DSP APPLICATION ASSIGNMENT

PULSE COMPRESSION TECHNIQUE IN MONO PULSE RADAR

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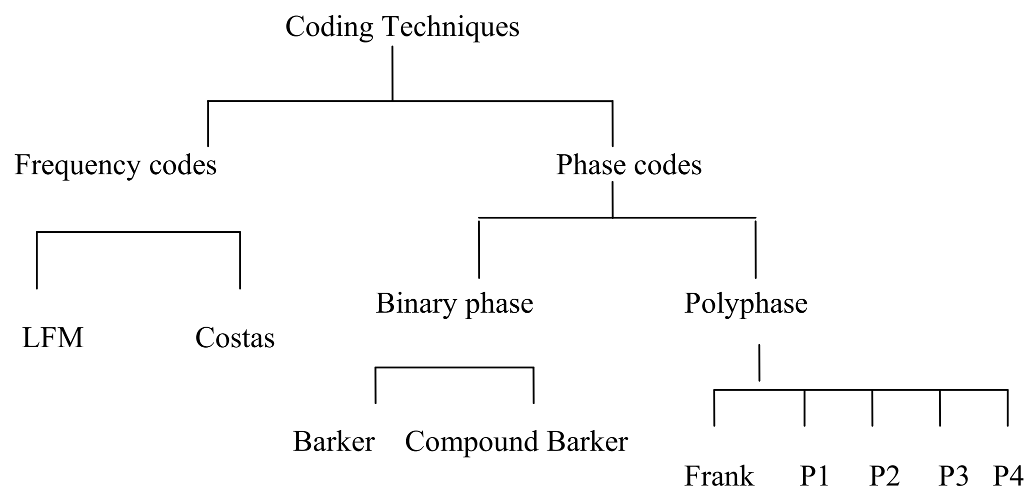
Abstract –In mono pulse radar one pulse is transmitted with particular duty cycle and frequency. Same pulse gets reflected from the target and is received by a receiving antenna after some duration of time. This duration between transmitted and received pulse is function of distance between radar and target. In pulse compression technique a modulated signals (eg. Angle modulated) is sent for duration Ton, instead of a single frequency signal in normal radar. We have implemented pulse compression using "Linear frequency modulation", "Barker Codes" and "Compound Barker Codes".

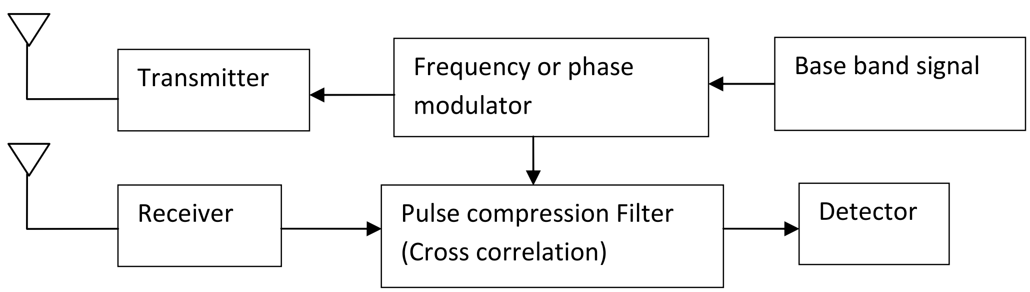
Introduction

Pulse compression is a signal processing technique mainly used in radar, sonar and echography to augment 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. The pulse is frequency modulated, which provides a method to further resolve targets which may have overlapping returns. Pulse compression originated with the desire to amplify the transmitted impulse (peak) power by temporal compression. It is a method which combines the high energy of a long pulse width with the high resolution of a short pulse width. The radar operating with very short pulse width which includes the advantages of Super range resolution, range accuracy small blind and minimum range. In addition to these advantage ,Narrow pulse width also assist radar operating in cluttered environment and also has an ability to perform limited target classification ,if operating with narrow pulse widths or sufficiently fine range resolution . Also note that pulse width cannot be reduced indefinitely because extremely narrow pulse width result in wider receiver band width and associated problem with noise. Lager the receiver band width effectively de sensitise the radar receiver and either force the transmitter to transmit higher level of peak power to compensate or consequential to reduction in range . In short , narrow pulse width are desirable , but they are not always feasible. Pulse compression radar make the use of signal processing technique to provide the most of the advantage of narrow pulse width whilst remaining with the peak power limitation of the transmitter .

Different coding techniques are used for pulse compression



General Block Diagram of Pulse Compression technique:



In case of LFM base band signal is ramp signal and modulation used is frequency modulation. Up or down LFM is transmitted for some duration. This transmitted signal is correlated with the noisy received signal, the point at which output of correlation is maximum gives us the delay value of received signal. Same technique is implemented for other pulse compression methods only difference is base band signal is different in each case.

1. LFM (Linear Frequency Modulation)

In LFM the frequency is swept linearly across the pulse width, either upward (up-chirp) or downward (down-chirp). Base band signal in this case is a ramp signal to frequency modulator.

For pulse width pw and bandwidth B. The LFM up-chirp instantaneous phase can be expressed by

$\Psi(t)= 2\pi(f0t + ut^2/2)$

Where $(pw/2) < t < (pw/2)$

f0 = radar center frequency

$u = (2\pi B)/pw$ is LFM coefficient

Thus, the instantaneous frequency is

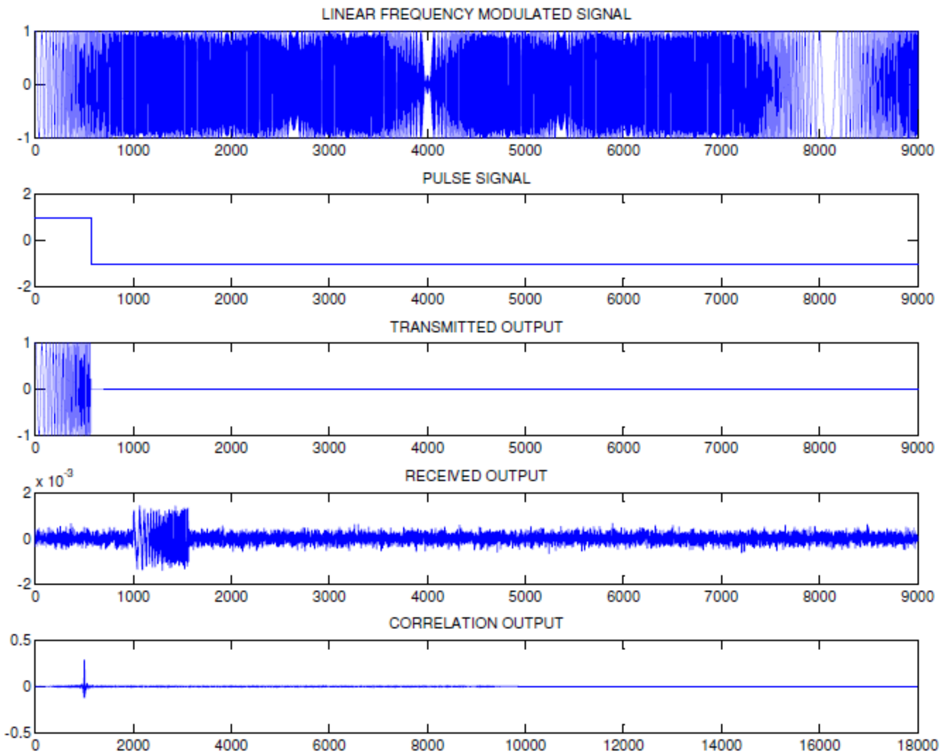
$f(t) = 1/2\pi \; d/dt\,(\Psi(t)) = f0+ut$

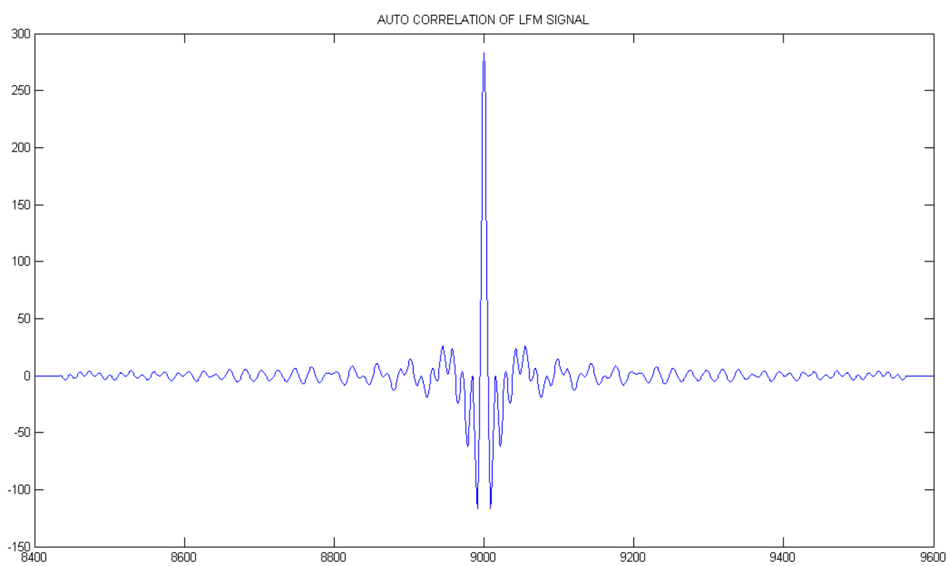
Similarly, the down-chirp instantaneous frequency is given by,

$f(t) = f0+ut$

where $-(pw/2) < t < (pw/2)$.

Simulation output is as shown in figures below:





Drawbacks

Linear FM is poor choice for an LPI waveform as

1. The instantaneous bandwidth of the signal is small and allows a narrowband receiver to detect the presence of the radar
2. The waveform is not programmable and a receiver only needs a small fraction of the chirp in order to calculate the slope and thereby derive some processing gain.
3. Range –Doppler cross coupling referring to the effect of the Doppler shift on the radar processor. Since the transmitted waveform is itself shifting in frequency, any target motion that produces significant Doppler shifts will cause an error in the received frequency and therefore an error in range measurement.
4. They produce range side lobes that are quite high. Range side lobes reduces as LFM coefficient increases.

2. Phase-Coded Pulse Compression

In digital pulse compression techniques, there are two type of phase coding

a) Binary phase code or Barker code.

b) Compound Barker code.

a) Binary pulse code

In this case the relative long pulse of width τ is divided into N smaller pulses, each of width $\Delta \tau = \tau/N$. Then the phase of each sub pulse is modulated to become either 0 or Pi related to Barker code taken as base band signal.

The compression ratio associated with binary phase code is equal to $\xi = \tau/\Delta \tau$ and the peak value is N times larger then that of long pulse .The goodness of compressed binary phase code wave form is depending heavily on the random sequence of the phase for individual sub pulse .

One family of the binary code that produce compressed wave form with constant side lobe level equal to unity in barker code. Barker code of length n is denoted by Bn as shown in figure.

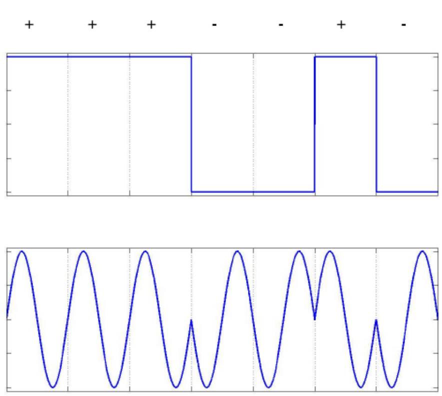


Fig. Binary phase code of length 7

Here is the table where code length, code element and side lobe reduction is given

Code Length	Code	Range Sidelobe Level (dB)	Processing Gain (dB)
2	+- OR ++	-6.0	3.0
3	++-	-9.5	4.8
4	++-+ OR +++-	-12.0	6.0
5	+++-+	-14.0	7.0
7	+++--+-	-16.9	8.5
11	+++---+--+-	-20.8	10.4
13	+++++--++-+-+	-22.3	11.1

Let's take an example of a barker code of length 13 and its elements are

+	+	+	+	+	-	-	+	+	-	+	-	+

For code length 13 "+ + + + + --+ + -+ -+" the Peak Side Lobe level.

PSL = 10 log (maximum side-lobe power / peak response power)
= -22.3 dB.

Integrated Side Lobe level

ISL = 10 log (total power in the side lobes / peak response power)
= -11.5 dB.

Figure below compares transmission and matched filtering of a 5 periods sine burst for uncoded and Barker coded sequence. The total energy in the five period sequence is five times greater than the one from the single period excitation.

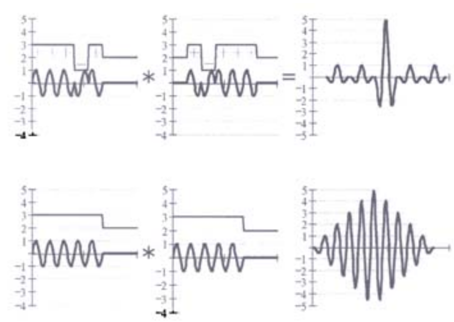
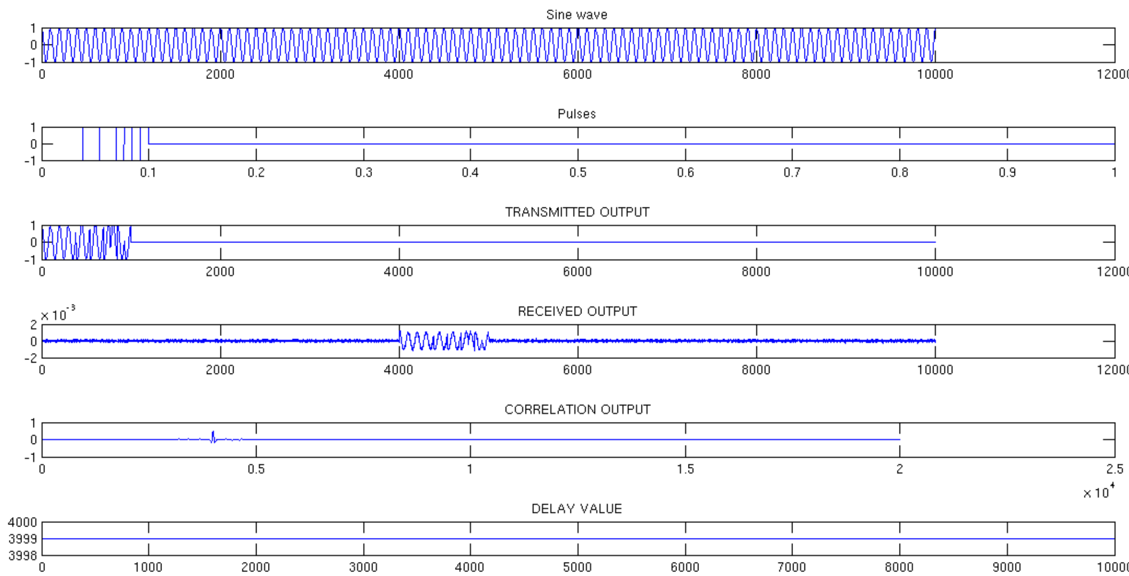
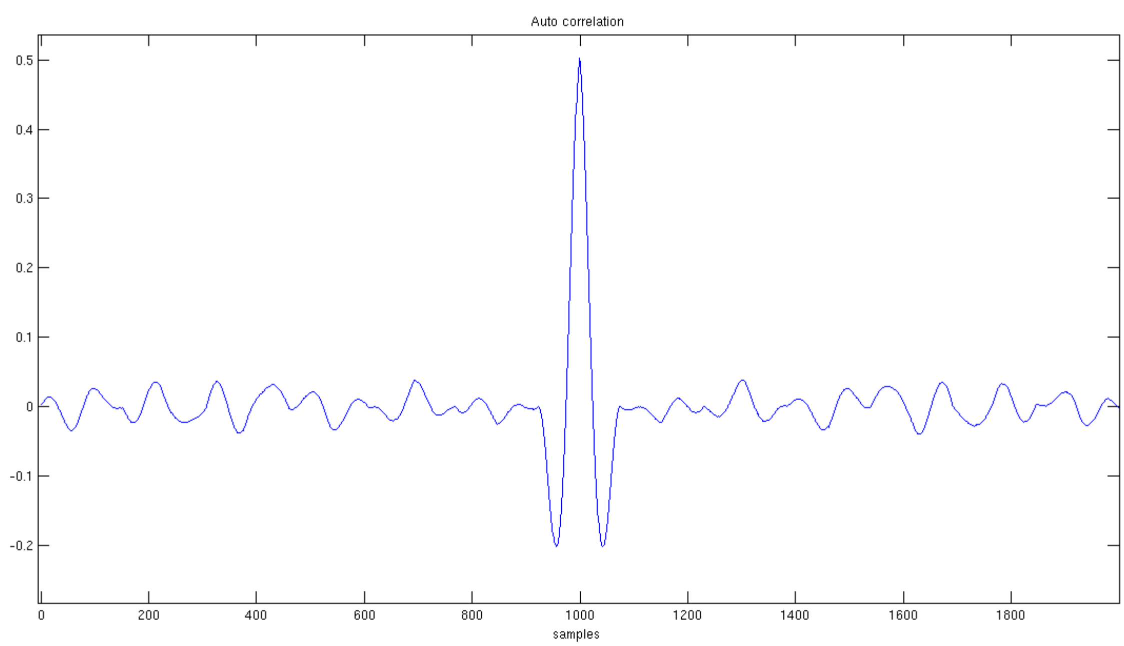


Fig. Comparison of 5 cycles uncoded (bottom) and 5 bits Barker coded – 5 bits (top) pulse sequence and resulting compressed outputs, * represents convolution operator.



Simulated results for barker code length of 13



Auto correlation for barker code length of 13

b) Compound Barker Codes

Barker codes can be combined to generate much longer codes. In this case, a Bm code can be used within a Bn code (m within n) to generate a code of length mn. The compression ratio for the combined Bmn code is equal to mn. These Barker codes called as Compound Barker codes (Barker code within a Barker code). Although a larger compression gain is achieved, the peak side lobes are not proportionally decreased.

Example of the compound barker code is given below.

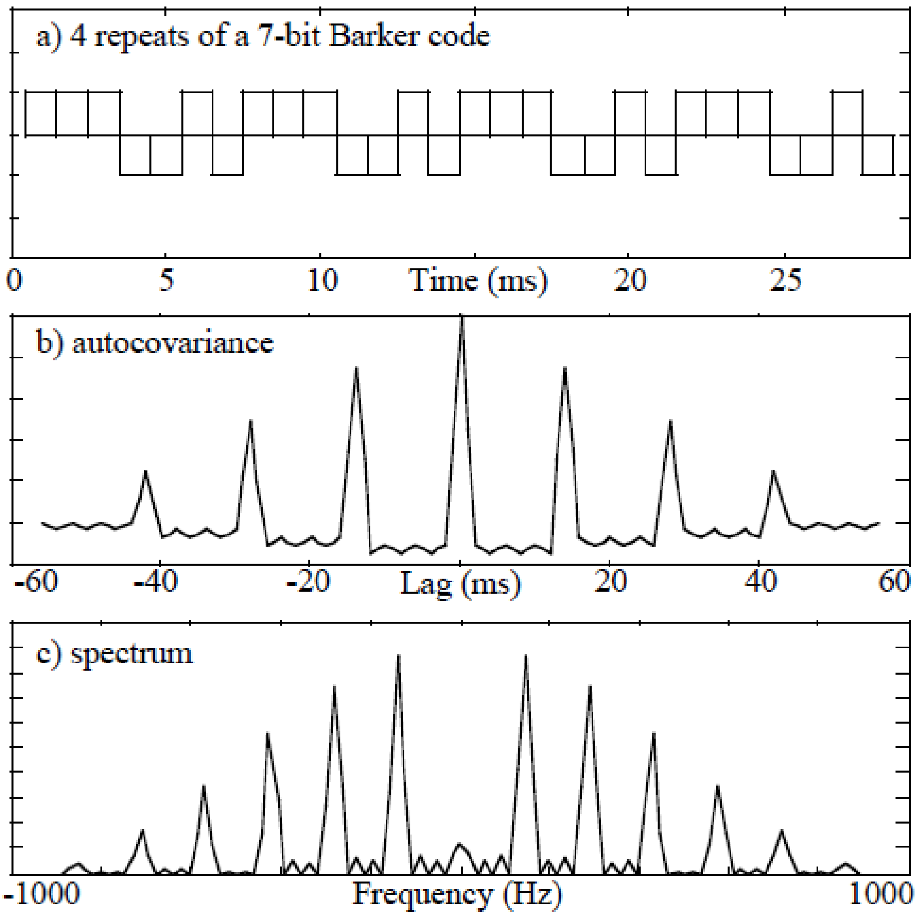
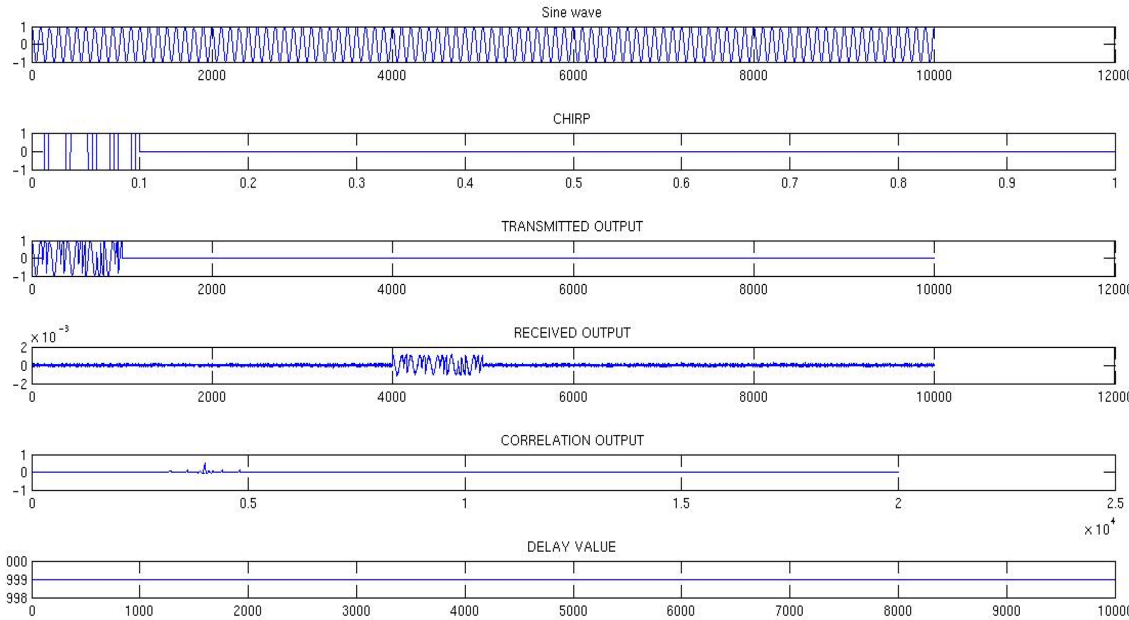
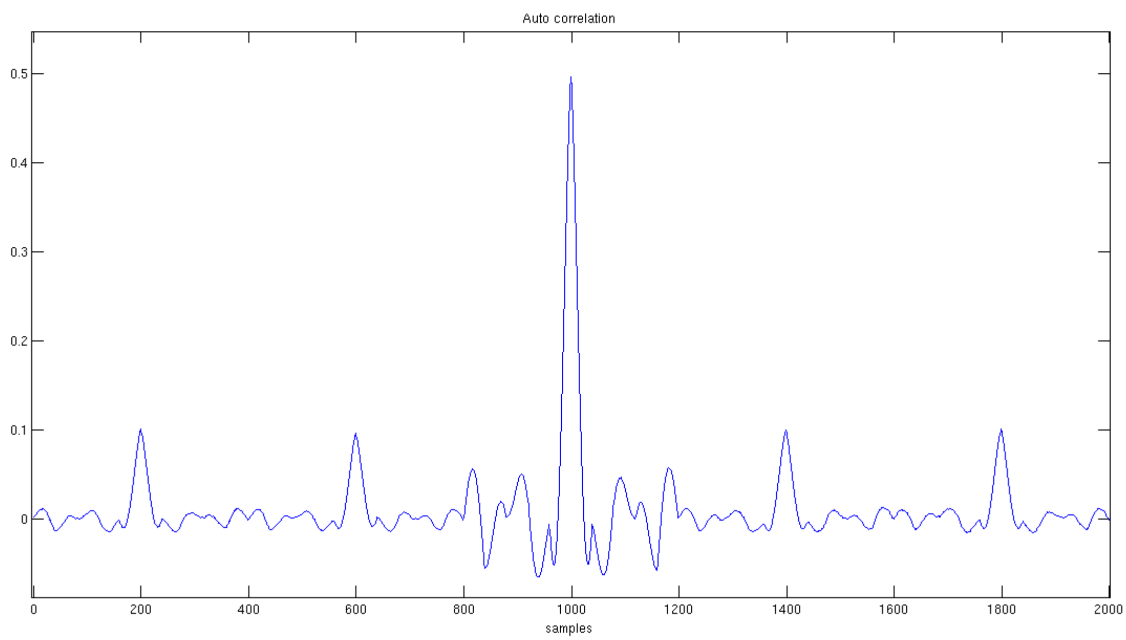


Figure 1. a) Schematic Representation of a repeat sequence code. The transmitted waveform consists of a seven bit Barker code repeated four times. b) The corresponding autocorrelation function. Values are small except at even multiples of the subcode length. c) The frequency spectrum of the code. The spectrum of an uncoded sinusoidal pulse of the same duration would consist of a single peak of width equal to the width of any individual peak in the above spectrum.



Simulated results for compound barker code length of 25 (5x5)



Auto correlation for compound barker code length of 25 (5x5)

Drawbacks of Barker Codes

1. Barker codes have limited code length. Although the code length can be increased by using compound Barker codes, thus increasing the processing gain, the side lobe level are not sufficiently decreased.
2. In addition to having a limited code length, Barker codes are very sensitive to Doppler shifts. The Doppler shift of the return waveform (due to motion of the target) can compress the waveform within the filter such that the matched filter gives incorrect results. That is, these codes are only perfect in time domain (unknown range, zero Doppler shift).
3. Barker codes are not considered LPI since they are easily detected by an intercept receiver that uses frequency doubling. Frequency doubling is a simple technique involves multiplying the receiver signal by itself and processing the result with an envelope detector.

Conclusion:

1. It is found that by using pulse compression technique the echoes which have time delays lesser than that of the pulse width can be detected and exactly measured.
2. Information of received signal can be retrieved by means of correlation even if the signal is totally embedded in noise. We got satisfactory outputs till -25dB SNR of received signal.
3. It was found that out of three types of compression techniques implemented (LFM, Barker and compound barker) compound barker code perform better in terms of PSL (Peak side lobe level).