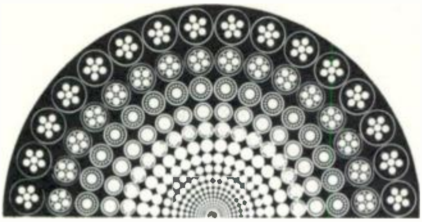
The Lenkurt DEMODULATOR

JUNE 1970

Cable Developments



Improvements in cable construction have eliminated some serious shortcomings and have increased overall performance.

Telephone service was still in its infancy when the transition from open-wire transmission to cables began. The motivating factors were quite simple: aerial congestion quickly became intolerable in the urban areas where service was concentrated and open-wire lines were highly susceptible to storm damage.

This transition has essentially taken place, although open-wire continues to set longevity records in some rural areas. Not only do the same factors that sparked the trend toward cable still apply, but a new one has been added – increasing public concern with aesthetic values. As yet, no method has been found to make aerial transmission lines (open-wire or cable) an asset to the environment.

One solution has been to bury the cable. Despite the industry's many years of experience with cable, both electrical and physical problems remain. There is room for improvement in traditional applications, and newer developments, such as PCM transmission, make new and greater demands on the cable plant.

Cable Matures

A multi-pair cable is far from an ideal transmission medium for either voice or carrier frequencies. Its shortcomings, such as the tendency to act as a lowpass filter, have been well documented (see the May 1970, Demodulator). Some of the solutions have also been presented: loading for voice frequencies, equalization and repeaters for carrier frequencies.

Equally important, however, is the physical construction of cable, because construction determines the electrical characteristics.

The basic characteristics of a transmission line largely depend on such factors as the size and material of the conductors, as well as their electrical proximity (physical spacing and the dielectric between them). Open-wire lines, of course, are insulated from each other by air space; so are most coaxial cables. However, multi-pair cables also must depend on other types of insulation.

The conductors in the first cables were wrapped with cotton string for insulation. Later, paper tape and pulp came into widespread use. These methods worked reasonably well as long as the insulation remained dry. Moisture can be kept out with a waterproof sheath. Lead has been widely used as a waterproof sheath, but it easily develops fatigue cracks which let in moisture. It is also heavy, difficult to handle, and expensive.

Another approach to keeping moisture out is to fill the cable sheath with dry air under pressure. Since this is quite expensive, it is often not economically justifiable, particularly for long cables that may contain only a few pairs.

A major advance was the development of Polyethylene Insulated Conductor (PIC) cables. This waterproof plastic insulation solved most of the problems caused by wet conductors, although PIC cables occasionally have defects allowing moisture to enter.

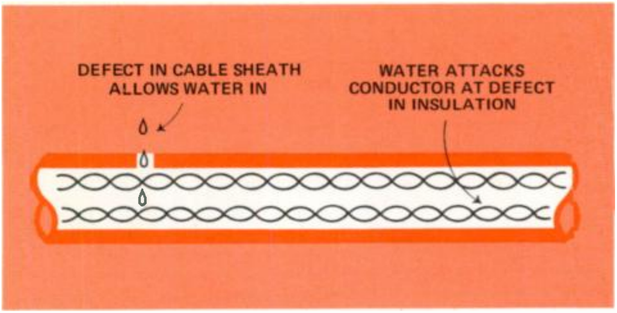


Figure 1. Cable acts as a pipe permitting water to enter the sheath at one point, then travel hundreds of feet before attacking the conductors.

Dry conductors alone are not enough for good transmission characteristics. Impure water has poor dielectric properties. And water inside a cable sheath, even though it does not reach the conductors, increases the capacitance between the conductors. In an extreme case where the cable is full of water, the transmission loss can increase about 55 percent at voice frequencies, and as much as 75 percent at carrier frequencies.

Polyethylene is also used to insulate and waterproof the sheathing. It usually forms an outer jacket over the metal sheathing, providing electrical shielding and mechanical support. This outer jacket is easily damaged while the cable is being buried. A lightning strike can also melt tiny holes in the jacket.

Another significant problem is the damage caused by gophers and other pests. In areas where such rodents are prevalent, cables are armored with a thick copper shield for protection.

Because about half the space inside a cable is filled with air, the sheath acts as a pipe. Thus any water that does penetrate can flow for hundreds of feet along the cable – even uphill where temperature variations create pressure differentials. This complicates repair, because some of the problems caused by moisture may not be close to the point where the water entered the cable (see Figure 1).

Keeping the Water Out

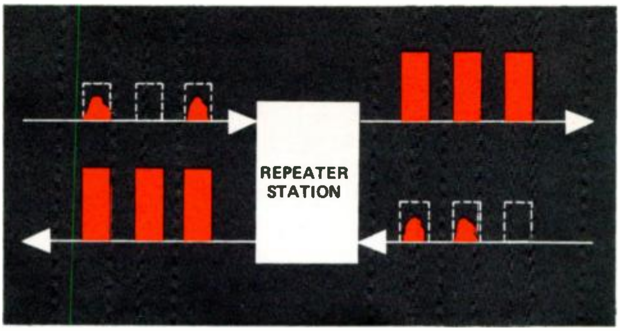
Many different methods have been tried to keep moisture out of cables. One early method was to fill the cable with kerosene. However, kerosene is lighter than water, causing it to float away when water enters.

Petroleum jelly, which has good electrical properties, has long been attractive as a water repellent in cables. The main problem with petroleum jelly is its low melting point. It is likely to melt and flow out of cables stored in the sun. At the same time, a stiff filling compound is not satisfactory because it does not allow the cable to flex easily.

Recently, petroleum jelly has been mixed with pulverized polyethylene to form an excellent filling compound. The addition of an antioxidizing agent allows the compound to retain its putty-like consistency for years.

This filling compound has necessitated some changes in the insulation surrounding the conductors. Since the compound can cause polyethylene to deteriorate, conductors are usually insulated with polypropylene. Furthermore, filling the cable increases the capacitance between conductors. Since the new cable must be interchangeable with older PIC cable, it has to meet mutual capacitance standards of 0.083 microfarads per mile. This is accomplished through a 40 percent increase in the thickness of the polypropylene

Figure 2. PCM systems use the same frequency band for both transmission directions; therefore, coupling from strong pulses leaving a repeater can seriously interfere with incoming pulses.



insulation on the conductors. The net result is a slightly larger cable.

While filled cable costs somewhat more than standard PIC cable, it offers a bonus in the form of reduced attenuation, particularly at carrier frequencies. Filling the cable permits the manufacturer to produce more uniform electrical characteristics. This can reduce attenuation as much as 15 percent compared with standard PIC cable (approximately 20 dB per mile at 772 kHz compared to about 23 dB per mile for 22-gauge PIC). This reduced attenuation is due to the filled cable's higher impedance and lower ac resistance caused by the thicker plastic insulation. This uncalculated bonus can result in fewer repeaters in a carrier system.

PCM Transmission on Cable

With few exceptions, cable carrier systems use four-wire transmission arrangements – two wires for each direction of transmission. In addition, "traditional" carrier systems that use frequency-division multiplexing normally use different frequency bands for the two directions of transmission. Otherwise, the low-level signal coming into the repeater could suffer severely from coupling by the high-level signal coming out of the repeater on an adjacent pair, as shown in Figure 2. This condition is defined as near-end crosstalk.

PCM systems, on the other hand, use the entire available frequency band for each direction of transmission. A primary cause of errors in PCM transmission is impulse noise produced by near-end crosstalk between PCM systems in the same cable sheath.

For this reason, it has been recommended that PCM systems, such as Lenkurt's 91A, use two separate cables dedicated to PCM transmission. Since one cable carries one direction, both cables can be filled to capacity. Another way to decrease the near-end coupling is to limit the cable fill to about 70 percent of capacity, when only one cable is used. Still another is to decrease repeater spacing to maintain the level difference between the two transmission directions.

A new development, called T-Screen* cable, shows substantial promise for PCM transmission. As shown in Figure 3, T-Screen cable incorporates a thin shield to divide the conductors into two separate compartments – effectively separating two cables in one sheath. The screen is made of polyester-insulated aluminum. The 4-mil screen is thick enough to provide the necessary electrical isolation, yet thin enough to flex with the cable without deforming.

The best results are obtained by combining the T-Screen with the

*Registered Trademark, Superior Continental Corporation

Figure 3. T-Screen cable uses an insulated shield to separate conductors effectively into two channels, thus reducing far-end crosstalk (FEXT), particularly for PCM transmission.

Courtesy of Superior Continental Corporation

filled-cable concept. The T-Screen decreases crosstalk (see Figure 4), and the cable filled with the petroleum jelly compound decreases attenuation and moisture problems. Reports from the field indicate that the use of this combination has permitted PCM repeater spacing to be "stretched" from 5,400 feet to 8,000 feet on 22-gauge cable. However, the savings obtained are partly offset by the increased cost of such cable (typically 5 to 20 percent, depending on the pair count).

Added economic advantages may be realized by using 24-gauge cable to produce 6,000-foot repeater spacing for PCM. Such spacing eliminates separate locations for carrier repeaters and voice-frequency loading coils, since standard H-88 loading coils are placed every 6,000 feet.

Coaxial Cable Developments

Like multi-pair cable, coaxial cable has been changing ever since its introduction to field use in the 1930's. Much of the change, however, has been in the application of coaxial cable, rather than in the basic design. The first commercial application in the United States carried 600 two-way voice channels on each pair of coax-

Courtesy of Superior Continental Corporation

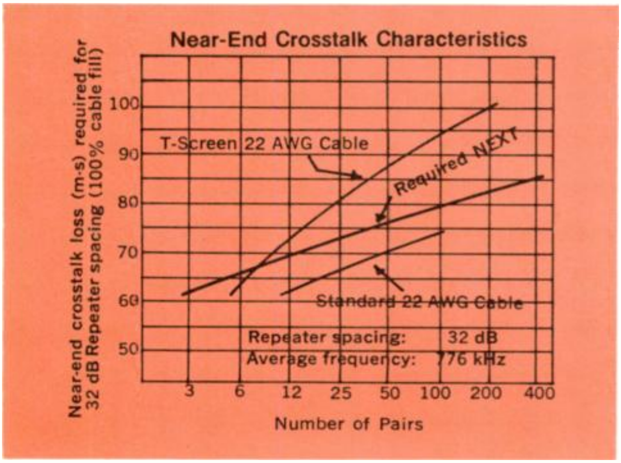


Figure 4. T-Screen cable substantially improves PCM crosstalk performance with 100 percent cable fill.

ials, using an L-1 carrier system. This version used a 0.27-inch cable and rubber discs to maintain separation between the conductors.

Soon, however, the standard size for high-density applications became 0.375 inches, as a compromise between cost and attenuation. Conductor separation was maintained with polyethylene discs to reduce the mutual capacitance. Increased circuit capacity was obtained by adding more coaxial "tubes" to a single cable, and by decreasing repeater spacing to permit more channels on each pair of coaxials.

Today, 20-tube cables are commonly used on heavy routes, and the L-4 carrier system transmits 3600 two-way voice channels on each pair of tubes.

While the electrical characteristics of an ideal coaxial cable are excellent, they are highly dependent on the physical relationship of the conductors. Since the outer conductor is hollow, and the inner conductor is normally held in place by thin discs about an inch apart, the tube is quite susceptible to crushing. Any such damage creates a discontinuity in the transmission path, resulting in deterioration of electrical characteristics.

Furthermore, the flexing involved in manufacturing, transporting, and laying the cable can cause fatigue in the outer conductor. For instance, flexing tests have shown that the conventional serrated-seam outer conductor develops "dimples" under each serration, even with normal handling.

Partly because of a desire to improve the mechanical and electrical characteristics of coaxial cable, and partly because of the specter of a world-wide copper shortage, Bell Telephone Laboratories set out to develop an improved coaxial cable. The result is CLOAX (corrugated-laminated coaxial) cable.

CLOAX uses a thin copper skin laminated to a tinned-steel sheet with a copolymer adhesive, as shown in Figure 5. The entire laminate is laterally corrugated to permit flexing and to add crush resistance.

Because this design uses a soldered seam and does not deform easily, it has more uniform electrical characteristics; therefore, its transmission loss is said to be lower than conventional serrated-seam coaxial, and it provides better interference protection. CLOAX uses one-third as much copper as the previous design; it has twice the crush resistance, and four times the bending life (see Figure 6).

One seeming dark spot in the CLOAX picture is that continuous exposure to high humidities tends to destroy the copolymer-to-copper bond. However, initial tests at Bell Laboratories indicate that once the cable is fabricated and buried, this bond is no longer critical. As long as the cable is not disturbed, the inside

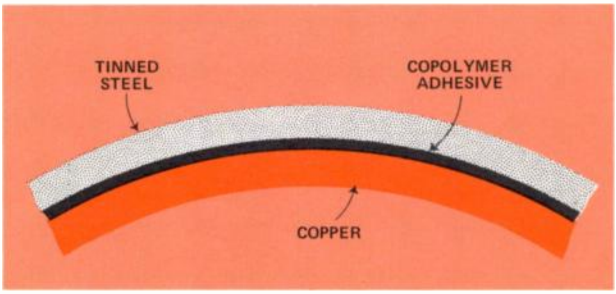


Figure 5. The CLOAX cable outer conductor and shell are a laminate of copper and steel – resulting in less copper, greater strength and improved electrical characteristics.

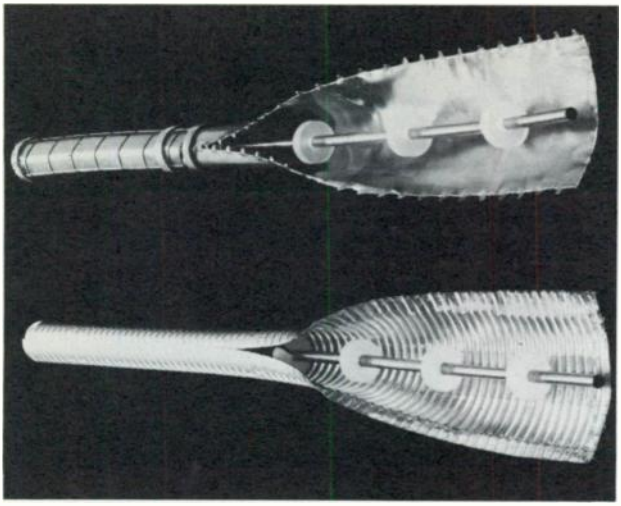


Figure 6. The serrated–seam coaxial cable, on the top, uses a double wrapping of helically wound steel tape to give it strength. The corrugated-laminated coaxial (CLOAX), on the bottom, has greater strength, without such wrapping.

diameter of the conductor does not change. Therefore, the electrical characteristics remain constant.

The Future of Cable

The more sophisticated forms of transmission – microwave radio, millimeter waveguides, lasers – tend to receive the publicity. They definitely occupy a position of importance in the communications industry, but they also have their shortcomings.

There is nothing particularly glamorous about cable, but it still has its place. With the number of telephone circuits doubling about every seven years, cable's future seems assured.

Some of the recent developments in cable technology have been mentioned here. There undoubtedly will be others in the future – improved electrical materials, better protection from interference, better mechanical characteristics. Major efforts, in all areas, will be directed toward improved economy. For many applications, there is presently no technique in sight to compete economically with cable.

Note from the Editor:

Book and Binder requests made on the Demodulator Survey Card could not be filled unless the proper money was enclosed. Please follow the instructions given on the last page of this issue and we will promptly fill your order.

We are making a concerted effort to fill all of your many requests – back issues, mailing list additions, etc. But, if by July 15 your requests have not been filled, *please* ask again. By that time we expect to be finished pulling staples and tallying the many thousands of survey cards we have received.

Thank you for your patience.

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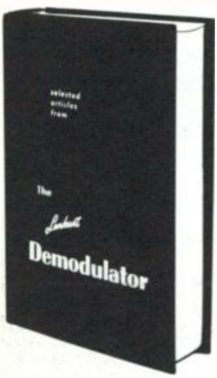
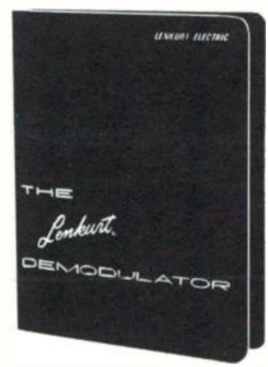


Reprint Book

A valuable collection of Demodulator articles published through December 1965. Over 700 pages of information on multiplex technology, microwave radio, digital data transmission, semiconductor devices, and general communications. $5.00 – postpaid; $7.50, foreign addresses, first class mail.



Binder

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