TALKING OVER WAVES

Long distance headaches register on delay board, left. DAD means delay all day. Repeater bays shown below amplify signals. Bottom, how four calls travel over one line at once

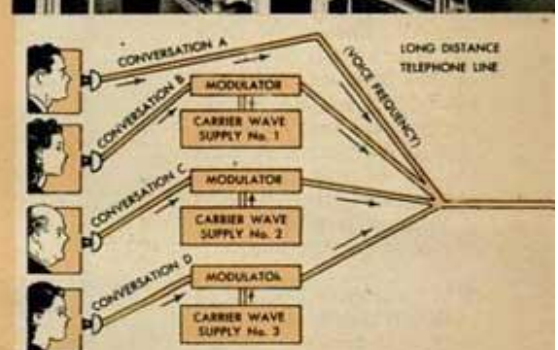
By S. G. Cooper

MODERN television stations have a range of not much more than 50 miles, but it won't be too long after the war before we have regional television networks and even a transcontinental chain. Strangely enough, we'll owe such networks to the telephone companies, which developed them incidentally while trying to make it possible to send several long distance conversations over the same pair of wires at the same time.

These networks, of course, will be wired and must not be confused with the radio networks which will use chains of satellite or relay transmitters to rebroadcast television and Frequency Modulation signals from a master station. Even now, the American Telephone and Telegraph Company is planning an experimental microwave radio relay between New York and Boston for long distance telephone calls and sound and television broadcasts.

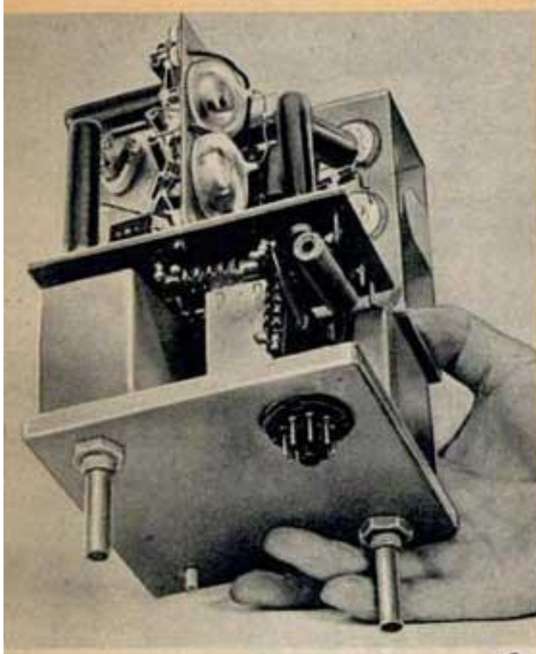
Stringing telephone lines across the country is an expensive job and ever since the first long distance lines were set up the telephone companies have been looking for ways to increase the number of usable channels without stringing more wires. Electric circuits have to be closed, so it takes two wires to complete each telephone circuit. This means that when you talk from coast to coast you are using 7,000 miles of copper wire.

The first answer to the problem was the "ghost" or "phantom" circuit. If two pairs of wires are strung between two cities, one conversation can go on over each pair. In addition, we can use each pair as one wire of a third circuit, allowing one more con-

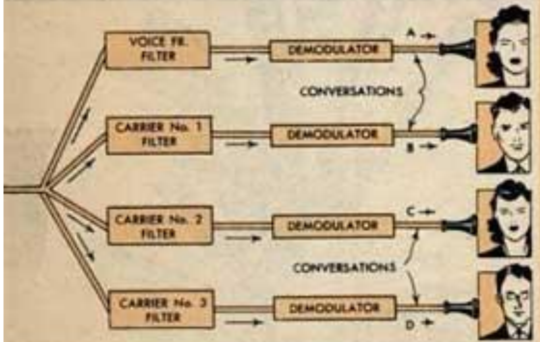


versation. This electrical trick gives a 50 percent increase in talking channels—and a corresponding cut in your long distance bill.

Phantom circuits, however, aren't enough. We have a much better way now, called a carrier system. The average human ear can pick up sound vibrations that go as high as 20,000 cycles per second, but ordinary speech can be understood well if it is limited to a band from 200 to 3,000 cycles. You wouldn't be satisfied if you heard a symphony orchestra held to this range, but it's quite good enough for talking and simplifies telephone design.



Pontoon method is used to lay submarine telephone cable across river, above. Coaxial cable amplifier, left, can handle frequency band up to 3,000,000 cycles wide



The carrier process makes this voice frequency system of waves ride piggy-back on one another. Radios work the same way, and the telephone carrier is really just wired radio.

In radio, the transmitter broadcasts a constant, high-frequency (carrier) wave; the voice current is fed into the transmitter and "modulates" or changes the carrier wave so that the result is a combination of the two. As the carrier is considerably higher in pitch, the combination modulated wave is reasonably close in frequency to it. At your receiving set the modulated wave is picked up, and a vacuum tube demodulates or strips off the carrier wave, leaving the voice current, which then is amplified and fed into the loudspeaker. Transmitters use different frequencies of carrier waves to avoid interference with each other.

When you speak into your telephone, the voice currents you set up travel to the central toll building, where they modulate a carrier wave, and the resulting signal goes over wires to a central office at its destination. There it is demodulated and the voice currents then pass through a local office to the phone which you are calling. To get more than one message on the wires at one time, different carrier frequencies are used, the jumbled mass traveling through the line as a whole. At the destination point it passes through electrical filters, each of which allows only a certain band of frequencies to get by. Thus the mass is broken up into its original number of modulated carrier waves. Each carrier wave then goes to its own demodulator for conversion into the corre-

Workmen grapple with one end of telephone cable laid under water

channels. This doesn't mean that six conversations can go on over the same pair of wires at once. It's a tricky job to balance a carrier circuit so the same wires can carry a two-way conversation with one carrier wave. Usually it isn't worth the trouble so half the channels are used for east-west communication and half for west-east. As well as the carrier conversations, one voice-frequency (200-3,000 cycle) conversation can be carried; this means that a four-wire "quad" (two pairs) can carry three complete carrier circuits on each pair, one voice-frequency circuit on each pair and one phantom voice-frequency circuit using both pairs. This adds up to a total of nine conversations taking place at the same time over the two pairs of wires.

Until recently, 30,000 cycles was about the highest frequency that could be used over wires. There is a big loss of power—telephone engineers call it attenuation—when you transmit signals either over cable or open wire, plus crosstalk difficulties, as nearby lines pick up a lot of interference at high frequencies. Two workable carrier systems for frequencies over 30,000 cycles were developed only a few years ago. The "K" carrier, for cables, gives 12 one-way channels in the band between 12,000 and 60,000 cycles. Two wire pairs are used, one for east-west and one for west-east conversations. The J-type carrier is for open wire strung on poles,

sponding voice current. If the voice current band is 3,000 cycles wide, then the carriers must be at least 3,000 cycles apart—preferably more, because the filters aren't perfect. The filters work something like your radio tuner, which often will bring in at the same time two stations whose frequencies are close together.

The biggest difference between radio and telephone carriers is in their frequency bands. The standard broadcast band ranges from 500,000 to 1,500,000 cycles, with short-wave bands of much higher frequencies. The ordinary phone carrier uses frequencies of 3,000 to 30,000 cycles, providing six

Splicing a coaxial cable, below left. At right, new cable carries six coaxials, many ordinary wire pairs

and has a frequency band of 36,000 to 140,000 cycles. The separation between carrier waves is 4,000 cycles, giving 24 one-way or 12 two-way channels on each pair of wires. With this system the old type of carrier can be used as well, making a total of 16 two-way channels on each pair. The J-type wave spacing gives a wider spread of voice frequencies, reproducing the human voice much better.

With these complicated electrical circuits, talking from Boston to San Francisco takes a lot of extra equipment. Without it, attenuation would make it impossible to carry a signal 3,500 miles, or probably even a tenth as far. Amplifiers—twin brothers to that in your radio, but called repeaters to make it harder—must be put into the circuit every so often to step up the strength of the current. A Boston-San Francisco circuit stops for amplification at New York, Harrisburg, Pittsburgh, Beaver Dam, Morrel Park, Davenport, Omaha, North Platte, Denver, Rawlins, Salt Lake City, Winnemucca and Sacramento. Power loss is terrific; to be heard clearly at San Francisco without repeaters, you would have to put in at Boston as much power as the sun delivers to the entire earth. The "K" cable carrier loss is so big that repeaters must be used every 16 miles.

Most repeater stations work automatically, with only an occasional visit from a service man. The weather isn't automatic, though, and temperature changes, sleet or high winds make the line resistance vary. This alters the strength of the signals coming through a repeater section and necessitates different amplification at each repeater. One carrier frequency is then used as a "pilot channel"; it carries no conversation, but just a steady signal. If the signal strength goes up or down, the repeater amplification is decreased or increased automatically to make up for it.

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Coaxial cable eventually will enable you to see scenes like that above by television, no matter where you live. The coaxial across the Delaware, third from left below, is dwarfed by regular cables

to 7,000,000 cycles, with repeaters at 3½-mile intervals. You can get away from high-frequency crosstalk, but any one who can tell the engineers how to get away from attenuation can name his own price. Newer type television probably will use a 1,000-mile screen instead of the present 525 and then the television channel on coaxial cable will have to carry even a wider frequency band, plus about 480 long distance circuits; yes, that's one wire pair.

There isn't much coaxial cable yet. The first line was installed between New York and Philadelphia and later extended to Washington. If the cable-laying program goes as scheduled, by the end of the year there will be coaxial routes from New York to Charlotte, Atlanta to Fort Worth, Terre Haute to St. Louis, Macon to Jacksonville and Stevens Point to Minneapolis. In time the network will reach from Boston to Atlanta and across the southern route to Los Angeles and San Francisco. Another main line will stretch from the eastern seaboard through Chicago to St. Louis and New Orleans. As well as creating a great many high quality long distance telephone channels, coaxial cable will make possible the first national television network.

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