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Improved Approach For Meteor Detection & Automation: A Cross Correlation Method

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Abstract: A simple but effective technique has been proposed for Atmospheric Radar signals to extract the sporadic events such as the meteor occurrences is presented at higher altitudes. VHF radars are also being used to detect the ionized meteor trail over the altitude region of 70-120 km as a tracer of background wind using correlation technique. The proposed cross correlation-based technique not only detects the occurrence of the meteor phenomenon, but also senses precisely the height at which the phenomenon observed. Correlation between the data collected from the successive range Bins is the basis for the meteor detection. This helps to automate for detecting the sporadic phenomenon.

Keywords: backscatter, scans, meteor, correlation.

I. Introduction

Mesosphere Stratosphere Troposphere (MST) Radar is a high-power pulse coded phase coherent VHF Radar, employing advanced signal and data processing techniques. A major MST Radar facility intended primarily for studies on low latitude middle atmosphere has been established at NARL, Gadanki, India in 1993. The operating frequency of the MST Radar is 53MHz with a peak power aperture product of 3 X 10^{10} Wm^2.

Atmospheric radar signal means the signal received by the Radar due to the backscattering property of the atmospheric layers. Generally, the received backscatter signals, otherwise called as Radar returns are very much associated with Gaussian noise. The noise dominates the signal as the distance between the radar and target increases and this led to decrease in Signal to Noise Ratio.

Meteor detection meant identifying and separating the scans that contain meteors from the normal ones. The occurrence of the radar meteor echoes is a sporadic phenomenon. Meteor concept is a random phenomenon. i.e., the day, month and year of their occurrence can be stated precisely but at which time in a day they occur can't be said. Even though it has been observed for several years, the 'Peak event' pinpoint time can't be stated accurately. Only the 'Day of Peak Event' **(DPE)** can be stated. The above statements strongly describe the **Degree of Randomness** of the phenomenon.

Different methods are designed for meteor detection in the past and they have their own limitations. In the present report, we propose to introduce new signal processing techniques to detect meteors, which provide very precise detection even for very low signal-to-noise ratio (SNR) meteor return signals.

II. The Mathematical Model of the signal: Signature of the Meteor Signal

Given the transmission of a T-µs pulse, the meteor return signal is also T-µs along with a corresponding Doppler frequency. We model the sampled, noise-free return signal as:

$m[n] = A\, e^{\{j(\omega_d+\varphi)\}\Delta[n-l_m]}$ (1)

where n =1, 2…, N_{IPP}

A - is the amplitude,

ω_d is Doppler frequency,

φ is the phase,

l_m is the location of the meteor,

N_{IPP} is the number of samples in one IPP,

T is time period of the transmitted pulse and

$\Delta[n]$ is expressed as

$\Delta[n] = u[n] - u[n-(T-1)]$ (2)

where u[n] is the unit step function.

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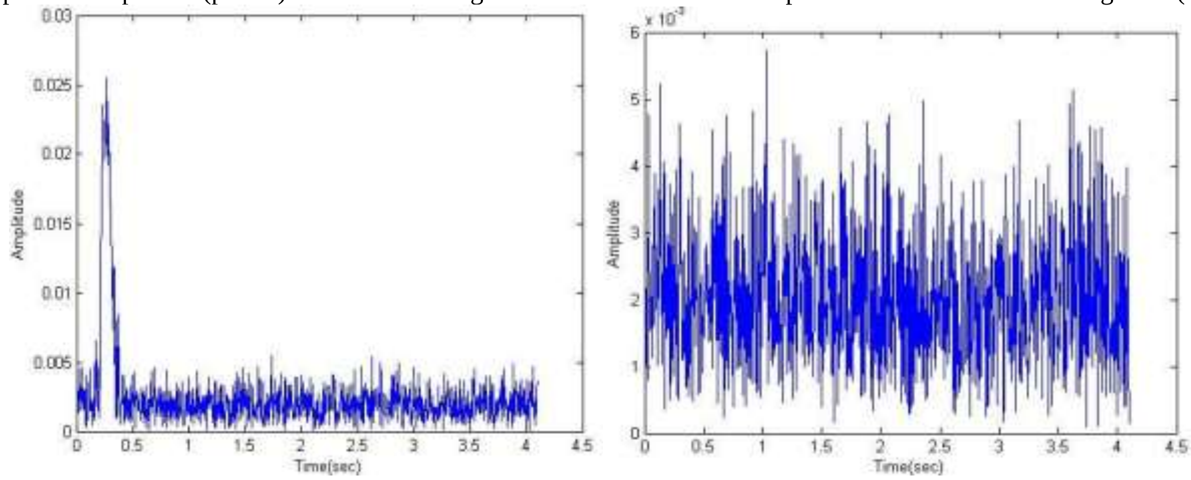
III. METEOR DETECTION

A. Traditional Method (Existing Technique)

The meteor detection technique based on the Traditional method is simply setting a threshold on observing some scans containing meteors. In this method, the data from the backscattered signal is plotted for all scans. Initially the scans containing the meteors are separated manually and an intense observation is made on these meteor scans. A sudden drastic jump in the amplitude (power) occurs in the range bin in which the meteor is present as illustrated in the Figure 1 (a)



(a) (b)

Fig 1: Range bins with and without meteor respectively

The Figure 1(b) depicts the distribution of the amplitude in a non-meteor Range bin. Here the difference between the peak and mean amplitude is very low suggesting no strange event has occurred whereas it happened in the meteor case as shown in the Figure 1(a). A threshold has to be set on observing the peaks of such events. This is not a simple event as all the peaks are not of equal value. A high threshold can detect strong meteors quite easily, but weak meteors are totally missed. Likewise, a low threshold may detect non-meteor scans as meteor-scans besides the correct detection of the meteor scans. One way to solve the problem is to choose an optimum threshold value, but this yields unsatisfactory results. Though this method appears to be simple in concept, the real difficulty lies in its execution. The two major disadvantages are:

1. A huge amount of data has to be observed physically before coming to a conclusion about the Threshold value. Moreover, the **extent to which observations must be made is Unknown**. The major reason for this is "The Meteor occurring is a random event".
2. This method cannot detect the **weak meteors** efficiently & effectively.

The proposed Correlation based technique overcomes these limitations. This method intensifies the detection process.

B. Correlation Method

The Correlation is a measure of similarity between signals. It is necessary to compare one reference signal with one or more signals to determine additional information based on the Degree of Similarity. Thus, it occupies a significant place in Signal Processing. The correlation is of two types.

1. Cross correlation.
2. Auto correlation.

Cross correlation

A measure of similarity between a pair of signals, x[n] and y[n], is given by the cross-correlation sequence

$$r_{xy}[l] = \sum_{n=-\infty}^{\infty} x[n]y[n-l] \qquad l = 0, \pm 1, \pm 2, \ldots \quad (3)$$

where l is Lag (Time-shift between the pair).

The order of the subscripts xy indicates that $x[n]$ is the reference sequence that remains unshifted in time whereas the sequence $y[n]$ is shifted 'l' units in time with respect to $x[n]$.

Auto correlation

The autocorrelation of a sequence is correlation of a sequence with itself. The autocorrelation of a sequence $x[n]$ is defined by

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$$r_{xx}[l] = \sum_{n=-\infty}^{\infty} x[n]x[n-l], \quad l = 0, \pm 1, \pm 2, \; \ldots. \; (4)$$

If we plot the autocorrelation of a sequence, it is as shown in the figure 2. The emphasis is on autocorrelation of a sequence because it is the ideal case. This plot can be taken as reference to compare the other plots to assess the percentage or degree of correlation. Hence it is shown.

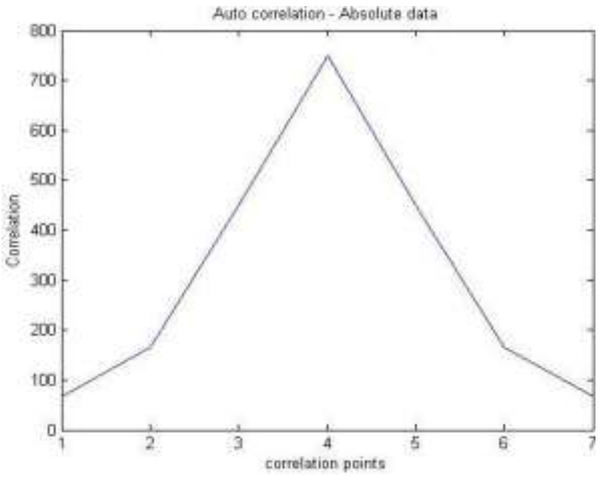

Fig 2: Ideal correlation plot

The fig. (2) is plotted for absolute data because it is difficult to analyse the plot obtained for the complex data.
Generally, the received backscattered signals otherwise called as Radar returns are very much associated with Gaussian noise. When there is no specific reflector, received signal is almost noise. If no strange event (Meteor event) has occurred then the signal in each Range bin is of same type almost i.e., Gaussian noise type. This lays the steppingstone for the Correlation based method.
Correlation between the adjacent heights (Range bins) forms the base for the meteor detection which can also be automated. As the meteor trail echo has a strength which is very much higher than that of the principal target, **it strongly disturbs the normal distribution of data at that level of height**. The process of detection involves extracting parameters from the correlation results and the meteor detection is declared when these parameters satisfy the threshold.
When correlation between two normal range bins is evaluated and plotted, a **TRIANGLE** like structure results (ref. Figure 4). This indicates that the Degree of Similarity between these signals is high (ref. Figure 2). If one of the range bins contains a meteor, the high power of the meteor which is several multiples of that of the noise elements destroys the collinearity of the data in that range bin. The reduction in the degree of similarity is directly proportional to the strength of the meteor. Also, in which range-bin the meteor has occurred can be known.
One of the advantages of this method is **"The Meteor rangebin can be known in the middle of the process itself"**. In other methods, only after the analysis of the entire scan is over the Meteor Range bin can be known. Inspecting the correlation plots **physical meteor classification** is also possible. i.e., Strong- Moderate-Weak meteors.

IV. PROPOSED METHOD AND APPROACH

The steps/block diagram of the proposed method involved in this method from the initial stage (right from the beginning) are shown in fig 3. The **Data converter** converts the binary coded information into understandable complex data format. In the **Correlation Processor**, examining the correlation patterns, creating the correlation parameters (indication of percentage of correlation), creating Peak Event Parameters etc takes place. The **Corr-Par Guide** is formed with list of parameters that serve for the Meteor Selection Process (MSP). Corr-Par Thresholder is a user defined thresholder which can be easily set.

Advantages

- 5% More meteor detection is reported.
- Weak meteors can be efficiently detected.
- No need of intense observation on the data for threshold setting.

Meteor Label

Upon detection, each meteor event is assigned a unique 'Label'. The sequence in the label is Research center, Radar name, year, month, day number, hour, and minute, seconds, and beam direction.

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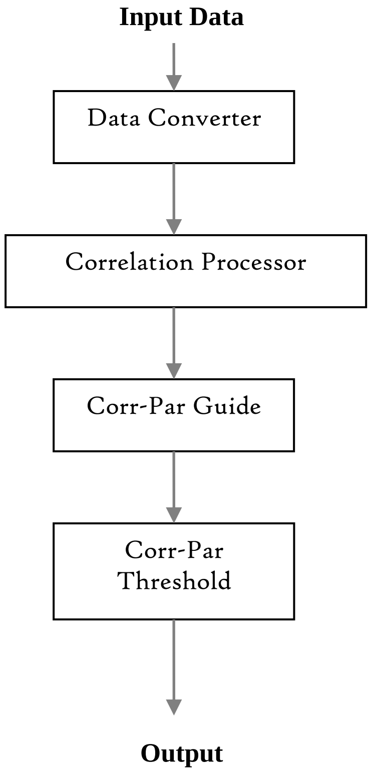

Fig 3: Block diagram of Correlation based meteor detection

C. Results

The fig. 4 depicts the absence of meteor when a plot is made between two successive range bins. The shape of triangle is highly symmetric which indicates the data present is successive range bins are highly correlated indicates that absence of meteor presence over that height. The top row of fig 5. represent before denoising case. The below row represents Figures represents after denoising case. From the above plot the strength of the meteor becomes clearly evident. The tilt in the sides of the triangular like structures forms the base for the physical classification of the meteors. This is a **Strong meteor.**

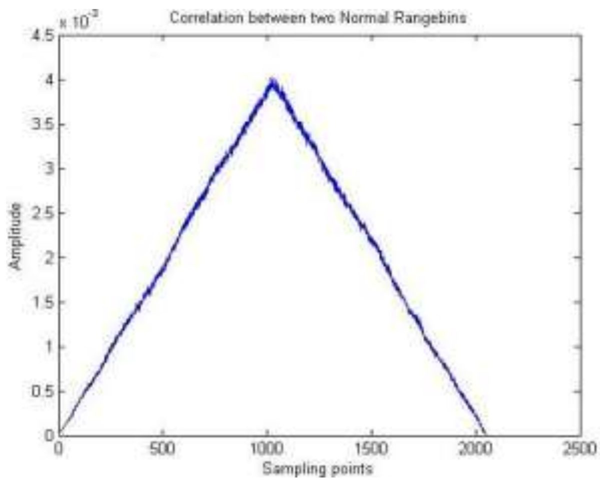

Fig. 4: The correlation plot of the absolute data of two adjacent Normal Range bins (absence of Meteor data)

The top rows fig. 6 represent before denoising case. The below row represents figures represents after denoising case. For weak meteors before processing is almost noise like structures which are very difficult to trace and so they are **missed detections** in Traditional method. From the above plot it is evident that the strength of the meteor low. The tilt in the sides of the triangular like structures forms the base for the physical classification of the meteors. This is a **Weak meteor.**

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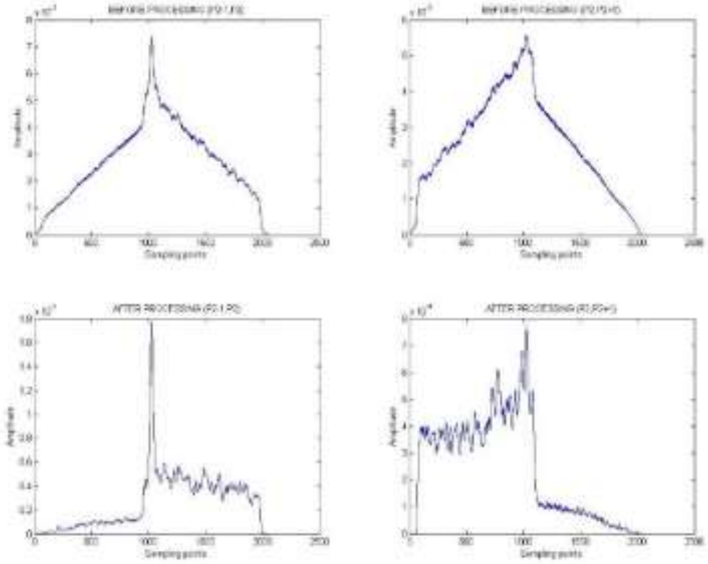

Fig. 5: The correlation plot of the absolute data of two adjacent Range bins presence of a showing strong meteor.

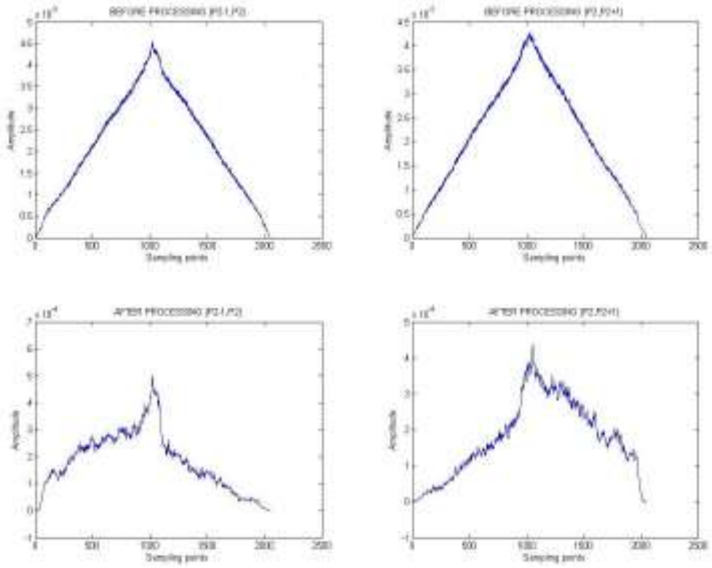

Fig. 6: The correlation plot of the absolute data of two adjacent Range bins presence of showing weak meteor.

V. CONCLUSION

Maximum meteor trails are observed at about and around 100 Km altitudes. A test data consisting of meteor, ionospheric and noise records was compiled, and the method was tested on this data. This method is also known as **Fast Detection Method** as it gives the information about features like Meteor Range bin, Type of the meteor i.e., Strong-Moderate-Weak before the completion of the analysis of the entire scan. The predicted results are compared with the conventional techniques and good improvement is reported.

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BIOGRAPHY

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