ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 2, February 2015

Effect of Hybrid Window Function Parameters CG-ICG-ENBW-SL on SNR of MST Radar Signals

D.Ravi Krishna Reddy[1], Dr.B.Anuradha[2]

Research Student, Department of ECE, S.V.U College of Engineering Tirupati, Andhra Pradesh, India[1]

Professor, Department of ECE, S.V.U College of Engineering Tirupati, Andhra Pradesh, India[2]

Abstract: In this paper, the effect of Hybrid Window parameters CG, ICG, ENBW and SL on the SNR values of the MST radar is computed. The six parts of multibeam observations of the lower atmosphere made by the MST radar are utilized for the analysis of results. Prior to the Fourier transformation, the in-phase and quadrature components of radar echo samples are weighted with Hybrid Window functions. It is noted that the increase of adjustable shape parameter 'α' of Hybrid windows increases ENBW and SL but decreases the CG and ICG. It helps to improve the SNR of MST radar return samples. Thus it is reported that the 'α=6' can be suggested for good results of SNR improvement in MST radar return signals. The optimum window parameters in turn yields optimum Kaiser-Hamming window function parameters are 'CG=1.0382, ICG=1.5233, ENBW=1.4134, SL=0.829', Cosh-Hamming window function parameters are 'CG=1.0169, ICG=1.4888, ENBW=1.4397, SL=0.8343',Hann-Poisson window function parameters are 'CG=0.1487, ICG=0.0784, ENBW=3.5467, SL=0.9602' and Kaiser Window function parameters are 'CG=0.4991, ICG=0.3660, ENBW=1.4695, SL=0.8410'.This relates to optimum main lobe width and side lobe attenuation to increase the signal to noise ratio of MST radar noisy data.

Keywords: Hybrid Windows, CG, ICG, ENBW, SL, SNR, DFT, Spectral Analysis.

1. INTRODUCTION

The discrete Fourier transform (DFT) in Harmonic analysis plays a major role in the radar signal processing. The data weighting window function with the DFT [6,13,20] is used to resolves the frequency components of the signal buried under the noise. The inappropriate window gives the corruption in the principal spectral parameters, hence it is ordered to consider criteria by the choice of data weighting window is used and made [4]. It was observed that the effects of 'α' in proposed Hybrid windows based on the Kaiser-Hamming window [12], Cosh-Hamming window [3], Hann-Poisson window[6] and Kaiser Window [19] functions on SNR of MST radar return signals. This paper presents the effect of the Hybrid Window parameters CG, ICG, ENBW and SL on the SNR values of the MST radar return signals and proposed an optimum value of 'α' with data.

2. DATA WEIGHTING WINDOWS

Windows are time-domain weighting functions are used in various signal processing applications, like beam forming, energy spectral estimation, power spectral estimation and digital filter design. Window functions are used to classify the cosmic data [5,10] and to increase the reliability of weather prediction models [14]. The application of FFT to a finite duration data gives the spectral leakage effect and picket fence effect. The data weighting window functions [15] can reduce these effects. The use of the data window functions affects the frequency resolution, variance and bias of the spectral estimations [13,20]. It is estimated that the number of observations are increased if the bias and variance tends to zero. Thus the problem with the spectral estimation of a finite duration data by the Fast Fourier Transformation method is the effect of providing efficient data windows or data smoothing schemes.

The data window functions are utilized to weight the time series of the quadrature phase and in-phase components of the radar return signals before to apply the DFT. The observed Doppler spectra represent the convolutions of the Fourier transforms of original signals projected onto the discrete frequencies [6].

3. SPECTRAL LEAKAGE

For signal frequencies, observed through the rectangular window, which do not correspond exactly to one of the sampling frequencies, the pattern is shifted such that non-zero values are projected onto all sampling frequencies. This phenomenon of spreading signal power from the nominal frequency across the entire width of the observed spectrum is called as spectral leakage [1,2,6]. The data windowing effect on the SNR improvement of MST radar returns signals are reported in literature [8,9,17,18,22]. By choosing the suitable values of shape parameters of adjustable windows, it is easy to provide SNR improvement with the optimum shape parameters [8,17,18]. Windows are classified into fixed or adjustable [24]. Fixed windows consist of only one independent parameter that is length of window; it controls the width of the main-lobe. The adjustable window functions having two or more independent parameters that can control other window characteristics [6,16]. The Kaiser and Saramaki windows [9,21] consist of two parameters and it provides close approximations to prolate discrete function to analyze the maximum energy concentration in main lobe.

DOI 10.17148/IJARCCE.2015.4297

ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 2, February 2015

The Dolph-Chebyshev window [16], [17] consists of two parameters and provides the minimum main-lobe width for maximum side-lobe level. For various applications the characteristics of main lobe width and ripple ratio can be controlled by adjusting two independent parameters like the window length and shape parameter. Kaiser window has a better side lobe roll-off characteristic other than the adjustable windows like Dolph-Chebyshev [17] and Saramaki [21] are special cases of ultra spherical window [25]. The quasi-monotonic (atmospheric) signal is superimposed on the background of white noise which is composed by the atmospheric radar. The spectral leakage from the signal exceeds the noise level computed with the help of Hildebrand and Sekhon [7] method and its response to underestimate signal-to-noise ratio.

4. HYBRID WINDOW FUNCTIONS

Kaiser-Hamming Window

It is obtained by combining a Kaiser window[19] and Hamming window and is defined in discrete time domain is

$$w_{KH}(n,\alpha) = \begin{cases} 0.54 + 0.46cos\left(\frac{2\pi n}{N}\right) + \end{cases}$$

Ioα1−2nN−12Ioα 0, otherwise , n≤N−12 (1)

Cosh-Hamming Window

It is obtained by combining a cosh window[3] and Hamming window and is defined in discrete time domain is

$$w_{CH}(n,\alpha) = \begin{cases} 0.54 + 0.46cos\left(\frac{2\pi n}{N}\right) + \frac{\cosh\left[\alpha\sqrt{1-\left(\frac{2n}{N-1}\right)^2}\right]}{\cosh(\alpha)}, |n| \\ 0, \quad otherwise \end{cases} \le \frac{N-1}{2} \quad (2)$$

Hann-Poisson Window

It is obtained by combining a Hann window and Poisson window functions[12] and is defined in discrete time domain is

$$w_{HP}(n,\alpha) = \begin{cases} \frac{1}{2}\left(1 + cos\left(\frac{2n\pi}{N-1}\right)\right) exp\left(-\alpha\frac{2|n|}{N}\right), & |n| \le \frac{N-1}{2} \\ 0, & otherwise \end{cases} \quad (3)$$

Kaiser Window

The Kaiser Window function [19] is defined by

$$w_K(n,\alpha) = \begin{cases} \frac{I_o\left(\alpha\sqrt{1-\left(\frac{2n}{N-1}\right)^2}\right)}{I_o(\alpha)}, & |n| \\ 0, \quad otherwise \end{cases} \le \frac{N-1}{2} \quad (4)$$

Where 'α' is the adjustable window shape parameter and $I_0(x)$ is characterized by the power series expansion as

$$I_0(x) = 1 + \sum_{k=1}^{\infty}\left(\frac{1}{k!}\left(\frac{x}{2}\right)^k\right)^2 \quad (5)$$

The parameters like length of the sequence N and window shape parameter 'α' are useful to get the desired amplitude response pattern of the Hybrid Window functions. Consider the number of FFT points in the MST radar data for each range bin is 512; the window length N is equal to 512. Therefore the 'α' can be varied to obtain the suitable Hybrid window function for the desired pattern of the magnitude response. As the 'α' increases the magnitude response of side lobe level decreases at the cost of main lobe width [6,13,20]. The results of SNR improvement of MST radar data are determined in form of MVBZ (Mean Value Below Zero) signal to noise ratio and MVAZ (Mean Value Above Zero) signal to noise ratio [8,17,18,22].

5. WINDOW PERFORMANCE ANALYSIS

The performance of window functions can be calculated from figure of merits like Incoherent Power Gain (ICG), Coherent Gain (CG), Equivalent Noise Band Width (ENBW) and Scalloping Loss (SL).

5.1 Coherent Gain

The average value of the window w (nT) is called the Coherent Gain (CG) and is defined as

$$CG = \frac{1}{N}\sum_n w(nT) \quad (6)$$

The Coherent Gain value of rectangular window is unity. In other windows its value is decreases because the window smoothly going to zero at the ends. It shows the reduction in signal power.

5.2 Incoherent Power Gain

The average value of the square of window w (nT) is called the Incoherent Power Gain (ICG) and is defined as

$$ICG = \frac{1}{N}\sum_n [w(nT)]^2 \quad (7)$$

Its value of rectangular window is unity and other windows it is decreases.

5.3 Equivalent Noise Band Width

The ratio between ICG & square of CG is called Equivalent Noise Band Width (ENBW) and is defined as

$$ENBW = \frac{ICG}{[CG]^2} = N\frac{\sum_n [w(nT)]^2}{[\sum_n w(nT)]^2} \quad (8)$$

It calculates the ability of a window function to extract the signal from back ground noise. The small value of ENBW provides better signal extraction from back ground noise. The ENBW value of rectangular window is unity and for other windows it is greater than unity.

5.4 Scalloping Loss

It is the ratio of signal frequency component power gain located halfway between DFT bins to the average value of the window (Coherent Gain) for a signal frequency component located exactly on the DFT bin

$$SL = \frac{\left|\sum_n w(nT)e^{-j\pi(n/N)}\right|}{\sum_n w(nT)} \quad (9)$$

6. HYBRID WINDOW FUNCTIONS APPLIED TO MST RADAR SIGNALS

The signal which is received by MST radar due to back scattering of atmospheric layers, the atmospheric radar signals is turbulent. The radar return signals from the atmospheric layers having very small amount of power and are emitted from it.

These signals are associated with Gaussian noise. This noise dominates the signal strength as the distance between the target and radar increases, it leads to decrease in signal to noise ratio so the detection of the signal is difficult.

The information on Doppler profile is provided from the power spectrum using FFT. The frequency characteristics of radar return signals are analyzed with power spectrum; this specifies the spectral characteristics of frequency domain signals.

The specifications of the MST radar data are given in Table 1. The signal to noise ratio analysis on MST radar data corresponds to the lower stratosphere obtained from the NARL, Gadanki, India.

The operation of radar was perform in East, West, North, South, Zenith-X and Zenith-Y direction in vertical direction of an angle of 10^0. The data collected from the six directions of MST radar are used to carry on the signal to noise ratio analysis.

The algorithm which is shown below uses MATLAB to observe the effect of shape parameter ‘α’ on the SNR of the MST radar signals.

7. ALGORITHM

- Obtain Hybrid windows with the specified ‘α’
- Tapering the radar data with window function weights specified in first step
- Compute the Fourier analysis of the above tapered data [11,23,24].
- Calculate the signal to noise ratio using the procedure [7,11,23,24].
- Calculate the Mean Value below Zero signal to noise ratios (MVBZ) [8,17]
- Calculate the Mean Value above Zero signal to noise ratios (MVAZ) [8,17]
- Update the value of ‘α’ repeat above steps except first step

8. MST RADAR DATA AND SPECIFICATIONS

The MST radar data is used for the computation of mean signal to noise ratio is

No. of Range Bins : 150
No. of FFT points : 512
No. of Coherent Integrations : 64
No. of Incoherent Integrations : 1
Inter Pulse Period : 1000µsec
Pulse Width : 16µsec
Beam : 10^0

Table 1: Specifications of MST radar

Period of Observation	July 2011
Pulse Width	16 µs
Range resolution	150 m
Inter Pulse Period	1000 µs
Number of Beams	6(E_{10y},W_{10y},N_{10x},S_{10x},Z_x,Z_y)
Number of FFT points	512
No.of Incoherent Integrations	1
Maximum Doppler Frequency	3.9 Hz
Maximum Doppler Velocity	10.94 m/s
Frequency resolution	0.061 Hz
E_{10y}	East West polarization with off-zenith angle of 10^0
W_{10y}	East West polarization with off-zenith angle of 10^0
N_{10x}	North South polarization with off-zenith angle of 10^0
S_{10x}	North South polarization with off-zenith angle of 10^0

9. RESULTS

The comparison of Hybrid Window functions in terms of MVBZ SNR and MVAZ SNR of six directions of MST radar as shown in Table 2.

Table 2: Comparison of Hybrid Window functions in terms of MVBZ and MVAZ for α=6.

Window function / Performance	Kaiser-Hamming window	Cosh-Hamming winow	Hann-Poisson window	Kaiser window
MVAZ East Beam	9.0492	9.0589	9.4716	9.0227
MVBZ East Beam	-7.7183	-7.6065	-6.3467	-7.4579
MVAZ West Beam	9.456	9.8704	10.1221	9.8173
MVBZ West Beam	-7.3926	-7.3761	-6.1929	-7.4008
MVAZ North Beam	12.3676	12.0566	11.5285	11.9854
MVBZ North Beam	-8.6476	-8.6478	-7.4632	-9.0491
MVAZ South Beam	11.3309	11.3818	11.6286	11.4509
MVBZ South Beam	-7.9159	-7.2855	-5.9061	-7.7165
MVAZ Zenith-X Beam	12.6054	12.5189	11.0969	12.5056
MVBZ Zenith-X Beam	-7.7399	-7.8081	-6.4615	-7.9345
MVAZ Zenith-Y Beam	14.4563	14.5777	14.0508	14.3362
MVBZ Zenith-Y Beam	-7.8919	-7.5457	-7.0831	-7.7180

The performance analysis of Hybrid Window functions for different shape parameters (α=1 to α=10) in terms of CG, ICG, ENBW & SL as shown in Table 3 to Table 6.

Table 3: Performance of Kaiser-Hamming Window

Shape Parameter	Kaiser-Hamming Window			
α	CG	ICG	ENBW	SL
1	1.4671	2.3022	1.0696	0.7165
2	1.3339	2.0255	1.1384	0.7499
3	1.2223	1.8273	1.223	0.7802
4	1.1418	1.6945	1.2999	0.8025
5	1.0829	1.5983	1.3629	0.818
6	1.0382	1.5233	1.4134	0.829
7	1.0028	1.4622	1.454	0.8368
8	0.974	1.4108	1.4871	0.8426
9	0.9499	1.3666	1.5144	0.8469
10	0.9295	1.328	1.5371	0.8501

Table 4: Performance of Cosh-Hamming Window

Shape Parameter	Cosh-Hamming Window			
α	CG	ICG	ENBW	SL
1	1.4184	2.1961	1.0915	0.7285
2	1.2653	1.9049	1.1898	0.7694
3	1.1682	1.743	1.2771	0.7966
4	1.103	1.6358	1.3445	0.814
5	1.0547	1.5545	1.3973	0.8259
6	1.0169	1.4888	1.4397	0.8343
7	0.9862	1.4339	1.4744	0.8405
8	0.9606	1.387	1.5031	0.8452
9	0.9389	1.3462	1.5271	0.8487
10	0.9202	1.3102	1.5472	0.8515

Table 5: Performance of Hann-Poisson Window

Shape Parameter	Hann-Poisson Window			
α	CG	ICG	ENBW	SL
1	0.379	0.249	1.7333	0.8797
2	0.298	0.1796	2.0222	0.9046
3	0.2418	0.1378	2.3568	0.9241
4	0.2014	0.1107	2.7278	0.9394
5	0.1715	0.092	3.1267	0.9511
6	0.1487	0.0784	3.5467	0.9602
7	0.1309	0.0682	3.9829	0.9673
8	0.1166	0.0603	4.4311	0.9728
9	0.1051	0.054	4.8885	0.9771
10	0.0955	0.0488	5.3531	0.9806

Table 6: Performance of Kaiser Window

Shape Parameter	Kaiser Window			
α	CG	ICG	ENBW	SL
1	0.928	0.8651	1.0047	0.6576
2	0.7948	0.6618	1.0476	0.7038
3	0.6832	0.5311	1.1377	0.7506
4	0.6026	0.4534	1.2485	0.7888
5	0.5438	0.4026	1.3613	0.8183
6	0.4991	0.3660	1.4695	0.8410
7	0.4637	0.338	1.572	0.8589
8	0.4349	0.3157	1.669	0.8732
9	0.4108	0.2972	1.761	0.885
10	0.3904	0.2817	1.8487	0.8947

The performance variation in CG/ICG and ENBW/SL due to increase in adjustable parameters for Kaiser-Hamming window shown in Fig.1 & Fig.2, Cosh-Hamming Window shown in Fig.3 & Fig.4,Hann-Poisson window shown in Fig.5 & Fig.6 and Kaiser Window shown in Fig.7 & Fig.8

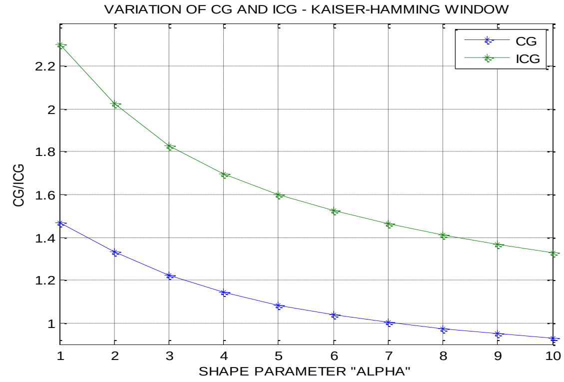

Fig.1

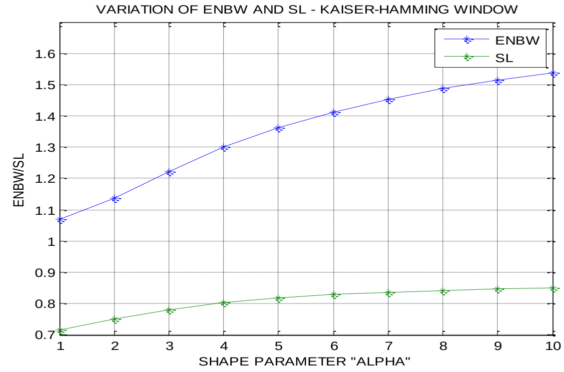

Fig.2

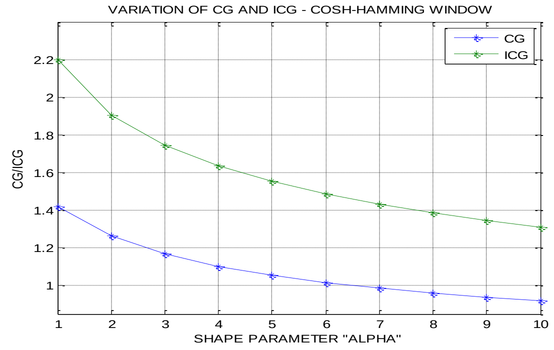

Fig.3

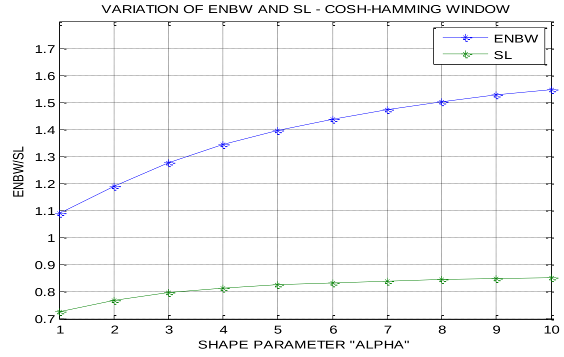

Fig.4

ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 2, February 2015

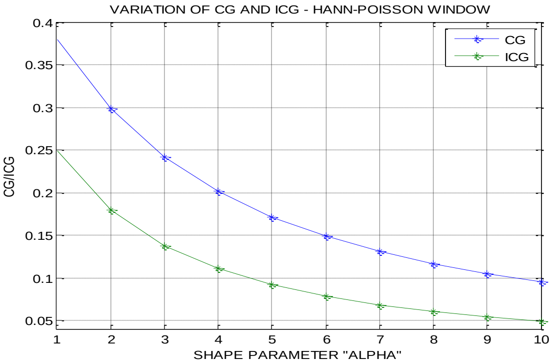

Fig.5

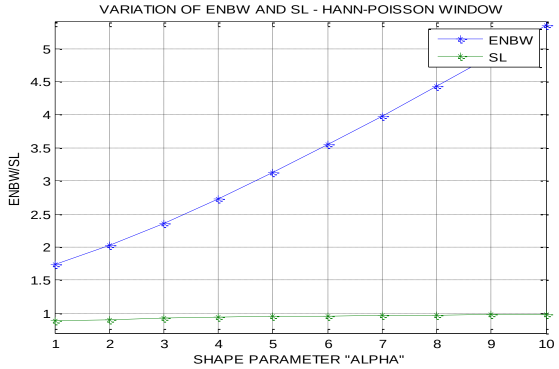

Fig.6

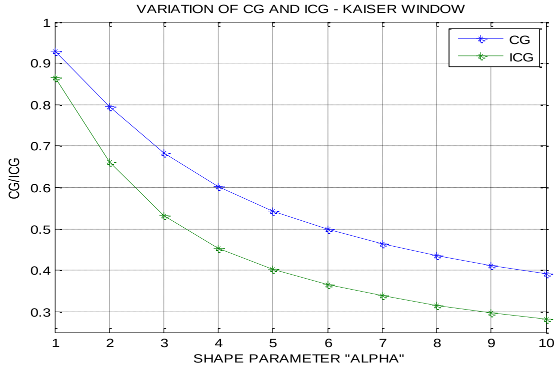

Fig.7

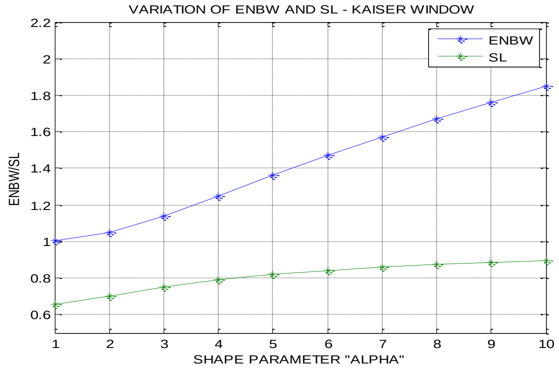

Fig.8

9. CONCLUSION

The SNR values for the six sets of MST radar data and performance analysis of Window functions is computed. The MVBZ SNR in all the cases increases with adjustable parameters . The increase in MVBZ continues up to a certain value of the adjustable parameters. Further increase in adjustable parameters has no appreciable change in MVBZ SNR. It is clearly shows that even the change in side lobe reduction contributes to the SNR improvement at the cost of main lobe width and it shows the improvement in SNR. By increasing the adjustable parameters the side lobe level is decrease and width of main lobe is the increases which compensates the increase in the MVBZ SNR. Therefore the MVBZ SNR value is almost constant of all the six sets of radar data. For all the six-sets of radar data there is no appreciable change in the MVAZ SNR with adjustable parameters. This result provides the back-scattered signal from the middle and upper most bins are very weak, improvement in SNR is more important in spectral estimation. For obtaining a good signal to noise ratio improvement, the selection of the adjustable parameters plays an important role.

REFERENCES

[1] Andrwas A, “Digital Filters Analysis, Design and Applications”, Tata McGraw-Hill, 1999.
[2] D.Hooper A, “Signal and noise level estimation for narrow spectral width returns observed by the Indian MST radar”, Radio Science. Volume No.34, pp.859-870, 1999.
[3] Falahati A, M.Nouri, Sajiadi S Ghaemmaghami “An Improved Window Based on CosineHyperbolicFunction”, Multidisciplinary Journals in Science and Technology, Journals ofSelectedAreasinTelecommunications (JAST), pp.8-13, July-2011.
[4] F.Woodman Ronald . “Spectral moment estimation in MST radars”, Radio Science., Volume No.20, pp.1185-1195, 1985.
[5] G.Caudal, B. Picard, E. Anterrieu , “Improved windowing functions for Y-shaped synthetic aperture imaging radiometers,” in Proc. IEEE International Geosciences and Remote Sensing Symposium (IGARSS ’02), vol. 5,pp. 2756-2758, Toronto, Canada, 2002.
[6] Harris J.F, “On the use of windows for harmonic analysis with the discrete Fourier transform”, Proc. IEEE Volume No.66,pp.51-.83, 1978
[7] H. Hildebrand P. and S.Sekhon R., Objective determination of the noise level in Doppler spectra, J. Appl. Meteorol., volume no.13, pp.808-811, June1974.
[8] H. Reddy .G. et al “The Effect of ‘β’ in Kaiser Window on the signal to noise ratio (SNR) of MST Radar Signals”, Asian Journal of scientific Research, ISSN-19921454, Vol.1, No.3, pp.203-212, 2008.
[9] James Kaiser F, “Nonrcursive digital filter design using I0-sinh window function” in Proc.IEEE Int. Symp. Circuits and Systems (ISCAS’74), pp.20-23, SanFrancisco, Claif, USA, April 1974
[10] J. Devlin M. ,Torbet E, W. Dorwart B., et al., “A measurement of the angular power spectrum of the microwave background made from the high Chilean Andes,” The Astrophysical Journal, volume 521, pp. 79-82, 1999
[11] K.Mitra S.., “Digital Signal Processing (DSP)-A Computer Based Approach”, Tata McGraw-Hill, 1998
[12] K.PRABHU M.M., “Window functions and their applications in Signal Processing” .Prentice Hall International. Inc, 1999.
[13] L.Jr.Marple S,”Digital Spectral Analysis with Applications”, Prentice-Hall Inc., Englewood Cliffs, NJ, 1987.
[14] Lynch P., “The Dolph-Chebyshev window: a simple optimal filter,” Monthly Weather Review, volume No. 125, pp. 655-660, 1997.
[15] Oppenheim V and W.Schafer Ronald, “Descrite Time Signal Processing” Prentice Hall International. Inc, 1998.
[16] Parks J. H.T , L. R. Rabiner, McClellan and., FIR Digital Filter Design Techniques Using Weighted Chebyshev Approximation, Proc. IEEE, Vol. 63, pp. 595 – 610, May 1976.
[17] Reddy G.Harnadth. et al “Improved SNR of MST Radar Signals: Dolph-Chebyshev Window Parameters”, International Journal of Electronics and Communication Engineering, ISSN 0974-2166, Vol. 1, No. 1, 2009.
[18] Reddy H.G et al “Effect of Windowing on SNR of MST Radar Signals”, engineering Today, Vol.9, No.11, pp.22-26, 2007.
[19] R. Woodman S and F. Kaiser James , “On the use of the I0-sinh window for spectrum analysis,” IEEE Trans. Acoustics, Speech, and Signal Processing, volume No.28, pp. 105–107, 1980.

DOI 10.17148/IJARCCE.2015.4297

[20] S.M.Kay , "Modern Spectral Estimation", Prentice-Hall, Inc., Englewood Cliffs, NJ, 1988.

[21] Saramki T, "Finite impulse response filter design," in Hand book for Digital Processing, S. K. Mitra and Kaiser, Eds., Wiley, New York, NY, USA, 1993.

[22] Subbaramireddy A Et. al "Two Level Multiple Taper Spectral Analysis Applied to MST Radar Signals", Journal of the Institution of Engineers (India) - ET, Vol.87, pp.61-66, July- 2006.

[23] V.K Anandan, "Atmospheric Data Processor – Technical User reference manual", NMRF publication, Tirupati, 1998.

[24] V.K Anandan, "Signal and Data processing Techniques for Atmospheric Radars", Ph.D. thesis, S.V. University, Tirupati. 1999.

[25] W. A. Stuart Bergen and Antoniou Andreas, "Design of Ultra spherical Window Functions with Prescribed Spectral Characteristics", EURASIP Journal on Applied Signal Processing volume no.13, pp.2053-2065, 2004.\

DOI 10.17148/IJARCCE.2015.4297