



Analysis of Radar Echoes using Soft Thresholding De-Noising Techniques

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ABSTRACT: In signal analysis, a lot of efforts are done to de-noise the signals well. Various techniques are used to de-noise and improve the SNR (Signal to Noise Ratio). The Empirical Mode Decomposition (EMD) is used to extort the Intrinsic Mode functions (IMF) for LAWP (Lower Atmospheric Wind Profiler) and MST (Mesosphere, Stratosphere, Troposphere Radar signals and apply soft thresholding technique to de-noise the signals for various beam directions. All the experiments can be done with MATLAB and using signal processing tool box. Soft thresholding can de-noise the signals better than the fourier transforms and wavelet transforms. The LAWP and MST radar signals return from atmosphere are non linear and non stationary in nature and various signal de-noising techniques can be used for obtaining better results and we can see Doppler profiles of various beam directions, SNR plots and their IMF's in results.

KEYWORDS: LAWP (Lower atmospheric wind profiler),EMD (Empirical Mode Decomposition), MST(Mesosphere, Stratosphere, Troposphere) IMF (Intrinsic mode function), SNR(Signal to noise ratio),soft thresholding, fourier transforms and wavelet transforms..

I.INTRODUCTION

Traditional methods like fourier transforms [3] and wavelet transforms are not suitable to analyse the non linear and non stationary signals. FFT is a simplest and basic method and it requires linearity. In this method the frequency of the signal is self-determining of time, and it is also appropriate only for stationary signals.

Wavelet Transforms is another method have a major drawback is fixed basis function and it shift out the structures from chosen signal due to its precedent basis function. There is a chance that the selected mother wavelet may or may not reflect the processes which is actually present in the analyzed signal. Due to the wrong selection of wavelets which are used to associate with signal, may calculate wrong coefficient and variance. This result is misleading and it has no meaning.

II.LOWER ATMOSPHERIC WIND PROFILER (LAWP) RADAR

The name itself indicates that it is a type of weather observing equipment to detect the wind speed and directions. The L-band Lower Atmospheric Wind Profiler (LAWP) is used for conducting research in the lower atmosphere. LAWP can be situated at the location Gadanki near Tirupati (13.47°N,79.18°E), National Atmospheric Research Laboratory (NARL) at India has been operating this 1280 MHz. The antenna array consist of 256 microstrip patch antenna elements arranged in a 16* 16 square matrix. Each element is fed by a dedicated 12- watt Transmit Receive Module (TRM). A passive two dimensional 16*16 butler beam forming network is designed to form multiple beams in the two-dimensional angular space. The TRM's are connected to the 256 output ports of the butler matrix. Beam width is about 4.6(degrees) and side lobe level is about 16.5 db. The radar works Doppler beam swinging technique. These radars attain enhanced range resolution with maximum average power (height coverage).However, LAWP radar[5] is

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relatively low-cost system and it is developed in India. Hence it is very important to develop de-noising algorithms for LAWP system. LAWP system gives good resolution wind profiler parameters in all weather conditions. Atmospheric radars working in the (40-60 MHz) band has some separate advantages.

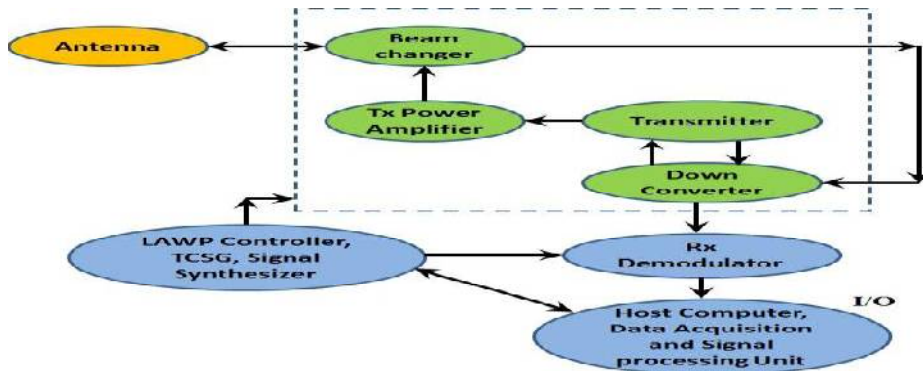


Fig 1: Block diagram of LAWP Radar

The vertical atmospheric motions can be measured at these frequencies, even during the rainfall. However, these radars have a serious constraint namely their inability to measure high-resolution winds in the first few kilometers. It probes up to about 5 km. The system should have a height motion of 100 m or better. The features of high spatial motion and fast system recovery time require operation at frequencies near 1000 MHz [8] and these wind profiler radars are very high sensitive, coherent and pulse Doppler Radars.

LAWP radar has applications beyond wind profiling. It is used for atmospheric and operational meteorology research. It can measure the complete Doppler spectrum of atmospheric targets with a time resolution on the order of 1min and a range resolution of about 100m. These LAWP data can be used to estimate the Moments, Noise Levels and UVW Computation. LAWP radar can be used to distinguish the clear-air scattering from the precipitation scattering arising from cloud and rain drops.

LAWP Radar wind profilers use either Spaced Antenna (SA) or Doppler Beam Swinging (DBS) technique for measuring the atmospheric winds. Present work uses DBS technique for measuring the atmospheric winds. Radar echoes are recorded in beam directions, viz. East, West, Zenith-x, Zenith-y, North, South directions. Here we are applying the technique of data set on 9 oct 2009.

III. EMPIRICAL MODE DECOMPOSITION

The Empirical mode (EMD) strategy is a calculation for the examination of multi segment flags that works by breaking the flag into various plentifulness and recurrence (AM/FM) zero mean signs, named characteristic mode capacities (IMFs). Rather than regular disintegration techniques, [2] for example, wavelets, which play out the review by anticipating the flag under thought onto various predefined premise vectors, EMD communicates the flag as a development of premise capacities which are flag subordinate, and are assessed by means of an iterative methodology called filtering. Albeit many endeavors have been made to expand the comprehension of the way EMD works and to enhance its execution still does not have a sound scientific hypothesis and is basically portrayed by a calculation. In any case, halfway because of the way that it is effectively and straightforwardly appropriate and somewhat on the grounds that it regularly brings about fascinating and valuable decay results, it has found an immense number of various applications such as biomedical watermarking and sound preparing to give some examples. Aside from the point particular uses of EMD recorded over, a more summed up errand in which EMD can be demonstrated valuable is flag de-noising. In this paper, propelled by standard wavelet thresholding and interpretation invariant thresholding, EMD-based de-noising strategies are produced and tried in various flag situations. In spite of the fact that the fundamental standards shared by wavelet and EMD thresholding continue as before, on account of EMD, the thresholding operation



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must be legitimately adjusted keeping in mind the end goal to be reliable with the exceptional qualities of the flag modes that outcome from EMD.

a. EMD Algorithm:

Given a non-stationary flag $x(t)$ [3] , the Empirical mode strategy calculation can be compressed into taking after strides :

1. Locate the neighborhood maxima and minima of the flag then interface all the maxima and minima of flag $X(t)$ using smooth cubic splines and acquire the upper envelope $X_u(t)$ and the lower envelope $X_l(t)$ separately.
2. Process the neighborhood mean esteem $m_1(t) = (X_u(t)+X_l(t))/2$ of information $X(t)$, subtract the mean an incentive from flag $X(t)$ and get the distinction : $h_1(t)=X(t)- m_1(t)$.
3. Accept $h_1(t)$ as new information and rehash steps(1) and (2) for k times, $h_{1k}(t)=h_1(k-1)(t)- m_{1k}(t)$, where $m_{1k}(t)$ is the mean estimation of $h_1(k-1)(t)$ and $h_{1k}(t)$. Step(3) is ended until the subsequent information fulfills the two states of an inherent mode work, characterized as $c_1(t)=h_{1k}$. The lingering information $r_1(t)$ is communicated as $r_1(t)= X(t)-c_1(t)$.
4. Expect $r_1(t)$ as new information and rehash steps (1),(2) and (3) and concentrate every one of the IMFs. End the filtering procedure until the n th deposit $r_n(t)$ turns out to be not as much as a foreordained number or the buildup ends up noticeably monotonic.
5. Rehash steps 1 to 4 till the leftover at no time in the future contains any helpful recurrence data. The first flag is equivalent to the whole of its IMFs. In the event that we have "n" IMFs and a last remaining $r_n(t)$, the first flag $X(t)$ can be characterized as appeared in underneath condition (1)

$$X(t) = \sum_{i=1}^n C_i + r_n \text{ -----(1)}$$

b. Intrinsic Mode Functions:

After the use of EMD if the buildup, r_1 still contains data of longer period segments, then it is again regarded as the new information and subjected to an indistinguishable filtering process from portrayed previously.

This filtering procedure can be ceased by any of the foreordained criteria: either when the part esteem c_n or the deposit r_n ,turns out to be not as much as the foreordained esteem or likewise when the buildup, r_n turns into a monotonic capacity from which no more IMFs can be separated.[13] The IMF parts save enough physical sense, we need to decide a foundation for halting the filtering procedure. This should be possible by restricting the span of the Standard Deviation (SD) which can be registered from the two sequential filtering comes about as appeared in the condition (2) underneath.

$$SD = \sum_{t=0}^T \left[\frac{|(h_{1(k-1)}(t)-h_{1k}(t))|^2}{h_{1(k-1)}^2(t)} \right] \text{ -----(2)}$$

A common incentive for Standard Deviation can be set in the vicinity of 0.21 and 0.3. In the present work, we concentrate on applying the Empirical Mode Decomposition prepare on LAWP radar information to get the Intrinsic Mode Functions. At first Hard thresholding (like de-noising in Wavelets) was utilized to treat Intrinsic Mode Functions and examined for the doppler reverberate location. On watching the outcomes, Soft Thresholding appeared to be suitable and was embraced for de-noising. At that point the mean clamor level was computed by Hildebrand Sekhon strategy .

IV. DENOISING

c.EMD de-noising using Thresholding:

Signal de-noising scheme based a multi resolution approach is referred to as Empirical mode decomposition de-noising [4] A smooth version of the input signal can be obtained by thresholding the IMFs before signal reconstruction. There are two types of threshold techniques.



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- a.) Soft Threshold
- b.) Hard Threshold

If $\Gamma[\tau_j]$ is a thresholding function, and τ_j is the threshold parameter, the threshold can be determined in different ways. Donoho and Johnstone proposed a universal threshold, τ_j for removing noise.

The method of soft threshold [9] is applied to process the radar data. After extracting the Intrinsic Mode functions in each range bin, de-noising techniques are employed before reconstruction of the Doppler spectra by using threshold levels.

d.Hard Thresholding:

Hard threshold removes the corresponding IMFs depending on the frequencies if τ_j is less than or equal to 1. The condition for hard threshold as shown in equation (3) and (4)

$$f_j(t) = \begin{cases} \text{IMF}_j(t) & \text{If } |\text{IMF}_j(t)| > \tau_j \\ 0 & \text{If } |\text{IMF}_j(t)| \leq \tau_j \end{cases} \text{-----(3)}$$

$$f_j(t) = \begin{cases} \text{IMF}_j(t) & \text{If } |\text{IMF}_j(t)| > \tau_j \\ 1 & \text{If } |\text{IMF}_j(t)| \leq \tau_j \end{cases} \text{-----(4)}$$

e.Soft Thresholding:

Soft thresholding process tends to shrink noise towards zero. By taking the median values of IMFs, σ_j and τ_j were calculated using equations (5),(6),and (7).

$$\tau_j = \tilde{\sigma}_j \sqrt{2 \cdot \log_e(N)} \text{-----(5)}$$

$$\sigma_j = \text{MAD}_j / 0.6745 \text{-----(6)}$$

$$\text{MAD}_j = \text{Median} \{ |\text{IMF}_j(t) - \text{Median} \{ \text{IMF}_j(t) \} | \} \text{-----(7)}$$

Where $\tilde{\sigma}_j$ is the estimation of the noise level of the j^{th} IMF (scale level) and MAD_j represents the absolute median deviation of the j^{th} IMF. The soft thresholding shrinks the IMF samples by τ_j towards zero as follows.

$$\hat{f}_j(t) = \begin{cases} \text{IMF}_j(t) - \tau_j & \text{If } \text{IMF}_j(t) \geq \tau_j \\ 0 & \text{If } |\text{IMF}_j(t)| < \tau_j \\ \text{IMF}_j(t) + \tau_j & \text{If } \text{IMF}_j(t) \leq -\tau_j \end{cases} \text{-----(8)}$$

After applying soft thresholding to the IMFs, signal can be reconstructed by adding[10] all IMFs which gives de-noised signal. Similarly this procedure is applied for all the range bins. Further, three point moving average method was applied to each range and also calculated the mean noise level for each range bin and subtracted the estimated the noise level from the signal for each range bin. The results of FFT and soft thresholding shown in below figures.

V. MOMENTS CALCULATIONS

Three lower order Spectral moments (zero, first and second) and SNR are calculated by using adaptive moments method [13]. These three spectral moment represents the signal strength (power), the weighted mean Doppler shift and width of the spectrum [2-4]. The moments were calculated for the data of 9th Oct 2009 and 28th may 2009 data by using FFT and Soft Thresholding.. The expressions for the first three moments are as follows.

The 0th moment representing the total signal power is

$$M_0 = \sum_{i=m}^n P_i \text{-----(9)}$$

The 1st moment representing the weighted mean Doppler shift is

$$M_1 = (1 / M_0) \sum_{i=m}^n P_i f_i \text{-----(10)}$$

The 2nd moment representing the variance, a measure of dispersion from the mean frequency is

$$M_2 = (1 / M_0) \sum_{i=m}^n P_i (f_i - M_1)^2 \text{-----(11)}$$

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Where m, n are the lower and upper limits of the Doppler bin of the spectral window. P_i, f_i are the powers and frequencies corresponding to the Doppler bins within the spectral window.

Signal-to-noise ratio (SNR) in dB is calculated by equation (12).

$$SNR = 10 \log \left(\frac{M_0}{N.L} \right) \text{-----(12)}$$

Where N and L are the total number of Doppler bins and mean noise level respectively which on multiplication gives the total noise over the whole bandwidth.

Doppler width, which is taken to be the full width of the Doppler spectrum is calculated as:

$$\text{Doppler Width} = 2\sqrt{M_2} \text{-----(13)}$$

VI. RESULTS

The results for two lawp data taken from NARL, Gadanki are 9 Oct 2009, 28 may 2009. De-noise the the signals by soft thresholding and also compared with FFT , original Doppler profiles and also corresponding imf's of different beams, and also plots of the snr, power, noise Doppler width and Doppler profile and also calculate the values and tabulated for two data sets.

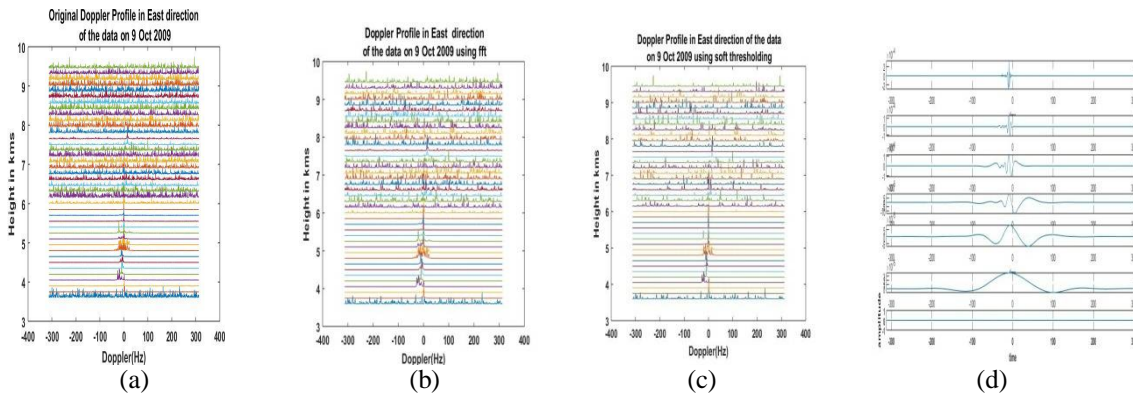


Fig 2: Original (a), FFT(b), Soft Thresholding(c), Doppler profiles and corresponding IMF of 5th range bin(d).

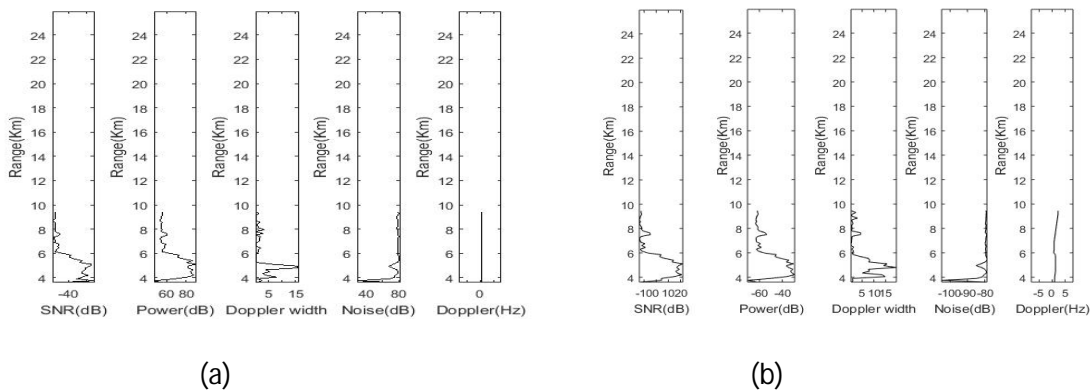


Fig 3: Plots of SNR, power, Doppler width, noise and Doppler of FFT (a) and Soft thresholding(b) in beam1 9 oct 2009(LAWP)

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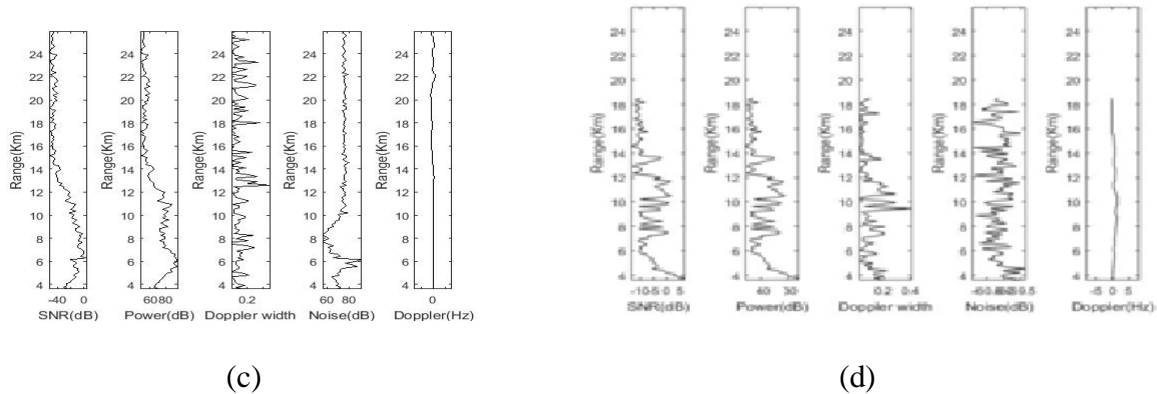


Fig 4: Plots of SNR, power, Doppler width, noise and Doppler of FFT(c) and Soft Thresholding (d) in beam 1 (28 may 2009)

Lower Atmospheric Wind Profiler (LAWP) Data					Mesosphere-Stratosphere-Troposphere (MST) Data				
Beam No	SNR (dB)	POWER (dB)	NOISE (dB)	DOP.WID (Hz)	Beam No	SNR (dB)	POWER (dB)	NOISE (dB)	DOP.WID (Hz)
	FFT	FFT	FFT	FFT		FFT	FFT	FFT	FFT
1	-32.1	60.5	73.33	6.125	1	-23.77	78.33	70.83	0.26
2	-42.5	72.2	72.5	5	2	-17.77	77.72	70.0	0.1
3	-34.22	66.5	64.2	3.2	3	-29.2	70.2	70.0	0.144
4	-34.0	68.125	70.0	8.22	4	-28.88	72.22	72.22	0.244
5	-34.0	66.3	71.14	4.44	5	-31.11	71.11	69.0	0.177
6	-26.11	63.5	71.8	3.03					

Table 1: Avg values of SNR, power, noise, Doppler width of different beams using FFT on 9 Oct 2009(LAWP) and 28 may 2009(MST) Radar data

Lower Atmospheric Wind Profiler (LAWP) Data					Mesosphere-Stratosphere-Troposphere (MST) Data				
Beam No	SNR (dB)	POWER (dB)	NOISE (dB)	DOP.WID (Hz)	Beam No	SNR (dB)	POWER (dB)	NOISE (dB)	DOP.WID (Hz)
	ST	ST	ST	ST		ST	ST	ST	ST
1	4.00	50.45	-65.8	7.8	1	3.72	23.0	-64.0	3.4
2	-2.86	48.3	-74.77	6.2	2	4.75	22.5	-59.55	0.316
3	7.0	44.0	-74.77	5.17	3	22.5	22.27	-59.54	0.34
4	-3.52	40.0	-84.22	8.5	4	10.0	28.8	-60.0	0.28
5	-2.70	53.5	-83.75	7.27	5	10.0	31.66	-61.5	0.25
6	-3.72	52.0	-84.37	10.55					

Table 2: Avg values of SNR, power, Doppler width, noise of different beams using Soft Thresholding on 9 Oct 2009(LAWP) and 28 may 2009 (MST) Radar data

VII. CONCLUSIONS

Extract the IMF's and applying soft thresholding technique to de-noise the LAWP Radar signals and compare the Doppler profiles of original and two different methods, and also get the corresponding IMF's and SNR, power, noise,



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Doppler width plots of various beams of two data sets of LAWP and also tabulate the values. It has been observed that there is an improvement in SNR, soft thresholding is effectively de-noise the signals

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