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EFFECT OF ISAR IMAGING ON SIGNAL LENGTH AND IMPROVEMENT IN RESOLUTION USING MFCFT

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ABSTRACT

For highly maneuvering targets as in case of RIC, algorithms like Discrete chirp Fourier transform is used to process the signal to get high resolution. In DCFT, the signal length is chosen to be a prime number else all the hotspots cannot be identified. To overcome this, a new algorithm named Modified Fast Chirp Fourier Transform where the signal length can be chosen to be any value i.e., not necessarily a prime number and also the resolution is high. In this paper, the superiority of this method is shown over DCFT through simulated results.

KEYWORDS: ***ISAR, DCFT, MFCFT,***

1. INTRODUCTION

ISAR imaging is a high resolution Radar imaging technique which generates a 2D image [1]. In order to generate a 2D ISAR imaging for higher order phase terms, Range Instantaneous Chirp (RIC) method is used. There are several algorithms namely, Radon Wigner transform, TC-Dechirp Clean technique, PHMT, S-transforms, etc are used for estimating the cubic chirp parameters of the obtained echo signal [2-3]. These algorithms are well sophisticated methods for RIC imaging but, involve a lot of computation which in turn increases the computational cost. In order to overcome this problem, a Fourier transform named, MFCFT is proposed. This is a modified version of DCFT. It will reduce the computational cost and also increases the signal to noise ratio. Out of all methods named above, MFCFT is found to be better in many ways like having less computation cost, less computation time and producing focused image. Before discussing MFCFT, it is necessary to know about DCFT.

2. DISCRETE CHIRP FOURIER TRANSFORM

DCFT for cubic chirps is represented as [4]

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

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

where x(n) is a chirp signal with signal length N, k represents the constant frequency and l represents chirp rate, m is rate of change of chirp rate and $W_N = e^{j2\pi/N}$. If signal parameters are not integers or not very close to integers then it leads to picket fence effect in DCFT which is shown in Fig.1. To avoid the severe picket fence effect and to increase the accuracy of parameter estimation MFCFT algorithm is used for cubic chirps [4]-[5]. In DCFT, another disadvantage is, the value of signal length should be a prime number then only all peaks present in a cell are clearly identified which is shown in Fig.2.

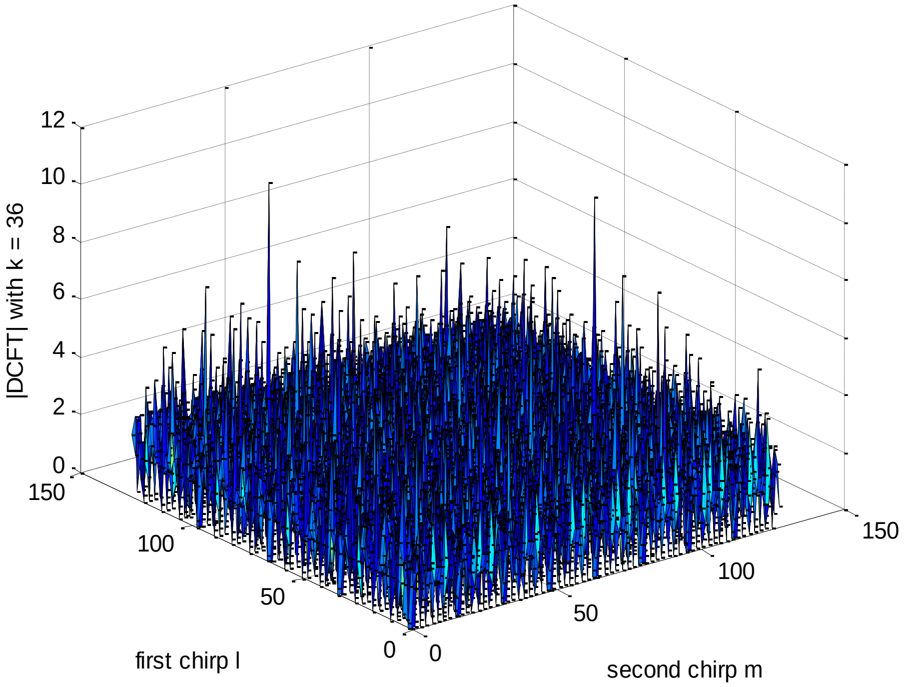

Fig.1. 3-D plot for DCFT when N=128

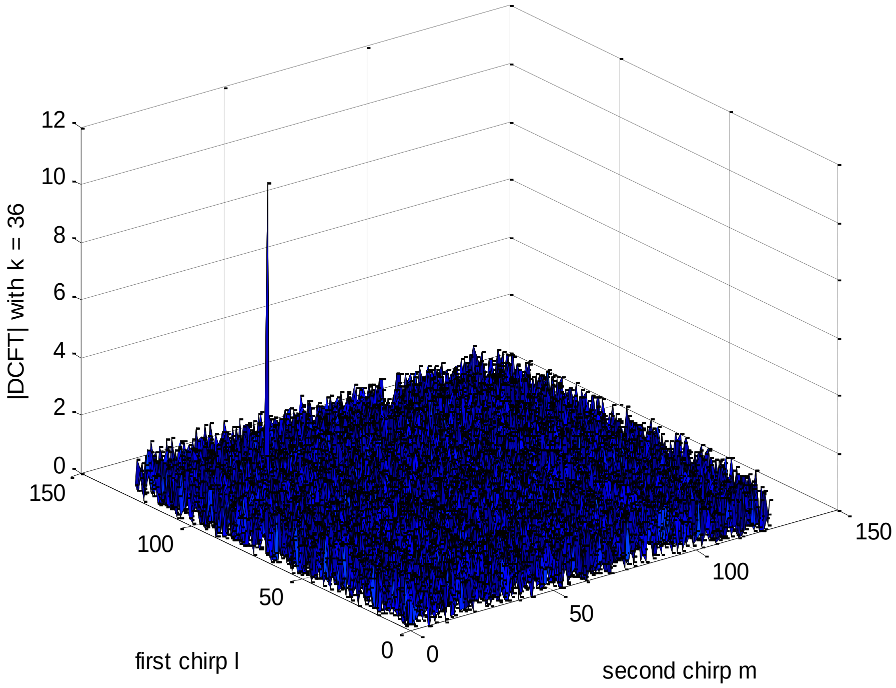

Fig.2. 3-D plot for DCFT when N=127

3. MODIFIED FAST CHIRP FOURIER TRANSFORM

MFCFT algorithm is represented by [6]

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

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

It is found to be better than MDCFT, because the estimated parameters are k varies from 0,1…,N-1, l varies from (0,1/N,…N-1/N) and m varies from (0,1/N,..,(N-1)/N). Here, the accuracy of parameter estimation increases compared to DCFT and shorter near the peak value is obtained, so that the time taken for computation is significantly reduced. Hence, MFCFT does not suffer from picket fencing problem. Additionally, it has no restriction on the value of signal length, which is a prime in case of DCFT. Fig.3 shows the 3D image for MFCFT algorithm for a signal length of N=128(which is not a prime number) and N=127(prime number).

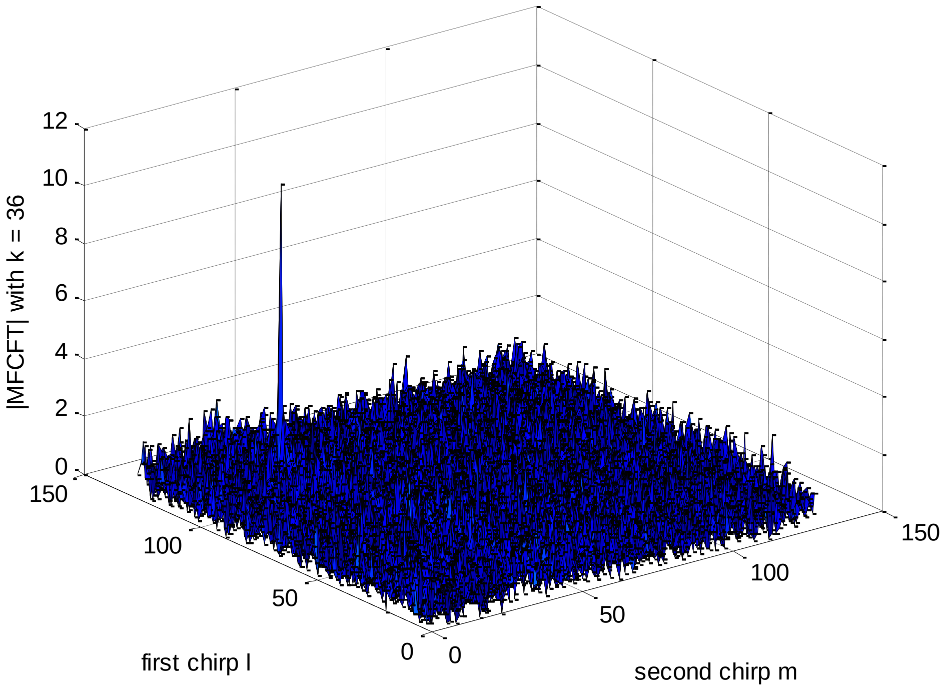

Fig.3 3-D output for MFCFT when N =128

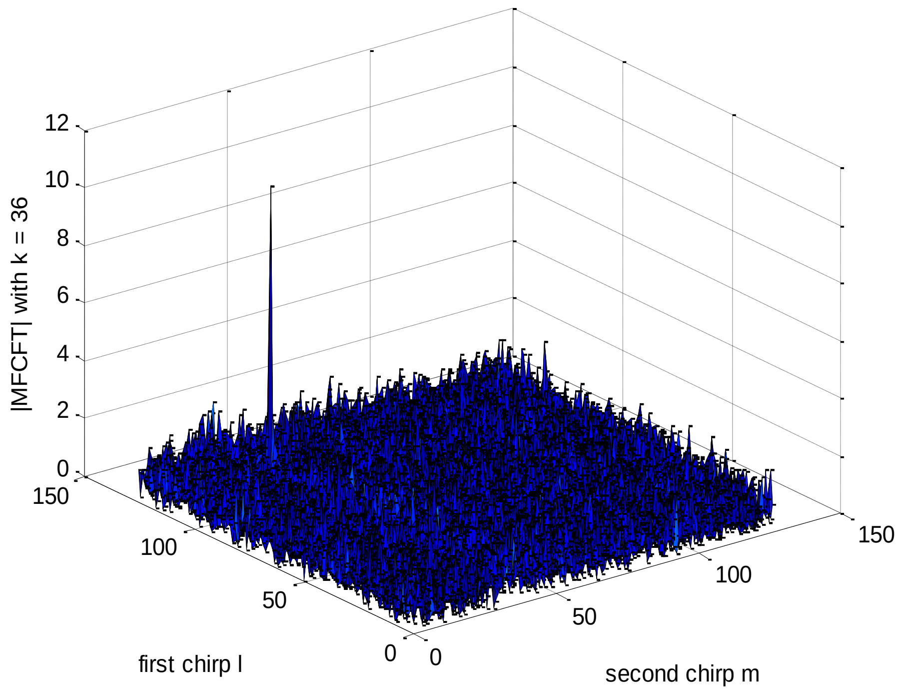

Fig.4. 3-D output for MFCFT when N =127

In both the cases i.e., Figs.3&4, the peaks are clearly identified avoiding the picket-fence problem irrespective of the value of signal length. Whenever imaging is done for a maneuvering target, it becomes necessary to take into consideration the higher order phase terms. Here, third order is considered and mathematical analysis is done for cubic phase terms. Assuming there are only P scatters present in a range cell, the echoes corresponding to each range cell can be expressed as the cubic phase signal, represented by $S(n_r)$ as

$$
\begin{aligned}
s(n_r) &= \sum_{p=1}^{P} A_p W_{N_r}^{f'_p n_r + \left(\gamma'_p / N_r\right) n_r^2 + \left(\beta'_p / N_r^2\right) n_r^3} \\
W_{N_r} &= \exp(-j2\pi / N_r) \\
A_p &= a_p \exp\left[-j(4\pi/\lambda)\Delta R_p(t_0)\right] \\
f'_p &= \left(\left(2\omega.r^T\right)/\lambda\right).(N_r / prf) \\
\gamma'_p &= \left(\left(\alpha.r^T\right)/\lambda\right).\left(N_r^2 / prf^2\right) \\
\beta'_p &= \left(\left(\zeta.r^T\right)/3\lambda\right).\left(N_r^3 / prf^3\right)
\end{aligned} \qquad (3)
$$

where prf is pulse repetition frequency, A_p is the amplitude, f_p' is the center frequency, γ_p' is the chirp rate and β_p' is derivative of chirp rate of azimuth echoes associated with Pth scatter.. Equation (3) represents the final cubic chirp equation for RIC method. Now the signal processing techniques like DCFT and MFCFT are applied to Equation (3), then, 2D image can be obtained. The results obtained with the MFCFT are found to be the better in terms of image resolution and also consumes less computation time. The steps to generate ISAR image using MFCFT includes the following

i. After applying equation (2) to (3) in each range bin, then the expression is represented by

$$S(k,l,m)=\frac{1}{\sqrt{N}}\sum_{n_r=0}^{N_r-1}s(n_r)W_N^{kn_r+(l/N_r)n_r^2+(m/N_r)n_r^3} \qquad (4)$$

and S(k,l,m) is modified transform of $s(n_r)$.

ii.The projection of S(k,l,m) will produce a Doppler image $I_D(k)$ in 3D with frequency f_p.

iii. All the main lobes of S(k,l,m) are clearly identified in Doppler image, which is obtained by the energy accumulation along axes of l and m and is given by

$$I_D(k)=\left|\sum_{l,k}S(k,l,m)\right| \qquad (5)$$

iv. If Doppler images of all range bins are added, then 2D image of target is obtained for cubic chirp signal.

4. SIMULATION RESULTS

The simulation is carried out for a missile target constructed with 47 scatters as shown in Fig.5.shows the simulated missile target with 47 scattering points and Fig.6 shows the ISAR image of missile target using MFCFT. From this, it can be observed that all the scattering points are clearly identified in the Fig.6 because MFCFT algorithm is used where the signal length need not be a prime number.

5. CONCLUSIONS

In this paper, ISAR imaging for RIC method using MFCFT is discussed. In DCFT method, the signal length need to be an integer then only all the scatters will be identified whereas in MFCFT there is no need for signal length to be an integer. The simulated results show the superiority of the method in terms of signal length and Resolution. Another advantage of MFCFT method is the computation time used for simulation is less compared to DCFT method. In future, it can be extended to fourth order terms where very high complex motions can be considered.

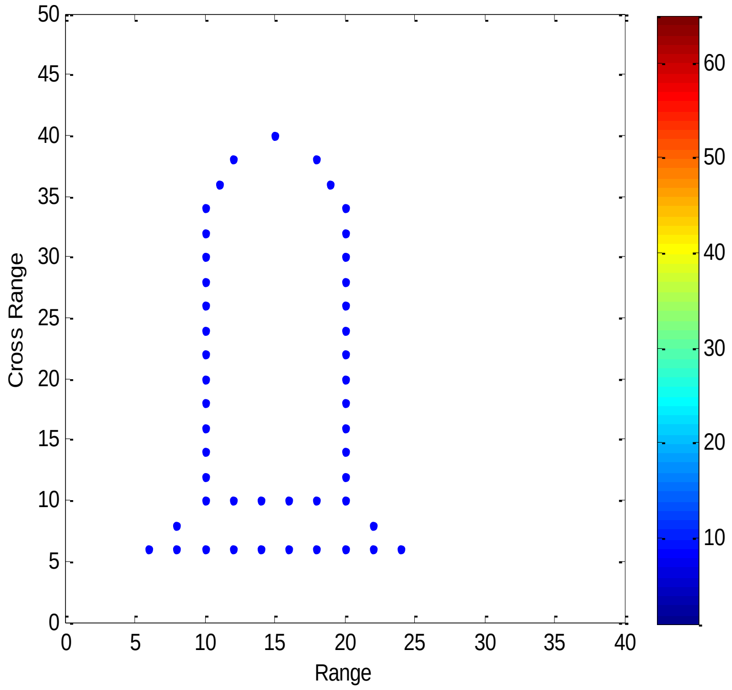

Fig.5. Missile target with 47 scatters

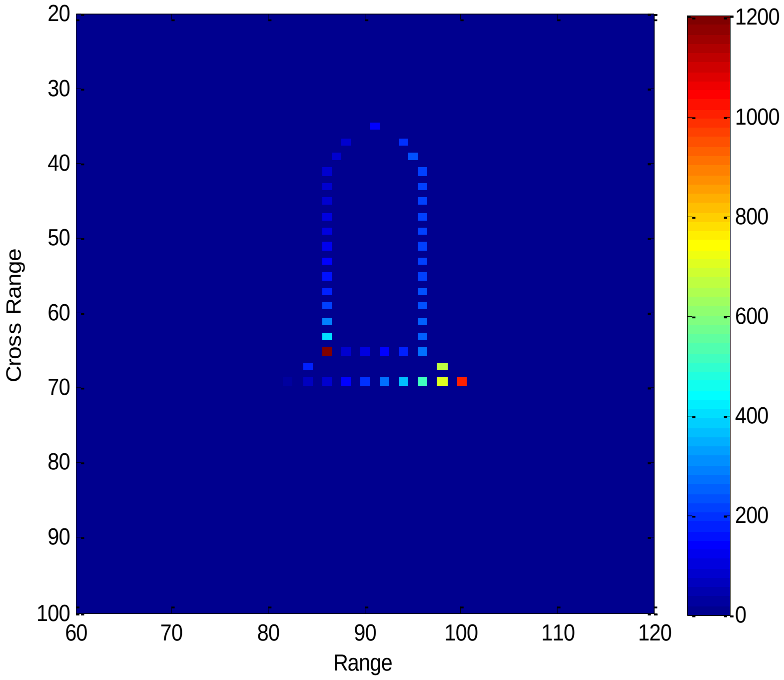

Fig.6. ISAR image for RIC using MFCFT

REFERENCES

(1) *Wehner D.R,(1995)," High Resolution Radar," Artech House Inc, 2nd Edition, , pp. 367-380.*

(2) *Zhao-Zhao. G, Ya-Chao. L, Mengdao. X, et. al, (2009), "ISAR Imaging of maneuvering targets with the range instantaneous chirp rate technique", IET Radar Sonar Navigation, Vol. 3, no. 11, pp. 449-460.*

(3) *Y.Wang, (2012),"Inverse synthetic aperture radar imaging of maneuvering target based on range instantaneous Doppler and range-instantaneous chirp rate algorithms", IET Radar Sonar Navigation, Vol. 6, Issue. 9, pp.921-928.*

(4) *Liang Wu, et.al., (2012), "ISAR Imaging of Targets With Complex Motion Based on Discrete Chirp Fourier Transform for Cubic Chirps", IEEE Trans. Geoscience and Remote Sensing,Vol.50, No.10, pp.4201-4212.*

(5) *N.Chitra, G.Anitha,K.S.Ranga Rao, (2013), "Analysis of Cubic Chirp Algorithms for Better Imaging of Target With Complex Motions and Comparison of Different ISAR Imaging Techniques", IJECT, Vol.4, Issue.4, pp.22-28.*

(6) *G.Anitha, K.S.Ranga Rao, (2017), "ISAR Imaging of maneuvering Targets based on a new Algorithm Modified Fast Chirp Fourier Transform for Cubic Chirps",International Journal of Engineering and Technology, Vol.9, No.3, pp.2310-2319.*