Chapter-VI

SNR Analysis Using Tukey Window
CHAPTER VI
SNR ANALYSIS USING TUKEY WINDOW

6.1 INTRODUCTION

The effect of Window shape parameter, ‘alpha’ (α) in Tukey window on the SNR of radar returns is discussed and proposed an optimum value of α with which data may be weighed using Tukey window. It is observed that the Tukey window can be used with “alpha” corresponding to the minimum of sidelobe attenuation of 18dB to taper the data for spectral analysis. From the results, it may be noted that there is effect of side lobe reduction in the improvement of SNR of noisy data. For ‘alpha’ greater than 0.8 the SNR improvement is better at higher range bins.

6.2 TUKEY WINDOW

Numerous investigators have constructed windows as products, as sums, as sections, or as convolutions of simple functions of other simple windows. These windows have been constructed for certain desirable features. The Tukey window, often called the cosine tapered window, is best imagined as a cosine lobe of width (α/2) N convolved with a rectangle window of width (1.0-α/2) N . Of course the resultant transform is the product of the two corresponding transforms. The window represents an attempt to smoothly set the data to zero at the boundaries while not significantly reducing the processing gain of the windowed transform. The window evolves from the rectangle to the Hanning window as the parameter α varies from zero to unity. The family of windows exhibits a confusing array of side lobe levels arising from the product of the two components transforms [72].

The window is defined by

\[ w(n) = \begin{cases} 1.0, & 0 \leq |n| < \frac{N}{2} \\ 0.5 \left[ 1.0 + \cos \left( \frac{\pi}{N} n \right) \right], & \frac{N}{2} \leq |n| < N \\ \end{cases} \]

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The window and its transform is shown in Figures 6.1 and 6.2 for values of \( \alpha \) equal to 0.50 and 0.75 respectively.

Figure 6.1: Tukey window \((\alpha=0.50)\) and its transform

Figure 6.2: Tukey window \((\alpha=0.75)\) and its transform

Tukey window has two parameters, the length of the sequence \( N \) and a shape parameter \( \alpha \). As the length of the window is fixed to 512 data points in case of MST Radar data used, the shape parameter \( \alpha \) can be varied. As the parameter increases the side lobe level of the frequency response decreases. In this chapter, the SNR variation of MST radar data as a function of shape parameter \( \alpha \) has been investigated.
6.3 TUKEY WINDOW APPLIED TO MST RADAR SIGNALS

Wind profile detection of a MST Radar signal means the measurement of Doppler of the signal due to scattering of the atmospheric elements. Atmospheric Radar signal is the signal received by the Radar due to the back scattering property of the atmospheric layers, stratified or turbulent. The back-scattered signal from the atmospheric layers is very small in terms of power with which it was emitted. The received back-scattered signals otherwise called as Radar returns are associated with Gaussian noise. The noise dominates the signal as the distance between the Radar and the target increases and this leads to a decrease in Signal to Noise ratio. This makes the detection of the signal difficult. Doppler profile information is obtained from the power spectrum using Fast Fourier Transform. Frequency characteristics of the back-scattered signals of the Radar are analyzed with power spectrum, which specifies the spectral characteristics of a signal in frequency domain.

Since the SNR is not constant and varies from bin to bin, therefore in this study, the window performance on the SNR values of the radar returns, the 150 bin atmospheric data is divided in to three equal parts. Each part consists of 50 bins viz. lower bins, middle bins and upper bins. In each of these three regions the mean value of SNR is computed for the SNRs below zero dB and the SNRs above zero dB.

The SNR analysis is performed on MST Radar data corresponds to the lower stratosphere obtained from the NARL, Gadanki, India. The Radar was operated in Zenith X, Zenith Y, North, South, West and East with an angle of 10° from the vertical direction. The data obtained from the six directions are used to carry on the analysis. The computation using Tukey window is done to study of the effect of “$\alpha$” on the SNR of the radar returns.

The implementation scheme is presented here.

a) Compute the Tukey window with specified $\alpha$.

b) Taper the radar data with the Tukey window parameters specified.
c) Perform the Fourier analysis of the above tapered data

d) Compute the SNR using the procedure mentioned in Chapter 2.7.

e) Compute the Mean Value Below Zero SNR (MVBZ).

f) Compute the Mean Value Above Zero SNR (MVBZ).

g) Update the value of \( \alpha \) and repeat the steps (b)-(f).

6.4 RESULTS AND DISCUSSION

The SNR computation discussed above for the six sets of Radar data is carried on and presented in Figures 6.3 to 6.8 and Figures 6.9 to 6.14. From Figures 6.3 to 6.8, in the case of East beam, SNRs (MVBZ) for the entire 150 bins taken into account, increases with the sidelobe attenuation factor \( \alpha \). But in the case of Zenith-X and Zenith-Y there is no appreciable change observed. In the case of West, North and South beams, MVBZ increases with \( \alpha \) upto 0.8 becomes steady. This may be attributed to the fact that the generation mechanism of the zenith beams is different. On the other hand in all the Six-sets of data, MVAZ is almost constant with the shape parameter.

From the Figures 6.9-6.14 it is observed that for the lowermost 50 bins, the MVBZ and MVAZ are not improved appreciably. Moreover, a slight and marginal decrease in both SNR's is observed. For the middle 50 bins and the uppermost 50 bins the increase in MVBZ values is almost 5dB - 6dB when the shape parameter reaches 0.8. This result is important since the back-scattered signal from the middle and uppermost bins is very weak and improvement in SNR demands for the design of windows with good sidelobe behaviour for spectral estimation.

Nothing the above observations, it is concluded that the Tukey window can be used with \( \alpha \) corresponding to the minimum 0.8 to taper the data for spectral analysis. Table 6.1 shows the maximum SNR improvement in different ranges using Tukey window by varying the window parameter.
Figure 6.3: Average SNR EAST Beam

Figure 6.4: Average SNR WEST Beam
Figure 6.5: Average SNR NORTH Beam

Figure 6.6: Average SNR SOUTH Beam
Figure 6.7: Average SNR ZENITH-X Beam

Figure 6.8: Average SNR ZENITH-Y Beam
TABLE 6.1: Tukey Window SNR improvement in dB

<table>
<thead>
<tr>
<th>Beam Direction</th>
<th>MVBZ</th>
<th>MVAZ</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lower bins</td>
<td>Middle bins</td>
<td>Upper bins</td>
</tr>
<tr>
<td></td>
<td>dB</td>
<td>dB</td>
<td>dB</td>
</tr>
<tr>
<td>East</td>
<td>2</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>West</td>
<td>0</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>North</td>
<td>1</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>South</td>
<td>0</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Zenith-x</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Zenith-y</td>
<td>0</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>