The Lenkurt® Demodulator

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CARRIER SYSTEM CO-ORDINATION

Much of the thought that goes into the design of carrier systems is devoted to co-ordination requirements. By properly applying the results of this thought, the carrier system user can plan his installations for the most efficient operation.

This article discusses the basic factors which influence the design and application of co-ordinating carrier systems.

A simple definition of the term co-ordination is: that property of a carrier system which enables it to operate together with other systems without interference. Various FCC rulings and international agreements impose a certain amount of co-ordination on radio systems. The radio-frequency spectrum is public property and these rulings and agreements aim to provide the best use for all users. On the other hand, a wire-line facility is private property. Its most efficient use requires a self-imposed co-ordination.

Carrier system co-ordination is a joint effort of both manufacturer and user. The manufacturer works toward co-ordination by designing his equipment so that it will work together with other systems. The user completes the job by applying the systems to properly engineered facilities.

There are two broad types of co-ordination. One of these may be called *intra-pair co-ordination.* This exists when two or more carrier systems operate on the *same* pair of wires without interfering with each other. The other type may be called *inter-pair co-ordination.* This exists when two or more carrier systems operate on *different* wire pairs without interfering with each other.

Also in This Issue

Intra-Pair Co-ordination

The basic requirements for intra-pair co-ordination are relatively simple. To operate on the same pair without interference, different systems must operate

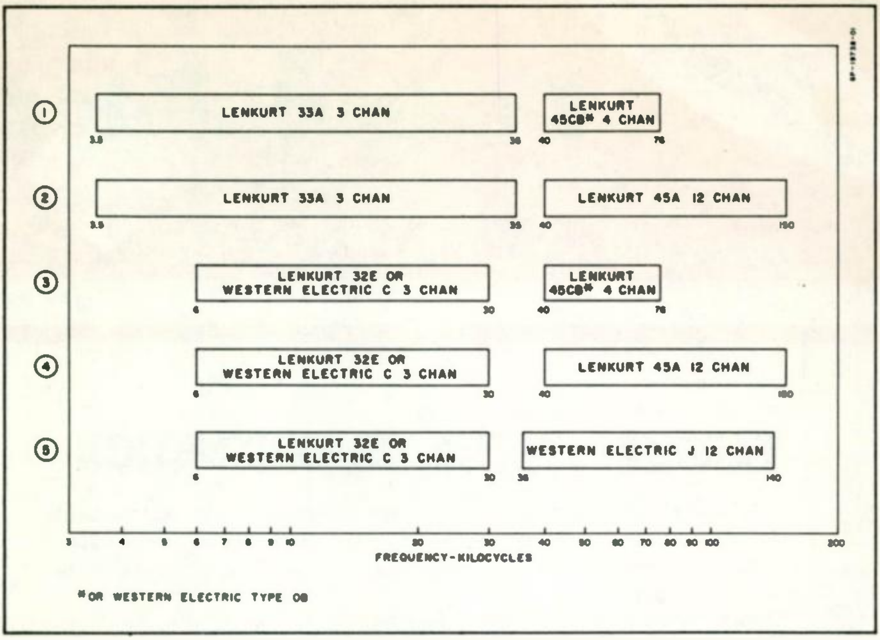

FIG. 1. Five combinations of open-wire carrier systems which co-ordinate on the same pair. All combinations shown may be superposed on physical voice-frequency circuits.

in different frequency ranges and at the proper levels.

The reason for frequency separation involves the first principle of carrier communications. The filters for one system pass only the frequencies assigned to that system and attenuate all others. Therefore, the frequency bands of different systems on the same pair cannot coincide or overlap.

Proper level means simply that one system cannot be so high in level that it leaks into another system through the line or directional filters. However, level difference is seldom a problem in intra-pair co-ordination. Modern, well-designed filters do a very effective job of suppressing out-of-band frequencies.

Carrier systems which co-ordinate on the same pair are available in many combinations. Figure 1 shows five co-ordinating open-wire combinations.

Inter-Pair Co-ordination

When two systems operate on separate wire pairs, their frequencies are physically separated. But a new source of interference arises from the inductive coupling that links paralleling wire pairs on an open-wire line or in a cable. As a result of this coupling, some of the signal energy in one pair transfers to an adjacent pair and may appear as *crosstalk*. When the crosstalk between two systems on separate wire pairs is kept to a satisfactory level, the systems may be said to co-ordinate on an inter-pair basis. The carrier manufacturer takes the first steps toward co-ordination with design that minimizes the effects of crosstalk coupling.

Crosstalk has its greatest effect at points where one system is at a high level and the other system at a low level. Such points exist at terminals and repeaters. The situation at a repeater station is shown in Fig. 2.

Here the west-east output of Repeater A consists of high-level signals. They have just been amplified by the repeater. The signals entering Repeater B in the east-west direction have been attenuated by the line and are at a low level. If the west-east frequency band of System A is the same as the east-west band of System B, the directional filters for the two directions will be the same. The near-end crosstalk from System A would then pass freely through the east-west branch of Repeater B and would be amplified and sent on to the west terminal of System B.

But if the west-east frequency band of System A differs from the east-west

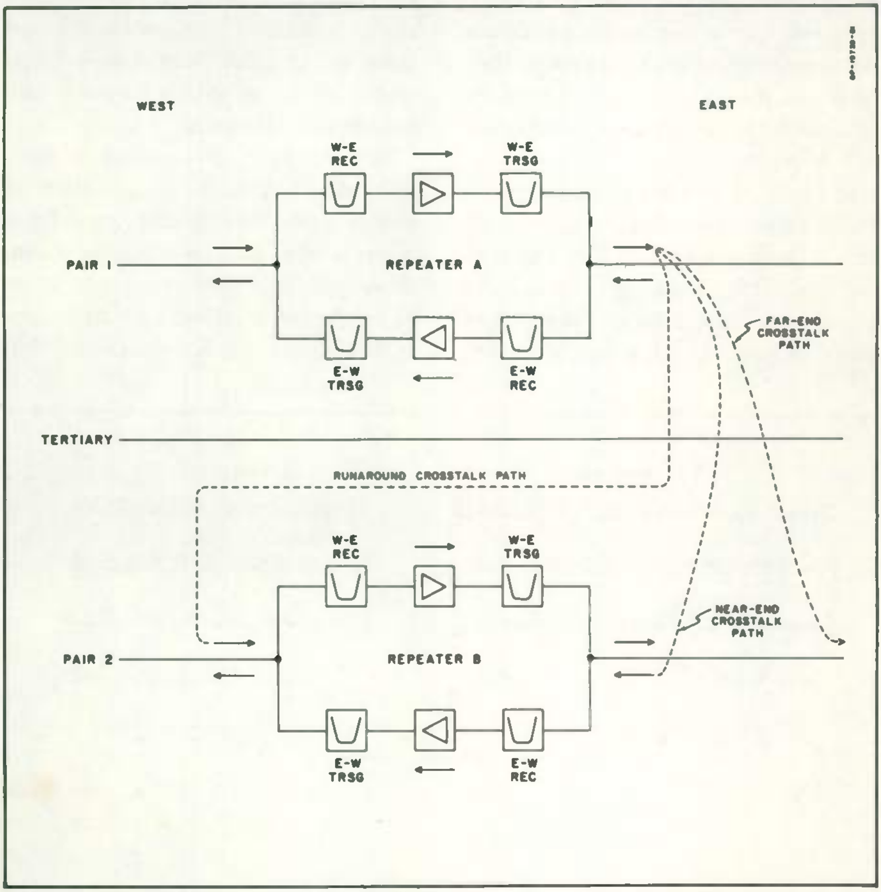

FIG. 2. Simplified block diagram of repeater station showing near-end, far-end and run-around crosstalk paths. Similar paths also exist for east-to-west transmission.

band of System B, the directional filters for these directions will be different. The directional filters of System B will then attenuate the crosstalk to a negligible level. Thus, to reduce near-end crosstalk, inter-pair co-ordination requires a basic frequency relationship between two systems: the east-west band of one system must differ from the west-east band of the other system.

Two-wire carrier systems use "grouped-frequency" operation in which channels in opposite directions use different frequency bands. This allows two carrier systems to co-ordinate on an inter-pair basis even though they both use the same over-all frequency allocation. In such cases, far-end crosstalk is also a factor. This is the crosstalk which is coupled from Pair 1 to Pair 2 (directly or through the tertiary) and is transmitted along Pair 2 toward the east. This crosstalk will be in-band to the west-east branch of the next terminal or repeater. However, after suffering coupling loss and line attenuation, it will arrive at a relatively low level.

Another form of interference that may occur at repeater stations is run-around crosstalk. Run-around crosstalk takes the path shown in Fig. 2. Here, the high-level output of Repeater A crosstalks to a tertiary, and the tertiary crosstalks to the west input of Repeater B. If the two systems use the same frequency allocations, the run-around crosstalk will be in-band to the west-east branch of Repeater B. In such cases, additional attenuation in the form of crosstalk suppression filters may have to be inserted in the run-around crosstalk path.

Another basic requirement of inter-pair co-ordination is co-ordination of energy levels. One system cannot be so high in level that its crosstalk on another pair is strong enough to cause objectionable interference. Any original difference in levels between sys-

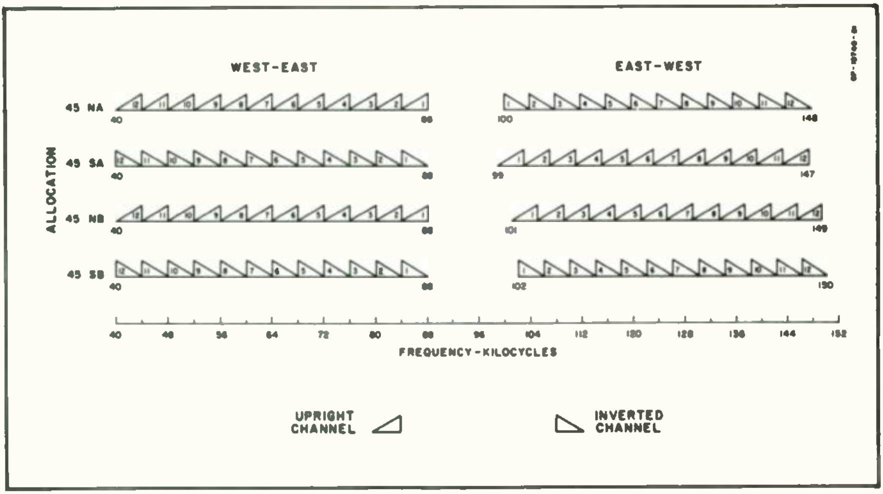

FIG. 3. Four frequency allocations for Lenkurt 45A open-wire system, showing channel inversion and staggering.

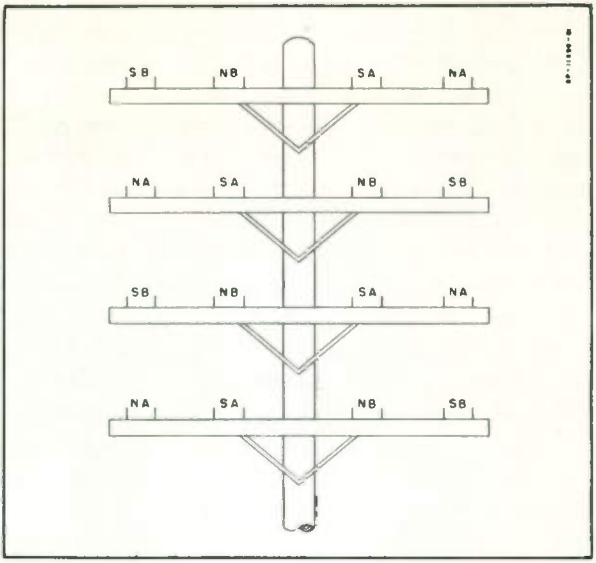

FIG. 4. Recommended pair assignments for Type 45A frequency allocations.

tems will only widen the difference that exists where one system is at a high level after amplification and the other is at a low level after line attenuation. Therefore, an important design step in co-ordination is keeping the transmitting level of the system as close as possible to the transmitting levels of the systems with which it is to co-ordinate.

But message power is not the only consideration in level co-ordination. The levels of signaling tones and carrier frequencies are also important. The carrier designer must plan his system so that signaling and pilot tones are at levels which do not interfere with other systems. When the carrier is transmitted, it must not be so high as to intrude on other systems. In systems where the carrier is not transmitted, the carrier must be sufficiently suppressed in the modulators and filters to prevent interference from carrier leak.

Level co-ordination is closely related to filter performance. Since filters are usually the ultimate stages in determining how much interference gets into the disturbed system, their design is important. Filters which offer high attenuation to out-of-band frequencies can ease the level co-ordination requirements for near-end crosstalk when two systems use the same frequency allocations, or for both near-end and far-end crosstalk when two systems use different allocations.

The carrier manufacturer can supplement his basic co-ordination efforts by designing his system to allow for different channel allocations. Figure 3 shows the various allocations of the Lenkurt 45A open-wire system. By proper choice of sidebands, the individual channels can be upright (upper sideband) or inverted (lower sideband). By a proper choice of carrier frequencies in the last stage of modulation, the allocations can be staggered. The facility can then be laid out so that adjacent pairs use systems with slightly different frequency allocations.

Channel inversion safeguards the

privacy of individual conversations. The signals which crosstalk from one pair to an adjacent pair are unintelligible. Staggering, on the other hand, reduces the effect of this unintelligible crosstalk. Crosstalk from one channel falls in a different portion of an adjacent disturbed channel and much of it will fall in the unused guard bands of the disturbed system.

Carrier designers can also further co-ordination by reducing the reflection effects of the system. Reflection occurs when signal energy meets an impedance mismatch in the transmission path. The reflected energy may then combine with crosstalk from other sources to increase the total crosstalk between systems. This reflected component of crosstalk can be controlled by closely matching the impedances of terminals and repeaters with the impedance of the transmission line.

Application of Co-ordinating Systems

All the effort that goes into the design of co-ordinating carrier systems is lost unless the systems are properly applied. This is where the user contributes his share to co-ordination. He can get the most efficient use out of the manufacturer's equipment only by applying it to properly engineered facilities.

One of the first considerations is line treatment. This means transposing, in the case of open-wire facilities, or capacitive balancing, in the case of cable facilities. Crosstalk increases with frequency. If new systems are to be added to existing facilities, the line treatment must be adequate to handle the crosstalk of the new frequencies.

In general, lines treated for a lower frequency will have excessive crosstalk coupling at a higher frequency. But compandors often allow a wide degree of leeway in this rule and their use should be considered. The 22-db crosstalk advantage between compandored systems has, in specific cases, allowed the use of frequencies as high as 150 kc on paralleling open-wire pairs transposed for only 30 kc.

Suppression measures are another consideration. Excessive crosstalk between two systems via a tertiary may be reduced to tolerable levels by the insertion of additional suppression in the tertiary path. As in the case of run-around crosstalk, crosstalk suppression filters may bring the interference under control.

The user can also contribute to co-ordination by keeping line reflections to a minimum. He does this by effectively reducing impedance mismatches in the line. This involves the proper matching of impedances at junctions where terminals and repeaters connect to the line or where open-wire connects to other open-wire or to cable.

Conclusion

The operating efficiency of a facility is largely the product of the combined co-ordination efforts of the carrier system manufacturer and the carrier system user. The manufacturer contributes by building certain co-ordinating features into his equipment. The user contributes by a proper choice of systems and proper engineering of the transmission path. But the goal of both manufacturer and user is the same—quality transmission at the lowest cost per channel-mile.

GROUP MODULATION

In Carrier Telephone Systems

Carrier telephony depends on a system's ability to translate the voice-frequency band into other sections of the frequency spectrum. In early low-frequency carrier systems, this was accomplished by a single direct-modulation step. That is, each voice channel modulated a separate carrier frequency which translated it to the proper position in the carrier spectrum.

This technique was also used on some early high-frequency systems but was costly and resulted in manufacturing difficulties. Now, most such systems use two or more steps of modulation. The second and higher steps involve the modulation of a single carrier by a group of channels. This is called *group modulation.*

Group modulation has three basic advantages over direct modulation: (1) it reduces the number of carrier frequencies required; (2) it permits the use of simpler filters for sideband selection; and (3) it facilitates the interconnection of channel groups at carrier frequencies. Any one of these reasons in itself would be sufficient to justify the use of group modulation.

Frequency Generation

The need for fewer carrier frequencies in group modulation can be illustrated by the modulation plan for a Lenkurt Type 45A carrier system. Figure 1 shows that this system needs eight separate carrier frequencies—four for the first stage of modulation, three for the second stage, and one additional frequency to create separate bands for opposite directions of transmission.

In the first step, the twelve voice-frequency input bands are separated into three groups called pregroups. Each contains four voice channels and each uses the same four carrier frequencies. A single frequency supplies three channels—one in each pregroup.

After pregrouping, a 12-channel group is formed by a second stage of modulation using three carrier frequencies—this time, one carrier frequency for each pregroup. In this stage, the four channels of a pregroup modulate just one carrier frequency rather than four separate frequencies. As a result, each pregroup is translated to occupy one-third of the band of frequencies from 40- to 88-kc. This channel grouping is called a basegroup.

If the direction of transmission is from west to east (or from south to north), the 12-channel basegroup of the 45A system needs no further frequency translation. It is transmitted as is. However, if the direction of transmission is east to west (or north to south), an additional modulation step is necessary so that opposite directions of transmission will use separate frequency bands.

To accomplish the additional step,

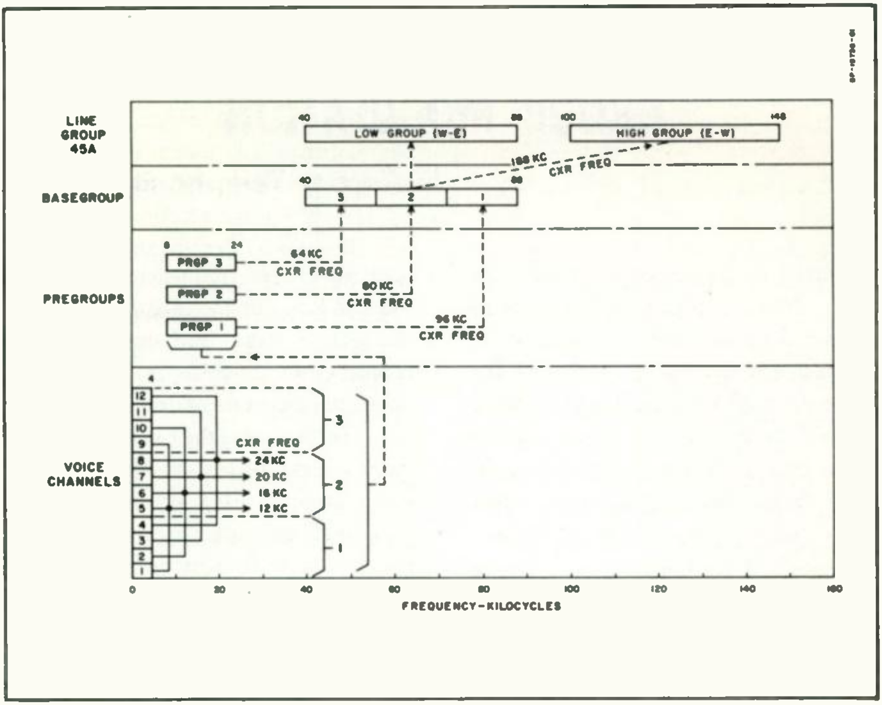

FIG. 1. Modulation plan for Lenkurt Type 45A carrier. Except for the high-frequency line group, this plan also applies to Type 45BN cable carrier and Type 45BX radio channelizing equipment.

only one carrier frequency is needed. All 12 of the channels in a basegroup modulate a frequency of 188 kc which translates them as a group to the frequency range from 100 to 148 kc. Thus the end result of the three modulation steps is that 12 east to west channels have been translated to the band from 100 to 148 kc.

Had direct modulation been used for the Type 45A system, 24 separate carrier frequencies would have been required—12 for each terminal. A large amount of carrier generation equipment would have been necessary and interchangeability of east and west terminals would not have been as practical.

Filter Requirements

In the process of translating a voice-channel or group of channels by modulation, two new frequency bands (sidebands) are created. Each is different from the original and different from the other. Only one is desired. It is selected and separated from the unwanted band by a filter—bandpass, high-pass, or low-pass depending upon circuit requirements.

In the modulation scheme of the 45A system, four band-pass filters are required to select the proper sideband from the first modulation step. Three sets of these filters are required for each terminal. Also required are three pregroup band-pass filters to select the proper sidebands from the second modulation step. A low-pass filter is used to select the 100- to 148-kc sideband of the third step for east to west transmission. A total of eight different filters are thus required. If a direct modulation scheme had been used, a total of 24 different filters would be needed—one for each channel for each direction of transmission.

A further advantage of the group modulation plan is that group filters are not subject to as stringent selectivity, impedance, and attenuation requirements as are the channel filters of a direct modulation plan. The most critical filters of a group modulation scheme are the individual channel band-pass filters. In the 45A system, the highest frequency channel filter must pass a band from 20 to 24 kc with less than 1 db variation from about 20.3 to 23.1 kc. At these frequencies, such a pass-band response is not difficult to achieve with ordinary L-C filters. At line frequencies, however, L-C filters providing such a precise response would be very difficult to design and manufacture. More expensive crystal or similar type filters would be needed.

Interconnection

One of the most important reasons for using group modulation is that it simplifies the interconnection of channel groups at carrier frequencies. By combining voice channels into standard pregroups and basegroups, whole blocks of channels can be shifted to any desired frequency range.

For example, there are occasions

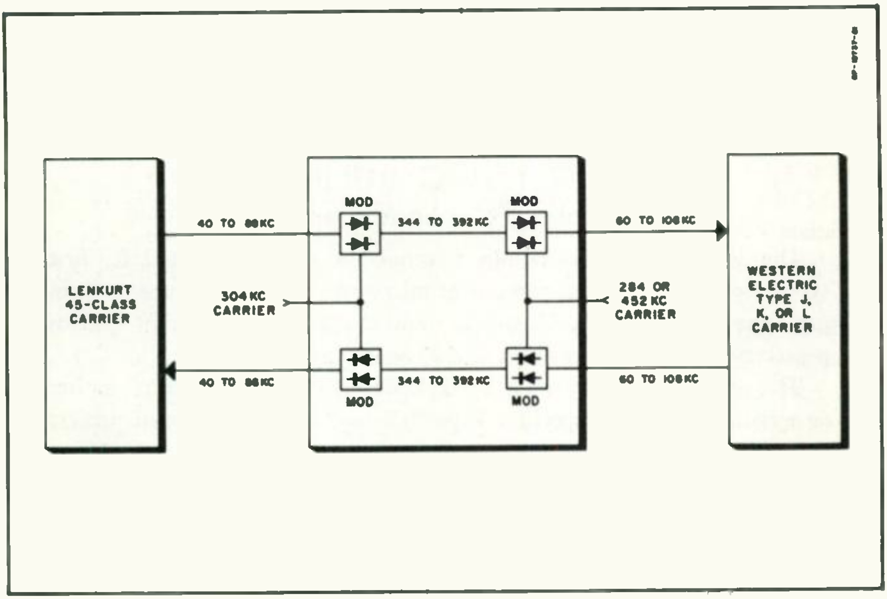

FIG. 2. Group modulation is used in the Lenkurt Basegroup Transfer Converter Unit to interconnect 45-class carrier to Western Electric J, K, or L systems at carrier frequencies.

when the interconnection of Lenkurt 45-class carrier with Western Electric Type J, K, or L carrier is desirable. A difficulty arises, however, because the Western Electric carrier uses a 60- to 108-kc basegroup while the 45-class basegroup is from 40 to 88 kc. Since the two frequency bands overlap, neither can be group-modulated in a single step to be made the same as the other. Two modulation steps are needed.

In transmitting from 45-class carrier to a J, K, or L system, the 40- to 88-kc group is first translated to 344 to 392 kc and then translated by a second modulation stage back down to 60 to 108 kc. From the Western Electric carrier to the Lenkurt carrier a similar process takes place with the 60- to 108-kc group being translated to 40 to 88 kc in two steps.

The basegroup transfer between 45-class and J, K, or L systems is accomplished with a special unit called a basegroup transfer converter. A block diagram illustrating its application is shown in Fig. 2.

Without group modulation, it would be necessary to demodulate both the Lenkurt and Western Electric basegroups to voice-frequency to interconnect them. This additional step would require two complete carrier terminals and be much more costly. It would reduce transmission quality as well.

Conclusion

Group modulation techniques have substantially reduced the complexity and costs of modern carrier telephone systems. Carrier facilities of similar type can interconnect at carrier frequency. Many high-cost components are avoided, and fewer frequency-generating units are needed. All of these advantages are achieved without substantially lowering transmission quality.

RECENT FCC RULINGS
Concerning Telephone Companies

The Federal Communications Commission recently granted its first "type acceptance" for common carrier microwave radio equipment to Lenkurt Types 72B and 72C. These are multi-channel, point-to-point systems operating in the frequency range of 890 to 960 mc.

The grant means that when a telephone or telegraph company applies for a radio license and specifies Type 72B or 72C, the FCC will process the application without question about the type of equipment. Other manufacturers have until July 1, 1957, to show that their equipment complies with Part 21 of the FCC rules in order to obtain type acceptance.

The FCC also amended Part 21 of its rules to permit common carrier frequency assignments with 100-kc spacing. This authorizes all channel frequencies which have been recommended by Lenkurt for Type 72 equipment operation. Part 21 originally called for 500-kc spacing.

BIBLIOGRAPHY ON CARRIER

This bibliography contains sources of material on the basic principles of carrier communications. The list may be helpful to readers who would like more background on general carrier theory. Information on availability and cost of these publications can be obtained from the publishers.

In addition to the sources listed, various periodicals of the American Institute of Electrical Engineers (33 W. 39th St., New York 18, N.Y.) and the Institute of Radio Engineers (1 E. 79th St., New York 21, N.Y.) contain many technical papers dealing with specific aspects of carrier and describing certain systems.

Two Bell System periodicals are also valuable sources of detailed information. These are The Bell Laboratories Record, published monthly by the Bell Telephone Laboratories (463 West St., New York 14, N.Y.) and the Bell System Technical Journal, published bi-monthly by the American Telephone and Telegraph Company (195 Broadway, New York 7, N.Y.).

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New Microwave System

A new Product Information Letter, designated **PIL-23**, describes MICROTEL—newest addition to Lenkurt's radio line.

MICROTEL is a 6,000-mc microwave system designed to provide high-quality operation with a minimum of installation and maintenance expense. Hundreds of toll-quality message channels can be transmitted over distances up to 300 miles.

Included in **PIL-23** are preliminary specifications, diagrams, and charts for MICROTEL equipment and its applications. Copies are available on request from Lenkurt or its distributors.

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