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Effect of shape parameter ‘α’ in Kaiser-Hamming and Hann-Poisson Window Functions on SNR Improvement of MST Radar Signals

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Abstract

In this paper the effect of window shape parameter ‘α’ in Kaiser-Hamming and Hann-Poisson window functions on the signal to noise ratio (SNR) values of the Indian Mesosphere-Stratosphere-Troposphere (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 proposed windows based on the Kaiser-Hamming and Hann-Poisson Window functions. The effects of data weighting with the change of the window shape parameter ‘α’ of the Kaiser-Hamming and Hann-Poisson Window functions are given in it. It is noted that the increase of variable window shape parameter ‘α’ increases the signal to noise ratio values and a better improvement is reported. For Kaiser-Hamming and Hann-Poisson Window functions are proposed to analyze the MST radar return signals to obtain optimum values of the window shape parameter. The results shows the improvement of signal to noise ratio of noisy data due to the effect of side lobe reduction and demands for the design of the optimal window functions.

Index Terms: Kaiser-Hamming and Hann-Poisson window functions, SNR, DFT and 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 [7,10,18] 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 [24]. It was observed that the effect of ‘α’ in proposed windows based on the Kaiser-Hamming [12] and Hann-Poisson [13] functions on SNR of MST radar return signals and proposed an optimum value of window shape parameter 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 [2,21] 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 [25] can reduce these effects. The use of the data window functions affects the frequency resolution, variance and bias of the spectral estimations [10,18]. 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 [7].

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 [1,6,7]. The data windowing effect on the SNR improvement of MST radar returns signals are reported in literature [4,8,15,16,17,20]. By choosing the suitable values of shape parameters of adjustable windows, it is

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easy to provide SNR improvement with the optimum shape parameters [4,15,16,17]. Windows are classified into fixed or adjustable [23]. Fixed windows consist of only one independent parameter that is length of window; it controls the width of the main-lobe. The variable window functions having two or more independent parameters that can control other window characteristics [7,9]. The Kaiser and Saramaki windows [8,19] consist of two parameters and it provides close approximations to prolate discrete function to analyze the maximum energy concentration in main lobe. The Dolph-Chebyshev window [4], [9] 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 [4] and Saramaki [19] are special cases of ultra spherical window [26]. 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 [5] method and its response to underestimate signal-to-noise ratio.

4. Window Functions

Kaiser-Hamming Window

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

$$w_{KH}(n,\alpha) = \begin{cases} 0.54 + 0.46cos\left(\frac{2\pi n}{N}\right) + \dfrac{I_o\left(\alpha\sqrt{1-\left(\frac{2n}{N-1}\right)^2}\right)}{I_o(\alpha)}, & |n| \leq \frac{N-1}{2} \\ 0, & otherwise \end{cases} \quad (1)$$

Hann-Poisson Window

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

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

Kaiser Window

The Kaiser Window function [3] is defined by

$$w_K(n,\alpha) = \begin{cases} \dfrac{I_o\left(\alpha\sqrt{1-\left(\frac{2n}{N-1}\right)^2}\right)}{I_o(\alpha)}, & |n| \leq \dfrac{N-1}{2} \\ 0, & otherwise \end{cases} \quad (3)$$

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

$$I_0(x) = 1 + \sum_{k=1}^{\infty}\left(\frac{1}{k!}\left(\frac{x}{2}\right)^k\right)^2 \quad (4)$$

The parameters like length of the sequence N and a window shape parameter 'α' are useful to get the desired amplitude response pattern of the Kaiser-Hamming and Hann-Poisson 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 Kaiser-Hamming and Hann-Poisson 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 [7,10,18]. 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 [4,15,16,17,20].

5. Kaiser-Hamming and Hann-Poisson 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 window shape parameter 'α' and a controlling parameter 'ε' on the SNR of the MST radar signals.

6. Algorithm and Data Specifications

- Obtain the Kaiser-Hamming and Hann-Poisson windows with the specified values of 'α'
- Tapering the radar data with window function weights specified in first step
- Compute the Fourier analysis of the above

tapered data [11,22,23].

- Calculate the signal to noise ratio using the procedure [5,11,22,23].
- Calculate the Mean Value below Zero signal to noise ratios (MVBZ) [4,16,17]
- Calculate the Mean Value above Zero signal to noise ratios (MVAZ) [4,16,17]
- Update the value of 'α' repeat above steps except first step

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	

7. Results

Average SNR of radar data for Kaiser-Hamming,Hann-Poisson and Kaiser windows as shown in Fig. 1 ,2 and 3 res.

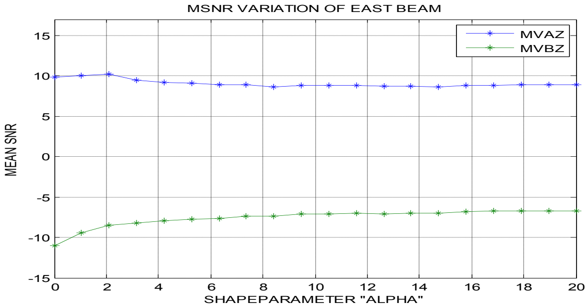

Fig.1(a): Average SNR EAST Beam

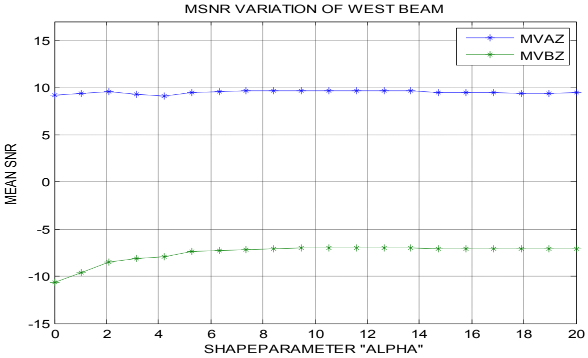

Fig.1(b): Average SNR WEST Beam

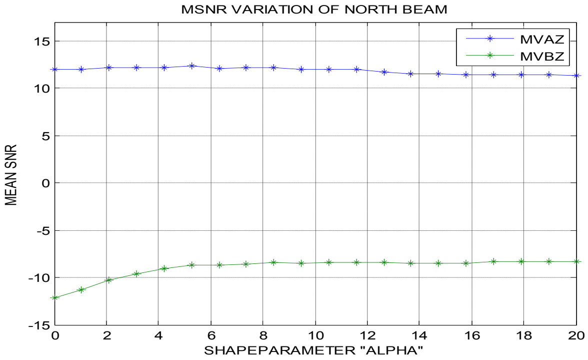

Fig.1(c): Average SNR NORTH Beam

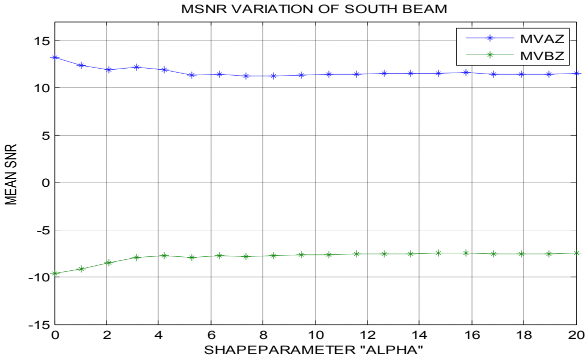

Fig.1(d): Average SNR SOUTH Beam

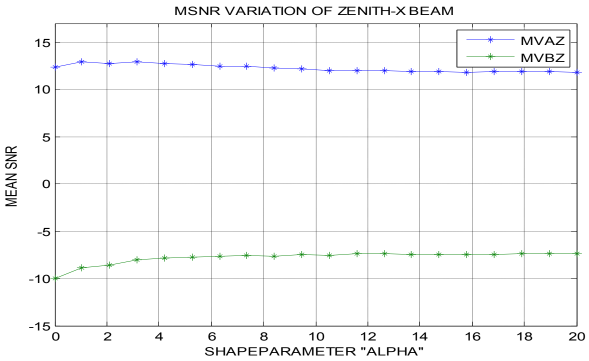

Fig.1(e): Average SNR ZENITH-X Beam

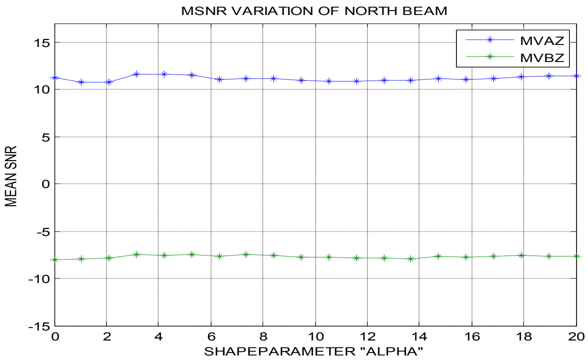

Fig.2(c): Average SNR NORTH Beam

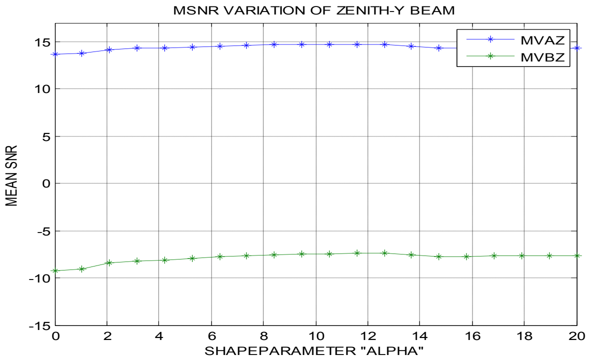

Fig.1(f): Average SNR ZENITH-Y Beam

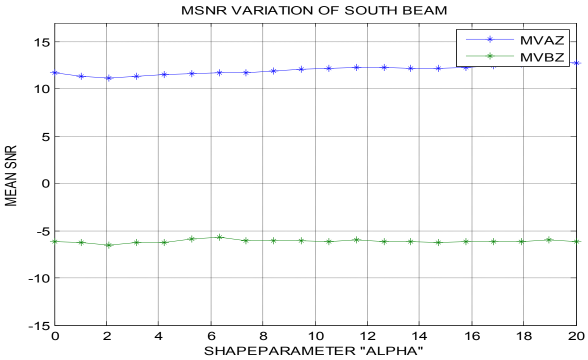

Fig.2(d): Average SNR SOUTH Beam

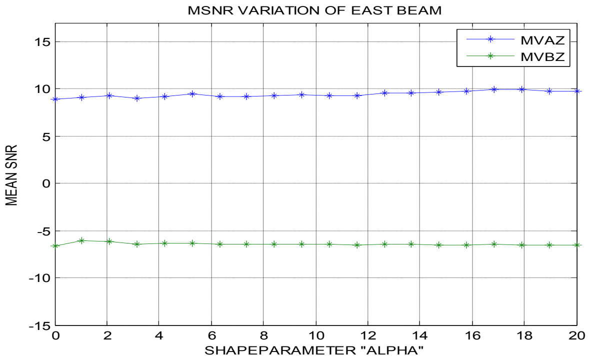

Fig.2(a): Average SNR EAST Beam

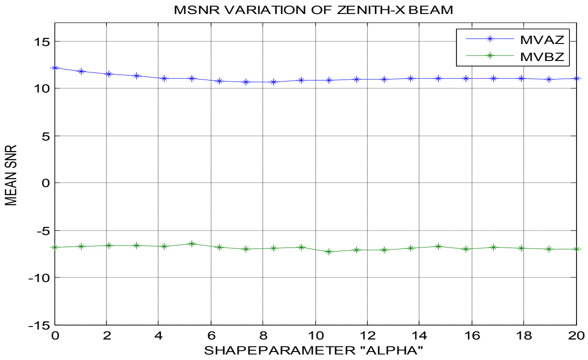

Fig.2(e): Average SNR ZENITH-X Beam

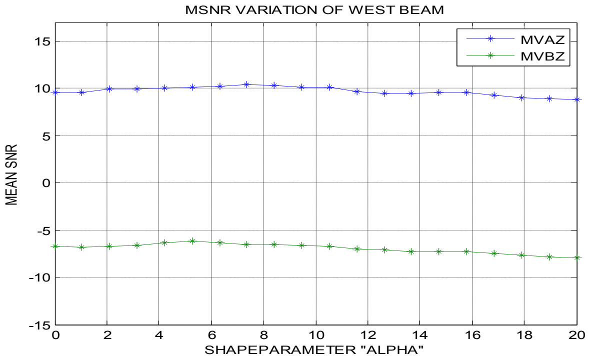

Fig.2(b): Average SNR WEST Beam

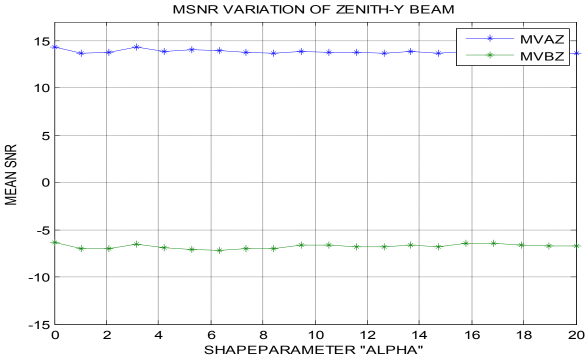

Fig.2(f): Average SNR ZENITH-Y Beam

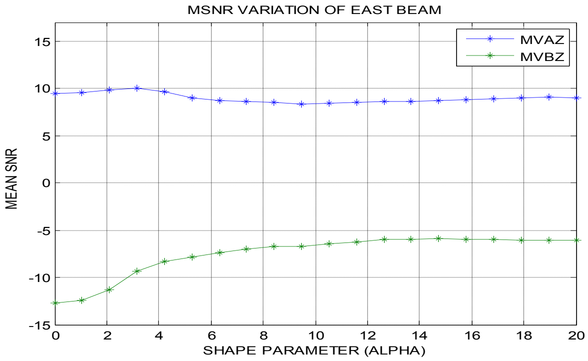

Fig.3(a): Average SNR EAST Beam

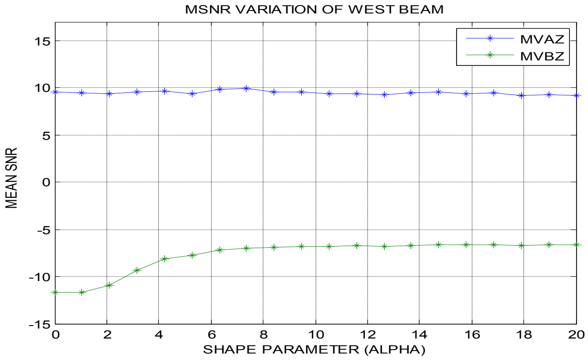

Fig.3(b): Average SNR WEST Beam

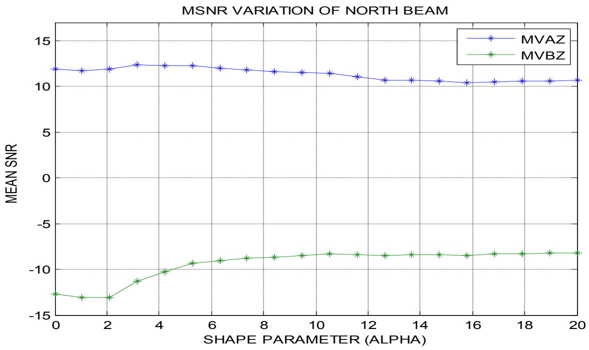

Fig.3(c): Average SNR NORTH Beam

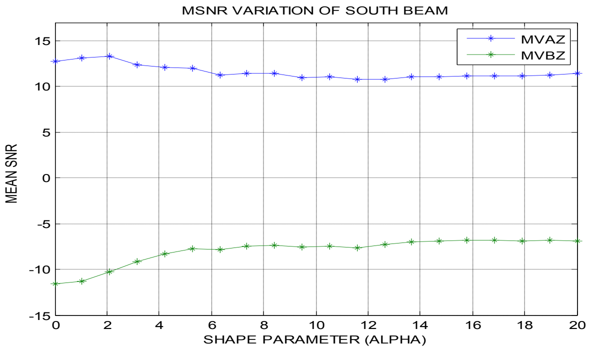

Fig.3(d): Average SNR SOUTH Beam

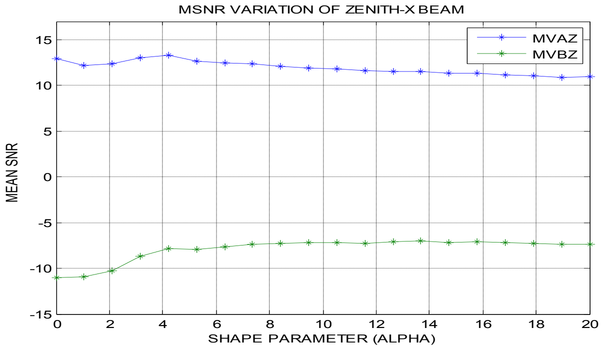

Fig.3(e): Average SNR ZENITH-X Beam

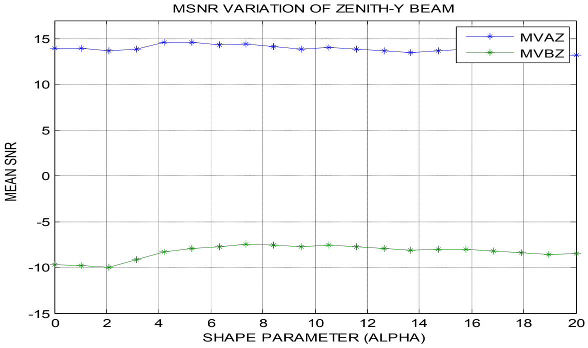

Fig.3(f): Average SNR ZENITH-Y Beam

The comparison of Kaiser-Hamming and Hann-Poisson Window functions in terms of MVAZ SNR and MVBZ SNR of six directions of MST radar as shown in Table 2.

Table 2: Comparison of Windows for α=6.

Window/ Performance	Kaiser-Hamming window	Hann-Poisson winow	Kaiser window
MVAZ East Beam	9.0492	9.4716	9.023
MVBZ East Beam	-7.7183	-6.3467	-7.458
MVAZ West Beam	9.456	10.1221	9.817
MVBZ West Beam	-7.3926	-6.1929	-7.401
MVAZ North Beam	12.3676	11.5285	11.99
MVBZ North Beam	-8.6476	-7.4632	-9.049
MVAZ South Beam	11.3309	11.6286	11.45
MVBZ South Beam	-7.9159	-5.9061	-7.717
MVAZ Zenith-X Beam	12.6054	11.0969	12.51
MVBZ Zenith-X Beam	-7.7399	-6.4615	-7.935
MVAZ Zenith-Y Beam	14.4563	14.0508	14.34
MVBZ Zenith-Y Beam	-7.8919	-7.0831	-7.718

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8. Conclusion

The SNR values for the six sets of MST radar data and performance analysis of Kaiser-Hamming and Hann-Poisson Window functions is computed. The MVBZ SNR increases with adjustable window shape parameter. The increase in MVBZ continues up to a certain value of the adjustable window shape 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 window shape 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 window shape 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 window shape parameters plays an important role.

References

[1] Antoniou Andrwas, "Digital Filters Analysis, Design and Applications", Tata McGraw-Hill, 1999.

[2] B. Picard, E. Anterrieu and G Caudal, "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.

[3] Fredric Kaiser J and Ronald Woodman S, "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.

[4] G.Harnadth Reddy. 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.

[5] Hildebrand, P. H and Sekhon R. S., Objective determination of the noise level in Doppler spectra, J. Appl. Meteorol., volume no.13, pp.808-811, June1974

[6] Hooper D.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.

[7] James Fredric Harris, "On the use of windows for harmonic analysis with the discrete Fourier transform", Proc. IEEE Volume No.66,pp.51-.83, 1978

[8] Kaiser F.J, "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

[9] L. R. Rabiner, McClellan and Parks J. H.T., FIR Digital Filter Design Techniques Using Weighted Chebyshev Approximation, Proc. IEEE, Vol. 63, pp. 595 – 610, May 1976.

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

[11] Mitra S.K., "Digital Signal Processing (DSP)-A Computer Based Approach", Tata McGraw-Hill, 1998

[12] M.M. PRABHU K, "Window functions and their applications in Signal Processing" .Prentice Hall International. Inc, 1999.

[13] M.Nouri, Sajiadi S Ghaemmaghami and Falahati A "An Improved Window Based on CosineHyperbolicFunction", Multidisciplinary Journals in Science and Technology, Journals ofSelectedAreasinTelecommunications (JAST), pp.8-13, July-2011.

[14] P. Lynch, "The Dolph-Chebyshev window: a simple optimal filter," Monthly Weather Review, volume No. 125, pp. 655-660, 1997.

[15] Reddy Harnadh.G et al "Effect of Windowing on SNR of MST Radar Signals", engineering Today, Vol.9, No.11, pp.22-26, 2007.

[16] Reddy .G.H. 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.

[17] Reddy .G.Harnadth. Et al "Improved SNR of MST Radar Signals: Gaussian Window parameter", JNTU Technology Spectrum, Vol.3, No.1, pp.97-104, 2010.

[18] S.L.Jr.Marple,"Digital Spectral Analysis with Applications", Prentice-Hall Inc., Englewood Cliffs, NJ, 1987.

[19] 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.

[20] S.R.Reddy 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.

[21] Torbet E, J. Devlin M. And 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

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

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

[24] Woodman Ronald F. "Spectral moment estimation in MST radars", Radio Science., Volume No.20, pp.1185-1195, 1985.

[25] W.Schafer Ronald and V.Oppenheim, "Descrite Time Signal Processing" Prentice Hall International. Inc, 1998.

[26] 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.