Impact Factor Value: 4.029 ISSN: 2349-7084
International Journal of Computer Engineering In Research Trends
Volume 4, Issue 7, July-2017, pp. 313-318 www.ijcert.org

Non-Stationary Signal Analysis A Modified Time Frequency Approach

[1]Devika, [2]Monalisa Nayak, [3]Kodanda Dhar Sa, [4]Dillip Dash

[1,2,3,4,5] *Department of Electronics and Tele Communication, Indira Gandhi Institute of Technology, Odisha, India*

Abstract:- Fourier investigation becomes invaluable when the signal contains non-stationary characteristics or transitory characteristics like transients and patterns that vary with time. As time domain and frequency domain representations are inadequate to give all the information possessed by the non-stationary signal. Therefore time-Frequency methods (TFMs) are used to analyze a signal in time and frequency domains simultaneously. This paper deals with the analysis of non-stationary signals by using short time Fourier transform; fractional Fourier transform to analyze the time frequency behavior of the non-stationary signal. A combination method is known as Short time fractional Fourier transform (STFRFT) also proposed here, which provides unique properties of the non-stationary signal. By using different windows like the rectangular window, Hamming window, Hanning window and Blackman window, the fractional Fourier transform of the chirp signal has been plotted. The MATLAB simulations were made to show the STFRFT of the signal.

Keywords: - Fourier Transform, FRFT, Non-Stationary signals, STFT, Window function

---

1. Introduction

The signal is the function of one or more independent variables that contains some information. It is not possible to extract all the information about the signal from a single representation. So a given signal can be represented in different ways. Despite the fact that the numbers of ways describing a given signal are many, the most popular, important and fundamental variables are time and frequency. The time domain indicates how a signal's amplitude changes over time and the frequency domain shows the frequency components contained in the signal along with the amplitude associated with each frequency component [1]. To convert a signal from one domain to another domain for extracting some other information contained in the signal which cannot be extracted from the signal in the first domain, transform method is used. There are many important types of transform like Fourier Transform, Fractional Fourier transform, and Laplace Transform.

There are several methods for extracting the time varying characteristics of the signal, among them simplest method, is the STFT (Short Time Frequency Transform). STFT uses a window function to extend Fourier Transform, but the short or time variant window results in a poor resolution in the time frequency domain [2]. J. Vill introduced Wigner Distribution in the signal processing field [3]. Wigner-Ville Distribution (WVD) could be used for moving target detection and parameter estimation, but WVD suffers from the interruption of cross-terms in the presence of multi-component signals [4]. Although the effect of interference can be suppressed by carefully selecting the kernel function of TFD, meanwhile, their time-frequency localization performance will be certainly degraded [5].

2. Non-stationary signals Spectral Analysis

A signal is a non-stationary if its measurement statistics change with time. In this case, some adaptive algorithms are used to track the statistics of the signals. The output of time –variant or the dynamic system will be a non-stationary signal. DFT can be employed for spectral analysis of a length-*N* sinusoidal signal composed of sinusoidal signals as long as the frequency, amplitude and phase of each sinusoidal component are time-invariant and independent of *N*. Examples of such non-stationary signals are speech, radar and sonar signals. DFT of the complete signal will provide misleading results. A practical approach would be to segment the signal into samples of short length with each sample centered at uniform intervals of time and compute DFTs of each subsequence. The frequency-domain of the long sequence is then given by a set of short-length DFTs, i.e. a time-dependent DFT.

© 2017, IJCERT All Rights Reserved

Therefore, to represent a non-stationary signal x[n] regarding a set of short length subsequences, x[n] is multiplied by a window w[n] that is stationary concerning time and move x[n] through the window [6].By applying Fourier Transform to Non-stationary signal, we extract the value of the frequencies from the figure exactly, but there is no information where the frequencies are located in time. Therefore, Fourier Transform is not much use for analyzing Non-stationary signals or time variant signals [7]. STFT is one of the known technique in signal processing to analyze non-stationary signals, which we will discuss elaborately in the next section.

3. Short time Fourier transform (STFT)

Short-time Fourier transforms (STFT), also known as time-dependent Fourier transforms of a signal. It is one of the best-known time-frequency representations of a time signal dates back to Gabor. Fourier analysis becomes insufficient when the signal has non-stationary or transitory characteristics like transients, trends, etc. To correct this, Dennis Gabor adapted the Fourier transform to observe small sections of the signal at a time. STFT is based on the Fourier Transform, and its basic idea is a moving window Fourier Transform [8]. The window is moving over the time domain, and the examination of the frequency content of the signal generates a 2-D time-frequency distribution called "spectrogram". The STFT of a signal s (t) is defined as:

$$\mathrm{STFT}(t,\omega) = \int s(t')w(t' - t)\exp(-j\omega t')dt' \qquad (1)$$

Where, t = time parameter, ω = frequency parameter, s (t') = signal to be analyzed, w (t'-t) = window function

4. Fractional Fourier transform (FRFT)

The FRFT is a generalized form of Fourier Transform. It belongs to the class of time-frequency analysis. It can be regarded as a counter-clockwise rotation of the signal through an angle which is not a multiple of $\frac{\pi}{2}$. In other words, it is a representation of the signal along the axis making an angle α with the time axis. If the rotation angle (α) is $\frac{\pi}{2}$, the result is Fourier Transform of the signal [10,11].

The FRFT of the signal $x(t)$ can be represented as

$$X_\alpha(u) = [x(t)] = \int_{-\infty}^{\infty} x(t)K_\alpha(t,u)dt \qquad (2)$$

Where α is the rotational angle of the FRFT, F^α denotes the FRFT operator, and $K_\alpha(t, u)$ is the kernel function of the FRFT, p is called the order of FRFT and is equal to 2α/π.

$$K_\alpha(t,u) = \begin{cases} \sqrt{\frac{1-j\cot\alpha}{2\pi}}\exp\left(j\frac{t^2+u^2}{2}\cot\alpha - jtu\csc\alpha\right), & \alpha \neq n\pi \\ \delta(t-u), & \alpha = 2n\pi \\ \delta(t+u), & \alpha = (2n+1)\pi \end{cases} \qquad (3)$$

5. Short-time fractional Fourier transform (STFRFT)

In the case of STFT, the window size is constant which results in a trade-off between time resolution and frequency resolution. If a larger window size is taken, the frequency resolution is good but time resolution decreases. In the case of smaller window size time, the resolution is good, but it decreases frequency resolution. So, the constant window size is the demerit of STFT.A powerful tool to examine the chirp signal is FRFT, as it concentrates the energy of the signal. However, it only discloses the FRFD frequency contents because it uses a global kernel. Sometimes it becomes necessary to know not only FRFD contents but also the changes happened from time to time 12. To understand the changes of FRFD contents that has happened from time to time STFRFT (Short Time Fractional Fourier Transform) is used. For STFRFT, we have to break the signal into smaller parts as in the case of STFT and then apply fractional Fourier transform instead of FFT to get fractional frequency domain signal. So by this process, we can get the advantage of the short waveform and also an additional degree of freedom in between time to frequency domain representation. The process of breaking the signal into smaller part can be done by windowing the signal. By using convolution theorem, we can apply a window to the signal and will get a smaller part as per the length of the window. Then Fractional Fourier transform will be applied to that smaller time domain discrete signal.

6. Simulations

In this section the time frequency analysis regarding STFT, FRFT and STFRFT are analyzed. The performance of the various window functions for the time frequency domain is studied.

STFT and FRFT analysis of LFM signal

A chirp signal of starting frequency 100Hz is taken, and STFT is calculated by taking the hamming window of size 128. The STFT is one of the powerful tools for the time frequency domain, but still, it lags in the predefined window size selection.

© 2017, IJCERT All Rights Reserved

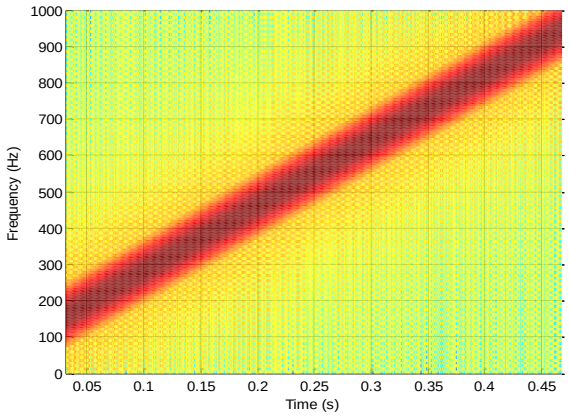


Fig 1: Short time Fourier transform of chirp signal

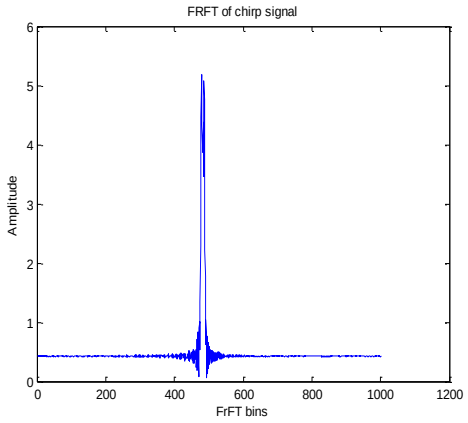


Fig 2: Fractional Fourier transform of

A chirp signal of starting frequency 50HZ is taken, and the order of the transform is taken as 0.5219. The FRFT over comes to the limitations of the STFT for LFM signals. FRFT has a good time-frequency aggregation and does not have crossing term. Therefore FRFT has an advantage in the time-frequency analysis of linear frequency modulation signal.

STFRFT

A chirp signal of starting frequency 50 Hz is taken. FRFT of a short part of the signal is done using the following windows to know the effect of windows on FRFT. The STFRFT algorithm is implemented in this paper from both theoretical and application aspects. The STFRFT-based time-frequency analysis method is reviewed, from which a theoretical time-frequency resolution and a quick calculation method are proposed. Then, the analysis method of multi-order STFRFT is developed based on multi-component LFM signal. The experiment data are used to demonstrate the high time-frequency resolution performance of STFRFT when dealing with multi-component micro Doppler signal.

The time frequency analysis of the STFRFT is analysed with various window functions like a rectangular window, Blackman window, Hanning window and hamming window and the performance of the windows are analysed by varying the window length.

Rectangular window

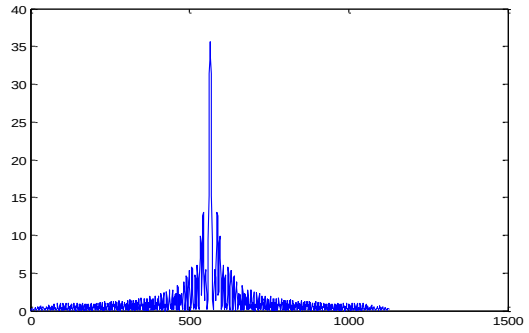


Fig 3a: STFRFT using rectangular window

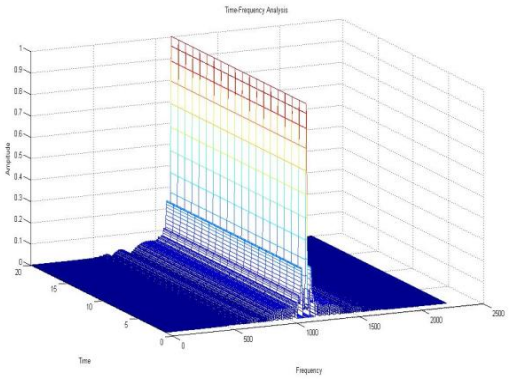
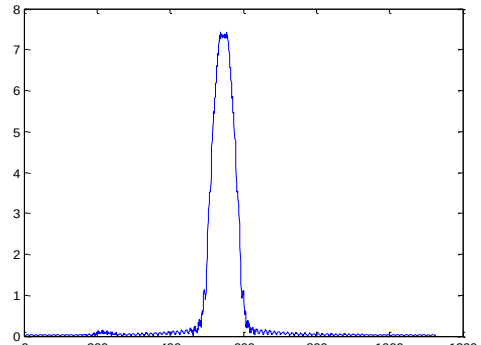


Fig 3b: Time frequency representation using rectangular window

Hamming window (window size 128)

© 2017, IJCERT All Rights Reserved



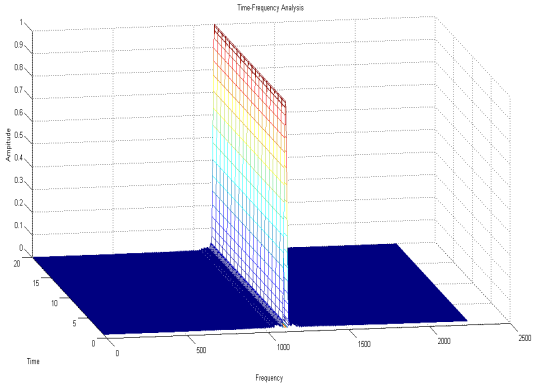
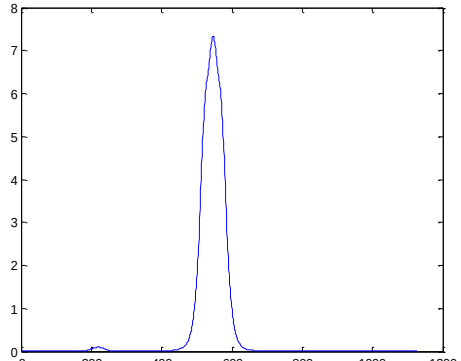


Fig 4: STFRFT using hamming window Fig 3b: Time frequency representation using rectangular window

Hanning window (window size 128)



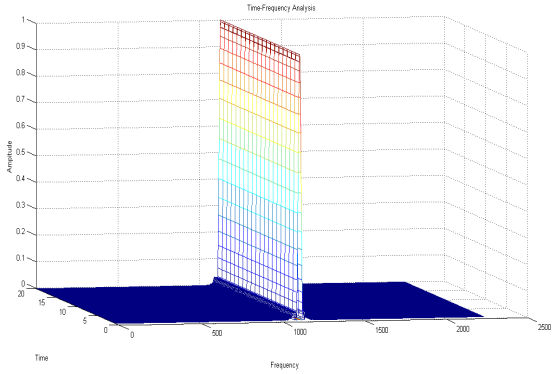
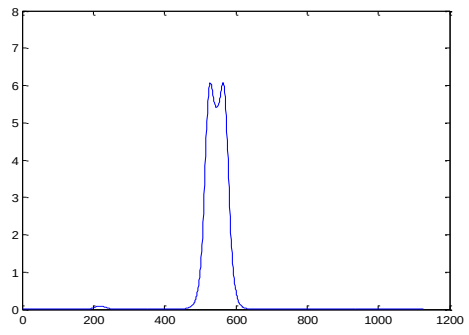


Fig 5: STFRFT using Hanning window Fig 3b: Time frequency representation using rectangular window

Blackman window



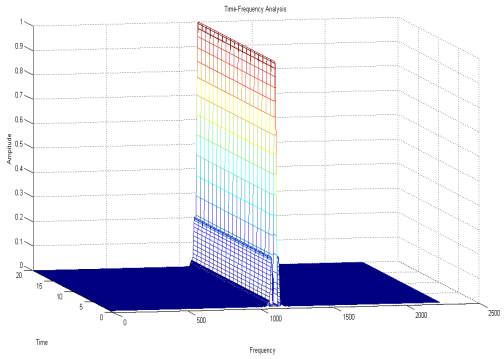


Fig 6: STFRFT using Blackman window

In the above simulation for various windows with different window lengths the time frequency analysis of the LFM signal is studied. According to the window function, the rectangular window is the simplest to implement whose window function is shown in figure 3. It can be observed that there are some side lobes present in the rectangular window.

© 2017, IJCERT All Rights Reserved

The performance of the Hamming and Hanning window is approximately same. However, as compared to the Hanning window, the side lobes are more in the case of Hamming window. Some extra lobes are presented in case if the Hanning window, generally in the order of second harmonics or third harmonics. However, the presence of extra cosine terms it became the cause to reduce the side lobes. As less is the side lobes more is the efficiency, and less power is lost, the Blackman window performs well in compared to all the other windows. The simulation results are also verified for the Blackman window and the STFRFT. The following simulation shows the STFRFT of a full chirp signal of starting frequency 100Hz and using Blackman window of size 128.

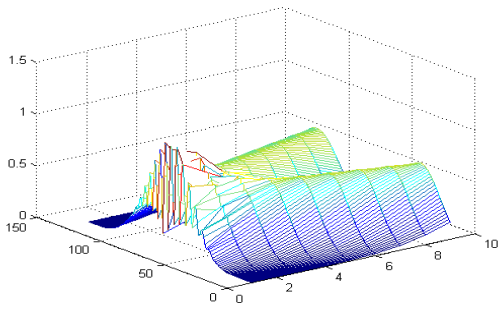


Fig 7: STFRFT of chirp signal using Blackman window Comparison in between Hamming Hanning and Blackman window

The consideration of Blackman window has more terms in compared to a hamming window that makes the Blackman window more suitable and efficient. Equivalent noise bandwidth is less for Hanning window than Blackman window whereas the equivalent noise bandwidth is less for Hanning window than the hamming window.

7. Conclusion

Non-stationary signals are the real time signals. To extract relevant information from this type of signals, a time-frequency analysis becomes a necessity as only time or only frequency analysis cannot give accurate information. The short time fractional Fourier transform eliminates the limitations of fractional Fourier transform. By using STFRFT, the limitations of short time Fourier transform still exist as the window size is constant. From the above study, we can conclude that the performance of the Blackman window is better as compared to other windows for the time frequency analysis using STFRFT.

Reference

[1] Qi L, Tao R, Zhou S, Wang Y., Detection and parameter estimation of multicomponent LFM signal based on the fractional Fourier transform. Science in China series F: information sciences, 2004, 47(2), pp. 184-98.

[2] Claasen T, Mecklenbräuker W., TIME-FREQUENCY SIGNAL ANALYSIS. Philips Journal of Research. 1980, 35(4/5), pp. 276-300.

[3] Rao P, Taylor F. Estimation of instantaneous frequency using the discrete Wigner distribution. Electronics letters, 1990,126 (4), pp. 246-8.

[4] Choi H, Williams W., Improved time-frequency representation of multicomponent signals using exponential kernels. IEEE Transactions on Acoustics, Speech, and Signal Processing, 1989, 37(6), pp. 862-71.

[5] Hossen AN, Heute U, Shentov OV, Mitra SK. Subband DFT—part II: accuracy, complexity and applications. Signal Processing, 1995,41(3), pp. 279-94.

[6] Hammond JK, White PR., The analysis of non-stationary signals using time-frequency methods. Journal of Sound and Vibration. 1996, 190(3), pp. 419-47.

[7] Chen VC, Ling H., Time-frequency transforms for radar imaging and signal analysis. Artech House, 2002.

[8] Narayanan VA, Prabhu KM., The fractional Fourier transform: theory, implementation and error analysis. Microprocessors and Microsystems, 2003, 27(10), pp. 511-21.

[9] Qu H, Wang R, Qu W, Zhao P., Research on DOA Estimation of Multi-Component LFM Signals Based on the FRFT. Wireless Sensor Network, 2009, 1(3), pp. 171-81.

[10] Sun HB, Liu GS, Gu H, Su WM, Application of the fractional Fourier transform to moving target detection in airborne SAR, IEEE Transactions on Aerospace and Electronic Systems, 2002, 38(4), pp. 1416-24.

[11] Tao R, Zhang F, Wang Y., Fractional power spectrum. IEEE Transactions on Signal Processing. 2008, 56(9), pp. 4199-206.

[12] Podder P, Khan TZ, Khan MH, Rahman MM. Comparative performance analysis of hamming, hanning and blackman window. International Journal of Computer Applications, 2014,96(18), pp. 2001-2006.

© 2017, IJCERT All Rights Reserved