UNIT – 8: MTI AND PULSE DOPPLAR RADAR – LECTURE 3

DELAY-LINE CANCELERS

The simple MTI delay-line canceller. The capability of this device depends on the quality of the medium used is the delay line. The Pulse modulator delay line must introduce a time delay equal to the pulse repetition interval.

For typical ground-based air-surveillance radars this might be several milliseconds. Delay times of this magnitude cannot be achieved with practical electromagnetic transmission lines. By converting the electromagnetic signal to an acoustic signal it is possible to utilize delay lines of a reasonable physical length since the velocity of propagation of acoustic waves is the necessary delay is introduced by the acoustic line, the signal is converted back to an electromagnetic signal for further processing.

The early acoustic delay lines developed during World War II used liquid delay lines filled with either water or mercury. Liquid delay lines were large and inconvenient to use. They were replaced in the mid-1950s by the solid fused-quartz delay line that used multiple internal reflections to obtain a compact device. These analog acoustic delay lines were, in turn, supplanted in the early 1970s by storage devices based on digital computer technology. The use of digital delay lines requires that the output of the MTI receiver phase-detector be quantized into a sequence of digital words. The compactness and convenience of digital processing allows the implementation of more complex delay-line cancellers with filter characteristics not practical with analog methods.

One of the advantages of a time-domain delay-line canceller as compared to the more conventional frequency-domain filter is that a single network operates at all ranges and does not require a separate filter for each range resolution cell. Frequency-domain doppler filterbanks are of interest in some forms of MTI and pulse-doppler radar.

Filter characteristics of the delay-line canceller

The delay-line canceller acts as a filter which rejects the d-c component of clutter. Because of its periodic nature, the filter also rejects energy in the vicinity of the pulse repetition frequency and its harmonics.

\[ V_1 = k \sin (2\pi f_d t - \phi_0) \]

where \( \phi_0 \) = phase shift and \( k \) = amplitude of video signal. The signal from the previous transmission, which is delayed by a time \( T = \) pulse repetition interval, is

\[ V_2 = k \sin [2\pi f_d (t - T) - \phi_0] \]

Everything else is assumed to remain essentially constant over the interval \( T \) so that \( k \) is the same for both pulses. The output from the subtractor is

\[ V = V_1 - V_2 = 2k \sin \pi f_d T \cos \left[ 2\pi f_d \left( t - \frac{T}{2} \right) - \phi_0 \right] \]
It is assumed that the gain through the delay-line canceller is unity. Thus the amplitude of the canceled video output is a function of the Doppler frequency shift and the pulse-repetition interval, or prf. The magnitude of the relative frequency-response of the delay-line canceller is the ratio of the amplitude of the output from the delay-line canceller, to the amplitude of the normal radar video.

**Frequency response of the single delay-line canceller**: \( T = \text{delay time} = 1/f_p \)

**Blind speeds**: The response of the single-delay-line canceller will be zero whenever the argument \( \Pi f_d T \) in the amplitude factor. The blind speeds are one of the limitations of pulse MTI radar which do not occur with CW radar. They are present in pulse radar because doppler is measured by discrete samples (pulses) at the prf rather than continuously. If the first blind speed is to be greater than the maximum radial velocity expected from the target, the product \( \Pi f_d T \). If the first blind speed must be large. Thus the MTI radar must operate at long wavelengths (low frequencies) or with high pulse repetition frequencies, or both.

**Double cancellation**: The frequency response of a single-delay-line canceller does not always have as broad a clutter-rejection null as might be desired in the vicinity of d-c. The clutter-rejection notches may be widened by passing the output of the delay-line canceller through a second delay-line canceller. The output of the two single-delay line cancellers in cascade is the square of that from a single canceller.

The two-delay-line configuration has the same frequency-response characteristic as the double-delay-line canceller. The operation of the device is as follows. A signal \( f(t) \) is inserted into the adder along with the signal from the preceding pulse period, with its amplitude weighted by the factor -2, plus the signal from two pulse periods previous. The output of the adder is therefore

\[
 f(t) - 2f(t + T) + f(t + 2T)
\]

which is the same as the output from the double-delay-line canceller

\[
 f(t) - f(t + T) - f(t + T) + f(t + 2T)
\]

This configuration is commonly called the **three-pulse canceller**.
MULTIPLE, OR STAGGERED, PULSE REPETITION FREQUENCY

The use of more than one pulse repetition frequency offers additional flexibility in the design of MTI doppler filters. It not only reduces the effect of the blind speeds but it also allows a sharper low-frequency cutoff in the frequency response than might be obtained with a cascade of single-delay-line cancelers.

The blind speeds of two independent radars operating at the same frequency will be different if their pulse repetition frequencies are different. Therefore, if one radar were "blind" to moving targets, it would be unlikely that the other radar would be "blind" also. Instead of using two separate radars, the same result can be obtained with one radar which time-shares its pulse repetition frequency between two or more different values (multiple PRF's). The pulse repetition frequency might be switched every other scan or every time the antenna is scanned a half beamwidth, or the period might be alternated on every other pulse. When the switching is pulse to pulse, it is known as a staggered pulse RADAR frequency (PRF).

An example of the composite (average) response of an MTI radar operating with two separate pulse repetition frequencies on a time-shared basis is shown below.