# Time-Frequency Techniques in Wrist Pulse Signals

**Nidhi Garg, Nikita Babbar**

***Abstract*: Wrist pulse signal has been the traditional way of diagnosing human health in India. It is a low frequency, non-stationary signal. There are broadly three techniques of analyzing a signal – time, frequency and time-frequency domain. The individual time and frequency domain representations of the signal do not provide much information on properties of a non-stationary signal. However, the time-frequency distributions of a non-stationary signal overcome these problems and provide more information about the pulse signal. This paper presents the various time-frequency distribution techniques for analyzing non-stationary wrist pulse signals .***

***Keywords:*** **wrist pulse signals, non stationary signal, time-frequency domain.**

## I. INTRODUCTION

A signal that changes in time is called a non-stationary signal. For example: music is a non-stationary signal. The representation of music in terms of musical notations consists of a sequence of notes (frequencies) played at different times. Similarly, wrist pulse signals (WPS) is also a non-stationary signal and we need both time and frequency information to analyze it correctly. The different approaches of analyzing a signal could be possible in either frequency domain, time domain or the combine analysis of time-frequency (t-f). Extensive examination has been done on WPS in time domain [1-2] as well as in frequency domain [3-4]. The categorization among subjects in good health and unhealthy state has also been seen on various time and frequency domain features analysis [5]. The individual domain approaches are well suited for a stationary signal. However, these approaches fail to analyze completely a non-stationary signal. The work in t-f domain has been done on various non-stationary bio-medical signals such as EEG and ECG as seen in [6-8].

Researchers also presented the techniques of working in time, frequency and joint time-frequency domain for WPS [9]. This paper marks the possibility of exploring WPS in time-frequency domain.

**Revised Manuscript Received on October 30, 2019.**
* Correspondence Author
**Nidhi Garg***, Department of Electronics and Communication, University Institute of Engineering and Technology (UIET), Panjab University (PU), Chandigarh, India. corresponding e-mail id: nidhi_garg@pu.ac.in, nidhi461@gmail.com
**Nikita Babbar** , Department of Electronics and Communication, University Institute of Engineering and Technology (UIET), Panjab University (PU), Chandigarh, India.



Therefore, the goal of this paper is to attempt and sketch out the essential concepts associated to characterize a WPS in t-f domain. A comparison of various techniques for representing WPS in time-frequency space is presented. To store and process the pulse signal ®LABVIEW has been used. It makes use of various Virtual Instruments (VIs) for processing.

## II. REPRESENTING A SIGNAL IN T-F SPACE

The Fig. 1 shows a simple non-stationary signal g(t). Obtaining Fourier transform of this signal will result in frequency information of the signal as the signal will be represented in frequency domain. However, if a window is used to sample this signal and then finding the frequency at each point while sliding the window will tell what frequency appears when, in a non-stationary signal, thus representing the signal in t-f space. This is the basic approach for representing a non-stationary signal in joint t-f space.

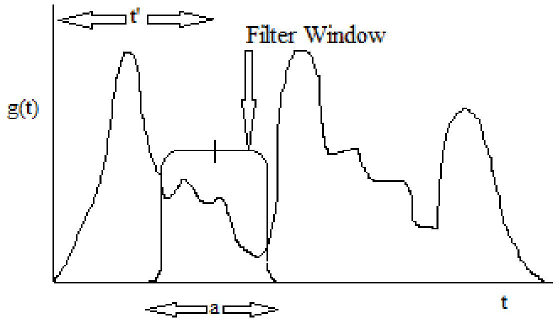


**Fig. 1.Sampling of a non-stationary signal using window.**

The joint time-frequency distribution gives information about both time as well as frequency together. The t-f distribution is greatly helpful in the analysis of transient signals such as bio-medical signals. The various techniques of representing a signal in t-f space are: CWD (Choi-Williams Distribution), WVD (Wigner-Ville Distribution), STFT (Short term Fourier Transform), Adaptive Spectrogram, Gabor Spectrogram, and CSD (Cone Shaped Distribution). These are mentioned in Fig. 2.

STFT of a non-stationary pulse signal g(t) is represented as:

$$G(t`,f) = \text{Fourier Transform}[g(t).w(t-t`)]$$

Where, the function w(t) is a rectangular window (used for sampling) of width ‘a’ that localizes the signal g(t) in time around time to Fourier Transform of the sampled signal. The WVD of pulse signal is analogous to STFT where the window used is just shifted version of the same signal. However, in the same approach, if Gaussian signal is used as the windowing function, then the resultant is the Gabor Transform of the pulse signal.

The Adaptive Spectrogram is analogous to Gabor Spectrogram except that it decomposes the signal using adaptive expansion before applying it to WVD. In Adaptive Spectrogram, only the WVD of auto-terms are summed up ignoring the cross terms between every two auto-terms. CWD and CSD both belong to Cohen's Class Distribution.

### III. APPROXIMATION OF T-F TECHNIQUES IN WPS

The pulse signals contributing to our database have been collected from 8 healthy female (age group 20-25) subjects after taking their consent. The signals were collected using pressure sensor and have been stored as tdms files in computer. The different techniques considered in support of characterizing the pulse signal in t-f domain have been shown in Fig. 2. Here, we present a comparative approximation of these techniques when applied on the WPS in terms of time-frequency (t-f) resolution and t-f cross-term interference. Fig. 3 exemplify the each of these techniques.

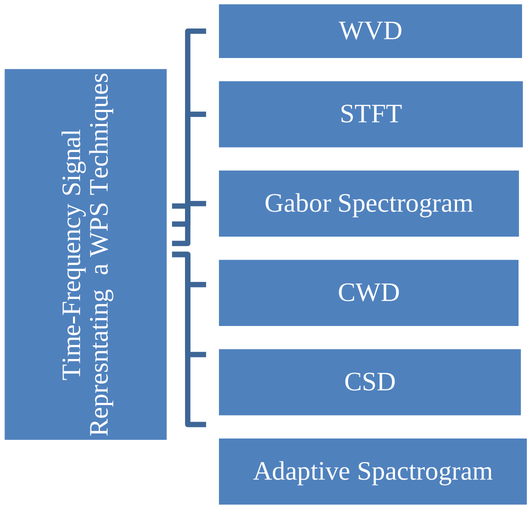


**Fig. 2.Time-Frequency Signal Representation Techniques**

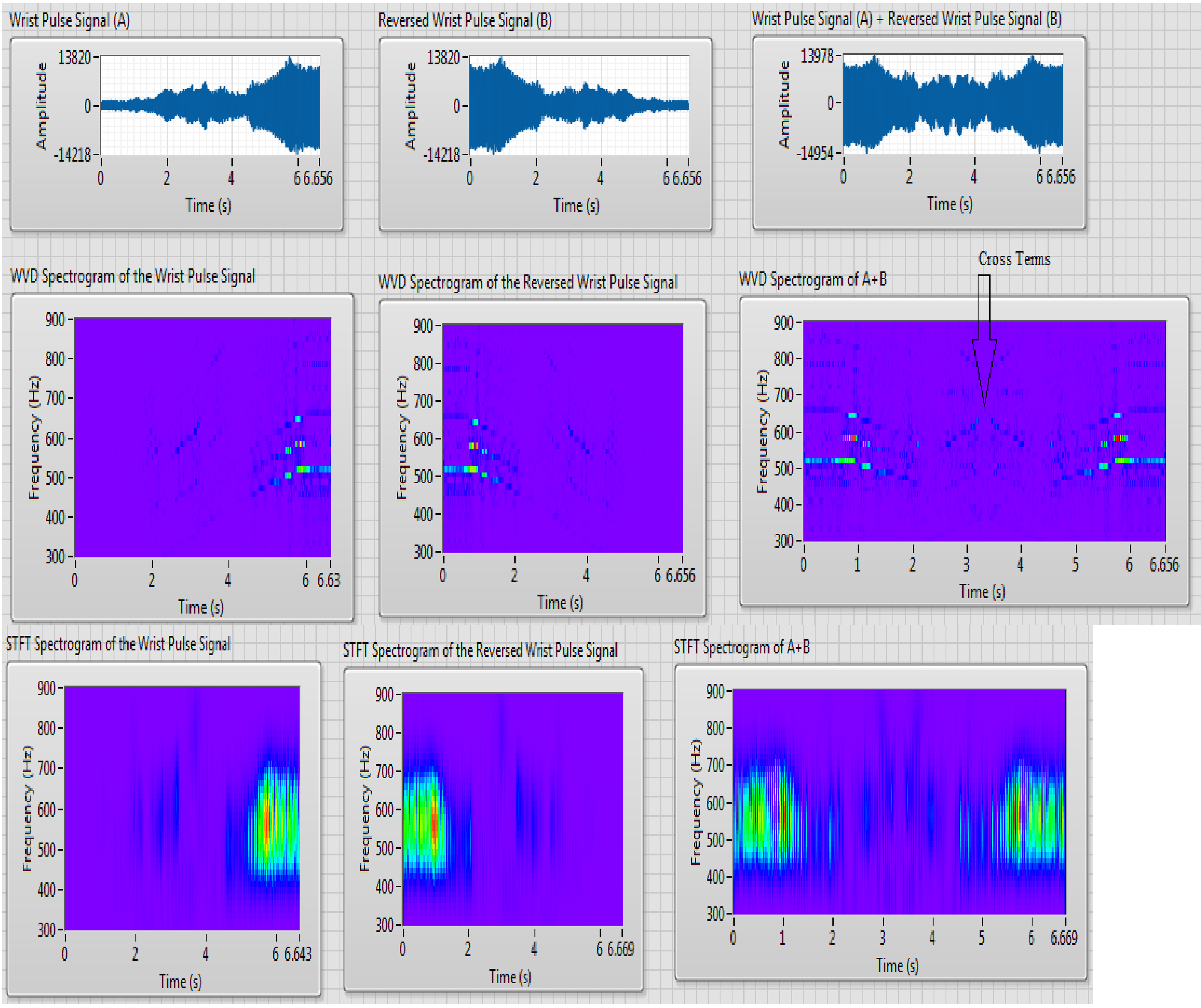


**Fig. 3.Comparison of different techniques for joint time-frequency analysis of wrist pulse signal**

*Retrieval Number: L25201081219/2019©BEIESP*
*DOI:10.35940/ijitee.L2520.1081219*
*Journal Website: www.ijitee.org*



*Published By:*
*Blue Eyes Intelligence Engineering*
*& Sciences Publication*

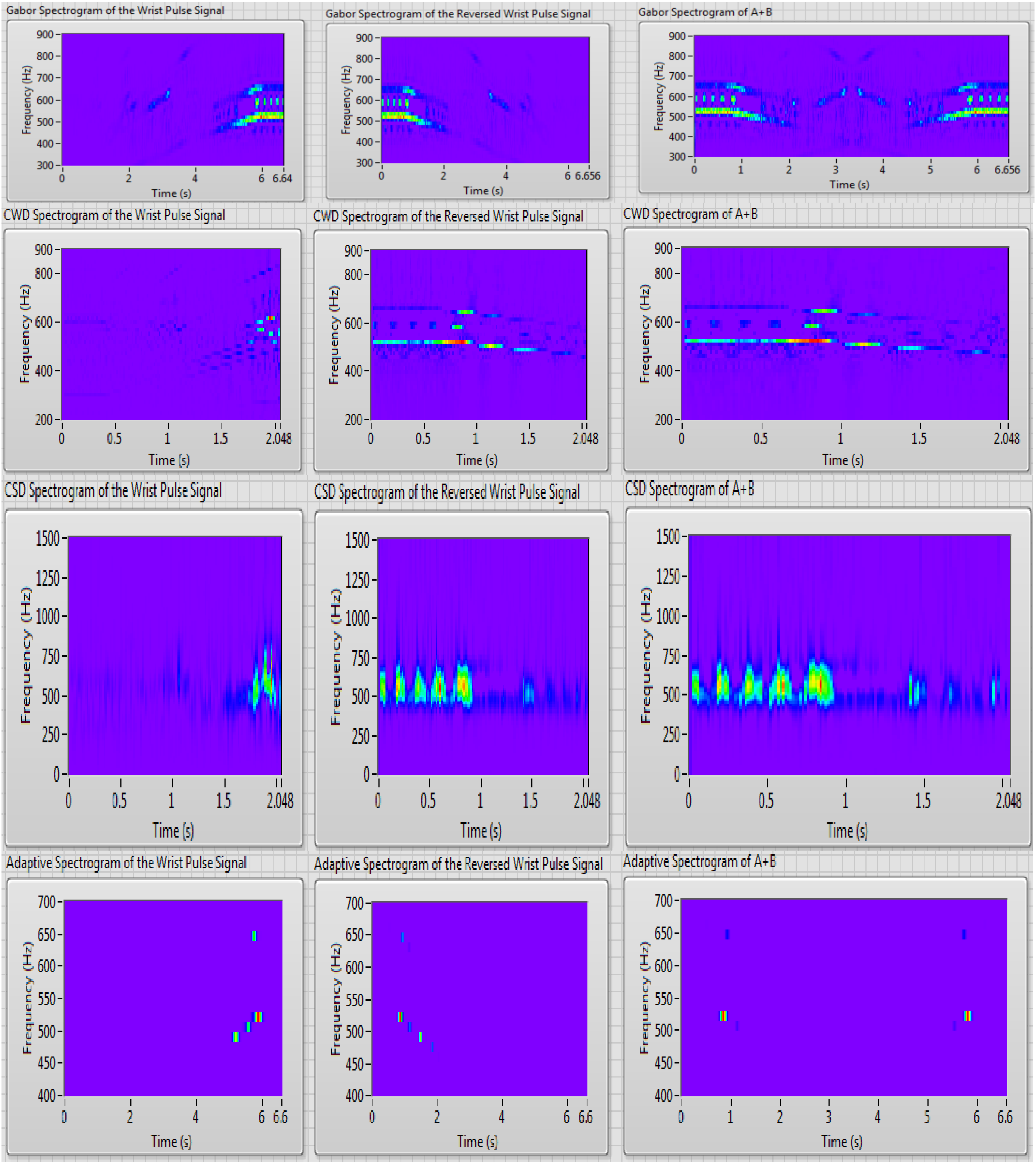


**Fig. 4. Comparison of different techniques for joint time-frequency analysis of WPS (Continued)**

A WPS of a healthy subject has been taken shown by (A) in Fig. 3. This pulse is reversed and named as (B). Another signal (A+B) is taken as the summation of the original and reversed pulse signal. The time-frequency distribution for each of these signals has been calculated using all the techniques mentioned in Fig. 2. All the outputs are mentioned in Fig. 3. The time-frequency analysis techniques are compared based on two factors: cross term interference and t-f resolution. The results are summarized in Table I.

As is evident from Fig.3, looking from the perspective of obtaining the least cross term interference, STFT, Gabor Spectrogram and Adaptive Spectrogram are preferable as they show minor or negligible cross-term interference. However, WVD, CWD and CSD generate strong cross term interference. STFT suffers from poor t-f resolution.

Therefore, STFT suffers from the trade-off between obtaining good time-frequency resolution and negligible cross term interference. Whereas, WVD and Gabor Spectrogram provide fine t-f resolution. CWD offers moderate resolution but CSD shows coarse resolution as compared to CWD. However, the Adaptive Spectrogram outperforms others in obtaining finest t-f resolution as it adapts to the characteristics of the input signal. Also, no cross term interference is seen as it ignores the cross-terms in the calculation and thus seems to be best suited for analyzing a non-stationary signal such as wrist pulse signal.

TABLE I. COMPARISON OF T-F TECHNIQUES FOR ANALYZING A NON-STATIONARY SIGNAL

| T-F Distribution Technique | Cross Term Interference | T-F Resolution |
|---|---|---|
| WVD | Generates strong cross term interference | Fine t-f resolution |
| STFT | Almost negligible | Coarse t-f resolution |
| Gabor Spectrogram | Minor | Fine t-f resolution |
| CWD | Generates cross term interference but lower than WVD | Moderate t-f resolution |
| CSD | Generates cross term interference but lower than WVD | Moderate t-f resolution |
| Adaptive Spectrogram | No cross term interference | Best t-f resolution |

## IV. CONCLUSION

Various methods for the inspection of non-stationary WPS were presented using joint time-frequency distribution techniques. The results of each of these techniques were compared based on the cross term interference and time-frequency resolution. Out of all these techniques, adaptive spectrogram resulted in best t-f resolution and does not include any cross term interference for the analysis of WPS.

## REFERENCES


1. Rangaprakash D and Narayana Dutt D, "Study of wrist pulse signals using time domain spatial features", Comput Electr Eng , http://dx.doi.org/10.1016/j.compeleceng.2014.12.016, 2015.
2. P. Zhang and H. Wang, "A framework for automatic time-domain characteristic parameters extraction of human pulse", EURASIP Journal on Advances in Signal Processing, 2008.
3. D. Y. Zhang, W. M. Zuo, D. Zhang and N. M. Li, "Wrist blood flow signal based computerized pulse diagnosis using spatial and spectrum features", J. Biomed. Sci. Eng. 3, 361, 2010.
4. C.T. Lee and L.Y. Wei, "Spectrum analysis of human pulse", IEEE Trans. Biomed. Eng., 348-352, 1983.
5. Kruti Parikh and Bhaskar Thakker, "Wrist pulse classification system for healthy and unhealthy subjects", International Journal of Computer Applications, Vol. 124-No. 15, 2015.
6. B. Boashash, Ghasem Azemi and Nabeel Ali Khan, "Principles of time-frequency feature extraction for change detection in non-stationary signals: Applications to new-born EEG abnormality detection", http://dx.doi.org/10.1016/j.patcog.2014.08.016 , 2015.
7. H. Tirtom, Mehmet. Engin and Erkan Zeki Engin, "Enhancement of time frequency properties of ECG for detecting micropotentials by wavelet transform based method", www.elsevier.com/locate/eswa, 2008.
8. R. Sudirman, A. K. Chee and W. B. Daud, "Modelling Of EEG signal sound frequency characteristic using time frequency analysis", Fourth Asia International Conference on Mathematical/Analytical Modelling and Computer Simulation, 2010.
9. Nikita Babbar and Nidhi Garg, "Progress and advancement in wrist pulse signal", International Conference on Advancement in Engineering and Technology (ICAET), 2016, in press.
10. Zhi-Yuan Su, Chuan-Chen Wang, Tzuyin wu, Yeng-Tseng wang and Feng-Cheng tang, "Instantaneous frequency-time analysis of physiology signals: the application of pregnant women's radial artery pulse signals", Science Direct, September 2007.
11. S. Upadhyaya, "Nadi vijnana – ancient pulse science", Chaukhamba Sanskrit Pratishthan Publishers, India 2005.
12. Abhinav, Meghna Sareen, Mahendra Kumar, Jayashree Santhosh, Ashok Salhan and Sneh Anand, "Nadi Yantra : A robust system design to capture the signals from the radial artery for assessment of the autonomic nervous system non-invasively", J. Biomedical Science and Engineering, 2, 471-479, 2009.


## AUTHORS PROFILE

**Dr. Nidhi Garg** is a Assistant Professor in the Department of Electronics and Communication Engineering at University Institute of Engineering and Technology, Panjab University, Chandigarh, India. She did B.Tech, M.E and Ph.D. in Electronics Engineering. She has published more than 24 technical research papers in SCI, Scopus and International journals and Conferences. She has guided around 15 M.E (ECE)/ M.Tech (Microelectronics) thesis till now. Her main area of interest includes Bio-Signal Processing, Digital System Design and Machine learning. email id: nidhi_garg@pu.ac.in, nidhi461@gmail.com