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ISAR Imaging And Range-Doppler Processing of Air Targets

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Abstract: Inverse Synthetic Aperture Radar (ISAR) is an effective technique for reconstructing high resolution Imagery from raw data collected by relatively small aperture antenna. ISAR technology utilizes the movement of the target rather than the emitter to create the synthetic aperture. ISAR produces high-resolution on two-dimensional images by taking into account the information in both range direction (received signals from target in time domain) and cross-range direction (Doppler). This paper deals with MATLAB based signal processing system to perform Range-Doppler processing in real-time for Linear FMCW (frequency Modulated Continuous Wave) radar systems. The Range-Doppler Image can be obtained after coherent integration of several frequency sweepings

Keywords: Pulse Compression; ISAR(Inverse Synthetic Aperture Radar); Range Doppler Algorithm;

I. INTRODUCTION

The entire signal processing schemes up to this point is analog. As the next step, the I and Q pairs at the output of the QD are sampled and digitized by using samplers and analog-to-digital (A/D) converters such that each range profile is digitized to M range cells (or range bins). The general block diagram for chirp pulse ISAR receiver is shown in diagram. The receiver processes the received signal pulse-by-pulse such that range profile corresponding to each pulse is obtained. Doppler frequency shifts for each range bin are determined with the help of Fourier transform operation so that the final 2D range Doppler image of the target is obtained. Let us analyze the ISAR receiver.

First, the chirp pulse return from the target is collected and fed to the intermediate frequency (IF) amplifier such that the signal level is amplified at the IF stage for further processing. Then, the matching filtering is applied to compress each of the incoming pulses, the output of the matched filtering (or the pulse compressor) is the compressed version of the received pulse. The result is nothing but the one-dimensional (1D) range profile of the target for that particular pulse. Then quadrature detection (QD) follows to detect the amplitude and the phase information of the returned signal at the baseband frequencies.

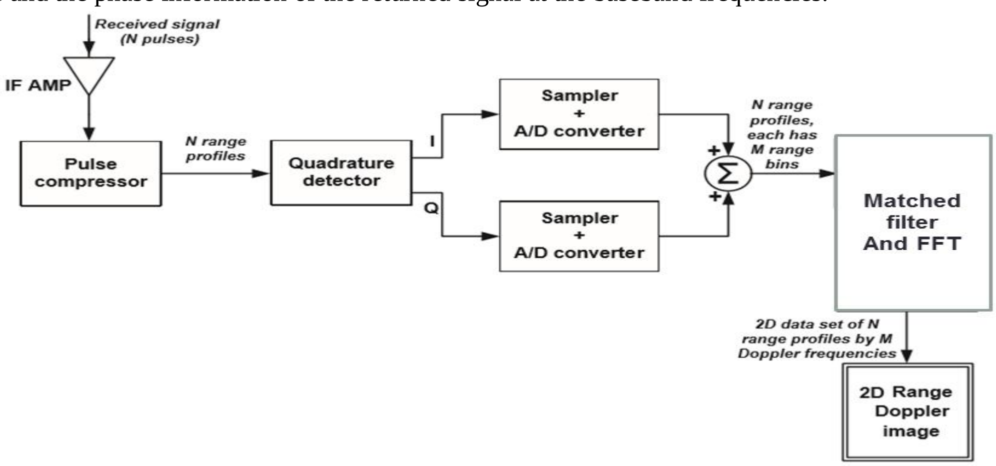

Figure 1, block diagram for chirp pulse ISAR receiver

Then, the digitized range profiles of length M are put side-by-side to align the range positions such that each range cell has to correspond to the same respective range positions along the target. Otherwise, image blurring occurs due to this range walk, the movement of range positions from profile to profile. The process of range alignment will be explained. After compensating the range walk in the 2D data set, 1D discrete Fourier transform (or DFT) can be applied along azimuthal time instants to transform the returns to Doppler frequency space. The resulting 2D matrix is the N-by-M Range-Doppler ISAR image of the target. We will present the detailed processes and the algorithm for range Doppler ISAR imaging.

Through this paper, we extend the estimation of scattering centre parameters to the case of ISAR imaging. The representation of a target by a set of individual scattering centers has shown promising results for applications where high resolution is needed. It is shown that a one-dimensional model can be used to create a two-dimensional ISAR image. After presenting the principle of ISAR matrix data collection and processing, we propose two methods for building the ISAR model matrix. We have extended the principle of one-dimensional scattering centre model to ISAR imaging.

II. METHODOLOGY

A. STEP 1: The key point for a successful ISAR image is to start the procedure by selecting the ISAR image size, that is, range and cross range window extends. If the range window extend is X_{max} and the cross range window extend is Y_{max}, then the size of the ISAR image X_{max} by Y_{max}, should be selected to cover the actual size of the target to be imaged. It is important to note that size of the Target changes in the ISAR image according to the look angle of the radar.

B. STEP 2: The other key selection is the range and cross range resolution, Δx and Δy, respectively. These numbers are so critical that they define how many pixels will lie on the target. Therefore, these resolutions are directly linked to the quality of ISAR image. After the resolution in the ISAR image is decide, the sampling points in range N_x and the sampling points in the cross range N_y can be calculated using the formulas below:

$$N_x = X_{max}/\Delta x$$

$$N_y = Y_{max}/\Delta y$$

If the target's range size is 15 m and cross range is 12 m and the resolution in both domains are selected as 15cm, the target's range will be displayed with 100 range pixels while the target's cross range will be displayed by 80 cross range pixels.

C. STEP 3: Once the ISAR size is determined, the resolution and frequency, Δf , and the aspect ΔØ can be determined by utilizing the Fourier relationship between frequency and range and angle and cross range.

$$\Delta f = c/2X_{max}$$

$$\Delta Ø = \lambda c/2Y_{max}$$

the angular width, Ω, will be equal to

$$B = N_x.\Delta f = N_x.c/2X_{max}$$

$$\Omega = N_y.\Delta Ø = N_y.\lambda c/2Y_{max}$$

D. STEP 4: If the frequencies will be centered around ft and the radar look angles will be centered around Øc, the back scattered electric field for those frequencies and angles are collected as Es(f,Ø).

E. STEP 5: At this final step we can take the 2-D IFT to get the final image. If the back scattered field data are collected within a small frequency bandwidth and the angles, then IFFT can be readily applied.

III. IMPLEMENTATION

In order to provide a useful target recognition function, it is clearly necessary for the radar being used to obtain high-quality target signature data. The waveform parameters used must support the acquisition of signature data, which minimizes distortion effects, such as ambiguities. The characteristics of the radar components must either contribute little to distort the measured target signature or the effects of the distortion must be characterized and compensated. The signal-to-noise ratio must be sufficiently high and the effects of interference clutter and jammers should be suppressed.

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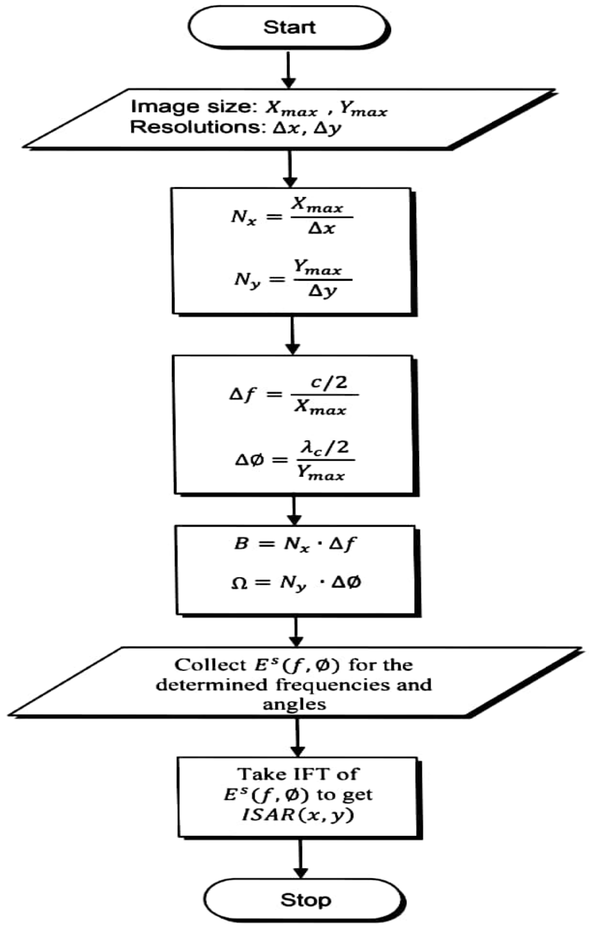

Figure 2, Flow chart for basic ISAR Imaging

1) Virtual target is generated by generating a number of scatters through which reflections is done.
2) Raw data is acquired in the form of array, processed and analyzed.
3) Algorithm is generated for Signal processing and analysis.

IV. RESULTS AND DISCUSSION

The target's relative motion with respect to the radar sensor provides angular diversity required for ISAR imaging. In practice the practical target like planes, helicopters and ships exhibit complicated motion during the flight.

Fictitious fighter consists of perfect point scatterers of equal reflectivity is shown in figure 3. The transmitted chirp pulse waveform is plotted in Figure 4.

This signal is used as the frequency-domain replica of the transmitted pulse to be used in matched filtering process. After applying the matched filter operation, the resultant range compressed data are plotted where the range profile for each azimuth time instant can be easily observed at different range bins. Finally, an IFT operation is performed along the pulse index so that the points in the cross-range dimension can be resolved as they appeared in the different Doppler frequency shift values. Therefore, the final ISAR image is obtained on the range-Doppler plane as depicted in Figure 6 where the point scatterers on the target are resolved well in range direction and fairly well in the cross-range direction due to some finite velocity of the target along the azimuth direction.

The range cross–range ISAR image in Figure 7 can only be constructed provided that the angular velocity of the target is known or estimated.

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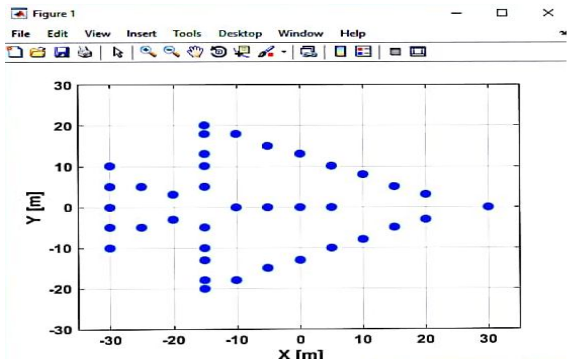

Figure 3, Aircraft point Scatters

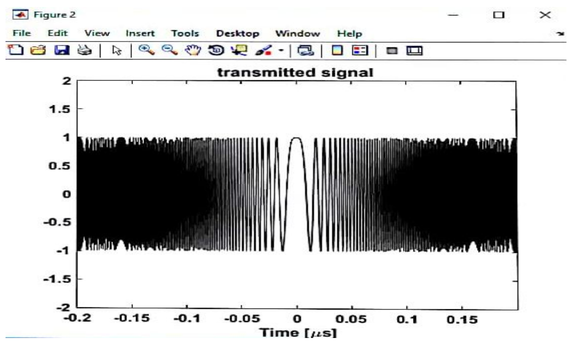

Figure 4, Aircraft transmitted LFM signal

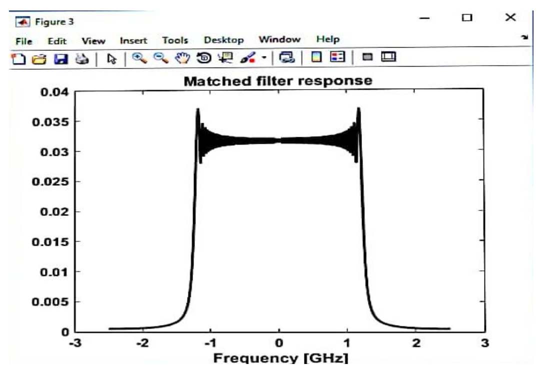

Figure 5,Spectrum of transmitted signal

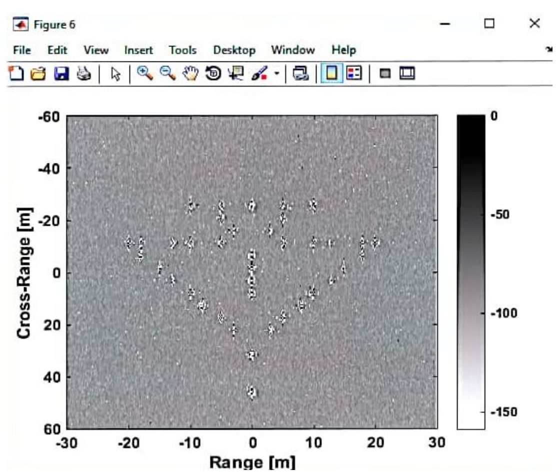

Figure 6, Aircraft Range(m) vs Dopplers range(m)

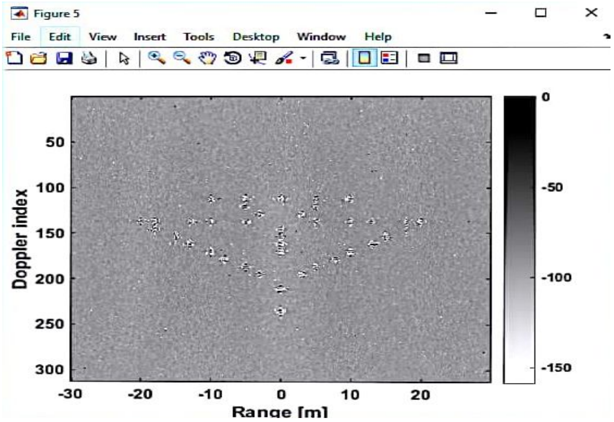

Figure 7, Aircraft Range(m) vs Cross range(m)

V. CONCLUSION

It is hoped that with the introduction of radar target recognition, the tragic friendly fire incidents and the shooting down of civil aircraft in error can be largely eliminated. It should also be making its contribution in coastal defence, for countering terrorism, illegal immigration. The effective use of both civil and military resources should also improve as targets become more reliably identified and assets are employed to directly match the threat being posed.

To find the maximum range at which it can see a target of a specified size. It is very difficult to apply this in real time as complexity increases

VI. ACKNOWLEGEMENT

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