MICROWAVES for Relaying TV Programs

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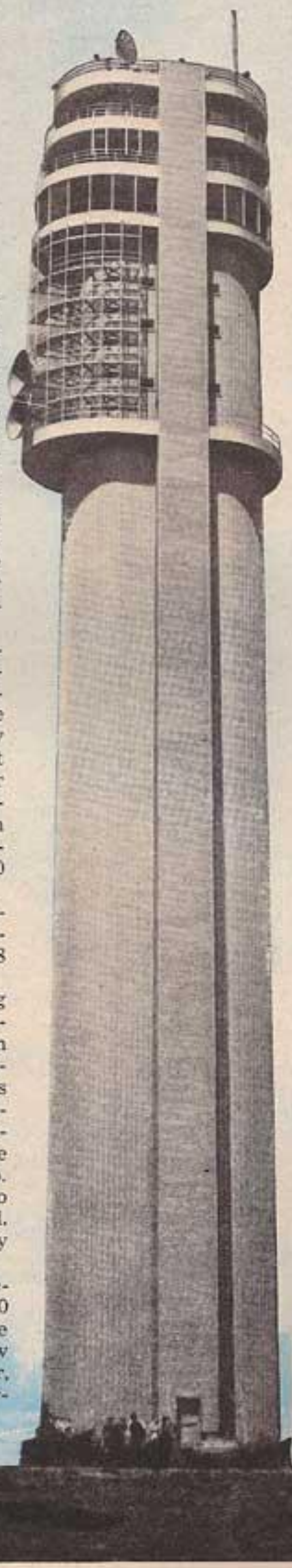
An up-to-date survey of the projected and existing relay facilities for network transmission of television.



THE writer has just completed a comprehensive survey of the microwave relay field as used for the transmission of television between various cities. It has been undertaken with the excellent cooperation of *Bell Telephone Laboratories, American Telephone and Telegraph Company, DeMornay Budd Incorporated, National Broadcasting Company, Columbia Broadcasting System, Allen B. DuMont Laboratories, Inc., General Electric Company,* and the *Western Union Telegraph Company.* All of these organizations are currently making use of microwaves for television relaying with or without connecting coaxial cables.

While the use of microwaves for television relaying is still in its infancy, it already is serving over a tenth of our population area. Its utilization to date despite the experimental nature and relatively early design of equipment, leaves no doubt in the mind of any television broadcaster as to its practicability and increasing utilization. Systems are already in operation in various parts of the ultra- and super-high-frequency spectrums between 900 and 7000 megacycles.

The principal systems which have actually been operating during the unprecedented growth of television during 1948 are:

A. The *Bell* system operated by the Long Lines Department of the *American Telephone and Telegraph Company* between New York and Boston with seven intermediate repeater-booster stations. It ties in at New York with coaxial cable to Washington, D.C. It has been sufficiently promising to justify immediate expansion of the system to Chicago as the next major step. For this purpose, 31 intermediate radio repeater-booster stations will be required. It will be completed in late 1949 or early 1950.

B. The *Philco* microwave relay system between New York and Philadelphia on 1370 and 1410 megacycles operated as part of the *NBC* television relay system between New York and Washington. Beyond Wyndmoor, Pa. it becomes the *RCA/NBC* system operating on approximately 7000 megacycles.

C. The *General Electric* system on approximately 2000 megacycles extending from New York City to Schenectady, N.Y. in one direction only.

D. The *Western Union Telegraph Company* microwave relay system now closing in the New York-Washington-Pittsburgh triangle and slated to next continue towards Chicago in its eventual nation-wide coverage.

E. The *Raytheon* system from Boston to New York undertaken experimentally and currently closed down pending further plans.

Fig. 2 shows the *Bell System's* coaxial cable and radio relay program as it exists at this time and as it is expected to become by 1950. While microwaves were retarded in civilian development by the high classification it held for purposes of national defense and the quest for suitable tubes to generate the necessary frequencies, coaxial cables had an opportunity to gain a foothold. At the present time, coaxial cables are being used to relay television programs wherever they are available. The *American Telephone and Telegraph Company* has set up a rate schedule which makes no distinction between microwave relays and coaxial cables. In fact, both may be used in the same system to bring the program to the distant radio receiver. The basic rate for leasing a single television or "video" channel is now $35 per month per airline mile for eight consecutive hours each day and $2 a month per airline mile for each additional consecutive hour. By the end of 1948, the *Bell System* expects to provide service for television program transmission so that about 40 million people will be residing in the areas which the facilities will be able to reach. Before the end of 1948, the mid-western network will be joined with the eastern network. Initially constructed in the experimental shops of the *Bell Telephone Laboratories,* the magnitude of the microwave relay program has made it necessary to now turn over the manufacture or production to the factories of the *West-*

Fig. 1. The microwave antenna tower of the Federal Telecommunications Labs at Nutley, N. J.

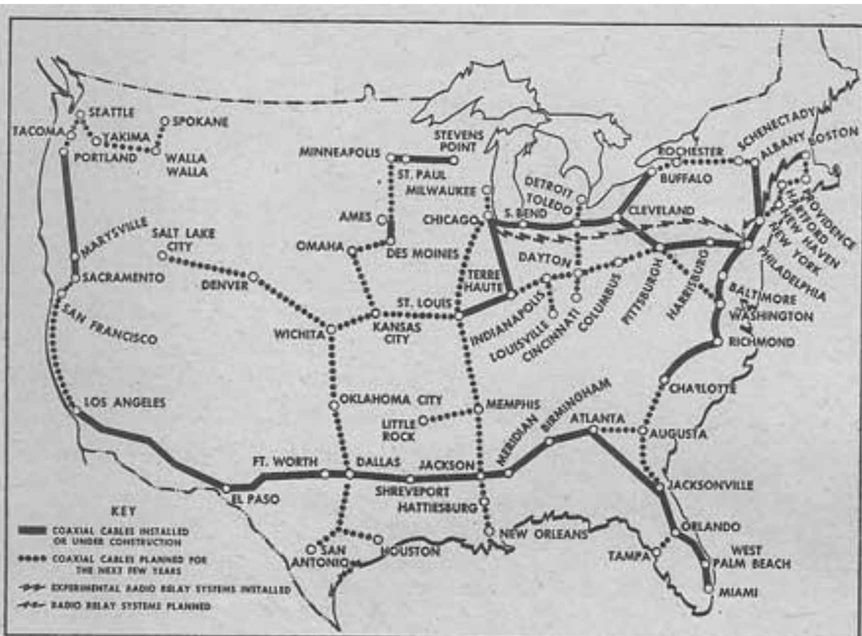


Fig. 2. The Bell System coaxial cable and radio relay routes.

ern Electric Company at Kearny, N.J. and Winston-Salem, North Carolina.

The use of coaxial cable in lieu of or in connection with a microwave relay system makes it necessary to reduce the channel-width to 2.7 megacycles. While coaxial cables are capable of handling much greater bandwidths, they can only do so by the use of more closely spaced booster stations in order to compensate for the excessive increase in attenuation with increase in bandwidth. The 2.7 megacycle channel-width represents the best compromise at present for coaxial cable transmission of television without excessive attenuation, or spacing the repeater-booster points closer than their present eight mile separations. Microwave systems, in practice, are being spaced about 30 miles apart and are not limited in bandwidth. Widths of 4½ to 6 megacycles are particularly convenient to provide. It will also not be too difficult a problem for microwaves to handle 20 megacycle bandwidth as color television goes into operation by such pioneering organizations as *Columbia Broadcasting System* and the *Radio Corporation of America*. At the present time, systems tying in with coaxial cable are engaging in narrower band television transmission than are systems which use microwave relay exclusively. The wider channel width is resulting in better transmission although the 2.7 megacycle channel is by no means unsatisfactory. The excellent engineering and design provisions have done much to offset the disadvantage of the narrower band. At the present time coaxial cable costs about a dollar a foot or about $5000 per mile material cost. One such cable comprises eight coaxial tubes, each capable of handling a program. When the right of way, cost of laying it underground, and the cost of frequent booster stations are included, the over-all cost of construction can reach a figure as high as $50,000 per mile as it runs rather than airline distance. It is not expected to equal that figure even for the most elaborate microwave installations. However, the cost of the *Bell* microwave relay system from New York to Boston may compare in cost with coaxial cable per channel because no expense was spared in the initial system. The individual buildings have cost approximately $60,000, access roads have been built at a cost of approximately $30,000 per station, duplicate spare bays have been provided for all equipment channels, elaborate emergency power facilities are included, along with alarm provisions for unattended operation and for complete utilities at each location. This cost can be greatly reduced per channel either by the use of less elaborate facilities or by having the same facilities accommodate additional channels of communication as the microwave relay program expands.

Fig. 3. Bell System's New York-Boston radio relay network.

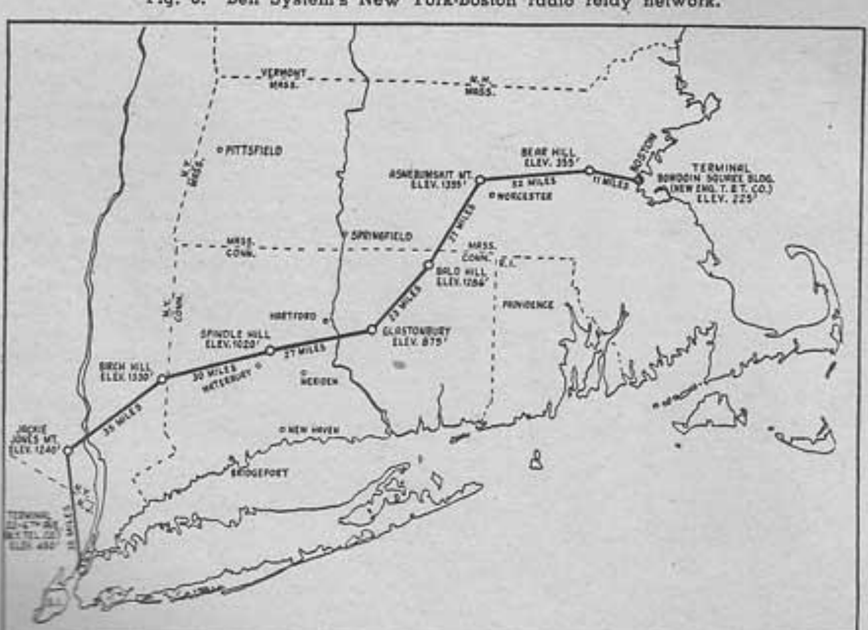


Fig. 9 shows the external and Fig. 8 the internal views of a typical radio relay station along the New York to Boston route. It is designed for unattended operation except for weekly inspection. On the ground floor are located the heating and air conditioning system, washroom, converter emergency power supply with bank of storage batteries and auxiliary emergency battery-driven generator. Behind a fireproof partition on the same floor, there is also provided a 20 kilowatt generator for emergency use. In the event outside power fails, there is quick emergency power of reduced amount followed by delayed emergency power of adequate amount. Within two seconds after outside power fails, the storage batteries automatically start a generator which can deliver power sufficient for the radio channel equipment only. In the meanwhile, the gas engine generator of 20 kilowatt capacity starts up and undergoes a warming-up period for stable operation requiring about eight minutes. At the end of that time, the larger generator takes over the load for the entire building in addition to the radio equipment. The battery generator then shuts off automatically. Emergency power of adequate amount can then be provided indefinitely subject only to the amount of fuel in the storage tank.

The equipment comprises four identical bays located on the second floor. These represent two channels actually operating (one in each direction) and two spare channels of identical type that can take over in the event any channel fails to function properly.

At the New York terminus two bays are provided. At the relay stations four such bays are necessary without the local monitoring and interconnection provisions to coaxial cables. The electrical load requirement is approximately two kilowatts per bay. The spare bays are also energized so that no time need be lost in changing over. Thus, the total equipment load is about 8 kilowatts at each relay station.

From the equipment, rigid waveguide transmission line extends upward to the four metal lens antenna horns mounted on what might be considered to be the equivalent of the fourth story. Special radio towers are not employed. The hilltop location itself furnishes the horizon while the rooftop is sufficiently elevated to clear trees and other local obstructions. Flexible waveguide connects from the vertical rigid waveguide to the horn antennas. The front of each horn is covered with fiberglas to prevent entry of moisture, insects, or superfluous material. Two of the horns face towards New York (one for transmission and one for reception operating 40 megacycles apart) while the other two face in the Boston direction adjacent relay station.

The possibility of any relay station responding to signals coming from more than the adjacent station alone is minimized by three provisions, namely:

1. The relay path is not a straight line from New York to Boston. It is deliberately run with some change in direction at each station as is evident from a study of Fig. 3.

2. The use of highly directive antennas having a beam width of only 1½ degrees. These provide both energy concentration and reduction in interference from undesired points.

3. Change in frequency at each repeater station either by alternating a pair of frequencies or by the use of additional frequencies as are available or required.

Fig. 4. Gasoline generator used to energize microwave field testing equipment in connection with preliminary work on the $500,000 microwave relay from Chicago to Milwaukee.

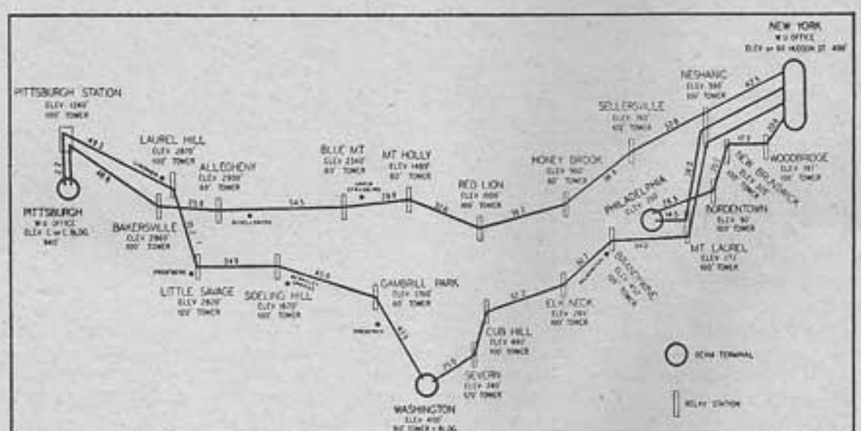


Fig. 5. Locations and tower elevations on the New York-Washington-Pittsburgh triangle.

Each relay station provides a new horizon of range as well as restoring the attenuated incoming signal to full power before being retransmitted. The

Fig. 6. Experimental microwave TV transmitter and antenna system at Hollywood for relaying signals to Mt. Wilson station.

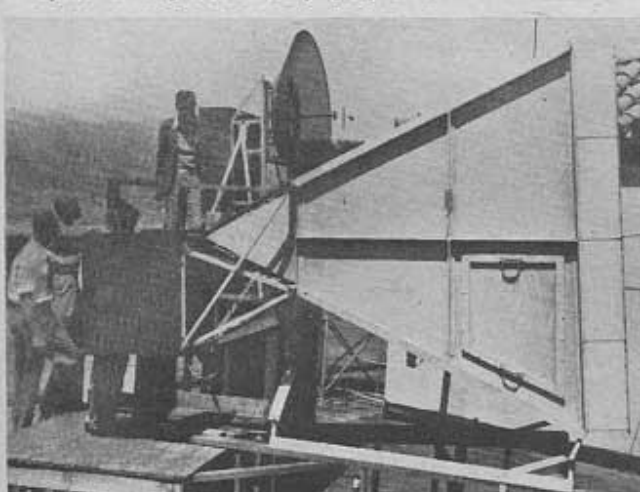


Fig. 7. Raytheon's experimental transmitting and receiving antennas and associated reflector systems at New York terminus.