Some Recent Developments in Long Distance Cables in the United States of America

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THE transmission history of long distance circuits, and particularly long distance cable circuits, has been one of continually improving standards. It has also been one of continual reduction of circuit costs. These have resulted largely from new developments to which have been added economies resulting from heavy growth and improved engineering.

To put it another way, present-day circuits are capable of transmitting a kilocycle of frequency range more cheaply than those of earlier days. As the cost per kilocycle of band width has been reduced, part of the cost reduction has naturally been used in furnishing telephone customers wider-band and generally better telephone circuits.

The accompanying chart is of interest in comparing the transmission frequency characteristics of what were considered good telephone circuits some time ago with what are considered good telephone circuits today and what are proposed for the future. At the left of the chart are shown various types of circuits which have been in use or proposed for New York-San Francisco service, a distance of a little over 3,000 miles. The original loaded transcontinental line, which remained in service from January 25, 1915, until April, 1920, when it was unloaded, gave a band width of only about 900 cycles.* The non-loaded circuit was better, giving about 1,800 cycles. The modern carrier telephone circuit is better still, giving about 2,700 cycles. The extra-light loaded type of cable circuit (H-44, which has been the standard loading system for long distance use for some time) will give a band even wider, extending up to at least 3,000 cycles.

At the right of the chart are shown typical characteristics for New York-Washington (about 225 miles) two-wire cable circuits with various loadings. The now obsolete heavy-loaded system, H-245, gave an effective range of 1,400 cycles, the medium-heavy loaded or H-174 gave 1,900 cycles while a new system which is being considered, called B-88, will give about 2,700 cycles. (At the present time H-174 two-

* The limiting frequencies are taken as those at which the loss is 10 db greater than the loss at 1,000 cycles.

wire circuits are restricted to shorter lengths, the curve being given simply for comparative purposes.)

In addition to this matter of frequency band width, there has been improvement in the 1,000-cycle efficiency of long distance circuits and also improvement with respect to noise and crosstalk. The original loaded transcontinental circuit, for example, gave, during good weather,

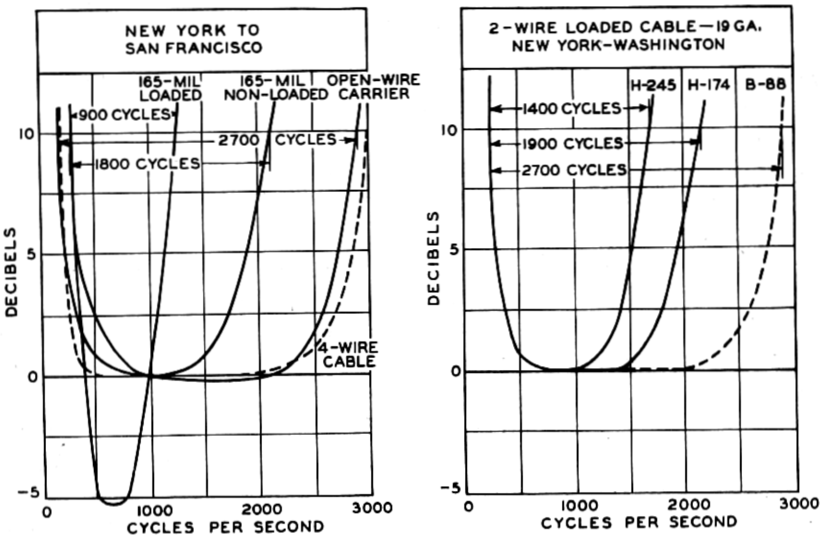

Fig. 1—Transmission-frequency characteristics of representative types of telephone circuits.

a 1,000-cycle transmission loss of about 20 db with a variation from this of at least 10 db during bad weather. The non-loaded circuit gave about 12 db during good weather with smaller variations. With both of these circuits the noise was somewhat in excess of 1,000 noise units. The carrier and cable systems compare very favorably with non-loaded voice-frequency circuits in the matter of transmission loss and are much quieter.

With the two-wire cable circuits shown, the H-245 circuit gave about 12 db loss at 1,000 cycles, the H-174 circuit 10 db loss and it is expected that the B-88 circuit will give about 9 db loss at 1,000 cycles. All of the cable circuits are strikingly quiet as compared with older type voice-frequency open-wire circuits. The cable circuits are also considerably better from the standpoint of crosstalk.

It is of interest to consider the effect on service of the change in standards of toll circuits as illustrated by the characteristics of the above circuits. One way of indicating this is by the repetitions occurring per unit time in commercial conversations. Assuming present commercial telephone instruments, typical terminal circuit and room noise conditions, following are some estimates on this basis:

Circuit	Repetitions per 100 Seconds
Loaded New York-San Francisco circuit	3
Non-loaded New York-San Francisco circuit	2
Carrier circuit, New York-San Francisco	1
H-44 cable circuit, New York-San Francisco	1
H-245 cable circuit, New York-Washington	1½
H-174 cable circuit, New York-Washington	1¼
B-88 cable circuit, New York-Washington	1

Short Cable Circuits

Consideration is now being given to giving up the H-172-63 two-wire circuits in favor of B-88-50 and H-88-50 two-wire circuits. H-172–63 four-wire circuits were given up some time ago. With the new two-wire circuits the important line constants and circuit characteristics are given in the following table.

H-88-50 loading is being considered particularly for those repeater sections less than about 40 miles in length while B-88-50 loading is being considered particularly for repeater sections whose lengths are greater than about 45 miles. For intermediate repeater section lengths the choice of loading will be dictated by various considerations applicable to the particular circuit layout involved.

With either of the above two-wire circuits, the following transmission results are anticipated:

> Circuits for terminal business up to about 250 miles in length to have a working net loss at 1,000 cycles of about 9 ± 2 db. The frequency range to extend from about 250 cycles to some frequency between 2,750 cycles and 3,000 cycles. Crosstalk between circuits to exceed 1,000 units in only about 1 per cent of the combinations. Noise measured at the receiving end of the circuit, including "babble," * less than 200 units.
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> Circuits for "via" business to be limited to lengths in the neighborhood of 100 miles so that adding a circuit link of this type to a built-up connection will not, in general, add more than about 2 or 3 db to the overall loss.

* Babble is the name given to the effect produced by a number of different circuits crosstalking into a particular circuit at a given time and producing an unintelligible murmur.

Long Cable Circuits

Present plans are to retain H-44-25 four-wire circuits for the intermediate and longer distances. This type of circuit is well known so it is unnecessary to go into its characteristics. With the idea of transmitting frequencies up to about 3,000 cycles with very little evidence of phase distortion, phase correctors are being considered for very long circuits of this type, say, circuits exceeding 1,000 miles in length.

Characteristic	*H*-88-50	*B*-88-50
Conductor gauge	No. 19 B. & S.	No. 19 B. & S.
Side circuit cable capacitance per mile	0.062 microfarad	0.062 microfarad
Phantom circuit cable capacitance per mile	0.1 microfarad	0.1 microfarad
Inductance of loading coils on side circuits	88 milhenries	88 milhenries
Inductance of loading coils on phantom circuits	50 milhenries	50 milhenries
Spacing of loading coils	6,000 feet	3,000 feet
Nominal cutoff frequency of side circuit	4,000 cycles	5,600 cycles
Nominal cutoff frequency of phantom circuit	4,200 cycles	5,900 cycles
Nominal velocity of propagation of side circuit	14,000 mi. per sec.	10,000 mi. per sec.
Nominal velocity of propagation of phantom circuit	15,000 mi. per sec.	10,600 mi. per sec.
Nominal impedance of side circuit	1,110 ohms	1,560 ohms
Nominal impedance of phantom circuit	670 ohms	940 ohms
1000-Cycle attenuation of side circuit at 55° F.	0.36 db per mile	0.28 db per mile
1000-Cycle attenuation of phantom circuit at 55° F.	0.30 db per mile	0.24 db per mile

Importance of High Velocity Circuits in Cable

Echo suppressors have proven quite effective in reducing the echo effects on long distance circuits. For very long distance cable circuits, however, echo is still a matter for concern, particularly with losses held down to figures such as those given in the paper by Mr. H. S. Osborne entitled "A General Switching Plan for Telephone Toll Service."

When cable circuit lengths become very great the actual delay suffered by the speech waves in traveling from end to end of the circuit becomes important quite apart from echo. We must look forward to the time when a subscriber in San Francisco will talk by cable across the United States to New York, then by cable and open wire to Newfoundland, by submarine cable to England and then by a long cable circuit, let us say, to Constantinople; in other words, a 10,000-mile circuit length. The highest velocity long distance cable circuits in use today will give, for conversations over such a circuit, about ½-second delay in going from one end to the other so that when one subscriber speaks the other's reply cannot possibly reach him in less time than one second. This is quite a long time interval. By utilizing speaking tube delay circuits, connections have been set up involving delays as great as this. Conversations are possible over circuits with such delays but the delay is a serious interference particularly when voice-operated devices are added which tend to lock out portions of the conversations. It is thus evidently important to seek higher velocity circuits.

Telephone Carrier in Cable

In seeking ways for obtaining high velocity circuits in cable in an economical manner, consideration has been given to the proposition of applying telephone carrier to long distance cables. For large groups of long distance circuits it appears likely that a carrier-frequency range can be advantageously used in cables, as wide or wider than the frequency range which has been exploited on open-wire lines. Experimental work on systems of this kind is actively under way at the present time.

The higher frequencies involved together with the accompanying attenuations and increased coupling between circuits introduce some very interesting and unusual noise and crosstalk problems, as well as problems of equalization and maintenance of transmission stability. Also, there are interesting economic problems of conductor size and type, loading versus no loading, repeater spacing, etc.

It is interesting to note that if non-loaded circuits are utilized, a velocity of transmission of about 100,000 miles per second would be obtained while with loaded circuits a velocity perhaps half as great. The non-loaded setup in particular would, therefore, provide circuits whose velocity, like open-wire circuits, would be great enough to leave no question of obtaining satisfactory conversations over any world-wide telephone network. It is too early, however, to predict just what the outcome of this development may be.