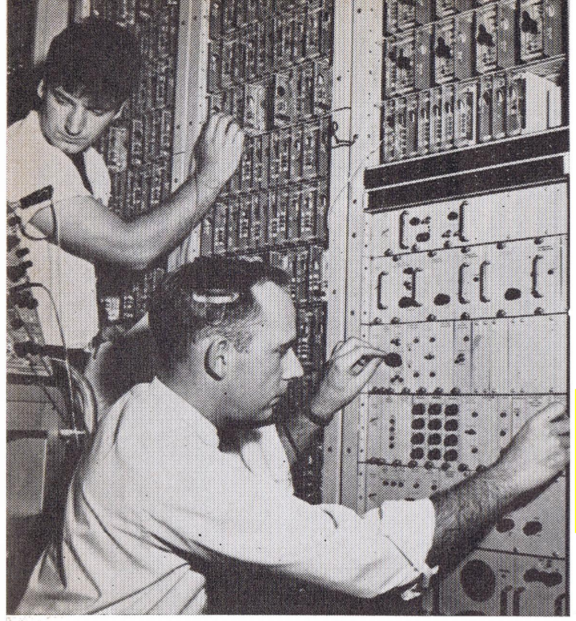
NEW VOICE, SIGNAL, DATA COMMUNICATIONS SPAN THE PACIFIC



Lenkurt Electric's engineers tune the 27A transmission system at a U.S. Navy radio station.

Navy Tests Approve Lenkurt Duobinary System

EVEN as Lenkurt Electric Company, Inc., San Francisco subsidiary of General Telephone & Electronics Corp. was announcing a U.S. Navy contract for its Duobinary-Datatel system (*see Off-the-Wire, page 16*), technical details of the tests which confirmed the system as feasible were being discussed by the communications industry.

U.S. Navy tests conducted on a multi-link communications circuit between California and the Hawaiian Islands have proved the feasibility of operating the 27A Duobinary-Datatel equipment in an integrated communications weather forecasting system. In the test, conducted on a regular schedule for four weeks, millions of bits of information were transmitted each day in signal patterns as long as 383 "computer words."

The binary data signals from the Monterey computer were transmitted in serial form at 2,400 bits per second as a duobinary wave by Lenkurt's 26B over wire telephone lines to a Navy radio station near Stockton, Calif., (*Figure* 1), where the 27A transmitters and receivers were installed. (The 26B is an assembly of terminal equipment employing the duobinary technique and engineered for the transmission of serial digital data over conventional wire line, cable, carrier, or microwave facilities.) At Stockton, the duobinary-coded signal patterns were converted back to binary serial data by the 26B receiver and inter-connected to the 27A transmitter.

Data signal patterns were accepted in serial form by the 27A, converted to 16 parallel channels of 150 bps, and transmitted as a duobinary wave with a pulse length of 6.6 msec per channel to overcome expected time smear of 3 to 5 msec. The 16 frequency-modulated FSK oscillator duobinary outputs were frequency-multiplexed at 170 cps spacing, with the low channel centered at 425 cps and the high at 2,975 cps, into a 3-kc bandwidth.

Microwave radio relayed the 27A transmission to a repeater station on Mount Diablo near the San Francisco Bay area (*Figure* 1), thence to another repeater on Skaggs Island for relaying to nearby Mare Island. Here the signals are broadcast by HF radio to Hawaii.

HF diversity reception was used, with diversity combiners on each of the 16 channels. The best input path was enhanced by a ratio squared-post detection combiner. The output of each channel combiner was converted by the duobinary technique back to conventional binary data at 150 bps, and the 16 channels were then combined by a parallel to serial converter to produce binary serial data at a synchronous speed of 2,400 bps. The binary serial stream was relayed by the 26B as a duobinary wave over wire line at 2,400 bps to a 26B receiver, which was interconnected to a computer at Pearl Harbor. The 26B fed the computer a binary serial stream at 2,400 bps. The computer checked the signals against the programmed signal pattern to determine if errors had occurred, and a correct-proceed or incorrect-repeat signal was transmitted back to the Monterey computer.

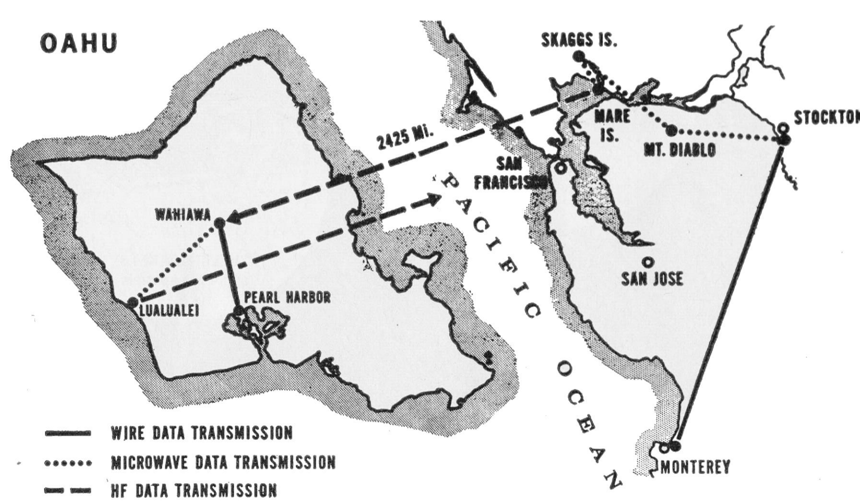


FIGURE 1. Multi-link communications circuit between California and Hawaii utilizes telephone wire, microwave and high frequency radio for transmission.

Long Lines Links U.S. and Japan

TODAY an overseas operator in Tokyo can dial direct to any of the 91 million telephones in North America and Oahu, Hawaii. At the same time, operators at overseas gateways in Oakland, Vancouver and Honolulu can now dial direct to any of the 8.4 million telephones in Japan. This marks another step towards the time when Americans will be able to dial their own calls to practically anywhere in the world.

Today reduced rates make possible a station call from the U.S. to Japan for $6.75 on Sunday, $9 person-to-person. When the single radio-telephone circuit between San Francisco and Tokyo was opened in 1934 the three-minute toll was $34.

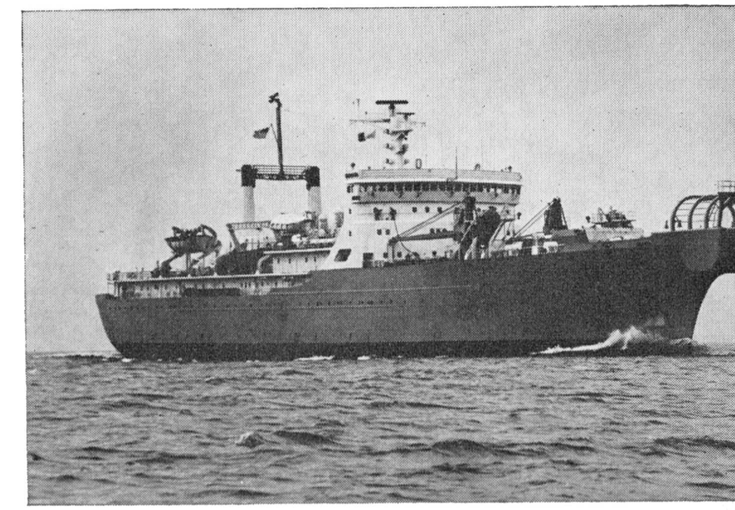
Just the other day these two facts, and others, were brought into sharp national focus when President Lyndon B. Johnson and Premier Hayato Ikeda conversed between Washington, D.C. and Tokyo—with the clarity of a crosstown call. The event, of course, was the inaugurating of the first telephone cable between the two conutries—a new 5,300 mile link from Hawaii to Japan via Midway, Wake and Guam. At Hawaii the cable joined existing lines to the U.S. mainland, Canada and Australia. Later this year additional cable between California and Hawaii and a hookup between Guam and the Philippines will be laid.

Memorable as the formal June 18 line-opening ceremonies were, the real drama of this communications achievement lies in the engineering feats project: The American Telephone and Telegraph Company, Kokusai Denshin Denwa Company, Ltd. (KDD) of Japan, the Hawaiian Telephone Company and RCA Communications, Inc.

Engineering Feats

These engineering developments, carried out over months and years in the laboratory and in the field, included producing an improved underseas cable, a highly-sophisticated repeater designed to last at least 20 years without attention, the designing and building of the most modern cable-laying ship in the world and the locating of a cable path through virtually uncharted ocean floor topography.

How each problem in the total project was solved is a complete story in itself . . . but most significant is



C.S. Long Lines, AT&T's 17,000-ton cable ship, proceeds at cable laying speeds up to eight knots.

that the results of the research necessary to overcome the obstacles is already leading to new products and services for the Telephone Industry outside the seemingly narrow scope of a submarine cable system.

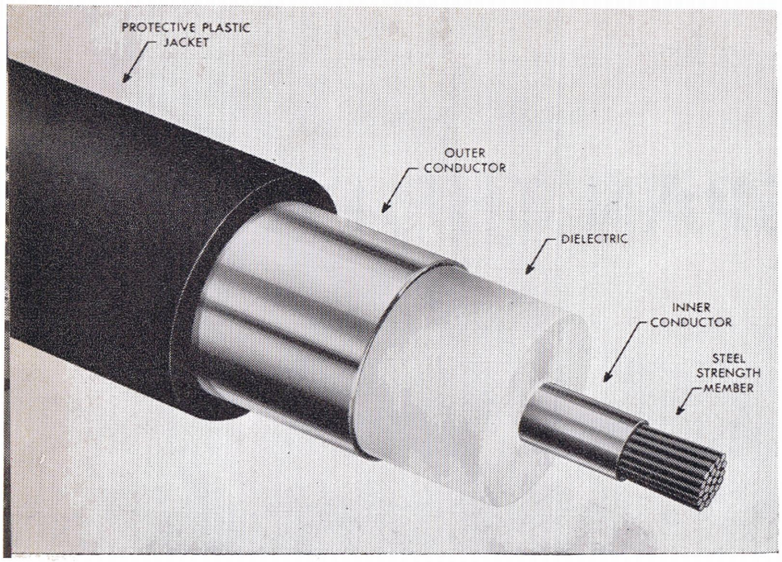
The New Cable System

The new SD system itself provides 128 3-kc spaced channels in both directions over a single cable — much improved over the SB system introduced in 1956 in the Atlantic which provided 48 3-kc channels and was itself a breakthrough advancement over earlier radio units.

Each channel can carry voice, data, telephonegraphs and other specialized commercial services. The cable does not have the frequency bandwidth required for television.

Exploratory work beginning in 1954 had already determined that a new system was necessary as part of a broad plant to improve transoceanic communications. And new equipment would be required to implement the plan. A new approach to cable and repeater design was required. The long, slender, flexible repeater which suited existing shipboard cable machinery had to be scrapped for a more conventional form to reduce parasitics and transit time so freeback amplifiers working in the megacycle range could be successfully designed.

The cable concept was changed and the strength was placed in the center conductor rather than on the outside to eliminate the tendency of the cable to untwist under tension. This made possible the laying of the 500 lb. repeaters in deep water. Such cable made possible a cable of reduced attenuation



Armorless cable used in deep-sea section of Hawaii-Japan system is 1¼" in diameter and can carry 128 simultaneous conversations.

with a very stable transmission characteristic without an increase in size or cost when compared with armored cable designs.

One decision led to another and resulted in new cable laying machinery and techniques which actually forced the building of a new cable laying ship.

Armorless Cable

The armorless cable has an inner core of steel wires around which is a tubular, inner conductor of copper. This is surrounded by a layer of high-density polethylene compound that insulates the inner conductor from the outer conductor, which is larger copper tube. A final layer of black plastic compound covers the whole. The overall diameter of the cable is 1¼"—approximately the same size as earlier telephone cable – and weighs 14 ounces per foot. Its breaking strength is 18,000 lbs.

The rigid repeater, the most sensitive part of the system, is spliced into the cable every 20 miles. A complex of 5000 parts sealed in a beryllium copper case, it is cylinder shaped three feet long and one foot in diameter. Within it the two directions of transmission are amplified in a common amplifier by use of directional filters. Parallel amplifiers, each containing three specially-created electron tubes, are used to provide protection against tube failure.

Located at Oahu, Midway, Wake, Guam and Ninomiya are the facilities housing electronic terminal and power requirement. Power for operating the repeaters is supplied over the inner conductor of the cable. A positive dc voltage is supplied to the cable at the A terminal between the inner conductor and ground and a negative potential at the B terminal. Current path is over the inner conductor, returning via sea ground.

The power supplies provide precise regulation of cable current to a value of 389 ma. Prime power is derived from a 48 volt battery. This is converted to 400-cycle power by solid-state inverters. The resulting voltage is stepped up and then rectified to produce the high voltage for the system.

Repeaters Boost Transmission

Cable transmission soss must be matched by the gain of 274 repeaters. Obviously, very small deviations in this match must be corrected before they accumulate or the system will be unuseable. A further restriction is placed on the signal level that can be tolerated at the input of each repeater to avoid damage to electron tubes.

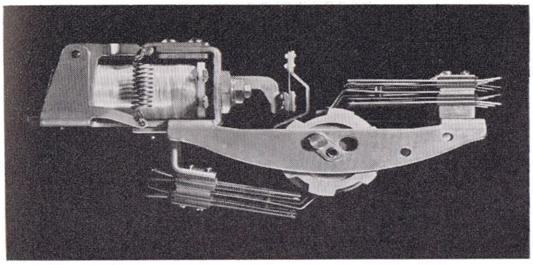
Basic equalization of the cable loss is accomplished by shaping the repeater gain to match the loss of the cable at a nominal sea-bottom temperature of 3°C and depth of 2000 fathoms. The shaping takes place in the input network, the output network, and the feedback circuit of the amplifier.

The lengths of manufactured sections of cable are trimmed to obtain the desired loss at the highest transmitted frequency. In this way it is possible to adjust, to a first approximation, for known departures from nominal sea-bottom.

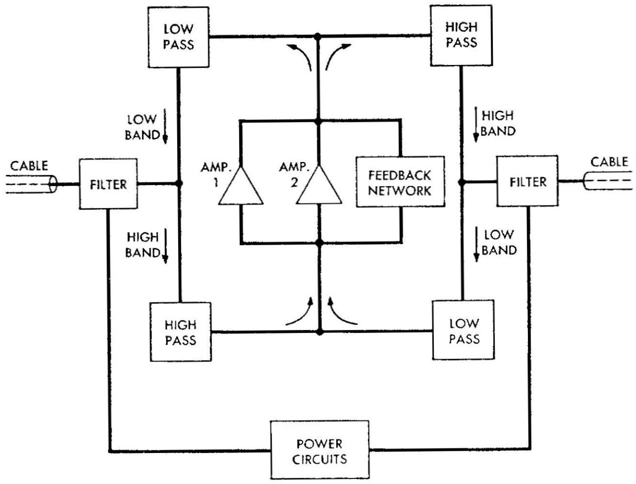
The accumulated factory cable deviations, plus those arising from uncertainties in ocean-bottom temperature and depth, temperature and pressure coefficients, and transmission effects introduced by the laying process, are equalized at 200 nautical mile intervals during the cable lay with the adjustable ocean-block equalizers mentioned earlier. These have an adjustable loss characteristic equivalent to about eight miles of cable.

The ocean-block equalizer also forms a convenient point for introducing a fixed equalizer to compensate

Equipment in the C.S. Long Lines' control center includes instruments for cable payout as well as complete shipboard communications system.



The new 216A selector (above) adjusts the ocean block equalizers which compensate for transmission deviations in the cable. It is one of 5,000 components in the rigid repeater, diagramed to the right.



The new 216A selector (above) adjusts the ocean block equalizers which compensate for transmission deviations in the cable. It is one of 5,000 components in the rigid repeater, diagramed to the right.

for accumulated repeater deviations. Without intermediate equalization of this type along the route, the requirements on the repeater characteristic would be so stringent that undue complexity in the amplifier circuitry would be required and manufacturing expense would be increased.

During laying, measurements are made at the end of the 200 nautical mile ocean-block being laid. As the cable reaches the bottom, its loss, which was high while on shipboard because of its relatively high temperature, begins to stabilize at nearly its ultimate value. Shortly before the equalizer goes overboard, It is adjusted for the desired block transmission as nearly as possible. After adjustment, the measuring equipment is connected to the output of the subsequent block and the process repeated until all the cable has been laid.

The adjustment of these equalizers is now being accomplished by a selector, mounted inside the equalizer housing. It is of special interest since with slight changes, a selector of similar type with the flexibility possible with various cam-contact pile-up combinations might be produced for other applications.

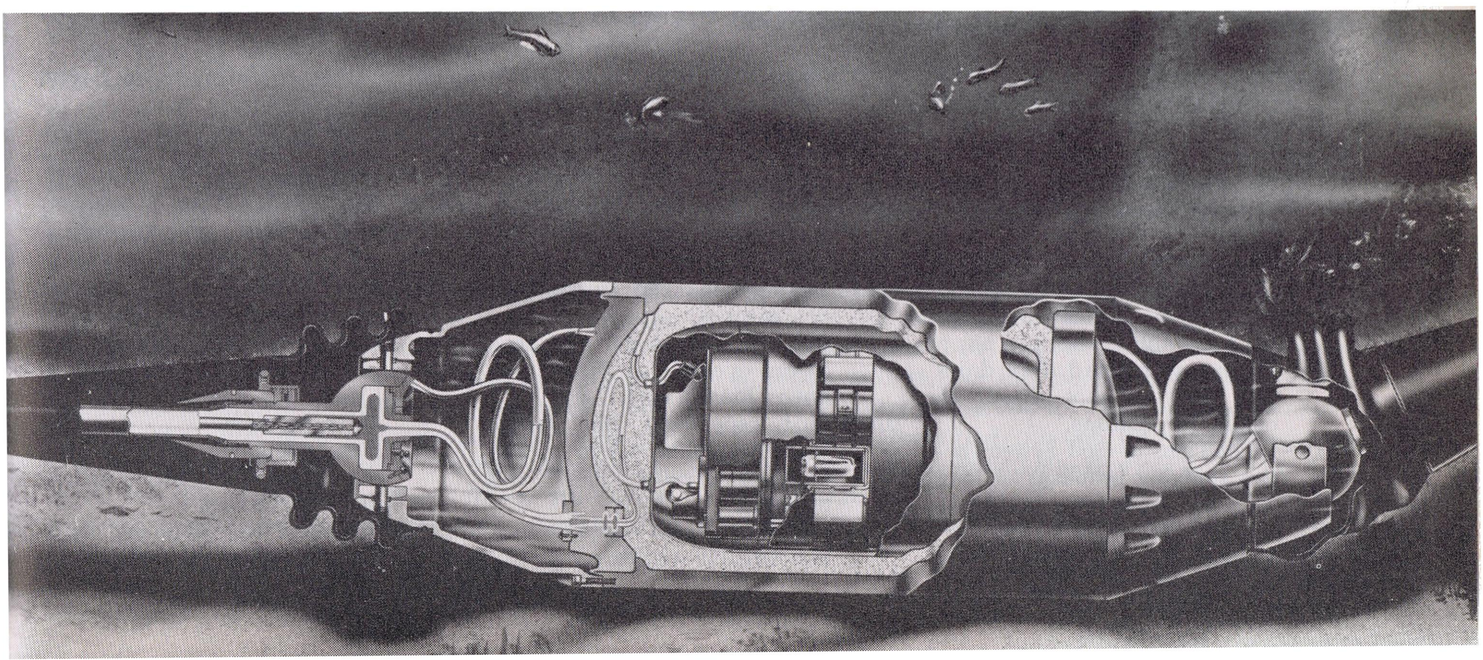
The 216A selector is designed to withstand a shock of 50g at a frequency of 35 cps. In addition, it must be capable of operating over a temperature range of 0 to 120°F.

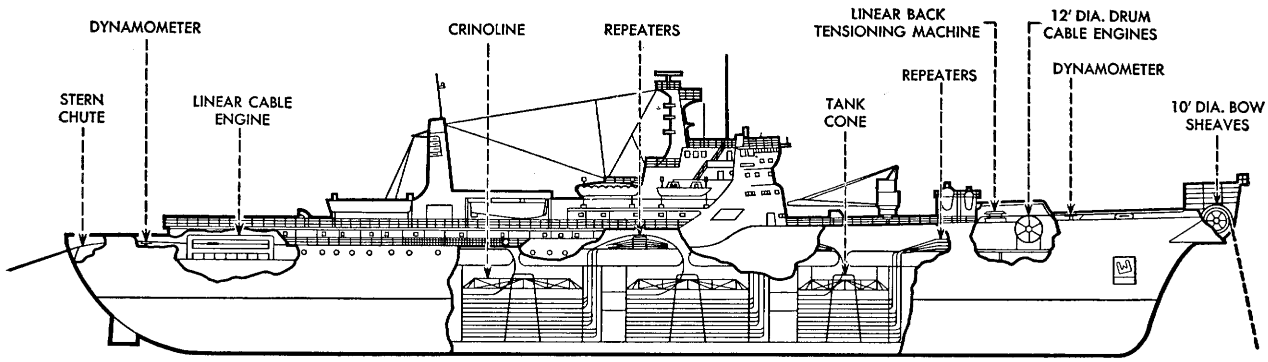
Of a design derived from the conventional rotary selectors used in central office applications the electromechanical pawl-and-ratchet stepping device. A 32 position ratchet wheel drives five cams and each cam operates a contact spring pile-up consisting of one make and one break contact combination. Each of the five sets of contacts controls a section of an equalizer network; the total equalization is determined by the number of sections made active according to the position of the selector rotor.

The cams are arranged to provide a switching sequence based on the Gray code that operates or releases only one of the five spring combinations in any one step. The over-all size of the selector is approximately two inches by three inches by seven inches.

Operation of the selector is similar to conventional rotary selectors in that the ratchet wheel and the cams are stepped on the release of the armature. When the magnet is energized, the armature is op-

Repeaters are spliced every 20 miles into the underseas cable. Each repeater takes about 63 weeks to manufactur and assemble by Western Electric Co., and undergoes a total of 1700 testing procedures.





The world's most modern cable ship is 511 feet long and can lay 2,000 nautical miles of cable without reloading or stopping. The air-conditioned vessel carries a crew of 90 and is powered by a steam-turbo electric propulsion system with twin screws.

erated causing tension in the coil driving spring. This tension makes the driving pawl move into engagement with the next ratchet tooth. When the magnet is de-energized, the ratchet wheel and cams are advanced by the tension in the driving spring, the armature returns to its released position, the driving pwal rests against the overthrow stop, and the retaining pawl falls into a ratchet wheel tooth holding the cam assembly in the stepped position.

The indirect drive used in the selector has the advantage of the rotor being locked in position after each step by the coil spring tension and the retaining pawl detent.

The shore terminal is the point at which signals are fed to the cable and received from the cable. A broadband signal which is the composite of 128 3-kc or equivalent channels is derived by conventional frequency division multiplex. In the transmitting path, this signal is shaped or predistorted to equalize the noise in all channels and then limited to prevent overloading of the undersea repeaters by excessive inputs which might be caused by trouble conditions. Further equalization following the limiting amplifier is used to adjust for various misalignments in the undersea system. These equalizers, both fixed and adjustable, allow signal levels to be optimized from the point of view of signal-to-noise performance while, at the same time, provide protection against overload of the submarine repeaters.

At the receiving terminal, equalization and amplification are provided to make the frequency response of the system flat from end to end. A signal restoring network is provided to complement the shaping introduced in the transmitting direction.

Once these and other design and manufacturing operations were completed, actual cable laying started from Hawaii in January 1964 under the direction of AT&T's long Lines Department. Five months later the job was completed, or just begun, depending on one's point of view. ■

Bibliography

R. D. Ehrbar and L. H. Morris, "SD Submarine Cable System," **Bell Laboratories Record,** February 1964.

R. D. Ehrbar, "Submarine Cable Laying System," **Bell Laboratories Record,** March 1964.

V. F. Bohman and R. W. McKenzie," Selector for Underwater Cable Equalizers," **Bell Laboratories Record,** April 1964.

V. L. Holdaway, W. Van Haste, E. J. Walsh, "New Electron Tubes for SD Submarine Cable Systems," **Bell Laboratories Record, July 1964.**

CABLE CHRONOLOGY

Important Events In The History of Transoceanic Telephone

1858–First Atlantic telegraph cable completed. Failed after 26 days.

1866–Second Atlantic telegraph cable opened, telegraph communications successfully established.

1876–Alexander Graham Bell invent-telephone. Hoped to attach speaking equipment to existing telegraph cables . . . not a whisper was heard. Bell dropped idea but not dream of talking to Europe.

1919–Technicians of Bell System began studying problems of long distance undersea telephone cables.

1921–Three non-repeatered telephone cables placed in service between Florida and Cuba.

1925–Planning well underway for a single circuit, repeaterless voice cable across North Atlantic.

1927–Inauguration of radiotelephone service with England minimized need for ocean cable.

1941–Testing begun on long-life repeater tubes.

1950–First two repeatered telephone cables opened for service between Florida and Cuba.

1956–First repeatered transatlantic telephone cable system opened between Newfoundland and Scotland.
Mainland-Alaska telephone cable placed in service.

1957–California-Hawaii cable system inaugurated.

1960–High-speed switching equipment, called TASI (for Time Assignment Speech Interpolation), doubles the number of calls on first and second transatlantic telephone cable.

1962–First single telephone cable opened for service between New Jersey and Bermuda. All previous systems used two cables – one for each direction of transmission.

1963–First telephone cable linking the U.S. directly with England placed in service.

1964–Hawaii-Japan telephone cable inaugurated.