Removal of Clutter by Using Wavelet Transform For Wind Profiler

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ABSTRACT: *Removal of clutter in the radar wind profiler is the utmost important consideration in radar. Wavelet transform is very effective method to remove the clutter. This paper presents a technique based on the wavelet transform to remove the clutter. In this technique we used Fourier transform and descrete wavelet transform after that applied inverse discrete wavelet transform for signal. These techniques applied for inphase and quadrature phase, total spectrum and single range gate. Very encouraging results got with this technique that have shown practical possibilities for a real time implementation and for applications related to frequency domain.*

Keywords: *Wind profiler, wavelet transform, Fourier transform, clutter, signal processing.*

I. INTRODUCTION

Wavelet analysis attracted much attention recently in signal processing. It has been successfully applied in many applications such as transient signal analysis, image analysis, communication systems and other signal processing applications. It is not a new theory in the sense that many of ideas and techniques involved in wavelets (subband coding, quadrature mirror filters etc.) were devolped independently in various signal processing applications. Especially, it has turned out that the specific features of wavelets can also be efficiently used for certain problems in the context of radar signal analysis. The aim of this paper is to give an overview on the analysis of RWP data and to explain how wavelets can be utilized for clutter removal.

The goal of RWP systems is to gather information concerning the three dimensional atmospheric wind vectors. Radio frequency pulses are emitted and backscattered from small in homogeneities in the atmosphere.

The reflected signal is sampled at certain rates corresponding to different heights. The Doppler shift of the atmospheric (clear-air) signal, which can assumed to be constant over the small measurement period (quasistationarity), generates a peak in the Fourier power spectrum.

II. FOURIER TRANSFORMS

The Fourier transform is as ubiquitous in radar signal processing as in most other signal processing fields. Frequency domain representations are often used to separate desired signals from interference; the Doppler shift is a frequency domain phenomenon of critical importance; and it will be seen that in some radar systems, especially imaging systems, the collected data are related to the desired end product by a Fourier transform. Both continuous and discrete signals are of interest, and therefore Fourier transforms are required for both. Consider a signal x (u) that is a function of a continuous variable in one dimension called the *signal domain.†* Its Fourier transform, denoted as $X(\Omega)$, is given by

$$X(\Omega) = \int_{-\infty}^{+\infty} x(u) e^{-j\Omega u}\, du \quad \Omega \in (-\infty,\infty) \quad (1)$$

And is said to be a function in the *transform domain*. The inverse transform is

$$X(u) = \frac{1}{2\pi} \int_{-\infty}^{+\infty} X(\Omega) e^{+j\Omega u}\, du \quad u \in (-\infty, \infty) \quad (2)$$

In Esq. (1) And (2), the frequency variable *is* in radians per unit of u. For example, if $u = t$, that is, u is in units of seconds, then is the usual radian frequency in units of radians per second; if u is a spatial variable in meters, then is spatial frequency in units of radians per meter. Equivalents transform pair using a cyclical frequency variable $F = \Omega/2\pi$ is

$$X(F) = \int_{-\infty}^{+\infty} x(u) e^{-j2\pi F u}\, du \quad F \in (-\infty,\infty)$$

$$X(u) = \frac{1}{2\pi} \int_{-\infty}^{+\infty} X(F) e^{+j2\pi F u}\, dF \quad u \in (-\infty,\infty)$$

If the signal domain is time ($u = t$), then F is in cycles per second, or hertz. The various wavelet analysis methods are described in comparison to the widely known Fourier transform. The Fourier transform only retrieves the global frequency content of a signal, all time information is lost. To overcome this problem the short time Fourier transform is developed, however this method suffers from a limitation due to a fixed resolution in both time and frequency. A multiresolution analysis of the local frequency content of a signal is made possible by wavelet analysis.

III. WAVELET TRANSFORMS

The term wavelet means a small wave. The smallness refers to the condition that this (window) function is of finite length (compactly supported). The wave refers to the condition that this function is oscillatory. The term mother implies that the functions with different region of support that are used in the transformation process are derived from one main function, or the mother wavelet. In other words, the mother wavelet is a prototype for generating the other window functions.

Like Fourier analysis, wavelet analysis deals with expansion of functions in terms of a set of basis functions. Unlike Fourier analysis, wavelet analysis expands functions not in term of trigonometric polynomials but in terms of wavelets which are generated in the form of translations and dilations of a fixed function called the mother wavelet. The wavelets obtained in this way have special scaling properties. They are localized in time and frequency, permitting a closer con nection between the function being

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represented and their coefficients. Greater numerical stability in reconstruction and manipulation is ensured.

The objective of wavelet analysis is to define these powerful wavelet basis functions and find efficient methods for their computation. It can be shown that every application using the fast Fourier transform (FFT) can be formulated using wave lets to provide more localized temporal (or spatial) and fre quency information. Thus, instead of a frequency spectrum, for example, one gets a wavelet spectrum. In signal process ing, wavelets are very useful for processing nonstationary signals. A major advance in wavelet theory was the discovery of smooth mother wavelets whose set of discrete translations Two different kinds of wavelet transform can be distinguished, a continuous and a discrete wavelet transform. The continuous wavelet transform is calculated by the convolution of the signal and a wavelet function. A wavelet function is a small oscillatory wave which contains both

The analysis and the window function. The discrete wavelet transform uses filter banks for the analysis and synthesis of a signal. The filter banks contain wavelet filters and extract the frequency content of the signal in various sub bands.

CONTINUOUS WAVELET TRANSFORM

At the most redundant end, one has the CWT. For CWT the parameters vary in a continuos fashion. This representation offers the maximum freedom in the choice of the analysis wavelet. The only requirement is that the wavelet satisfies an admissibility condition; in particular it must have zero mean. The condition is also crucial to be CWT invertible on its range.

DISCRETE WAVELET TRANSFORM

Here, we have discrete function *f(n)* and the definition of discrete wavelet transform (DWT) is given by

$$C(a,b) = C(j,k) = \sum_{n \in Z} f(n)\,\psi_{j,k}(n)$$

Where $\psi_{j,k}$ is a discrete wavelet defined as:

$$\psi_{j,k}(n) = 2^{-j/2}\psi(2^{-j}n - k)$$

The parameters a,b are defined in such a way that $a = 2^{j}, b = 2^{j} k$. Sometimes the analysis is called dyadic as well. One of the function of wavelet transform is Daubechies.

DAUBECHIES

The Daubechies familie is named after Ingrid Daubechies who invented the compactly supported orthonormal wavelet, making wavelet analysis in discrete time possible. The first order Daubechieswavelet is also known as the Haar wavelet, which wavelet function resembles a step function. Higher order Daubechies functions are not easy to describe with an analytical expression. Theorder of the Daubechies functions denotes the number of vanishing moments, or the number of zero moments of the wavelet function. This is weakly related to the number of oscillations of the wavelet function. The larger the number of vanishing moments, the better the frequency localization of the decomposition.

IV. WIND PROFILING RADARS

Conventional Doppler weather radars, which are designed to detect hydrometeor, are not sensitive enough because of their short wavelengths to detect the clear air, except under unusual conditions. The development of modern wind profiler is an outgrowth of research work done with radars designed to probe the ionosphere, where longer wavelengths and extreme sensitivity was required.

BASIC PRINCIPLE OF WIND PROFILING RADARS

Wind profiling radars depend upon the scattering of electromagnetic energy by minor irregularities in the index of refraction of the air. The index of refraction is a measure of the speed at which electromagnetic waves propagate through a medium. For wind profiling, this medium is the atmosphere. A spatial variation in this index encountered by a propagating electromagnetic (radio wave) causes a minute amount of the energy to be scattered (or dispersed) in all directions. Most of the energy incident on the refractive irregularity propagates through it without being scattered.

V. SIGNAL PROCESSING

The purpose of radar signal processing is to extract desired data from radar backscattered echoes. The desired data usually concerns the detection of a target of interest, the location of the target in space.

The accuracy of the data available from radar is limited by thermal noise introduced by the radar receiver, echoes from targets of no interest (clutter), and externally generated interface.

Radar signal processing is used to enhance signals and to suppress clutter and externally generated signals. In the case of atmospheric radars the target generated by the process of refractive index fluctuations. These signals are very weak even for powerful radar systems. So, sophisticated signal processing technique is required to extract these signals.

An elementary form of radar consists of transmitter, antenna and an energy detecting device, which may be receiver. Single antenna is used for both transmission and reception. The signal transmitted by the transmitting antenna gets reflected by the target and is re-radiated in all directions. This energy re-radiated in the backward directions, is of prime interest to radar.

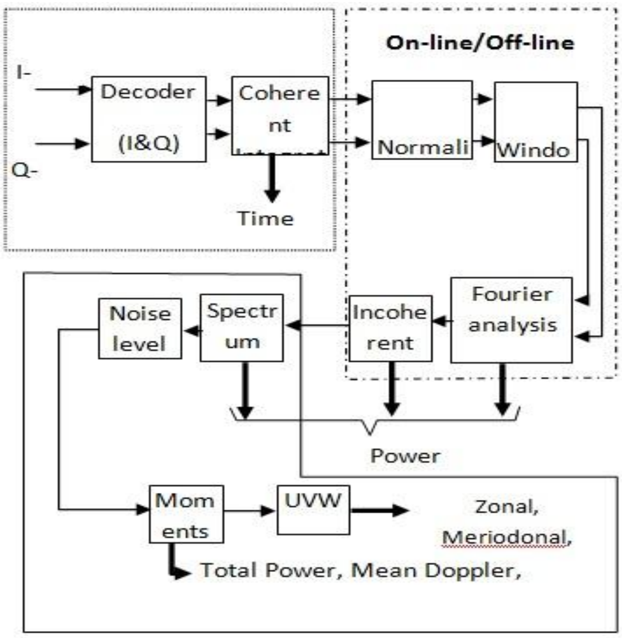

Fig (a): Processing steps for extraction of parameters

The receiving antenna captures the returned signals and channels it to the receiver, where it is processed to detect the presence of target and to extract its location and relative velocity. The distance of the target is determined by measuring the time taken for the radar signal to travel between target and radar the shift in carrier of the reflected wave is a measure of the target's relative velocity and may be used to distinguish moving objects from stationary objects. to the target and back. If relative motion exists

NARL LAWP

Most important feature or NARL LAWP is the simplified active array configuration. In this configuration, each element of the planar micro strip patch antenna array is fed directly by dedicated low power solid-state transceiver module consisting of a power amplifier (PA) and LNA connected to the common antenna port through a circulator. A transmit/receive (T/R) switch switches the input port between the PA and LNA. These transceiver modules are made with commercially available communication components, making them low cost and affordable. Signal-to-Noise Ratio (SNR), thereby the range performance is significantly improved as the feed loss is eliminated. This configuration reduces the antenna size significantly (at least by a factor of 4-6) when compared to a conventional passive array system for the given range performance and makes the wind profiler compact and transportable. The second important feature of this system is the utilization of a low power two-dimensional passive multi-beam forming network, which simplifies the beam formation.

IN-PHASE AND QUADRATURE COMPONENTS

Method and apparatus are disclosed for correcting amplitude and phase imbalances between the "in phase" and "quadrature" channels of a digital signal processor by determining a correction coefficient from a test signal periodically introduced into the quadrature phase detector of a radar system.

The frequency spectrum of the signal at the output of the phase detector in response to each such test signal is utilized to produce a correction coefficient for application to radar return signals passing through the phase detector during normal radar operation, thereby providing true quadrature radar return signals for digital processing.

The ground clutter signal characteristic with a 90-degree phase difference between I and Q components. The mountains through the radar beam causes a frequency sweep, and a localized appearance during the dwell period. This type of vibrating signal can be analyzed with the discrete wavelets. The frequency presentation of a discrete wavelet that covers a band of frequencies.

In the time-domain, the wavelet consists of real and imaginary sinusoidal wavelets that closely match with the mountain signal.The discrete wavelet transform can be calculated using a Fast Fourier Transform. To avoid frequency leakage, a strong radar return signal should first be removed with the wavelet method.

Figure1.shows the inphase signal in which we have both signals.which are before and after wavelets.

Figure2.shows the Quadrature phase signal in which we have both signals. which are before and after wavelets.

By using wavelet transform remove the clutter in inphase and quadrature signals.

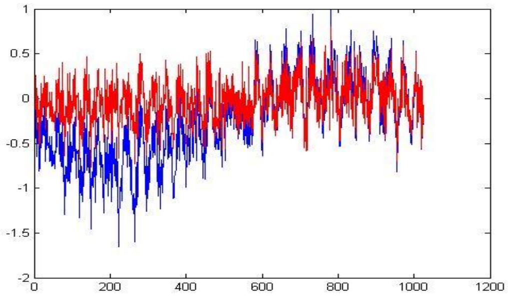

Figure 1. Time-series data from a 1280MHz wind profiler.The original inphasecomponent is shown in blue, the wavelet re moved clutter component in red.

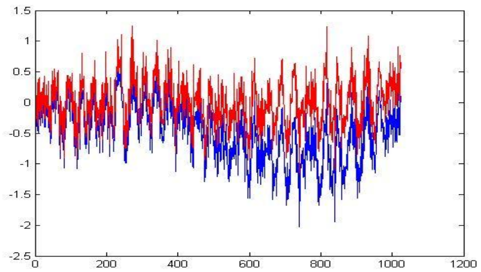

Figure 2. Time-series data from a 1280MHz wind profiler.The original quadrature component is shown in blue, the wavelet re moved clutter component in red.

Figure3. Shows the power spectrum compared to the after wavelet. This spectrum for single range gate. The descrete waveet transform is used for to remove the clutter which is present in the range gate

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Figure4. Shows the power spectrum before the wavelet transform. In which clutter is present.

Figure5. Shows the power spectrum after the wavelet. In which clutter is removed.We collect the LAWP data upto 7km.

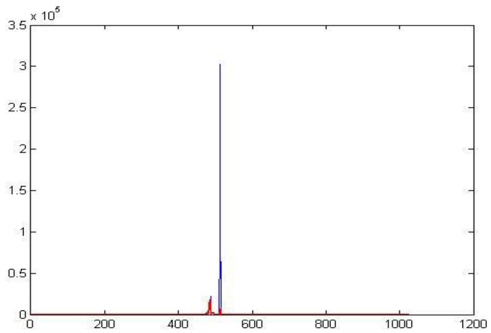

Figure 3. power spectrum (blue) is compared to the removed clutter power spectrum (red).

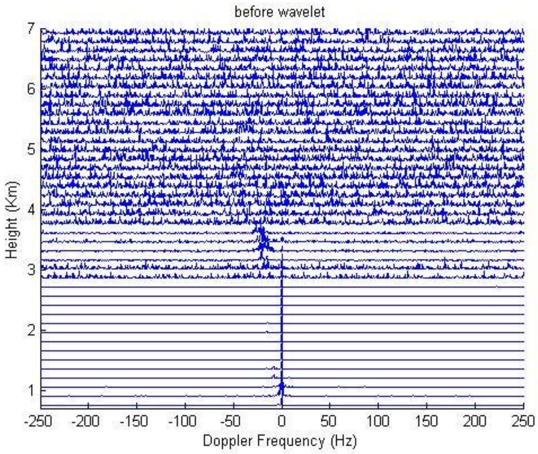

Figure4. Power spectra before wavelets.

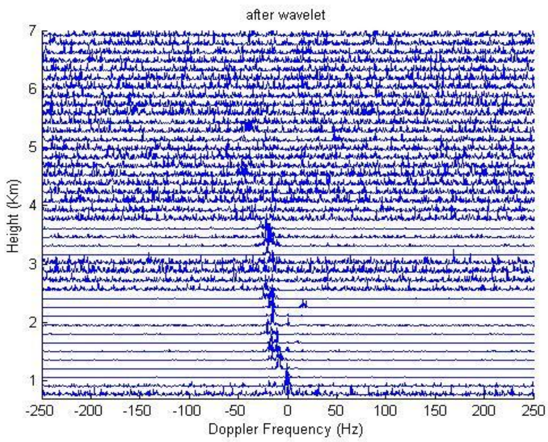

Figure5. Power spectra after wavelets.

VI. CONCLUSION

The wavelet transform method presented in this paper can efficiently remove clutter appearing in wind profiler. Signals represented in the time domain can be evaluated for their properties in the frequency Domain by applying signal analysis.

The most commonly known method to analyze a time signal for its frequency content is the Fourier transform. The wavelet transform is a relatively new technique which has some attractive characteristics.

It has been found by the discrete wavelet transform.

The raw data is stored in host processor first it converts into spectral data. Spectral data is also stored in digital receiver. The spectral data is processed by MATLAB programming. The clutter is removed from the inphase and quadrature phase signals and also from the total spectrum by using the discrete wavelet transform for LAWP radar which is used at NARL, Gadanki. By using different wavelet transform techniques the clutter is removed from the wind profiler.

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