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Range Doppler ISAR Imaging Using SFCW

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ABSTRACT
The Inverse Synthetic Aperture Radar (ISAR) is an effective technique for reconstructing high resolution image from received raw data collected by relatively small antenna. ISAR generates an electromagnetic image of moving target with respect to radar. In this paper we discuss about the technique of ISAR imaging of moving target and moving radar using range Doppler algorithm for this Stepped Frequency Continuous Wave (SFCW). ISAR radars are commonly used on vessels or aircraft and can provide a radar image of sufficient quality for target recognition. The Doppler frequency shift produces back scattered data that is received by the radar, the target mainly consists of many scatter points, which are very necessary to analyze the performance of the target. The Matlab simulation produces high resolution on two dimensional images it gives range (received signal from target in time domain) and cross range(Doppler). The Range-Doppler images can be used later for identification and classification algorithms.

Keywords: ISAR; Doppler frequency; range Doppler; scattering; cross-range; azimuth; back scatter

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I. INTRODUCTION

Radar systems are designed to detect the high speed targets as fighter planes, armed helicopters and missile. In this paper Inverse Synthetic Aperture Radar (ISAR) is discussed as a powerful signal processing technique where the image of the target presented in two dimensions. Here the target is considered to be moving and the data is collected on a finite number of stepped look angle in the real world. The radar sends stepped frequency continues wave (SFCW) to catch different pulses and find out the Range Doppler ISAR image in two dimensions (range and azimuth).

In synthetic aperture radar (SAR), radar moves and target remains constant. It is further evolved as ISAR, in which the radar is kept constant and the target is in motion. The radar can be on ground/ sea water or aerial. In any case the electromagnetic wave is transmitted, it travels in free space and hits the target in its path and returns the echo signal consisting of scattered point data. In this paper 615 scattering points are taken into view. After receiving the back scattering data ISAR image is generated by Range Doppler (RD) algorithm process. Range Doppler algorithm gives 2D information of the target in ISAR image format. The target considered to be a ship with Range and Doppler as the parameters. In general a ship consists of 3 motions that is roll, pitch, yaw are shown in Figure 2 [4].

II. LITERATURE SURVEY

The extraction of target images using ISAR is studied in this paper, it is done by appending time-related variations of the target motions in accordance to the angular rate. The resolution images are generated by using spectral estimation technique and also by applying preprocessing techniques along with Fourier Transform on Range Doppler (RD) algorithm [3]. The signal received from target is analyzed and concerned conclusions of velocity and range of the target are retrieved.

The carrier signal modulation is achieved by FMCW radar. FMCW allows signal propagation delay analysis for regulating the range of the target. The transmitted and received signal is linear frequency modulation wave and is in shown in Figure 1. The FMCW Radar amplifies the signal received and combined with a local oscillator to generate beat frequency which in turn is directly proportion to distance.

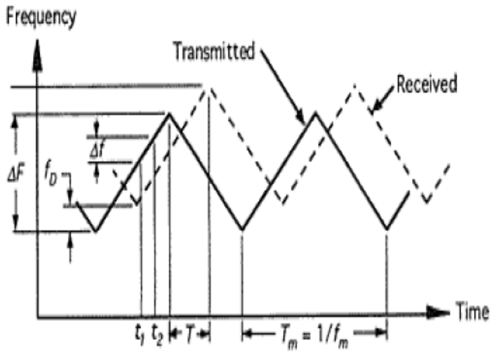

Figure 1. Transmitted and received signal in linear FMCW radar in frequency-time domain.

According to the Figure 1, if Δf is bandwidth of transmitted signal, T_m is the time period of modulator signal, R is range, dotted line is the delay of transmitted signal, Δf is frequency difference between known as beat frequency and C is propagation velocity [5]. The range R is given as

$R = (C * \Delta f * Tm)/2 * \Delta f$ (1)

After the collection of range information of the target, the Doppler is estimated. This method of Range-Doppler processing utilizes a 2-fold features of 2D FFT, one sample frequency, of the whole sweeps, so as to change the de-chirp data into beat frequency domain, resulting in range profile estimation, followed by the second sample to acquire Doppler information. For noise perturbed system, the necessary identification of signal is done by matched filter or windowing characteristics to reduce the side-lobes.

Once the Range-Doppler information is collected, the lined up work is to establish the schemes of range resolution to show difference between targets as same trajectory but which is in different range. It is obtained by using pulse compression techniques where the transmitted signal gets modulated and next it gets correlated with the received signal.

The range resolution is

$R = C/2\Delta f$ (2)

Since the presence of few constituents like the clutter rejection and short-term rendering by the filter bandwidth, the range resolution of number of samples in FFT interval is given as N_s

$N_s = 2 * R_{max} / \Delta r$
(3)

The radar signal processing includes the rational integration of number of samples and also after collecting data of various factors like frequency, resolution, aspect, the positions of look angles, Range-Doppler matrix by 2D FFT, concerned positions of different scattering centers, the resultant image is achieved by performing 2D IFT at the last stage.

III. MOTIVATION

ISAR imaging of a target is acquired as result of its rotational motion in the view of fast moving target, gathering the information of deals with the estimation of scattering points with respect to target's relative motion. One of the important studies of ISAR imaging is the typical range Doppler ISAR technique. It is not constrictive when motion of the target produces high order Descriptions in the stage of received signal comparative to each scatter. Due to this varying distortion is resultant which is directly proportional to the rate of change of instantaneous range of the target. Frequently, the image integration time and target's rotational displacement are few seconds and few degree's respectively. The outcome of this is the target estimation viewed in the ISAR image turns out as a blurred image. This makes the target identification and image projection a very complex process.

To optimize the difficulties in connection with ISAR imagining and to frame it feasible for real time application, a method is proposed based on suppositions that exists in the target's motion and receiver positions characteristics likewise pitch, yaw, roll as shown in Figure2, the Figure 2 [7]. Represent the resultant 2D ISAR image of pitching yawing and rolling [9]. This paper present on construction of good resolution focused image of the moving target. The key outline of this is to obtain an ISAR image of a target using Matlab simulation for SFCW (stepped frequency continues wave) and analyzing its range compression images over a cross range.

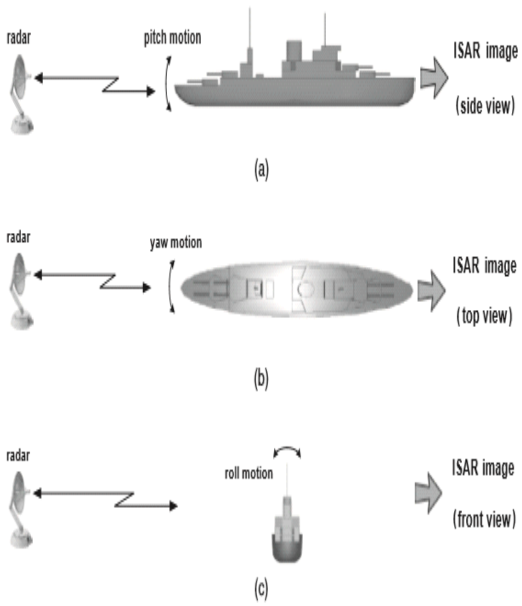

Figure 2. Resulting 2D ISAR images for (a) pitching (b) yawing (c) rolling platform

IV. PROPOSED METHODOLOGY

This paper explains the MATLAB modelling of the signal processing to find out moving targets. Here, the scattering centers of target are considered, as a factor of representing a 2D ISAR image of a target in motion. The concerned positions and sizes of the scattering points are achieved, the data of the range and cross range profiles are noted in a Range-Doppler matrix [8] and a equivalent ISAR image. The key objectives of this methodology are:

- To explore the real time applications of ISAR imaging principles.
- To observe and understand the fundamentals of radar signal processing course of action, detection of moving target, imaging and Doppler processing.
- To execute the concepts of SFCW radars, pulse compression and range resolution techniques and signal optimization [3].
- To employ proper formulation on noise and some other disorder. That obstructs the signal receiving.

represented as ISAR image using 2D IFT [11].

The very first step is study of signal circumstances. This involves the deriving of physical features of the target, such as orientation, physical size, relative size, velocity in accordance with the radar and some different characteristics [6]. At the initial stage the image size is chosen, then the range and cross-range are obtained. If the range is X_m and cross range is Y_m then the relative size of target to be imaged would be as X_m*Y_m. Once the target size is selected the corresponding range and cross range resolution are drawn with theory of N sampling points [10]. Figure 3&4 represents SFCW radar receiver and SFCW transmitted waveform respectively.

After determining these, the frequency resolution and aspect ($\Delta\phi$) are concluded using Fourier concepts. The angular frequency (Ω) and frequency bandwidth (B) are computed if the frequency is at center that is f_c. Radar look angles at aspect $\Delta\phi$, the reflected scattering data of electric fields are collected and

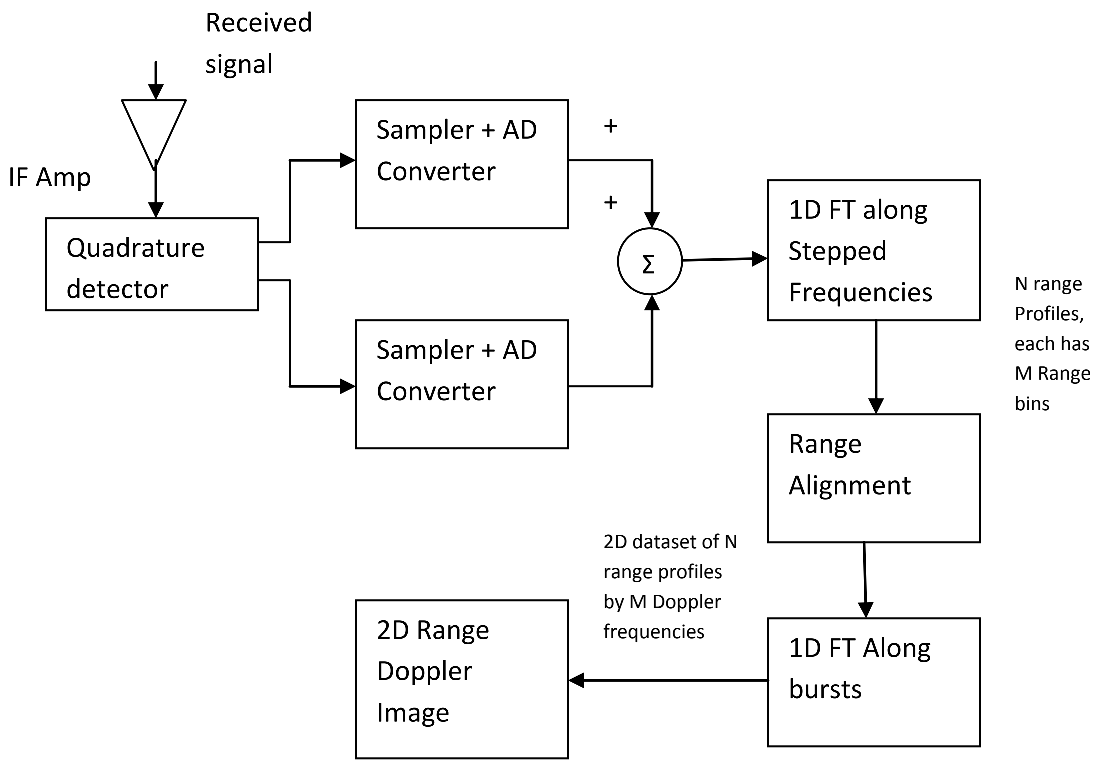

Figure 3.ISAR receiver block diagram for stepped frequency radar.

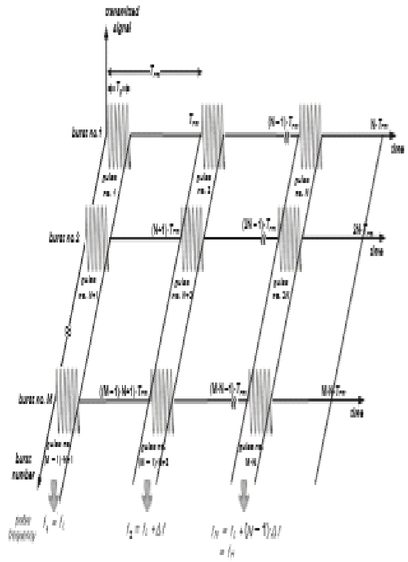

Figure 4. Waveforms of stepped frequency transmitted signal

V. SIMULATION RESULTS

In this paper, pitching ship is considered as shown in Figure 2 ,where the target go through rotational motion so that the concerned position of scattered in every down range is alike in a particular integration time.

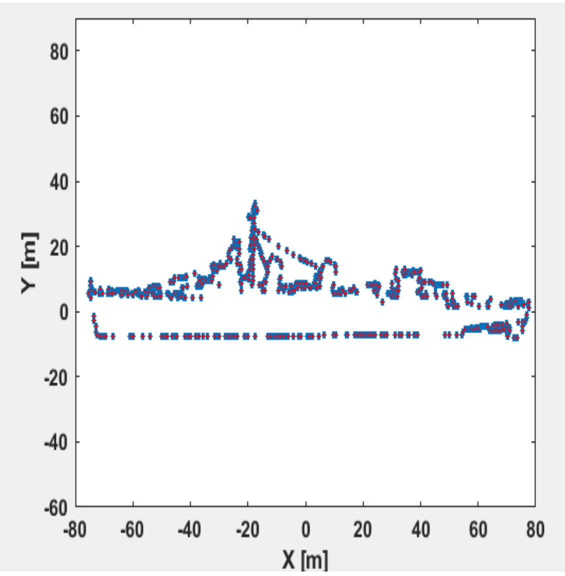

Figure 5. Target with prefect point scatters

If N pulses are transmitted in a certain integration period, then their exists N range profiles as shown in Figure 6, and is shown as range bins with respect to azimuth time which can be approximated for various bursts.

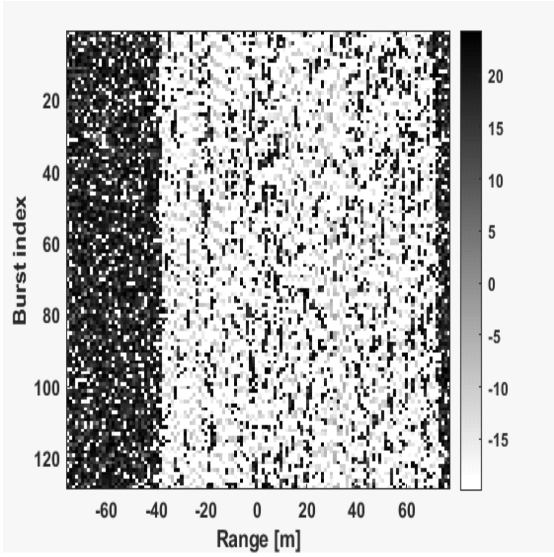

Figure 6. Range bins with respect to azimuth time

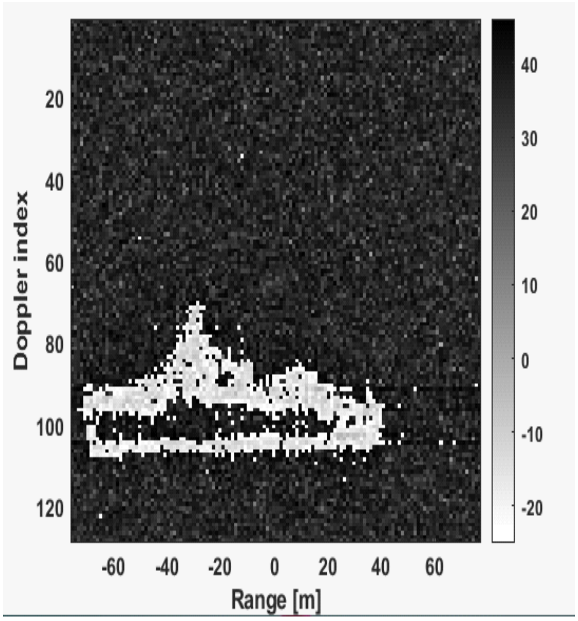

Figure 7. Range Doppler ISAR image of the target

VI. CONCLUSION

In this paper the ISAR image generation of moving target with the use of stepped frequency continuous waveform is proposed. This Matlab simulation technique is based on the transform parameters of an assumed moving target model

- The Doppler Frequency shift backscattered information is received by the radar,which is transformed to time and Doppler Frequency
- The analysis of Doppler Frequency made it possible to find the scattering points along with the Cross-Range axis

- The range compression is employed for every digitized pulse by using pulse compression technique and formed IFT technique and resultant is high reliable clear ISAR range Doppler image.

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