A Novel method of extracting Range information, Angle of arrival and Doppler shift using a Pulsed Radar

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ABSTRACT

The main aim of any Radar system is to detect a target and track the same. For this we have to extract the Range information, Angle of arrival and Doppler shift accurately. At the same time, we should have the capability to resolve multiple targets. For good range resolution we require a narrow pulse and for good accuracy in Angle of arrival as well as Doppler shift we require wide pulse. This paper explores the possibility of getting all of them together by a dual mode of operation of Radar. The Radar makes use of a Phase coded pulse and a uncoded wide pulse alternatively to get the good accuracy in extracting all these parameters. This is possible by using the solid state transmitters which can operate with high duty ratio and multiple coherent digital receivers which make use of fast sampling ADCs and digital down converters.

Keywords: *Range; Angle of Arrival; Doppler shift; Pulsed Radar.*

1. INTRODUCTION

A narrow pulse in a radar system provides a good range resolution where as wider pulse helps in providing better Doppler extracting capability along with angle of arrival(in both azimuth and elevation), Here we are proposing a scheme which makes use of a wide pulse and a subdivided wide pulse (‘n’ sub pulses) with phase coding. The receiver and transmitter are having the capability to handle both simultaneously. The wide pulse is having a width of ‘T_W’ and the sub pulse width is ‘t_B’ (bit time). The number of sub pulses used are „n‟ with in ‘T_W’ i.e., $n\ t_B = T_W$.

The transmission is done at a carrier frequency ‘f_C’. The sub pulses are phase coded by “$A_C \cos \omega_C t$” and “$A_C \cos \omega_C t$ ” where A_C is the peak amplitude of the carrier. The sub pulses can be represented by +1 and -1. The bit pattern follows a certain pattern so that its auto correlation function is having a peak at zero and a very low value at any other shift. This property helps us in getting good resolution without sacrificing signal to noise ratio (SNR). SNR corresponds to wider pulse. Range resolution corresponds to narrow sub pulse.

II. UNCERTAINTY TIME

The uncertainty in time of receiving an echo ‘Δt’ depends on the pulse width and SNR. In the proposed scheme the bandwidths of transmitter and receiver correspond to the narrow sub pulse ‘t_B’.

B = Bandwidth = $1/t_B$,

Electronic Noise = KTB Where K = Boltzmann’s constant T= temperature in °K

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ISSN 2348 - 7550

Hence SNR depends on bandwidth 'B'. The received signal is sampled at a higher rate than '$1/t_B$'. Let it be 'm' times more than '$1/t_B$'.The uncertainty in the time of receiving an echo is equal to

$\Delta t = \pm$ pulse width / (2 √(SNR))

For wider pulse

$$\Delta t = \pm T_W / (2 \sqrt{(SNR)})$$

If SNR = 10 dB then

$$\Delta t = \pm T_W / (2 \sqrt{(10)})$$

$$\approx T_W / 6$$

If SNR = 20 dB then

$$\Delta t = \pm T_W / (2 \sqrt{(100)})$$

$$\approx T_W / 20$$

In case of phase coded pulse for 10 dB SNR, the uncertainty is

$$\Delta t = \pm t_B / (2 \sqrt{(10)})$$

$$\approx t_B / 6$$

In case of phase coded pulse for 20 dB SNR, the uncertainty is

$$\Delta t = \pm t_B / (2 \sqrt{(100)})$$

$$\approx t_B / 20$$

Hence it is possible to get range accuracy better than the accuracy corresponding to pulse width. To get better accuracy in range we propose the following scheme

If we sample the echo at 'm' times with in 't_B'we can accurately determine the range information. We can improve by a factor of 3 in case of 10dB SNR and by a factor of 10 in case of 20 dB SNR. These are the upper limits set by the Signal to Noise Ratio. If we sample the received signal at ' m' times more than „$1/t_B$", we can improve 'Δt' at least by' m' times provided m' is within the limit set by SNR..

The block diagram of the proposed receiver scheme is given in Fig 1.

International Journal of Advanced Technology in Engineering and Science
Vol. No. 11, Issue No. 12, December 2023
www.ijates.com
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ISSN 2348 - 7550

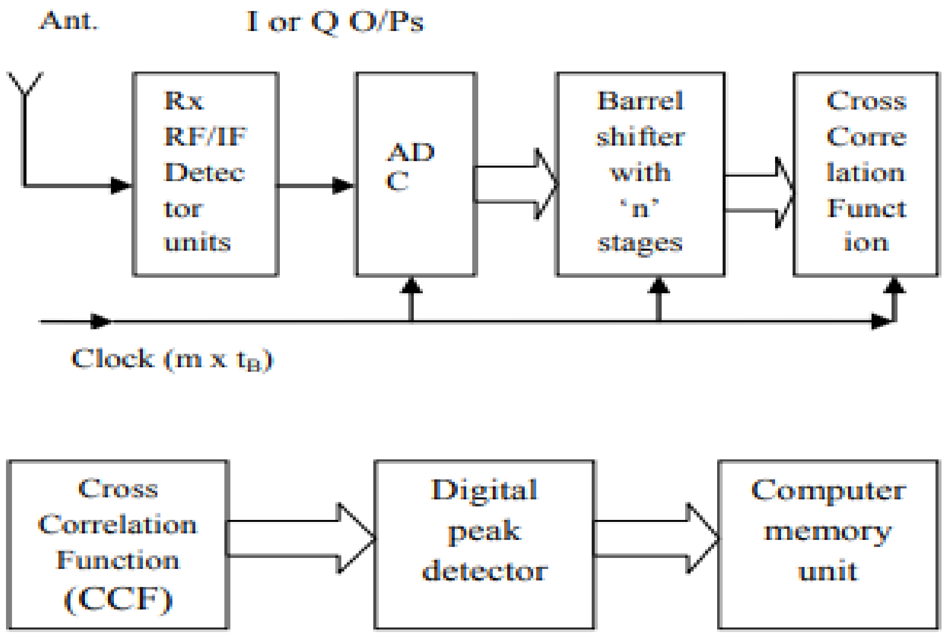

Fig 1. Block diagram of Proposed Receiver

III. DIGITAL PEAK DETECTOR UNIT

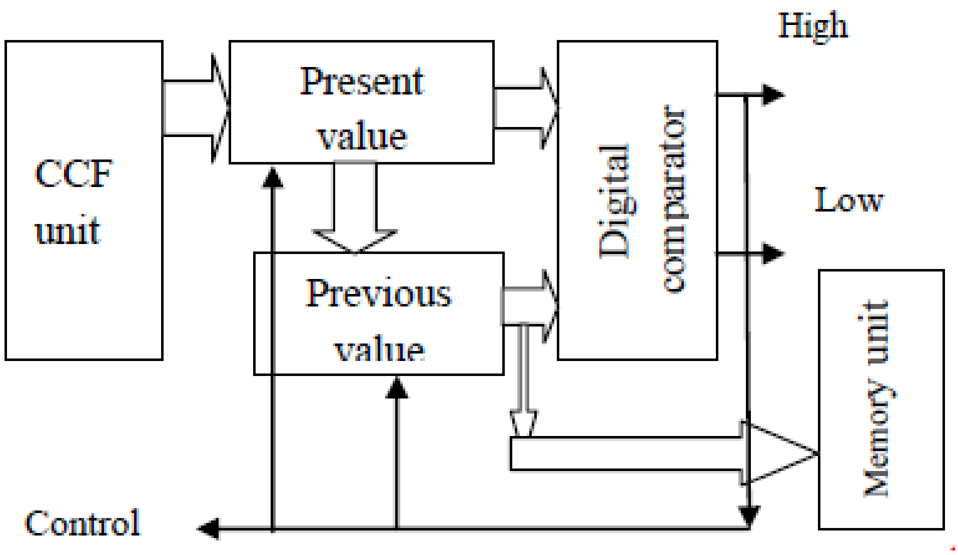

Fig 2: Digital peak detector unit

The I & Q outputs are digitized separately by ADCs and the sampling frequency is chosen to be 'm' times more than '$1/t_B$' The contents are transferred in to the Barrel shifter using the clock and are fed to the "Cross correlation function" unit. The CCF unit contains a replica of the phase coded transmitted pulse (in the form of

+ 1s and -1s). The sampled received signal is cross correlated with the replica of the transmitter code and the peak value of the CCF output is tracked using the digital peak detector unit.

The peak value is obtained once for every transmitter pulse i.e., with in the inter pulse period (IPP). The unit for I Channel only shown in the block diagram. Same type of unit is made use off for Q channel also. The peak detection of CCF is done by using two registers and a digital comparator. The registers hold the previous value and the present value of CCF. Depending up on the digital comparator output the latest peak value is retained till a new peak value is obtained. The process goes on for the whole Inter pulse period and finally the highest peak value is transferred to computer memory.

The CCF peak values are obtained for both I and Q channels. Using I & Q values we can obtain the amplitude of the received echo as well as the Doppler shift

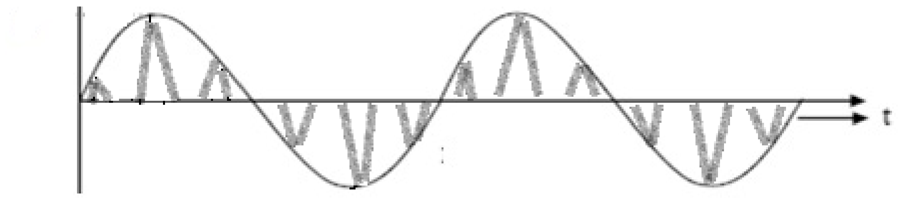

Fig 3. Doppler shifted peak values

The Doppler shift affected CCF peak values are shown in the diagram given in Fig 3. Because we are sampling the I &Q outputs at „m" times the bit rate, the peaks shown above have a step structure as shown in Fig 4 instead of a single value.

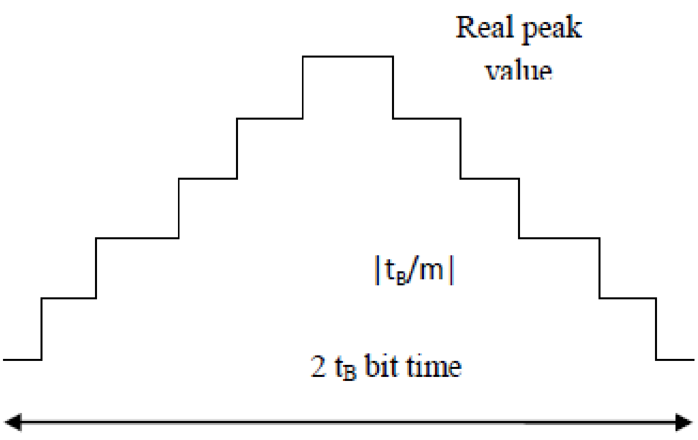

Fig 4 Peak values after sampling

By sampling the output at 'm' times the bit rate the chance of missing the peak is very less. But all these samplings, Analog to Digital conversions, and other processes require faster devices and faster processing capability. These requirements can be met by the present day devices of ADCs, memories, FPGAs and processors.

International Journal of Advanced Technology in Engineering and Science
Vol. No. 11, Issue No. 12, December 2023
www.ijates.com
ijates ISSN 2348 - 7550

In our scheme of operation we plan to use wide pulse and phase coded pulse alternatively with double the PRF required. With the present day solid state transmitters the duty ratio requirement can be met. The receiver band width is set to the phase coded pulse. By sampling the received echo at 'm' times the bit rate, the bandwidth reduction is possible for the uncoded wide pulse by simply adding all the samples (equivalent to all +1s in a coded pulse) and finding out the peak as in the case of coded pulse.

The CCF peak value in the case of wide pulse looks like as shown in Fig 5.

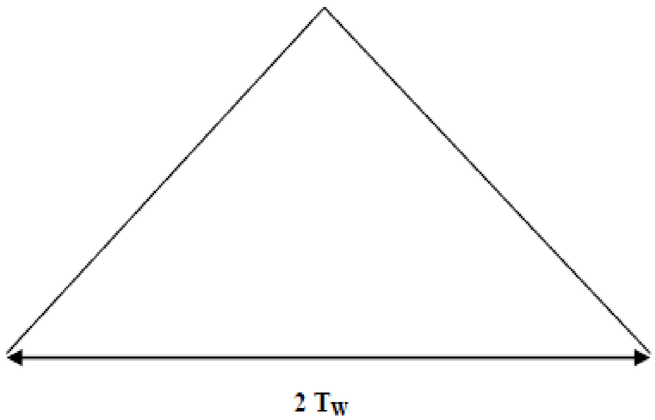

Fig 5. CCF peak value of wide pulse

In the above CCF, the fine structure is similar to what is shown in Fig 4. in the case of coded pulse.

IV. ANGLE OF ARRIVAL

As mentioned earlier wide pulse is more suitable for Doppler extraction where as phase coded pulse is more suitable for range information extraction. Another important parameter to be found out in case of a radar is Angle of arrival from the target at the receiver point in both azimuth and elevation planes. The antennae are arranged as shown in Fig. 6.

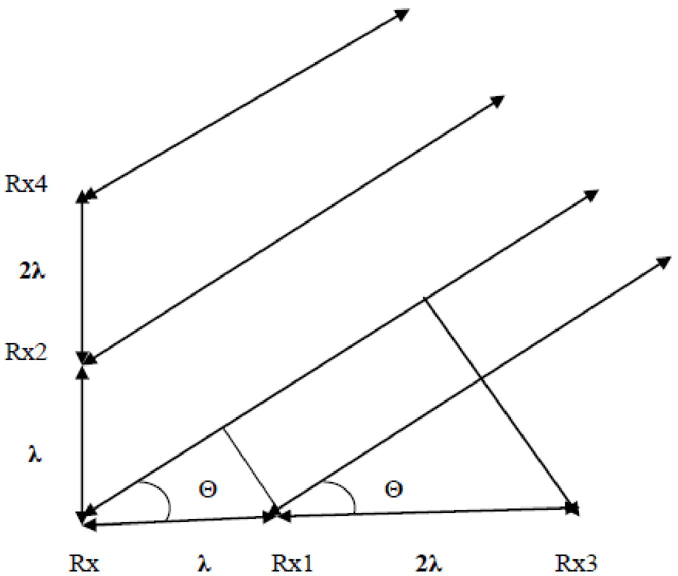

Fig 6. Measurement of Angle of arrival

In Fig 6.

Θ = angle of arrival in elevation plane

Φ = angle of arrival in azimuth plane

Rx = Reference receiver

Rx1 = 1st receiver } Elevation plane

Rx2 = 2nd receiver

Rx3 = 3rd t receiver } Azimuth plane

Rx4 = 4th receiver

A 0° to 360° phase detector using digital techniques will be used for the purpose. The phase difference between the output of reference receiver and the Rx1 will enable us to know the path difference between target to reference receiver and target to Rx1. The distance between reference Rx and RX1 is λ. The path difference is equal to λ cos θ. The path difference is directly proportional to phase difference.

$$\text{Phase Difference} = (360° \text{x path difference}) / \lambda$$

Fast comparators and R-S Flip Flops are used for finding phase difference by converting time difference to phase difference. Time difference is measured by using high speed counters working at a clock frequency of 1 GHz corresponding to a time resolution of 1 ns.

From the above equation we can find out path difference. In turn we can find out Θ. In the same way we can find out the azimuth angle φ from the receiver outputs of Reference Rx and Rx3.

Rx1 and Rx3 will give the Θ and Φ respectively in a coarse way. The receivers Rx2 and Rx4 will enable us to improve the accuracy of Θ and Φ measurement by a factor of 3 as they are located at a distance of 3λ from reference receiver. The phase difference ambiguity is resolved by Rx1 and Rx3 outputs.

V. CONCLUSION

By making use of a Phase coded pulse and a uncoded wide pulse alternatively Range information, Angle of arrival and Doppler shift can be extracted with good accuracy. This can be done by using the solid state transmitters which can operate with high duty ratio and multiple coherent digital receivers where fast sampling ADCs and digital down converters are used.

REFERENCES

[1]. Merrill L. Skolnik, Introduction to Radar Systems, 3rd Edition, McGraw Hill Book Company, 2001

[2]. R.C. Dixon, Spread Spectrum Systems, John- Wiley & Sons, 1984

[3] Satija, U.; Trivedi, N.; Biswal, G.; Ramkumar, B.; Ramkumar, B. Specific Emitter Identification Based on Variational Mode Decomposition and Spectral Features in Single Hop and Relaying Scenarios. *IEEE Trans. Inf. Forensics Secur.* 2018, *14*, 581–591

[4] Chan, Y. T., and F. L. Jardine (1990), Target localization and tracking from Doppler-shift measurements, *IEEE J. Oceanic Eng.*, 15, 251–257.