# RADIO ENGINEERING

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*Methods of Transmitting Intelligence by Pulses.*—The most widely used method of employing pulses to transmit intelligence is by *pulse position modulation*, also sometimes called pulse time modulation. Pulse position modulation utilizes short pulses of constant amplitude that have a repetition frequency at least several times the highest frequency contained in the intelligence to be transmitted. The time of occurrence of these pulses

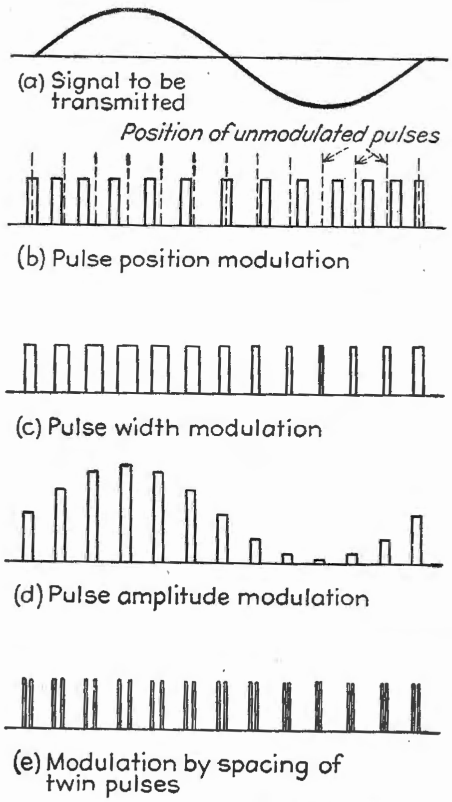


FIG. 15-30.—Various methods of pulse modulation.

is then varied in accordance with this signal.[1] Such pulses are illustrated in Fig. 9-24, which also shows one method of producing pulses that are modulated in position. These pulses are used to modulate or key a microwave oscillator such as a magnetron, klystron, or reflex klystron giving a transmitted signal such as shown in Fig. 15-30*b*. At the receiver the intelligence thus transmitted may be recovered from the pulses in a number of ways. One simple way is to rectify the incoming signal as it

[1] Throughout this discussion, the term *signal* denotes the intelligence that is to be transmitted.

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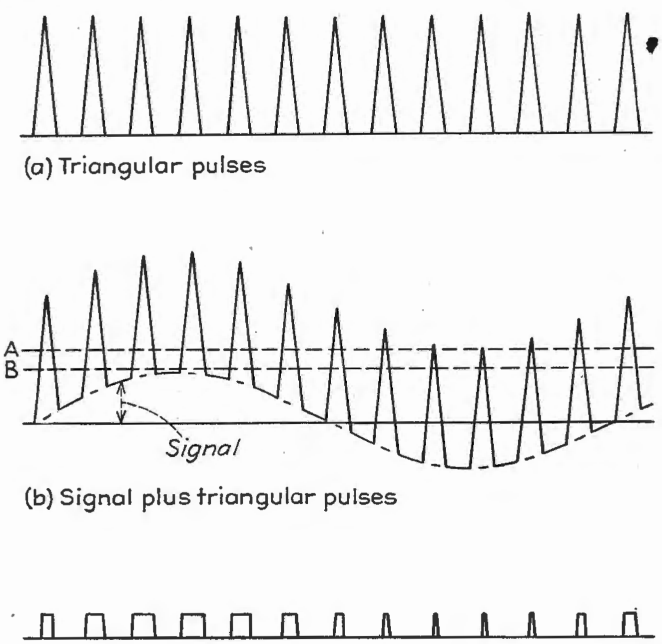
comes out of the intermediate-frequency amplifier, thereby obtaining pulses similar to those modulated upon the transmitter. These pulses can be considered as representing a carrier wave of the pulse repetition frequency, which is phase-modulated by the intelligence being transmitted, together with harmonics of this pulse repetition frequency similarly modulated. The fundamental-frequency carrier and its frequency-modulation side bands may be separated by appropriate filter circuits, passed through a chain of harmonic generators to increase the




(a) Triangular pulses

(b) Signal plus triangular pulses

(c) Pulses obtained by selecting amplitude range AB

FIG. 15-31.—Method of modulating the width of pulses in accordance with a signal.

frequency deviation, and then applied to an ordinary frequency-modulation receiver.

Pulse position modulation is not the only means by which pulses may be used to transmit intelligence. Another possibility is to vary the width of the pulses in accordance with the signal to be transmitted, giving *pulse width modulation* as shown in Fig. 15-30*c*. Such a wave can be produced by superimposing triangular pulses upon the signal, and then using for the transmitted pulse the portion of the wave lying between two properly chosen amplitude levels, such as *A* and *B*, Fig. 15-31. Another possibility is to modulate the amplitude of successive pulses in accordance with the signal to be transmitted, giving the result illustrated in Fig.

15-30*d*. Finally, one can use a combination of pulses to transmit the signal. An example of this is illustrated Fig. 15-30*e*, in which the pulses appear in pairs, with the spacing between the pulses in each pair being varied proportionally to the instantaneous amplitude of the signal being transmitted.

*Time Multiplex.*—The minimum permissible spacing between pulses is about 0.4 times the time corresponding to a single cycle of the highest frequency contained in the signal to be transmitted. Thus, a 100-μsec pulse spacing is quite adequate to transmit 3500 cycles. Furthermore, the pulses themselves can be quite short, such as 1 μsec, and in pulse position modulation it is not necessary to shift the pulses by over ±5 μsec at the peak amplitude of the signal in order to obtain satisfactory pulse position modulation. Thus, only about 10 μsec of each 100-μsec interval is actually required for transmitting the intelligence. The remaining 90 μsec can be used by other pulses transmitting other signals.

This leads to what is termed *time multiplex*, in which successive intervals of time are assigned to different channels. Thus, in the case cited above, one could simultaneously transmit eight signals assigned successive 12-μsec time intervals (10 μsec for the pulse, plus an additional 2 μsec to provide protection against adjacent channels), and send an extra-long synchronizing pulse during the remaining 4 μsec of each 100-μsec period. Such a time multiplex signal can be obtained by generating the pulses for each individual channel just as though this channel were acting alone, except that the pulses for the successive channels have a progressive time difference, which in the case indicated above would be 12 μsec. The mixture of pulses obtained in this way from the various channels is then modulated on the microwave oscillator in any convenient manner. At the receiving end of the system, the receiver output will deliver pulses that are identical with those that were modulated on the transmitter. This output is then applied to a system consisting of a series of gates, one for each channel, with inputs connected in parallel. These gates are controlled by the synchronizing pulse, which can be distinguished from the other pulses by its greater width. The control is such that the gate associated with a given channel is open during the particular 12-μsec part of the 100-μsec period in which the pulses of that channel are transmitted.

*Signal-to-noise Ratio.*—A noise-suppressing action occurs in pulse systems that is analogous to that encountered in frequency modulation. In particular, if the signal amplitude is appreciably greater than the noise, then it is possible to derive pulses from the receiver output that are almost completely free of noise. This can be understood by considering the ideal case of a pulse having vertical sides and an amplitude moderately greater than the noise, as illustrated in Fig. 15-32. If now one arranges matters so that amplitude levels less than *A* of the combined noise and