The Lenkurt Demodulator

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Some Engineering Features of the

NEW TYPE 45BN CABLE CARRIER SYSTEM

The new Type 45BN cable carrier equipment is used to transmit up to 24 toll-quality voice and signaling channels over two pairs in a toll or exchange-type cable. Extensively tested in the field during the past year, the new system has met or exceeded performance expectations.

This article describes the new system and discusses some of the factors that influenced its design.

The Type 45BN cable carrier system is one of several 45-class systems which use identical channelizing and grouping equipment. Like the other 45-class systems, it is highly miniaturized with plug-in units which, in turn, have many plug-in subassemblies. Wherever possible, the plug-in units and their subassemblies are interchangeable with each other and with corresponding units in other 45-class systems. Figure 1 shows two of the prototype terminals used in the field trial in 1954.

The 24 channels of the 45BN system are transmitted over two pairs (or a quad) in a toll or exchange cable. Separate 100-kc bands of frequencies are used for the different directions of transmission. One direction of transmission uses frequencies from 40 to 140 kc and the other direction uses frequencies from 164 to 264 kc.

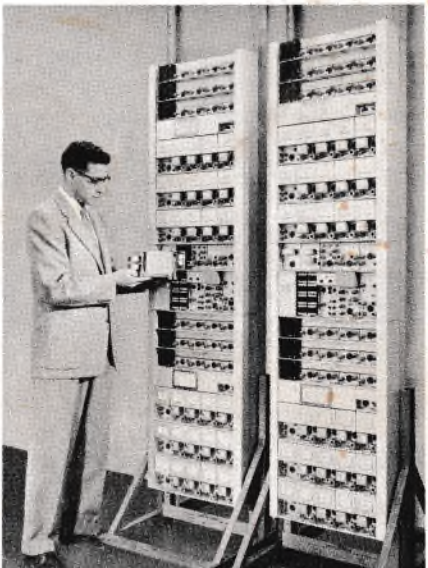


FIGURE 1. Two of the prototype terminals of Type 45BN carrier that were field tested in Wisconsin in 1954.

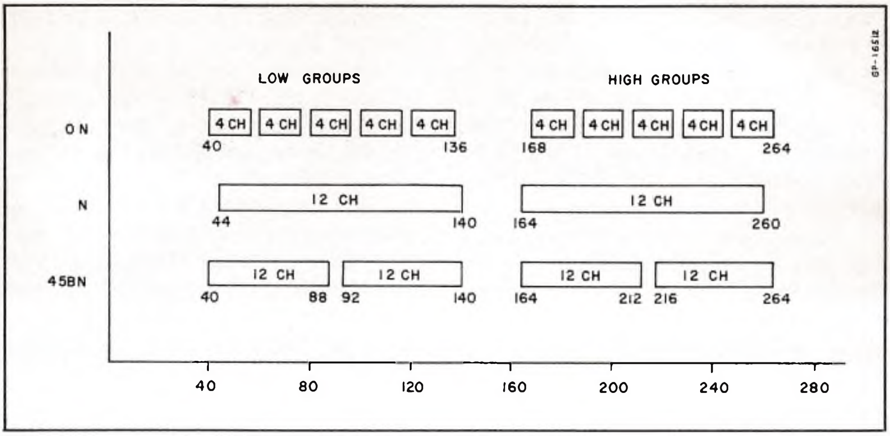


FIGURE 2. Frequency allocations of Lenkurt Type 45BN cable carrier and Western Electric Types N and ON cable carrier.

Either band is usable in either direction. The use of separate frequency bands and separate pairs for opposite directions of transmission electrically isolates the transmitting and receiving paths. The particular frequency bands of 40-140 kc and 164-264 kc were chosen to coordinate with the Western Electric Types N and ON cable carrier systems.

Design Considerations

Much of the required design work on the 45BN system was completed more than a year ago. The channelizing and grouping equipment used with this equipment is the same as that designed for use with the 45A and 45BX carrier systems. The system terminal equipment (equipment required to transmit and receive 24 channels over the cable facility), however, required a major design effort.

Some of the most important factors that influenced the design of the 45BN system were: (1) cable transmission characteristics, (2) coordination with other cable carrier systems, and (3) synchronization of carrier frequencies at distant terminals.

The basic design of a carrier system is determined largely by the transmission characteristics of the medium over which it is to be used. Cable carrier is no exception. The most important cable characteristics considered in the design of 45BN carrier were: (1) attenuation per unit of length, (2) variation of attenuation with frequency (slope), (3) variation of slope and impedance with frequency, and (4) coupling between cable pairs.

The attenuation of different types of toll and exchange cable varies widely depending on the construction of the cable and the gauge of the conductors. A typical 19-gauge quadded toll cable will attenuate a 40-kc signal approximately 3 db per mile and a 264-kc signal about 8 db per mile. Exchange type cable generally has higher losses.

The attenuation of cable pairs largely determines the maximum distance signals that can be transmitted without being repeatered. For 19-gauge toll cable, a maximum repeater spacing of about 8 miles can be used in the 45BN system. For exchange cable, shorter repeater spacings are required.

Compared with open-wire lines or radio circuits, cable has a large variation of attenuation with frequency. An 8-mile repeater section of toll cable, for example, will have a total slope of about 19 db across a 100 kc band. Equalization of this amount of slope is accomplished in 45BN equipment by a system of pre-equalization in the carrier terminals and frequency transposing (frequency frogging) in the repeaters.

Variation of slope with frequency has been a major consideration in determining the frequency bands used by cable carrier systems. At voice and low carrier frequencies, there is considerable variation in slope which is difficult to equalize. Above 40 kc, however, slope is nearly constant and readily equalized by frequency transposing repeaters. At low frequencies, there is also a large change in characteristic impedance with frequency. To avoid these undesirable variations in line characteristics, most single cable carrier systems transmit only frequencies above 40 kc.

Coordination

An important factor in the design of the 45BN system was the requirement that it coordinate with the Western Electric Types N and ON cable carrier systems. Both of these systems operate within the frequency spectrum from 40 to 140 kc and 164 to 264 kc. They are in general use by the Bell System and other telephone systems in the United States and Canada.

To coordinate with these carrier systems, the frequency allocation of the 45BN was also designed to occupy the spectrum from 40 to 264 kc. Terminal gains and transmission levels were arranged to minimize interference and crosstalk between systems. Because of these measures, Type 45BN carrier can be used in the same cable with Type N or ON carrier without impairment of operation of either the N, 45BN, or ON systems. Type 45BN has also been designed to operate through Type N repeaters. Figure 2 shows the frequency allocations of the Type 45BN, N and ON carrier systems.

A common coordination problem solved by the 45BN system is in the expansion of routes where additional channel groups must be transmitted part of the way over cable carrier and part of the way over an open-wire carrier on a lead that has pairs already equipped with Western Electric Type J or other equivalent carrier. For maximum economy and transmission quality, this application requires that the carrier system to be installed on the cable portion of the route coordinate with the existing cable carrier and at the same time be interconnectable on a carrier frequency basis with the open-wire carrier system. Similarly, the new open-wire system must coordinate with the Type J carrier or its equivalent. The Lenkurt 45BN cable carrier system interconnected with the Type 45A open-wire system is the only combination presently available which meets these requirements. This combination results in substantial savings in equipment costs and floor space compared to other arrangements using voice frequency interconnections between systems.

Synchronization

The use of frequency transposing repeaters such as the Western Electric Type N, tends to cause some error between the frequencies sent into the cable and the frequencies received from the cable. Were this error left uncorrected, distortion and frequency shift would result.

To eliminate this source of distortion, a synchronizing unit is employed in the receiving terminal of the 45BN system to automatically correct for any frequency error introduced by the repeaters. A precise 96 kc pilot tone (accuracy approximately one part per million) is injected into the system before the final stage of transmitting terminal modulation and is transmitted along with the voice channels. At the receiving terminal, the equipment units are arranged so that the original 96-kc tone is received by the synchronizing unit as a 208 kc tone plus or minus any frequency error accumulated from the repeaters.

The 208-kc tone plus or minus the error is modulated with a 96-kc tone (also accurate to approximately one part per million) from the receiving terminal carrier sypply. From the output of the modulator, the upper side-frequency of 304 kc minus or plus the error is selected, amplified and used to demodulate the received group of channels. The lower sideband of this modulation step is selected and passed on to the basegroup unit. In this last modulation step, the frequency error is contained in both the demodulating carrier and the received signal. Since the frequency error is the same in both cases, subtraction of the received signal band from the 304 kc carrier to form a lower sideband cancels out the error. The signal passes on to the basegroup unit essentially free of frequency error (within two parts per million). A block diagram illustrating the operation of the synchronizing circuit is shown in Figure 3.

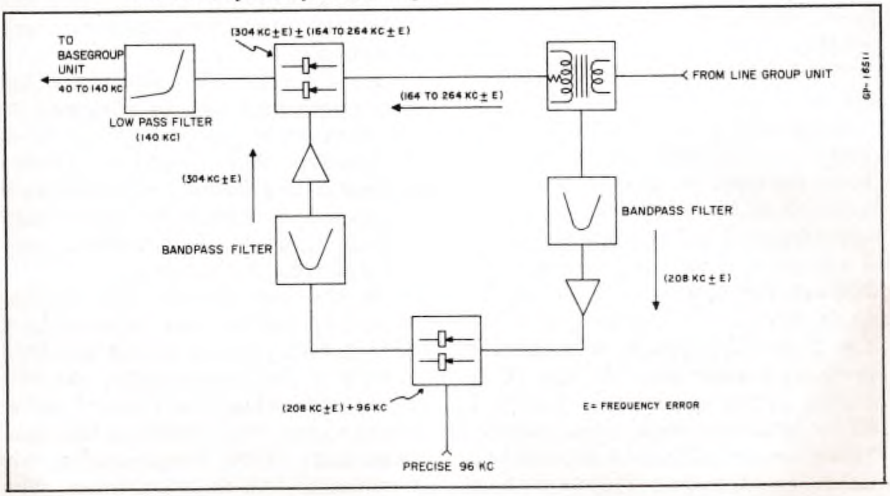
Equipment Description

A functional arrangement of a 24-channel type 45BN terminal is shown in the block diagram of Figure 4. The units enclosed by the solid lines can be divided into three functional groups. These are (1) compandors, (2) channelizing and grouping equipment, and (3) transmission equipment.

Compandors are an essential part of speech channels transmitted over a 45BN system. Even when the 45BN system is an intermediate link in a 45-class carrier frequency network, all such speech channels that operate over the 45BN system must be equipped with compandors at their voice frequency terminations. Lenkurt compandors, being separate units, can be placed in the voice frequency circuit at any convenient point. They do not have to be located at the 45BN carrier terminals.

The need for compandors arises from the large amount of crosstalk

FIGURE 3. Shifts in the transmitted band of frequencies are corrected in the receiving terminal by this synchronizing circuit.



coupling that exists between cable pairs. Compandors reduce the effect of the crosstalk coupling by about 22 db. This reduction is sufficient to permit operation of a 45BN system over as many as 25 or more repeater sections with acceptable crosstalk and noise performance. Channels without compandors, transmitted over just one 8-mile repeater section, would have poor crosstalk performance.

When channels are used only for the transmission of voice-frequency telegraph, telemetering or other telegraph type intelligence, the crosstalk conditions are such that operation of such channels without compandors is permissible. In fact, the use of compandors on such channels should be avoided.

Channelizing and Grouping Equipment

The channelizing and grouping equipment required to terminate 24 channels transmitted over 45BN cable carrier consists of two 12-channel basegroup channel banks. These same type channel banks are also used for channelizing other types of 45-class carrier. A basegroup channel bank consists of 12 channel units and three pregroup units. The channel units modulate each channel into the proper 4-kc band in the spectrum from 8 to 24 kc. They also provide signaling and automatic regulating facilities for each channel.

The pregroups modulate each group of four channels into a 16-kc band between 40 and 88 kc. Pregroup 1 is modulated to the spectrum from 72 to 88 kc and pregroups 2 and 3 are modulated to occupy the spectrum from 56 to 72 kc and 40 to 56 kc. The combined output of the three pregroups is a band of frequencies between 40 and 88 kc. In the receive direction the 40 to 88 kc band of frequencies is separated and demodulated into individual voice channels. Figure 5 shows a typical basegroup channel bank.

Transmission Equipment

The basic function of the transmission equipment in the transmit direction is to condition two basegroups for transmission over the cable pair. The transmission equipment consists of a basegroup unit, synchronizing unit, and line group unit.

The basegroup unit modulates one of the two 40 to 88 kc basegroups to occupy the spectrum from 92 to 140 kc. It then combines the output of this modulation stage with the other 40 to 88 kc group to form a 24-channel group from 40 to 140 kc.

The synchronizing unit adds 8 db of slope to the 24-channel group and injects a 96 kc pilot tone for synchronization and repeater gain control. The pilot tone level, being much higher than the speech levels, controls the gain of the power sensitive system repeaters.

If the terminal is to transmit the high group of frequencies, the 40 to 140 kc band is modulated by the line group unit to occupy the frequency spectrum from 164 to 264 kc. It is then filtered, amplified, and applied to the cable pair. If the terminal is to transmit a low frequency group, only the filtering and amplification are required.

In the receive direction, the line group unit can be strapped to receive either a low group or a high group. If a low group is received it is filtered and modulated to become a high group. If a high frequency group is received, only the filtering is required.

In the high group, the original 96 kc regulating tone appears as a 208-kc tone plus or minus any frequency error contributed by the repeaters. This tone is used in the line group unit to control a flat gain regulator which compensates for variations in cable attenuation. The

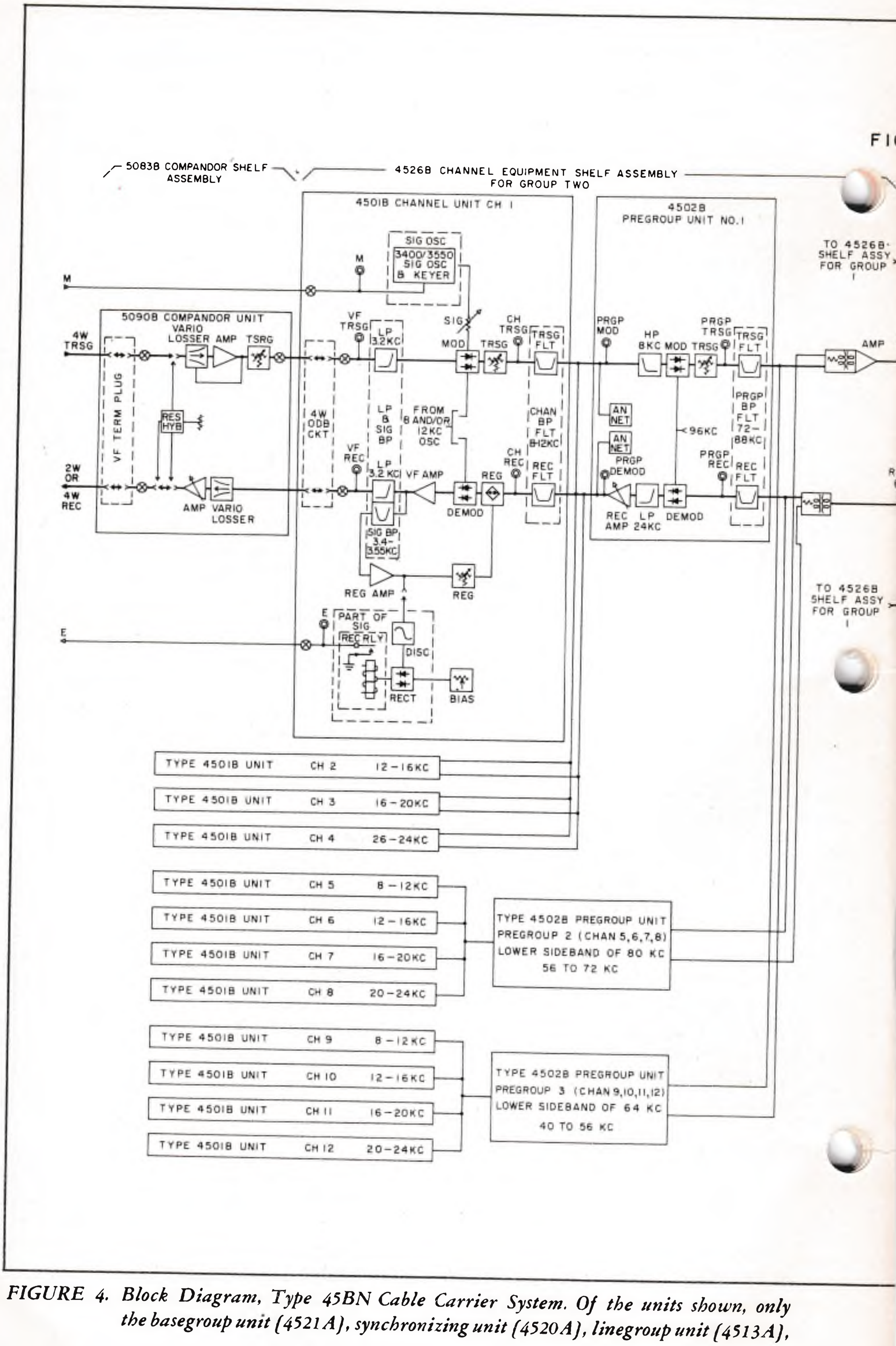
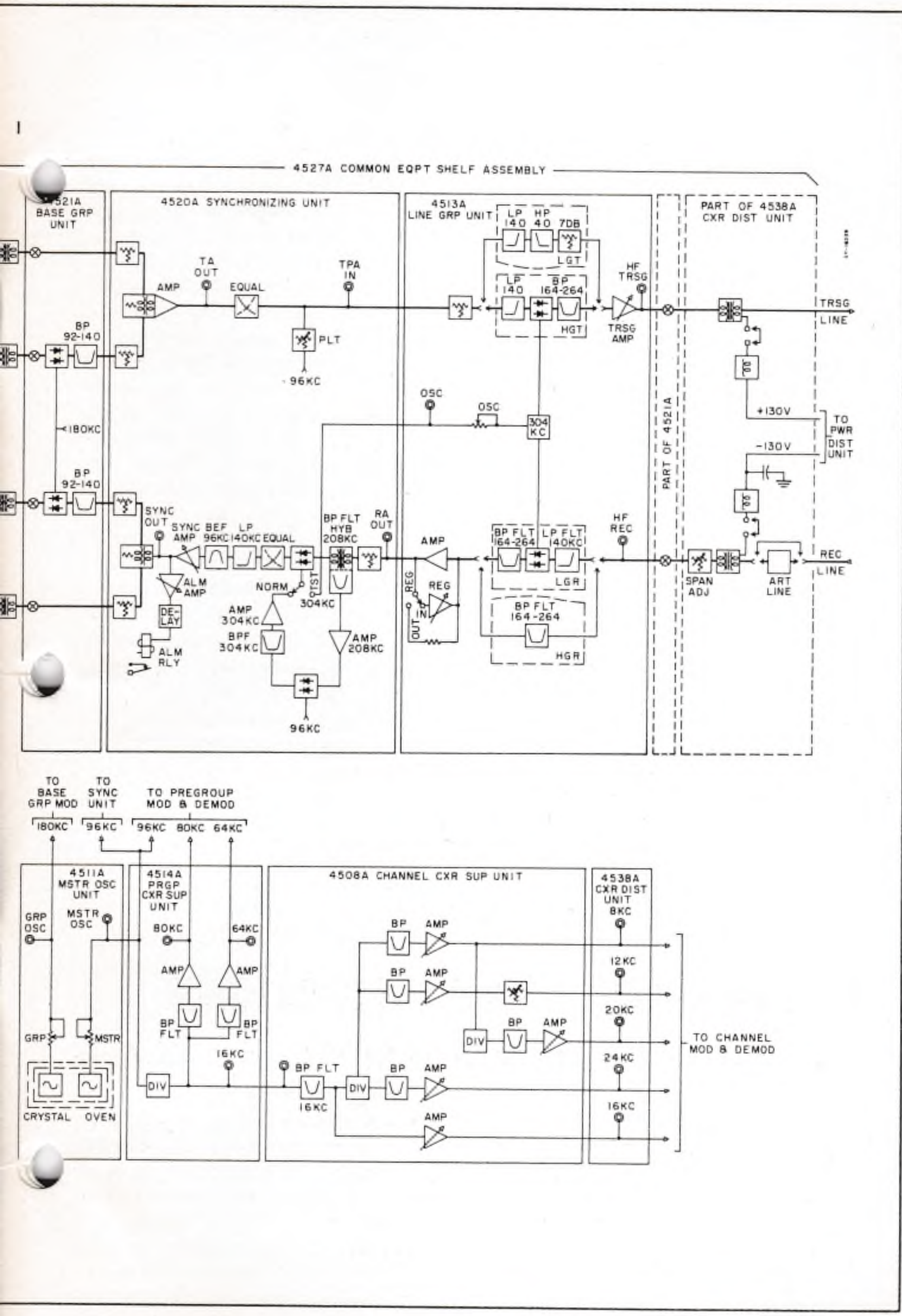


FIGURE 4. Block Diagram, Type 45BN Cable Carrier System. Of the units shown, only the basegroup unit (4521A), synchronizing unit (4520A), linegroup unit (4513A),



and the carrier distribution unit (4538A) are peculiar to the 45BN system. The others are used with more than one type of 45-class carrier.

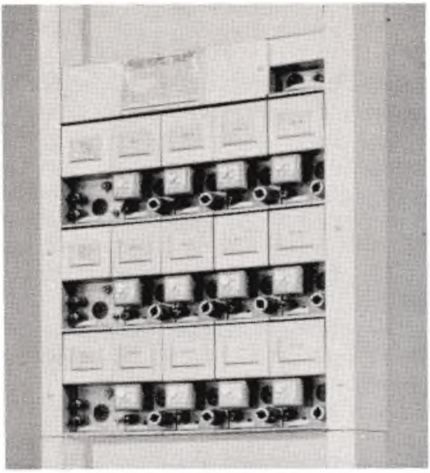


FIGURE 5. Typical 45-class basegroup channel bank. This assembly provides channelizing and grouping equipment for 12 voice and signaling channels, yet occupies only 22 5/8 inches of vertical rack space.

regulated 24-channel group is then passed to the synchronizing unit where the frequency error is removed and the high frequency group demodulated to the low group frequencies of 40 to 140 kc. This band of frequencies is then passed to the basegroup unit where the portion from 92 to 140 kc is demodulated to 40-88 kc, thus again forming two 12-channel basegroups. The basegroups can then be demodulated or transferred to other systems as required.

Field Trial

Since May, 1954, prototype terminals of the Type 45BN cable carrier system have been undergoing a field trial in Wisconsin. These prototype installations have given Lenkurt engineers the opportunity to test and evaluate the system design and operation under a variety of actual field conditions. The trial system was installed on a 100-mile section of toll cable that also contained 17 Western Electric Type N systems. At one end of the cable the 45BN was interconnected with two 12-channel 45A systems on a carrier frequency basis.

As a result of these tests of 45BN equipment, several improvements have been made that were not incorporated in the original design. The performance of the 45BN system during the field trial has proven that the system meets all performance requirements for either terminating or via circuits in the nationwide toll network, and that satisfactory operation in regular service can be expected.

ADDITIONAL FREQUENCY ALLOCATIONS

For The Type 45BX Carrier System

Five new 24-channel frequency allocations are being made available in Type 45BX multiplexing equipment for radio and microwave. The new allocations permit up to 120 voice channels to be transmitted and received over a single wideband radio system.

Previous 45BX frequency allocations were identical to those of the 45BN cable carrier system and contained two 24-channel groups in the frequency spectrum from 40 to 264 kc. The new allocations were planned specifically for radio use and locate five 24-channel groups in the frequency range from 12 to 528 kc. The previous allocations were designated XA and XB while the new allocations are designated

RA, RB, RC, RD, and RE. Figure 1 shows the actual frequency ranges of all seven allocations.

Although the new allocations are designed specifically for radio use, they do not make the previous XA and XB allocations obsolete. For those installations where no more than 48 channels will ever be required, the XA and XB allocations are the most economical. The XA and XB allocations are also more readily interconnected with Type 45BN cable carrier.

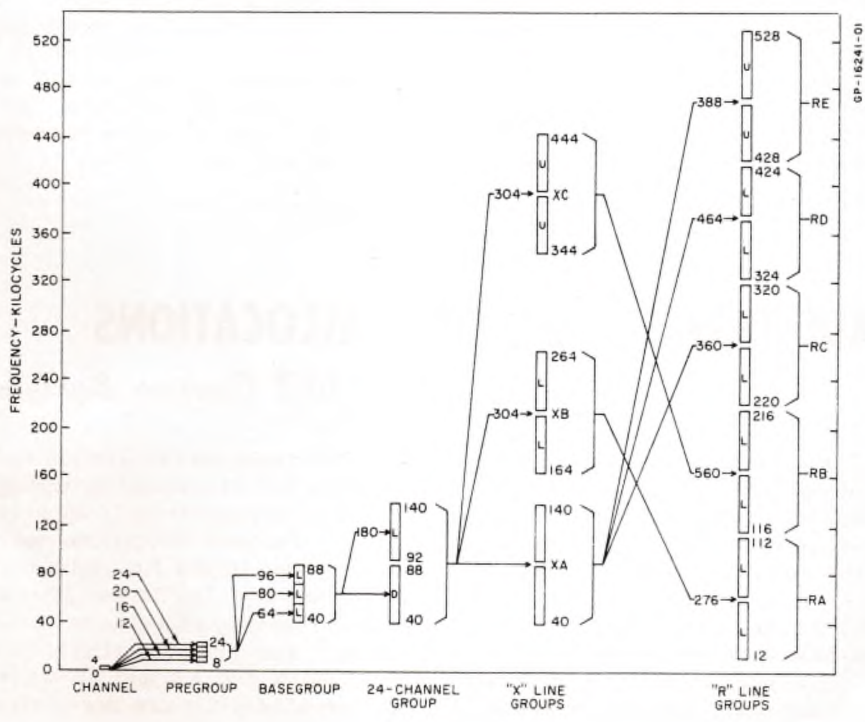
Because of the unitized design of 45-class equipment, existing Type 45BX channelizing systems using either or both the XA and XB allocations can be adapted in the field to use the future R allocations (if desired) by the installation of simple additional group modulating equipment. In this manner, presently installed 45BX systems can be expanded to obtain greater capacity from existing radio systems.

Modulation Plan

A modulation plan for the 45BX system is shown in Figure 1. Group modulating techniques are used to obtain the X allocations from standard 45-class, 40-88 kc, 12-channel basegroups. The R allocations are obtained from the X allocations by one additional group modulation step.

In the first modulation stage, five 24-channel groups are formed from 10 basegroups. All five are the standard XA allocation. A second stage of modulation places three of these 24-channel groups in the final R-allocation range from 220 to 528 kc. The remaining two XA groups are passed through an intermediate stage before being modulated into the R-allocation range from 12 to 216 kc. One of these intermediate steps is the standard

FIGURE 1. Frequency allocation and modulation plan for 45BX carrier system. Both the X and R allocations are shown.



XB allocation, and the other is a special allocation (XC) derived from the same modulation step as the XB except that an upper sideband is selected instead of a lower sideband.

The final result is the 10 evenly spaced 12-channel groups shown in Figure 1. Additional groups to expand the 45BX system to 240 or 360 channels can be simply provided by additional modulation of 24-channel groups with the XB allocation. A block diagram of the equipment arrangement for 120 channels is shown in Figure 2.

Application Features

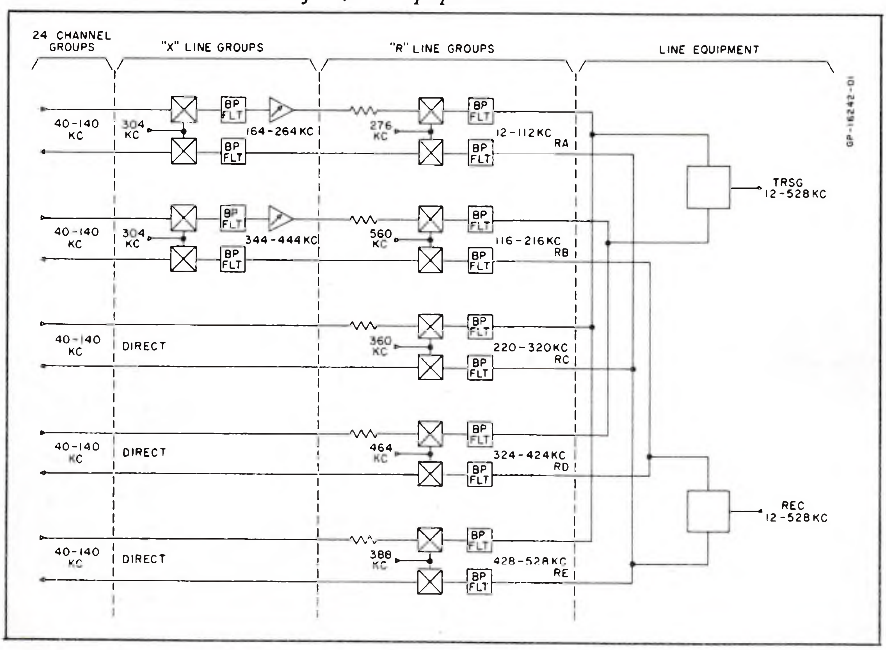
The R allocations provide a practical means of utilizing the available bandwidth of most point to point radio systems. With these allocations, Type 45BX equipment can be adapted to radio systems with channel capacities as low as 4 or 12 or it can be used over wideband systems with large channel capacities.

Four kilocycle slots between 12 channel groups provide sufficient separation between groups so that practical bandpass filters can be used to drop and reinsert channel groups at intermediate points between end terminals.

An important reliability feature of 45BX multiplexing equipment is that each 24-channel group is independent of the other groups. The only equipment common to all groups in a system is an inert hybrid junction. Equipment failures in any one group will not affect the remainder of the system.

All basic features of 45-class carrier equipment are retained in the new allocations. The 45BX with the R allocations is interconnectable with other 45-class carrier systems on a carrier frequency basis. Additional information on the new R frequency allocations for Type 45BX equipment is contained in Product Information Letter No. 16. Copies are available from your distributor.

FIGURE 2. Block diagram showing equipment arrangements for deriving and combining the R allocations for 45BX equipment.



Introducing

A NEW EDITOR

For The Lenkurt Demodulator

P. C. DeMuth, who has many years of experience in telephone transmission engineering, will become editor of The Lenkurt Demodulator effective with the July issue.

In addition to handling the editorship of The Demodulator, he will act as a consultant to the Applications Engineering Division at Lenkurt.

Mr. DeMuth has been active in the telephone field more than 40 years and is considered an authority on transmission engineering problems. He has had wide experience in the application of carrier to open-wire circuits.

He began his telephone career in 1913 with the Southwestern Bell Telephone Co. at Houston, Texas, where he gained outside plant engineering experience on exchange and toll circuits.

He was assistant transmission and protection engineer for Southwestern Bell at Dallas when he transferred in 1920 to the Engineering Department of the American Telephone and Telegraph Co. in New York.

For three years he worked on inductive interference and coordination matters for A. T. and T., then for eight years concentrated on crosstalk and transposition design, particularly for carrier frequency operation.

From 1932 until his retirement from A. T. and T. in 1954, Mr. DeMuth worked on general phases of open-wire and open-wire carrier transmission engineering. During this period he had close association with development and application of the H, C5, O, and ON carrier systems.

In his many years of work in transmission engineering, he has become well acquainted with telephone plant in the United States and Canada. He has participated in field transmission tests in many of the states.

Mr. DeMuth is a life member of the Telephone Pioneers of America. He is a native of the state of Virginia.

As editor of The Demodulator he will succeed A. M. Seymour, who is the newly appointed manager of Lenkurt's Technical News Dept.

Now in its fourth year of publication, The Demodulator goes monthly to communications engineers in every state and U.S. territory, every Canadian province, and 66 foreign countries. Circulation of the magazine has grown steadily since the first issue was published by Lenkurt in March, 1952.

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Recently Issued Publications

Telemetering and remote control applications of Lenkurt **44-Series Signal Transmission Equipment** are described in a new bulletin **Form 44-P4.** Also included are descriptions of the individual tone transmitting and receiving panels and a technical summary of their characteristics.

Lenkurt's **44 series** of signal transmission equipment permit up to 44 duplex tone channels to be transmitted and received over a single wire pair or radio circuit.

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