IFERP

ISSN (Online) 2394-6849

International Journal of Engineering Research in Electronics and Communication Engineering (IJERECE)
Vol 4, Issue 3, March 2017

Improved Hilbert Huang Transform for Processing Radar Signals

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***Abstract* - Hilbert-Huang transform (HHT) is a new technique for processing and analyzing the non-linear and non-stationary signal, however it still has some drawbacks. This method has inadequacy estimating both the maximum and also the minimum values of the signals at both ends of the border, or envelopes. Traditional HHT produce boundary error in empirical mode decomposition (EMD) method. to overcome this disadvantage, this paper proposes an improved empirical mode decomposition algorithm for processing complex signal. Our work mainly focuses on two aspects. On one hand, we develop a method to get the extreme points of observation interval boundary by introducing the linear extrapolation into EMD. This method is simple however effective in suppressing the error-prone effects of decomposition. On the other hand, a completely unique envelope fitting technique is proposed for processing complex signal, that employs a method of non uniform rational B-splines curve. This technique will accurately measure the average value of instantaneous signal, which helps to achieve the accurate signal decomposition. In this paper new technique was implemented on nonlinear and non stationary radar signal, which not only eliminated end effect but also observed SNR improvement compared with HHT.**

***Index Items*-; Empirical mode decomposition Improved Hilbert-Huang transform; HHT;Improved Empirical mode decomposition; cubic spline;B-spline.**

I. INTRODUCTION

The echoes that are received from MST region represents atmospheric background information and is considered to be generated through a random method. Radar signals are terribly weak and contaminated with noise, therefore de-noising of the signal is necessary. Most of the approaches aim to enhance Signal to Noise ratio (SNR) for improving the detection ability.The most common approach is that the FFT, that is simplest and straightforward among all the methods, needs linearity. However, Fourier Transforms are unsuitable for applications that use nonlinear and non stationary signals. Additionally, alternative technologies, like wavelet transforms, cannot resolve intra-wave frequency modulation, that happens in signal systems composed of multiple varying signals. Wavelet transform is widely used as a traditional methodology to eliminate noise or de-noising.

In recent years, Hilbert-Huang transform(HHT) that was proposed by Norden E Huang was introduced to time frequency analysis of signals. Hilbert-Huang transform (HHT) applies empirical mode decomposition (EMD) technique to decompose the non stationary signal into a series of intrinsic mode functions (IMFs). This ability makes HHT competitive in processing various complex signals. With HHT, complex signals may be decomposed into multiple single-frequency signals that may further be processed by intrinsic mode function of EMD. When the non stationary signals are decomposed into IMFs through EMD, these signals will simply be obtained by hilbert transform of each mode function. By doing that the instantaneous frequency and amplitude of each IMF were obtained.

However, there are inadequacies of traditional HHT it's straightforward for traditional HHT to produce boundary error in EMD method as a result of traditional HHT isn't good at estimating both the maximum and also the minimum value of the signals at both ends of the border.EMD is the most crucial method of the HHT. Since the first step of EMD is evaluate the envelope of the analyzed signal, the upper and lower envelopes are based on the maximum andMinimum of signals. The uncertainty that whether end of signal could be a maximum value or minimum value will result in the distortion of the envelope and also the destruction of further signal decomposition. On the other hand, negative end effects are found at the Hilbert transform of IMF that forms a spectral leakage that affects the data analysis. To overcome this deficiency, this paper proposes an improved empirical mode decomposition algorithm of processing complex radar signal. Basic technique is that to get the extreme points of observation interval boundary by introducing the linear extrapolation into EMD. This technique is simple however effective in suppressing the error-prone effects of decomposition. The method will determine the extreme of signal endpoint; therefore, it makes the endpoint within the fitting envelope and ensures the integrity of the original data. now proposing a completely unique envelope fitting methodology for process complex signal, that employs a methodology of non uniform rational B-splines curve This method will accurately measure the average value of instantaneous signal, that helps to realize the accurate signal

decomposition. It adopts a piece wise curve fitting methodology to avoid fitting overshoot or fitting undershoot and therefore makes the envelope smooth and might contain the entire data.
Improved EMD to analyze the special signals and simulation experiments show that our proposed methodology takes advantage over its rivals in processing complex signals for time frequency analysis..

II.EMPERICAL MODE DECOMPOSITION:

Empirical Mode Decomposition is an adaptive technique introduced to investigate non-linear and non-stationary signals. It consists in a local and fully data-driven separation of a signal in fast and slow oscillations. EMD is a method of breaking down an signal without neglecting the time domain. It has been compared with alternative analysis like Fourier Transforms and wavelet decomposition. This method is useful for analyzing natural signals, that are most often non- linear and non-stationary.
EMD filters out functions that form an entire and nearly orthogonal basis for the original signal. Completeness depends on the methodology of the EMD. The methodology in which it's decomposition implies completeness. The functions, named as Intrinsic Mode Functions (IMFs), are therefore enough to describe the signal, although they're not essentially orthogonal. The actual facts that the functions into that a signal is decomposed are all in the time-domain and of the same length because the original signal permits variable frequency in time to be preserved. Getting IMFs from real world signals is very important because natural processes often have multiple cause, and every of those causes may happen at specific time intervals. This sort of data is obvious in an EMD analysis, however quite hidden in the Fourier domain or in wavelet coefficients.

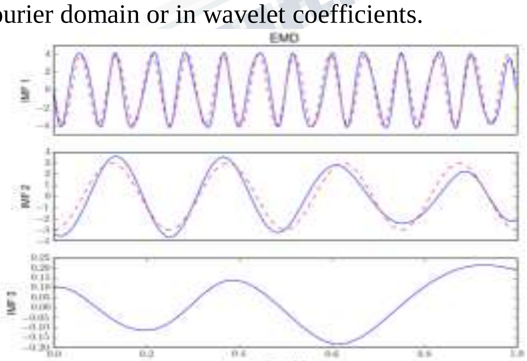

Fig (1) Representation of IMF's

EMD then means the following steps :

Step 1: Initialize: n = 1; r0(t) = x(t)
Step 2: Extract the nth IMF as follows:
a) Set h0(t) := rn 1(t) and k := 1
b) Identify all local maxima and minima of hk 1(t)
c) Construct, by cubic splines interpolation, for h k 1(t) the envelope Uk 1(t) defined by the maxima and the envelope Lk 1(t) defined by the minima
d) Determine the mean mk 1(t) =0.5 (Uk 1(t) Lk 1(t)) of both envelopes of hk 1(t). This running mean is called the low frequency local trend. The corresponding high frequency local detail is determined via a process called sifting.
e) Form the k th component hk(t) = hk 1(t) - mk1(t)
f) if hk(t) is not in accord with all IMF criteria, increase k to k + 1 and repeat the Sifting process starting at step[b]
g) if hk(t) satisfies the IMF criteria then set xn(t) = hk(t) and rn(t) = rn 1(t) -xn(t)
If rn(t) represents a residue, stop the sifting process; if not, increase n to n + 1 and start at step 1again.

III. ISSUES OF EMD ALGORITHM

The traditional EMD algorithm will decompose complex signal into a series of IMFs, however it has the following problems.
First, traditional EMD will cause end effects for either side of endpoints don't seem to be processed. On one hand, both ends of the data can show the divergent phenomena with the EMD algorithm. The first step of EMD is to get the upper and lower envelope of the signal to be analyzed through the signal extrema.
The signal end cannot be determined to be a maximum or a minimum, and it makes the envelope distorted and affects the EMD decomposition. for instance, once the first decomposed component is fault, the latter decomposition can show an equivalent results distortion. Thus, the obtained IMFs arefalse. On the other hand, serious end effect will appear within the Hilbert transform of IMF which will form a spectral leakage that affects the data analysis. To modify the Hilbert spectrumto reflect the characteristics of the original signals, we must solve this drawback effectively.
Second, the cubic spline fitting in traditional EMD algorithm can cause the overshoot and undershoot phenomena; that's, the envelope isn't complete, and this may result in the decomposed IMFs that are not true.
IV. Improved Empirical ModeDecomposition Algorithm

International Journal of Engineering Research in Electronics and Communication Engineering (IJERECE)
Vol 4, Issue 4, March 2017

When HHT is used to analyse the signals, there exists endeffects and incomplete curve fitting envelope, which can affect theaccuracy of analysed results. To overcome this drawback,must found a solution to suppress the end effect and find a newenvelope fitting method.

A Method of inhibiting the End Effect. For a relativelylong data sequence analysis here considering radar signal which is non linear and non stationary, the distributionof the extreme points of the ends and discard some datathat guarantee that both ends of the extreme value point areextreme value point of original radar backscattered data, thereby minimizing thedistortion of signal envelope. However, such operations forthe short data sequence analysis are not feasible. A linear extrapolation is used to determine the end extreme so as tomake the fitting envelope contain the maximum data set.

This novel algorithm, which is used to determine the extreme of endpoint oforiginal data.

Themethod is described as follows.

The original EMD algorithm proposed by Huang used cubicspline function to fit upper and lower envelope of the signaland then calculated the mean of the fitted upper and lowerenvelope. Because the power is low and easy to calculate,cubic spline curve fitting is simpler compared to other curve fitting methods, however, thecubic spline fitting will cause the overshoot and undershootphenomena, so that the envelope fitting deviates from theactual signal envelope; that is, the envelope is in complete.

In order to solve the overshoot and undershoot problemof cubic spline curve fitting, a nonuniform rational B-spline fittingmethod is used to fit the upper and lower envelope of signal,resulting in the mean envelope. Nonuniform rational Bspline curve fitting envelope compared with fittingenvelope by cubic spline function.

function.

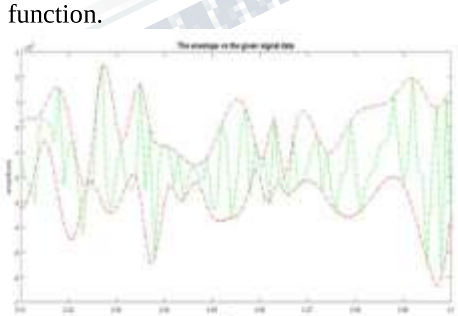

Figure 2.1 Lower and Upper Envelopes of radar data in dotted line using Cubic Spline

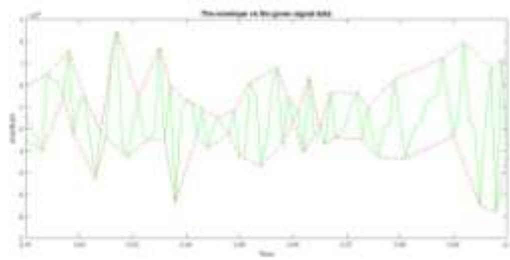

Figure 2.2 Lower and Upper Envelopes of radar data in dotted line using B Spline

IV. SIMULATION RESULTS

Improved EMD algorithm with B spline interpolation is implemented on the radar data 22JUL2009.IMF's for Improved EMD are shown below which represents end effect has been eliminated in improved EMD.

HHT algorithm is used to evaluate SNR,

IMF's for improved EMD are shown below

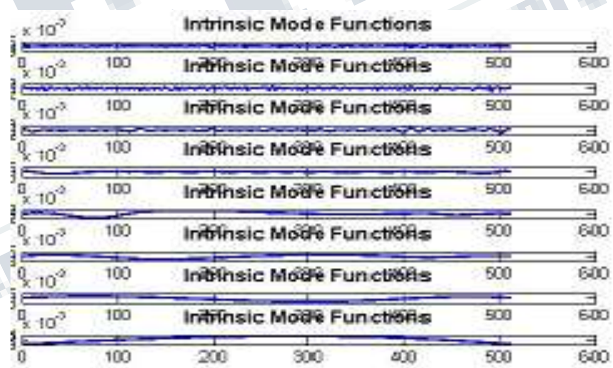

Figure 3.SNR plots for wavelet, HHT and improved HHT are compared for different beams of Radar data

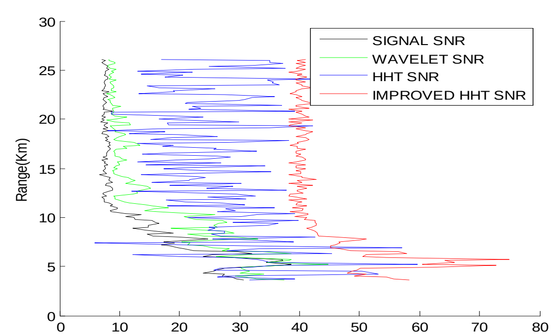

Figure 4.1 SNR for East beam of radar data 22JL2009 was compared with HHT and Improved HHT

ISSN (Online) 2394-6849

International Journal of Engineering Research in Electronics and Communication Engineering (IJERECE)
Vol 4, Issue 4, March 2017

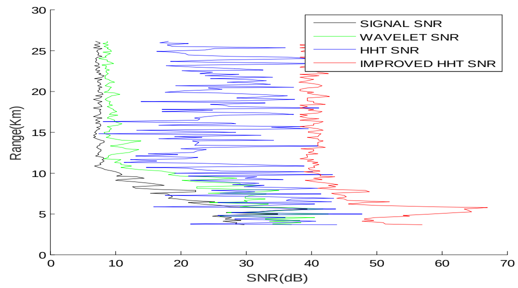

Figure 4.2 SNR for North beam of radar data 22JL2009 was compared with HHT and Improved HHT

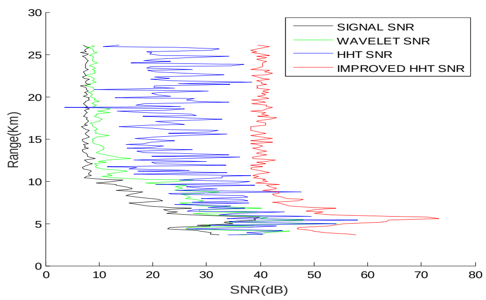

Figure 4.3 SNR for Zenith X beam of radar data 22JL2009 was compared with HHT and Improved HHT

V. DISCUSSION &CONCLUSION

EMD and Improved EMD algorithm has been applied to all the 6 beams viz. east, west, zenithx, zenith y, north and south beamsfor the 1st bin of the data of 22 July 2009.Intrinsic mode functions obtained by applying Improved EMD on a set ofthe atmospheric data for beam 3 are illustrated by the Figure(3),Figure 3.shows the IMFs extracted after applying the IEMD

Forcomparison of results, SNR has been plotted for a data set using Db9 wavelet, EMD and then with improved EMD. The results are plotted in Figure.4(1),4(2 &4(3)) The results showed an improvement of SNR when Improved HHT is used.

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