Volume 4, Issue 6, June 2014 ISSN: 2277 128X
International Journal of Advanced Research in Computer Science and Software Engineering
Research Paper
Available online at: www.ijarcsse.com

Formation of Focused ISAR Image to be used In Safety Applications of Intelligent Transport System

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Abstract- This paper deals with application of Radar (ISAR) image for the safety applications in Intelligent Transport System (ITS).Comparative performance of conventional Fourier transform and joint time-frequency transform for the formation of Radar image is given here, Matlab(version 10) is used as the simulation platform and finally by comparing images obtained by two techniques ,the work is validated.

Key words – ITS, ISAR, Radar image, Fourier transform, STFT, Matlab

I. INTRODUCTION

Collision avoidance in vehicular transport system is a major concern in now a days, for this purpose intelligence is invoked in transport system to make Intelligent Transport System (ITS) where a Radar is able to detect and classify moving targets (vehicles) by creating proper images (Radar image) at the Radar receiver and by providing this information to all the vehicles in its range, collisions can be avoided. The Radar is used for this purpose is called Inverse Synthetic Aperture Radar (ISAR) and imaging technique is called ISAR imaging. Radar transmits electromagnetic waves to a target and receives the reflected signals from the target, reflected energy back from the target is called Radar Cross-section(RCS). The spatial distribution of the reflectivity function of the target, referred to as the image of the target, can be reconstructed from the received signals. A radar image is usually mapped onto a range and cross-range plane. The range resolution of a radar image is directly related to the bandwidth of the transmitted radar signal, and the cross-range resolution is determined by the effective antenna beamwidth, which is inversely proportional to the effective length of the antenna aperture. To achieve high cross-range resolution without using a large physical antenna aperture, synthetic array processing is widely used. Synthetic array radar processing coherently combines signals obtained from sequences of small apertures at different angle-aspects to the target to emulate the result from large aperture [12]. Rest of the paper is organized as, section II deals with the literature reviews in the domain of Radar imaging.Section III describes the concepts of Radar imaging of moving targets.Section IV describes image formation techniques and section V shows the results and finally concluding the paper.

II. LITERATURE SURVEY

An evaluation index based on differential entropy and the theory of Bayesian compressive sensing is devised and the adaptive compressive sampling procedure without any prior information of the measured signals is presented and to verify the proposed adaptive sampling algorithm has good performance numerical simulations performed on random step signal and real radar signal and 2D image is produced[1].SAR image of a light rail way train by Ku band radar is produced by coherent and incoherent imaging as well as co-pol and cross-pol interferometric imaging technique, along-track interferometric-phase images provides the speed variation of the train and incoherent imaging results indicate that for bistatic or multi-static radar imaging[2].Limitations to estimate significant wave height using the square root of the SNR is overcome by a non-linear method incorporating Artificial Neural Network(ANN) which uses multilayer perceptrons in which information is given by wave monitoring system[3]. Interferometry is used to obtain the height information which makes possible to obtain a 3-D reconstruction of a target, aiding image focusing, image interpretation and target classification, where interferometric information depends highly on geometry and targets dynamics[4].Stationary targets are classified based on the high-range resolution profile (HRRP) extracted from 3-D Through Wall Imaging technique, the dependence of the image on the target location is discussed using a system point spread function approach, A target image alignment technique based on deconvolution of the image with the system Point Spread Function [5]. Target features like distance, radial velocity, and radial longitudinal dimension are extracted from range-Doppler radar images by exploiting the concepts of High Resolution Radars properties ,this procedure is proposed to obtain some features from the HRR non-cooperative targets to enable their classification.[6] The 2-D tomographic approach combines a linear inverse scattering model, based on the Kirchhoff approximation, with the finite-difference time-domain (FDTD) technique for electromagnetic imaging in the presence of multipath propagation of interest for through-wall and urban sensing scenarios, FDTD is exploited to evaluate the incident field and Green's function in non canonical scenarios[7]. Chunyang Dai et al [8] proposed a novel imaging configuration with multiple GNSS transmitters and one receiver, which can be equivalent to a large sparse two-dimensional antenna arrays, focused sparse targets on the Earth's surface via compressive sensing even in zero coherent integration time can be obtained. RASCAN holographic radar reveals the plan shape of shallow buried objects, an experiment showed that a clod of loam soil buried in powdered loam soil was recognizable in a radar image again it was shown that a thin film inserted between dielectrically similar materials also provides recognizable reflection and finally blind tests were performed for realistic surrogates for dinosaur footprints. The radar image formed by this technique has no recognizable pattern for the case of microscopic air gap at the footprint parting plane. However, when the air gap was replaced by very thin clay film, the shape of the toes became recognizable.[9] J. Sánchez-Oro et al[10] proposed to obtain radar images by using a radar signal surveillance application that works in real-time, in 360 degrees, with long range up to 400 meters away from the detector, with daylight or night, or even with adverse climatology like fog presence, detecting and tracking high speed vehicles in urban areas. Yangyang Li et al [11] proposed a novel SAR image segmentation algorithm using a multi-objective evolutionary algorithm based on decomposition with non-local means de noising (MISD). MISD is an effective multi-objective method with decomposition to solve SAR image segmentation, to de noise the SAR images and retain the details, non-local means to remove the noise are employed.

III. RADAR IMAGING OF MOVING TARGETS

To obtain the Radar image of a target it is needed to store RCS values of that target in range and cross-range profiles for different frequencies and aspect angles at the radar receiver where a 2D matrix is formed of RCS values upon which different transformation and imaging operations are formed to obtain radar images, for this purpose a light vehicle is considered here which is moving with a uniform velocity shown in fig. 1

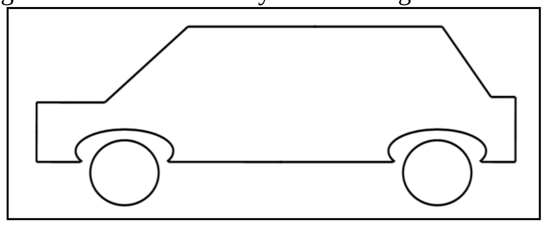

Figure 1. Light Vehicle

A radar mounted in ground can only see the side views of each target as in fig1, side view of the target (fig 1) can be considered as combination of rectangular, triangular and circular flat plates, RCS values of those flat plates can be obtained[13] then by combining them RCS values of the target can be obtained.

RCS function for Rectangular flat plate,

$$\sigma_{rec\tan gular} = \frac{4\Pi a^2 b^2}{\lambda^2} \left(\frac{\sin(ak\sin\theta\cos\varphi)}{ak\sin\theta\cos\varphi}\frac{\sin(bk\sin\theta\sin\varphi)}{bk\sin\theta\sin\varphi}\right)^2 (\cos\theta)^2 \quad (1)$$

Where,

a $\rightarrow$ height of the rectangular flat plate

b $\rightarrow$ length of the rectangular flat plate

$\lambda \rightarrow$ wave length of the incident wave

$\theta \rightarrow$ aspect angle

$\varphi \rightarrow$ incident angle on the plate

$$k = \frac{2\Pi}{\lambda}$$

RCS function for Triangular flat plate,

$$\sigma_{triangular} = \frac{4\Pi A^2}{\lambda^2} (\cos\theta)^2 \left[\frac{(\sin\alpha)^4}{\alpha^4} + \frac{(\sin 2\alpha - 2\alpha)^2}{4\alpha^4}\right] \quad (2)$$

Where,

A $\rightarrow$ area of the triangular flat plate

$\alpha \rightarrow ka\sin\theta\cos\varphi$ [$k = \frac{2\Pi}{\lambda}$; a $\rightarrow$ height of the plate; $\varphi \rightarrow$ incident angle on the plate]

$\lambda \rightarrow$ wave length of the incident wave

$\theta \rightarrow$ aspect angle

RCS function for Circular flat plate,

$$\sigma_{circular} = \frac{\lambda r}{8\Pi\sin\theta(\tan\theta)^2} \quad (3)$$

Where,

r $\rightarrow$ radius of the circular flat plate

$\lambda \rightarrow$ wave length of the incident wave

$\theta \rightarrow$ aspect angle

From (1), (2) and (3) ,RCS values of rectangular, triangular and circular flat plates can be stored in range and cross-range profiles in a 2D matrix format

So, RCS values of the total target= Σ RCS values of rectangular flat plates + Σ RCS values of triangular flat plates + Σ RCS values of circular flat plates (4)

IV. IMAGE FORMATION

Conventional way of forming images of a target is to perform Fourier transform on the 2D RCS matrix, Fourier transform is being applied to obtain Doppler information, but for moving target, Doppler frequency shifts are time-varying. So, the images developed using conventional method are not focused, to get the distinguishable image of a target Joint time-frequency transform is performed on the 2D RCS matrix.In this paper both the imaging techniques are performed and compared. Short time-frequency transform is used here as the Joint time-frequency transform method, which is given by

(5)

$$STFT\{x(t)\}(\tau,\omega) \equiv X(\tau,\omega) = \int_{-\infty}^{\infty} x(t)\omega(t-\tau)e^{-j\omega t}\,dt$$

Where $w(t)$ is the window function, commonly a Hanning window or Gaussian bell centered around zero, and $x(t)$ is the signal to be transformed. $X(\tau,\omega)$ is essentially the Fourier Transform of $x(t)w(t-\tau)$, a complex function representing the phase and magnitude of the signal over time and frequency.

Table I. Parameters for Radar Imaging

Frequency range	
Distance range	22-29 GHz
Bandwidth	5 GHz
Aspect angle range	0 – 0.6 radian

V. RESULTS & CONCLUSION

MATLAB (version 10) is used as the simulation platform.RCS matrix is first constructed for the target whose image is to be obtained by using (4), after those two types of transformation techniques are applied on the RCS Matrix.

1. Conventional Fourier transform is performed over the RCS Matrix to get the radar image of the desired target.
2. Short Time Fourier Transform (STFT) is performed over the RCS Matrix to get the radar image of the desired target

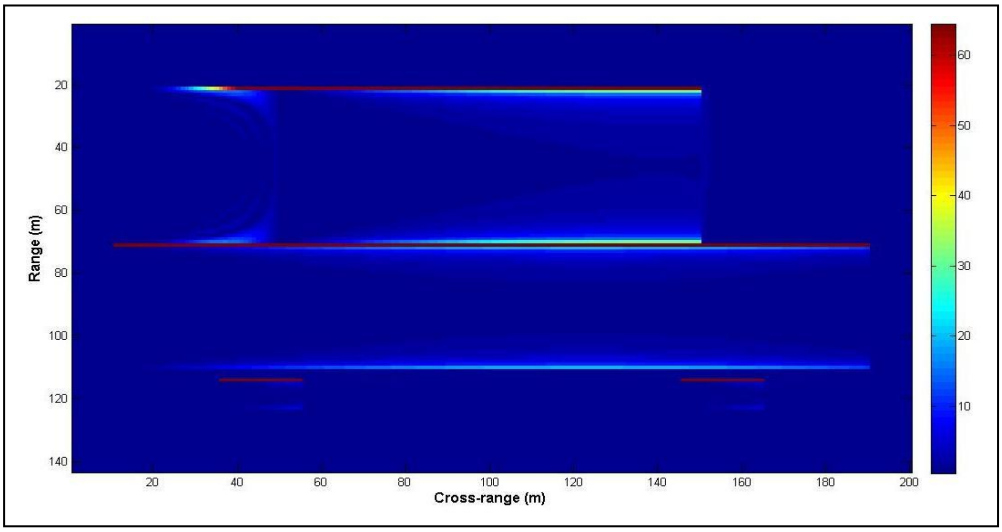

Figure 2. Radar Image of the vehicle by conventional method

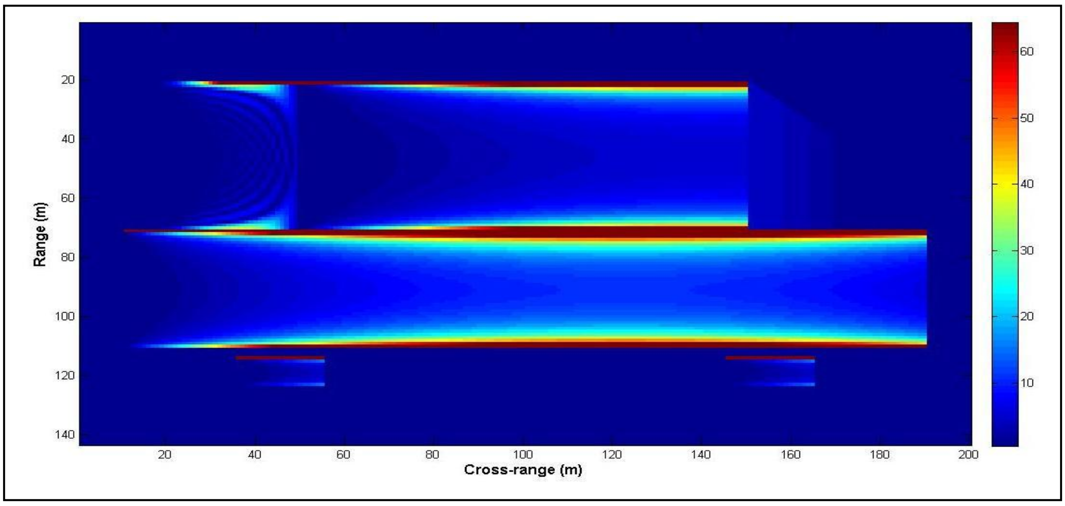

Figure 3. Radar Image of the vehicle by Joint time-frequency transform method

Formation of Radar Image by conventional Fourier transform method and by joint time-frequency transform method are shown in figure 2 & figure 3,where image of figure 3 is more focused than image of figure 2.It is because of the fact that Fourier transform is used to retrieve Doppler information but due to complex motion of a target, the Doppler frequency shifts are actually time varying so Doppler spectrum becomes smeared and the image is blurred in case of conventional method but when joint time-frequency transform, where high resolution in both time and frequency domain exists is used, image formed is more clear and focused. In Intelligent Transport System, when target detection and classifications are done by forming Radar images of the targets, it is more obvious to select joint time frequency transform to obtain the time and frequency information from the RCS matrix and to form the Radar image.

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