COMMUNICATIONS

FOR NOVEMBER, 1937

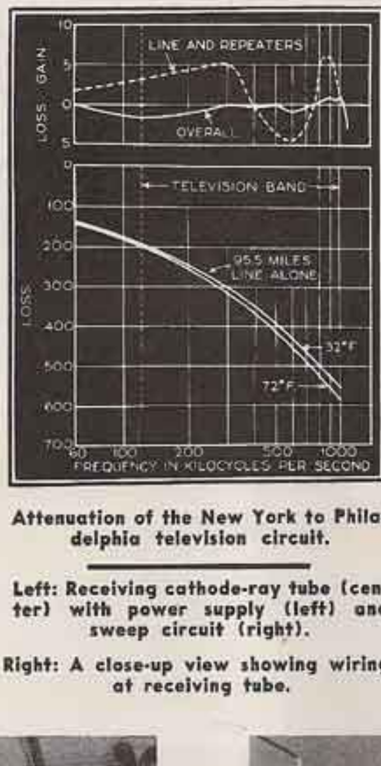
COAXIAL CABLE TELEVISION TRANSMISSION

ON NOVEMBER 10 there was an experimental demonstration of motion pictures transmitted over the coaxial cable between New York City and Philadelphia. In the Bell Telephone Laboratories in New York a sound-picture film was run through a transmitter and its two records—sound and scene—were converted into electric currents and transmitted to Philadelphia. There the picture was reproduced large enough for a group of ten people to see easily, while the accompanying sound came from a loudspeaker. The sound picture described, by voice and animated diagrams, the coaxial cable system and explained briefly the operation of the picture transmitter and receiver. Some films typical of the news-reel theatre were also transmitted.

The cable which extends between New York and Philadelphia contains two coaxial conductor units. Each unit is formed by a flexible copper tube and a single wire enclosed by the tube and held at its center by thin disks of hard rubber. Along the route are unattended installations of special amplifying equipment which receive their power over the inner wires of the two coaxials. The cable with its amplifiers and with its terminal equipment is an experimental installation for the development of broad-band transmission.

Each coaxial conductor unit with its associated one-way amplifiers is capable of transmitting simultaneously the currents of two hundred and forty different telephone transmitters. Using separate units for transmission in opposite directions, the system provides for two hundred and forty simultaneous conversations. The million-cycle range of each unit is utilized by carrier-current methods. In the present arrangement the transmitters are formed into twenty groups of twelve each. Each transmitter is limited to a frequency band of four kilocycles; and the bands from the twelve transmitters of each group are raised to successive positions between sixty and one hundred and eight kilocycles. Twenty complicated currents are thus obtained. These currents by another modulation are spaced in the range from sixty to one thousand and twenty kilocycles. This system of multi-channel telephony was recently tested over a looped back circuit equivalent to thirty-eight hundred miles; and transmission was satisfactory.

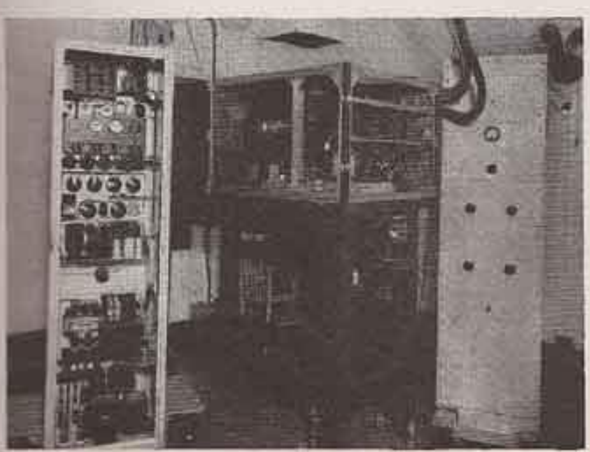
Another question remained: Can the system transmit satisfactorily a single message the frequency components of which occupy its entire range, that is, a current of the kind required in television programs? To study that possibility there were constructed in Bell Tele-

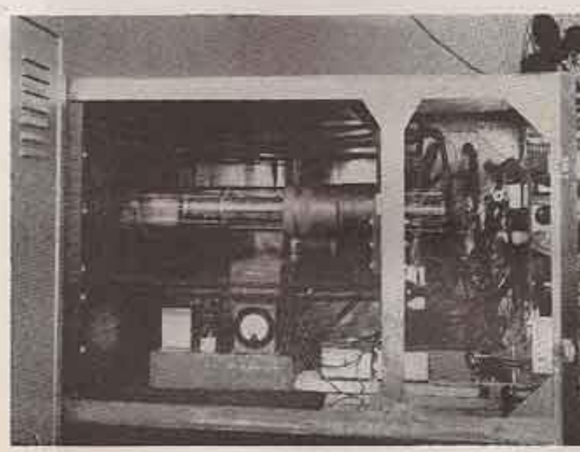


Attenuation of the New York to Philadelphia television circuit.

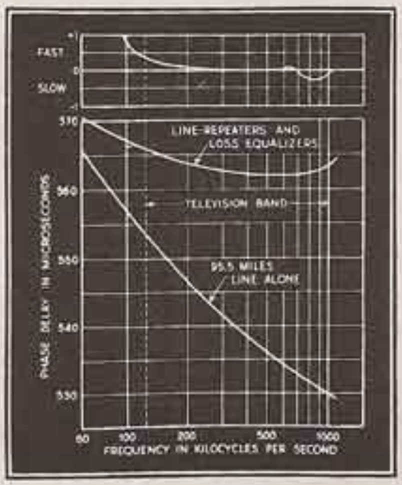
Left: Receiving cathode-ray tube (center) with power supply (left) and sweep circuit (right).

Right: A close-up view showing wiring at receiving tube.



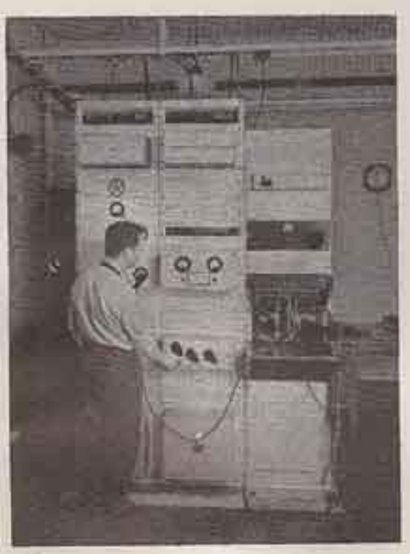


The scanning disc of the experimental motion-picture transmitter in Bell Telephone Laboratories.



Phase delay of New York—Philadelphia circuit.

The Philadelphia terminal of the coaxial cable showing carrier-current equipment.



phone Laboratories a transmitter to originate a signal of that range of frequencies and a suitable receiver, both of which utilize some of the present techniques of television.

For a signal which can be repeated over and over a motion picture is used; it moves uniformly past a picture gate where lenses in a large rotating disc sweep across it a light beam three-thousandths of an inch square. The light passing through the film enters an electron multiplier. The resulting current contains frequencies between 0 and 806 kilocycles. Since the coaxial cable is not designed to transmit frequencies below 60 kc, however, the original frequency band from 0 to 806 kc had to be raised by modulations to a higher position in the frequency spectrum.

This is accomplished through a double modulation. The first modulation employs a carrier of 2376 kc and results in a lower sideband from 1570 to 2376 kc and an upper sideband from 2376 to 3182. A filter then removes all of the upper sideband except a small section of its lower frequencies which is passed by the sloping corner of the filter characteristic. A second modulation with a carrier of 2520 results in an upper sideband from 4090 to 4896 kc and a lower sideband from 950 kc to 144 with the addition of a group of somewhat lower frequencies corresponding to the vestigial upper sideband passed by the first filter. A second filter easily removes the upper sideband, and is accurately designed to cut off the vestigial frequencies below 144 kc, so that the frequencies transmitted run from 144 to 950 kc.

In transmission over the cable the lowest frequencies fall behind the highest, taking about twenty millionths of a second longer in travel. In that time the cathode beam can move forty times its width. The effect is the same as if the finer the picture details the more out of synchronism were scanning disc and cathode beam. For the transmission, however, delay equalizers were developed to keep together all the components of the current to a precision corresponding to the motion of the beam for half its width. In the study of such problems of broad-band transmission this picture-transmitting apparatus is a valuable research tool, although the detail which it permits is only that corresponding to the million-cycle range of the amplifying and terminal equipment with which the cable is at present equipped. The frequency limits of transmission are not inherent in the cable itself, but in whatever terminal or intermediate amplifying equipment may be associated with it. Amplifiers designed for a still wider band are under development, which will permit more telephone channels and more detail in a transmitted scene.

According to a statement issued by Dr. Frank B. Jewett, president, Bell Telephone Laboratories, the demonstration was *not* the first transmission of television image currents for long distances over wires. The first such demonstration was made by the Bell System in 1927 when television image currents were transmitted from Washington to Bell Telephone Laboratories in New York and there reproduced. In that demonstration transmission was over specially conditioned telephone circuits of ordinary construction. The characteristics of such circuits were sufficiently good for the poor grade of television picture then attainable by the equipment for scanning and reproducing (50 lines, corresponding to a frequency bandwidth of approximately 22,500 cycles).

The demonstration was *not* one designed to show an improved television per se. In fact, the images (240 lines) were inferior in grain to those produced by the most modern television equipment (441 lines or better). This was not due to any limitation imposed by the scanning or reproducing apparatus but to the limitations imposed by the experimental terminal and repeater equipment now on the New York-Philadelphia cable. This equipment limits the top frequency of the transmitted current to approximately 1,000,000 cycles so that a 240-line picture is about the finest grain image that can be transmitted.

What the demonstration did show for the first time is the unique and economical utilization for television currents of the frequency band of a long coaxial cable. Instead of transmitting the television currents by the double-sideband method common to radio broadcasting, a method for single-sideband transmission was developed, thus utilizing to the fullest the frequency range for which the cable system was equipped. The double-sideband method has been used in Europe for transmission of 180-line images over coaxial cable. In that transmission each sideband occupied only about one-third of the transmission range of the cable system, amounting to the television use of the available frequency range at only 33 percent efficiency. In the method which has just been demonstrated at Philadelphia a single-sideband is obtained by double modulation and precise filtering; and this sideband is placed to avoid the first 100 kilocycles of the frequency range of the cable system where transmission is unsatisfactory and the various components cannot easily be amplified. There was also introduced compensation for the different velocities of transmission of different frequency components. The result is the delivery of an essentially perfect replica of the almost infinitely complex current produced at the sending end by the scanning equipment.

These are results never before obtained. As soon as the present experiments are completed the experimental 1,000,000-cycle repeaters on a portion of the cable are to be replaced by experimental 2,000,000-cycle repeaters, as the next orderly step in the development of equipment which will give a coaxial cable system capable of accommodating the maximum number of telephone channels which it is economical to handle on such a cable or the widest band of frequencies which the best television scanning and reproducing apparatus may require.

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CHOOSING CONNECTING LINK BETWEEN CRYSTAL GENERATOR AND AMPLIFIER

BEFORE the announcement of the first commercial crystal microphone in 1931, the radio or electronic engineer had little reason to concern himself with the transmission of electrical energy from relatively high-impedance sources, aside from two possible exceptions, the condenser microphone and the photo cell.

In any case their problems were not entirely similar, and as a great deal has been accomplished since then, it is the purpose of this article to present the existing information in its simplest form.

There has been and continues to be a certain degree of mysticism connected with the name crystal, while actually a piezo crystal is about the simplest form of device for converting electrical to mechanical energy or the reverse. For all practical purposes a crystal when used in a microphone, phonograph pickup, vibration pickup or a similar device, can be considered as a capacitance generator having negligible internal resistance, but high internal capacitive impedence. Since the device is a capacitance and has effectively no series resistance, a capacitance connected in parallel with it will only reduce the voltage output and no frequency distortion will occur since this reduction will be the same for all frequencies.

The expression for computing the voltage loss in db caused by a capacitance load across a crystal-generator device is as follows: db loss = 20 log $(1 + C_1 / C_2)$ when C_1 represents the capacitance in microfarads of the load and C_2 the capacitance in microfarads of the crystal device. Since the impedance of a shielded cable is effectively capacitive reactance, a cable can be considered as a capacitive load on the crystal device. Thus it is a simple matter to compute the loss that can be expected from a length of cable of known capacitance.

Another point that might be considered here is the proper input resistance to use in the amplifier. The input impedance of an amplifier is essentially resistive when connections are made directly to the grid, which is the usual case if crystal generators are being used, and since the internal impedance of crystal generators is capacitive the problem can be considered as similar to that of choosing a grid resistor for a condenser-resistance coupled amplifier. Neglecting tube capacitances, in the latter case, the low-frequency cut-off of the stage is determined by the relationship between the coupling condenser and the grid resistor. The higher the value of the grid resistor, the lower the frequency which the amplifier stage will pass for a given coupling condenser. The same is true of a crystal device, the crystal capacitance represents the coupling condenser. The tube measures the voltage drop in the grid resistor and this is vectorially at right angles to the reactance drop in the crystal generator. The total impedance of the crystal-generator circuit is therefore the vectorial sum of the reactance of the crystal and the grid resistance, i. e., the square root of the sum of the squares of these values. The useful voltage is therefore proportional to the resistance R divided by the impedance, and the loss in decibels for a resistance R is given by

$$\text{db los} = 20 \log \frac{\sqrt{R^2 + X^2}}{R}$$

When R = the grid resistance in ohms

$X = \text{crystal reactance} = \dfrac{159{,}000}{fC}$

C = capacitance of crystal in microfarads

f = frequency in cycles per second.

For example, let us assume we have a grid resistor with a resistance of 500,000 ohms and a crystal device with a capacitance of 0.005 microfarad and we wish to determine the voltage loss at 60

$$\text{Then } X_c = \frac{159{,}000}{60 \text{x} 0.005} = 530{,}000 \text{ ohms approx.}$$

$$\text{and } 20 \log \frac{\sqrt{500{,}000^2 + 530{,}000^2}}{500{,}000}$$

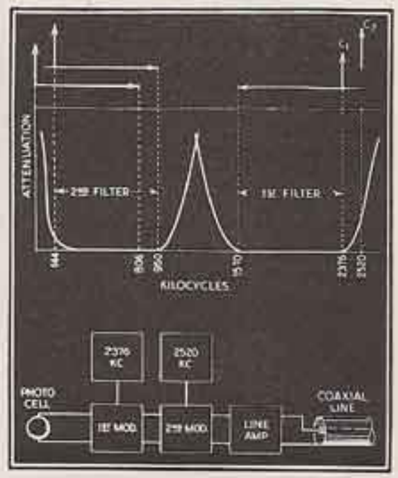
$= 20 \log 1.4572$

$= 3.26$ db loss at 60 cps.

It should be pointed out here that for a combined parallel capacitive and resistive load, the capacitance to be considered when determining the size of resistor to use is the sum of the crystal capacitance and cable or load capacitance.

C. K. GRAVLEY
in "Brush Strokes"

The apparatus which raises the video frequencies to a suitable value for transmission.



Depicting the action of the filters used to secure single-sideband transmission.

Sending motion pictures from the Bell Telephone Laboratories over the coaxial cable.