The Lenkurt Demodulator

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Choice of

OPEN WIRE FACILITIES

for Carrier Operation

The choice of a suitable type and size of wire is one of the important factors involved in engineering open-wire communication facilities. With multi-channel carrier operation, considerations of strength as well as transmission have become more important than ever. This has led to increasing use of copper-steel instead of copper wire in major segments of the communication industry.

This article presents a brief review of the relative characteristics and costs of the two types of wire and some of the considerations involved in the use of copper-steel wire.

Before the advent of carrier communication and for a number of years thereafter, copper wire was employed almost exclusively for open-wire toll circuits of any substantial length and importance. For economic reasons it was general practice to employ the smaller sizes of wire (mostly 104-mil diameter), particularly after the vacuum tube repeater came into general use.

With the advent and increasing use of carrier superposed on the basic open-wire facility, it became more apparent than ever that small-size copper wire lacked the mechanical strength necessary to better safeguard service, particularly in areas subject to sleet storms, abnormally high winds, or other heavy loading conditions. This led to the use of the larger sizes of copper wire (usually 128-mil diameter) on lines which were to be developed for maximum carrier usage, particularly where the frequencies above 30 kilocycles were involved.

Shortly after the start of World War II, copper-steel instead of larger sized copper wire was employed for two important projects, mainly because of the need for conserving copper as a war measure. One of these involved the construction of a new line, with

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104-mil 40 percent conductivity copper-steel wire arranged for maximum carrier usage, from Danby, California to Yakima, Washington—a distance of about 1,300 miles.

The other project was the Alaskan Highway communication system involving the construction of a similar type of line with 128-mil 30 percent conductivity copper-steel, between Edmonton, Alberta (Canada) and Fairbanks, Alaska—a distance of about 2,000 miles.

Both of these lines traverse very rugged terrain and are subject to severe weather conditions, particularly the Alaskan Highway line. In both instances, the information available indicates that copper-steel wire has given satisfactory performance.

Present Trends and Objectives

Since the end of World War II, outstanding progress has been made in the development of multi-channel open-wire carrier systems which are sufficiently flexible and economical for deriving both long-haul and short-haul communication channels. As a result, carrier exploitation of the basic open-wire facility to the maximum degree practicable has become a primary objective in many segments of the communication industry, not only for reasons of economy but also to provide better transmission performance. This has led to the concept of a substantially "all-carrier" open-wire plant.

As the industry works toward the all-carrier concept, service continuity of open-wire conductors becomes increasingly important. Consequently, the provision, among other things, of a maximum of wire strength consistent with economic considerations is desirable. Therefore, the advantages offered by the use of copper-steel wire are of considerable interest.

Relative Strength and Cost

Fig. 1 shows graphically the relative breaking strength of 104- and 128-mil copper and copper-steel wire in terms of 165-mil copper wire, and also their approximate recent material costs per pair-mile. For comparing strength, 165 copper is chosen because it is the largest size wire which has been used to any general extent in telephone plant and is in mechanical equilibrium with the standards used by a large segment of the industry in the mechanical design of the supporting structure; that is, poles, cross-arms, pins, guys, etc.

As indicated, 104 copper-steel has nearly the breaking strength of 165 copper wire; 128 copper-steel is substantially stronger. At the same time copper-steel wire is considerably cheaper. As a result fewer dollars buy more pounds of breaking strength. Under such circumstances there would appear to be little question as to the desirability of employing copper-steel instead of copper wire for new construction or major wire replacements. The practicability of doing this, however, is governed mainly by transmission considerations relating to voice frequency operation.

Relative Losses

Fig. 2 shows the approximate relative losses of copper and the two varieties of copper-steel (30 and 40 percent conductivity) wire. Data are given for 104-mil and 128-mil wire only, since these have become the wire sizes of principal interest in engineering toll open-wire plant. Smaller sizes are ordinarily undesirable for mechanical and transmission reasons; larger sizes are uneconomical for general use and, in the case of copper-steel, their strength is not in equilibrium with that of the ordinary types of line construction.

As indicated in Fig. 2, the losses of copper and 40 percent copper-steel wire do not differ substantially over the major portion of the carrier frequency range. Consequently, 40 percent copper-steel wire has proved to be suitable for carrier operation. Its somewhat greater loss below 30 kc has usually been offset by the availability of adequate carrier terminal or repeater gains, particularly when low slope basic equalizers are used.

The loss of 30 percent copper-steel is also sufficiently close to that of copper wire to permit its use at frequencies above 30 kc without incurring any substantial transmission or economic penalty. However, at 30 kc and lower frequencies, the greater loss of 30 percent copper-steel, in comparison with either copper or 40 percent copper-steel, is one of the factors which makes its use less desirable for toll applications notwithstanding its greater strength. For this reason, further consideration of 30 percent copper-steel wire is omitted in the discussion which follows.

Although copper-steel wire is generally suitable for carrier operation, its use for voice frequency facilities is subject to a number of transmission considerations.

Voice Frequency Message Circuits

Fig. 2 shows that the loss of copper-steel wire is much greater than that of copper in the voice frequency range. In addition, its impedance characteristics

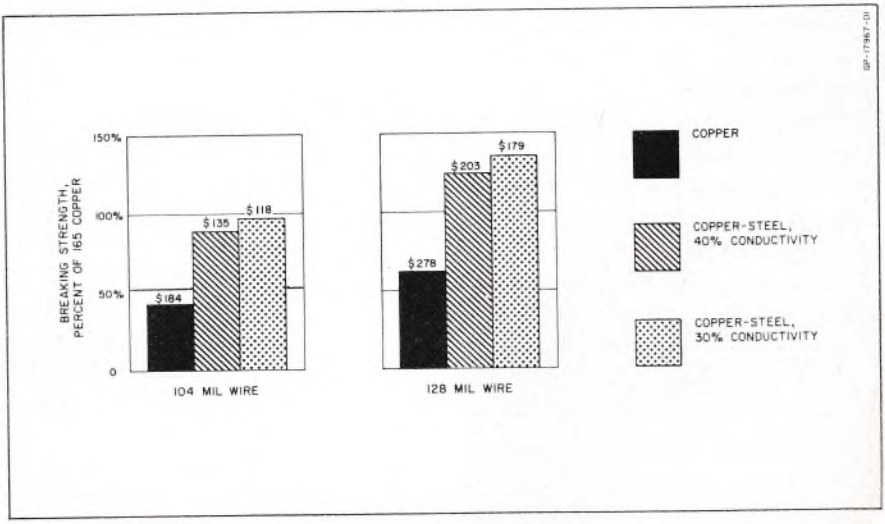

FIG. 1. A comparison of the relative breaking strength of copper and copper-steel wire. The approximate material cost per pair-mile is shown for each type of wire.

are known to be substantially different, particularly below 1 kc. These characteristics tend to make the use of copper-steel wire difficult where repeater layouts and entrance or intermediate cable loading systems based on copper wire are involved.

In situations of this kind and in the case of new open-wire routes, additional repeaters can be provided to offset the greater loss of copper-steel wire. This entails additional expense and the impedance matching problem remains a factor to be reckoned with. Considerations such as these, together with the poorer transmission performance of two-wire voice-repeatered circuits as compared to carrier facilities, make it desirable to dispense with voice repeatered message operation on open-wire pairs to be fully developed for multi-channel carrier use whenever it is practicable to do so. This has become a recognized practice with a number of telephone companies.

When voice frequency message circuits are not repeatered, they tend to be so short (frequently less than the minimum economic length for short-haul carrier) that satisfactory transmission can ordinarily be obtained with either type of wire.

Phantoming

Copper-steel wire is somewhat more susceptible to series resistance unbalances than copper wire. These unbalances tend to increase noise, but past experience does not indicate this to be a controlling factor in the use of copper-steel wire for carrier operation.

The tendency of unbalances to cause crosstalk between a phantom and either or both of its component sides limits the operation of phantoms derived from copper-steel wire to the shorter lengths. However, present practices tend to avoid phantoming new open-wire facilities—either copper or copper-steel—whenever it is practicable to do so. This results from their susceptibility to the effects of noise and crosstalk, their restrictive influence on carrier and program operation, and their tendency to add to the cost and complexity of composite set arrangements for dial signaling or d-c telegraph operation.

Program Transmission

The low frequency loss and the impedance characteristics of copper-steel wire also offer some difficulty in program transmission and equalization. These difficulties can usually be overcome by spacing program repeaters at shorter intervals—particularly when new routes are being established—and the use of special equalization methods. Detailed consideration of the particular situation involved may also suggest other more desirable alternatives.

Telephoto

The characteristics of copper-steel wire make it difficult, if not impracticable, to meet the impedance matching requirements involved in telephoto transmission in the voice frequency range. This difficulty could be overcome through the use of impedance matching equipment which could be designed and made available for that specific purpose. However, the economy of this procedure appears questionable since it is feasible to employ carrier channels for telephoto transmission.

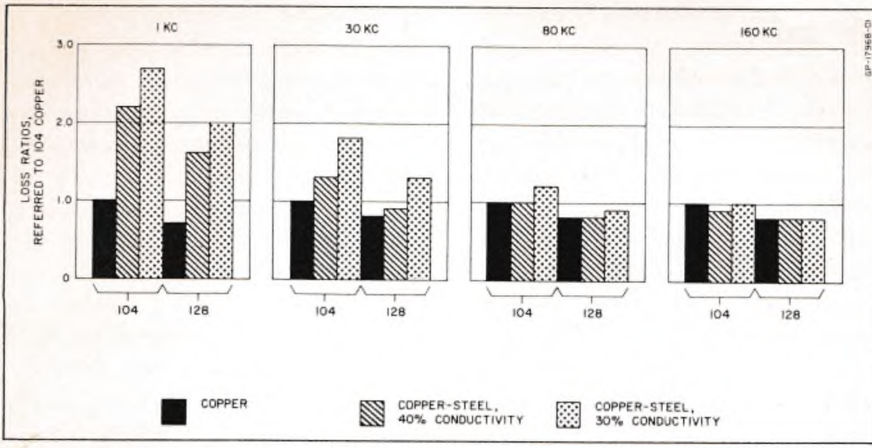

FIG. 2. Relative losses of copper and copper-steel wire for several frequencies.

As a matter of fact, telephoto is presently being operated on carrier channels to a substantial extent and the trend in that direction is increasing. Here again, present thinking emphasizes the use of carrier with a higher degree of mechanical dependability in the basic open-wire facility as compared to a sacrifice in such dependability in favor of voice frequency operation.

Long-Span Construction

The greater strength of copper-steel, as compared to copper wire, offers substantial economy through the use of long-span construction. Lines employing this type of construction can be developed for maximum carrier usage when the average pole spacing is not greater than about 300 feet. In such instances it is, of course, necessary to transpose on adjacent instead of alternate poles and in irregular terrain to employ floating transposition brackets somewhat more frequently than might be necessary with average pole spacings up to about 150 feet. These measures tend to increase transposition costs, but they do not preclude the use of long-span construction for carrier lines when that type of construction is otherwise practicable and results in worthwhile economy.

Conclusion

Because of the extent to which service can be interrupted by the failure of wire employed for multi-channel carrier operation, it is desirable to provide a maximum of strength consistent with economic considerations. Copper-steel wire can be employed successfully for such operation to obtain increased service security at lower material costs.

The use of copper-steel wire for several types of facilities operating in the voice frequency range is subject to some difficulties. These can be avoided through the alternative use of carrier with resulting worthwhile improvements in transmission and little, if any, substantial increase in overall costs. Consequently, voice frequency considerations should not, in general, prevent the use of copper-steel wire, particularly for new construction.

DISTORTION MEASUREMENT

in Wideband Radio

The transmission of carrier channels over wideband radio systems requires that the "intermodulation" of different frequencies be very slight. The measurement of this intermodulation is a very useful means of checking system performance and alignment.

Intermodulation results from nonlinear characteristics of amplifiers and other components in the signal path. When the input to an amplifier or other device is a pure tone, nonlinearity is evidenced by an output waveform which consists of the original tone plus its harmonics. In actual communication practice, the input signal is rarely a pure tone but is usually a complex wave made up of many individual frequencies. Nonlinearity causes the individual frequencies to amplitude-modulate each other. The output exhibits distortion in the form of a wave which contains not only the original fundamental frequencies and their harmonics but also certain new frequencies which are the sums and differences of the original fundamentals and of their harmonics. These new components are known as intermodulation products and this type of distortion is often called intermodulation distortion.

In narrowband radio applications, many of the intermodulation products fall outside the passband of the system and are of little concern. However, in a wideband system such as a multi-channel radio-carrier installation, the products generated in one voice channel may

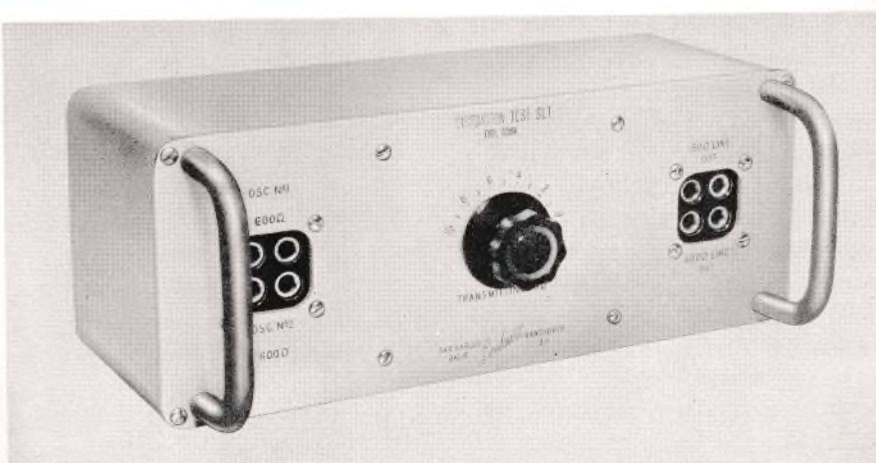

FIG. 1. Type 7281A Test Set used in testing Lenkurt Type 72 radio equipment. Transmitting pad controls level of reference signal.

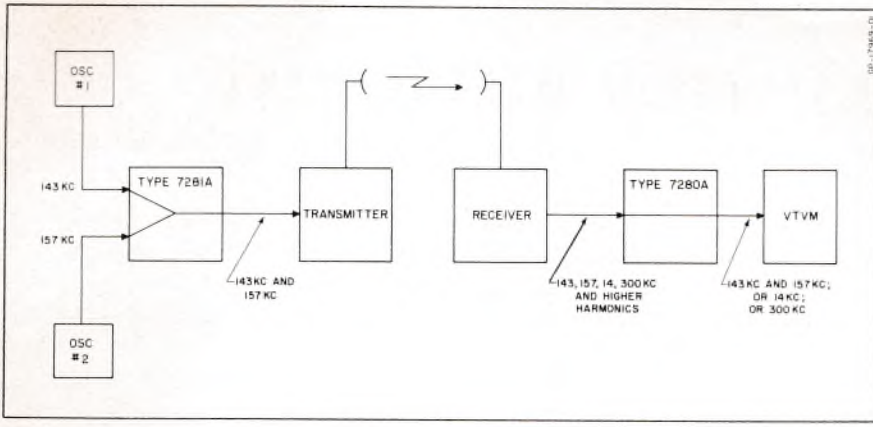

FIG. 2. Block diagram of typical test arrangement. Signal frequencies shown are those used in testing Lenkurt Type 72B radio equipment.

appear as unwanted crosstalk or babble in other channels.

The nonlinearity of a system can be determined either by measuring the harmonics which result from an input of a single tone or by measuring the intermodulation products which result from an input of more than one tone. The second method more closely duplicates actual operating conditions and provides a sensitive evaluation of distortion using simple test equipment and procedure.

To meet the need for performance testing of radio equipment in the field, Lenkurt has designed the Types 7280 and 7281 Distortion Test Sets. These units provide a compact, portable means of measuring distortion in Lenkurt Types 72A, 72B, 72C and other similar radio equipment. Both test sets are self-contained units requiring no external source of primary power. Each weighs only three pounds.

The 7281 Test Set is basically a junction device which combines the output signals from two external oscillators. A lowpass filter removes any unwanted harmonics which may be present in the outputs of the oscillators. The transfer characteristic of the 7281 Test Set being essentially linear (non-distorting), a combined waveform made up of the two original fundamental frequencies appears at the output. This combined waveform constitutes a reference signal which is transmitted over the system under test.

At the receiver output, the reference signal, along with its intermodulation products, is applied to the input of the Type 7280 Test Set. A switch on the front panel controls appropriate bandpass filters which individually select the reference signal, the fundamental sum frequency, or the fundamental difference frequency. Higher order products are slight in magnitude and their presence in the reference signal may be disregarded. At the output of the 7280 Test Set the individual levels of the three signals are read on a vacuum tube voltmeter. The db difference between the reference level and the sum and difference levels is a measure of the linearity of system performance.

Lenkurt Electric Co.
San Carlos, Calif.

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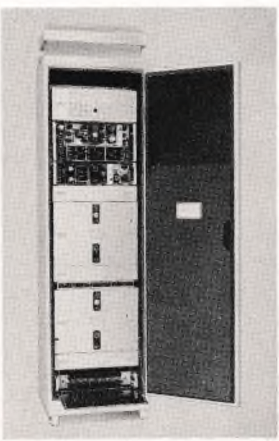

Weatherproof Housing

A new weatherproof rack cabinet, Type 565A, will permit carrier equipment to be installed in exposed locations. The cabinet can be pole-mounted, and provides about 66 inches of rack space. One of the many applications of this housing is for pole-mounting of up to three channels of open-wire carrier equipment, as illustrated here. Additional applications include the housing of repeaters, power supplies, line filters, and protection equipment.

Lenkurt ELECTRIC CO. SAN CARLOS, CALIF. VANCOUVER, B. C.

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Editor . . . . P. C. DeMuth

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