International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 1 Jan-Feb 2021, pp: 905-911 www.ijaem.net ISSN: 2395-5252

Comparison of Conventional and Recent developed Analysis Techniques of Ground Motion Time History

Vaneeta Devi[1] and Sunil Kumar[2]
[1,2]*Assistant Professor, College of Technology, G.B.PantUniversity of Agriculture and Technology, Pantnagar, Uttarakhand*
Corresponding Author: Vaneeta Devi

Submitted: 25-01-2021 Revised: 05-02-2021 Accepted: 10-02-2021

ABSTRACT: Time series analysis and Fourier Transform (FT) are available conventional techniques generally used for the study of spectral features exist in the recorded ground motion time histories like Seismogram and Accelerogram. But both these techniques describe only one feature at a time in ground motion time history which is insufficient to understand the comprehensive information of time history. Since the ground motion time histories consist time varying frequency content and need TFA analysis. Therefore, the recently developed Time Frequency Technique (TFA) techniques are one of the appropriate techniques to study the time varying spectral content of a ground motion time history. TFA splits the time history information in two domains, (Time and frequency domain simultaneously), which result in revealing localized temporal information of frequencies. The 2D representation of TFA is known as Spectrogram. In this paper a time history called seismogram, recorded by Department Earthquake Engineering at IITR observatory from radio linked local seismological network around Tehri Dam for the purpose of monitoring local seismicity of the dam reservoir region, has selected to study the spectral features by FT and Short-Term Fourier Transform (STFT), TFA techniques and results have analyzed and compared. Results obtained from STFT TFA show better picture of the temporal spectral content in the recorded time history data than the conventional techniques. The aim of this paper is to compare FT and SFT TFA techniques. The Advance Signal Processing toolkit of transform using LabVIEW software developed by National Instrument (NI) has been used for processing.

KEYWORDS: Ground motion time history; FT; Short Term Fourier Transform (STFT); Time–Frequency Analysis (TFA);

I. INTRODUCTION

The traditional 1D Fourier Transform is one of the most widely used processing technique to process the time history records in the field of science and engineering. FT reveals the frequencies content present in a time history like seismogram/accelerogram signals in seismology and earthquake engineering. Since information present in a seismogram varies with time, FT insufficient to provide basic characteristics i.e. time localized individual frequency information and temporal variation of frequencies in a time history (Auger et al., 1996; Flandrin, 1999; Hlawatsch and Boudreaux-Bartesl, 1992; Hlawatsch et al., 1995; Marks-II, 2009; Newland, 1998; Debnath, 2002; Drai, 2002; Ding, 2009; Gahlot, 2014; Kumar et al., 2015; and Vaneeta Devi and M.L. Sharma, 2016). Major research efforts have been dedicated in the past decades to sharpen seismological data processing to interpret the physical processes using various outcomes of data processing techniques. Due to variation in time and frequency content of seismograms, techniques like Time-Frequency Analysis (TFA) which includes time information for the frequencies present in signals are preferred. TFA techniques represents a 1D time domain signal into 2D as a function of time and frequency and show how the frequencies content in seismogram varying with time. In this concern, different types of TFA approaches are developed for analysis, processing and synthesizing the non-stationary signals like seismogram (Gahlot, 2014; Kumar et al., 2015; and Vaneeta Devi and M.L. Sharma, 2016). Sinha et al., 2005; Castagna and Siegfried, 2003 applied STFT to generate mono-frequency images from the broadband seismic data and had summarised some drawbacks of FT. The widely used Short-Time Fourier Transform (STFT) method produces a Time-Frequency spectrum by taking the Fourier transform of data windows (Cohen, 1995), which leads to a trade-off between temporal and spectral resolution.

STFT TFA distribution is classified as linear distribution which decompose the time history in time and frequency domain as well as helps to revert it in time domain (Cohen, 1995, Hlawatschand Boundreaux-Bartels, 1992). The concept in STFT algorithm is to divide the signal into small segments of some window function. Then, Fourier analysis is performed on each window segment to get the frequency present in each segment. Next, this window function is moved to a new segment of the signal and the above-mentioned process is repeated. In this way, time-frequency plane also called 'spectrogram' is formed with colour intensity showing amplitude coefficients as a function of time and frequency. The amplitude distribution is defined by the Short-Time Fourier Transform through linear integral,

STFT (τ,f)=∫_(-∞)^(+∞)▒〖x(t) γ(τ-t) e^(-j2πft) 〗 dt
(1)

where, x(t) is the time domain seismogram, γ (τ-t) localised windowing function and e^(-j2πft) is Fourier kernel.

Seismogram: A Seismogram is an ID record of time history recorded at seismic station by seismograph. It consists time, amplitudes and frequencies information of the ground motion caused by the earthquake/ seismic activities, which evolved over time at a specific distance/ location. It is used to interpretate the recoded data to study the seismic activities at a location.

Fourier Transformation (FT): It is the technique that decomposes the time domain data to frequency domain and reveals information of the frequencies and its amplitude of a time history.

Short Term Fourier Transformation (STFT): It is the technique that decomposes the time history/ seismogram data to frequency domain, time domain and their respective amplitude. It shows the gradual temporal variation of frequencies in a time history/ seismogram. indeed, it represents the 3D plan i.e time, frequency and amplitude of as seismogram. The 3D representation of this technique is known as spectrograms.

Study Data: A seismograms of magnitude(M) in range of 2.5-3.0 at epicentral distance (D) range 80-90km have taken in this paper to analyses and compare output of the FT and STF TFA techniques. Table 1 listed the detail of the time histories (seismograms) recoded in the aforesaid region and figures 1(a), (b) and (c) show their variation in time domain. These seismograms have sampled at the rate of 100 sps on short period seismometer (model CMG 40 T-1; sampling rate 1-100Hz) which were deployed around Tehri Dam region to monitor the local seismicity in the region. All these seismograms are analyzed by FT and STFT TFA techniques and only first in list is discussed in this paper. The obtained graphical user interfaces (GUI) using LabVIEW software are compared to select the suitable technique for the analysis of time varying frequency content signals.

Table1 Time histories in epicentral distancerange D=80-90 km

S.	Julian Date	O.T. Hr: Min:	Sec.	Distance D (km)	Local Magnitude (M_L)
1	2011348	23:55:00	38.82	79.12	2.51
2	2009032	15:32:00	29.75	72.37	2.59
3	2011322	09:50:00	39.94	73.36	2.98

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 1 Jan-Feb 2021, pp: 905-911 www.ijaem.net ISSN: 2395-5252

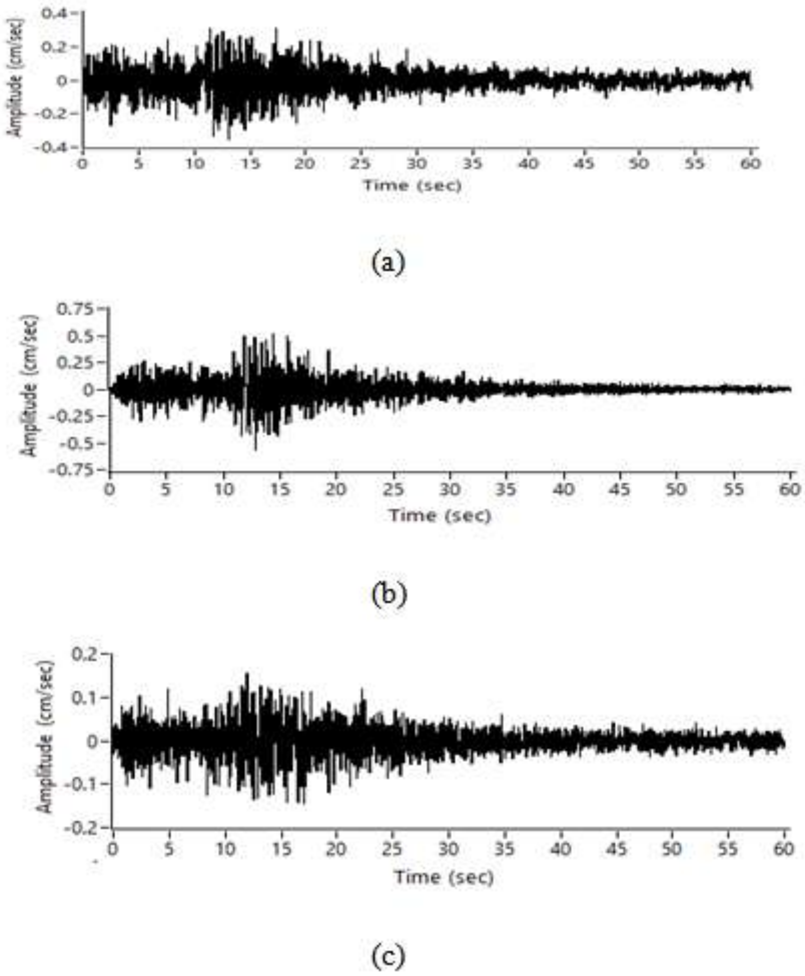
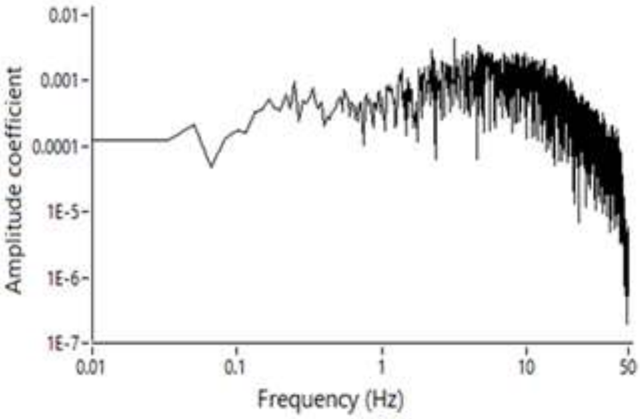


Fig.1 Time history/ Seismograms of magnitude M (2.5-3.0) at D (80-90km)

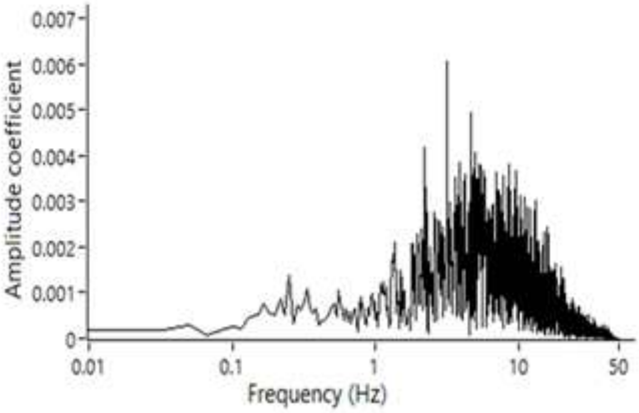
II. RESULTS AND DISCUSSION:

FT of the seismogram time history (S.No.1 given in the table1, fig 1 (a)) has been plotted on log-log scale and log linear scale and shown in figure 2. The logarithmic FT plot of the seismogram decipher the sample rate or Nyquist frequency in the seismogram and reveals more clearly the range of frequency 1 to 10 Hz present in seismogram. whereas the linear scale FT deciphers the amplitudes of the individual frequencies clearly. Both FT plots providing the information of the frequencies and its amplitude, none of the plots are revealing the localised time evolution of frequency in the seismogram/ earthquake signal.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 1 Jan-Feb 2021, pp: 905-911 www.ijaem.net ISSN: 2395-5252



(a)



(b)

Fig 2 FT of the seismogram given in table1 s.no. 1 on (a) log-log scale (b) log linear scale

The Short-Time Fourier Transform, equation (1), consists two localised analysis window function which is non zero only in the interval (0, N-1) where N is the window length and wight function. Window function is a mathematical function which select the portion of the signal to be analyses. Actually, the temporal frequency information in a time varying time history seismogram/ earthquake signal is highly depends on the size and shape of the window function. Time histories given in table1 are analysed with different windows namely; Flat top, Blackman, Low sildelobe, Hamming and Hanning or Hann window to select a suitable window for analysis of seismograms at acceptable resolution. The STFT TFA technique suffers with resolution problem i.e. it follows the uncertainty principle which says that window either have high resolution in frequency or high resolution in time but not both at the same time. So, for all selected windows, window length has kept same i.e. window length (N) 512 sample. The STFT spectrograms of seismogram (given in s.no. 1 of table 1 and fig 1(a)) have been shown in figure3 (a) Flat Top Window (b) Backman window and (c) Lowsidelobe window with and figure 4 (a) Hamming Window (b) Hanning window with window length (N) 512 sample and 99% window overlapping. However, all seismogram given in the table 1 are analysed and studied thorough. But in this paper only STFT spectrogram of seismogram given in s.no. 1 of table 1 and fig 1(a) has discussed. All the spectrograms, see figure3 and figure 4, clearly exhibit the variation pattern of frequencies and the range of frequencies (1 to 10 Hz) with colors ramp/index present in seismogram. The colors ramp/index coding provides the information of temporal evolution of frequencies amplitude values. After thorough study of spectrogram of different windows, it has been observed that Haaning and Hamming windows (fig 4 a, b and c (enlarged view)) providing same and significant good temporal resolution of frequencies presents in seismograms/ earthquake signal than otherwindows, thus can be accepted for spectral decomposition analysis of seismograms. All the spectrograms reveal that a range of 1-10 Hz frequency are present

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 1 Jan-Feb 2021, pp: 905-911 www.ijaem.net ISSN: 2395-5252

in the recorded seismograms/earthquake signal. Since the arrival recorded time of the earthquake signals/ seismograms are assigned as 0 sec., a frequency of 5.5 Hz which has maximum amplitude is extracted from Hann spectrogram and recorded between 12.5 sec to 13.5 sec.

III. CONCLUSION:

In this paper both conventional FT and recent STFT TFA techniques have applied on recorded seismograms or earthquake signals as mention in the table 1 and figure 1. The result obtained by using these two techniques are comprehensively compared. The analysis has done with signal processing tool in LABVIEW NI software. The considered seismograms have analysed for different windows namely; Flat top, Blackman, Low sildelobe, Hamming and Hanning or Hann window to select a suitable window for analysis of seismograms at acceptable resolution. Analysis of seismogram with Haan window has provided better time-frequency resolution than another window for constant window length. The traditional FT technique used for analysis of seismogram is insufficient, because it does not reveal the temporal evolution of frequencies lies in the spectrogram/earthquake time history.

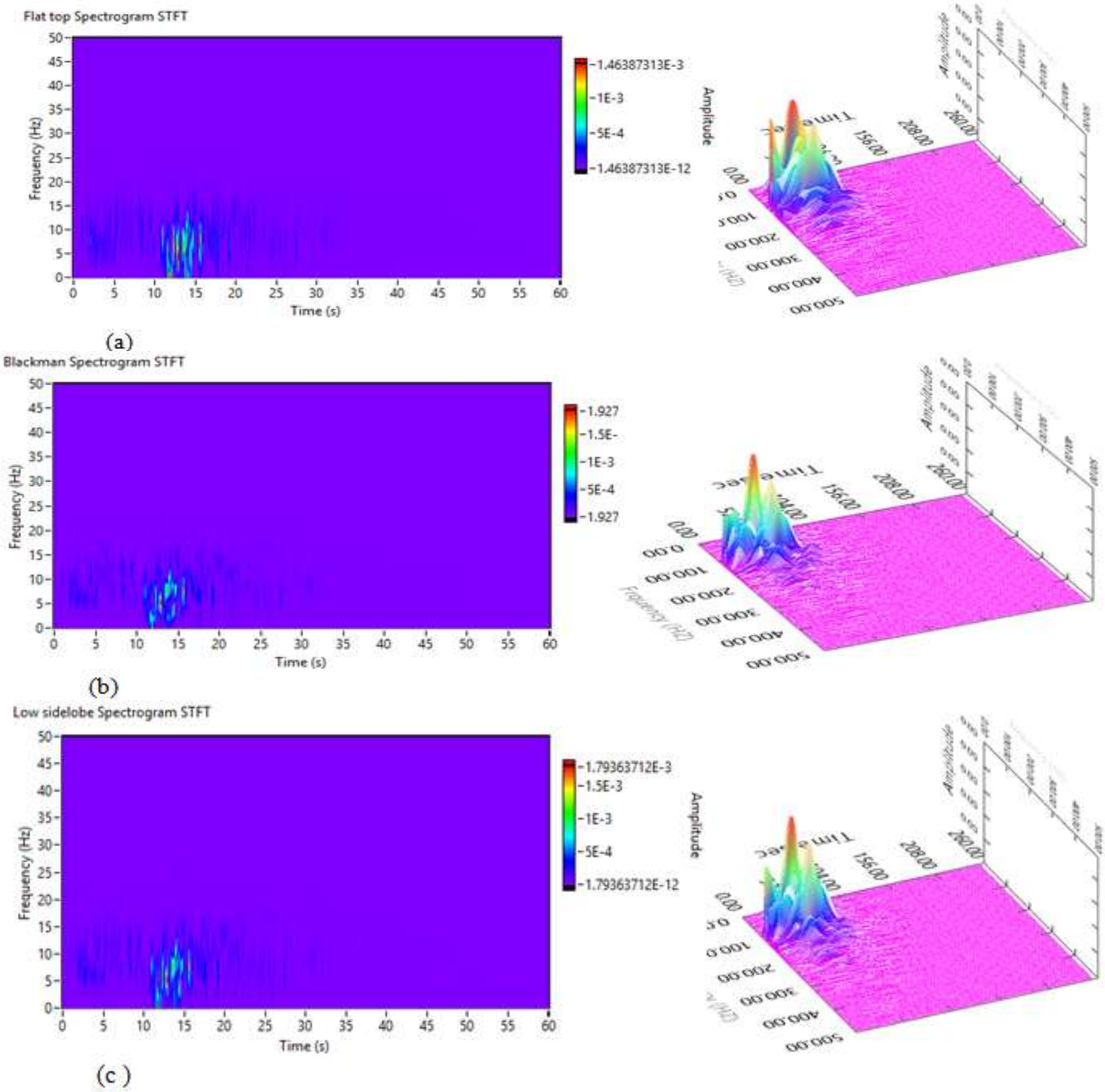
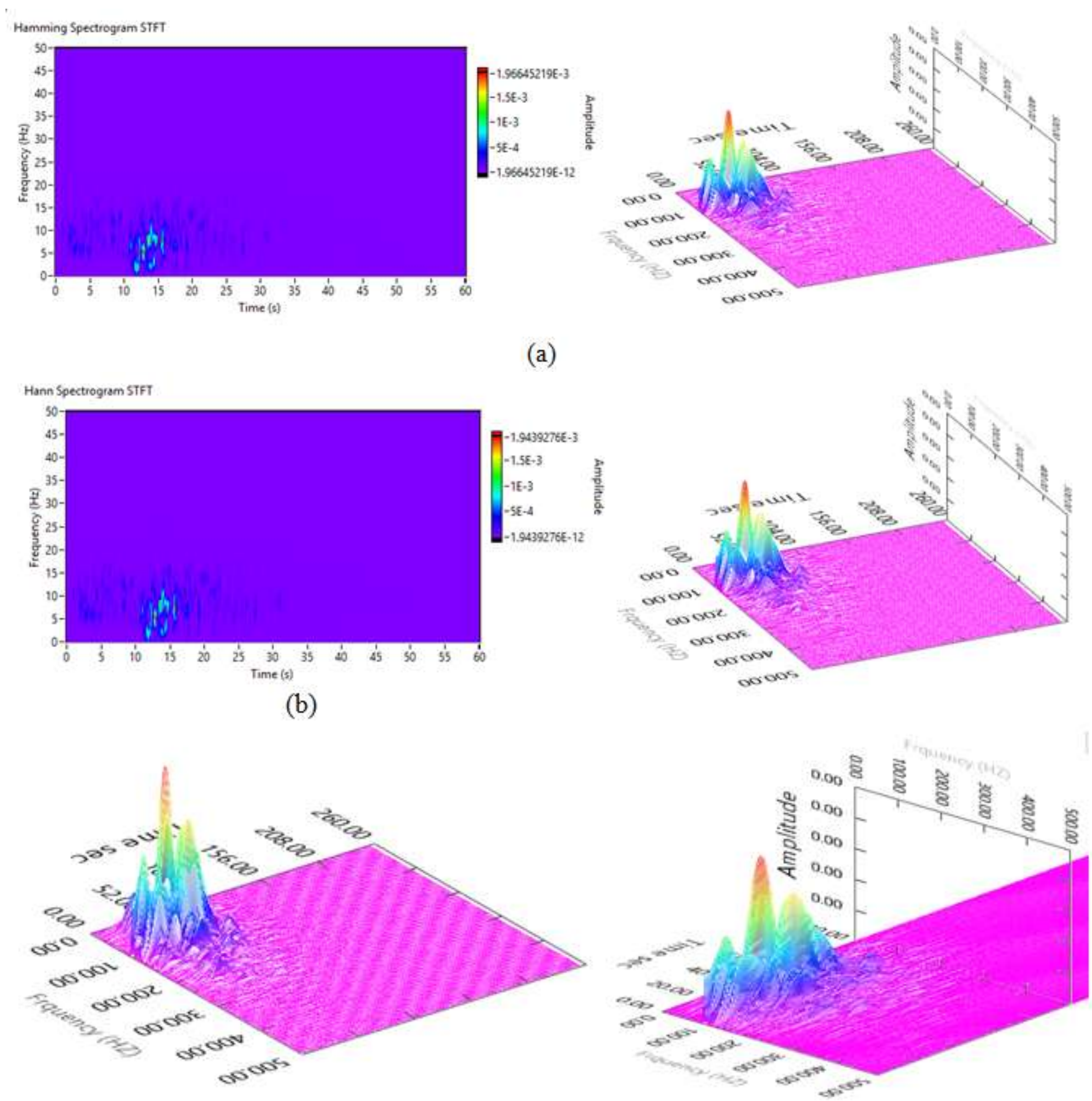


Fig.3 STFT spectrograms of seismogram (given in table1 S.No.1 fig 1a) with 3D view on the right side of spectrogram (a)Flat Top Window (b)Backman window and (c)Lowsidelobe window

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 1 Jan-Feb 2021, pp: 905-911 www.ijaem.net ISSN: 2395-5252



(c)

Fig.4 STFT spectrograms of seismogram (given in table1 S.No.1 fig 1a) with 3D view on the right side of spectrogram (a) Hamming Window (b) Hanning/Hann window and (c) Enlarge 3D view for hanning window

Whereas, recently developed STFT TFA technique provided much better information in addition to temporal evolution of frequencies. Hence STFT TFA technique is suitable for the analysis of seismogram/ earthquake time history which has time varying frequency content.

Acknowledgements

The authors would like to thank Porf. M. L Sharma for the encouraging discussions about the use of NI LABVIEW software in Earthquake Engineering filed to explore the P- and S-wave frequencies in ground motion time history. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

REFERENCE:

[1]. Agilent Technologies, 2008. Spectrum analyser with resolution bandwidth setting. Advanced Design System Documentation.

[2]. Albright, M. and Qian, S.,2001. A Comparison of the Newly Proposed Gabor Order Tracking Technique vs. Other Order Tracking Methods," SAE Paper Number 2001-01-1471.
[3]. Angrisani, L. and D'Arco, M., 2002. A Measurement Method based on a Modified Version of the Chirplet Transform for Instantaneous Frequency Estimation," IEEE Trans. I&M, vol.51, pp.704-711.
[4]. Cohen, L. ,1995. Time- Frequency Signal Analysis. Prentice Hall, New York.
[5]. Huerta-Lopez, C.I., Shin, Y. J., Powers, E. J, and Roesset, J. M., 2000. Time-Frequency Analysis of Earthquake Records. Paper 1724, Pro. of the12WCEE. Auckland, New Zealand.
[6]. Sharma M.L., Gupta S.C., Narayan J.P and Kumar A. , 2009. Seismological Network around Tehri Region Preliminary seismological bulletin, BULL 2009(I to IV), Deptt. of Earthquake Engineering IIT Roorkee.
[7]. Sharma M.L., Gupta S.C., Narayan J.P and Kumar A., 2010. Seismological Network around Tehri Region Preliminary seismological bulletin, BULL 2010 (I to IV), Deptt. of Earthquake Engineering IIT Roorkee.
[8]. Devi Vaneeta and Sharma M.L., 2016. Spectral Estimation of Noisy Seismogram using Time-Frequency Analyses International Journal of Geotechnical Earthquake Engineering Vol. 7 January-June 2016. pp.19-32.
[9]. Devi Vaneeta and Sharma M.L., 2018 Advances in Extraction of Signal from Ground Motion Time Histories using Time-Frequency Analysis In T. G. Sitharam, J. S. Vinod (Eds), Recent Challenges and Advances in Geotechnical Earthquake Engineering, (pp.1-30) DOI: 10.4018/978-1-5225-6948-0.ch001.