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RESEARCH ARTICLE

HYBRID WINDOW FUNCTIONS: SIGNAL TO NOISE RATIO IMPROVEMENT OF MST RADAR SIGNALS

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ABSTRACT

In this paper the effect of window shape parameter ' α ' in Hybrid 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 Hybrid windows based on the Kaiser-Hamming, Cosh-Hamming, Hann-Poisson and Kaiser Window functions. The effects of data weighting with the change of the window shape parameter ' α ' of the Hybrid 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 Hybrid 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.

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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 (James Fredric Harris, 1978; Kay, 1988; Marple, 1987) 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 (Woodman Ronald, 1985). It was observed that the effect of ' α ' in proposed Hybrid windows based on the Kaiser-Hamming, Cosh-Hamming (Nouri *et al.*, 2011), Hann-Poisson (Prabhu, 1999) and Kaiser Window (Fredric Kaiser and Ronald Woodman, 1980) functions on SNR of MST radar return signals and proposed an optimum value of window shape parameter with data.

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 (Picard *et al.*, 2002; Torbet *et al.*, 1999) and to increase the reliability of weather prediction models (Lynch, 1997). The application of FFT to a finite duration data gives the spectral leakage effect and picket fence effect. The data weighting window functions (Schafer Ronald and Oppenheim, 1998) can reduce these effects. The use of the data window functions affects the frequency resolution, variance and bias of the spectral estimations (Kay, 1988; Marple, 1987).

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 (James Fredric Harris, 1978).

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

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frequency across the entire width of the observed spectrum is called as spectral leakage (Antoniou Andrwas, 1999; Hooper, 1999; James Fredric Harris, 1978). The data windowing effect on the SNR improvement of MST radar returns signals are reported in literature (Harnadth Reddy, 2009; Kaiser, 1974; Reddy Harnadh, 2007; Reddy, 2008; Reddy Harnadth, 2010; Reddy, 2006). By choosing the suitable values of shape parameters of adjustable windows, it is easy to provide SNR improvement with the optimum shape parameters (Harnadth Reddy, 2009; Reddy Harnadh, 2007; Reddy, 2008; Reddy Harnadth, 2010). Windows are classified into fixed or adjustable (Anandan, 1999).

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 (James Fredric Harris, 1978; Rabiner *et al.*, 1976). The Kaiser, 1974 and Saramaki, 1976 windows 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 (Harnadth Reddy, 2009), (Rabiner *et al.*, 1976) 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 (Harnadth Reddy, 2009) and Saramaki, (1993) are special cases of ultra spherical window (Stuart Bergen, 2004). 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, (1974) method and its response to underestimate signal-to-noise ratio.

Hybrid Window Functions

Kaiser-Hamming Window

It is obtained by combining a Kaiser window (Fredric Kaiser and Ronald Woodman, 1980) and Hamming window and is defined in discrete time domain is

$$w_{KH}(n, \alpha) = \begin{cases} 0.54 + 0.46 \cos\left(\frac{2n\pi}{N}\right) + \frac{I_0\left(\alpha \sqrt{1 - \left(\frac{2n}{N-1}\right)^2}\right)}{I_0(\alpha)}, & |n| \leq \frac{N-1}{2} \\ 0, & \text{otherwise} \end{cases} \dots\dots\dots (1)$$

Cosh-Hamming Window

It is obtained by combining a cosh window (Nouri *et al.*, 2011) and Hamming window and is defined in discrete time domain is

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

Hann-Poisson Window

It is obtained by combining a Hann window and Poisson window functions (Prabhu, 1999) and is defined in discrete time domain is

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

Kaiser Window

The Kaiser Window function (Fredric Kaiser and Ronald Woodman, 1980) is defined by

$$w_K(n, \alpha) = \begin{cases} \frac{I_0\left(\alpha \sqrt{1 - \left(\frac{2n}{N-1}\right)^2}\right)}{I_0(\alpha)}, & |n| \leq \frac{N-1}{2} \\ 0, & \text{otherwise} \end{cases} \dots\dots\dots (6)$$

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

$$I_0(x) = 1 + \sum_{k=1}^{\infty} \left(\frac{1}{k!} \left(\frac{x}{2}\right)^{2k}\right) \dots\dots\dots (7)$$

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 (James Fredric Harris, 1978; Kay, 1988; Marple, 1987). 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 (Harnadth Reddy, 2009; Reddy Harnadh, 2007; Reddy, 2008; Reddy Harnadth, 2010; Reddy, 2006).

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.

Table 1. Specifications of MST radar

Period of Observation	July 2011
Pulse Width	16 μ s
Range resolution	150 m
Inter Pulse Period	1000 μ s
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	

Table 2. Comparison of Hybrid Windows Performance in terms of MVAZ and MVBZ for $\alpha=6$.

Window/ Performance	Kaiser-Hamming window	Cosh-Hamming window	Hann-Poisson window	Kaiser window
MVAZ	9.0492	9.0589	9.4716	9.023
East Beam				
MVBZ	-7.7183	-7.6065	-6.3467	-7.458
East Beam				
MVAZ	9.456	9.8704	10.1221	9.817
West Beam				
MVBZ	-7.3926	-7.3761	-6.1929	-7.401
West Beam				
MVAZ	12.3676	12.0566	11.5285	11.99
North Beam				
MVBZ	-8.6476	-8.6478	-7.4632	-9.049
North Beam				
MVAZ	11.3309	11.3818	11.6286	11.45
South Beam				
MVBZ	-7.9159	-7.2855	-5.9061	-7.717
South Beam				
MVAZ	12.6054	12.5189	11.0969	12.51
Zenith-X Beam				
MVBZ	-7.7399	-7.8081	-6.4615	-7.935
Zenith-X Beam				
MVAZ	14.4563	14.5777	14.0508	14.34
Zenith-Y Beam				
MVBZ	-7.8919	-7.5457	-7.0831	-7.718
Zenith-Y Beam				

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 performed 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 ' on the SNR of the MST radar signals.

Algorithm and Data Specifications

- Obtain the Hybrid 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 (Mitra, 1998; Anandan, 1998; Anandan, 1999).
- Calculate the signal to noise ratio using the procedure (Hildebrand and Sekhon, 1974; Mitra, 1998; Anandan, 1998; Anandan, 1999).
- Calculate the Mean Value below Zero signal to noise ratios (MVBZ) (Harnadth, 2009; Reddy, 2008, Reddy and Harnadth, 2010)

- Calculate the Mean Value above Zero signal to noise ratios (MVAZ) (Harnadth, 2009; Reddy, 2008, Reddy and Harnadth, 2010)
- 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	: 1000 μ sec
Pulse Width	: 16 μ sec
Beam	: 10^0

RESULTS

Average SNR of radar data for Kaiser-Hamming, Cosh-Hamming, Hann-Poisson and Kaiser windows as shown in Fig. 1,2,3 and 4 res. The comparison of Hybrid Window functions in terms of MVAZ SNR and MVBZ SNR of six directions of MST radar as shown in Table 2.

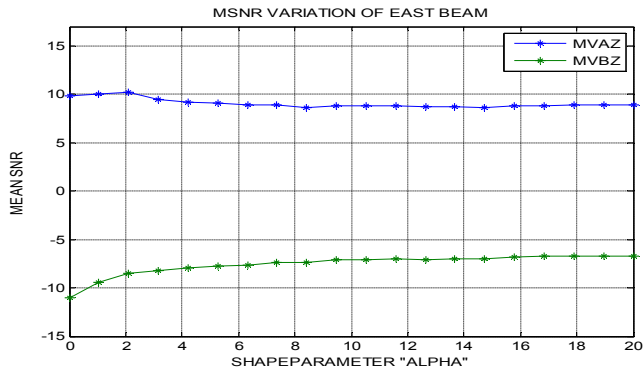


Fig.1(a): Average SNR EAST Beam

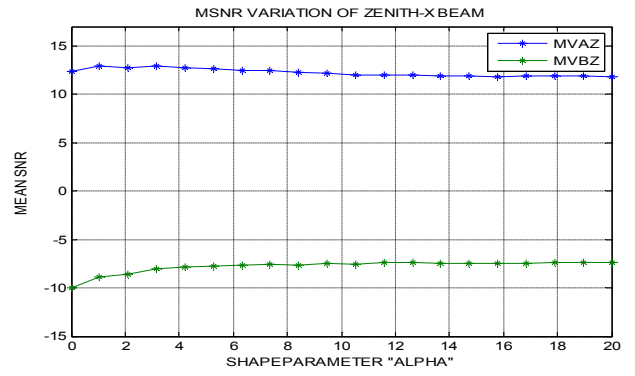


Fig.1(e): Average SNR ZENITH-X Beam

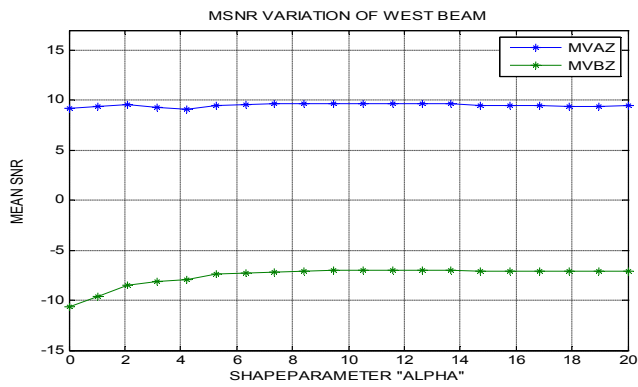


Fig.1(b): Average SNR WEST Beam

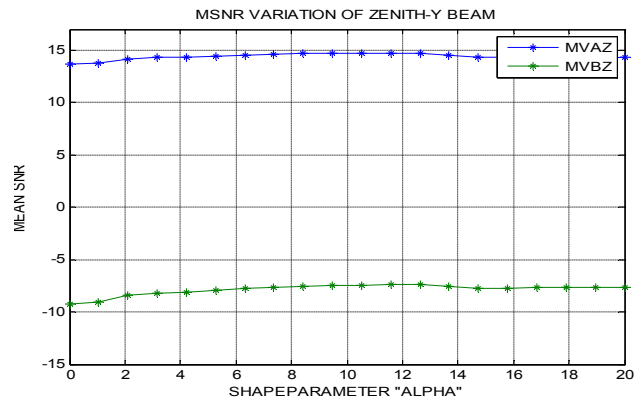


Fig.1(f): Average SNR ZENITH-Y Beam

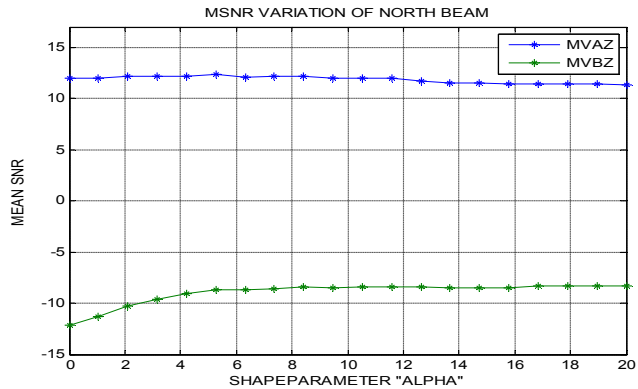


Fig.1(c): Average SNR NORTH Beam

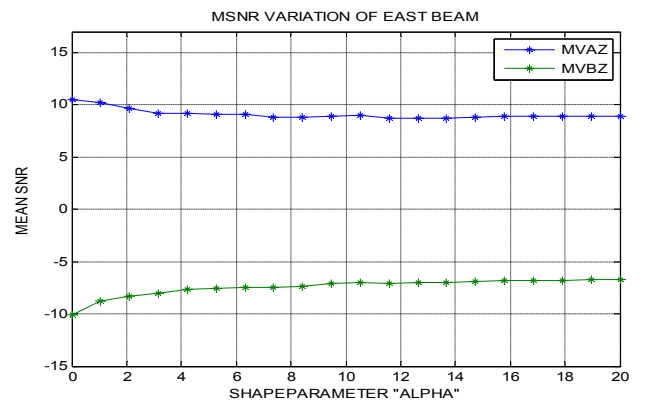


Fig.2(a): Average SNR EAST Beam

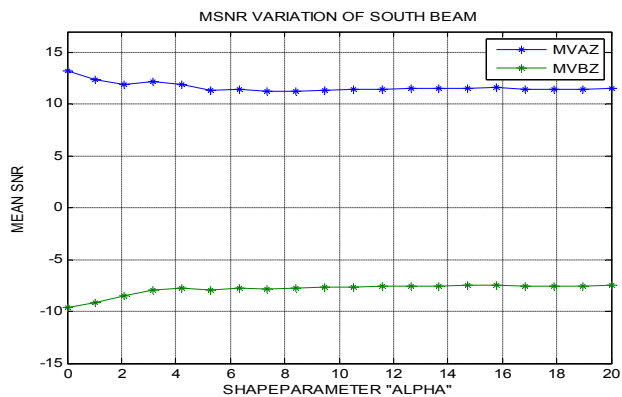


Fig.1(d): Average SNR SOUTH Beam

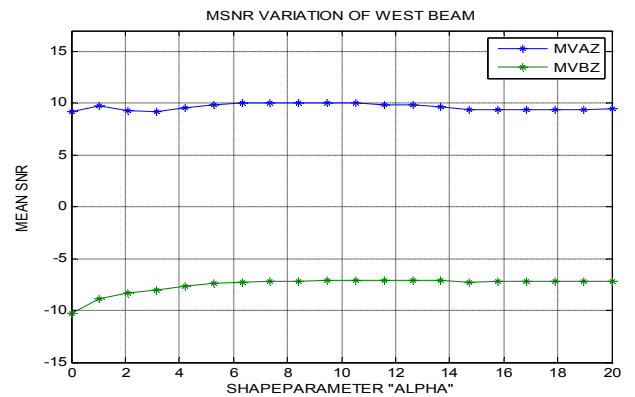


Fig.2(b): Average SNR WEST Beam

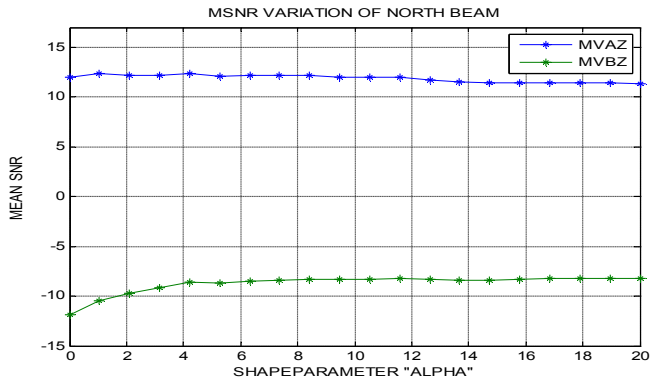


Fig.2(c): Average SNR NORTH Beam

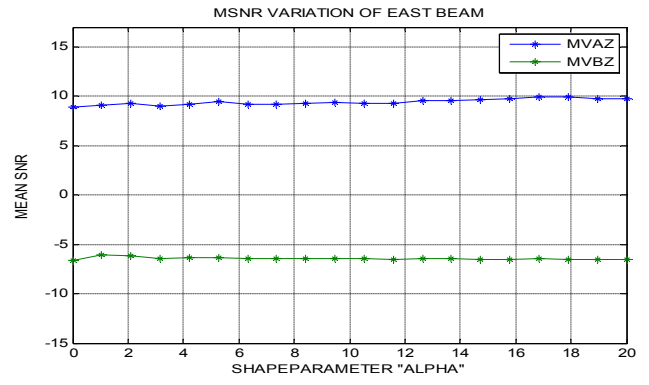


Fig.3(a): Average SNR EAST Beam

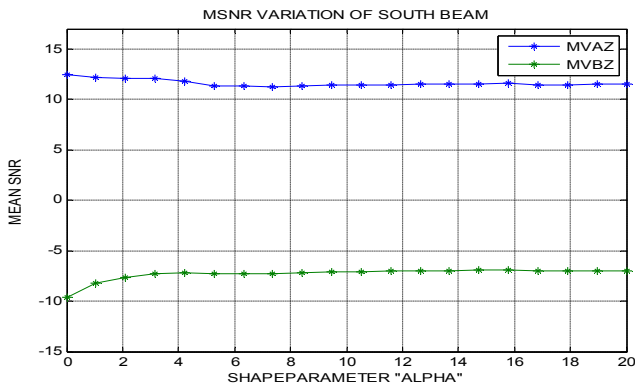


Fig.2(d): Average SNR SOUTH Beam

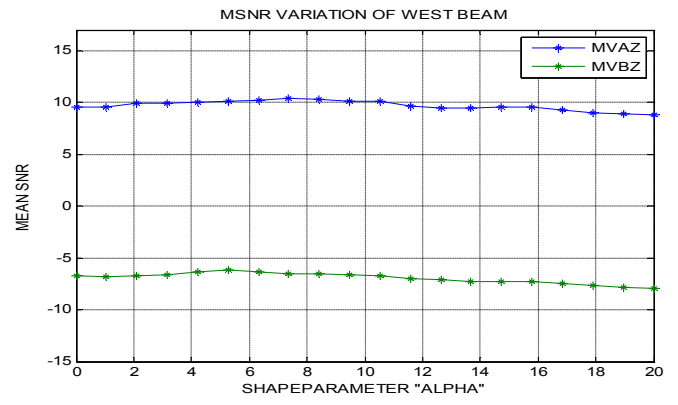


Fig.3(b): Average SNR WEST Beam

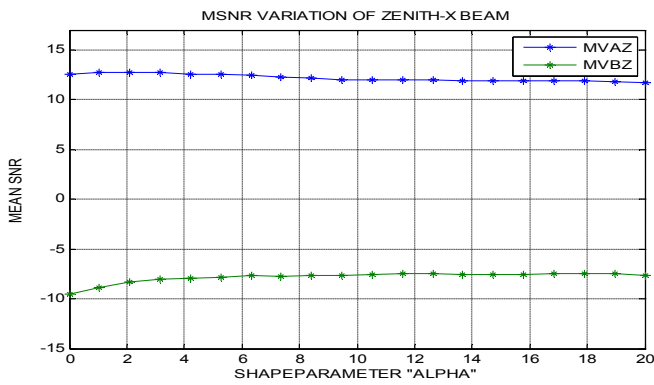


Fig.2(e): Average SNR ZENITH-X Beam

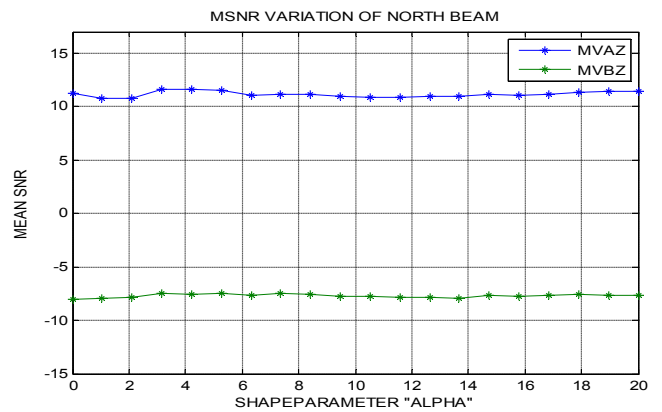


Fig.3(c): Average SNR NORTH Beam

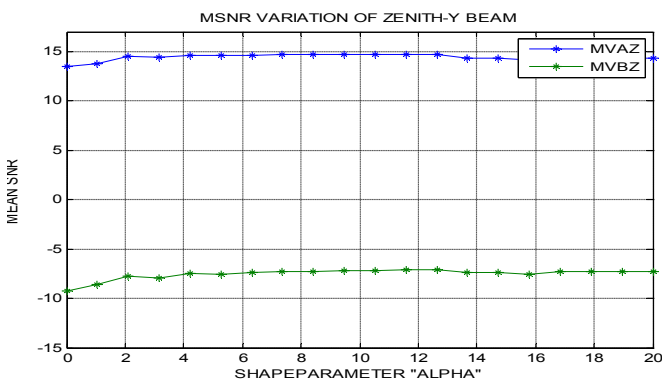


Fig.2(f): Average SNR ZENITH-Y Beam

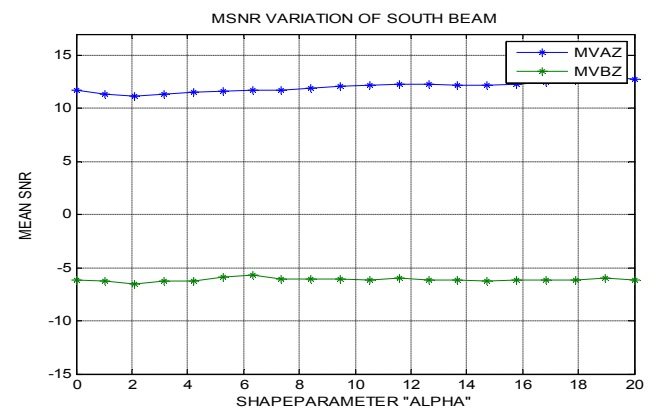


Fig.3(d): Average SNR SOUTH Beam

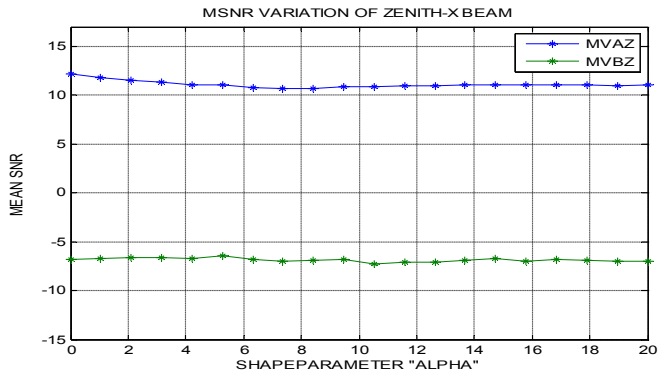


Fig.3(e): Average SNR ZENITH-X Beam

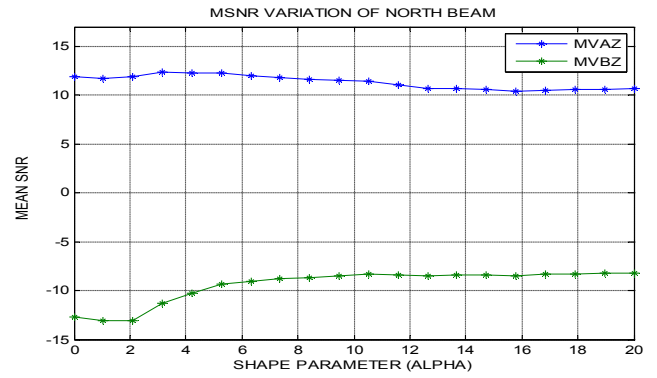


Fig.4(c): Average SNR NORTH Beam

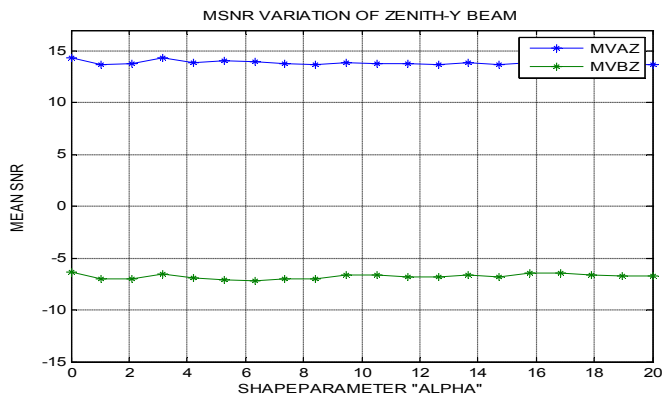


Fig.3(f): Average SNR ZENITH-Y Beam

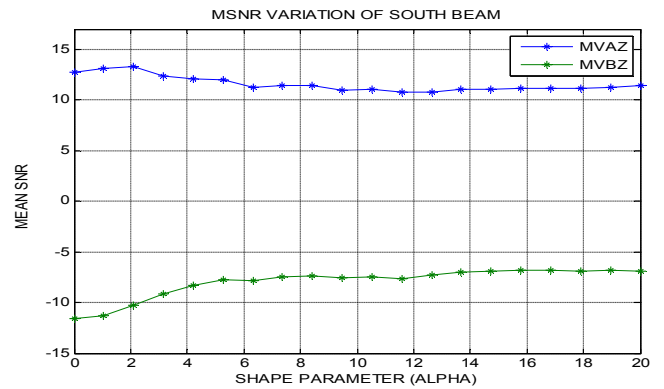


Fig.4(d): Average SNR SOUTH Beam

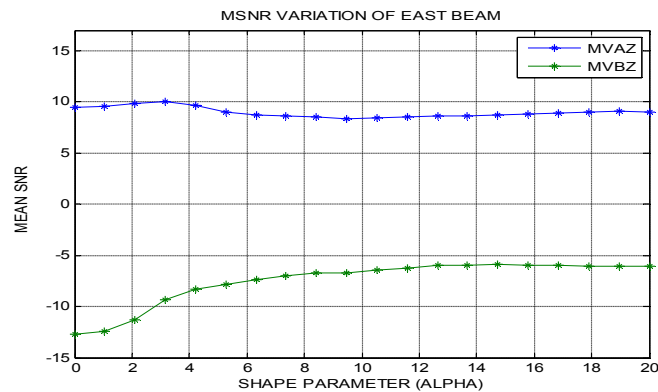


Fig.4(a): Average SNR EAST Beam

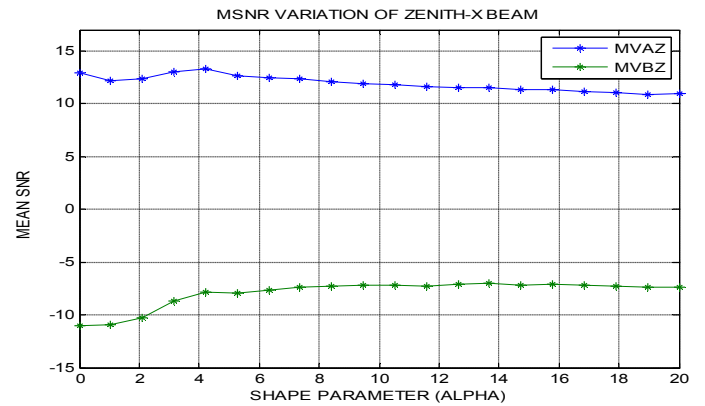


Fig.4(e): Average SNR ZENITH-X Beam

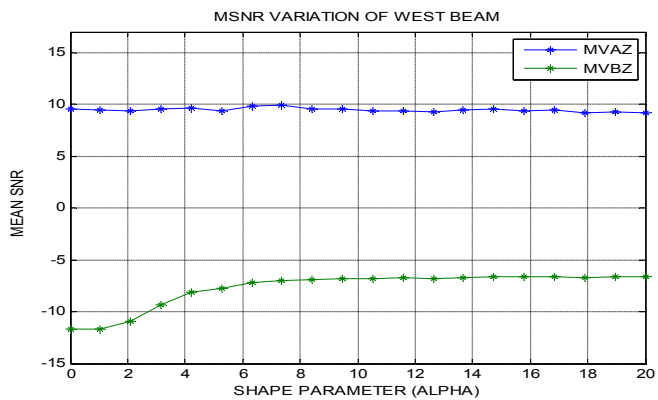


Fig.4(b): Average SNR WEST Beam

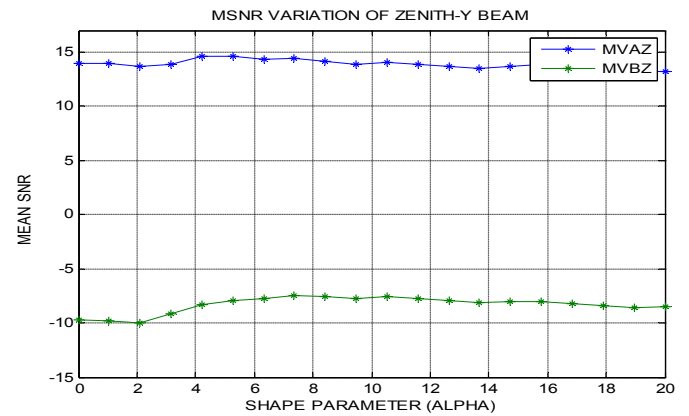


Fig.4(f): Average SNR ZENITH-Y Beam

Conclusion

The SNR values for the six sets of MST radar data and performance analysis of Hybrid Window functions is computed. The MVBZ SNR increases with adjustable window shape parameters. 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 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

- Anandan, V.K. 1998. "Atmospheric Data Processor – Technical User reference manual", NMRF publication, Tirupati.
- Anandan, V.K. 1999. "Signal and Data processing Techniques for Atmospheric Radars", Ph.D. thesis, S.V. University, Tirupati.
- Antoniou Andrwas, 1999. "Digital Filters Analysis, Design and Applications", Tata McGraw-Hill,
- Fredric Kaiser, J. and Ronald Woodman, S. 1980. "On the use of the 10-sinh window for spectrum analysis," IEEE Trans. Acoustics, Speech, and Signal Processing, volume No.28, pp. 105–107.
- Harnadth Reddy, G. 2009. *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.
- Hildebrand, P. H. and Sekhon, R. S. June 1974. Objective determination of the noise level in Doppler spectra, *J. Appl. Meteorol.*, volume no.13, pp.808-811.
- Hooper, D.A. 1999. "Signal and noise level estimation for narrow spectral width returns observed by the Indian MST radar", Radio Science. Volume No.34, pp.859-870.
- James Fredric Harris, 1978. "On the use of windows for harmonic analysis with the discrete Fourier transform", Proc. IEEE Volume No.66, pp.51-83.
- Jr.Marple, S.L. 1987. "Digital Spectral Analysis with Applications", Prentice-Hall Inc., Englewood Cliffs, NJ.
- Kaiser F.J. April 1974. "Nonrecursive digital filter design using 10-sinh window function" in Proc. IEEE Int. Symp. Circuits and Systems (ISCAS'74), pp.20-23, San Francisco, Calif, USA.
- Kay, M.S. 1988. "Modern Spectral Estimation", Prentice-Hall, Inc., Englewood Cliffs, NJ,
- Mitra, S.K. 1998. "Digital Signal Processing (DSP)-A Computer Based Approach", Tata McGraw-Hill.
- Nouri, M., Sajiadi, S., Ghaemmaghami and Falahati, A. July-2011. "An Improved Window Based on Cosine Hyperbolic Function", Multidisciplinary Journals in Science and Technology, *Journals of Selected Areas in Telecommunications (JAST)*, pp.8-13, Lynch, P. 1997. "The Dolph-Chebyshev window: a simple optimal filter," Monthly Weather Review, volume No. 125, pp. 655-660,
- Picard, B., Anterrieu, E. and Caudal, G. 2002. "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,
- Prabhu M.M. K. 1999. "Window functions and their applications in Signal Processing" .Prentice Hall International. Inc.
- Rabiner, L. R. McClellan and Parks J. H.T. May 1976. FIR Digital Filter Design Techniques Using Weighted Chebyshev Approximation, Proc. IEEE, Vol. 63, pp. 595 – 610.
- Reddy Harnadh, G. *et al* 2007. "Effect of Windowing on SNR of MST Radar Signals", engineering Today, Vol.9, No.11, pp.22-26.
- Reddy S.R.A. *et al* July- 2006. "Two Level Multiple Taper Spectral Analysis Applied to MST Radar Signals", *Journal of the Institution of Engineers (India) - ET*, Vol.87, pp.61-66,
- Reddy, G. and Harnadth *et al*. 2010. "Improved SNR of MST Radar Signals: Gaussian Window parameter", JNTU Technology Spectrum, Vol.3, No.1, pp.97-104.
- Reddy, G.H. *et al* 2008. "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.
- Saramki, T. 1993. "Finite impulse response filter design," in Hand book for Digital Processing, S. K. Mitra and Kaiser, Eds., Wiley, New York, NY, USA.
- Schafer Ronald, W. and Oppenheim, V. 1998. "Describe Time Signal Processing" Prentice Hall International. Inc.
- Stuart Bergen, W. A. and Antoniou Andreas, 2004. "Design of Ultra spherical Window Functions with Prescribed Spectral Characteristics", *EURASIP Journal on Applied Signal Processing*, volume no.13, pp.2053-2065.
- Torbet, E, J. Devlin M. and W. Dorwart B. *et al.*, 1999. "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.
- Woodman Ronald, F. 1985. "Spectral moment estimation in MST radars", Radio Science., Volume No.20, pp.1185-1195.
