TARGET DETECTION BY RADAR USING LINEAR FREQUENCY MODULATION

Thesis submitted in partial fulfillment of the requirements for the degree of

Bachelor of Technology

In

Electronics and Communication Engineering

By

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CERTIFICATE

This is to certify that the work on the thesis entitled **Target Detection by Radar using Linear Frequency Modulation** by **Goutam Acharya** and **Swayangsiddha Pandey** is a record of original research work carried out under my supervision and guidance for the partial fulfillment of the requirements for the degree of **Bachelor in Technology** in the department of **Electronics and Communication** Engineering, **National Institute of Technology, Rourkela**.

Place: NIT Rourkela

Date: May, 2014

Prof. Ajit Kumar Sahoo

Professor, ECE Department

NIT, Rourkela, Odisha

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I would like to thank administrative and technical staff members of the Department who have been kind enough to advise and help me in their respective roles.

Last, but not the least, I would like to acknowledge the love, support and motivation I received from my parents and therefore I dedicate this thesis to my family.

Goutam Acharya (110EI0234)

Swayangsiddha Pandey (110EC0177)

ABSTRACT

Range Detection is the maximum distance across which a target can detect a target. Range Resolution is the ability of the Radar to distinguish between two closely spaced targets. Range Resolution can be enhanced by using short duration pulses. But using short duration pulses results in less Range Detection. To overcome these shortcomings pulse compression techniques are used. We use a Linear Frequency Modulated (LFM) Wave for pulse compression purposes as it gives a wide operating bandwidth. It involves two types of correlation processes: matched filter processing and stretch processing. Matched Filter is used for narrow band and Stretch Processor is used for wide-band signals. In this thesis we have analyzed both these processes and the effects of Time-Bandwidth Product, change in Doppler Frequency and effect of different kinds of windows on the LFM wave. Also masking effect is observed on the echo of a distant target due to the echo of a nearby target. The various methods to remove the masking effect are inspected.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 BASIC RADAR

Radar is an acronym for **RA**dio **D**etection and **R**anging. It is an electromagnetic system used for detecting and locating objects by transmitting the signals and receiving the transmitted signals from the objects within its range. The echoes received are used to extract information about the target such as range, angular position, velocity and other characteristics. The reflected energy that is returned to the radar not only indicates the presence of a target, but by comparing the received echo signal with the transmitted signal, various information can be extracted regarding the target[4].

The basic principle of radar is shown is Figure 1.1. A transmitter generates a signal (a short pulse or sine wave) that is radiated into the space through a antenna. A part of the transmitted signal is intercepted by the target object and is reflected back in many directions. The reflected signal is collected by the antenna of the radar which inputs it to a receiver. Processing occurs to detect the presence of the target and to determine its location. A single antenna is generally used on a time-shared basis for both transmitting and receiving where the radar signal is a continuous series of pulses. Range can be measured by calculating the time the signal takes to travel to the target and return back.

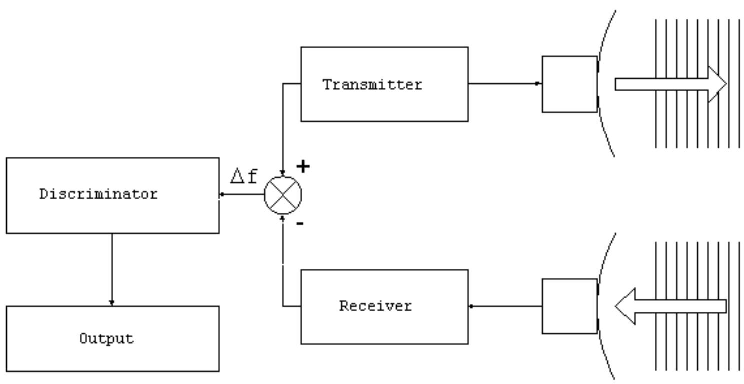


Fig 1.1- *Basic Principle of Radar*

1.2 RANGE OF A TARGET

The range to a target is determined by the time it takes for a radar signal to travel to the target and back. Suppose T_R is the time taken by the signal to travel to a target situated at a distance R and back. Thus the total time taken is given by

$$T_R=2R/c$$

Where c is the speed of light, c=3 x 10^8 *m/s.*

Thus the range to the target is

$$R=cT_R/2$$

1.2.1 Maximum Unambiguous Range

Once a signal is radiated into space sufficient time has to elapse to allow all echo signals to return before the next pulse is transmitted. If the time between signals is too short, an echo signal from a long range object may arrive after the transmission of the next pulse. Such an echo may be misleading. Maximum unambiguous range is given by

$$R_{un}=cT_p/2$$

Where T_p *is the pulse repetition period*

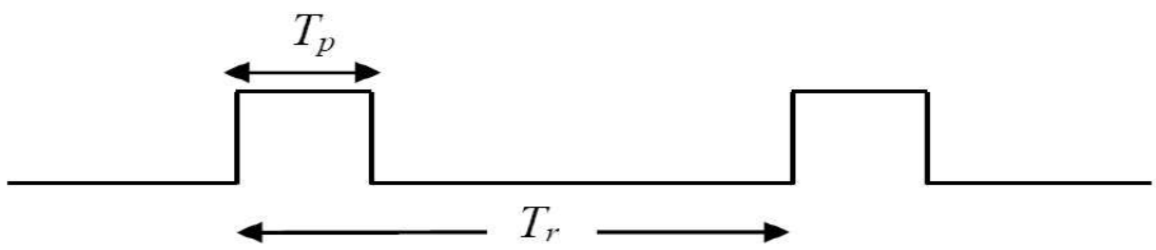


Fig 1.2-*A Radar Pulse*

Two important factors must be taken into consideration before designing a Radar

1. Range Resolution
2. Range Detection

1.3 RADAR DESIGN

1.3.1 Range Resolution

It is the ability of the Radar to detect and distinguish between two closely spaced targets. Range resolution depends on the pulse width of the transmitted pulse. The range resolution is given by

$$R_{res}=\frac{c}{2B}$$

Where B is the bandwidth of the transmitted pulse

Hence smaller the bandwidth of the transmitted pulse the greater is the range resolution.

1.3.2 Range Detection

It is the ability of the RADAR to detect objects within a long range. The greater the distance of the object the RADAR can detect the better the Range Detection. The maximum range detection depends on the strength of the received echo. The radiated pulse should have a high energy to receive a high strength echo.

1.3.3 Designing the transmitter

A very short pulse requires high peak power to get the adequate energy for large distance transmission. However to handle a high peak power pulse the radar equipment becomes heavier and sparking occurs in the antenna instruments. A pulse having a low peak power and a longer duration has to be used at the transmitter for a good range detection. At the receiver end, the echo should have a short width and high peak power for a better range resolution[4].

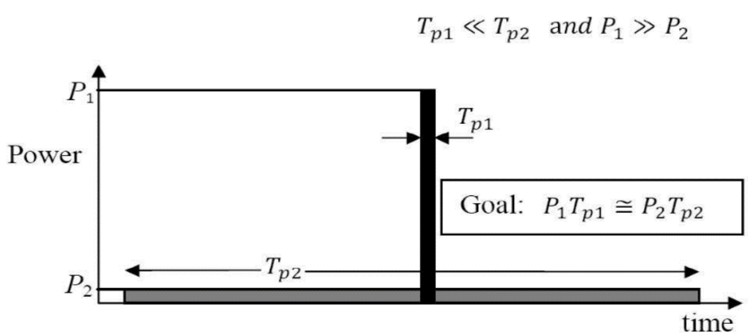


***Fig 1.3**-Transmitter and Receiver Signals*

Hence pulse compression is carried out.

1.4 OBJECTIVE OF THE THESIS

- Pulse compression through various correlation operators and their response to wide-band and narrow-band signals
- Analyzing the LFM signal considering the time bandwidth product, Doppler Effect and effect of windows.
- Masking effect removal using matched filter and stretch processor.

1.5 ORGANIZATION OF THESIS

- Chapter 2- this chapter analyses the pulse compression through linear frequency modulation in depth. It examines the matched filter response on a LFM wave, effect of windows, and effect of Doppler shift on LFM waves.
- Chapter 3-this chapter discusses the stretch processing technique in pulse compression. Stretch processing is mainly used in case of wide-band signal.
- Chapter 4- this chapter tell us about the masking effect and the various methods to remove it. It discusses the stretch processing technique for masking effect removal
- Chapter 5- It concludes the thesis and tells us about the future work on the topic

1.5 CONCLUSION

The introduction to Radar is given. The equations for range and the maximum unambiguous range is given. The various factors to be considered while designing an antenna is mentioned and the type of pulse required for each case is discussed. After considering all the factors the need for pulse compression is shown. The objective of the thesis is also discussed.

Chapter 2

Pulse Compression

2.1 PULSE COMPRESSION INTRODUCTION

Pulse Compression technique is continuously used in Radars and Sonars and echography to increase the range resolution, range detection as well as increase the signal-to-noise ratio (SNR). This is achieved by modulating the transmitted pulse and then correlating the received pulse with the transmitted signal[1].

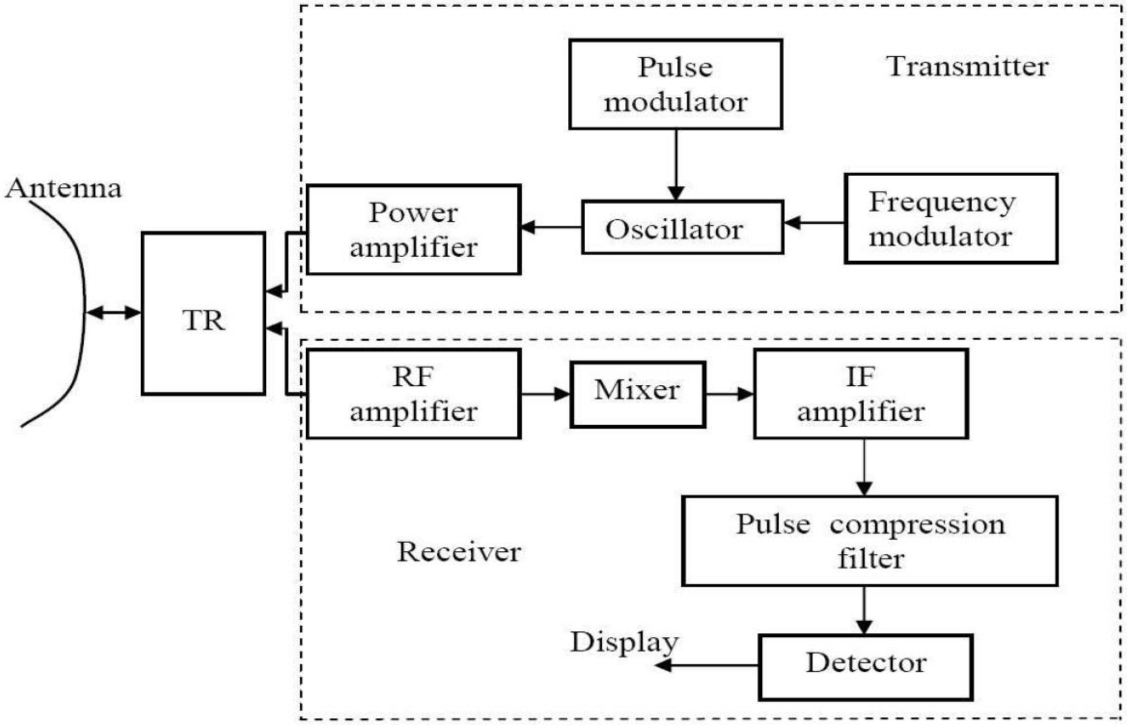
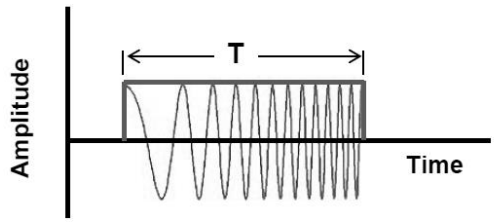


Fig 2.1-*Block diagram of a radar antenna*

Several methods of pulse compression of pulse compression have been used in the past. The most common and popular among them is the Linear Frequency Modulation (LFM) which was invented by R.H Dickie in 1945. The other popular pulse compression techniques include Costas codes, Binary-phase codes, poly-phase codes and non-linear frequency modulation.

2.2 LINEAR FREQUENCY MODULATION

Linear Frequency Modulation is used in radar systems frequently to achieve wide-operating bandwidths. In this case the frequency of the transmitted wave either increases (up-chirp) or decreases (down-chirp) with time.



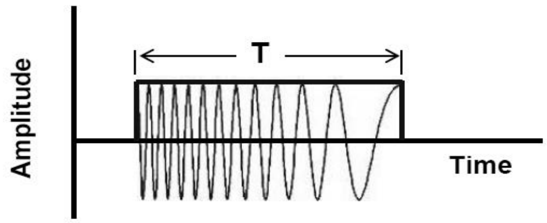


Fig 2.2*-Increasing Frequency(Upchirp)*

Fig2.3*-Decreasing Frequency(Downchirp)*

The instantaneous phase of the chirp signal is expressed as:

$$Ø(t) = 2\pi(f_1 t + \frac{1}{2}kt^2)$$

$$K = \frac{B}{T}$$

Instantaneous Frequency is given by

$$f(t) = \frac{d(f_1 t + \frac{1}{2}kt^2)}{dx} = f_1 + kt$$

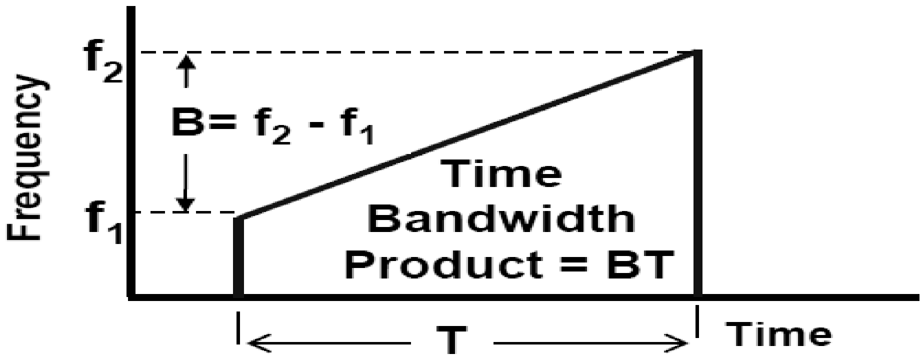


Fig 2.4-*Relationship between frequency and Time in LFM wave*

Frequency increases linearly with time and hence is called as Linear Frequency Modulation. The response of an unmodulated pulse and an LFM pulse are shown below

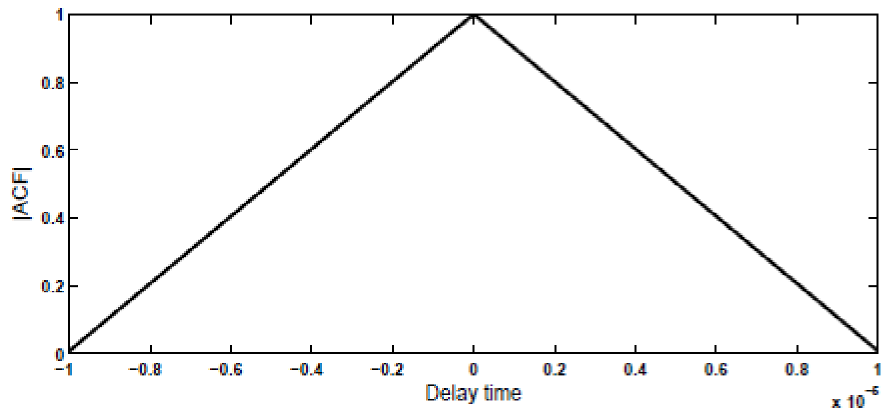


Fig 2.5-*Unmodulated Pulse matched filter response*

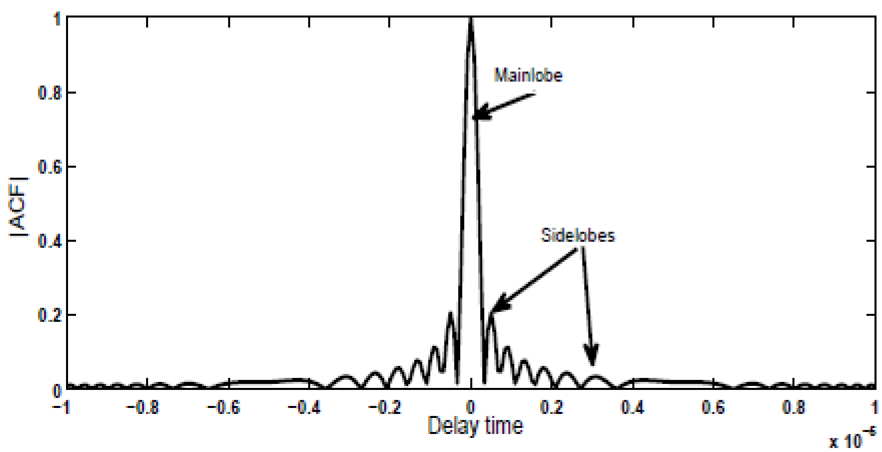


Fig 2.6-*Frequency modulated pulse matched filter pulse*

2.3 MATCHED FILTER

In radar applications the reflected pulse is used to determine the presence of the target. The reflected signal is corrupted with Additive White Gaussian noise (AWGN). The probability of detection depends upon the signal-to-noise ratio (SNR) rather than the exact shape of the signal received. Hence it is required to maximize the SNR rather than preserving the shape of the signal. A filter that maximizes the output SNR is called **matched filter**. A matched filter is a linear filter whose impulse response is found for a signal in such way that the output of the filter yields maximum SNR when the signal along with noise is passed through it. A matched filter essentially performs an auto correlation between the transmitted signal and the received signal[4].

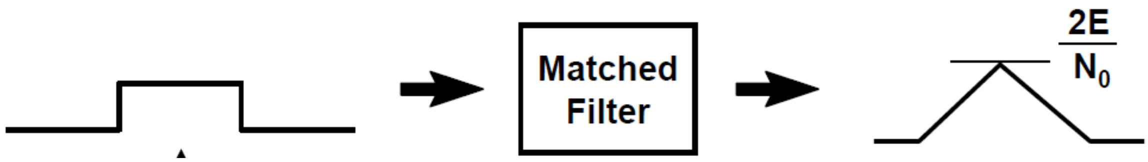


Fig 2.7*-Matched Filter response*

2.3.1 Matched Filter Basics

The signal power to noise power is given by

$$\left(\frac{SP}{NP}\right)_{out} = \frac{|s_0(t_0)|^2}{\overline{n_0^2(t)}}$$

SP-Signal Power

NP-Output Noise Power

$s_0(t_0)$-value of signal at $t=t_0$

$\overline{n_0^2(t)}$ -mean square value of noise

If S(f) is the Fourier transform of s(t), then $s_0(t)$ is obtained as

$$s_0(t) = \int_{-\infty}^{\infty} H(f)S(f)e^{j2\pi ft}df$$

The value of $s_0(t)$ at $t=t_0$ is

$$s_0(t_0) = \int_{-\infty}^{\infty} H(f)S(f)e^{j2\pi f t_0} df$$

$$\overline{n_0^2(t)} = \frac{N_0}{2} \int_{-\infty}^{\infty} |H(f)|^2 df$$

Substituting we get

$$\left(\frac{SP}{NP}\right)_{out} = \frac{\left|\int_{-\infty}^{\infty} H(f)S(f)e^{j2\pi f t_0} df\right|^2}{\frac{N_0}{2}\int_{-\infty}^{\infty} |H(f)|^2 df}$$

Using Schwarz inequality, the numerator can be written as

$$\left|\int_{-\infty}^{\infty} H(f)S(f)e^{j2\pi f t_0} df\right|^2 \leq \int_{-\infty}^{\infty} |H(f)|^2 df \int_{-\infty}^{\infty} |S(f)e^{j2\pi f t_0}|^2 df$$

the equality holds good when

$$H(f) = K_1[S(f)e^{j2\pi f t_0}]^* = K_1 S^*(f)e^{-j2\pi f t_0}$$

where K_1 is an arbitrary constant and $*$ stands for complex conjugate. Using the equality sign which corresponds to maximum SNR output we get

$$\left(\frac{SP}{NP}\right)_{out} = \frac{\int_{-\infty}^{\infty} |S(f)|^2 df}{\frac{N_0}{2}} = \frac{2E}{N_0}$$

It is obvious that the maximum SNR is a function of the energy of the signal but not the shape. Taking inverse Fourier transform of the impulse response of matched filter is obtained as

$$h(t) = K_1 s^*(t_0 - t)$$

Taking Convolution the equation for $s_0(t)$ is obtained as the auto-correlation of the sent signal

$$_{K_1=1,t_0=0} \int_{-\infty}^{\infty} s(\tau)s^*(\tau - t)d\tau$$

Thus it is observed that the matched filter essentially performs the auto-correlation between the transmitted signal and the received signal.

2.4 AMBIGUITY FUNCTION

2.4.1 Matched Filter Response of Narrow band-pass signals

The output of the matched filter is obtained as

$$s_0(t) = Re\left\{u_0(t)e^{j2\pi f_0 t}\right\}$$

It is observed that the matched filter output of narrow band-pass signal has a complex envelope u_0(t) which is obtained by passing the complex envelope u(t) through its own matched filter.

2.4.2 Matched filter response of a Doppler shifted signal

The output is obtained as

$$\chi(\tau, f_d) = \int_{-\infty}^{\infty} u(t)u^*(t-\tau)e^{j2\pi f_d t}dt$$

This is the Ambiguity Function (AF)

The Ambiguity Function describes the output of the matched filter when the input signal is delayed by τ and Doppler shifted by f_d relative to the values for which the matched filter is designed.

SIMULATIONS

Time Bandwidth Product – 5

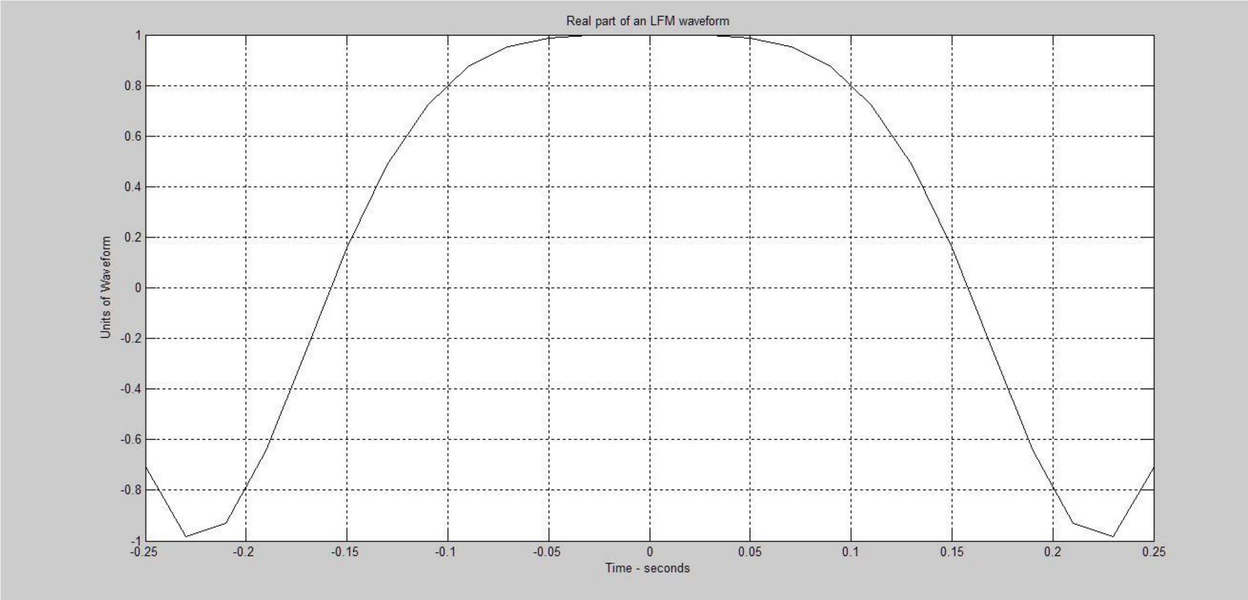


Fig 2.8-*Real Part of LFM waveform*

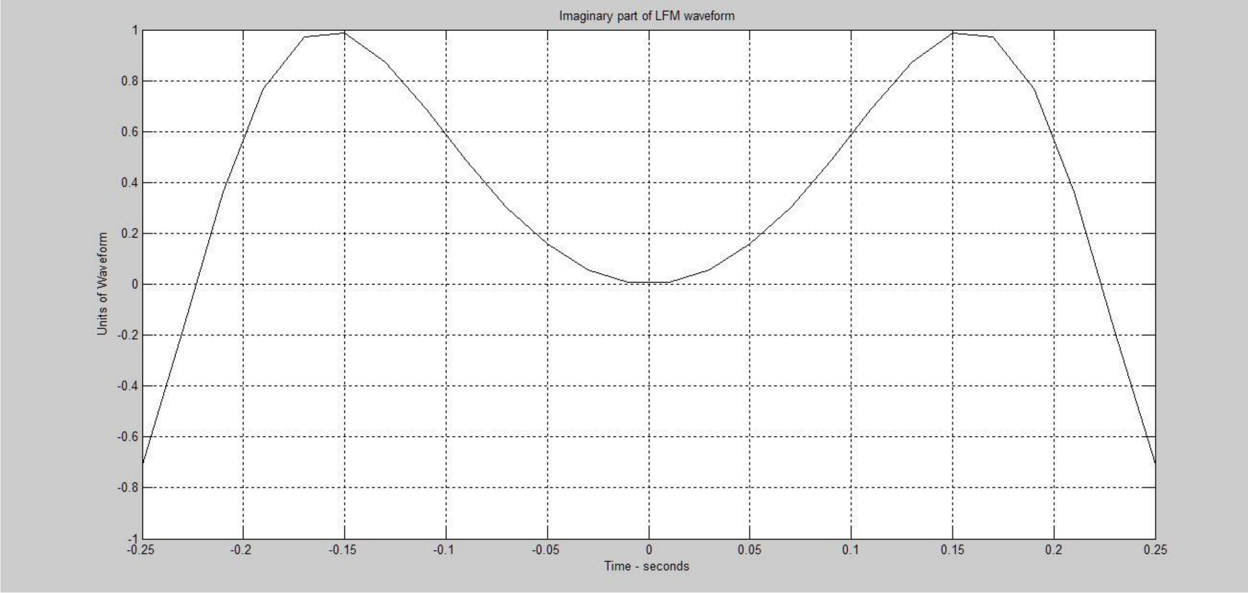


Fig 2.9-*Imaginary Part of LFM waveform*

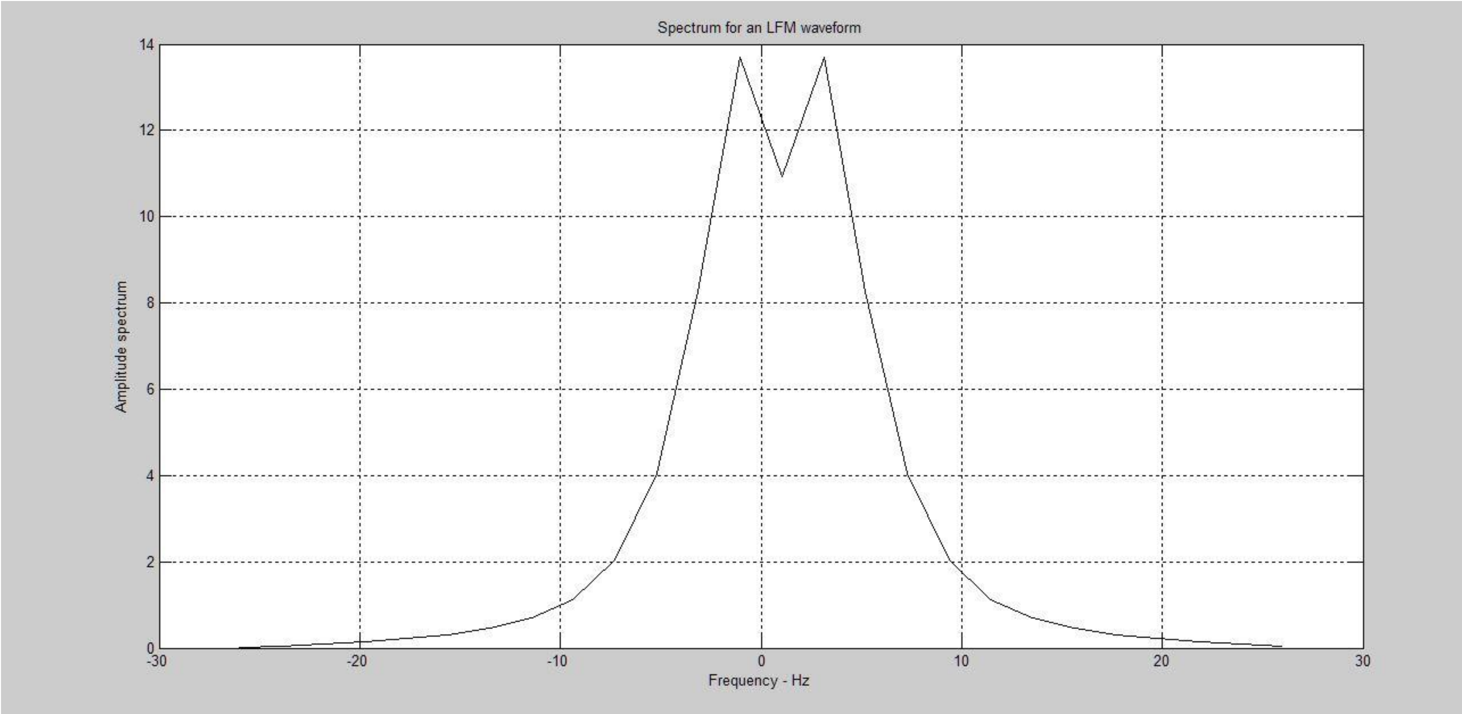


Fig 2.10-*Frequency Spectrum of LFM waveform*

2.5 WINDOW FUNCTIONS

Windows are expressions which have a specific value within a given range and have a value of zero outside the range. One example is a rectangular window which has a constant value inside the interval and have a zero value outside. When the window function is multiplied with the given signal they only give a value where they overlap and give zero outside.

The LFM wave was introduced in the following 5 windows

2.5.1 Rectangular Window

The rectangular window has a constant value over its length.

w(n)=1.0 for n=0, 1, 2, ….. , N-1

where N is the length of the window and w is the window value.

It just limits the signal to a given finite range.

2.5.2 Hanning Window

The hanning window looks like the half cycle of a cosine wave. It is given by the equation.

$$w(n)=0.5-0.5\cos\frac{2\pi n}{N}$$

For n=0,1,2, … , N-1

where N is the window length and w is the window value.

2.5.3 Hamming Window

The Hamming window is similar to a Hanning window. The equation is given by

$$w(n)=0.54-0.4\cos\frac{2\pi n}{N}$$

For n=0,1,2,….,N-1

2.5.4 Kaiser Window

The Kaiser window is a more flexible smoothing window whose shape can be changed using the parameter β. w=Kaiser(L, beta) returns a L-point Kaiser window in the column vector w. β parameter affects the side-lobe attenuation of the Fourier transform window.

2.5.5 Blackmanharris Window

The BlackmanHarris does window sampling using a 'sflag'. This can either be periodic or symmetric. The periodic flag is generally used for Fourier transform so that spectral analysis can be done. The equation is given by

$$w(n)=a_0-a_1\cos\frac{2\pi n}{N}+a_2\cos\frac{2\pi 2n}{N}-a_3\cos\frac{2\pi 3n}{N}$$

where $-N/2<n<N/2$ and window length is given by $L=N+1$.

Peak Side-lobe Ratio (PSR)

It is given by

$$\text{PSR} = 10\log_{10}\frac{Peak\ Lobe\ Power}{Side\ Lobe\ Power}$$

Simulation Results

The LFM signal with a time-bandwidth product of 50 and 500 was taken and passed through the above 4 windows and the simulation was viewed using MATLAB.

SIMULATIONS

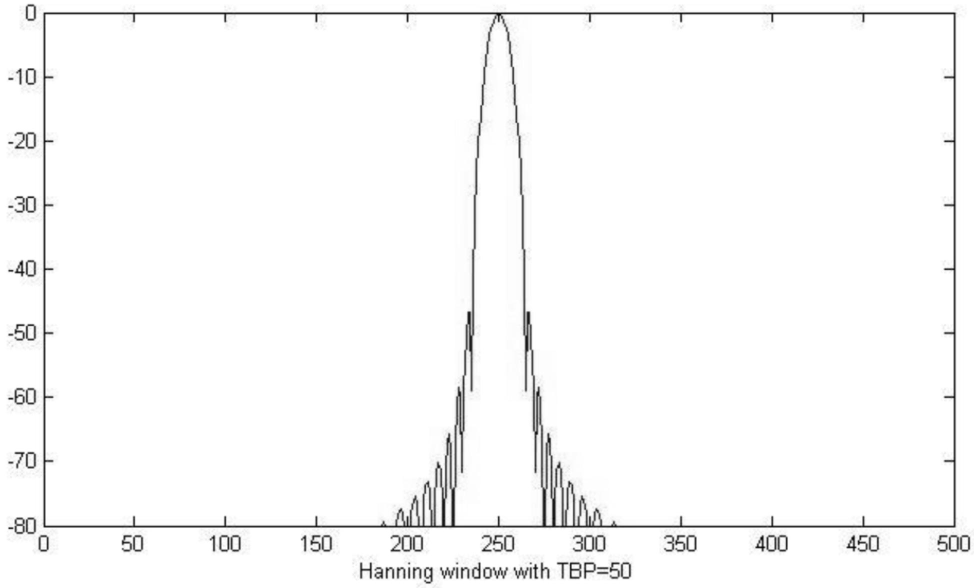


Fig 2.11-*LFM signal of TBP 50 through a Hanning window*

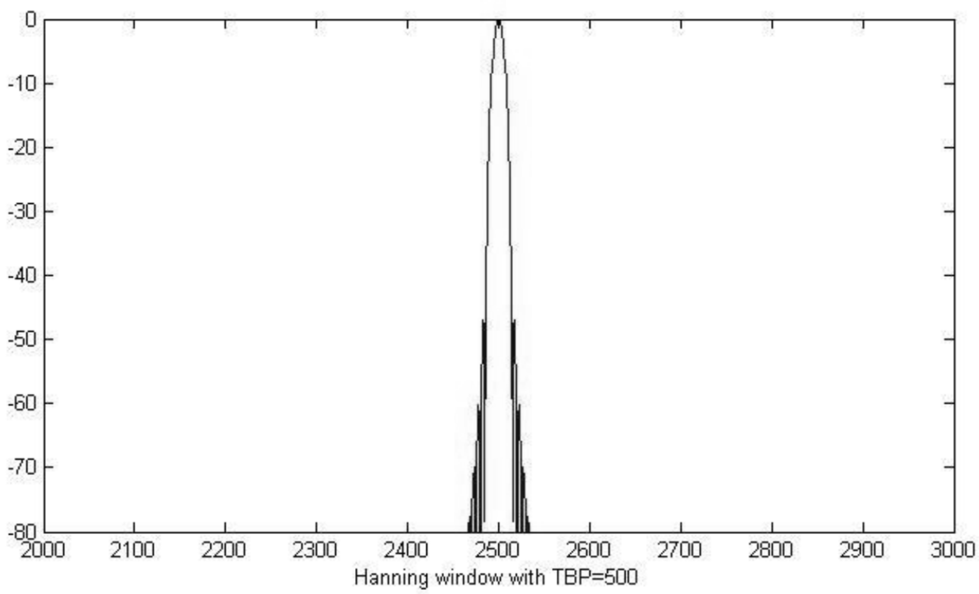


Fig 2.12- *LFM signal of TBP 500 through a Hanning window*

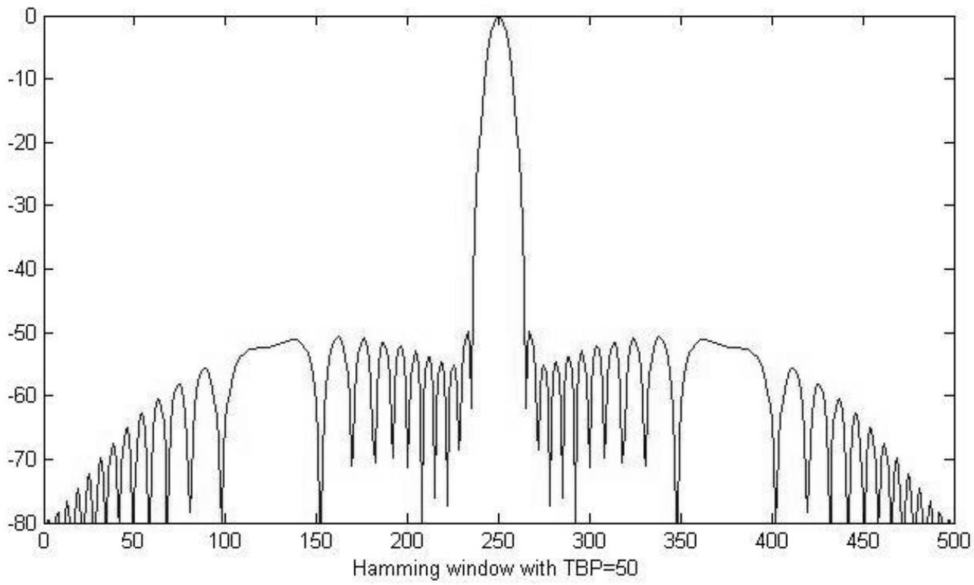


Fig 2.13- *LFM signal of TBP 50 through a Hamming window*

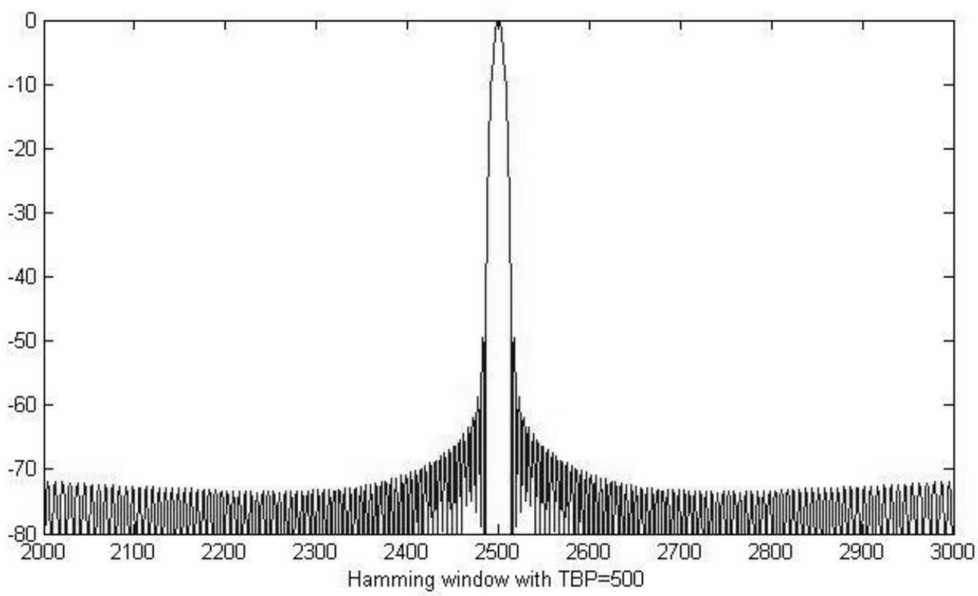


Fig 2.14- *LFM signal of TBP 500 through a Hamming window*

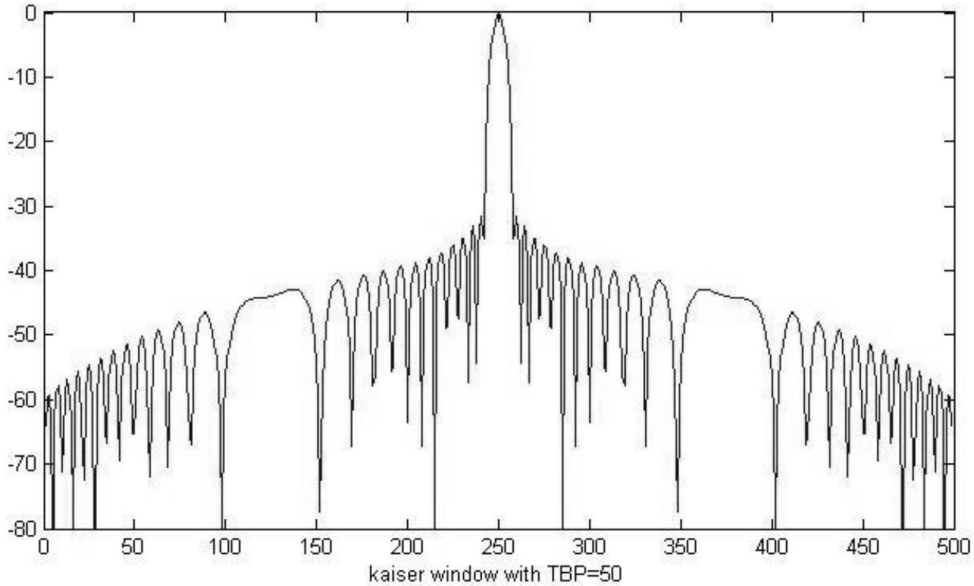


Fig 2.15- *LFM signal of TBP 50 through a Kaiser window*

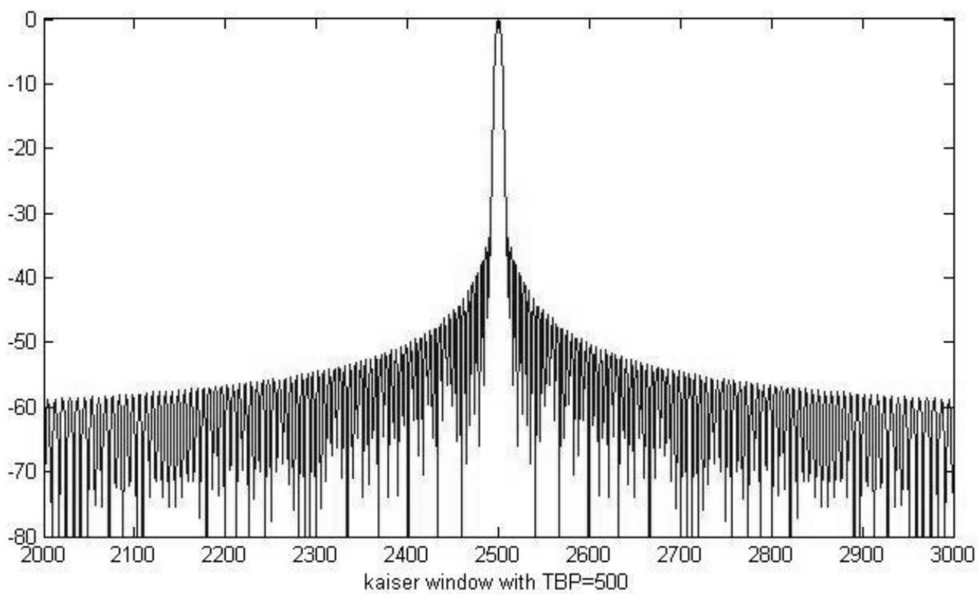


Fig 2.16- *LFM signal of TBP 500 through a Kaiser window*

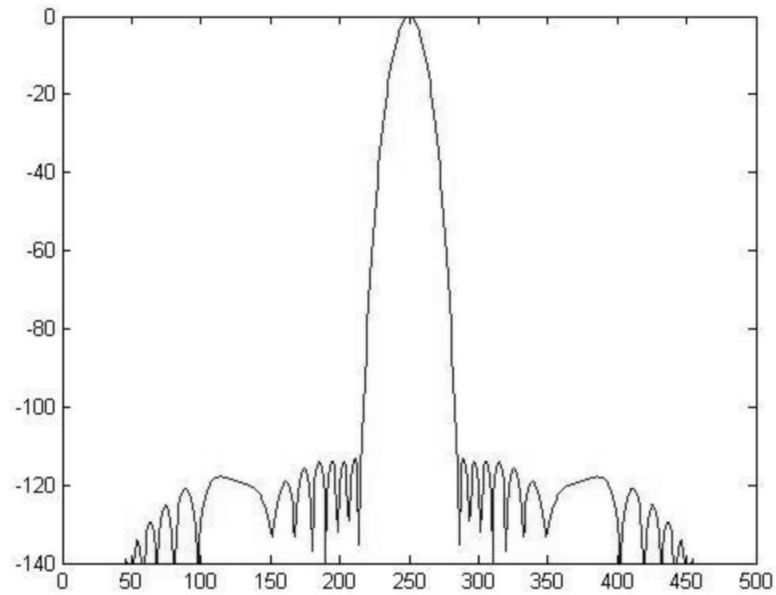


Fig 2.17- *LFM signal of TBP 50 through a Blackmanharris window*

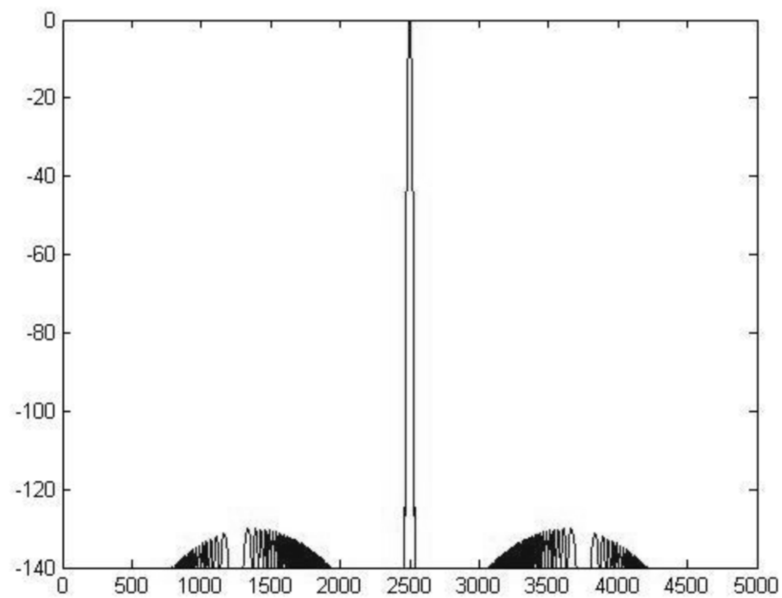


Fig 2.18- *LFM signal of TBP 500 through a Blackmanharris window*

***Table 2.1**: PSR values with respect to TBP for different windows*

WINDOW TYPE	PSR WITH TBP 50	PSR WITH TBP 500
Hanning	*-46*	*-46.5*
Hamming	*-50*	*-50.5*
Kaiser	*-33*	*-34*
Blackmanharris	*-118*	*-130*

Inferences

- We can observe that the Blackmanharris window gives the best PSR and hence is best suited for ide-lobe reduction and rectangular window has the worst PSR value and is unsuitable for side-lobe reduction.
- TBP values least affects the side-lobe reduction while using windows. In higher order cosine windows like the Blackmanharris window the effect of TBP on PSR value is large.
- The value of β used in a Kaiser window gives the relation between side-lobe level and the main lobe width. Higher values of β gives better side-lobe reduction but also result in widening of the main lobe. Widening of the main lobe leads to reduction in range resolution.

2.6 DETECTION OF TARGET

Simulation Results

The LFM signal was used to detect three targets and the received echo was allowed to pass through 3 windows.

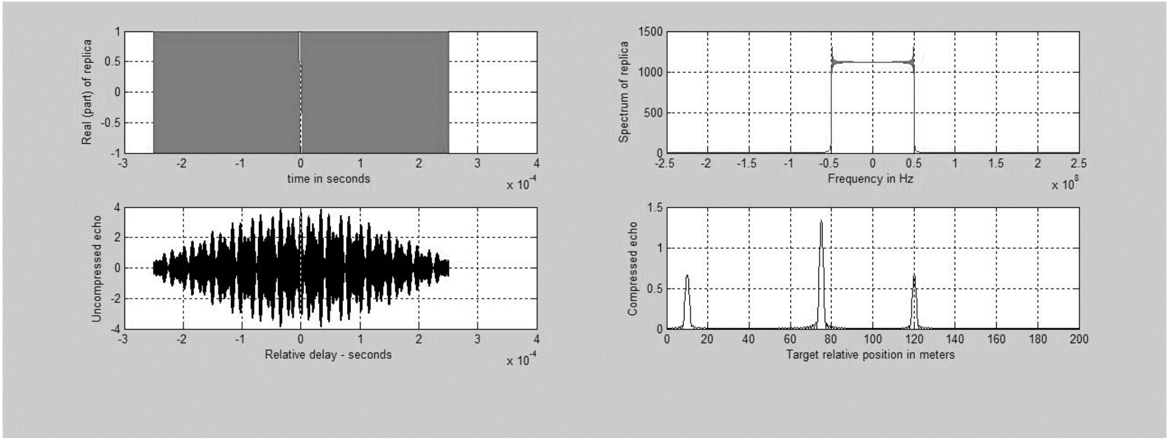


***Fig 2.19**- Detection of 3 targets using a LFM wave*

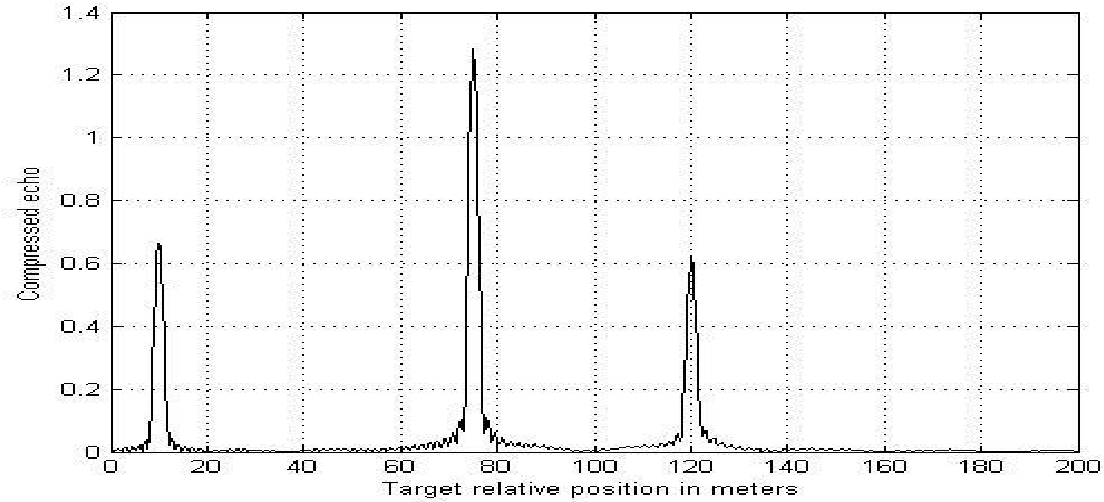


Fig 2.20-*Detection of 3 targets using a LFM wave passed through a Kaiser window*

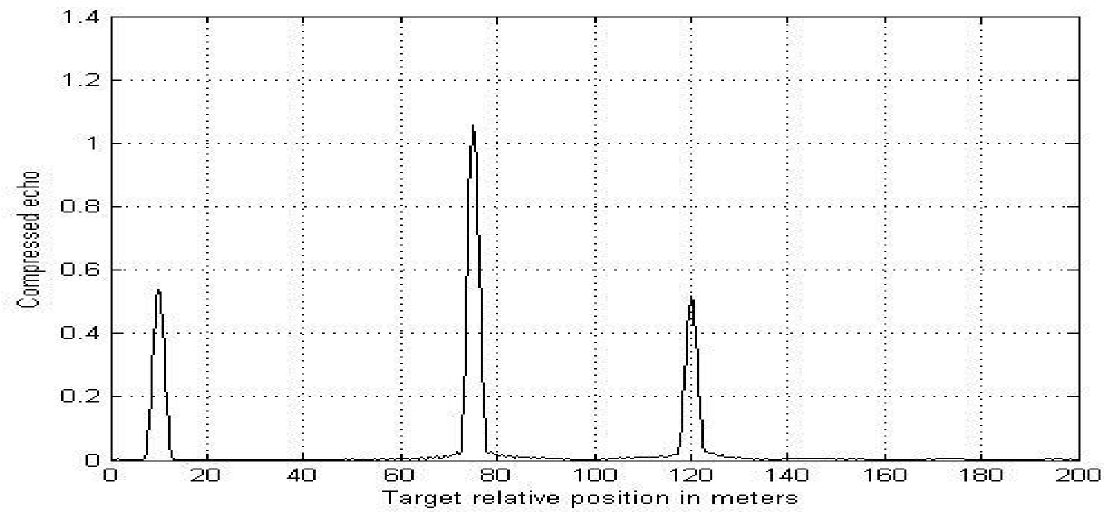


Fig 2.21- *Detection of 3 targets using a LFM wave passed through a Hamming window*

2.7 DOPPLER EFFECT ON LFM SIGNALS

The Doppler Effect is observed in signals when there is a moving target. Radars use the Doppler frequency shift to extract information about the velocity of the target. The Doppler frequency is given by f_d in the ambiguity function of the matched filter

$$\aleph(\tau, f_d)=\int_{-\infty}^{\infty} u(t).u*(t-\tau)\, e^{i2f\pi f dt}\, dt$$

The Doppler Effect is checked by passing the signal through the windows and studying the change in PSR. The LFM signal was passed through the four windows with varying Doppler frequency and the results were studied.

SIMULATIONS

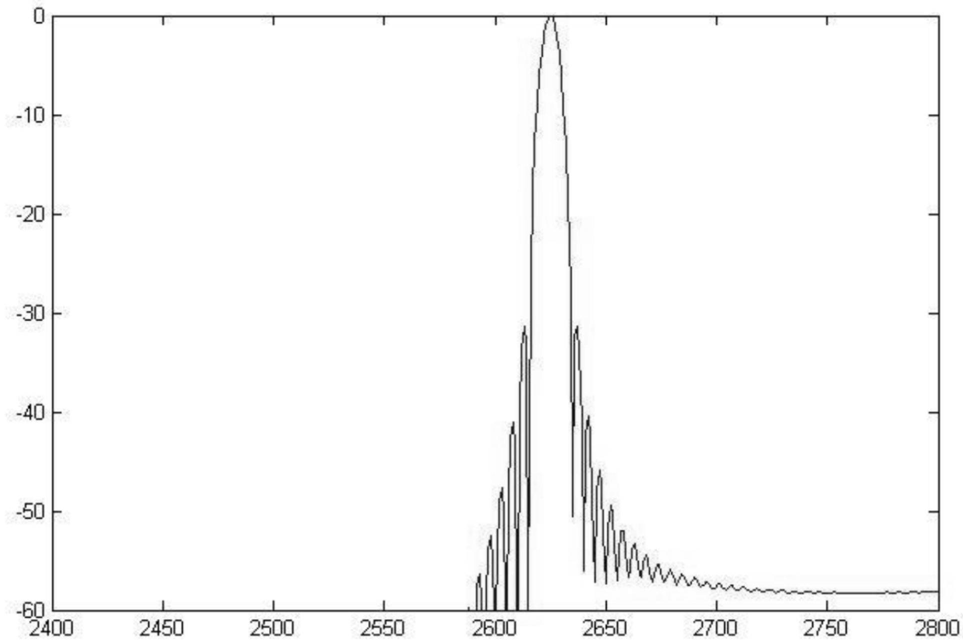


Fig 2.22-*LFM signal having f_d/B=0.1 passed through a Hanning window*

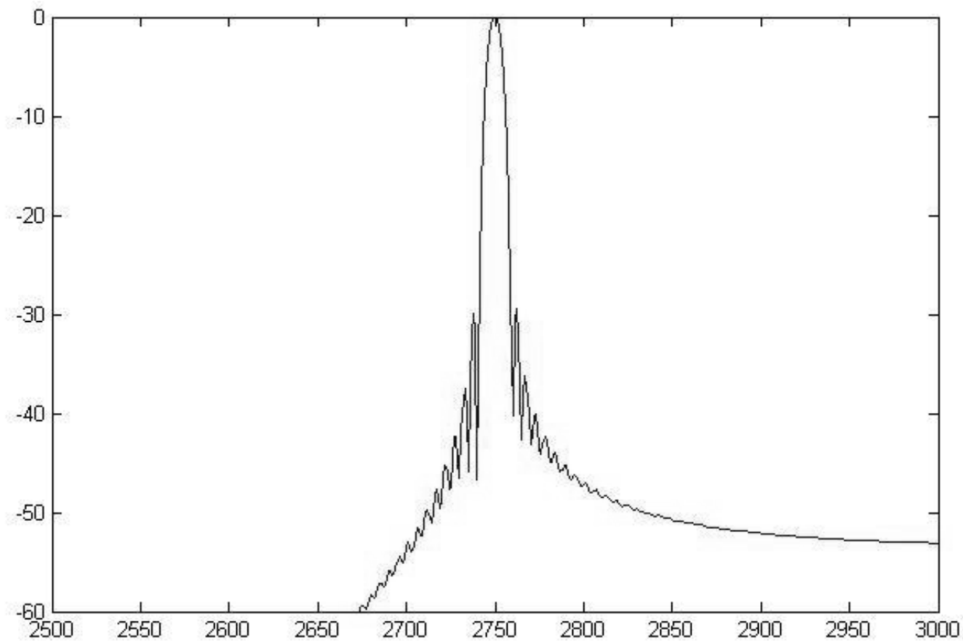


Fig 2.23- *LFM signal having f_d/B=0.2 passed through a Hanning window*

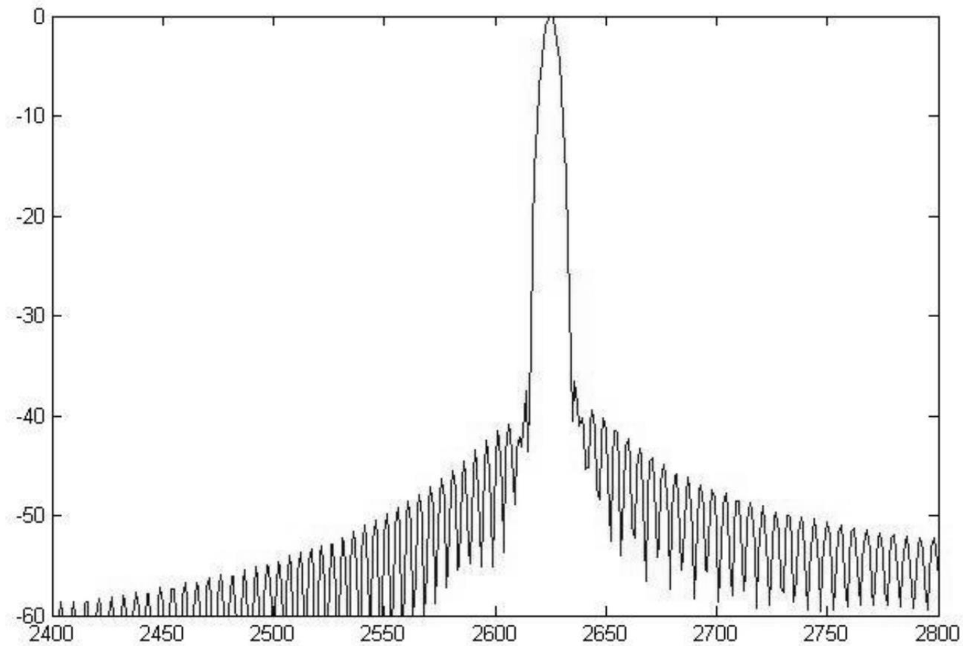


Fig 2.24- *LFM signal having $f_d/B=0.1$ passed through a Hamming window*

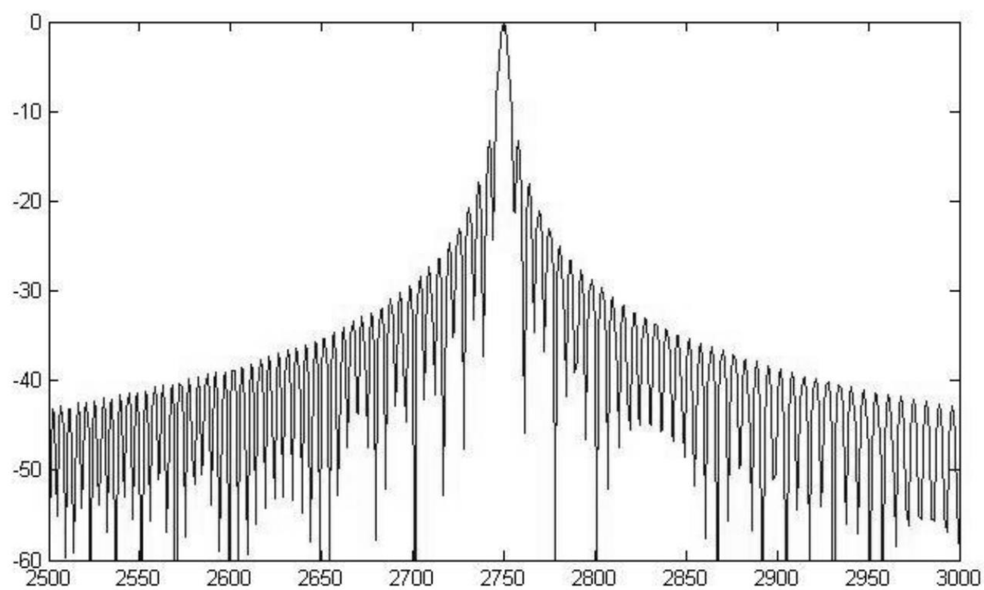


Fig 2.25- *LFM signal having $f_d/B=0.2$ passed through a Hamming window*

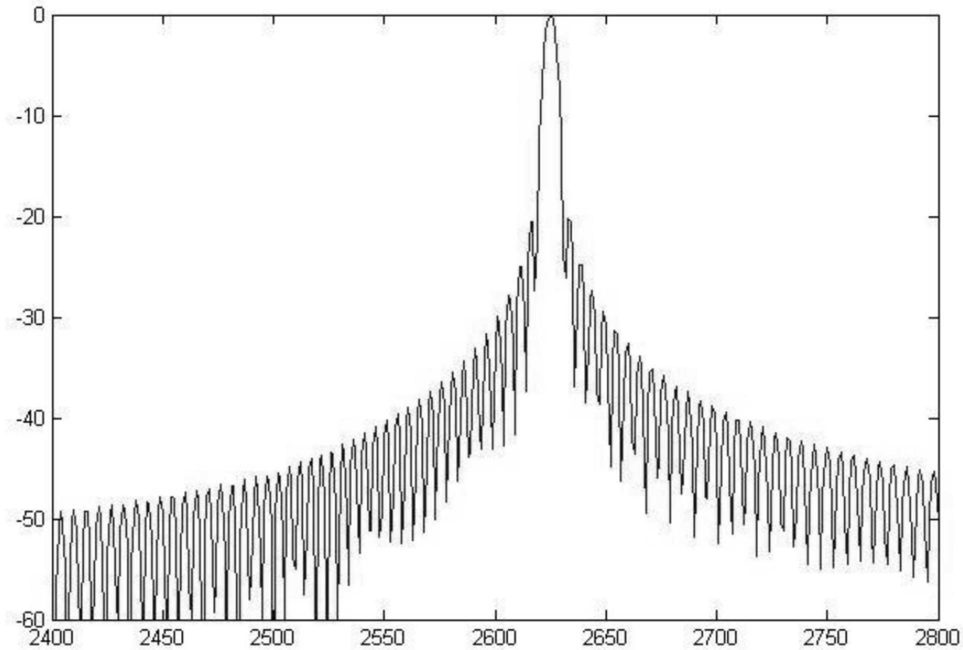


Fig 2.26- *LFM signal having $f_d/B=0.1$ passed through a Kaiser window*

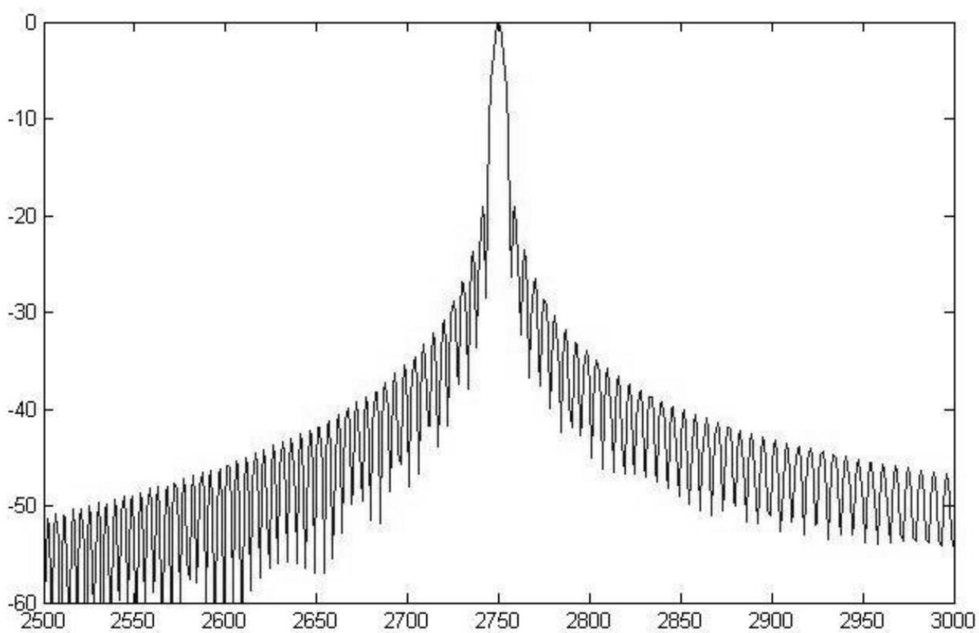


Fig 2.27- *LFM signal having $f_d/B=0.2$ passed through a Kaiser window*

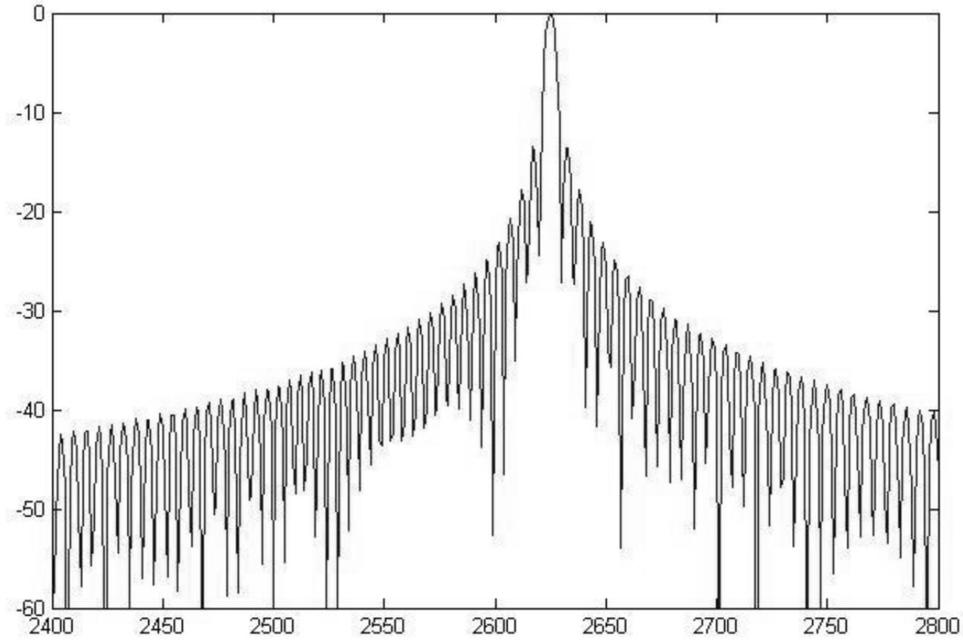


Fig 2.28- *LFM signal having $f_d/B=0.1$ passed through a Rectangular window*

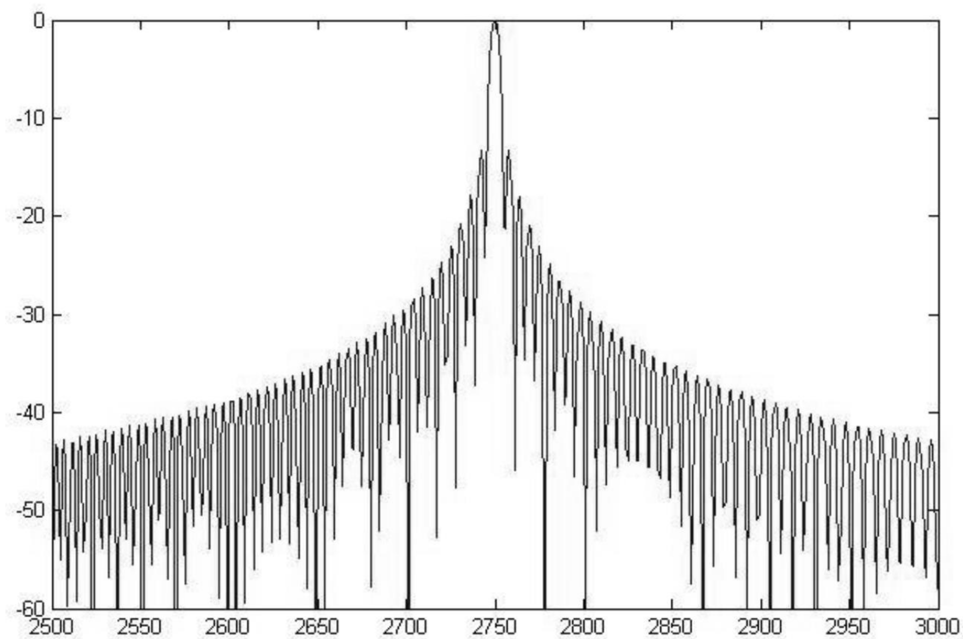


Fig 2.29- *LFM signal having $f_d/B=0.2$ passed through a Rectangular window*

Table 2.2*-PSR values for various f_d/B values for different windows*

Window Type	PSR (f_d/B=0.1)	PSR (f_d/B=0.2)
Hanning	-31	-30
Hamming	-38	-32
Kaiser	-24	-20
Rectangular	-15	-12

Inferences

- PSR value decreased with increase in the Doppler Effect when passed through the windows (Kaiser, Hanning, Hamming and Rectangular).
- We see that the rectangular window gives the worst value of PSR and hence is unsuitable for use while the Hamming window gives the best PSR value and can be used for detection of the target velocity through the Doppler Effect.

2.8 CONCLUSION

Linear Frequency Modulation is used for Radar Pulse Compression Techniques because it provides a wide operating bandwidth. It is one of the popular used methods for pulse compression. The design of matched filter was reviewed and it was found that performing the auto-correlation between the transmitted signal and the received signal gives the maximum SNR. To obtain side-lobe reduction windowing techniques was used. The LFM signal was passed through 5 windows and the relationship between PSR and TBP product was observed. We found that the PSR value increased with increase in TBP. We also observed that the Blackmanharris window provided the best PSR value and thus is the best suited window for side-lobe reduction. Besides the Doppler Effect on the PSR value was also studied.

CHAPTER 3

STRETCH PROCESSING

3.1 INTRODUCTION

Stretch processing or "active correlation" provides high range resolution in pulse compression. Normally it is used for LFM waveforms having high bandwidth. Stretch Processing is used to process large bandwidth signals using narrowband techniques. Stretch processing has simple requirements like a analog to digital converter a and a FFT processor. During processing, first we have to mix the received signal with the replica of transmitted signal. After this we give the output to the ADC converter. Finally narrowband filters are used.

When we have targets at a close range, then the output of LPF have constant tones corresponding to the respective target's position. It converts time delay into frequency. This is because mixing the received signal with reference signal and then performing low pass filtering is same as subtracting received frequency chirp from replica.

The Block Diagram for Stretch Processor is given

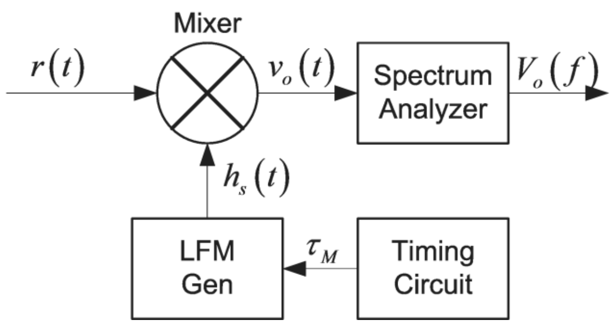


Fig 3.1-*Block Diagram for a Stretch Processor*

The main parts in the block diagram are a mixer, a spectrum analyzer, a LFM generator and a timing circuit

3.2 STRETCH PROCESSOR CONFIGURATION

The radar transmitted signal is given by the following equation-

$$s(t)= \cos(2\pi\left(f_0 t + \frac{B}{2\mathcal{J}'} t^2\right)) \quad 0<t<\mathcal{J}$$

Where f0 is the start frequency of the LFM signal, the reference signal is given by

$$S_{ref}(t)=2\ \cos(2\pi\left(f_0 t + \frac{B}{2\mathcal{J}'} t^2\right)) \quad 0<t<T_{rec}$$

Where T_{rec} is the received window and is given by

$$T_{rec} = \frac{2(R_{max} - R_{min})}{c}$$

Here we have assumed that there is a point scattered at a range rather received signal is given by

$$S_r(t)=a \cos 2\pi f_0 (t - \Delta\tau) + \frac{\mu}{2}(t - \Delta\tau)^2$$

Where 'a' is proportional to the target range cross section, antenna gain and range attenuation and $\frac{2R}{c}$ is the time delay.

The output of the mixer is the multiplication of the received signal and the reference signal. The low pass filtering of the signal is done. Since $\mathcal{J}'= \frac{2R}{c}$ the above signal is approximated. Taking the FFT transform of the signal results in a peak at some frequency which indicates the presence of a target.

SIMULATION

Table 3.1*-Simulation Parameters for Stretch Processing*

Bandwidth	10 GHz
Scattered Range	1.5, 7.5, 15.5
Frequency (f0)	5.6 GHz
Win	Kaiser

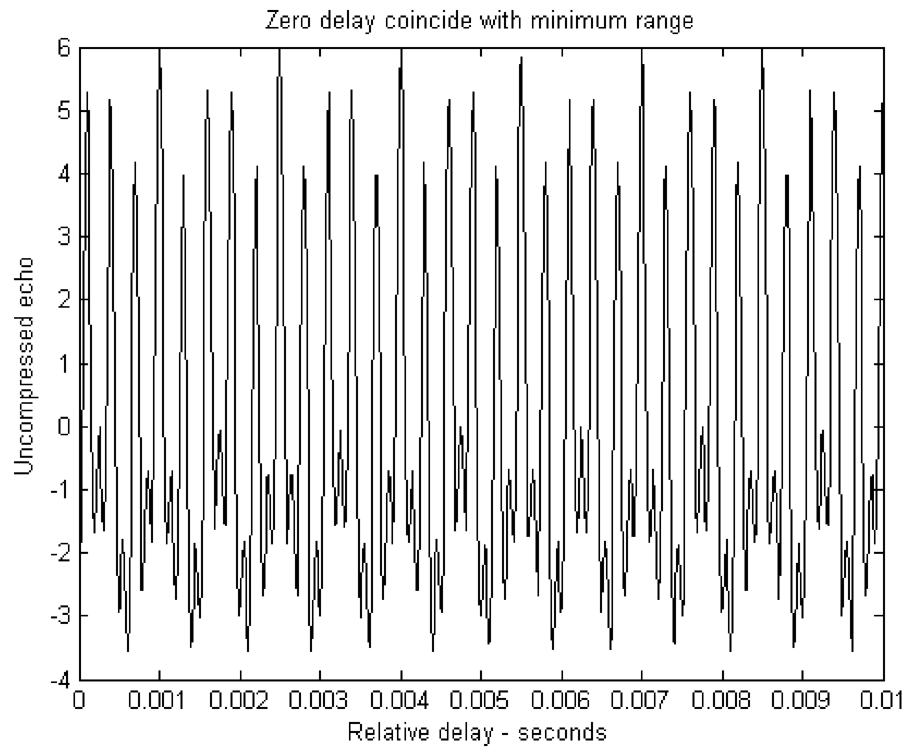


Fig 3.2-*Uncompressed Echo of Stretch Processing for 3 targets*

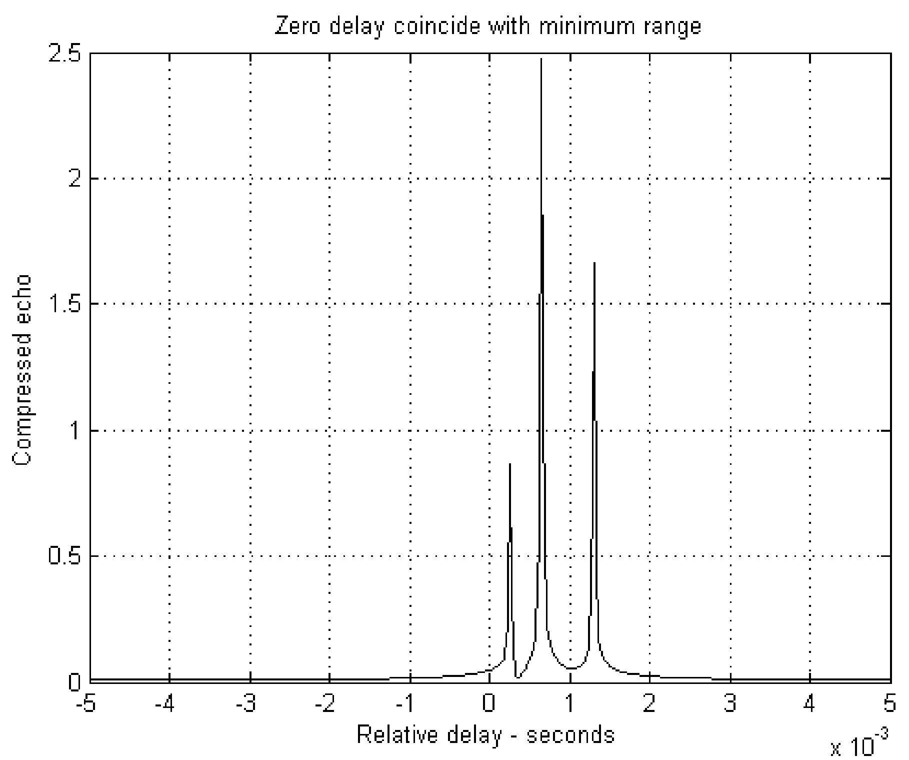


Fig 3.3-*Detection of targets*

3.3 CONCLUSION

A stretch processing helps the signal processor to get rid of its bandwidth problem by rejecting all-range processing to obtain a narrow-band processor. In case of a matched filter we search for targets over the entire pulse repetition interval (PRI). However in stretch processing we are confined to a range extent that is smaller than the uncompressed pulse duration. We can't use stretch processing for search applications because it requires looking for targets spread over a large range. We could however use stretch processing for track purposes where we already know the location of the target but want to obtain a more accurate measurement for it.

CHAPTER 4

MASKING EFFECT

4.1 MASKING EFFECT INTRODUCTION

When noise is present in radar signal processing we have to perform correlation between transmitted and received signals. The received signals collected from the nearby targets usually generate very high side lobes in the above correlation function. The signals received from long distance targets are weak. The weaker echoes are masked by the strong echoes of nearby targets. This effect is known as **Masking Effect.**

Masking effect can be minimized or removed by different methods. Doppler shift is one of the old methods for removing masking effect. However it doesn't remove all strong echoes completely. We can use method based on signal stretch processing, which gives an improved result than the previous described methods. We can detect weak targets in the presence of the strong echoes.

In practical situation, in addition to other targets the weather clutter echoes and ground clutter echoes are also present at receiver signal. In pulse radar the noise reflected echoes are separated in time. When these are characterized in integration time the clutter and target echoes overlap causing interference known as masking effect.

For single target detection we use matched filter which is tuned to range and velocity of the target. So in case of multiple targets it can't be possible. When the matched filter is tuned to the nearby target echo from far target is considered as noise, so it becomes difficult to track it. If we tune the matched filter with far target the strong echoes increases the noise level.

4.2 METHODS TO REMOVE MASKING EFFECT

- Removal of ground clutter and weather cutter from the received signal .we can use adaptive lattice filter for this purpose.
- Elimination of nonzero Doppler clutter. For this we can produce a model of the target echoes having non-zero Doppler frequency and subtract from received signal.
- We can have target echo modelling by considering the time shift and Doppler shift of transmitted signal. This method is used for comparatively slow moving targets.

4.3 Masking Effect Removal using Range Doppler Function

Initially we have to calculate the range Doppler cross-correlation function. Then in second step we have to find maximum of the Doppler cross-correlation function and thus locate the strongest echoes. The coordinates of maximum help in estimation of the target velocity and range and modelling of strong target echo. We have to subtract the modelled signal from the received signal.

This resulting signal consists of all noise signal and weak echoes which have to be processed further using adaptive echo cancellation till all the noise floor is delivered and echoes are removed. All the calculations are done in time domain. For better quality of cancellation there should be better resampling of reference signal.

In the third stage cancellation of strong echoes are covered in frequency domain. Here we subtract the product of estimated complex amplitude and normalized strong echo from the received signal. For this purpose we sort the strong echoes accordingly from strongest to weakest.

In the final and fourth stage the range Doppler cross coefficient is estimated and the weak targets are detected. This procedure is effective for point targets and applicable for medium and low range resolution radar. For high range resolution we have to implement stretch processing in point cancellation method.

4.4 Masking Effect removal using Stretch Processing

4.4.1 **Linear Interpolation Method**

Here we calculate the linear combinations of adjacent original samples for the computation of new samples. It is one of the simplest re-sampling methods, known as method of curve fitting. It is very fast but has poor accuracy.

4.4.2 Poly-phase method

It uses poly phase filter which is effective way of upsampling by an integer N and simultaneously downsampling by another integer factor M. They obtain a stretch factor M/N which is usually close to 1. Firstly from an oversampled point set we calculate sample values using simple poly phase resampler. Secondly we use a simple linear interpolation for finding more accurate value at a required point between samples.

4.4.3 Spectrum based method

This method is based on the conversion of signal to spectral domain and making manipulation in the domain. After manipulation spectrum is converted back to time domain. This method allow resampling factor of N/M. It uses an efficient IFFT algorithm. If the resampling factor can't be expressed as a ratio of two integer then chirp z transform resampling method is used.

Table 4.1- *Simulation Parameters for Masking Effect*

Bandwidth	0.1 GHz
Scatter Range	20, 100
Radar Cross-Section	2, 0.05
Time Period	5 μs

SIMULATION

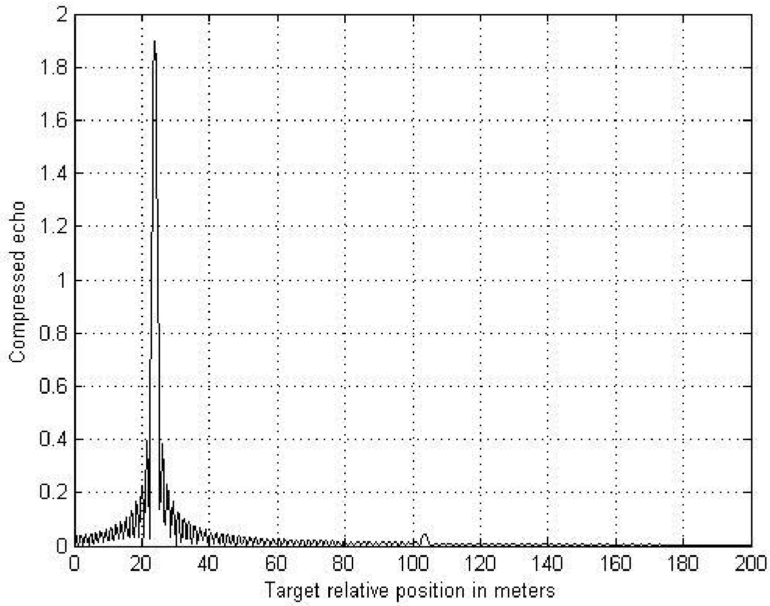


Fig 4.1*-Masked output using only matched filter*

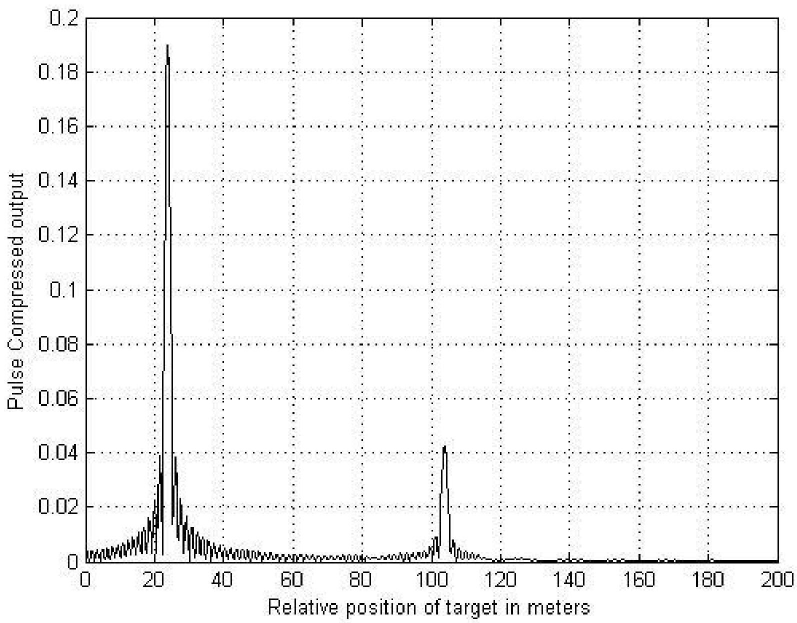


Fig 4.2*-Unmasked output using only matched filter*

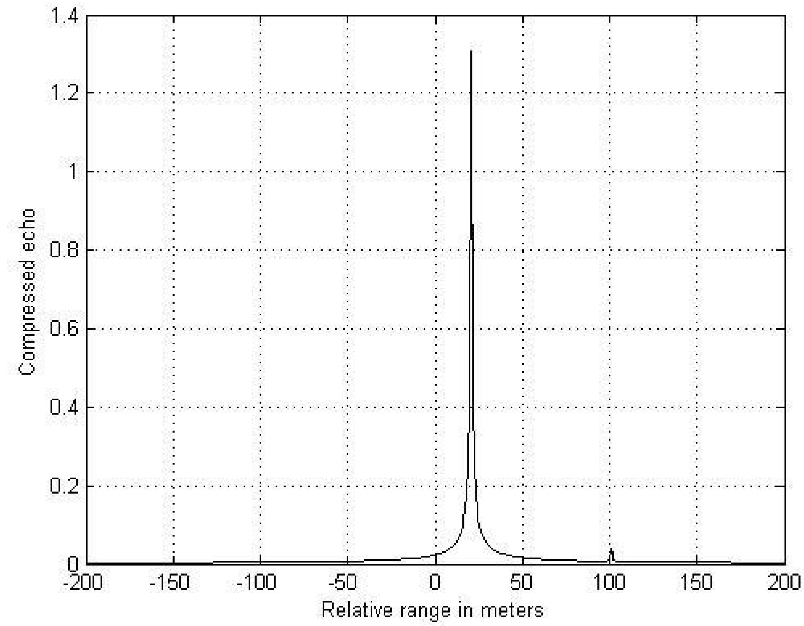


Fig 4.3*- Masked output using matched filter and stretch processing*

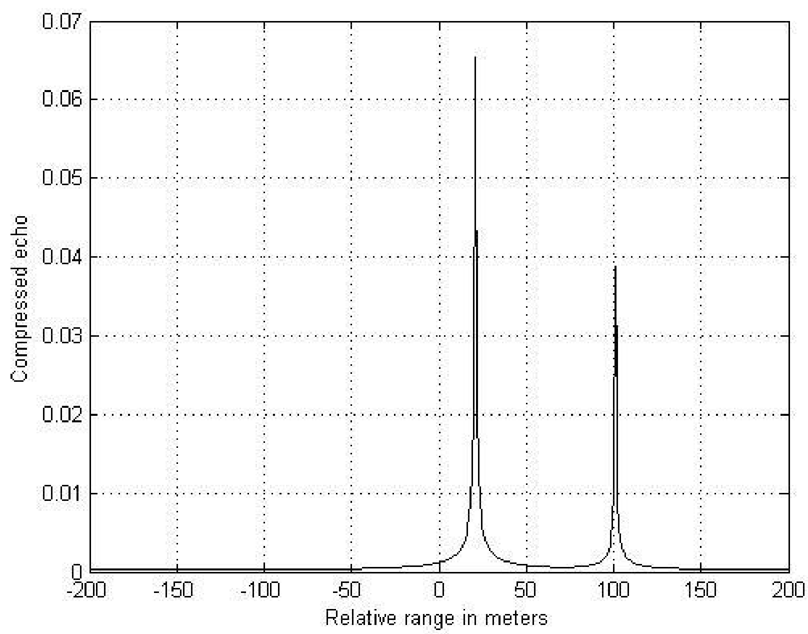


Fig 4.4*- Unmasked output using matched filter and stretch processing*

4.5 Conclusion

In radar pulse compression we have used both Matched filter and Stretch processing. Both are suitable for side lobe reduction and improving SNR value. But Matched filter is generally used for narrowband signal and Stretch processing is used for wideband signal. In case of stretch processors give up all range processing to get the narrow band signal processors whereas match filter look for targets in entire waveform pulse repetition interval(PRI). So we can’t use stretch processing for search purpose as it requires look for a large range extend. Instead we use it for tracking as we already know the range approximately. Matched filter can also be used for wideband signal but only up to a certain range.

CHAPTER 5

CONCLUSION AND FUTURE WORK

5.1 CONCLUSION

From the thesis we saw that pulse compression could be achieved using two methods; using a matched filter or through stretch processing. Matched Filter performs a correlation between the received signal and the replica of the transmitted signal. Stretch Processing converted the time delay between the signals into frequency. Stretch Processing is preferred because it gives enhanced range resolution. It also provides better side-lobe reduction than matched filter processing.

Besides the effect of windows on the LFM signals was studied. The LFM wave was passed through 5 windows

1. Rectangular Window
2. Hanning Window
3. Hamming Window
4. Kaiser Window
5. Blackmanharris Window

We also noticed that the better side-lobe reduction was achieved by using the Blackmanharris window.

Masking Effect was examined. Masking Effect is observed when strong echoes of a nearby target mask the weaker echoes from distant targets. The various methods to remove masking effect were discussed and the stretch processing method to remove masking effect was implemented.

5.2 FUTURE WORK

Pulse Compression was achieved through linear frequency modulation. Other techniques for pulse compression can be implemented. Phase-coded Modulation methods can also be used for achieving pulse compression. Costas Codes, Baker Codes etc. are used for this purpose. Besides non-linear frequency modulation technique can also be implemented.

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