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Implementation of wideband Radar to ISAR imaging using Modified Fast Chirp Fourier Transform

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Abstract: *In this paper, ISAR imaging for a wide frequency range is explained, by using a proposed method known as Modified Fast Chirp Fourier Transform(MFCFT). Radar imaging is generally performed in the L,S and C band frequency, ranging from 1-8 GHz. But, sometimes it becomes necessary to image a target in wideband frequency i.e., from 1-40GHz range. Here, in this paper, ISAR imaging is done for wideband (1-40GHz) frequencies. When imaging is done in this range of frequencies, the basic methods like RD and RID fails to reproduce images for this wide range, whereas the proposed method reproduces images with high resolution.*

Keywords - *ISAR, MFCFT, RD, RID,RIC.*

I. INTRODUCTION

ISAR is a high resolution Radar imaging that reproduces images with high quality in two dimensional plane [1]. The basic method of ISAR imaging is RD technique, which is used for smoothly rotating targets where the phase of return echo is considered as constant. In case of maneuvering targets, RID method is used where phase of echo signal is considered as quadratic [2]. For targets with very high complex motions like pitch, roll and yaw, Range Instataneous Chirp (RIC) method is used where the phase is considered as cubic chirp [3]. The existance of RIC method has taken place due to the failure of above said methods for cubic phase terms. Fast Fourier transform is used to process the echo signal to reproduce 2D image in RD method and Time frequency transforms[4] like Short Time Fourier Transform (STFT) [5] and Gabor transform [6] are used to process the signal in RID method [7]. Several algorithms like Modified Wigner Ville distribution [8], Product High-Order Matched-Phase Transform [9], Product Generalized Cubic Phase Function [10], TC Dechirp technique [11], Discrete Chirp Fourier Transform and Modified Discrete Chirp Fourier Transform [12]. In RIC method, a new method named MFCFT is used for processing the echo signal and obtaining 2D image.

II. MODELING FOR MFCFT ALGORITHM

The imaging model is shown in Fig.1.

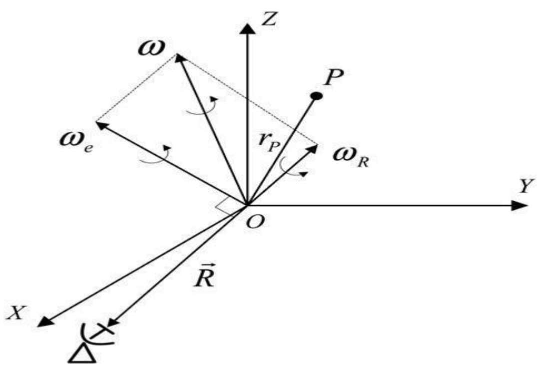

Fig.1. Imaging model

Assume the transmited signal is a LFM waveform represented by

$$S(t_1,t_2)=rect\left(\frac{t_1}{T}\right)\exp\left[j2\pi\left(ft+\frac{1}{2}\gamma t^2\right)\right]$$

$$where \quad rect\left(\frac{t_1}{T}\right)=\begin{cases}1, & \left|\frac{t_1}{T}\right|\le\frac{1}{2}\\ 0, & \left|\frac{t_1}{T}\right|>\frac{1}{2}\end{cases} \qquad (1)$$

where f, γ and T, denote the carrier frequency, chirp rate and pulse width respectively, t is the full time given by t_1+t_2, t_1 being the fast time and t_2, the slow time. t_2 is given by n/prf and n=0,1,…N. The received signal is represented as

$$S_p(t_1,t_2)=\sigma_p rect\left(\frac{t_1-2R_p(t_2)/c}{T}\right)\exp\left[j2\pi\left(f(t_1-2R_p(t_2)/c)+\frac{1}{2}\gamma\left(t_1-2R_p(t_2)/c\right)^2\right)\right] \qquad (2)$$

where $R_p(t_2)$ is the distance between p^{th} scatter and Radar at time t_2 and σ_p represents the reflection coefficient. For this received signal keystone formatting is applied to remove the migration through range cell [13]. Assume that if the number of scatters in a certain range bin is P, the azimuth echoes corresponding to this range bin is expressed as the cubic phase signal. The azimuth echo signal is written as the cubic chirp signal represented in discrete form as [14],

$$S(n)=\sum_{p=1}^{P}A_pW_N^{f_pn+(\gamma_p/N)n^2+(\beta_p/N^2)n^3} \qquad (3)$$

where

$$W_N=\exp\left(\frac{-j2\pi}{N}\right)$$

$$A_p=a_p\exp\left(-j\frac{4\pi}{\lambda}R_p(t_0)\right)$$

$$f_p=\left(\frac{2\omega r^T}{\lambda}\right)\left(\frac{N}{prf}\right) \qquad (4)$$

$$\gamma_p=\left(\frac{\alpha r^T}{\lambda}\right)\left(\frac{N^2}{prf^2}\right)$$

$$\beta_p=\left(\frac{\zeta r^T}{3\lambda}\right)\left(\frac{N^3}{prf^3}\right)$$

The proposed method, MFCFT, is represented for cubic chirps as

$$X(k,l,m)=\frac{1}{\sqrt{N}}\sum_{n=0}^{N-1}x(n)W_N^{kn+(l/N)n^2+(m/N)n^3} \qquad (5)$$

$$where \quad 0\le k,\ l,m\le N-1$$

where k, l and m represent constant frequency, chirp rate and derivative of chirp rate respectively. In case of DCFT, the parameter estimation is done for k, l, m values between 0 to N-1 due to which it suffers from picket fence effect. The disadvantage with this method is peak values cannot be identified. Therefore, in MFCFT parameters k, l, m are estimated as k Є(0,1,…N-1), l Є(0,1/N,…(N-1)/N), m Є(0,1/N,…(N-1)/ N). So, as the accuracy increases, a shorter near the peak sample interval can be obtained, and MFCFT will not suffer from picket-fence effect. In MFCFT, the value of signal length need not be a prime number as in DCFT. If the proposed algorithm is applied for cubic chirp signal represented in (3), then the MFCFT for higher order phase terms is written as

$$S(k,l,m) = \frac{1}{\sqrt{N}} \sum_{n}^{N-1} S(n) W_N^{kn + \left(l/N\right) n^2 + \left(m/N\right) n^3} \qquad (6)$$

where S(k,l,m) is the MFCFT of s(n). The projection of S(k,l,m) in 3D will produce a Doppler image with center frequency f_p. The Doppler image $I_D(k)$ can be obtained by the energy accumulation along axes of l and m where all the main lobes of S(k,l,m) are clearly identified and is given by

$$I_D(k) = \left| \sum_{l,m} S(k,l,m) \right| \qquad (7)$$

If the Doppler images of all range bins are added, ISAR image of the target for cubic chirp signal is obtained. It may be noted that the proposed algorithm will be found to be more and more effective as higher and higher order terms are considered because exponent of N is defered with.

III. WIDEBAND RADAR

Generally, Radar imaging is done at microwave frequencies (L, S, C, X, Ku, K, Ka) normally in 1-40GHz frequency range. Previously ISAR imaging has been implemented by taking only one frequency in this range for all the above said algorithms. In this paper, the ISAR imaging for cubic chirp signals using proposed method is implemented for wideband frequencies in 1- 40GHz range and the superiority of this algorithm is shown by comparing with STFT and Gabor transform. In case of Range Instantaneous Doppler (RID), where the received echo has quadratic phase terms, the imaging is done at L, S, C band frequency only. If it is done in this frequency range (1-8 GHz), all the images using Gabor transform and STFT is found to be good. If the frequency is increased to higher ranges like (X, Ku, K, Ka), then RD and RID techniques fails to reproduce high resolution images and are blurred. But, in case of MFCFT, high resolution images are reproduced throughout the frequency range (1- 40GHz). In the next section the results are discussed.

IV. SIMULATION RESULTS

The simulation is carried out for a ship target constructed with 13 scattering points as shown in Fig.2 using MATLAB software. All the scatters are having equal amplitudes (assumed). The results are obtained for proposed algorithm, MFCFT for a range of frequencies (1-40GHz). Along with a comparison is shown between STFT, Gabor transform and MFCFT, so that, the superiority of MFCFT over STFT and Gabor is clearly observed with the obtained results.

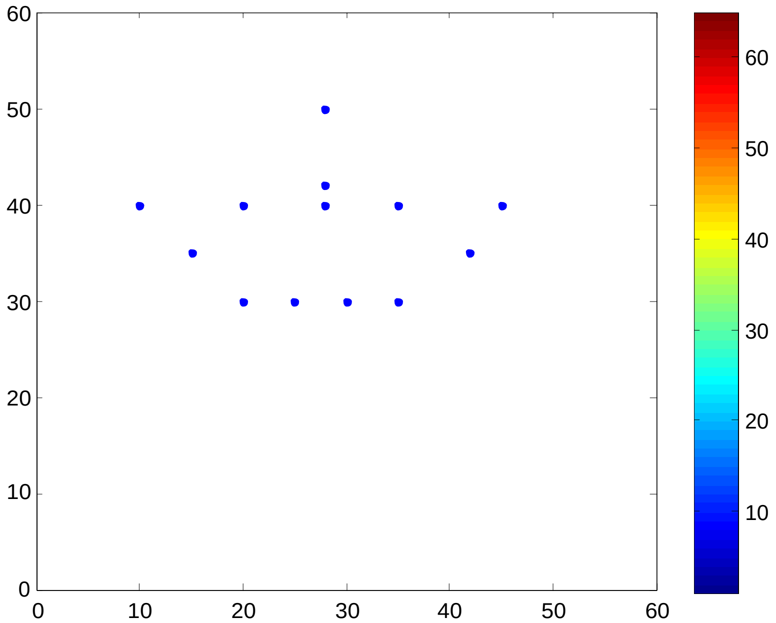

Fig.2. Simulated ship with 13 scatters

Frequency (F) =3GHz

Fig.3, 4 and Fig.5 represents ISAR imaging using STFT, Gabor and MFCFT respectively for a frequency of 3GHz. In Fig.3, the hot spots are identified but the image is not having high resolution. In case of Fig.4, all the hot spots are clearly identified and in Fig.5, all scatters are identified and image is having a high resolution.

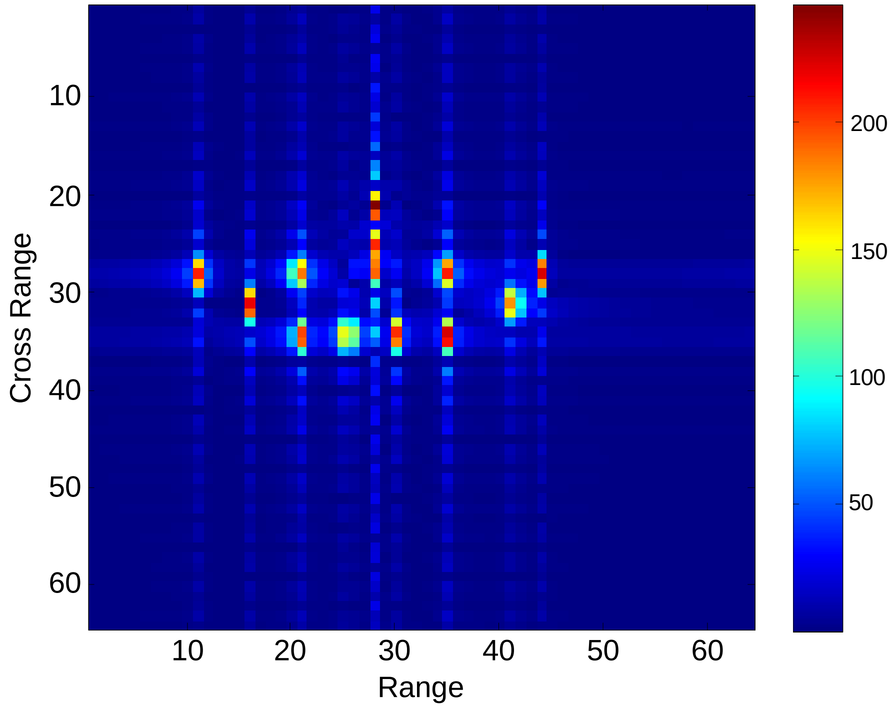

Fig.3. ISAR image using STFT for F=3GHz

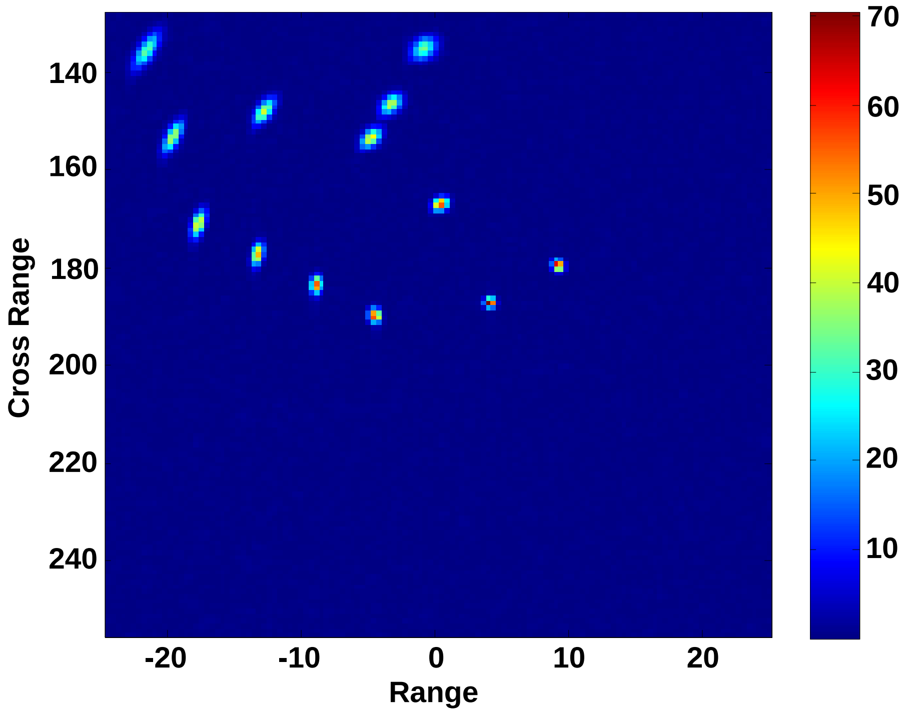

Fig.4. ISAR image using Gabor transform for F=3GHz

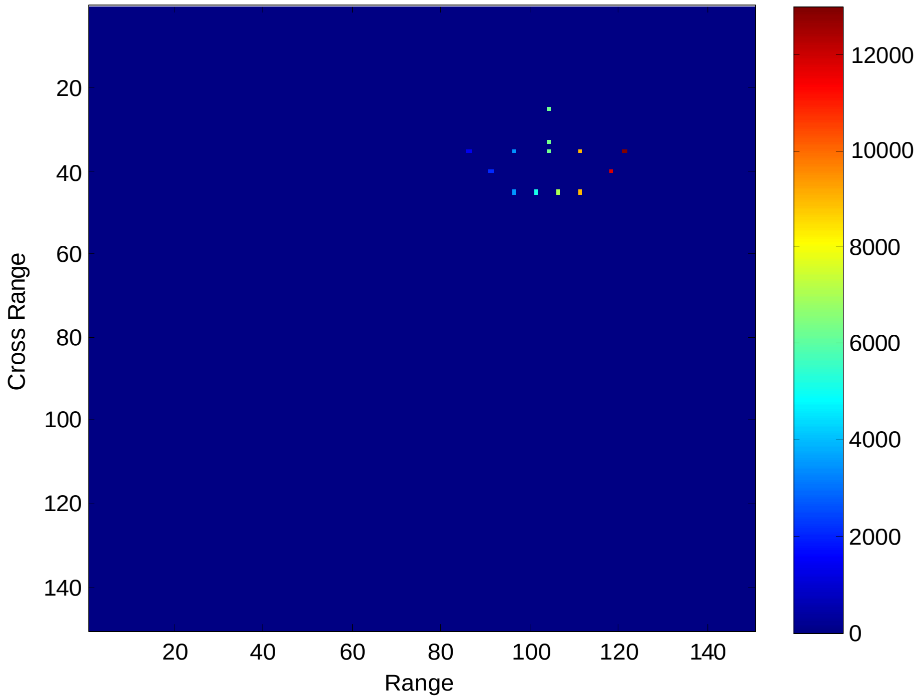

Fig.5. ISAR image using MFCFT for F=3GHz

Frequency=8GHz

Fig.6, 7 and 8 shows ISAR image using STFT, Gabor transform and MFCFT respectively when the frequency is 8GHz. For a frequency of 8GHz, ISAR image using STFT and Gabor are not reproduced exactly, and that using MFCFT is having good resolution.

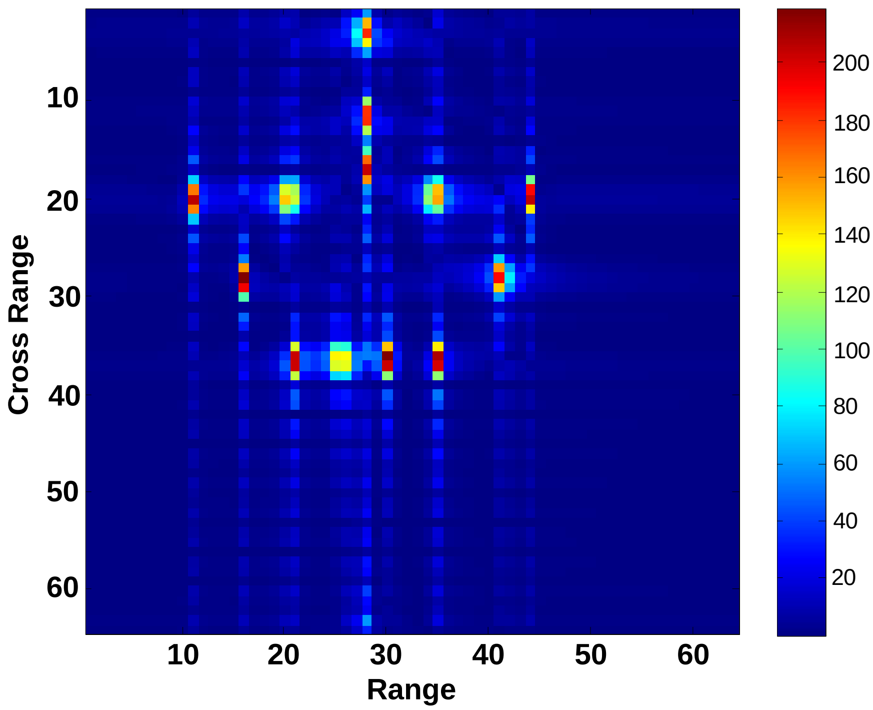

Fig.6. ISAR image using STFT for F=8GHz

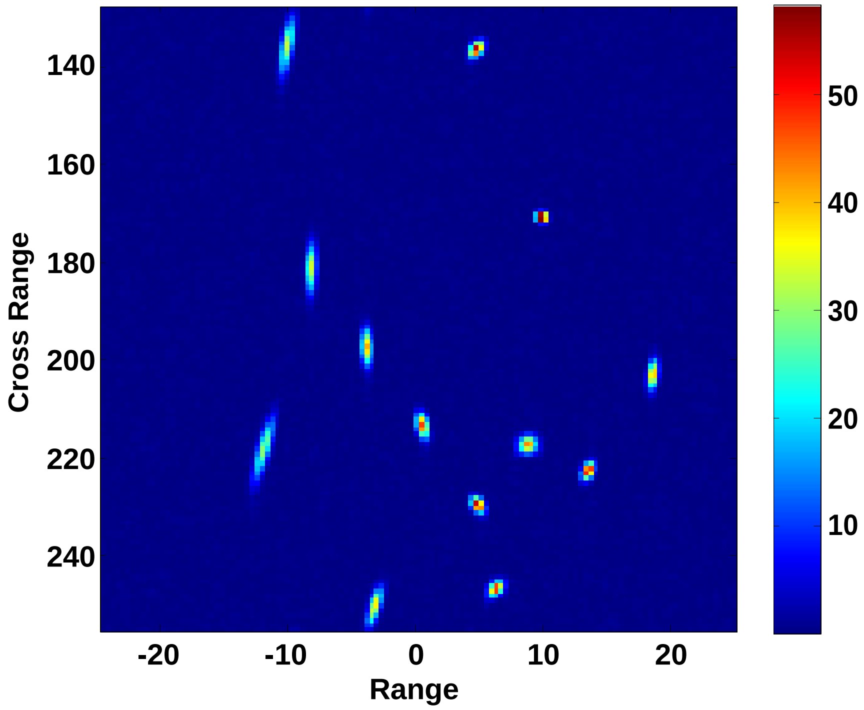

Fig.7. ISAR image using Gabor transform for F=8GHz

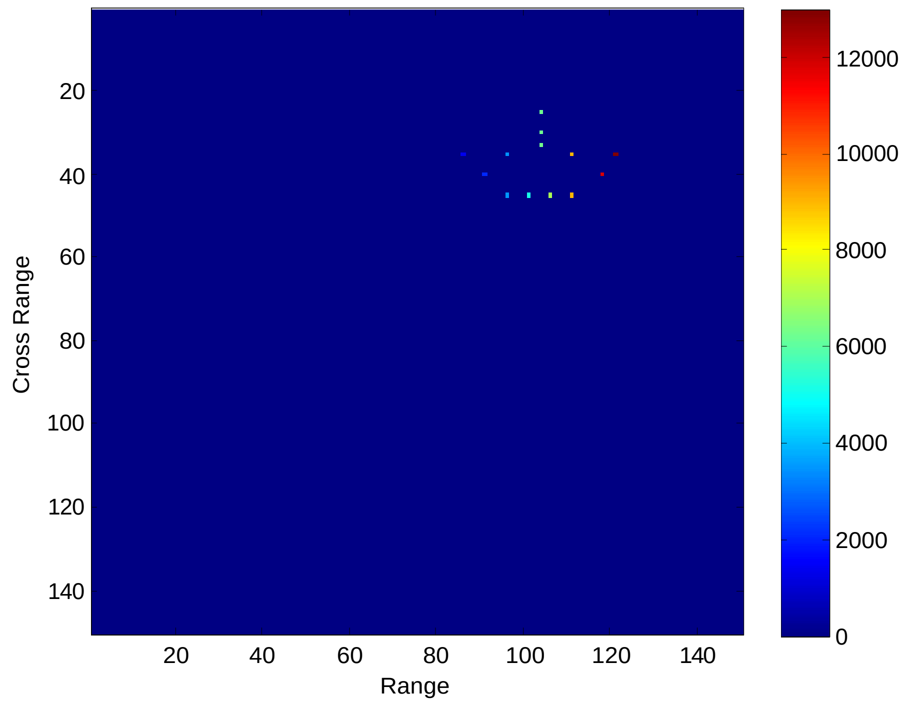

Fig.8. ISAR image using MFCFT for F=8GHz

Frequency=15 GHz

Fig.9, 10 and 11 shows ISAR image using STFT, Gabor and MFCFT respectively for 15GHz frequency. When frequency is 15 GHz, ISAR images for STFT and Gabor is found to be blurred and the hotspots are not identified clearly whereas in case of MFCFT the image is obtained with high resolution.

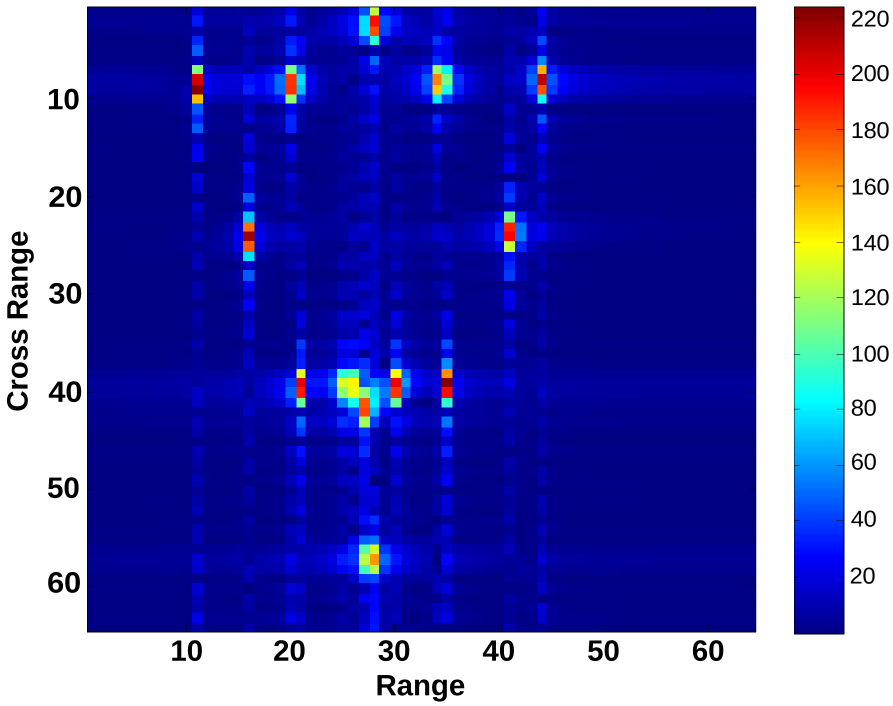

Fig.9. ISAR image using STFT for F=15GHz

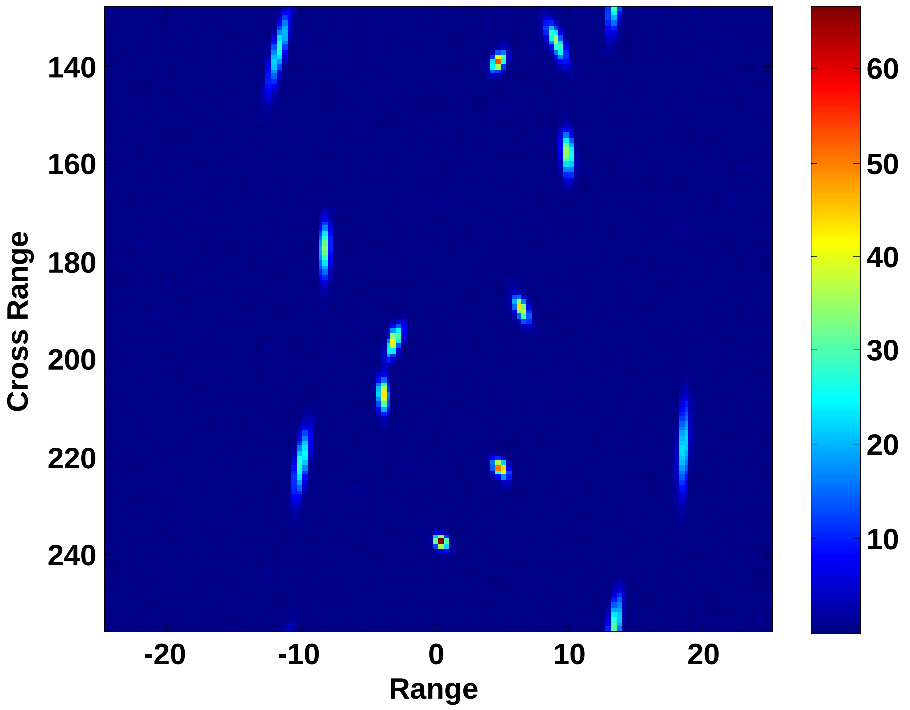

Fig.10. ISAR image using Gabor transform for F=15GHz

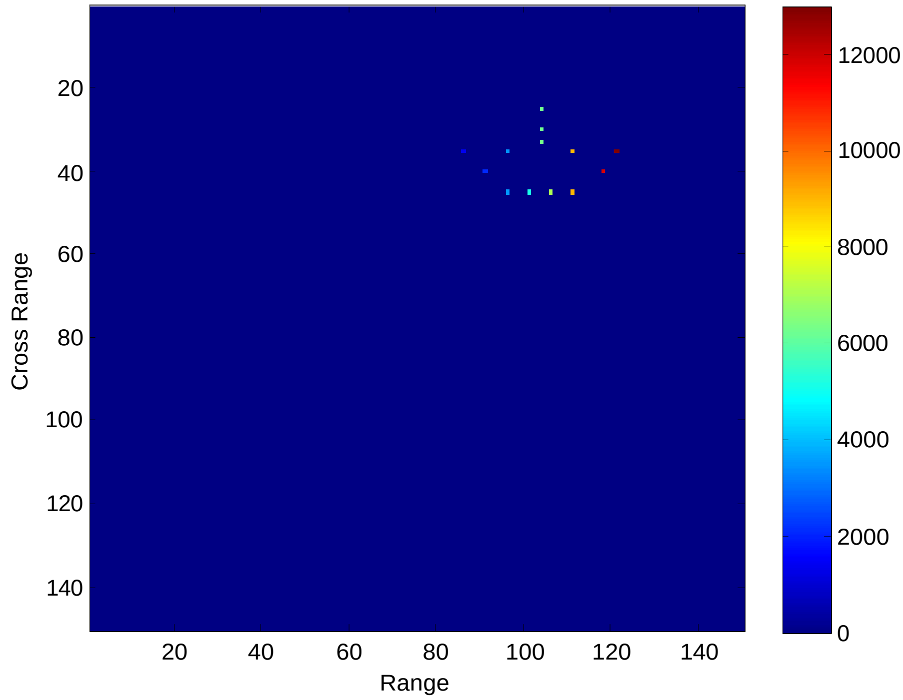

Fig.11. ISAR image using MFCFT for F=15GHz

Frequency = 40 GHz

Fig.12,13 and 14 shows ISAR image using STFT, Gabor and MFCFT respectively for 40GHz frequency. Even when the frequency is 40GHz, ISAR imaging using MFCFT method is having high resolution compared to STFT and Gabor.

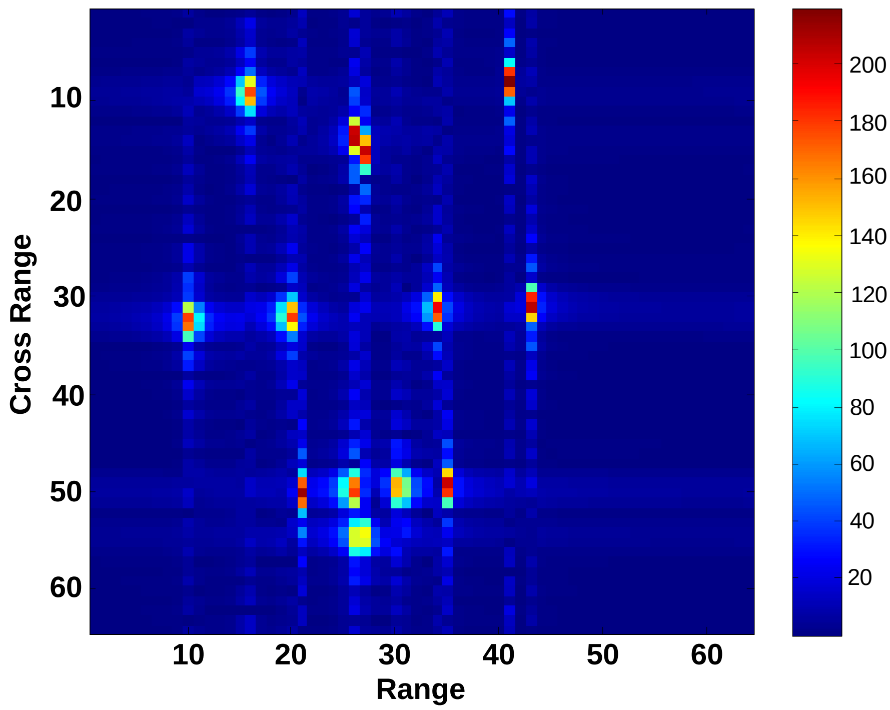

Fig.12. ISAR image using STFT for F=40GHz

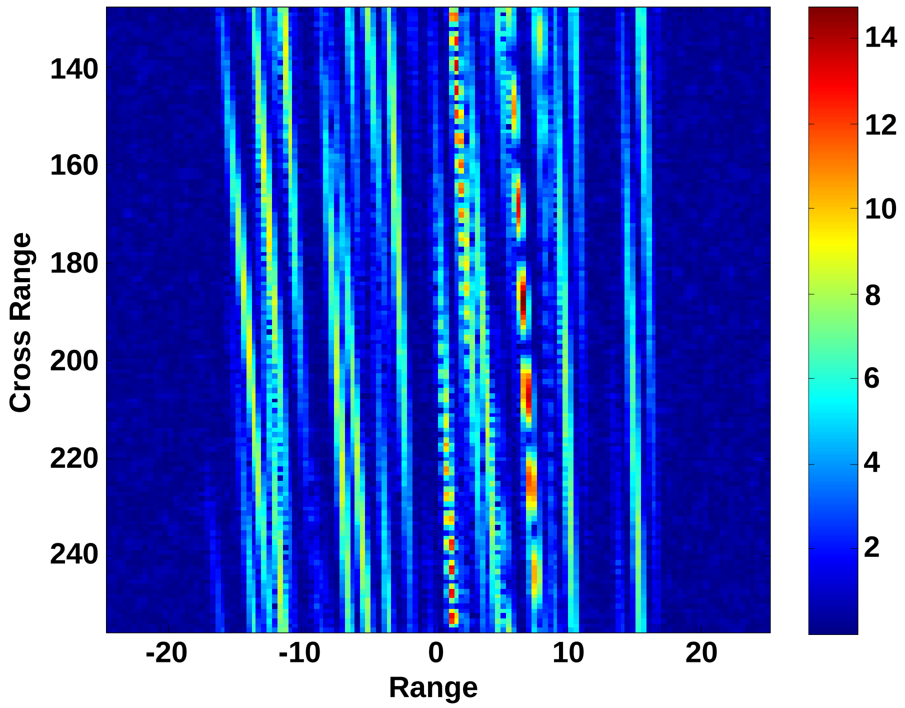

Fig.13 ISAR image using Gabor transform for F=40GHz

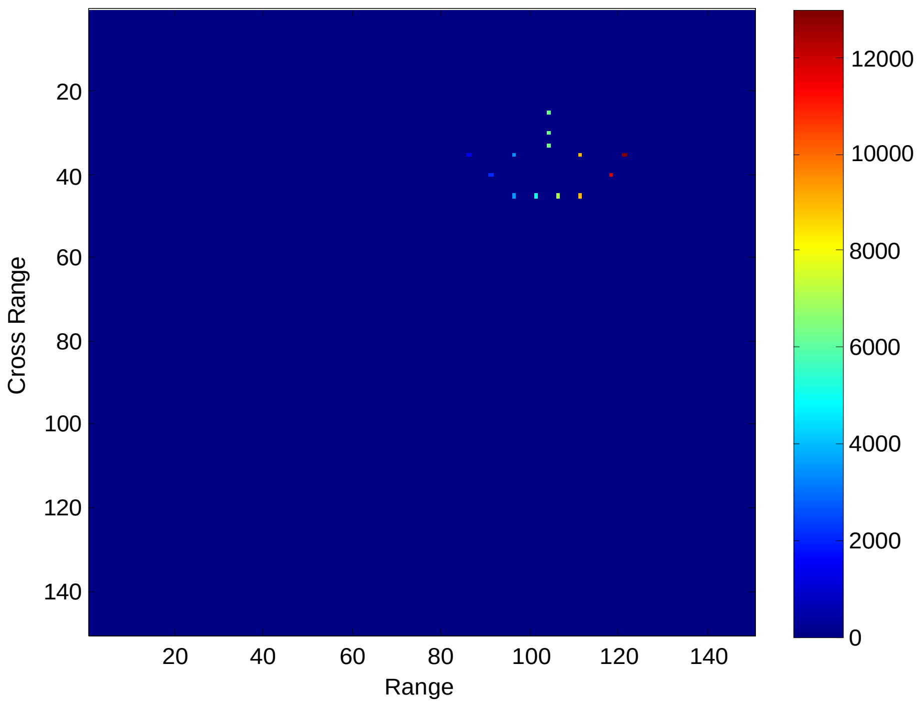

Fig.14. ISAR image using MFCFT for F=40GHz

V. CONCLUSIONS

In this paper, ISAR imaging for cubic chirp signals is done for wideband radar frequencies ranging from 1-40GHz using proposed method. The simulation is carried out for a ship target using STFT, Gabor and MFCFT. From the obtained results, ISAR imaging using proposed method is found to be far better compared to STFT and Gabor transform.

REFERENCES

[1] D.R.Wehner, High-Resolution Radar, 2nd ed. Norwood, MA: Artech House, 1995.

[2] F. Berizzi, E. D. Mese, M. Diani, M. Martorella, High-resolution ISAR imaging of maneuvering targets by means of the range instantaneous Doppler technique: Modeling and performance analysis, IEEE Trans. Image Process, 10(12), 2001, 1880–1890.

[3] G.Zhao-Zhao, L.Ya-Chao, X.MengDao, W.Genyuan, Z.Shou-Hong B.Zheng, ISAR Imaging of manoeuvring targets with the range instantaneous chirp rate technique, IET Radar, Sonar and Navigation, 3(11), 2009, 449-460.

[4] V.C. Chen, S. Qian, Joint time-frequency transform for radar range-Doppler imaging, IEEE Trans Aerospace Electron Syst 34, 1998, 486–499.

[5] V.C. Chen, Applications of time-frequency processing to radar imaging, Proc SPIE, 2762,1996, 23–31.

[6] Lee.T.S, Image representation using 2D Gabor wavelets, IEEE Trans. Pattern Analysis and Machine Intelligence, 18(10), 1996, 959-971.

[7] S.Qian, D. Chen, Joint time-frequency analysis methods and applications, Prentice Hall PTR, San Francisco, CA 1996

[8] M.Xing, R.Wu, Y. Li, Z.Bao, New ISAR imaging algorithm based on modified Wigner Ville distribution, IET Radar Sonar Navigation, 3(1), 2009,70-80.

[9] Yong Wang, Yicheng Jiang, ISAR Imaging of a Ship Target Using Product High-Order Matched-Phase Transform, IEEE Geoscience and Remote Sensing Letters,6(4), 2009, 658-661.

[10] Yong Wang, Yicheng Jiang, Inverse Synthetic Aperture Radar Imaging of Maneuvering Target Based on the Product Generalized Cubic Phase Function, IEEE Geoscience and Remote Sensing Letters, 8(5), 2011, 958-962.

[11] Y. Li, R.Wu, M.Xing, Z.Bao, Inverse synthetic aperture radar imaging of ship target with complex motion, IET Radar Sonar Navigation, 2(6), 2008, 395-403.

[12] Liang Wu, Xizhang Wei, Degui Yang, Hong qiang Wang, Xiang Li, ISAR Imaging of Targets With Complex Motion Based on Discrete Chirp Fourier Transform for Cubic Chirps, IEEE Trans. Geoscience and Remote Sensing, 48(11), 2012, 4201-4212.

[13] G.Anitha, K.S.RangaRao, Some studies on the Effect of Resolution with different ISAR Imaging Techniques, IEEE International Conference on Computer Communication and Systems ICCCS 14, 2014.

[14] G.Anitha, K.S.Ranga Rao, Comparison of various Algorithms for RD, RID and RIC methods using ISAR imaging, IJAER, 11(5), 2016, 3364-3368.