Figure 8.7 Blind speed.

8.5 MTI Radar (Moving Target Indication)

Moved or shifted targets can be detected in many ways and with many methods and particularly due to:

- Doppler shift
- Range change from scan to scan
- Direction change from scan to scan

At first glance it is not therefore so necessary to integrate the elaborate Doppler signal processing. In practice is it however so that the echoes from moved targets are not received alone, but are rather surrounded by clutter, the echoes of all the reflecting objects found in the resolution region. This clutter mostly masks the echoes of moved objects. By analyzing the Doppler shift, targets, which lay 20 – 30 dB under the clutter lever, can be discovered and selected. There are even examples for the detection of signals smaller by 70 - 90 dB. Circuits, which distinguish these echoes of moved targets from the clutter, are designated as Moving Target Indicators (MTI).

8.5.1 MTI with Delay-Line Canceller

By being given a video signal of a pulse Doppler Radar on a display terminal with sweep (A-Scope) according to Figure 8.8c and then successively representing the echoes of the following pulses, then one can obtain the curves a-e in Figure 8.8. If one uses a display terminal with memory and “writes” the echoes on top of one another, then one obtains Figure 8.8Σ. Fixed targets deliver constant echo amplitudes, while moving targets deliver sine-shaped amplitudes as in Figure 8.8c.

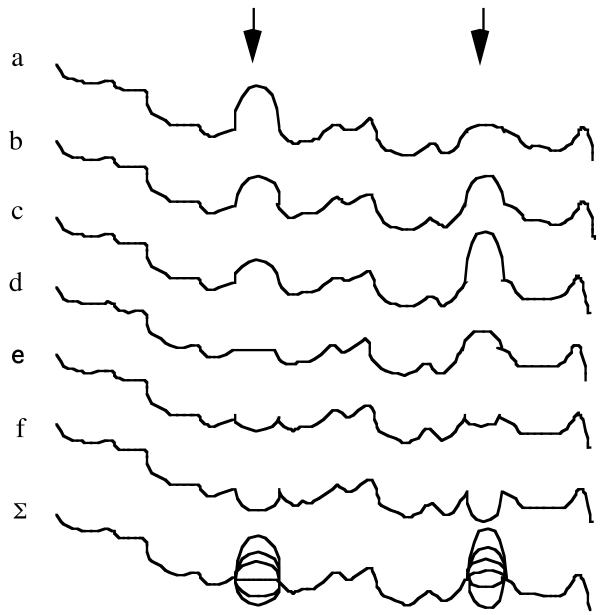

Figure 8.8 Time behaviour of moving targets (↓) on an oscilloscope.

For automatic analysis the fact that fixed-target echoes are constant from pulse to pulse is used. Bipolar video signals are separated into to channels, from which one is delayed by the pulse duration $T = 1/f_p$. Then both are subtracted. The procedure is illustrated in Figure 8.9.

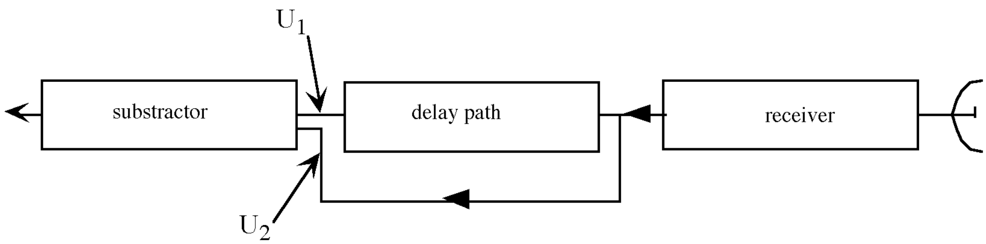

Figure 8.9 MTI with Delay-Line Canceller.

The output of the subtractor can be utilized for the brightness modulation of a PPI scope (Plane Position Indicator). The delay time is equal to the period T of the signal. With electromagnetic waves the necessary delay times within the µs - ms range cannot to be reached. Instead one converts the signal into an acoustic wave and thereby achieves a larger delay time around a factor of 10^5. For some years digital delay methods have been used in addition to the analog methods. The signal is sampled and read into a shift register. The "range gates" determine the cycling (see section 8.6). Examples for MTI Radar and Delay Line Cancellers are shown in Figures 8.10 and 8.11. A single Delay Line Canceller shows a sine characteristic for the suppression of the clutters. If one sets two Single Delay Line Cancellers one behind the other, then a squared sine characteristic results. In continuation, all well-known filter structures (Butterworth, Chebyshev, Bessel, Elliptical, etc.) can be realized. In addition the MTI function can be obtained on the IF side. The equations from above apply with the substitution $\omega_d \rightarrow \omega_{ZF} \pm \omega_d$. Good circuits suppress fixed targets to 1% (voltage).

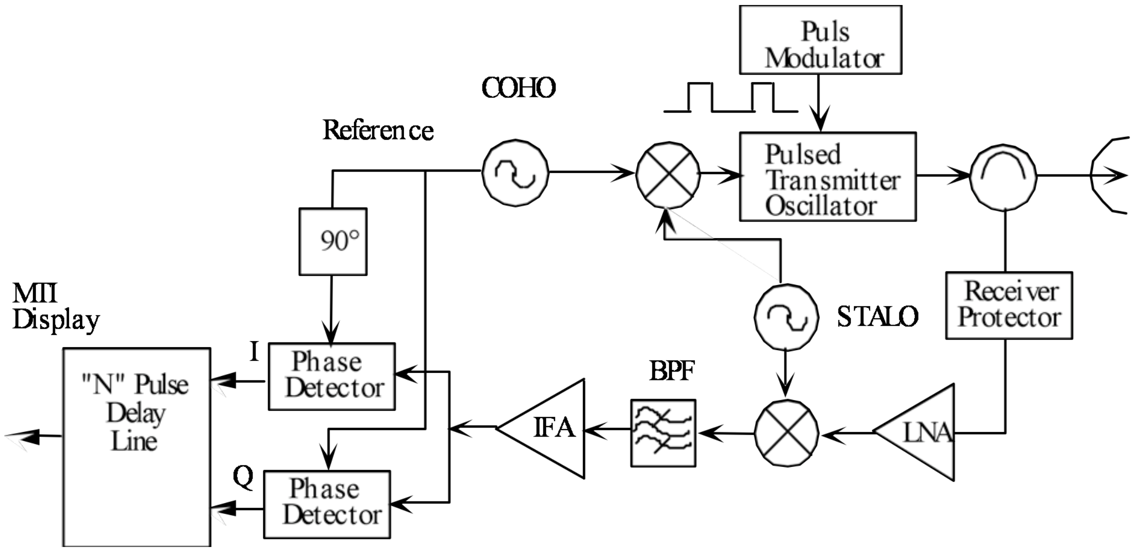

Figure 8.10 Block diagram of MTI Radar.

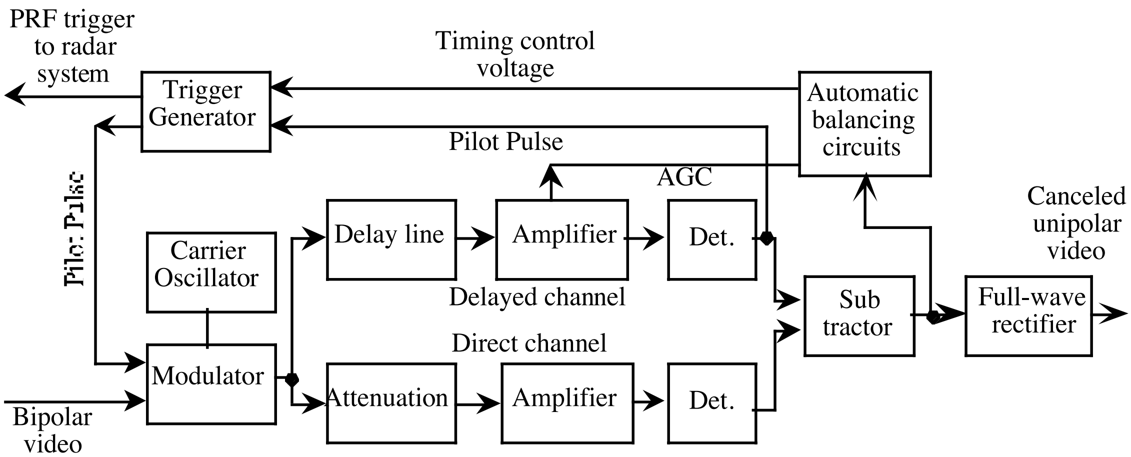

Figure 8.11 Block diagram of a Delay Line Canceller.

8.6 Filterbank Procedure

Here, identified as the filterbank analysis procedure, digital signal processing was quickly devolved and put to use. Range and Doppler frequency regions are divided into sub-regions, which are processed separately. Figure 8.12 shows this division into sub-regions for the range.

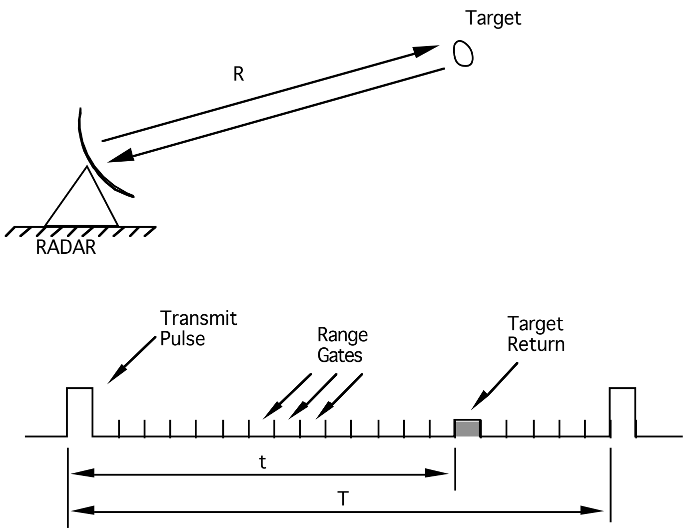

Figure 8.12 Range sub-regions of pulse Radar (range gates).

The earlier "range gates" were digitally switched analog paths. The Doppler frequency is similarly subdivided into frequency regions. A block diagram of the entire arrangement is shown in Figure 8.13.

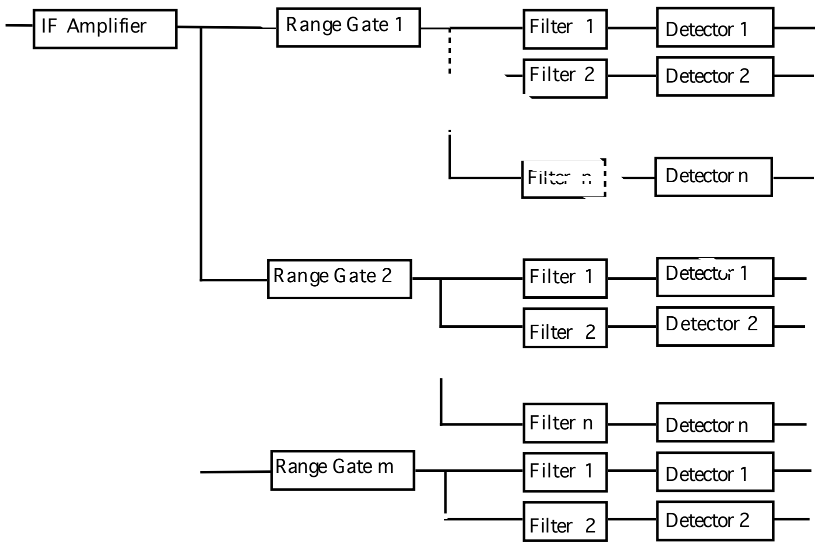

Figure 8.13 Range gates and Doppler filter arrays.

The false alarm rate with this procedure is considerably lower than MTI with delay line cancellation because of the low bandwidth of the filter. With new devices the video signal (bipolar) is sampled and processed by computer. Here, the Fourier transform replaces the filter.

8.7 Impulse Integration for Increasing the Sensitivity

With all Radar devices, which are not agile from pulse to pulse, several pulses are reflected from a target with each sample instance. One identifies the summation of all pulses from a target as integration. The detection becomes even better the more reflected energy from the target is received and integrated. From the Radar equation possibilities for an apparent energy increase can be seen. They each exist only for only one pulse. In this section the dwell time for a target will also be considered. It results in the hits per scan n_B and depends on the following:

- Pulse repetition rate f_p [Hz],
- Half-power bandwidth of the antenna θ_B [Grad],
- Scan-rate of the antenna $\dot{\Theta}_S$ [Grad/sec].

$$n_B = \frac{\Theta_B f_p}{\dot{\Theta}_S} \tag{8.10}$$

Common by rotating Radar systems:

$$10 < n_B < 15 \tag{8.11}$$

For systems with high PRF (Pulse Doppler for short ranges), values of a few hundred for n_B can be obtained. The integration can always take place at two different places in the signal path:

- IF Integration ⇒ Pre-detection or Coherent integration,
- Video Integration ⇒ Post-detection or Incoherent integration.

Coherent integration (pre-detection) is only seldom used, since it assumes a constant phase between transmission and receiving for the pulses to be integrated. The integration can then, for example, take place through a narrow IF filter, whose bandwidth is inversely proportional to the target dwell time. A sample rate of 360°/sec and a 2° half-power bandwidth result in a dwell time of 1/180 sec. That means that the integration filter has a bandwidth of 180 Hz. The integration effect is obtained by the energy storage in the filter. The quality of the filter determines the integration efficiency. In the following the non-coherent integration will be described in more detail.

8.7.1 Incoherent Integration

For incoherent integration the following considerations apply. If n pulses are summed in an ideal integration, then the S/N ratio at the output of the integrator improves by a factor n. This practically cannot be achieved by incoherent integration, since additional noise develops when rectifying. The improvement, which can be achieved by an operator with a storage tube, is approximately proportional to $\sqrt{n}$. From Marcum [6] the achievable improvement, henceforth identified as integration efficiency, is calculated.