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System Design for Multiple Objects Tracking Radar

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ABSTRACT

The system design issues of continuous wave radar for airborne purpose are discussed here. Three different techniques are found suitable for this purpose. We can improvise them for different use.

1.0 INTRODUCTION

Continuous wave radar transmits electromagnetic wave continuously and receives the reflected wave from different objects. Signal processing is done to calculate the magnitude and phase delay of the echo and find the distance to the object. The signal processing associated with radar can be divided into analog and digital domain [1][2]. For long range application magnetic resonance antenna [3] is used and for short range multiple object tracking we use normal antenna. We demodulate the signal by a direct down conversion method. This reduces the noise. For short range multiple objects tracking we favor phase delay detection using a PRN sequence in digital or in analog domain. The section I introduces the subject. The section II describes the single tone radar and the next two sections describe the multiple objects tracking radar. The section V compares the different methods. We conclude the paper in the next section.

2.0 SINGLE TONE RADAR

In case the transmitted signal is a single tone (A_1'*cos(w_ct)) and 90 phase generates the sin(w_ct).

The signal in the antenna will be

$$X(t) = A_1 * \cos(w_c t) + A_2 * \cos\,(w_c t + w_n t + \theta)$$

Where w_c is the carrier frequency, A_1 and A_2 are the amplitudes of the signal and the reflected wave, w_n is the Doppler frequency and θ is the phase angle.

We put a subtractor with automatic gain controller of A_1'*cos(w_ct) where A_1' is nearly equal to A_1.

So the signal to be demodulated is

$$Y(t) = (A_1 - A_1{}') * \cos(w_c t) + A_2 * \cos\,(w_c t + w_n t + \theta)$$

After demodulation in I and Q the signal will be after low pass filter,
$Y_I = (A_1 - A_1') + A_2*\cos(w_n t+\theta)$ and $Y_Q = -A_2*\sin(w_n t+\theta)$.

We pass them through capacitance and square them to add. We get distance from the amplitude A_2^2.

3.0 MULTIPLE OBJECT TRACKING RADAR USING DFC

In case we try to find the objects more than one, we use spread spectrum method of finding the distance from the reflected waves. Now we have to find the number of objects and their distances. The reflected waves will have their own Doppler frequencies. The received signal after subtraction will be,

$$Y = A_2(t) * \cos(w_c t + w_{n2} t + \theta_2) + A_3(t) * \cos(w_c t + w_{n3} t + \theta_3) + A_4(t) * \cos(w_c t + w_{n4} t + \theta_4)$$

We demodulate the signal using the carrier used for transmission and get in In-phase components,

$$Y_1 = A_2(t) * \cos(w_{n2} t + \theta_2) + A_3(t) * \cos(w_{n3} t + \theta_3) + A_4(t) * \cos(w_{n4} t + \theta_4)$$

Similarly we can get the Quadrature phase component. We sample the signal Y_1 at T_c or multiple of(T_c /n)using the clock derived for transmission and digitize it. Then we correlate the signal with PRN code for synchronization. At first we lock to the strongest reflected wave and subtract it and go for next synchronization. This is the principle of decision feedback cancellation [4]. Only drawback of this method is introduction of noise due to analog to digital conversion before correlation. It may be acceptable in some cases and not in other where we use optimum detection principle. Again the $1/T_b$ should be smaller than the maximum Doppler frequency. The schematic is shown in Figure 1.

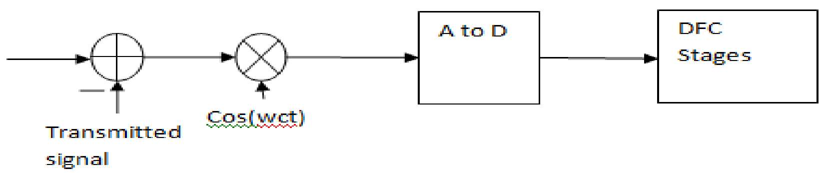

Figure 1. DFC based multiple objects tracking.

In case there are multiple objects in a cluster and then they are from similar distance and similar velocity. Their identity could be found out using DFC method provided the distance found out from phase delay and associated amplitude will show the number of objects. The DFC block diagram is shown in Figure 2.

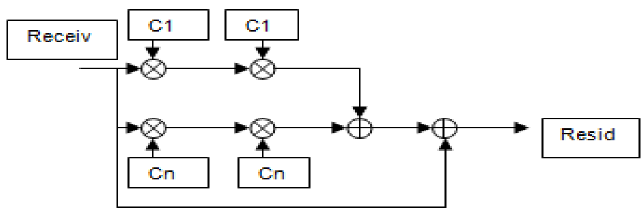

Figure 2. Single stage of decision feedback cancellation scheme.

4.0 MULTIPLE OBJECT TRACKING RADAR USING OPTIMUM DETECTION

The previous method is attractive as it can distinguish multiple objects like missiles in airborne radar. Only drawback is that analog to digital conversion will introduce noise and the precision will lower the detection capability. Hence we opt for Optimum detection with single stage of decision feedback cancellation in analog domain. The transmitted signal is Manchester code differentially encoded. It is shown in Figure 3.

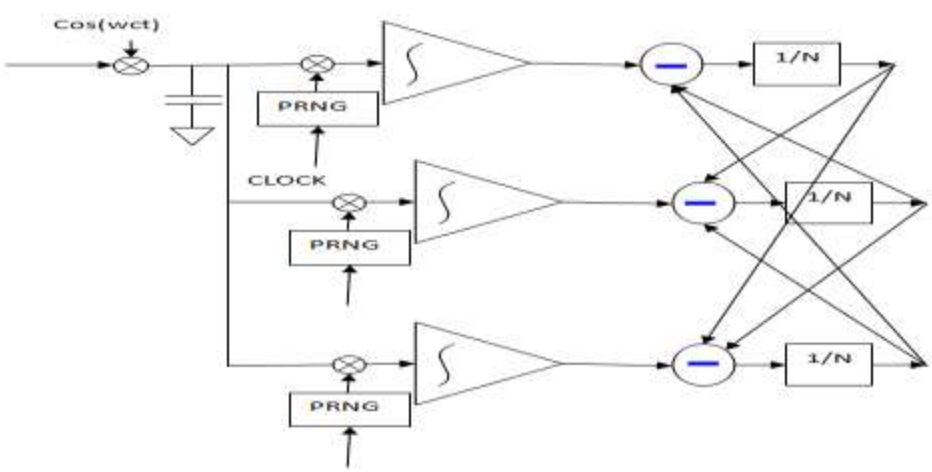

Figure 3. Optimum detection and tracking

The synchronization is alleviated as we take all the fingers for correlation. We do a linear subtraction of the signal from the correlated values and find the exact correlated values for multiple objects. It is optimum as we use double integration of noise and a high pass filtering. This lowers the noise variance considerably.

The objects will found at a considerable distance, but track only when they are at T_b distance which is $c*T_b$ where c is the electro-magnetic field propagation velocity.

We also can use $[C_1\text{-}C_1(t\text{-}T_c)]$ code which has zero cross-correlation with its other reflected waves [5]. C1 is a pseudo random sequence and T_c is a chip delay with rotation.

COMPARISON

The Optimum detection of multiple objects is the most suitable. It consumes more power than normal single object tracking radar, but, it is better than decision feedback cancellation along with AtoD method**.** The optimum detection may get rid of the subtractors if the Manchester coded data with double coded PRN sequence are used.

CONCLUSION

Here we described three different methods of object detection by continuous wave radar. The simplest is the single tone radar which has a capability of detecting one object. We can also use it differently, but the other two methods can find multiple objects. Their performance can be found out in field test.

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