NOWROSJEE WADIA COLLEGE , PUNE

CERTIFICATE

THIS IS CERTIFY THAT MR. OMKAR DILIP GAVALI
HAS COMPLETED THE PROJECT WORK ENTITLED.

"PHYSICS OF THE GUITAR"

In partial fulfillment of B.Sc. (Physics) of Pune University

During the academic the year 2018-2019

26/02/2019

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25/04/2019

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16.03.19

Internal Examiner

16.3.2019.

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Date :- 16/3/2019

Project Summary

Title: Physics of the Guitar

Aim: • To study the physics of Acoustic guitar.

• Compare two different methods of measuring frequency of the strings, first an android application named Spectrum analyser and second using Digital Storage Oscilloscope (DSO).Comparing their observations and drawing conclusion.

• Analyse Fast Fourier Transformation (FFT) and wave graphs of all the strings, their chords and few notes.

Summary: Acoustic guitar refers to hollow bodied guitar without electric amplification with six strings namely e, B, G, D, A, E. A sound is produced when a string is vibrated and different strings vibrate at different frequencies which in turns gives us different sounds. With the help of tuning keys one can tune guitar into a standard harmonic range. A guitarist usually uses a tuner or any other android application like Spectrum analyser to tune his guitar. In order to check how accurately the android application is, readings were captured from both Spectrum analyser and DSO which is a more accurate instrument to measure frequency of a string. After comparing the readings with the DSO it can be concluded that the readings taken from The Spectrum Analyser app are not reliable. The first 3 readings that is of e, B, G strings show 1-3 % error which is tolerable but the remaining 3 strings D, A, E shows 36%, 46%, 36% error respectively. It can observe that the strings with more percentage of error are the strings with lower frequencies ranging from 100 Hz -199 Hz. With these observations it can inferred that the algorithm of the android application might not be precise for lower frequencies.

Conclusion: Wave forms of different chords and notes to see the harmonic behaviour of the strings can be studied. In this way the project included from studying the dynamics of the guitar to finding inaccuracies in an android application and finally able to study different wave forms and FFT graph of the strings on DSO.

Mr. Omkar Dilip Gavali

CHAPTER 1

INTRODUCTION :-

In this project, we have studied the frequency at which Guitar strings vibrate using an Android app and then using more reliable system Digital Storage Oscilloscope (DSO). Later ,we studied FFT and Wave form of all 6 strings , Notes, Chords .

About the Guitar :-

"Acoustic guitar" refers to hollow bodied guitar without electric amplification. The guitar is fretted musical instrument that usually has six strings the strings of a six string guitar are tuned to E, A, D, G, a fourth apart except for the major third interval between B and G. it is typically played with both the hands by strumming or plucking the strings with either a guitar pick or the fingernails of one hand while simultaneously fretting with the fingers of the other hand the sound of the vibrating strings is projected either acoustically, by means of the hollow chamber of the guitar, or through an electrical amplifier and a speaker. The tone of an acoustics guitar is produced by the strings vibration , amplified by the hollow body of the guitar , which acts as a resonating chamber. Every string has a fixed ideal frequency at which it vibrates.

About the Spectrum Analyzer :-

This allows the user to see Real time FFT Audio spectrum Analyzer for your Android device. It is a powerful audio tool to visualize and

analyze signals from android device. It provide features like scaling signal average, screenshots ,pause/resume button ,frequency marker , peak hold .

Digital Storage Oscilloscope :-

A digital storage oscilloscope is an oscilloscope which stores and analyses the signal digitally rather than using analog techniques . The input analogue signal is sampled and then converted into a digital record of the amplitude of the signal at each sample time . these Digital values are then turned back into an analogue signal for display on a Cathode Ray Tube (CRT) ,or transformed as needed for the various possible types of output-liquid crystal display ,chart recorder ,plotter or network interface.

Fast Fourier Transform (FFT) :- A Fast Fourier transform can be used in various types of signal processing .it shows various types of frequencies.It is an algorithm that computes the discrete Fourier transform (DFT) of a sequence. It shows the peak frequency when a string or chord is played.

Physics Of Guitar :-

Thicker strings vibrate more slowly, producing lower notes. Each time you pluck a string, you actually create several standing **waves**. There's the first fundamental wave, which determines the pitch of the note, but there are also **waves** called overtones, whose frequencies are multiples of the first one. Sound is transmitted via a pressure wave within a material. Such a pressure wave can form when an object,

vibrating back and forth rapidly, pushes air forward to make way for itself, then moves away again, leaving a partial vacuum behind. A string that is under more tension will vibrate more rapidly, creating pressure waves that are closer together, and hence have a higher frequency. Thicker or longer strings, on the other hand, vibrate more slowly, creating pressure waves that are farther apart, and thus that have a lower frequency. The loudness of a sound corresponds to the amplitude of a pressure wave; the higher the pressure at the peak of the wave, the louder the sound seems to us. The only real way to get a louder sound out of a string is to put more energy into the string, probably by plucking it harder.

The wavelength of a sound wave traveling through the air is the physical length of the wave. If you could freeze a sound wave in time and space (and if you could see the wave), measuring the distance from one peak of the wave to the next peak would give you the wavelength.

An open chord, as played on a guitar, is the chord that you get by strumming a properly-tuned guitar without touching the strings. A harmonic is a frequency at which a string can vibrate; the lowest frequency at which a string can vibrate is one where the wavelength of the wave on the string is twice the length of the string itself. This lowest frequency is called the "**fundamental".** The *n*th harmonic corresponds to a string wavelength of 1/*n*times the wavelength of the fundamental. An overtone is much like a harmonic; the *n*th harmonic is the (*n*-1) th overtone. One of the properties of waves, when applied

to this situation, states that only integer values of *n* can exist on a string effectively. A standing wave is a sound wave that oscillates back and forth, often either along a string or between the ends of a pipe. A node exists at the point or points where, in a pipe containing a standing wave, the pressure is equal to the ambient pressure outside the pipe.

GUITAR CHORDS.

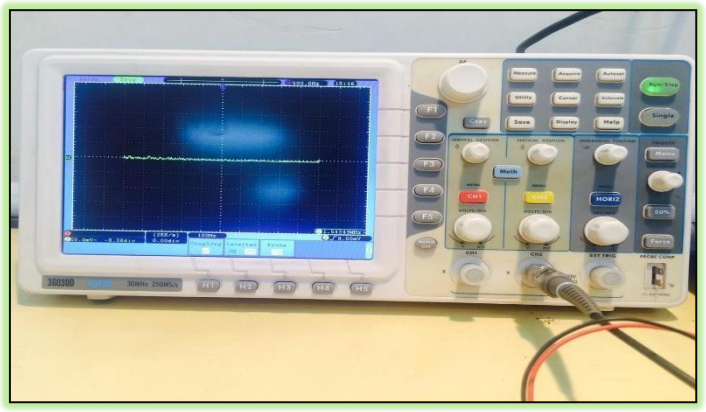
In music a Guitar chord is a set of notes played on a guitar. A chords notes are often played simultaneously.

OBJECTIVES :-

- To note the frequency of :- 1) Strings 2)Chords 3) Notes of e string using an application Spectrum Analyzer.
- Again note down the frequency using Digital Storage Oscilloscope (DSO) which is more accurate.
- Comparing the readings from the Application with the the reading observed on the DSO.
- Finding the accuracy of the android application by calculating the error percentage.
- Studying the FFT and the wave graphs Of Notes and Chords.

CHAPTER 2

PROCEDURE AND EXPERIMENTAL SET UP



A DSO as shown above is connected to a condenser microphone which is kept near the guitar to pick up the frequency of the guitar. Then we get the graph on the digital screen .Only for wave form we change the setting of the DSO.

While dynamic microphones are popular for stage use, due to their rugged construction ,condenser microphones have always been preferred type for Recordings. The one in the above picture which we used works on batteries.

We use this set up for recording the sound of the strings , guitar notes and chords. The setup remains the same for all . Some pictures of the complete setup are shown below.

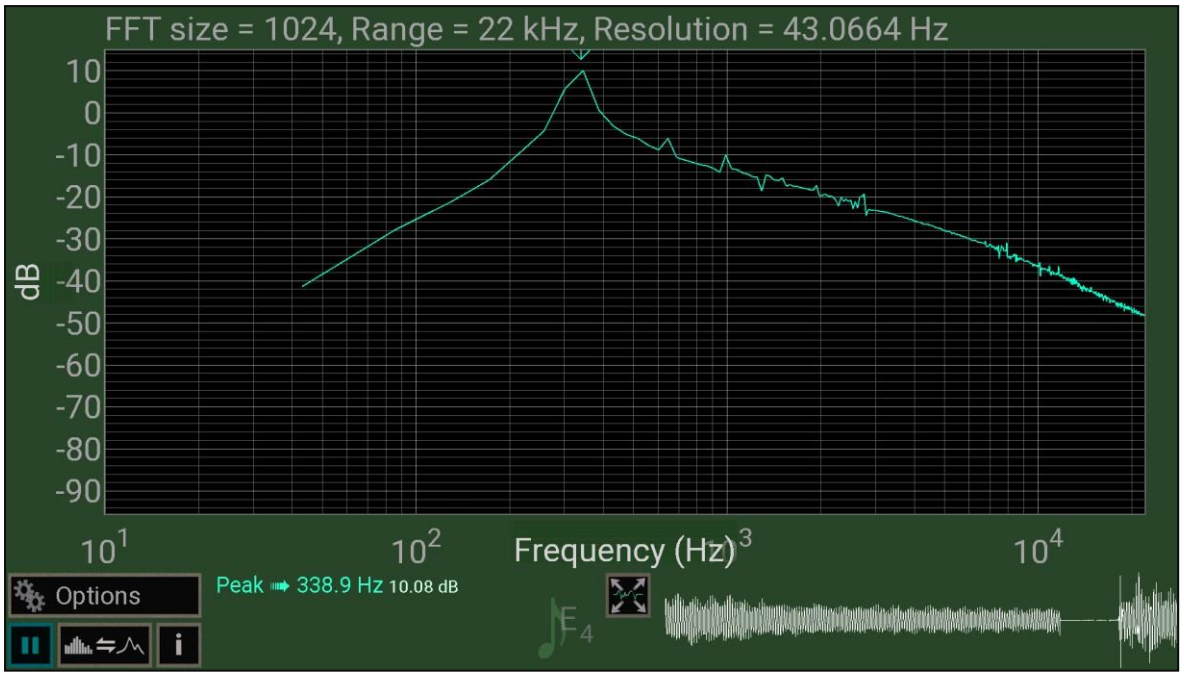
The setup consists of a guitar, DSO, crocodile wires, condenser microphone, ,a quite place .

CHAPTER 3

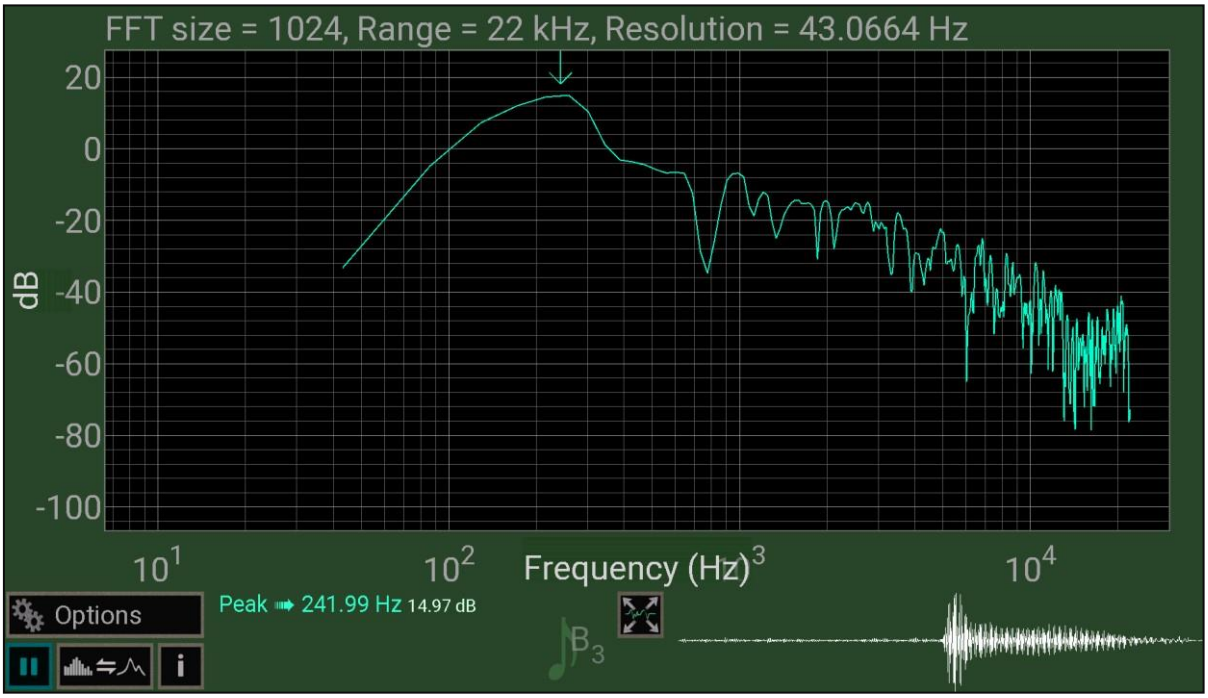
OBSERVATIONS

Recording the frequencies of the strings using spectrum analyser app.These are the observed values .

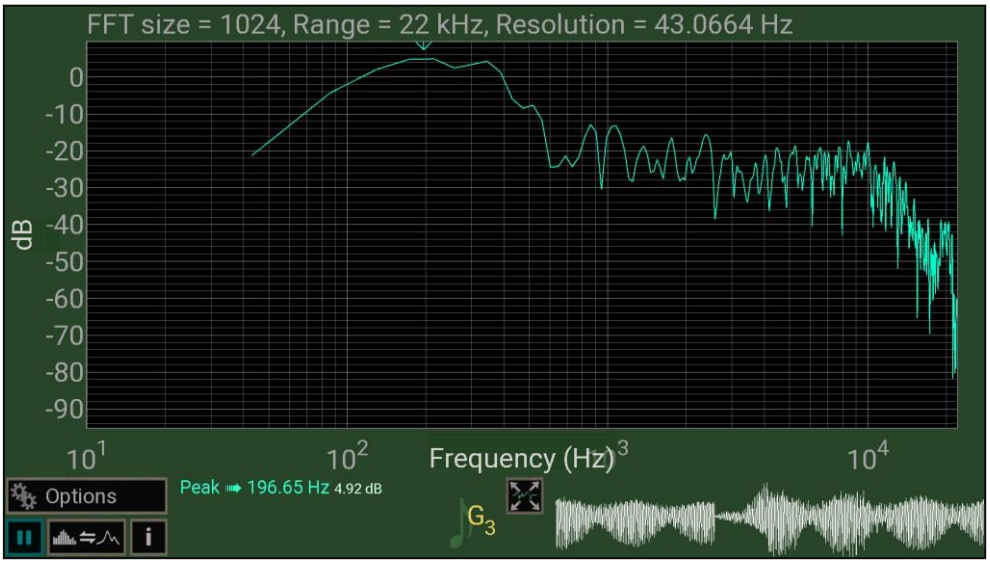
E STRING(338.9 Hz)



B STRING(241.99 Hz)

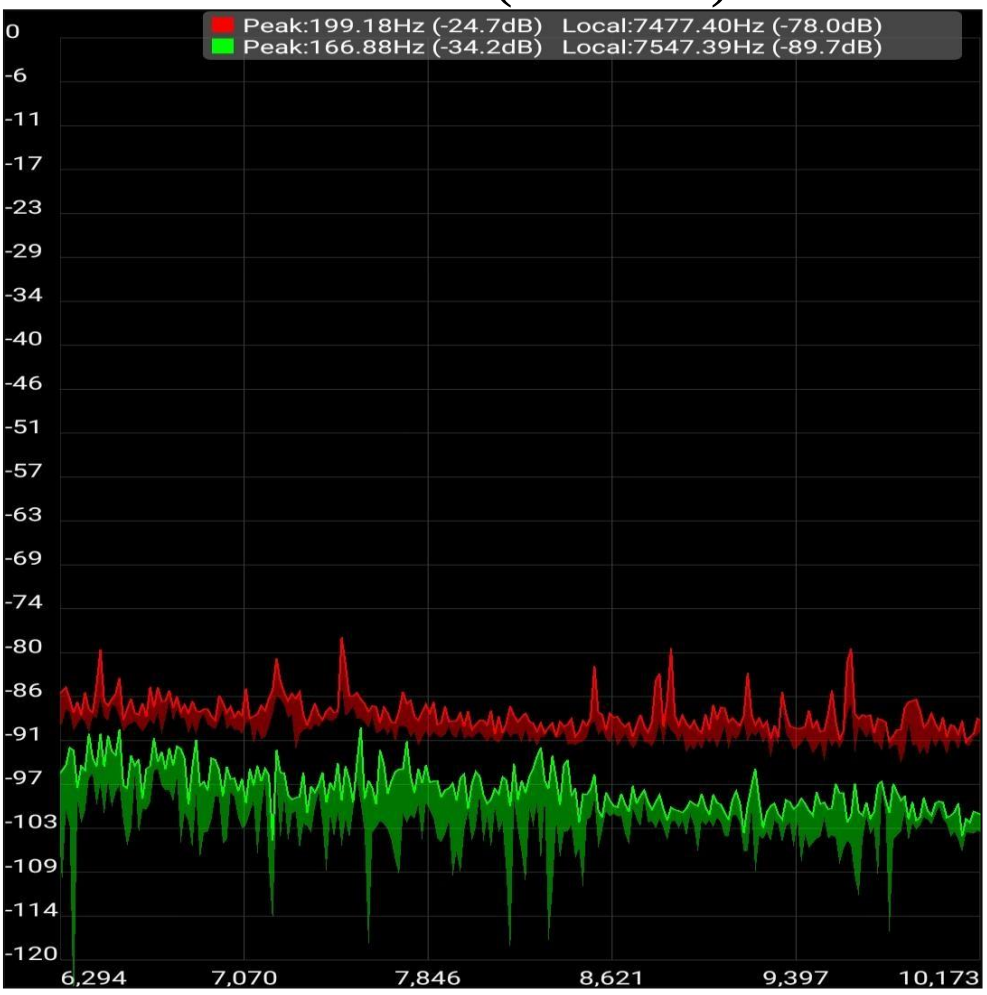


G STRING(196.65 Hz)

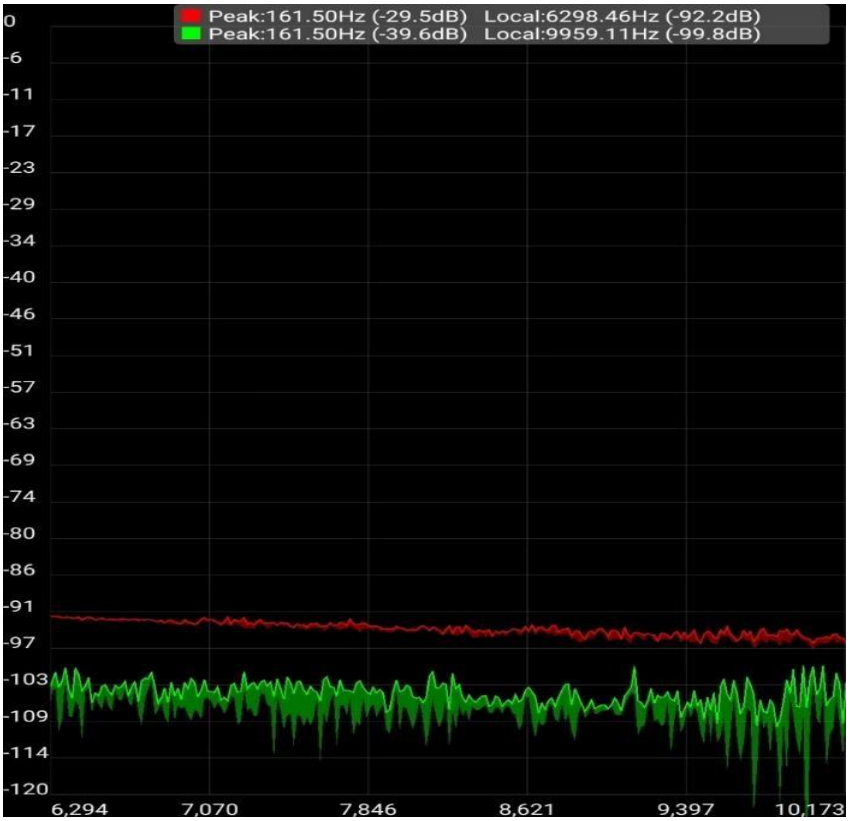


Another app which is similar to spectrum analyser.

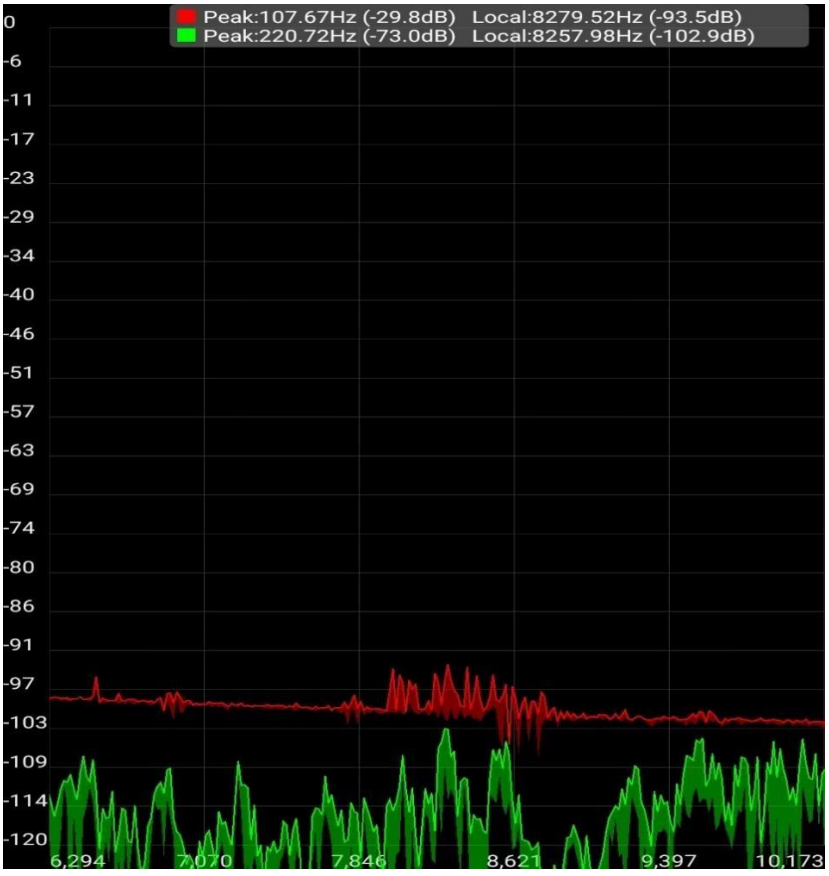
D STRING(199.1Hz)



A STRING(161 Hz)



E STRING (107 Hz)



Observation Table

String	Frequency	Scientific Pitch Notation	Observed values	Error %
1 (E)	329.63 Hz	E4	338.9 Hz	2.7 %
2 (B)	246.94 Hz	B3	241.9 Hz	2.0 %
3 (G)	196.00 Hz	G3	196.65 Hz	0.3%
4 (D)	146.83 Hz	D4	199 Hz	36.0%
5 (A)	110.00 Hz	A2	161 Hz	46.0%
6 (E)	82.41 Hz	E	107 HZ	36.0%

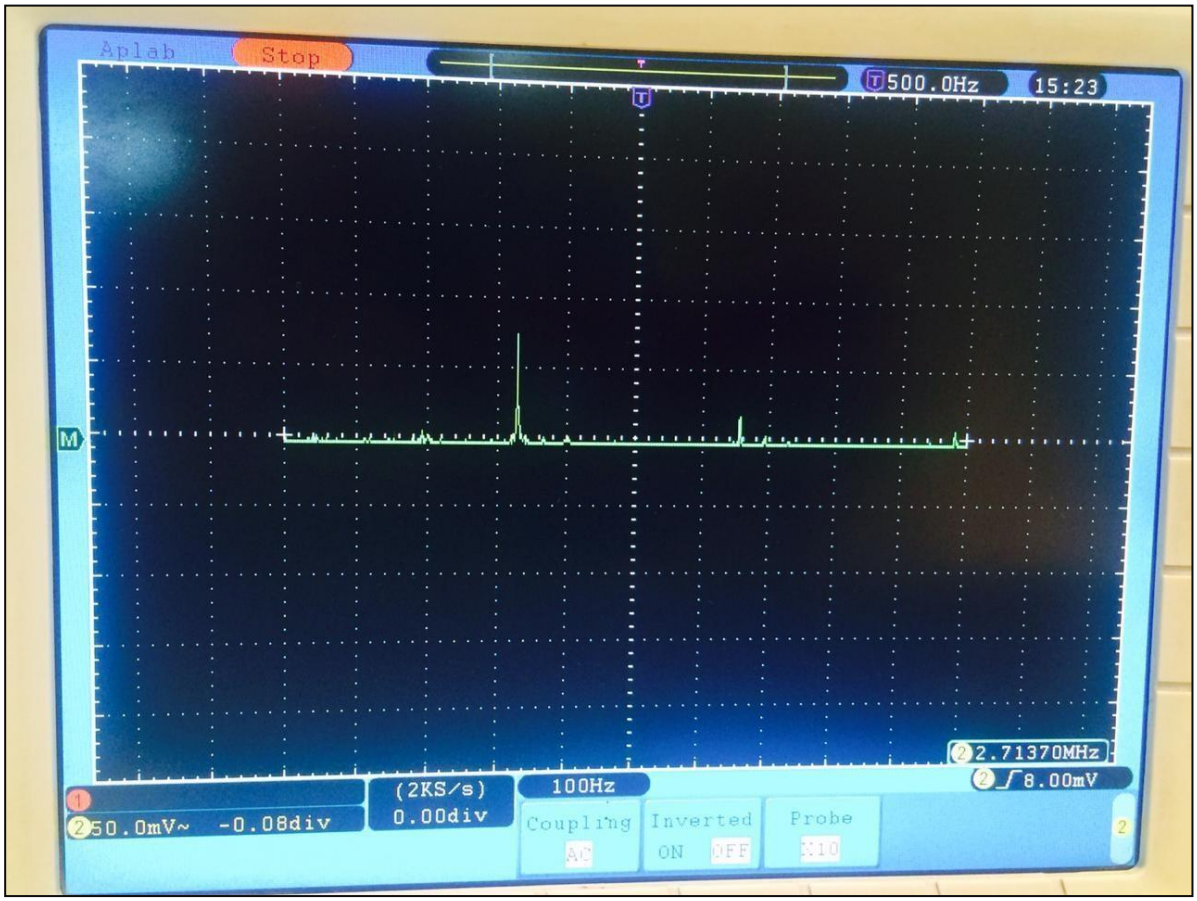
These observations conclude that the readings taken from the Spectrum Analyzer app. Are not reliable , as the first 3 readings of E , B , G strings show 1-3 % error which is fine but the remaining 3 strings D, A,E shows 36 %, 46 %, 36% error respectively. This may be because of various factors, some of them are mentioned below .

- Too much noise while recording.
- The algorithm is not accurate for lower frequencies.
- Wrong adjustment of the set up.
- String plucked wrongly .
- Too much distance between the source of the sound and mike.

These errors can be minimized if one takes care of the above things or trying a more reliable app. for this purpose. Another method to get accurate results is using DSO (Digital Storage Oscilloscope) , using DSO w also get detail information about its wave form .

Now we are going to check the frequency of the strings using DSO. Using this we get more accurate results We will check each string one by one.

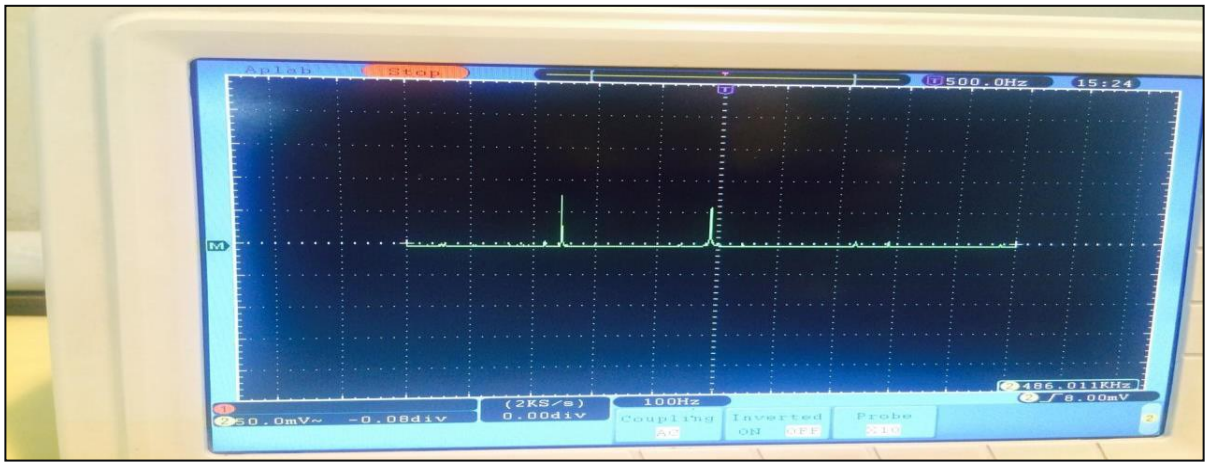
E STRING (329 Hz)



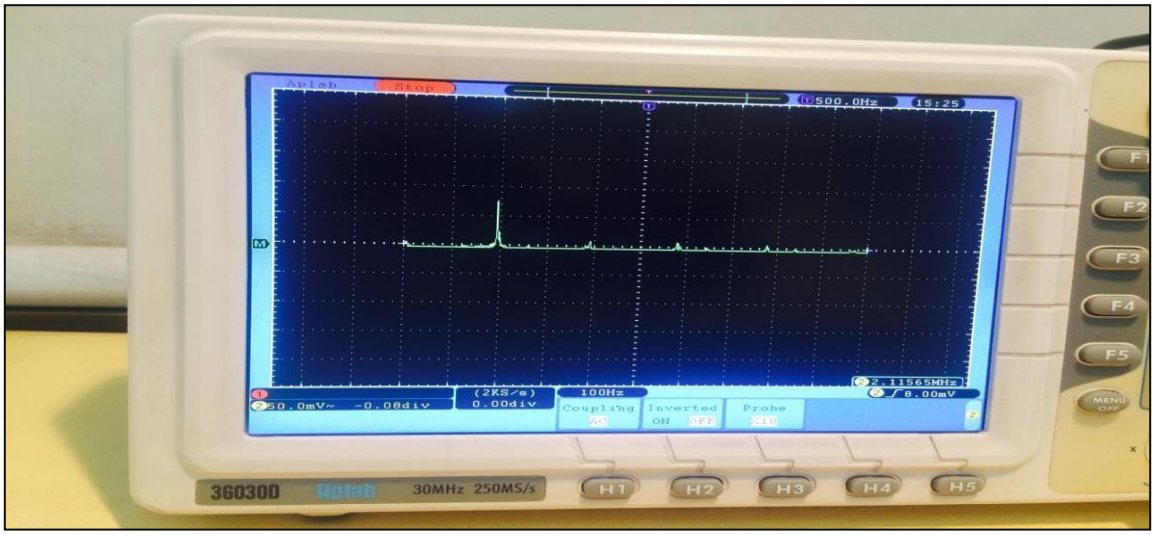
Here 1 cm = 100 Hz

So as seen above the peak is at 330 Hz .Similary we check and calculate the frequencies of other stringd. It is clear that dso shows us more accurate values. Now we continue with other strings to prove for other strings too.

B STRING (246 Hz)



G STRING (196 Hz)



E STRING (82 Hz)

As we can see above the observations taken from the DSO are very accurate . The FFT whose 1cm is equal to 100 Hz and the peak shows the frequency of that string, sometimes we see more than one peak , it is called harmonics.FFT is a graph which shows comparison between Time VS Frequency

STUDYING THE BEHAVIOUR OF 'E' STRING NOTES USING FFT AND WAVE FORM

NOTES ON E STRING	EXPECTED VALUE
F	349.2 Hz
F#	370 Hz
G	392 Hz
G#	415 Hz
A	440 Hz
A#	466 Hz
B	493 Hz
C	523Hz
C#	554Hz

Now as we found out that DSO is more accurate now we will study the notes of the E string which is also the first the most thinnest.

We will see the peak frequency as well as well as its wave form. To obtain the wave form we have to set the DSO to wave form display. This analysis will help us understand the behavior of the strings ,as we study the notes frequency which just increases as we move to the next fret of the E string.