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Research paper

Designing a waveform using LFM, NLFM for MIMO radar

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Abstract

We propose a waveform that includes Linear frequency modulation and non linear frequency modulation wave applicable for MIMO radar. The wave form consists of three segments where the boundary segment consists of LFM content and the middle segment consists of NLFM. The time frequency component in the middle segment is controlled. The range and Doppler side lobe suppression is improved. The genetic algorithm is implemented to suppress the side lobes in the auto correlation and cross correlation functions. The performance is analysed by using ambiguity function .

Keywords: MIMO radar, Linear frequency modulation (LFM) ,Non linear frequency modulation(NLFM),Ambiguity function

1. Introduction

MIMO radar plays a major part in object detection and estimation in radar concept receiving the signals from different transmitting units and processing it for the required information is a complicated task, alone by the signal processing unit. Selecting the transmitted signal according to the application is very important task. Space time coding waveforms improves the performance of detecting the objects [1].

Orthogonality is a serious parameter that is to be followed in the radar waveform design. If multiple transmitting signals are taken, to receive it with minimum amount of fading, orthogonal signals are selected [2] to increase the Orthogonality among the signals, parametric diversity is maintained. The achievement of coherent processing gain is done by designing a weight vector which will focus on the particular area of the sector [3]. Multi beam technique is developed to detect multiple targets in the environment and multi beam techniques should satisfy the pulse compression properties [4].

Transmit beam pattern methods are developed in waveform design techniques which improves the cross correlation properties [5][12].covariance matrix is optimized to decrease the side lobes in the auto correlation functions the effective response of the autocorrelation and cross correlation functions are the main lobes should be narrow and sharp and the side lobes should be low and the effective suppression of side lobes to be done [6].

Already OFDM signals are implemented in communication systems. OFDM signals are in radar waveform design as they provide excellent orthogonality false alarm is detected easily using the MIMO-OFDM techniques [7][10][11]. Statistical simulated annealing concepts are developed to selected the right waveform in the conditions applied[8]. Advanced antennas are used in improving the performance of MIMO systems[9]

2. MIMO radar

In MIMO radar M and N denote the number of transmitting antennas and number of receiving antennas, d_T and d_R are the spacing between transmitting and receiving antennas.

The response of receiving antennas

$$\begin{bmatrix} y_1(t) \\ y_2(t) \\ \vdots \\ \vdots \\ y_N(t) \end{bmatrix} = A_r(\theta) A_t^T(\theta) \begin{bmatrix} s_1(t-\tau_0) \\ s_2(t-\tau_0) \\ \vdots \\ \vdots \\ s_M(t-\tau_0) \end{bmatrix}$$

The steering vectors which is represented at the transmitting side and receiving side are

$$A_r(\theta) = \left[1, e^{-j\phi_t}, e^{-j2\phi_t}, -----, e^{-j(M-1)\phi_t}\right]^T$$

$$A_t^T(\theta) = \left[1, e^{-j\phi_r}, e^{-j2\phi_r}, -----, e^{-j(N-1)\phi_r}\right]^T$$

τ_0 represents time delay[13],[14]

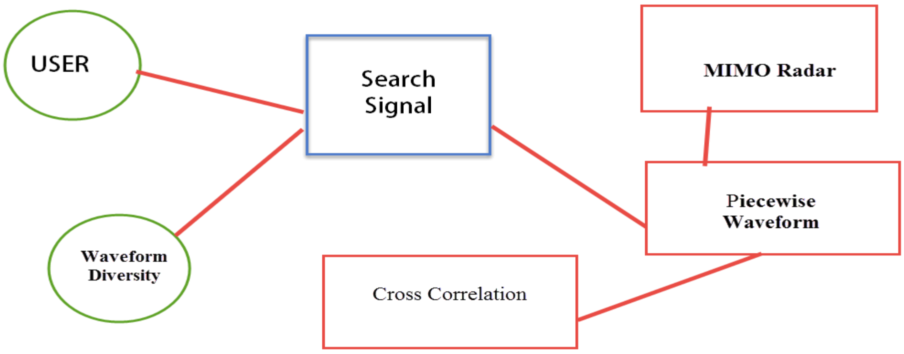
At the n^{th} receiving antenna the echo received is represented as

$$\hat{y_n}(t) = \sum_{k=1}^{K} \sum_{m=0}^{M-1} n_{m,n}^k S_m(t-\tau_k) e^{j2\pi v_k t} . e^{j2\pi \psi_k (y_{m+n})}$$

k represents the targets

$n_{m,n}^k$, τ_k , v_k , ψ_k are the amplitude coefficients.

3. Block diagram



In the wave form design, initially we are taking the signals which will follow the condition that instantaneous frequency is proportional to time and the signals which are not proportional to time and maintaining sub pulses. The main criteria are to assuming the target statistics and ignoring the interference.

MIMO radar can be assumed as statistical where the target response is statistically independent and coherent MIMO where the apertures are closely spaced. Normally we use unequally spaced antenna. Wave form diversity is for better localization and detection. Diversity represents the choice of multiple wave forms and their cross correlation is checked, then that is applied into the system.

4. Proposed model

Let's assume the transmitted signal as

$$S_m(t)=\left\{S_{m,0}(t),\ldots\ldots\ldots\ldots,S_{m,l}(t),\ldots\ldots\ldots,S_{m,L-1}(t)\right\}$$

L represents the number of sub pulses.

Taking one large segment and it is subdivided into three small segments. The boundary pulses are taken as the linear FM pulses and middle one is taken as the nonlinear FM pulse. On comparing bandwidths of the pulses, their bandwidths are maintained equally.

$\chi^{P_{p,q}}_{m,m',ll'}(\tau,v)$ is CAF between segments

$$\chi^{P_{p,q}}_{m,m',ll'}(\tau,v)=e^{j2\pi f_{q,ml'\tau}}.e^{-j\pi\mu_{m'l'}\tau^2}\int_{-\infty}^{\infty}e^{j2\pi(f_{p,ml}-f_{q,m',l'}+v+\tau\mu_{m'l'})}+e^{j\pi(\mu_{ml}-\mu_{m'l'})t^2}dt$$

5. Results

As shown in the figure 1 , the arrangement of the targets are made accordingly in the range from 20km to 80 km

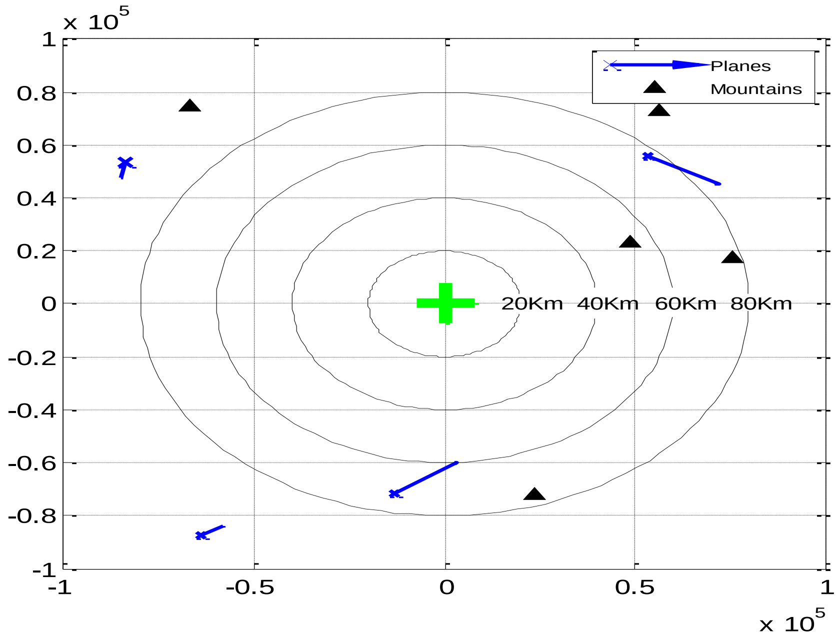


Fig. 1: Arrangement of targets

The MIMO Radar parameters taken are
PRI[m SEC]: 0.8
PW : 2% of the PRI
Amplitude 10^N Volts:10
Antenna velocity(rad/sec):pi/3
Absolute threshold: 1e-14
Ambiguity rate[khz]:50
Radar BW[Mhz]:0.02
Cross correlation:32
Antenna connected
Up date rate[sec]:0.05
RCS:100
Digital noise level[10^-n]:-9
Electro magnetic noise[10^-n]:-13
Wave form:proposed form

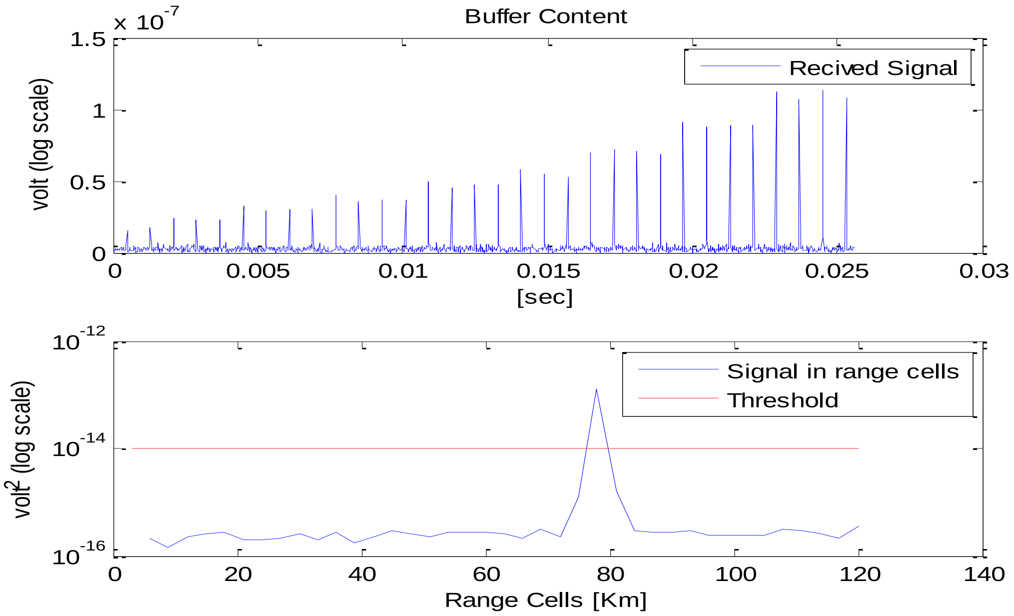


Fig. 2: Buffer content and range cells

The data concentrates on the target of range at 80 kms, As we identify the voltage above threshold in fig 2 and 3,we are detecting that target with high accuracy

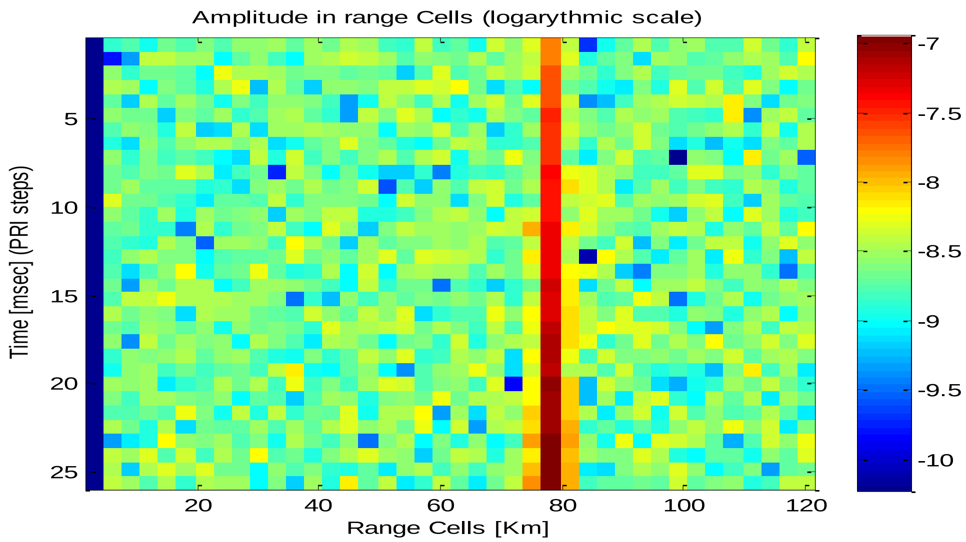


Fig. 3: Amplitude in Range cells(logarithmic scale)

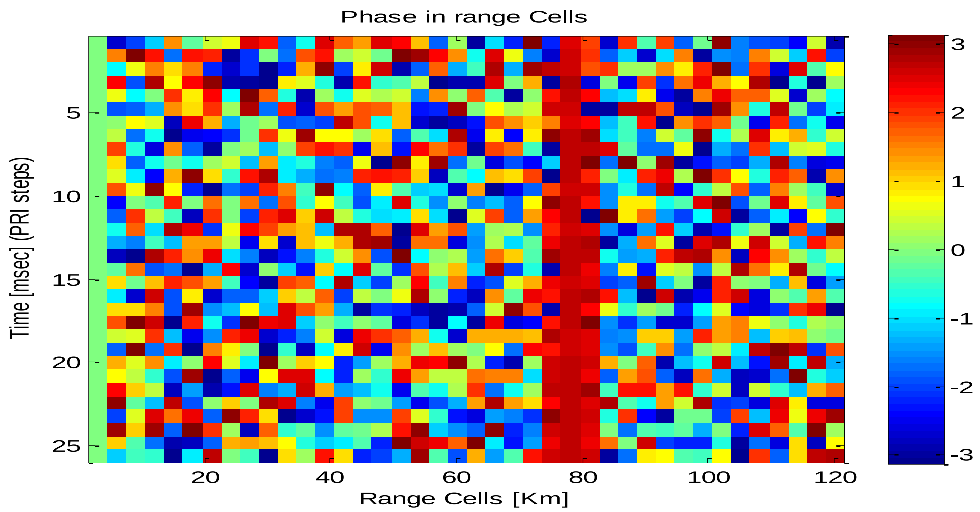


Fig. 4: Phase in Range cells(logarithmic scale)

Figure 3 and 4 shows the amplitude and phase in the range cells, clearly we can observe the distraction around 80kms range gives the identification of the target with accurate measurements

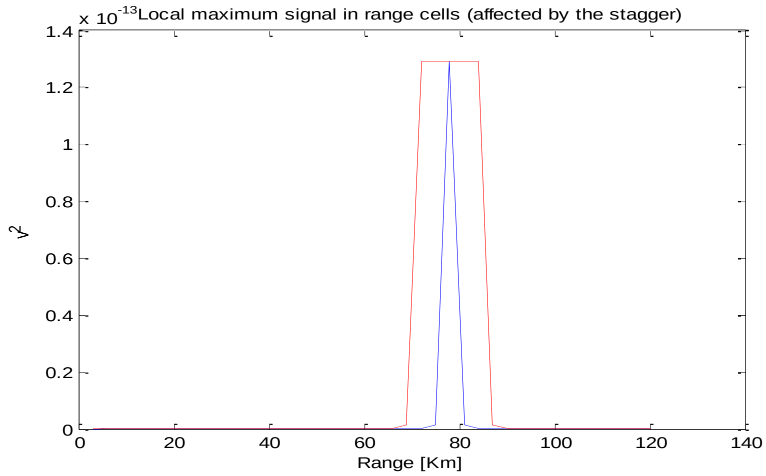


Fig. 5: Local maxima signal in range cells

Figure 5 shows that even the stagger is there, the detection is accurate

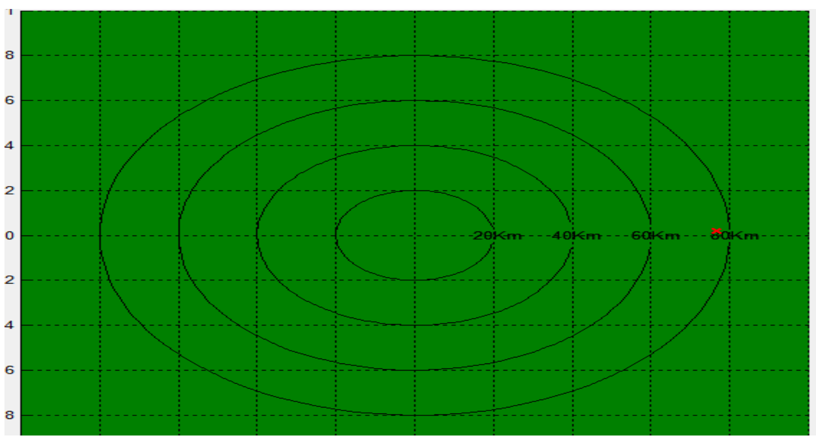


Fig. 6: Analysis of one target

Figure 6 shows the target approximation, when compared to the figure 1, the target is Estimated so accurately

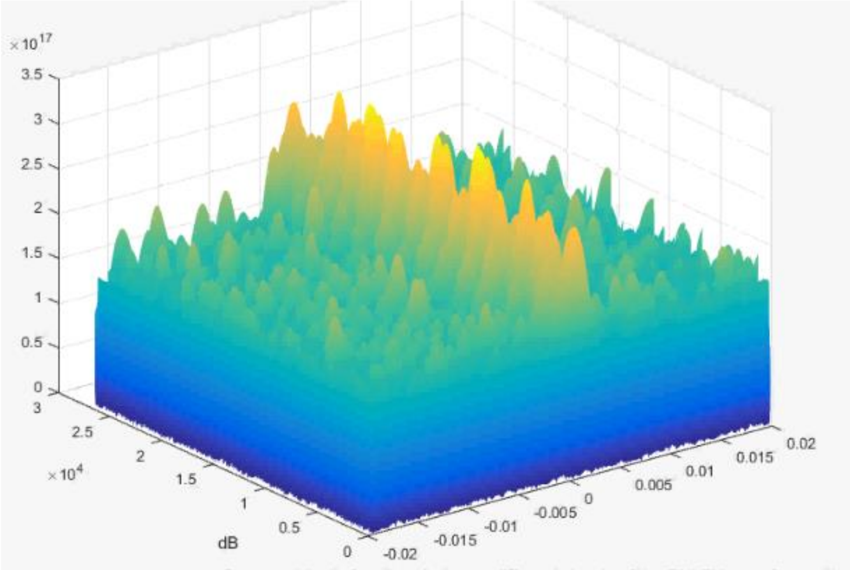


Fig. 7: Target angle/reception angle ambiguity function

Figure 7 shows the MIMO Radar ambiguity function where we can observe the target angle and the reception angle.

6. Conclusion

In this paper, we adopted a new method in generating the waveform for the MIMO radar. Diversity in the waveform is observed by dividing the segments into further sub pulses and implementing different strategies in the sub pulse design. The Wave form is examined by taking the 32 number of pulses and the respective ambiguity function and cross correlation functions are observed. The slow time coding technique is implemented. There is a tremendous improvement in suppressing the side lobes.

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