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Wavelet and Spectral Analysis of the *Tabla*–an Indian Percussion Instrument

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Abstract- *Tabla*is a percussion instrument, mainly used as an accompaniment in Indian classical music with vocalists, instrumentalists, and often with classical dance performers, for upholding and sustaining rhythm. The *Tabla*comprises two drums that are structurally different and produce a range of overtones. This paper describes the spectral characteristics of the most frequently played syllable *Na*over five *Tabla*variants viz. *Kali 1 C Sharp (Tipe), Pandri 2 D, Pandri 1 C, Kali 5 G Sharp,* and*Pandri 2 D (Dalya)*, using two different analysis techniques viz.1) Wavelet analysis using MATLAB,and 2) FFT using:a) Origin 8, and b) DSO in real time. Wavelet analysis is used in general for analyzing localized variations of power within a time series and to determine the frequency distribution in the time-frequency domain, while the FFT computes the transformation of the original time domain signal to a representation in the frequency domain. The FFT therefore, is used to determine the prominences viz. the overtones in the syllable played. Origin is used as it offers customizable graph templates and auto-recalculation on changes to data and analysis parameters

Index Terms - FFT, MATLAB,Origin,percussion,*Tabla*, wavelet transform

1 INTRODUCTION

The *Tabla*comprises of a pair of drums:the right-hand drum specially used for treble, referred to as the *dayan*, and the left-hand drum used for bass called the *bayan*. The *dayan* is carved from a block of dense wood whereas the *bayan* is made up of either copper, brass, aluminum. Both utilize a stretched animal skin membrane for percussion [1], [2]. The most important characteristics of the *Tabla*is loadingof the membranes: the *dayan*loaded at the center and the *bayan*loaded off-center, bothusinga mixture of flour paste with Psilomelane powder that is mined as a manganese ore in Bhavnagar region of the state of Gujrat in India.

The *Tabla*is available in five different models varying in diameterviz. *Kali 1 C Sharp (Tipe), Pandri 2 D, Pandri 1 C, Kali 5 G Sharp,* and*Pandri 2 D (Dalya)*, with diameters 13.5 cm, 13.8 cm, 14 cm, 15.1 cm and 17.4 cm respectively. The *Tabla*player is free to choose one out of these variants depending upon the accompaniment.Asingle syllable *Na* played by a professional *Tabla*player (belonging to the Centre of Performing Arts, S. P. Pune University), on each of the five models was captured for comparison.The syllable *Na*is produced by holding the last two fingers lightly against the *Syahi* and using the index finger to strike the chat region of the *Tabla*.

2 EXPERIMENTAL SETUP

The response produced by the *Tabla*is picked up by a condenser microphone (Ahuja CTP 10 DX) that is suspending in the near field over the top of right-hand side drum viz. the *dayan*. The signal is analyzed using a digital storage oscilloscope (Aplab D36040; 40 MHz) and an FFT for the same is obtained in real time.

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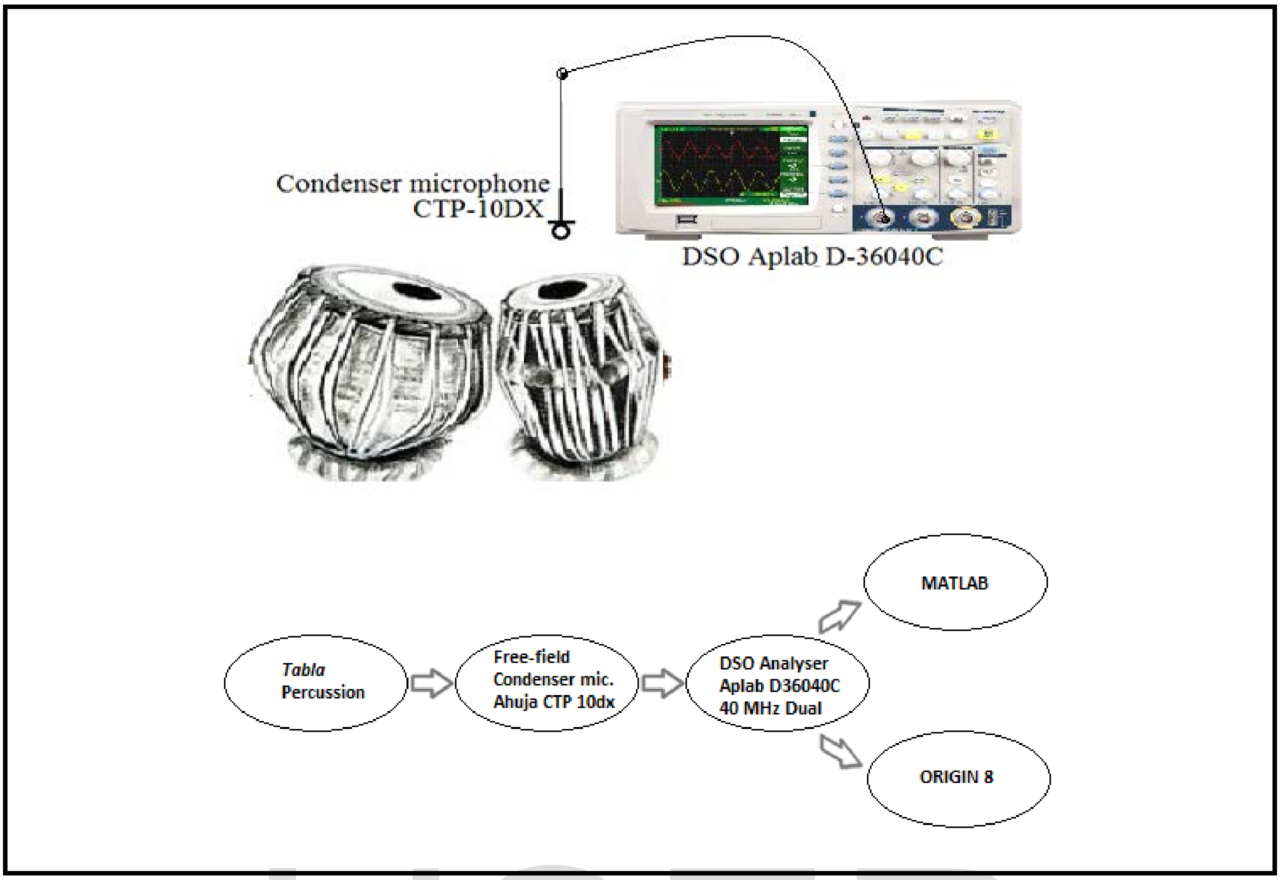

Fig. 1 Experimental Setup

3 ANALYSIS TECHNIQUES: WAVELET VERSUS FOURIER ANALYSIS

Wavelets are mathematical functions that break data into different frequency components revealing each component with a resolution matched to scale. Wavelet analysis has a marked advantage over Fourier especially when the signal comprises transients and discontinuities [3]. Fourier analysis simply breaks up a signal into sine waves of various frequencies while wavelet analysis involves breaking up of a signal into shifted and scaled versions of the mother wavelet. Wavelet analysis also brings up characteristics like trends, breakdown points and discontinuities in higher derivatives and self-similarity [4], [5]. It also significantly denoises a signal without appreciable degradation. Hence, wavelet analysis allows complex information in music and speech patterns to be decomposed into elementary forms at different positions and scales and subsequently reconstructs those with high precision [6]. Wavelet and Fourier analysis of the syllable *Na* played on the *Tabla*was carried out using MATLAB and Origin, and also by obtaining FFTs in real time using a DSO.

4 RESULTS AND DISCUSSION

Figure 2 shows the wavelet analysis of the syllable *Na* for the five differet*Tablas*viz. *Kali 1 C Sharp (Tipe), Pandri 2 D, Pandri 1 C, Kali 5 G Sharp* and the*Pandri 2 D (Dalya)*.The first two plots in blue and green represent the FFTs for the normalized and actual frequencies respectively. The first plot in the second row represents the Butterworth 10th order band-stop filter frequency applied to the original signal (sixth plot).The fourth plot shows the result of this application. Filtration is necessary in order to get rid of the background noise present in the signal. The sixth plot represents the exponentially decaying original signal. The fifth plot represents the power spectral density obtained by deploying the Welch function using MATLAB [6], [7].

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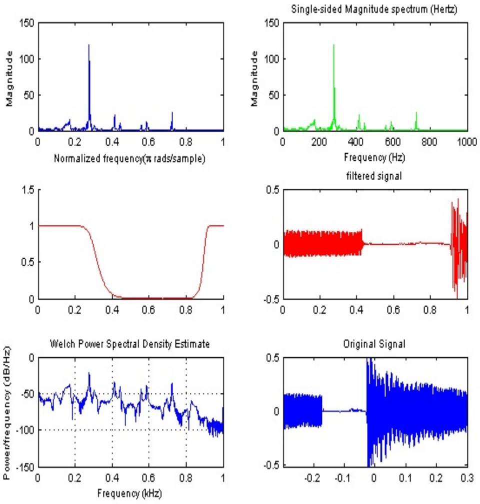
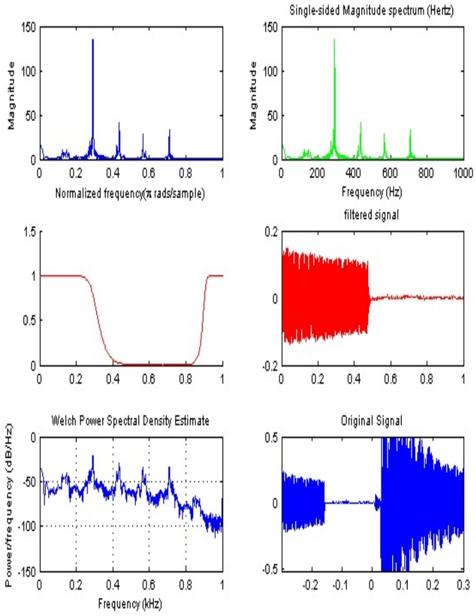
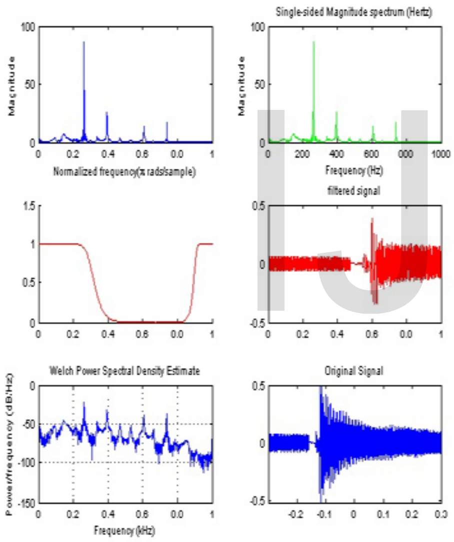


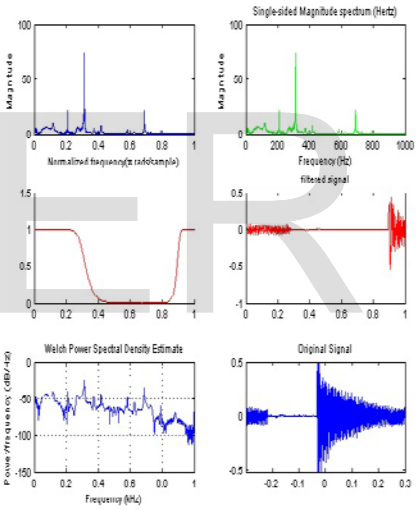
1) *Kali 1C Sharp (Tipe)*



2) *Pandri 2D*



3) *Pandri 1C*



4) *Kali 5 G Sharp*

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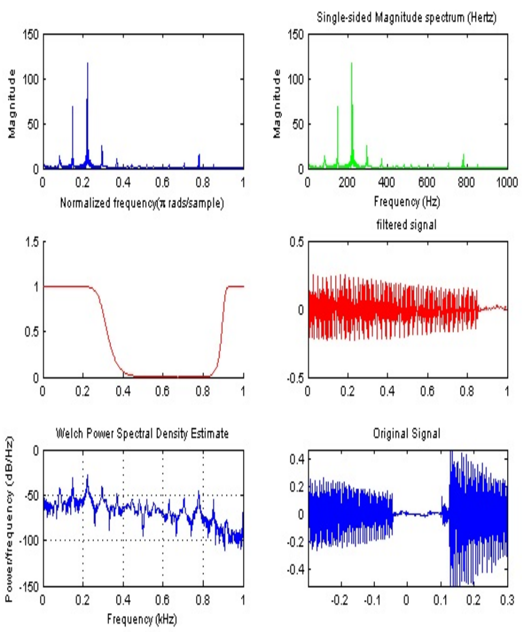
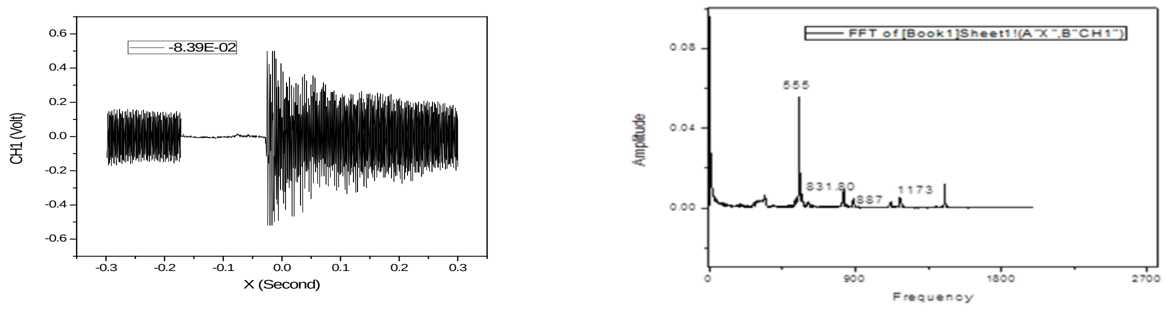


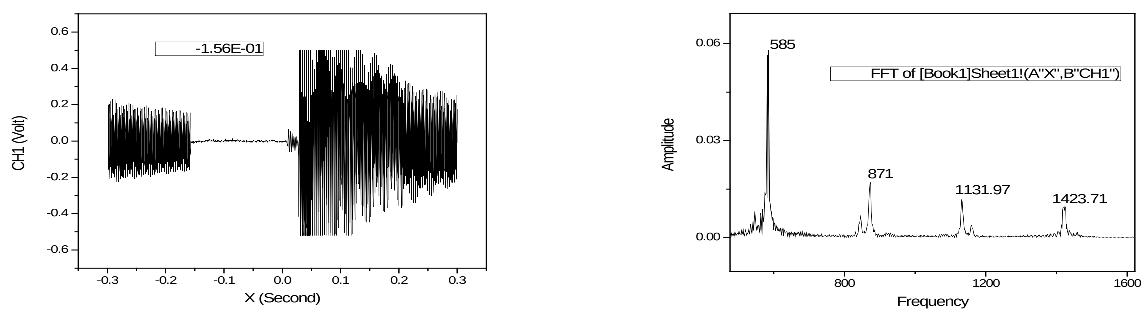
5) *Pandri 2 Dalya*

Fig. 2. Wavelet transforms using MATLAB

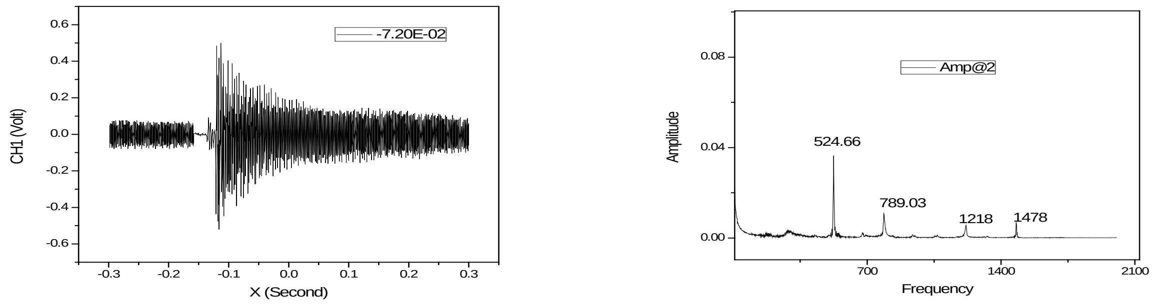
Fig. 3 shows spectral analysis using Origin: FFTfor the syllable *Na*in case of each of the five different *Tablas*viz. *Kali 1 C Sharp (Tipe), Pandri2 D, Pandri 1 C, Kali 5 G Sharp* and the*Pandri 2 D (Dalya)*. The first cell in each of the rows shows the exponentially decaying syllable amplitude while the second cell shows the FFT for the sameobtained using Origin 8.The DSO, in the process of storage, generates three files viz. write.dat, write.bmp and write.csv along with time and frequency domain bitmaps. The write.dat file is used to generate the FFT while the write.csv file is utilized for wavelet analysis using Origin 8.



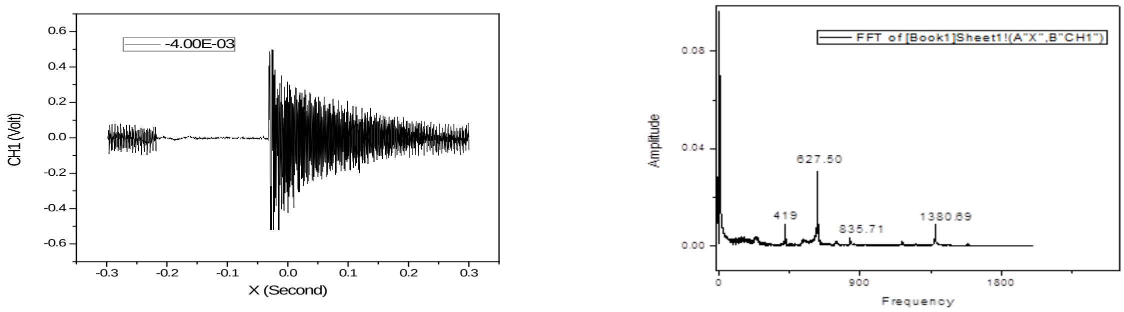
1)*Kali 1 C Sharp (Tipe)*



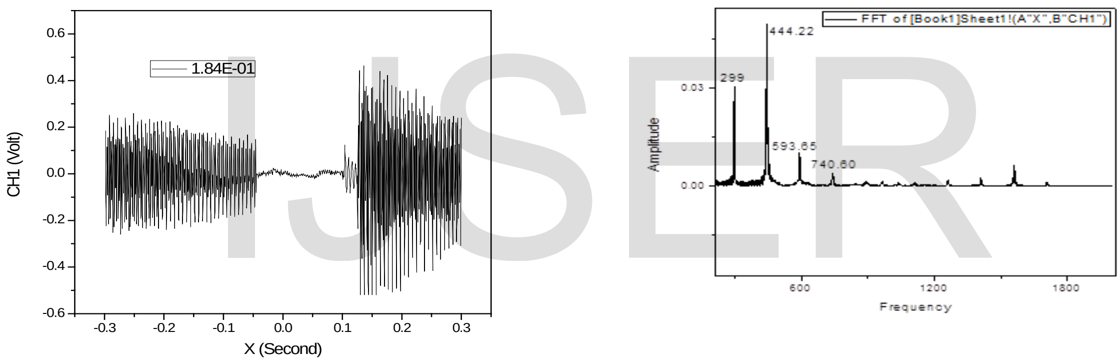
2)*Pandri 2 D*



3)*Pandri 1 C*



4)*Kali 5 G Sharp*

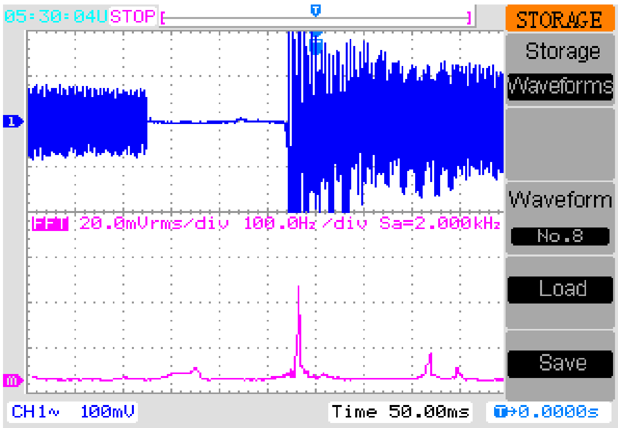


5)*Pandri 2 D (Dalya)*

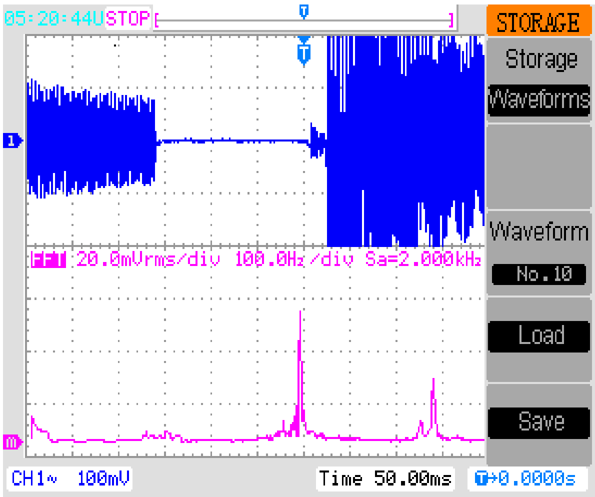
Fig. 3. Fast Fourier Transforms using Origin 8

Fig. 4 shows spectral analysis using DSO: FFT in real time for the syllable *Na* in case of each of the five different *Tablas* viz. *Kali 1 C Sharp (Tipe), Pandri 2 D, Pandri 1 C, Kali 5 G Sharp*, and the*Pandri 2 D (Dalya)*. The first cell in each row shows the exponentially decaying syllable amplitude while the second cell shows the FFT for the same obtained using the DSO. The oscilloscope utilizes three files viz. write.dat, write.bmp and write.csv concurrently to produce the bitmap on the screen.

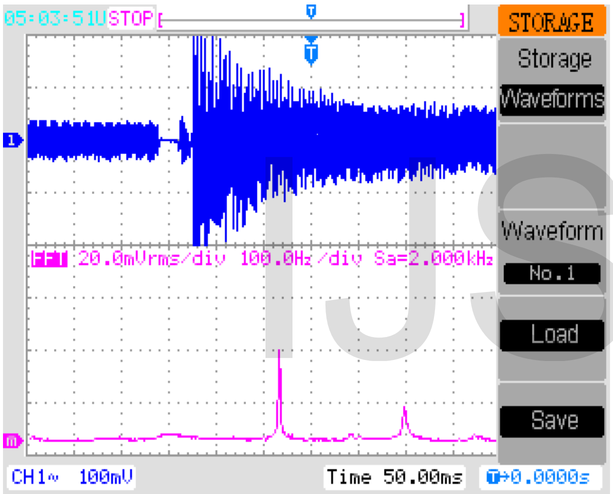
The DSO displays both, the time and frequency domain signal. The upper half within each cell shows time domain signal for the exponentially decaying syllable amplitude (*Na*) while the lower half shows the frequency domain signal viz. the FFT obtained in real time.



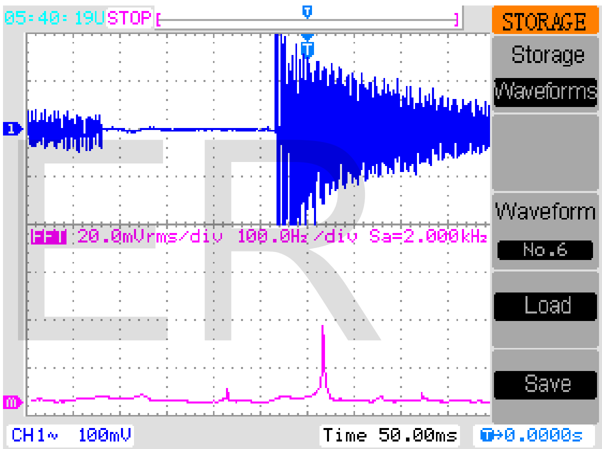
1) *Kali 1C Sharp (Tipe)*



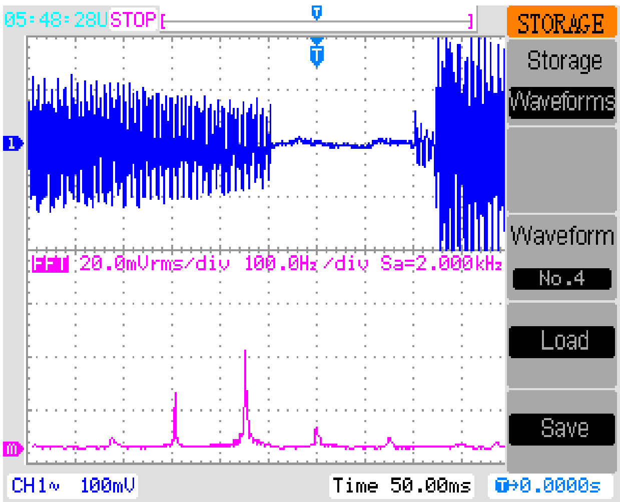
2) *Pandri 2D*



3) *Pandri 1C*



4) *Kali 5 G Sharp*



5) *Pandri 2 Dalya*

Fig. 4. Real time Fast Fourier Transforms using DSO

5 COMPARISON OF RESULTS USING DIFFERENT ANALYSIS TECHNIQUES

The bar-charts in Fig. 5 show a comparison between peak frequencies for the syllable *Na* obtained using all three techniques for each of the *Tabla*variants viz. *Kali 1 C Sharp (Tipe), Pandri 2 D, Pandri 1 C, Kali 5 G Sharp* and*Pandri 2 D (Dalya)*. Groups 1, 2, 3 and 4 respectively show peak frequency values obtained from: 1) Wavelet Analysis using MATLAB (Table 1, Column IV); 2) FFT using Origin 8 (Table 1, Column V); 3) Real time FFT using DSO (Table 1, Column VI). In each group, the first bar shows peak frequency values of the double-sided magnitude spectrum obtained using wavelet analysis, the second bar shows peak frequency values obtained using Origin 8, while the third bar shows peak frequencies obtained from the frequency domain signal using DSO.

Sr No	Type of *Tabla*	Membrane diameter cm	MATLAB	FFT (Origin 8) Hz	FFT DSO (real time) Hz
1	*Kali 1 C Sharp*	13.5	560, 820, 880, 1180	555, 831, 887, 1173	560, 840, 890
2	*Pandri 2D*	13.8	580, 860, 1140, 1400	585, 871, 1131.97, 1423.71	590, 880
3	*Pandri 1 C*	14.0	540, 780, 1220, 1480	524.66, 789.03, 1218, 1478	535, 800
4	*Kali 5 G Sharp*	15.1	440, 640, 840, 1380	419, 627.50, 835.71, 1380.69	419, 630
5	*Pandri 2 Dalya*	17.4	280, 410, 560, 750	299, 444.22, 593.65, 740.60	300, 450, 595, 750

Table 1. A comparison of peaks/overtones obtained for the syllable *Na* using various techniques

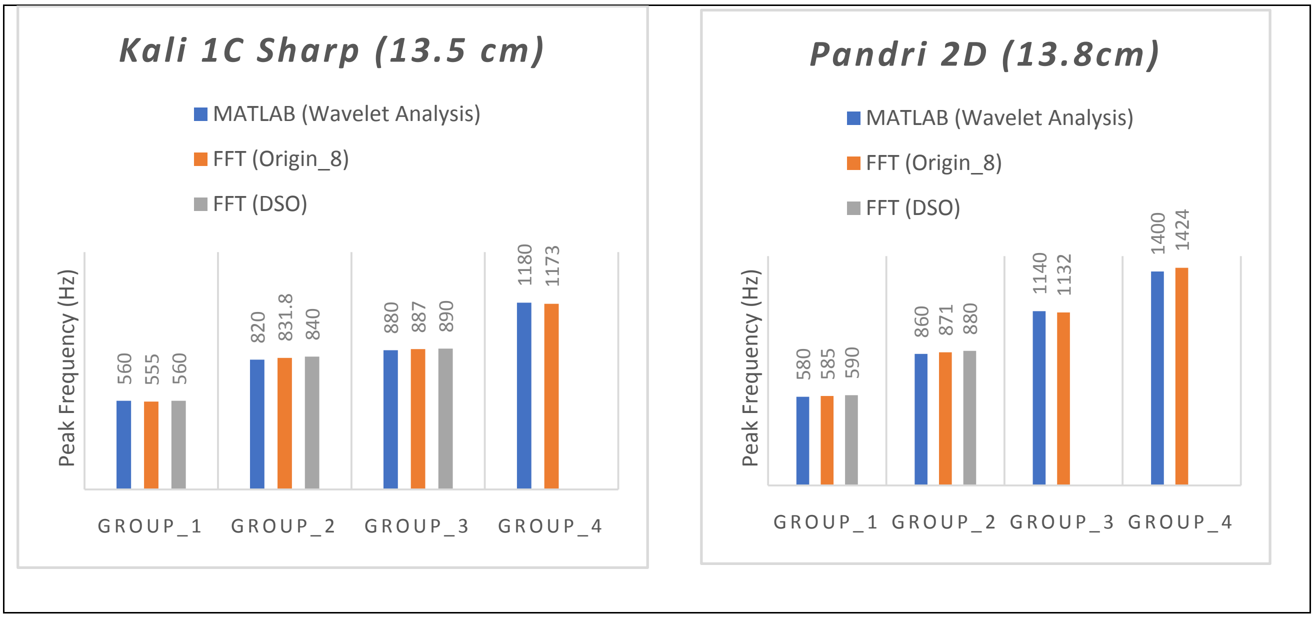


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Fig. 5. Comparison of peak frequency values obtained for the syllable *Na* using various techniques for the entire range of *Tablas*

6 CONCLUSION

The peak frequency values for the fundamental and the overtones corresponding to each *Tabla*variant viz. *Kali 1 C Sharp (Tipe)*, *Pandri 2 D, Pandri 1 C, Kali 5 G Sharp*,and the*Pandri 2 D (Dalya)*, obtained using all three analysis techniques, are found to be in agreement i.e. lie within a 5% spread one another, except for the*Pandri 2 Dalya* where, in Group 2, the values for the second harmonic lie within 10%. In addition to the fundamental even the second, third and fourth overtones show proximity. As all three techniques deliver almost equal values for corresponding peak frequencies, we could safely conclude that the analysis techniques are reliable and the values acceptable.

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