The Lenkurt Demodulator

NEWS FROM LENKURT ELECTRIC

VOL. 9 NO. 10 OCTOBER, 1960

The Difficult Problem of Exchange Trunk Carrier

In most fields of endeavor, progress or improvement is measured in terms of increasing values and larger numbers. Aircraft fly faster, missiles soar farther; radio transmitters increase in power and antennas become ever larger.

One group of engineers, at least, is working hard to reverse this trend toward larger numbers. Their project is to produce a carrier system for transmitting messages shorter *distances than any other carrier system has been designed for. The problem is greater than it sounds.*

Carrier was invented to save money. The first telephone circuits were simple loops, joined at a common office. As the telephone came into greater use, local offices were connected together by special circuits called *trunks*, and which were not associated with any particular customer's telephone. The main difference between loops and trunks is that loops are always associated with a specific customer (or small group of customers), while a trunk serves any or all the customers, in turn.

The first telephone and telegraph messages were transmitted over metallic wires, each wire or pair of wires carrying one message circuit or channel. It wasn't long before ways were discovered for obtaining additional channels on the same wire by so-called phantom and simplex arrangements. However, only a very limited number of additional channels could be obtained in this way. More circuits required additional wires, and these became quite expensive as distances increased.

The problem was relieved by the development of carrier systems which permitted many different message channels to be transmitted over a single pair of wires. Because carrier equipment may be quite complex, it was economical only on long circuits, where the cost of additional wire or cable exceeded the cost of the carrier equipment. In addition to providing more channels over existing paths, carrier was found to provide a superior transmission quality.

Carrier Economics

For very long transmissions, many repeaters are required, and these have the characteristic of amplifying distortion and exaggerating small variations in level, as well as amplifying the message. Thus, the longer the system the greater the care required in regulating levels and reducing distortion. For this reason, carrier equipment designed for toll or "long haul" service tends to be quite elaborate and relatively costly.

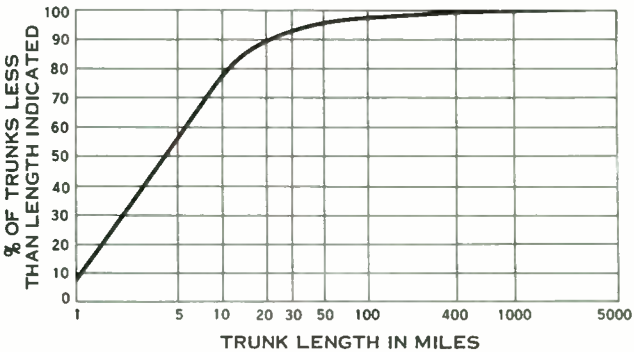
For shorter distances, the same complex terminal equipment may be too expensive. Furthermore, shorter systems don't need all the features found in a long system. Regulation need not be so complex, and somewhat more noise contributed by the carrier equipment can be tolerated. This allows some cost reduction and permits the system to be competitive with wire or cable over shorter spans than possible with toll carrier equipment.

Even if carrier equipment is stripped of some of its refinements for short-haul use, there is a limit as to how far this can be extended. Under no circumstances can the quality or reliability of the equipment be reduced. Components and mechanical construction must be no less dependable than in the finest toll system. Thus, the cost of carrier systems cannot be reduced in direct proportion to their length. There is always a certain minimum cost for terminal equipment, no matter how short the system may be. By contrast, the cost of wire or cable circuits is almost directly proportional to their length; a two-mile cable circuit costs almost exactly half as much as a four-mile circuit.

As recently as 1957, the Chief Engineer of the American Telephone and Telegraph Company stated that it was difficult to "prove in" carrier systems at distances below about 15 miles, although he expected that the rising cost of outside plant and the ingenuity of carrier system designers would eventually reduce this distance.

There is considerable incentive for reducing the economic prove-in distance below 15 miles. As shown in Figure 1, 85% of all trunk circuits in the Bell system are less than 15 miles long. In the independent telephone companies and the General Telephone System, 94% of all trunks are less than 15 miles long! New concentrations of business and commerce in large cities, and the

Figure 1. Only 15% of Bell System trunks exceed 15 miles, even with long toll circuits included. About 94% of all other trunks in U.S. are shorter than 15 miles.



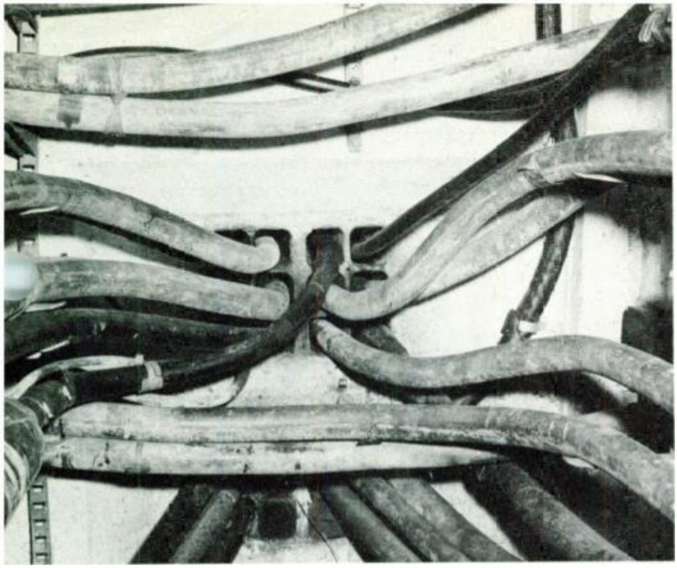


Figure 2. Typical manhole in metropolitan area. When all cable ducts become filled, additional circuits may be obtained by adding new conduit, replacing old cable with finer gauge, or by using carrier.

continued shift of the population from the city to suburban areas is expected to maintain—or even increase—the preponderance of shorter trunk circuits.

Better Transmission

Aside from considerations of cost, carrier offers many transmission advantages over voice-frequency circuits. On spans which are too short to require repeaters, loss will vary with circuit length and the gauge of cable or wire that is used. As a result, there may be considerable level variation between circuits. This is particularly undesirable if these circuits interconnect with toll offices. Although voice-frequency repeaters provide a means of controlling transmission levels, this may be their only justification on short trunks. Not only does carrier provide this same control over loss, permitting transmission level to be independent of the length or nature of the circuit, but it also provides many additional high-quality circuits at low cost.

A special advantage of modern exchange carrier is its flexibility in expanding plant to meet new demand. As cable circuits become fully utilized, carrier systems can be added one by one to meet demand. This provides a means for orderly expansion even in areas where demand is much greater than expected. The cost of expansion can be spread out over a long period of time, since channelizing equipment may be purchased only when needed. By contrast, cable expansion requires the entire expenditure to be made at one time.

Since growth of facilities is largely controlled by available capital, comparative costs usually determine the method used for obtaining additional circuits. An exception may occur in large cities where telephone cable and other utilities must be buried underground in conduits. As demand for service has increased, conduits may have been filled to capacity. When this occurs, streets may have to be opened, and new conduit added. Some cities sharply restrict how often this may be done, and other measures must be found. Often, large-gauge cable is replaced with smaller-gauge cable, thus increasing the number of circuits available in the limited space. While this affords a temporary solution, it cannot be continued indefinitely because the smaller cable degrades transmission. Eventually, more conduit and cable must be installed, or additional circuits must be obtained by using carrier. Under these circumstances, even toll carrier may provide a *relatively* economical solution. It is not an optimum solution, however, since the refinements usually built into toll carrier may not be removable, yet they require space, power, and increased investment.

More typical is the situation in suburban areas and between small towns. Aerial cable is almost universally used for trunks between exchanges and switching offices. Unlike underground cable which must be installed in conduit, there is little problem in adding circuits as demand grows, particularly with the newer, light-weight cables. Even though the cost of cable and voice-frequency repeaters varies in almost exact proportion to the distance, some sort of trunk terminating equipment is required at each end of the cable circuits, and this cost is independent of trunk length. Carrier systems are usually competitive only when they can provide the additional channels at a cost lower than the cost of new cable and its accessory equipment, other factors being equal.

Economic Design

Since cost considerations dominate the use of exchange carrier, the design engineer must find some way of resolving the conflict between cost and keeping the carrier equipment fully adequate. Several approaches to solving this problem are open.

One is to eliminate the need for additional expenditure in central office equipment. Following this approach, well-designed exchange trunk carrier systems eliminate the need for additional trunk circuit repeaters which extract signaling and supervisory information from the two-wire transmission path. This function should always be incorporated into exchange trunk carrier equipment.

Another approach for resolving the conflict requires new techniques, ad-

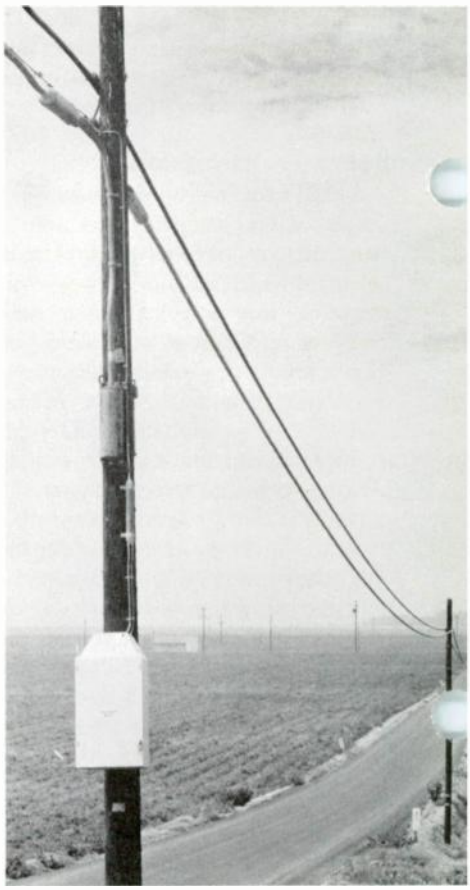


Figure 3. Many exchange trunks use aerial cable. Here, 81A carrier repeaters share pole with older loading coil pots. Most short-haul carrier systems are designed for 6000-foot ("H") spacing of repeaters, same as most voice-frequency loading.

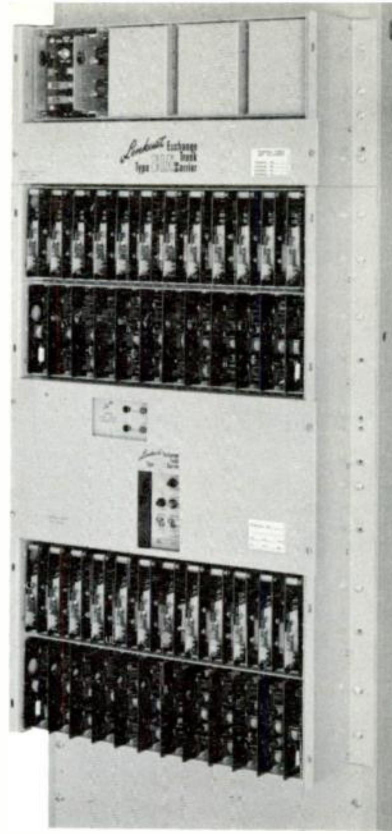


Figure 4. Improved mechanical design concept and complete transistorization permits unusual space economy in the 81A system. Single 11½ foot rack holds 96 channels, complete with carrier supply, power supply, and all trunk signaling.

vances in the state of the art. Since the end of World War II, there have been an abundance of these. The invention and development of the transistor and its related family of semiconductors is one of the most significant. The new carrier system designs now appearing avoid the use of electron tubes, and by so doing achieve reliability of a sort rarely available with electron tubes.

New methods of assembly and mechanical construction have appeared which are particularly suitable for transistors, and which not only decrease costs, but actually improve reliability and serviceability of equipment (See DEMODULATOR, *June*, 1960). Such state-of-the-art improvements, however, are not restricted to short-haul carrier, but improve all carrier systems.

Specialized Design

Another approach, and one that is particularly appropriate for short-haul carrier, is that of *specialization*. Under this concept, quality is not compromised, but every design decision is based on achieving the desired performance under the special conditions for which the system is intended. Instead of seeking versatility and broad capabilities, the designer concentrates on doing the limited task particularly well — and economically.

Many engineering factors can be varied to achieve savings without losing quality. The type of modulation used is one such factor. Three types of modulation are used almost exclusively in frequency-division carrier: (1) single-sideband, suppressed-carrier, (2) double-sideband, suppressed-carrier, and (3) double-sideband, transmitted-carrier. Toll carrier almost invariably uses single-sideband, suppressed-carrier modulation in order to carry as many channels as possible in the available bandwidth. When the carrier is suppressed, common amplifiers can accommodate more channels before overloading and increased non-linear distortion become likely. This is of dubious advantage in short-haul systems because these systems don't need to transmit very many channels over one facility. A carrier channel unit must be more complex and costly if the carrier is suppressed, and this is more of a handicap

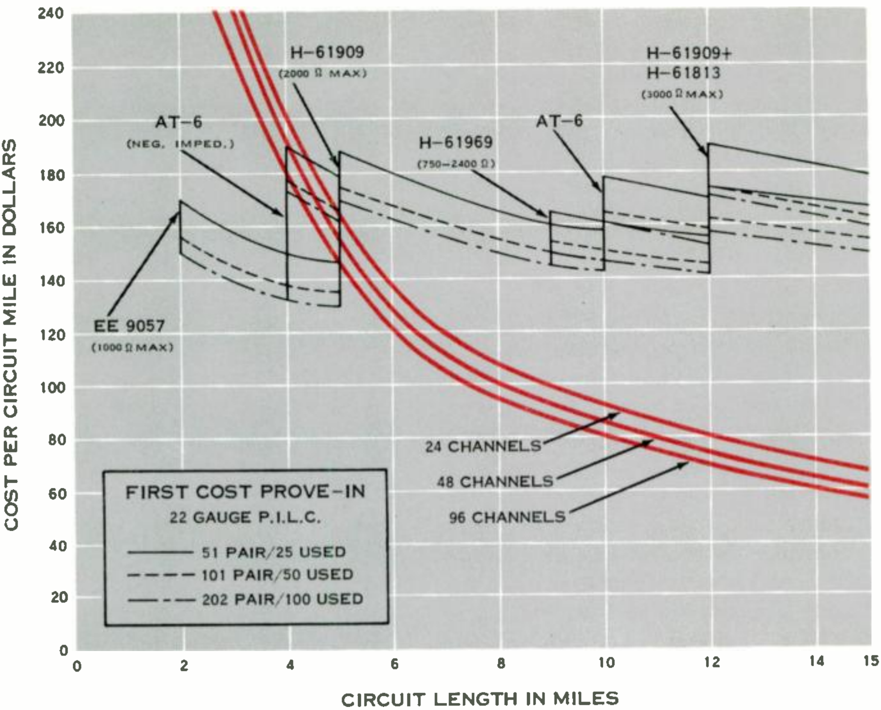


Figure 5. Economic prove-in curves for 81A Exchange Trunk Carrier System as compared with several commonly used types of cable. Cable costs show total installation and material, based on average value of 125% of material, and include negative impedance repeaters or trunk repeaters suitable for distance indicated. Carrier costs include all equipment, suitable repeaters, and installation based on 140% of equipment cost.

to a short-haul system than to a toll system.

An additional difficulty which affects cost and complexity, is that when the carrier is suppressed at the transmitting end, it must be re-inserted at the receiving end. This requires very close control of carrier frequencies at both ends. In the case of single-sideband, all carrier frequencies should be within a few cycles per second of each other. The problem is much greater for double - sideband, suppressed - carrier. The transmitting carrier (which is suppressed) and the carrier which is re-inserted at the receiver must be locked in phase as well as frequency. Should these get out of synchronism by as much as 90° (¼ cycle), severe distortion results.

Although there are various ways of coping with these problems, the solutions require a more complex system, one which may be more difficult to maintain. Because of the additional complexity, there are more chances of failure, since more parts and more functions are required to do the same job.

Both single-sideband, suppressed-carrier, and such modulation methods as phase or frequency modulation are useful in *extending* or lengthening systems, but are less practical for short-haul systems, because their advantage in overcoming noise or interference is less needed. Again, the additional complexity adds unnecessary cost, both in the initial investment and in future maintenance. In general, the simplest design that will provide the desired performance is to be preferred.

Another engineering factor that can be manipulated in designing carrier systems is the distribution of functions between common equipment and channel equipment. If the system is to have more than just a few channels, it is more economical to reduce the channelizing equipment and add to the common equipment. The traditional argument against this is that the operation of *all* channels depends on the reliability of the common equipment. However, in very short-haul applications, it seems preferable to perform as many functions as possible with common equipment in order to reduce complexity and costs of channel units. Failure of the common equipment is of relatively less consequence on short trunks than it would be on long-distance trunks where more costly transmission mileage would be tied up and a much greater percentage of the total communications network involved.

Of course, as much care as possible must be taken in designing common equipment, in order to eliminate as many chances of failure as possible. For instance, active devices, such as electron tubes, are more likely to fail than such passive devices as diodes, capacitors, and the like. Thus, common equipment (or any equipment) will tend to be more reliable if it accomplishes its duties with passive devices rather than active devices. The allocation of duties between common equipment and restricted equipment such as channel units, and between active components and passive components, requires some of the most sophisticated and knowledgeable engineering design to be found in carrier communications.

Conclusions

The art of specialization of equipment design is really a form of refinement. The resulting equipment achieves great efficiency in its assigned task, but at the cost of reducing the variety of tasks for which it is suited. In this respect, it may be likened to the relationship between a general-purpose carving knife and a surgeon's scalpel. Although the scalpel will never replace the carving knife, it is much to be preferred for its special task!

The recent appearance of modern short-haul carrier systems, such as the Lenkurt Type 81A, which proves-in against aerial cable at distances less than five miles (see Figure 5), is a step forward in improving transmission quality and providing a tool with which telephone companies can provide better service at lower cost. •

Bibliography

1. H. R. Huntley, "Where We Are and Where We Are Going in Telephone Transmission," *Communication and Electronics;* March, 1957.
2. A. B. Clark, "Some Recent Developments in Long Distance Cables in the United States of America," *Bell System Technical Journal,* Vol. 9, No. 3; July, 1930.
3. L. B. Bogan and K. E. Young, "Simplified Transmission Engineering in Exchange Cable Plant Design," *Communication and Electronics;* November, 1954.
4. H. R. Huntley, "Transmission Design of Intertoll Telephone Trunks," *Bell System Technical Journal,* Vol. 32, No. 5; September, 1953.

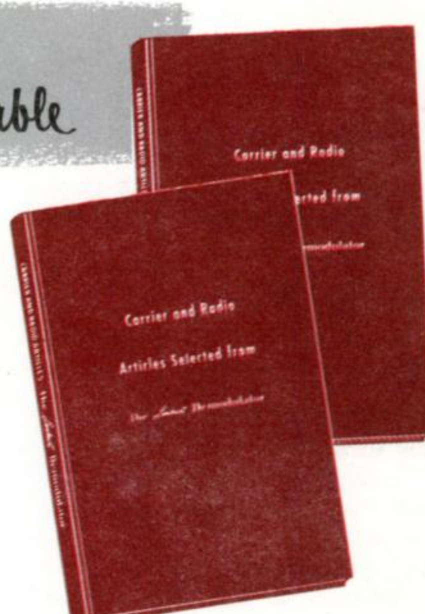
Lenkurt Electric Co.
San Carlos, Calif.

Bulk Rate
U.S. Postage
Paid
San Carlos, Calif.
Permit No. 37

MR. J. J. O'BRIEN
6606 FIFTH ST.
RIO LINDA, CALIF.
159-1159

Form 3547
Requested

Reprint Book Again Available



The 32 most-requested articles from the first seven years of *The Lenkurt Demodulator* have been compiled into book form.

The attractive, cloth-bound book is titled CARRIER AND RADIO ARTICLES SELECTED FROM THE LENKURT DEMODULATOR, and costs $2.50, postpaid. Address all orders to *Editor, The Lenkurt Demodulator, San Carlos, California.* Please send check or money order payable to Lenkurt Electric Co., with your order.

SAN CARLOS, CALIFORNIA, U.S.A.

a Subsidiary of General Telephone & Electronics

GENERAL SYSTEM

The Lenkurt Demodulator is a monthly publication circulated free to individuals interested in multi-channel carrier, microwave radio systems, and allied electronic products. Permission to reproduce material from the *Demodulator* will be granted upon request. Please address all correspondence to the Editor.

Automatic Electric Sales Corporation and Automatic Electric International, Inc., Northlake, Illinois, and Automatic Electric Sales (Canada) Ltd., are distributors of Lenkurt products.