Phase Modulation

a. General.

(1) Besides its amplitude, the frequency or phase of the carrier can be varied to produce a signal bearing intelligence. The process of varying the frequency in accordance with the intelligence is frequency modulation, and the process of varying the phase is phase modulation. When frequency modulation is used, the phase of the carrier wave is indirectly affected. Similarly, when phase modulation is used, the carrier frequency is affected. Familiarity with both frequency and phase modulation is necessary for an understanding of either.

(2) In the discussion of carrier characteristics, carrier frequency was defined as the number of cycles occurring in each second. Two such cycles of a carrier are represented by curve A in figure 8. The starting point for measuring time is chosen arbitrarily, and at 0 time, curve A has some negative value. If another curve B, of the same frequency is drawn having 0 amplitude at 0 time, it can be used as a reference in describing curve A.

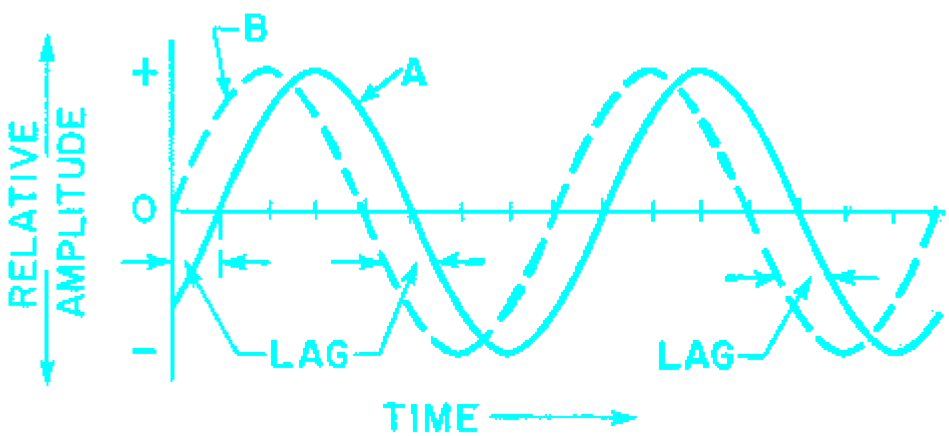

Figure 8. Determining relative phase from a curve of the same frequency.

(3) Curve B starts at 0 and swings in the positive direction. Curve A starts at some negative value and also swings in the positive direction, not reaching 0 until a fraction of a cycle after curve B has passed through 0. This fraction of a cycle is the amount by which A is said to lag B. Because the two curves have the same frequency, A will alsays lag B by the same amount. If the positions of the two curves are reversed, then A is said to lead B. The amount by which A leads or lags the reference is called its phase. Since the reference given is arbitrary, the phase is relative.

c. Phase Modulation.

(1) In phase modulation, the relative phase of the carrier is made to vary in accordance with the intelligence to be transmitted. The carrier phase angle, therefore, is no longer fixed. The amplitude and the average frequency of the carrier are held constant while the phase at any instant is being varied with the modulating signal (fig. 11). Instead of having the vector rotate at the carrier frequency, the axes of the graph can be rotated in the opposite direction at the same speed. In this way the vector (and the reference) can be examined while they are standing still. In A of figure 11 the vector for the unmodulated carrier is given, and the smaller curved arrows indicate the direction of rotation of the axes at the carrier frequency. The phase angle, □ , is constant in respect to the arbitrarily choosen reference. Effects of the modulating signal on the relative phase angle at four different points are illustrated in B, C, D, and E.

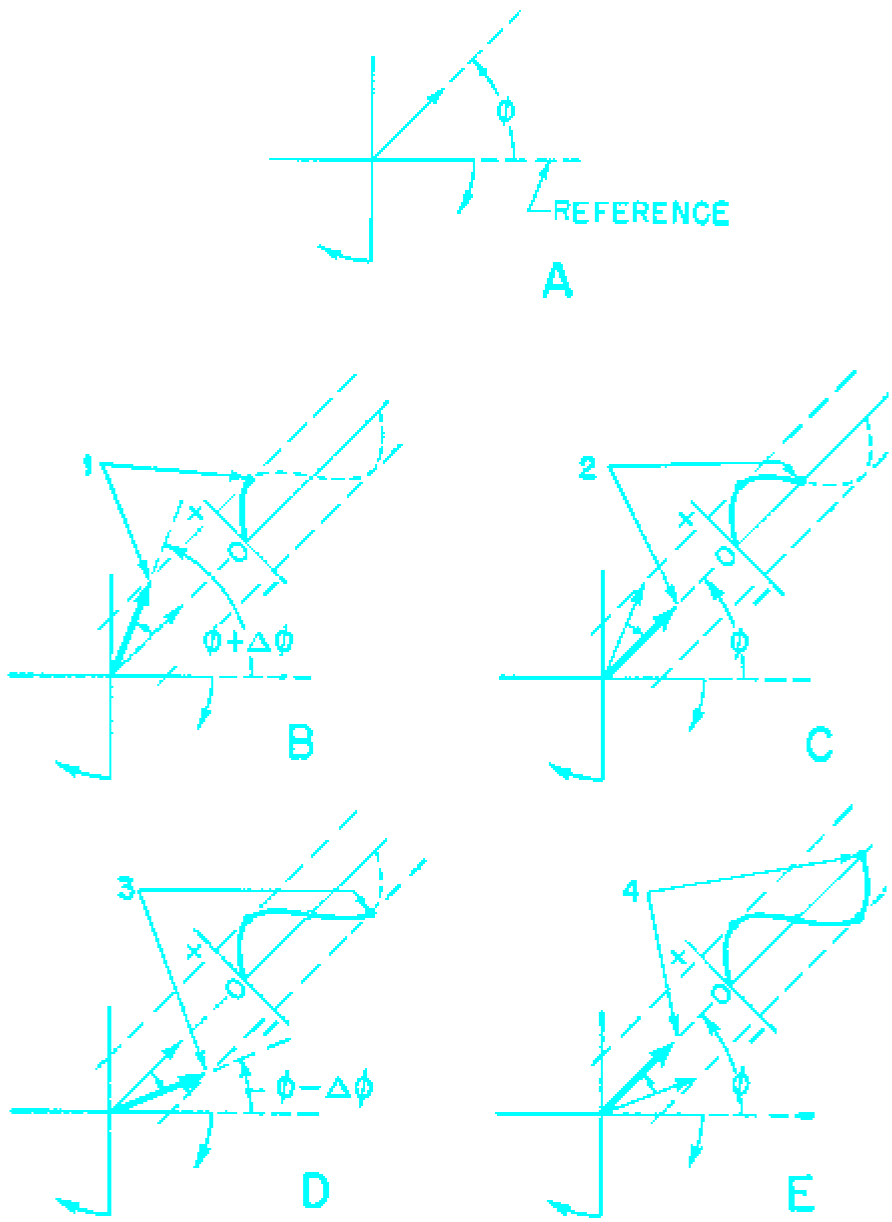

Figure 11. Successive vector representation of a phase-modulated carrier.

(2) The effect of a positive swing of the modulating signal is to speed the rotation of the vector, moving it counterclockwise and increasing the phase angle, □ . At point 1, the modulating signal reaches its maximum positive value, and the phase has been changed by the amount □ □ . The instantaneous phase condition at 1 is, therefore, (□ □ □).Having reached its maximum value in the positive direction, the modulating signal swings in the opposite direction. The vector speed is reduced and it appears to move in the reverse direction, moving towards its original position.

(3) For each cycle of the modulating signal, the relative phase of the carrier is varied between the values of (□ □ □) and (□ □ □).These two values of instantaneous phase, which occur at the maximum positive and maximum negative values of modulation, are known as the phase-deviation limits. The upper limit is □ □ ; the lower limit is □ □ The relations between the phase-deviation limits and the carrier vector are given in the figure 12, with the limits of +/- □ □ indicated.

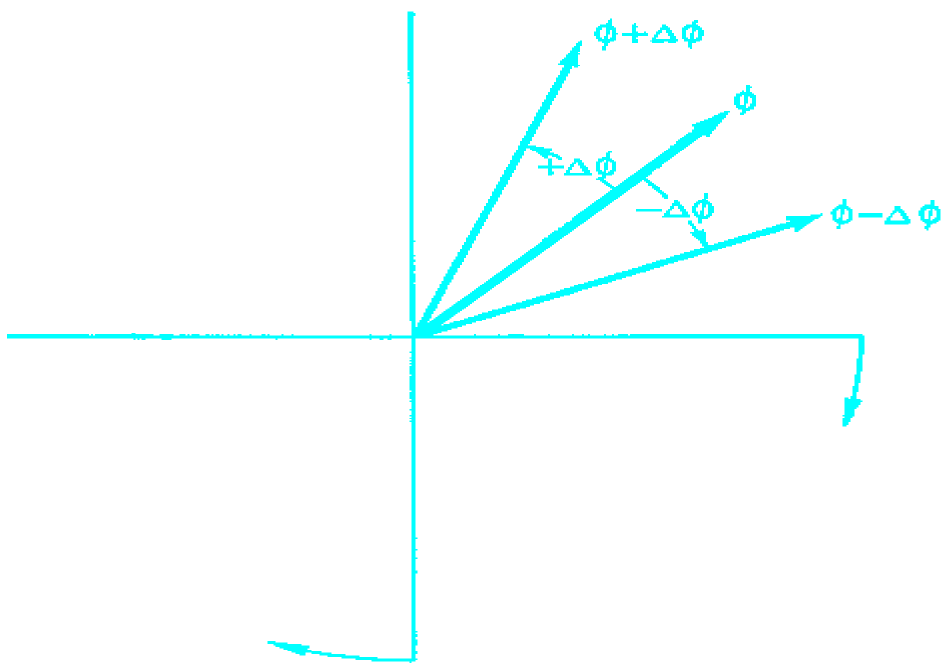

Figure 12. Phase-deviation limits of a modulated carrier.

(4) If the phase-modulated vector is plotted against time, the result is the wave illustrated in the figure 13. The modulating signal is shown in A. The dashed-line waveforem, in B, is the curve of the reference vector and the solid-line waveform is the carrier. As the modulating signal swings in the positive direction, the relative phase angle is increased from an original phase lead of 45° to some maximum, as shown at 1 in B. When the signal swings in the negative direction, the phase lead of the carrier over the reference vector is decreased to minimum value, as shown at 2; it then returns to the original 45° phase lead when the modulating signal swings back to 0. This is the basic resultant wave for sinusoidal phase modulation, with the amplitude of the modulating signal controlling the relative phase characteristic of the carrier.

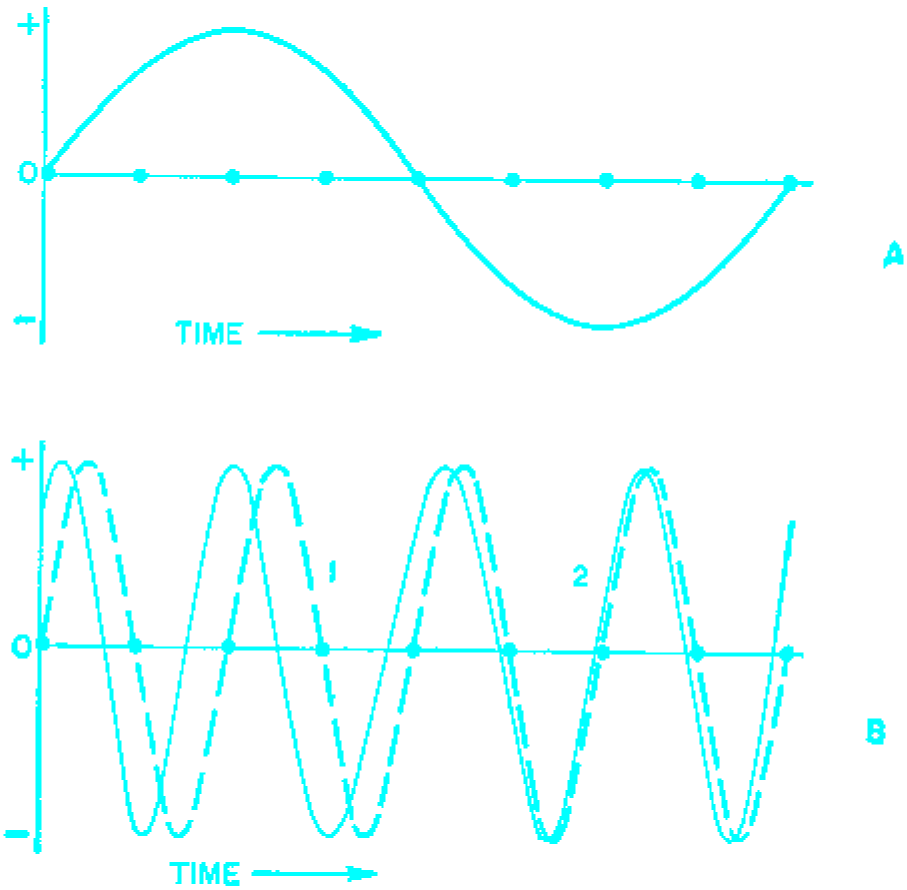

Figure 13. Phase-modulated carrier over 1 cycle of modulating signal.

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