esaki Diode Amplifier*, 1962 Solid-State Circuit Conf., Philadelphia, Pa.

Tung, S. K., see Basseches, H.

Valentine, C. G., see Holt, H. O.

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

Walsh, W. M., Jr., *Magnetic Properties of Nucleic Acid Samples*, Mich. State Univ., E. Lansing, Mich.

Webster, E. R., see Frisch, H. L.

West, F., see Ham, J. H.

Willey, L. F., see Ballentine, W. E.

Wood, Mrs. E. A., *The Strange Case of Ferroelectricity and Sodium Niobate*, Polytech. Insti., Brooklyn, N. Y.

Wood, Mrs. E. A., *The Other Half of Our Scientific Manpower*, Soc. Meeting, High School, Washington, D. C.

Wood, Mrs. E. A., *Buttercups and Rockets*, Albertus Magnus College, New Haven, Conn.

Wood, Mrs. E. A., *Minerals, Molecules and Magnets*, Albertus Magnus College, New Haven, Conn.

Yariv, A., see Boyd, G. D.

PATENTS

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

Anderson, H. P.—*Bistable Circuit Using Avalanche Effect in a Double Base Diode*—3,026,425.

Borden, D. C.—*Automatic Amplitude Control and Pulse Shaping Circuit*—3,025,413.

Breed, R. N.—*Telephone System*—3,027,424.

Davis, C. G.—*Self Timed PCM Encoder*—3,026,510.

Davis, C. G.—*Slow Readout PCM Encoder*—3,026,511.

Davis, K. H. and Norwine, A. C.—*Continuous Recording System with Indexing Means*—3,024,321.

Felker, J. H.—*Transistor Amplifier Circuits*—3,025,412.

Flaschen, S. S. and Pearson, A. D.—*Glass Composition and Coated Article*—3,024,119.

Froehlich, F. E.—*Magnetic Core Circuits*—3,027,547.

Geyling, F. T.—*Strain Gauges and Accelerometers*—3,023,627.

Graham, R. E.—*Transmission of Quantized Signals*—3,026,375.

Gretter, R. W.—*Cable Engine Pressure Regulating Equipment*—3,024,956.

Harmon, L. D. and Mattke, C. F.—*Photosensitive Transducer with Parallel Readout*—3,027,528.

Jackson, F. R., Jr.—*Phantastron Circuit with Output Waveform Linearization Means*—3,025,469.

Jacobitti, E., James, D. A., Morrison, C. G. and Newsome, J. B.—*Class Translator Circuits*—3,025,357.

James, D. A., see Jacobitti, E.

Jordan, H. G., Purgett, L. J., Restall, W. E., Jr. and Schweizer, P. E.—*Switching Device*—3,027,432.

Ketchledge, R. W.—*Automatic Gain Control System*—3,027,518.

Marcatili, E. A. J.—*Microwave Devices for Waveguides of Circular Cross Section*—3,025,478.

Mattke, C. F., see Harmon, L. D.

May, C. J., Jr.—*Signal Transmission Gate*—3,027,524.

Morrison, C. G., see Jacobitti, E.

Mumford, W. W. and Tatsuguchi, I.—*Microwave Coupling Arrangements*—3,026,490.

Newsome, J. B., see Jacobitti, E.

Norwine, A. C., see Davis, K. H.

Pasternak, J. P.—*Insulation Stripping Wire Connector*—3,027,536.

Pearson, G. L.—*Semiconductive Device*—3,027,501.

Purgett, L. J., see Jordan, H. G.

Restall, W. E., Jr., see Jordan, H. G.

Schweizer, P. E., see Jordan, H. G.

Sullivan, J. L.—*Compatible Ringing Circuit*—3,026,377.

Tatsuguchi, I., see Mumford, W. W.

Thomas, D. E.—*Null Type Transistor Alpha Greater Than Unity Measuring Set*—3,026,479.

Thomas, D. E.—*Null Type Transistor Beta Measuring Set*—3,025,468.

Vaughan, H. E.—*Electromagnetic Coupling Arrangements*—3,027,548.

Woodin, E. A.—*Electronic Switching Network*—3,027,427.

Yostpille, J. J., see Lee, R. C.

Following is a list of the authors, titles and places of publication of recent papers published by members of the Laboratories.

Abrahams, S. C., *The Crystal and Magnetic Structure of Cupric Fluoride Dihydrate at 4.2°K*, J. Chem. Phys., 36, pp. 56-61, Jan., 1962.

Abrahams, S. C., and Prince, E., *The Crystal Structure of Cupric Fluoride Dihydrate at 298°K*, J. Chem. Phys., 36, pp. 50-55, Jan., 1962.

Atalla, M. M., see Spitzer, W. G.

Benson, M. L., Crutchfield, F. L., and Hopkins, H. F., *Application of TOUCH-TONE Calling in the Bell System*, A.I.E.E., Dec. 21, 1961.

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

Brownell, R. M., *Direct Observation of Outward-Progressing Flux Change in Tape-Wound Cores at Power Frequencies*, J. Appl. Phys., 33, pp. 118-120, Jan., 1962.

Chynoweth, A. G., Logan, R. A., Thomas, D. E., *Phonon Assisted Tunneling in Silicon and Germanium Esaki Junctions*, Phys. Rev., 3, pp. 877-881, February 1, 1962.

Clogston, A. M., *Impurity States in Metals*, Phys. Rev., 125, p. 439, Jan. 15, 1962.

Clogston, A. M., Matthias, B. T., Peter, M. Williams, H. J., Corenzwit, E., Sherwood, R. C., *The Local Magnetic Moment Associated with an Ion Atom Dissolved in Various Transition Metal Alloys*, Phys. Rev., 125, p. 541, Jan. 15, 1962.

Corenzwit, C., see Clogston, A. M.

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

Crutchfield, F. L., see Benson, M. L.

DeMonte, R. W., *Networks Simulating Impedance of Loaded Cable Facilities in Communication and Electronics*, A.I.E.E., January, 1962.

Denton, R. T., and Snow, W. B., *Origin of Noise in a Ferromagnetic Parametric Amplifier*, IRE, 50, p. 208, Feb., 1962.

Dunn, H. K., *Methods of Measuring Vowel Format Bandwidths*, J. Acous. Soc. Am., 33, pp. 1737-1746, Dec., 1961.

Flanagan, J. L., Book Review *"Acoustic Theory of Speech Production"* by Faut, G., J. Acoust. Soc., 34, p. 137, Jan., 1962.

Flanagan, J. L., and Bird, C. M., *Minimum Phase Responses for the Basilar Membrane*, J. Acoust. Soc. Am., 34, pp. 114-118, Jan., 1962.

Frisch, H. L., *The Time Lag in Transport Theory*, J. Chem. Phys., 36, p. 510, Jan., 1962.

Fuller, C. S., and Wolfstirn, Miss K. B., *Kinetics and Equilibria Involving Copper and Oxygen in Germanium*, J. Appl. Phys., 33, p. 438, Jan., 1962.

Gnanadesikan, R., see Wilk, M. B.

Guttman, N., *A Mapping of Binaural Click Lateralizations*, J. Acoust. Soc. Am., 34, pp. 87-92, Jan. 1962.

Hopkins, I. L., *A Suggested Technique for Measuring Stress Relaxation Modulus and Creep Compliance and for Testing Linear Viscoelastic Theory*, J. Appl. Polymer Sci., 6, pp. 52-53, 1962.

Hopkins, H. F., see Benson, M. L.

Hutson, A. R., and White, D. L., *Elastic Wave Propagation in Piezoelectric Semiconductors*, J. Appl. Phys., 33, p. 40, Jan., 1962.

Huyett, Miss M. J., see Wilk, M. B.

Logan, B. F., see Sherwood, R. C.

Logan, R. A., see Chynoweth, A. G.

Logan, B. F., see Schroeder, M. B.

Mason, W. P., *Semiconductor Transducers*, Electronics, 35, pp. 35-39, Feb. 23, 1962.

Matthias, B. T., see Clogston, A. M.

McSkimin, H. J., and Thomas, D. G., *The Elastic Moduli of Cadmium Telluride*, J. Appl. Phys., 33, p. 56, Jan., 1962.

Muir, D. 3rd, *The Penultimate Electronic Key*, QST., XLVI, pp. 15-19, March, 1962.

Peter, M., see Clogston, A. M.

Prince, E., see Abrahams, S. C.

Schroeder, M. B., and Logan, B. F., *Colorless-Artificial Reverberation*, IRE Trans., 6, p. 209, Nov.-Dec., 1961.

Sherwood, R. C., see Clogston, A. M.

Sikorski, M. E., *Sensitive Tunnel Diode Pressure Transducers*, 1962 Internal. Solid-State Cir. Conf., Digest of Tech. Papers, 5, pp. 74, 75, and 106, Feb., 1962.

Singer, F. J., *Compatibility in Communications*, Electrical Engr., 81, p. 94, Feb., 1962.

Smith, G. W. Jr., *Dual Requirements for Optimizing Orthonormal Approximations of Impulse Responses*, IRE Trans., 8, pp. 486-487, Dec., 1961.

Snow, W. B., see Denton, R. T.

Snyder, L. C., *Huckel Molecular Orbital Computations to Describe the Benzidine Rearrangement*, J. Am. Chem. Soc., 84, pp. 340-347, Feb. 5, 1962.

Spitzer, W. G., Crowell, C. R., and Atalla, M. M., *Mean Free Path of Photoexcited Electrons in Au*, Phys. Rev., 8, p. 57, Jan. 15, 1962.

Thomas, D. E., see Chynoweth, A. G.

Thomas, D. G., see McSkimin, H. J.

van Bergeijk, W. A., *Studies with Artificial Neurons, II: Analog of the External Spiral Innervation of the Cochlea*, Kybernetik, 1, pp. 102-07, December, 1961.

Walrafen, G. E., *Ramon Spectral Studies of Aqueous Solutions of Selenious Acid*, J. Chem. Phys., 36, pp. 90-93, Jan. 1, 1962.

White, D. L., see Hutson, A. R.

Wilk, M. B., Gnanadesikan, R., and Huyett, Miss M. J., *Probability Plots for the Gamma Distribution*, Technometrics, 4, pp. 1-20, Feb., 1962.

Williams, H. J., see Clogston, A. M.

Wolfstirn, Miss K. B., see Fuller, C. S.

AUTHORS

Harold Seidel

Harold Seidel, the author of "Low - Noise Microwave Amplifiers" in this issue, was born in Brooklyn, New York. He received the B.E.E. from the College of the City of New York in 1943 and the M.E.E. in 1954. He later attended the Polytechnic Institute of Brooklyn and received the D.E.E. degree in 1954.

Mr. Seidel joined Bell Telephone Laboratories in 1953. During his career at the Laboratories he was involved in two phases of investigation of microwave problems. The first was a concern with general electromagnetic problems, particularly in regard to waveguide applications. The second phase of his investigations concerned microwave ferrite devices.

Mr. Seidel, a member of the I.R.E. and Sigma Xi, resigned from the Laboratories in 1961.

A. E. Earp

A. Eugene Earp, co-author of "TH Microwave Carrier Supply" is a native of New Jersey and has resided in Basking Ridge, N. J. since 1948. He joined the Drafting and Design Group of the Laboratories in 1944. In 1952 he was transferred to the Transmission Development Department where he has been concerned with equipment design problems associated with TD and TH Microwave Radio and, more recently, the Telstar satellite. He attended Stevens Institute of Technology and Fairleigh Dickinson University.

Arthur F. Perks, co-author of "TH Microwave Carrier Supply" was born in Lowell, Massachusetts and now lives in Warren Township, New Jersey. During World War II he served in the U.S. Navy aboard an LST in the European-African-Middle Eastern Theater of Operations. After the war, he received his technical
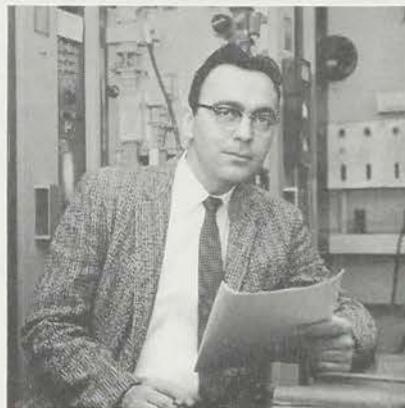
A. F. Perks

training from Capital Radio Engineering Institute, Washington, D. C. From 1947 to 1952 he was employed in the radio and television broadcasting field and then spent a year on the development of a high power transmitter at the Research Laboratories for Electronics at the Massachusetts Institute of Technology. Mr. Perks joined the Laboratories in 1953,

and was first engaged in the development of the Compandor of the XP-1 carrier system. He later transferred to the TH Radio Group working on the Microwave Carrier Supply and the Automatic Protection Switching for that system. He is currently engaged in the development of the Ground Receiver of the TSX-1 Project. He is an associate member of the I.R.E.

R. H. Higgins, a native of Warwick, Rhode Island, received his B.S.E.E. degree from the Uni-

R. H. Higgins

versity of Rhode Island in 1956. After joining the Laboratories, he graduated from the Communications Development Training Program in 1959 and obtained his M.S.E.E. from New York University in 1960. In his five years at the Laboratories, he was engaged in the development of the TH Radio Relay System, first on the microwave receiver and later on the automatic protection switching system. Mr. Higgins, a member of Tau Beta Pi, the American Physical Society, and the Institute of Radio Engineers, is currently employed by Harrison Laboratories, Inc. in Berkeley Heights, N. J. A resident of Summit, N. J., he is co-author of "Automatic Protection Switching System for TH Radio" in this issue.
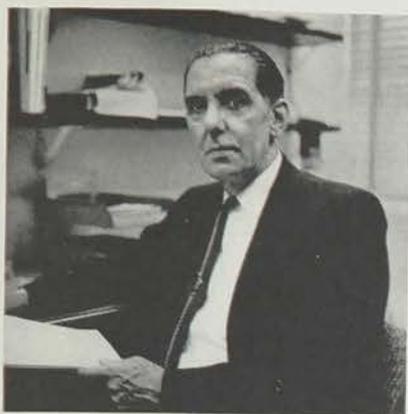
L. M. Klenk

L. M. Klenk, a resident of Little Silver, N. J., joined the Laboratories in 1929. He was stationed at the Laboratories branch location in Deal, N. J. from 1932 to 1953. During this period he was engaged in the equipment design of short-wave transatlantic and multichannel short-hop transmit-ting equipment. During World War II, he designed radar tracking equipment and countermeasure equipment. From 1953 to 1960 he participated in the design of the TH microwave carrier supply, auxiliary channel, and protection switching equipment. At present, Mr. Klenk is engaged in the design of part of the ground station transmitter for the Telstar project. Author of "Automatic Protection Switching for the TH Radio System," Mr. Klenk is a member of IRE.
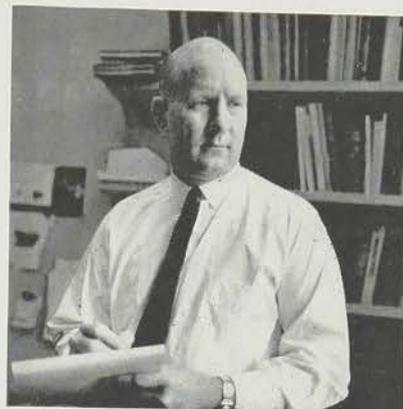
W. R. McClelland

W. R. McClelland, a native of Montreal, Canada, received the BSc(hons) degree in Mathematics from McGill University in 1948. In 1953 and '54 he continued his studies at the University of London. Mr. McClelland joined Bell Telephone Laboratories at Murray Hill in 1957 where he was engaged first in the development of the Radio System and then on the design of the TH Automatic Projection Switching System. He later worked on the Telstar Project. At present, Mr. McClelland is doing graduate work in Rutgers University while on an educational leave of absence.
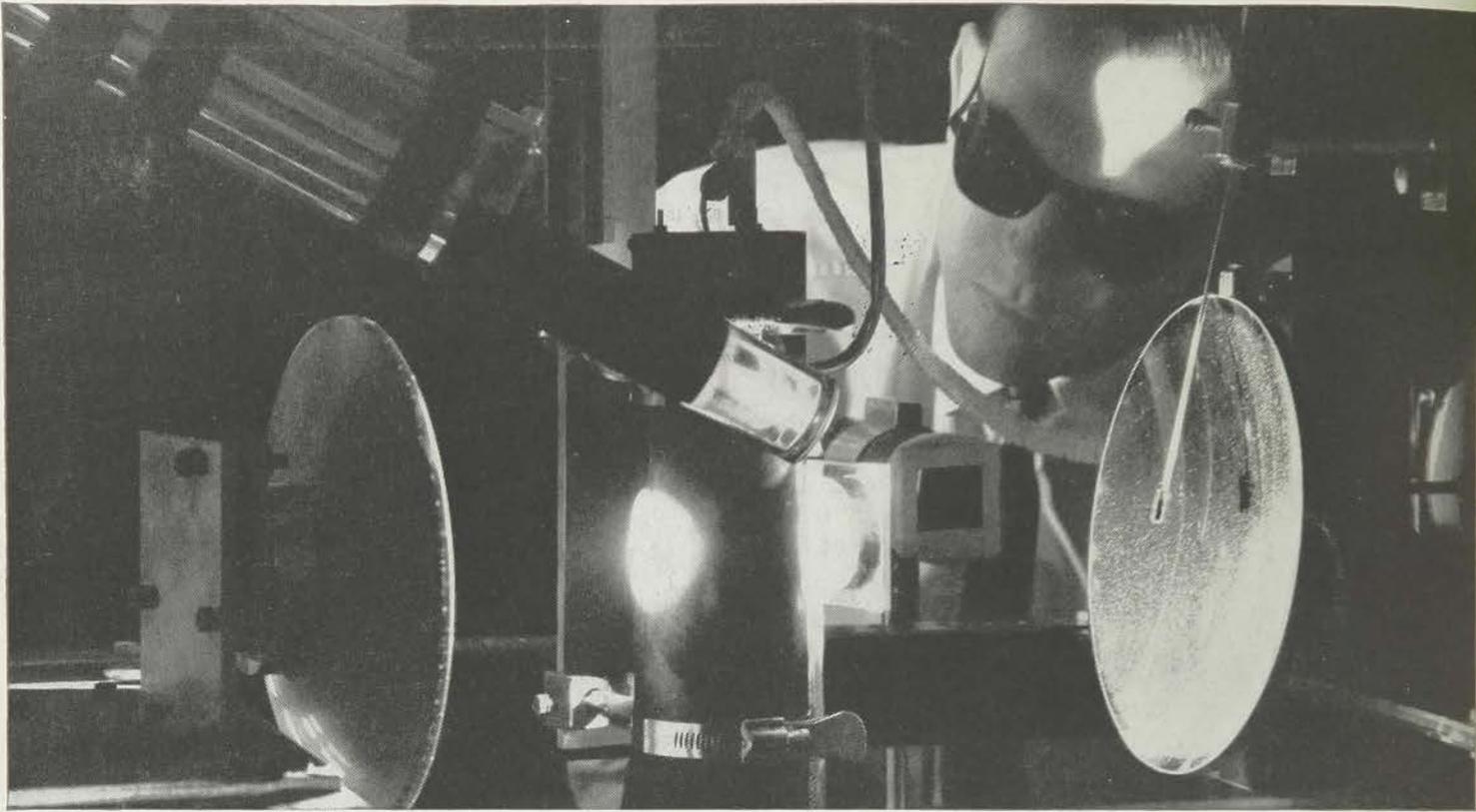
Exploring the possibilities in Coherent Light

At Bell Laboratories, Donald F. Nelson studies a beam of coherent red light produced by a continuously operating ruby optical maser. The heart of the device is a uniquely shaped ruby crystal immersed in liquid nitrogen in the tubular glass dewar extending from upper left to center. Light from the mercury arc lamp (lower center) is reflected by round mirror at left to mirror at right and then is focused on the ruby crystal to produce maser action. Coherent light emerging from end of dewar is picked up by a detector.

Is it feasible to take advantage of the enormous bandwidth available at optical frequencies? Could coherent light, for example, be sent through protecting pipes to provide high-capacity communication channels between cities?

To study such possibilities it is, first of all, necessary to have a source of continuous coherent radiation at optical frequencies. Such a source was first produced when Bell Laboratories scientists developed the gaseous optical maser.

Recently, our scientists demonstrated the generation of continuous coherent light by solid materials. Using a crystal of neodymium-doped calcium tungstate, a material developed at Bell Laboratories, continuous optical maser action was obtained in the near infrared. It has also been attained with visible light, using a new optical "pumping" arrangement to excite a ruby crystal. (See illustration above.)

Multichannel light highways for communications are still far from realization. But with continuous sources of coherent light available, it becomes possible to explore the problems of modulating, transmitting, detecting, amplifying and, in general, controlling light for possible communications applications.

BELL TELEPHONE LABORATORIES
World center of communications rese