Comparison of Analog and Digital Pulse Compression Technique and Reduction of Side lobes Using Transversal Filter

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Abstract—**Pulse compression technique is usually used in RADAR system in order to raise the signal to noise ratio (SNR) improving the target detection and range resolution Because of masking of small targets by the side lobes of large nearby targets, a problem may arise in pulse compression technique. This paper has proposed a technique to suppress the side lobes by using a transversal filter in digital pulse compression and compared the result of analog and digital pulse compression technique. It is revealed that the digital pulse compression with transversal filter is better for reduction of side lobes of nearby targets.**

Keywords— Barker code, Matched filter,Pulse compression, SNR and Transversal filter

I. INTRODUCTION

Pulse compression is a signal processing technique mainly used in radar, sonar to increase the range resolution as well as the signal to noise ratio. This is achieved by modulating the transmitted pulse and then correlating the received signal with the transmitted pulse [1, 2]. The main purpose of this technique is to raise the signal to maximum side lobe (signal-to-side lobe) ratio to improve the target detection and range resolution abilities of the radar system. The lower the side lobes, relative to the main lobe peak, the better the main lobe peak can be distinguished. Analog pulse compression involves the use of analog methods to generate and process pulse compression waveforms. Pulse compression is accomplished here by adding frequency modulation to a long pulse at transmission and by using a matched filter receiver in order to compress the received signal. This technique is called “correlation processing”. The second technique is called “stretch processing” and is normally used for extremely wide band radar operations [3]. Digital pulse compression technique consists of frequency coding, binary phase coding (barker code), poly-phase codes, pseudo-random (PRN) codes. The performance of digital pulse compression technique depends on its auto correlation function. A transversal filter can be added to improve the performance of such kind of technique.

II. SYSTEM MODEL

In analog pulse compression technique, the output of the matched filter, y (t) is the compressed pulse which is just the inverse Fourier transform of the product of the signal spectrum and the matched filter response.

$$y(t) = \frac{1}{2\pi}\int_{-\infty}^{\infty} |H(\omega)|^2 \exp(j\omega t)\, dw \qquad (1)$$

Here received echo is fed into a matched filter whose frequency response is the complex conjugate $H^*(\omega)$ of the coding filter. A filter is also matched if the signal is the complex conjugate of the time inverse of the filters impulse response [4, 5]. This is achieved by applying the time inverse of the received signal to the pulse-compression filter. The output of this matched filter is given by the convolution of the signal $h(t)$ with the conjugate impulse response $h^*(-t)$ of the matched filter

$$y(t) = \int_{-\infty}^{\infty} h(\tau)\, h^*(t-\tau) d\tau \qquad (2)$$

Pulse compression technique is the practical implementation of a matched filter system [2] as shown schematically in the figure below

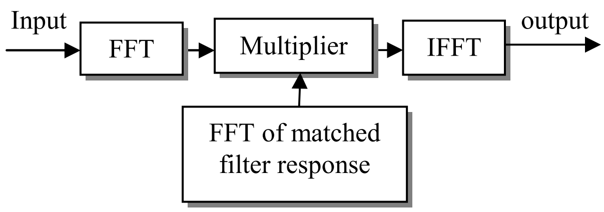


Fig. 1. A block diagram of Analog Pulse Compression based on FFT and Inverse FFT.

In digital pulse compression technique (Barker code), a relatively long pulse of width τ' is divided into N smaller pulses, each is of width $\Delta\tau = \tau'/N$. Then, the phase of each sub-pulse is randomly chosen as either 0 or π radians relative to some CW reference signal. It is customary to characterize a sub-pulse that has 0 phase (amplitude of +1 Volt) as either “1” or “+.”

The compression ratio associated with binary phase codes is equal to $\xi = \tau'/\Delta\tau$, and the peak value is *N* times larger than that of the long pulse.

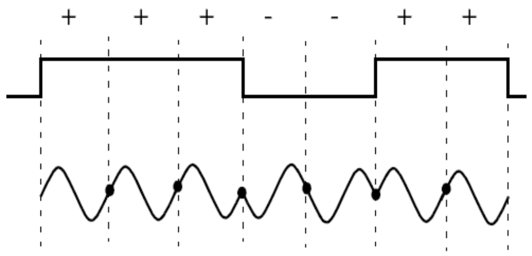


Fig. 2. Binary Phase Code of length 7

The most side lobe reduction offered by a Barker code is $-22.3\ dB$, which may not be sufficient for the desired radar application. However, Barker codes can be combined to generate much longer codes. In this case, a B_m code can be used within a B_n code (*m* within *n*) to generate a code of length *mn*. The compression ratio for the combined B_{mn} code is equal to *mn.* Some side lobes of a Barker code autocorrelation function can be reduced to zero if the matched filter is followed by a linear transversal filter [6] with impulse response given by

$$h(t) = \sum_{K=-N}^{N} \beta_k \delta(t - 2k\Delta\tau) \qquad (3)$$

Where *N* is the filter’s order, the coefficient $\beta_k(\beta_k = \beta_{-k})$ is to be determined, $\delta(\bullet)$ is the delta function, and $\Delta\tau$ is the Barker code sub-pulse width. A filter of N order produces N zero side lobes on either side of the main lobe. The main lobe amplitude and width do not change. This is illustrated in Figure 2.

Let us consider the input of the matched filter is B_{11} and assume order N=4. The auto correlation for a B_{11} code is

$$\phi_{11} = \{-1,0,-1,0,-1,0,-1,0,-1,0,-1,0,-1,0,-1,0,-1,0,-1,0,-1-1,0\}$$

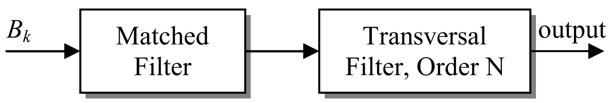


Fig. 3. Block diagram of barker code followed by a Transversal filter

III. SIMULATION

Simulation has been carried out for analog pulse compression technique using matched filter. For the analog compression we have used chirp frequency of 5.6 GHz and chirp bandwidth of 1GHz. Scattering range of 150 km is also used.

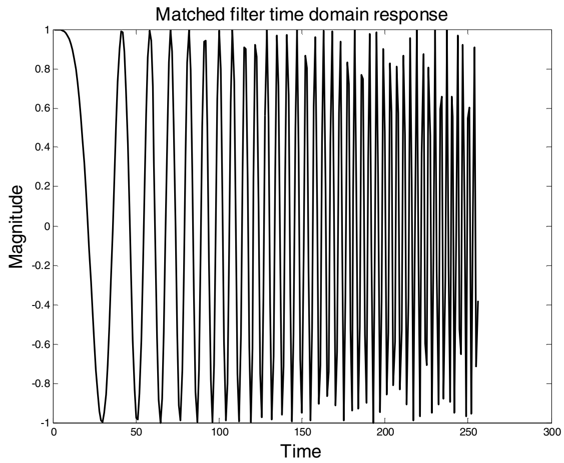


Fig. 4. Matched Filter Time Domain Response

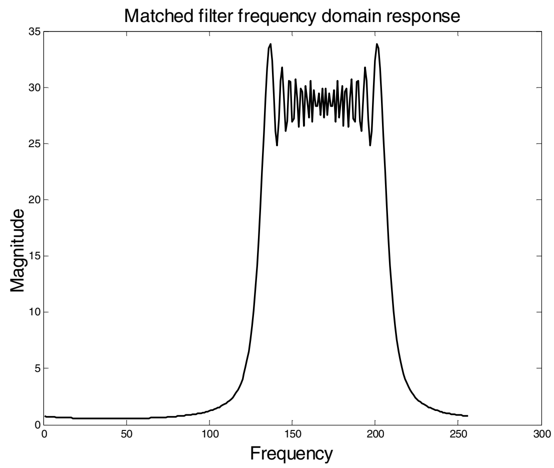


Fig. 5. Matched Filter Frequency Domain Response

In digital pulse compression, barker code, auto correlation of binary signal is accomplished. Here we used the barker code of length 13. In general, the autocorrelation function (which is an approximation for the matched filter output) for a B_N Barker code will be $2N\Delta\tau$ wide. The main lobe is $2\Delta\tau$ wide; the peak value is equal to *N*. There are $(N-1)/2$ side lobes on either side of the main lobe.

Figure 4 and Figure 5 show the time domain response and frequency domain response of matched filter respectively. Here by applying Fast Fourier Transform, the frequency domain response of matched filter has been shown.

Figure 6 represents the barker code of length 13. By doing the auto correlation of binary signal we can get the barker code i.e. binary phase coding. Then the output of the matched filter is used as the input of the Transversal filter of order N. Finally by this process the desired output of digital pulse compression can be achieved.

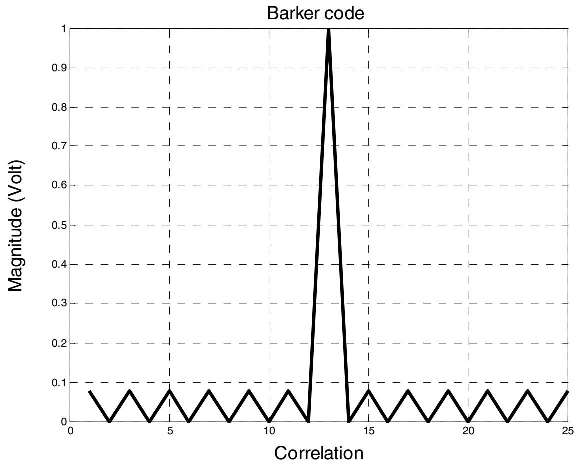
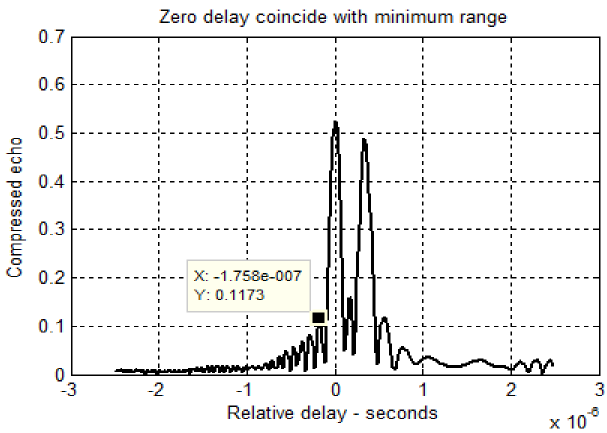


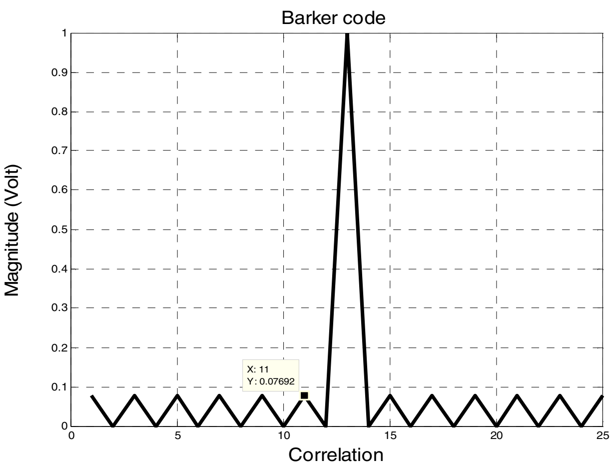
Fig. 6. Barker Code of length 13

IV. RESULT AND DISCUSSION

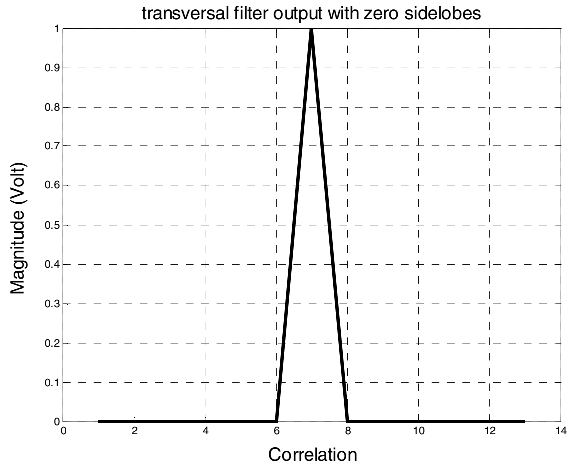
In this paper, the side lobe between analog pulse compression technique and digital pulse compression technique (by using barker code) has been compared.



(a)



(b)



(c)

Fig. 7. Compressed echo using (a) analog pulse compression technique (b) Digital pulse compression (c) Digital pulse compression followed by transversal filter

TABLE I. Comparison of side lobe for different types of technique

Pulse Compression Technique	Peak Side lobe Level (Volt)
Analog(using matched filter)	0.1173
Digital(using barker code)	0.07692
Digital(followed by a transversal filter)	Almost zero

From the figure 7 the side lobes of different pulse compression technique can be seen. The side lobes are different in different pulse compression technique. In digital pulse compression technique the side lobe is less than the analog pulse compression technique. The side lobe is 0.1173 volt in analog pulse compression using matched filter and it is 0.07692 volt in digital pulse compression using barker code. The side lobe is reduced to zero when the transversal filter is used.

V. CONCLUSION

This paper presents a method for reduction of side lobes in RADAR technology. Comparison of various side-lobes has been simulated in the case of analog and digital pulse compression technique. It is seen that the side lobes are different while using different types of pulse compression technique. It has been revealed that side lobes are lower for digital pulse compression. Using transversal filter with barker coding, the side lobe tends to zero which results improved signal to noise ratio (SNR) and thus leads to better detection capability. Due to inherent nature of the proposed system, it is flexible, easy to implement and capable of handling Ultra Wide Band (UWB) signals.

VI. REFERENCES

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