The Lenkurt® Demodulator

NEWS FROM LENKURT ELECTRIC

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MULTIPLEXING AND MODULATION

In Carrier Telephone Systems
Part I

Multiplexing is the means by which a number of circuits may be combined for transmission over a common transmission medium. Modulation is the process by which multiplexing may be effected. Although a number of different types of modulation are possible, only two basic multiplexing methods—frequency division and time division—are in common use. For the two different multiplexing methods, any one of several types of modulation may be used.

In this article, frequency-division multiplexing is defined and its use with the various standard methods of amplitude modulation is discussed. Frequency modulation (another form of modulation which may be used in frequency-division multiplexing), time-division multiplexing and modulation methods used with time division are considered in a subsequent article.

Even at the time of the invention of the telephone, the advantages of transmitting several information circuits over a common medium were recognized. Since then much effort has been expended in developing multiplexing techniques. In present-day practical systems one of two basically different multiplexing methods is employed—frequency division or time division.

Frequency Division

Frequency division is so called because each multiplexed circuit is preassigned a specific frequency band (channel) for transmission of its information. In this way, individual circuits may be combined on a facility and simultaneously transmitted over a common transmitting medium. The concept of multiplexing is shown diagrammatically in Figure 1; and the technique for frequency-division multiplexing (FDM) is shown in Figure 2.

In combining a number of circuits for frequency-division multiplexing, the principal requirement is that the technique include a method of translating the original circuit frequencies into the frequency band assigned for transmission. Any one of a number of modulation processes may be used for this purpose. Forms of either amplitude modulation or angle modulation are often used, with amplitude modulation being the most common.

Modulation

In telecommunications, modulation is used in many different applications. For example, the conversion of sound energy into electrical energy by a telephone transmitter is a form of modulation. However, in frequency-division multiplexing, modulation is the word used to describe the process in which an electrical wave acts to change a characteristic —for example amplitude or frequency— of a second wave. The resulting wave then contains properties of both original waves.

In the process of modulation, there are three basic waves —modulating wave, carrier wave and modulated wave. The modulating wave may be made up of any type of information which has been converted into electrical impulses. In carrier telephony, the modulating wave is the complex electrical wave form of speech obtained from the telephone transmitter.

The carrier wave is normally a single-frequency electrical signal that has been derived from a frequency generator (oscillator). The frequency of the carrier wave establishes the circuit position in the available frequency spectrum.

The modulated wave is the resultant output wave of the modulation process;

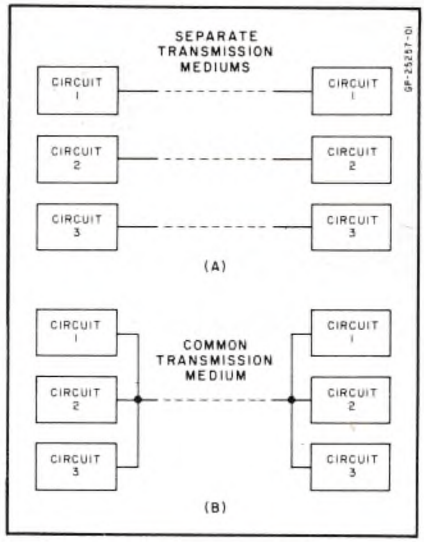

Fig. 1. Illustrating the more effective utilization of a transmission medium by multiplexing. (a) Without multiplexing separate facilities are required for each circuit. (b) With multiplexing the three circuits may use one transmission path.

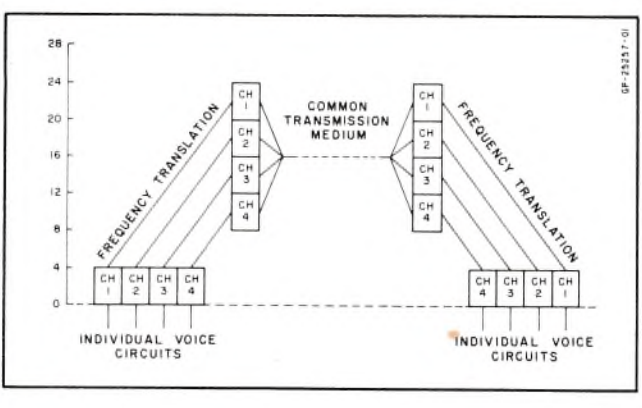

Fig. 2. In frequency-division multiplex systems, each circuit (channel) is translated to its own position in the frequency spectrum before being applied to a common transmission medium.

it contains the carrier wave modified by the action of the modulating wave.

Amplitude Modulation

In amplitude modulation, the amplitude of the carrier wave is controlled by the modulating wave. As shown in Figure 3, the resultant modulated wave has the same frequency as the carrier, but the carrier wave amplitude varies in direct relation to the modulating wave. In fact, the curves through both the positive and negative peaks of the modulated wave are identical to the modulating wave, and they are called the wave envelopes. The modulation factor, m, is a measure of the degree of modulation. For a sinusoidal variation as shown in Figure 3, the modulation factor —normally called the *modulation index* and sometimes the *degree of modulation*— is equal to the peak amplitude of the envelope minus the amplitude of the unmodulated carrier divided by the amplitude of the unmodulated carrier. For more complex signals, the modulation index is more difficult to determine since it will vary from one instant to another. In any case, the modulation index is the fractional extent by which the modulation varies the amplitude of the carrier, and is often expressed as percent modulation by multiplying the modulation index by 100.

From Figure 3 it is apparent that the maximum amount that the carrier amplitude can be varied, without loss of signal, is equal to the carrier amplitude. When this occurs, 100 percent modulation is obtained.

An analysis of the modulated wave resulting from amplitude modulation shows that the modulated wave consists essentially of the carrier wave and frequencies above and below the carrier wave. These side frequencies are separated from the carrier by a frequency equal to that of the modulating wave. Where a complex modulating wave—such as speech or music— is used, the side frequencies above and below the carrier each consist of a band (sideband) of frequencies. A sideband includes all of the frequency components of the modulating wave.

Three important factors in the use of amplitude modulation are derived from an analysis of the modulated wave: (1) the sidebands obtained from a complex wave each have the same bandwidth as the original modulating

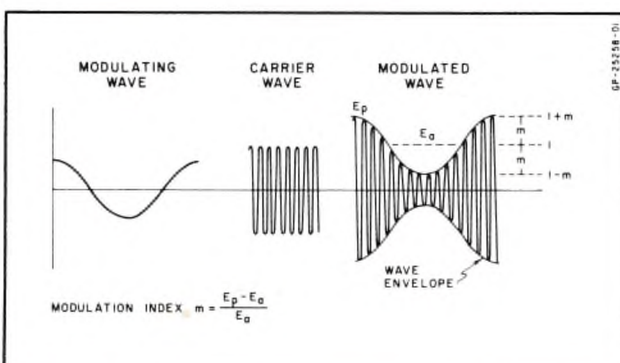

Fig. 3. Amplitude modulation. The amplitude of the carrier is varied by the modulating wave. The frequency of the modulated wave envelope is the same as the modulating wave.

wave; (2) the same intelligence is contained in each sideband; (3) the frequencies in the upper sideband have the same relative relationship as the modulating wave, but those in the lower sideband have an inverse relationship. Not so apparent is the fact that the power distribution in the sidebands is directly related to the distribution of power in the modulating wave.

Double Sideband

As a result of amplitude modulation, the frequency band of the modulating wave is translated to a different position in the frequency spectrum. It is this ability of translation during the modulation process which is used in combining circuits for frequency-division multiplexing. If both sidebands and the carrier are used, the multiplexing technique is called double-sideband amplitude modulation (DSB-AM, or normally AM).

Although AM is quite commonly used in radio broadcasting, a disadvantage of this method in carrier telephone multiplexing is the magnitude of power in the carrier in relation to the sideband (information) power. Even with 100 percent modulation, the power in each sideband is only 1/4 of that in the carrier. Since the power in the sidebands is proportional to the square of the modulation index, for low modulation levels the sideband power will become only a fraction of the carrier power.

In multiplexing, this is quite important because of the number of channels that are involved. The various parts of the system common to more than one channel must be designed to be capable of handling a large amount of power that is not useful in the transmission of information. In addition, the sideband-to-noise power is relatively low.

For these reasons, it is common in double-sideband multiplexing either to

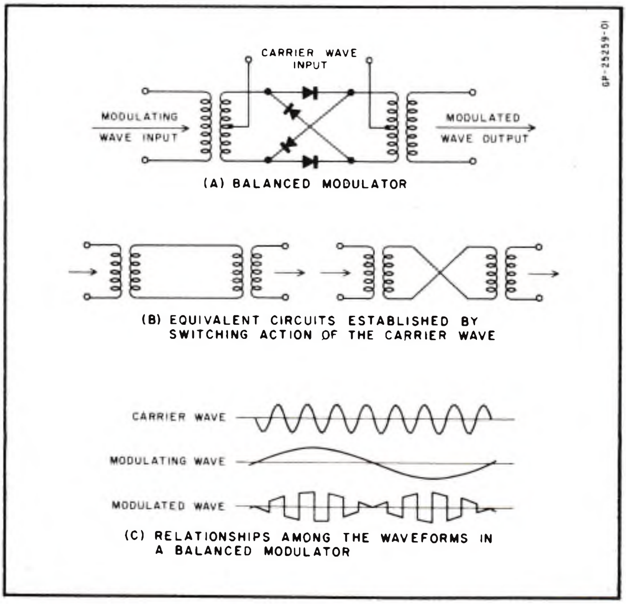

Fig. 4. A balanced modulator may be used where it is desired to suppress the carrier. The modulated wave then contains the upper and lower sidebands.

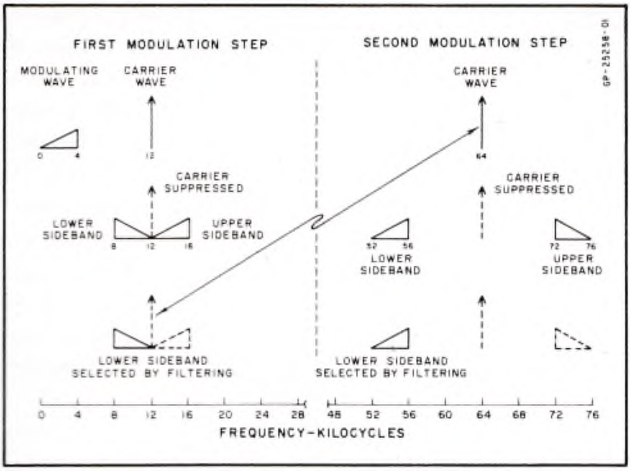

Fig. 5. A number of modulation steps are sometimes required to position a channel in the carrier frequency spectrum. Where SSB-SC is used, the carrier and unwanted sideband are removed at each step of modulation.

suppress the carrier (DSB-SC) or to transmit the carrier at a relatively low level. Where the carrier is suppressed, some method of deriving a carrier frequency at the receiving terminal is necessary. This may be done either by separately generating the carrier frequency, deriving the carrier frequency from the transmitted sidebands, or by transmitting a separate tone from which the demodulating frequencies may be derived.

After the carrier is suppressed, it is possible to increase the sideband power and still keep the power handling capacity of common equipment units below that which would have been required if the carrier were transmitted. This increases the operating range of the equipment considerably.

Some of the advantages of DSB-SC multiplexing are: (1) the relative simplicity of the modulation process; (2) relatively lenient filter requirements, particularly in the transmitting direction; and, (3) the relative immunity to distortion which may occur in transmission. A particular disadvantage is the bandwidth used for the information transmitted.

Single Sideband

In amplitude modulation, the two sidebands produced each carry the same information. If only one sideband were transmitted, the required bandwidth could be reduced at least in half.

The frequency separation between the carrier and each sideband is equal to the frequency of the modulating wave. Where a complex modulating wave such as speech or music is used, the sideband frequencies may differ from the carrier frequency by a few cycles per second up to several kilocycles. Unless the low frequencies are restricted to above about 200 cycles, the problem of suppressing the carrier and the unwanted sideband, without undue distortion of the wanted sideband, becomes very difficult. The loss of the low frequencies has very little effect on the quality or fidelity of speech, and is usually tolerated to a very high degree in music. For this reason single-sideband suppressed-carrier multiplexing is suitable for carrier telephony, and in fact has been the most commonly used method.

The principal advantage of SSB-SC is the efficient bandwidth utilization in the transmission of information. In toll telephone applications, the increased channel capacity that can be obtained in a limited bandwidth far outweighs the necessary complexity of equipment design. In addition to bandwidth conservation, the reduced bandwidth improves the signal-to-noise ratio as compared to a DSB-SC system. However, SSB-SC systems suffer from an inherent delay limit which is a result of filtering out one sideband and the carrier; and, an SSB-SC system cannot be used directly for pulse transmission because of the low frequency limit.

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A NEW CARRIER TELEPHONE SYSTEM for Narrow Band Radio

A general description of Lenkurt's new **Type 45CX Carrier Telephone System** is given in bulletin, Form 45CX-P4. The Type 45CX is a four-channel carrier telephone system designed for light route radio circuit applications, and may be obtained separately or as a part of the Lenkurt Type 911 Radio System. Copies of the recently issued publication, Form 45CX-P4, may be obtained from Lenkurt's offices and distributors.

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