The Lenkurt Demodulator

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The Use of

FILTERS

in Carrier Telephone Systems

In frequency-division multiplex, the frequency spectrum is divided into discrete frequency bands for the transmission of information. The frequency bands are normally separated by electrical wave filters. Although the design of electrical wave filters involves a combination of specialized knowledge and art, filter applications may be readily understood through a knowledge of the characteristics of basic filter types.

In this article, the characteristics of the basic classes of filters are described, and the use of filters in a number of applications is explained.

Filters are essentially devices which have particular resonance characteristics. Although any device which exhibits a resonance to electrical waves may be used, the most commonly employed filter components are capacitors and inductors. In the simplest case, a simple series circuit consisting of a capacitor and inductor is a filter.

Because of the exacting requirements of filters used in carrier telephone applications, most filters contain a number of meshes (or two-terminal networks) which consist of an inductor and one or two capacitors. Depending upon the characteristics desired, the meshes are arranged in various series and shunt combinations in relation to the metallic path of the transmission line.

Design parameters for a filter are obtained from such factors as: (1) the impedance, both input and output, into which the filter must work; (2) the frequency range to be passed; (3) the attenuation of frequencies which may be present on either side of the desired frequency range; (4) the loss that may be tolerated in the pass band; and, (5) whether similar filters will be operated in parallel (flanking). Each of these factors should also be considered in the application of filters.

Filters may be classified in a number of ways. A commonly used method is to classify the filter type by means of the relationship between the pass-band and the cut-off frequency. With this method, there are four basic types: (1) low-pass filters; (2) band-pass filters; (3) band-elimination filters; and, (4) high-pass filters. In Figure 1, typical circuit configurations and attenuation-

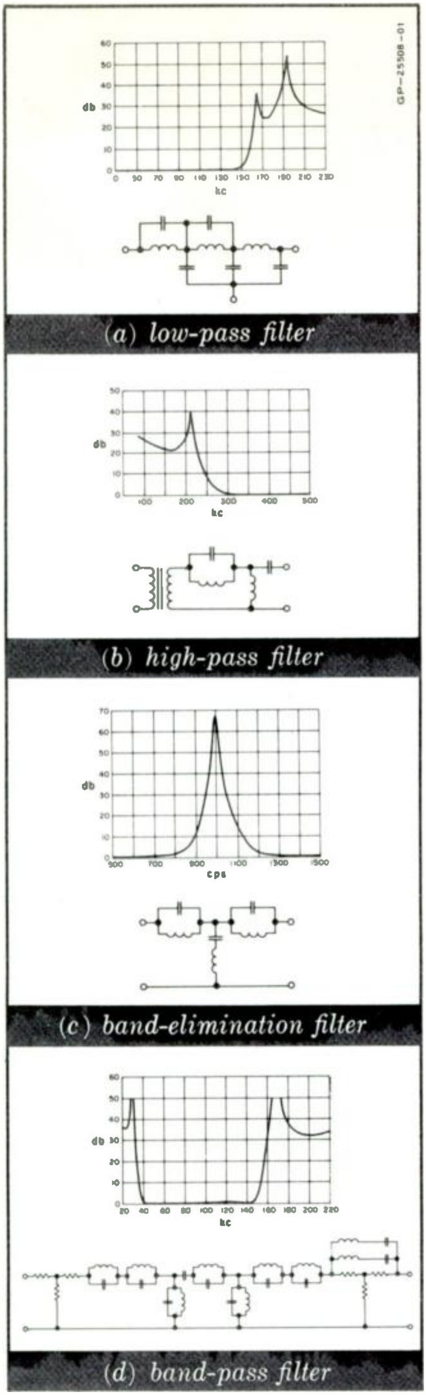

Fig. 1. Illustrating the four basic filter types.

frequency characteristics are shown for each filter type. From these general characteristics, filters may be selected for specific applications.

Low-Pass Filters

An ideal low-pass filter is one that has been designed to pass frequencies from 0 up to the cut-off frequency, and to effectively suppress all frequencies above the cut-off frequency. In a practical filter, the out-of-band attenuation will vary with frequency.

A typical low-pass filter application is shown in Figure 2. Here the filter is used at the input of the transmitting branch of a carrier channel. The function of this low-pass filter is to restrict the range of frequencies that may be passed into the carrier channel. In this application, the cut-off frequency is in the order of 3.2 kc. However, frequencies above cut-off will enter the channel, but will be considerably reduced in amplitude.

Where out-of-band signaling is employed, the maximum possible attenuation is required at the signaling frequencies in order to avoid false signaling. In the application shown in Figure 2, out-of-band signaling frequencies of 3400 cps and 3550 cps are used. Speech signals at these frequencies entering the circuit are adequately suppressed as shown by the attenuation peaks (often called infinite points) as shown in the attenuation-frequency characteristics.

Band-Pass Filters

Restricting the input frequency range is only one step in the process of minimizing the bandwidth required for the transmission of speech over carrier-derived channels. Additional filtering is also required at the output of the channel modulator.

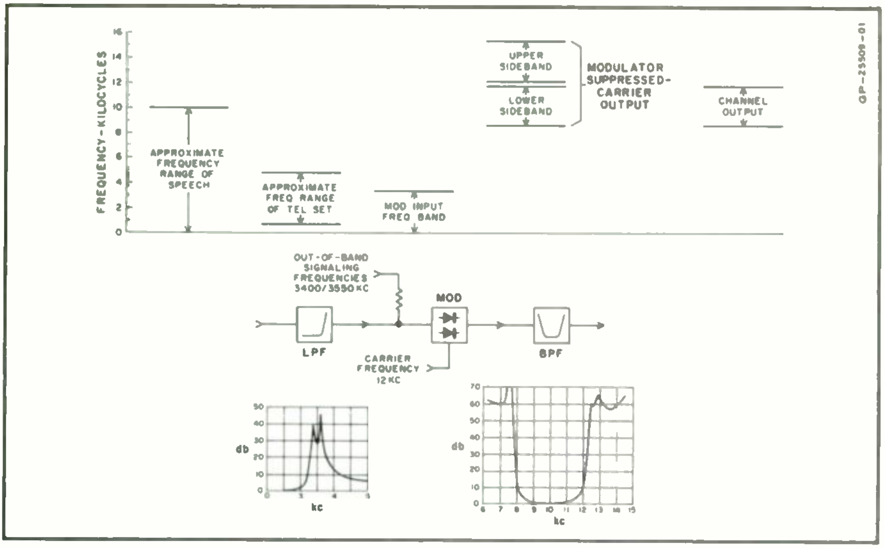

Fig. 2. Use of a low-pass and a band-pass filter in the transmitting branch of a carrier channel. In the upper portions of the diagram, the frequencies which may occur in the various parts of the circuit are shown. Also shown are typical characteristics of the filters used.

Modulation of the voice and signaling frequencies can be accomplished in any one of a number of ways. Where suppressed-carrier, amplitude modulation is employed, the modulator output contains two principal sidebands. One sideband is above and the other one is below the carrier frequency. As shown in Figure 2, the frequency range occupied by each sideband depends upon the frequency range of the original modulating frequencies. Each sideband contains all of the intelligence that was present in the original modulating wave. Either one or both sidebands may be transmitted depending upon the type of carrier system.

When a number of carrier channels are included in a system, the channels normally occupy adjacent frequency bands. Interference between channels is kept to a minimum by limiting the channel frequency band. This is readily accomplished by using a band-pass filter. In Figure 2, the band-pass filter selects only the lower sideband. Since the unwanted sideband would cause crosstalk in an adjacent channel band, the relative attenuation of the filter must be sufficient to keep crosstalk to within acceptable limits.

Band-Elimination Filters

Occasionally, it is necessary to prevent either a range of frequencies or a single frequency from passing beyond a certain point in a circuit. For example, the frequency range of a voice channel may be reduced to permit transmission of a carrier telegraph channel over the same circuit. A more common application is the elimination of a single-frequency pilot tone—such as is used for regulation or frequency control. This application is illustrated diagrammatically in Figure 3.

In this case, the pilot signal is used both for regulation and frequency con-

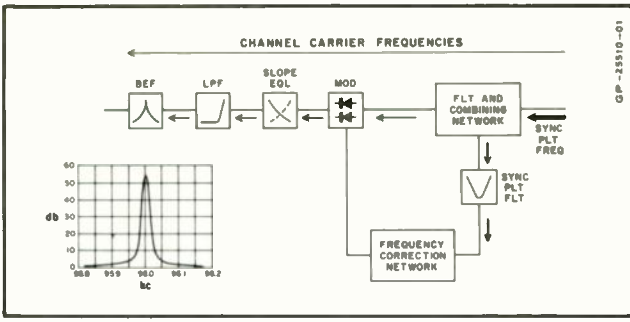

Fig. 3. It is sometimes necessary to severely attenuate a pilot signal to avoid interference. For this purpose, a band-elimination filter is inserted in the common line after the pilot pick-off point.

trol, and is transmitted at a relatively high level when compared to the message level. At pilot pick-off points, a portion of the signal is accepted by the regulator and control circuits on a bridging basis. The remainder of the pilot signal passes through along with the carrier channel frequencies. Level reduction of this pilot frequency to an acceptable minimum is achieved by inserting a band-elimination filter directly into the receiving circuit.

Where low-level pilots are used, it is not always necessary to eliminate the pilot. However, when systems which use pilot signals are interconnected on a carrier frequency basis elimination of pilot frequencies is often necessary. In this case, band-elimination filters are used with the interconnecting equipment.

High-Pass Filters

The ideal high-pass filter passes with a minimum of attenuation all of the frequencies above the filter cut-off frequency, and effectively suppresses all frequencies below cut-off. High-pass filters may be used separately, but are quite often used in conjunction with a low-pass filter. Such filter combinations are used where it is necessary to separate two frequency bands being transmitted over a common line.

The requirements for these filter combinations are different for each application. For this reason, rather than to call such filters by a name which is a combination of the filter types used, the filters are often denoted on the basis of their application. Examples are: (1) directional filter; (2) line filter; and (3) junction filter.

Directional Filters

For two-wire carrier systems, separation of the transmitting and receiving bands is necessary at terminals and repeaters. The filter combination normally used for this purpose at the two- to four-wire junction is called a directional filter. In addition to separating the two frequency bands, the filter provides impedance matching at the junction.

Directional filters are normally designed as a part of the carrier equipment, and therefore are only required to pass the frequency bands used in the carrier system. For this reason, directional filters may consist of two band-pass filters or a low- and high-pass filter combination. Figure 4 illustrates the use of directional filters at a repeater location.

Line Filters

The most effective means of utilizing a wire pair is to sub-divide the available

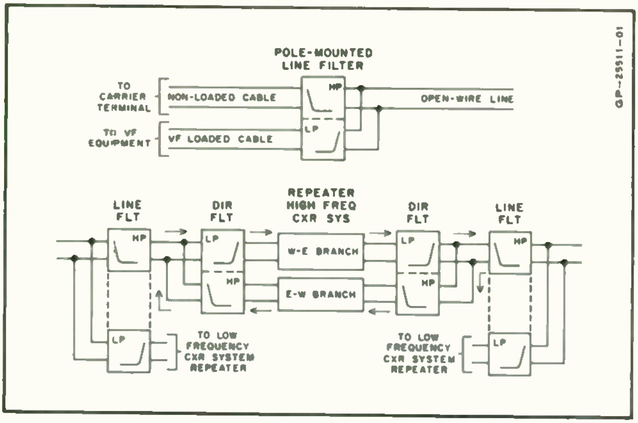

Fig. 4. A line filter is used to separate the frequency bands used by two carrier systems or by a carrier system and a voice circuit. Directional filters separate the frequency bands of a carrier system used for the two directions of transmission.

frequency band into carrier channels. Quite often this can only be achieved by using two or more carrier systems. At terminals and repeaters, and sometimes at intermediate points, it is necessary to separate the frequency bands of the different carrier systems. The devices most commonly used for this purpose are called line filters and junction filters.

Line filters normally consist of low-pass and high-pass filter sections. The low-pass section will effectively transmit all frequencies below cut-off, and the high-pass section will pass frequencies above cut-off which are in the normally used carrier frequency spectrum. Two types of line filters are commonly used: (1) main-station line filters; and, (2) auxiliary-station line filters.

Main-station line filters are used at terminals and main repeater stations where all carrier systems on the line are repeatered. These filters provide the desired out-of-band metallic suppression, but have relatively low longitudinal suppression characteristics. Therefore, these filters may be used for phantom operation, and are intended for use when low-frequency equipment is connected to the equipment side of the low-pass filter section. Two applications of main-station line filters are shown in Figure 4.

Auxiliary station line filters are designed for use at intermediate repeater stations where only the high-frequency carrier system is repeatered. For this reason, the low-pass sections are designed to be connected directly together. To prevent excessive longitudinal coupling around the repeater, these filters are designed to provide longitudinal suppression which is in the same order of magnitude as the suppression in the metallic path. This high order of longitudinal suppression virtually negates operation of auxiliary-station line filters on phantom circuits.

Junction Filters

Junction filters are similar to main-station line filters, but are normally designed for applications at non-gain points—such as at the junction of open-wire lines and intermediate cables. Since a number of these filters may be used between terminals, the suppression is kept low to prevent appreciable degradation of the frequencies near the limits of the pass band.

A STACKABLE 264-CHANNEL CARRIER SYSTEM

For Radio Applications

In most radio systems, the message channels initially installed are only those that are necessary to meet current traffic requirements. To meet the demands of future growth, it is important that the channel capacity of the multiplex equipment used be readily expandable. One way in which this may be accomplished is by using a basic building block concept. This technique is employed in the Lenkurt Type 45BX Carrier Telephone System by building up to line frequencies from either 24- or 48-channel groups depending upon the line frequency. Not only is expansion facilitated in this design concept, but the restriction of active circuit components to a maximum of 48 channels increases the overall system reliability. In addition, transmission path frequency control may be easily applied to small groups of channels. This is particularly important where drop-off and branching arrangements are included in a system.

Many of the applications features of the Lenkurt 45BX system are made possible by the use of single-sideband, suppressed-carrier, amplitude modulation, and because of the manner in which the line frequencies are obtained. Thus, 264 carrier-derived channels are obtained in the frequency range 12 to 1288 kc.

Initial modulation steps are identical with those used for other 45-class systems, thereby permitting interconnection at carrier frequencies. The complete

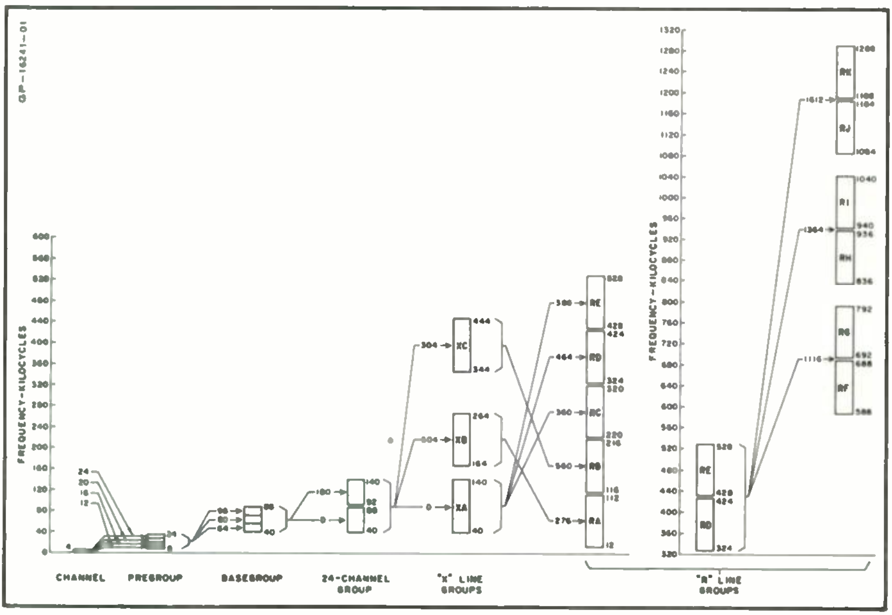

Fig. 1. Modulation plan of the Type 45BX Carrier Telephone System.

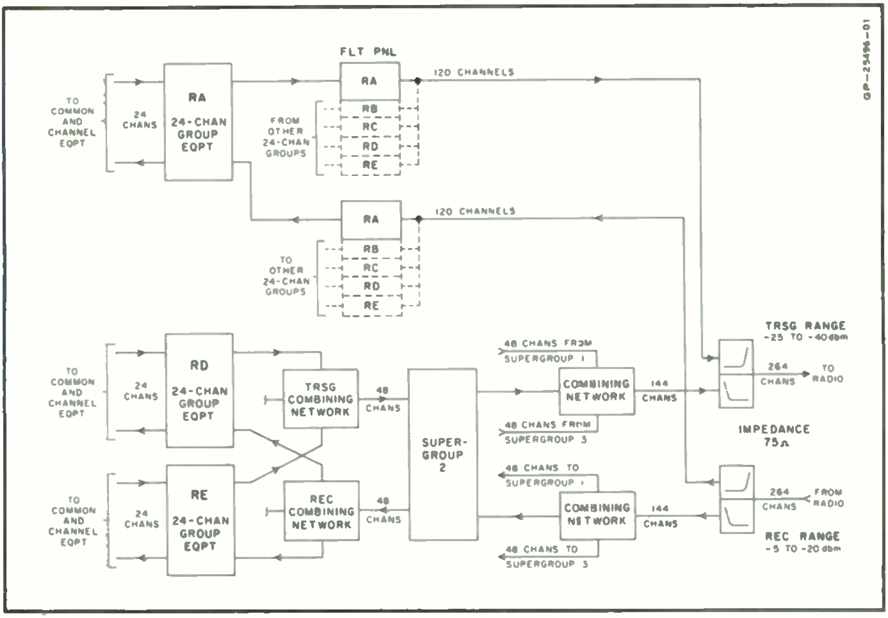

Fig. 2. A simplified block diagram of a 264-channel 45BX system is shown. Similar equipment is used for each basic 24-channel group. Additional modulation steps, either on a 24- or 48-channel basis, are required to derive the line frequencies.

modulation plan is shown in Figure 1. As shown in the figure, the basic building block is the 24-channel group in the frequency range 40 to 140 kc. Preceeding modulation steps are performed by equipment that is similar for each 24-channel group included in the system. The final line frequencies for either the X or R allocations are obtained by one or more additional modulation steps. In this way, no active elements are common to more than 24 channels for the X allocation and the first five R groups (RA, RB, RC, RD and RE). Passive circuit elements are used in either the combining networks or filters that are required for connecting the groups to the common transmission medium.

Expansion of a basic system to 120 channels may be achieved with no more than 24 channels using the same active common equipment. When the system is to be expanded beyond 120 channels, the additional modulation step required is provided by 48-channel supergroup equipment. Active circuitry in equipment, common to more than 24 channels, is completely paralleled to insure maximum reliability. For example, the failure of an amplifier in the parallel configuration will not degrade system performance.

Three supergroups are used, each of which will place the 48 channels obtained from a combination of an RD and an RE group in their position in the line frequency spectrum. This is shown, for the 264-channel system, in the modulation plan of Figure 1, and in the simplified block diagram of Figure 2.

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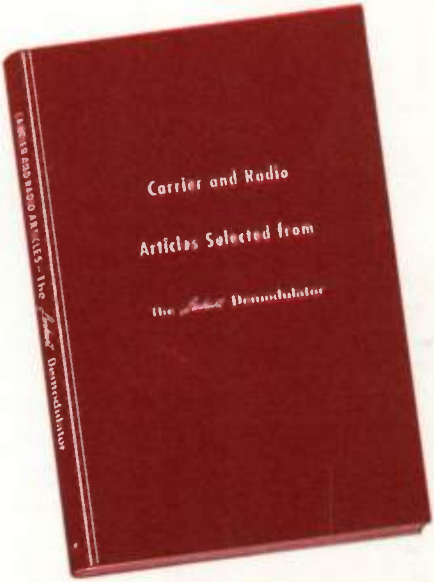
NEW PUBLICATION

To fill the many requests received, 32 articles selected from the past issues of The Lenkurt Demodulator have been compiled and published in **book** form. The articles are grouped under four chapter headings. Chapter titles are: (1) Measurements in Carrier and Radio; (2) Carrier Wave Transmission; (3) Data Transmission—including AM and FM telegraph systems; and, (4) Microwave Equipment and Transmission. The book is titled **Carrier and Radio Articles Selected from The Lenkurt Demodulator,** and is priced at $2.50. Orders should be addressed to the Editor, The Lenkurt Demodulator, Lenkurt Electric Co., Inc., San Carlos, California. Please send check or money order payable to Lenkurt Electric Co., Inc., with your order.



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