# Effects of String Tension to Fundamental Frequency of Sound and Body Vibration of Sape

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**ABSTRACT** Sape is one of the popular stringed type traditional musical instruments in Sarawak, Malaysia. It was normally played to a form of ritualistic music to induce trance in the past. It is now gradually became a social instrument to accompany dances and for entertainment and therefore, there is a growing interest in this instrument. This paper discusses the effects of the string tension to the sound frequency and body vibration produced. This effect was investigated using three sapes made from the same wood but with different sizes. The study began by tuning the string of the instrument into three different tensions (high, medium & low). The string was plucked as in ordinary play which causes the body of the sape to vibrate, and at the same time generate sound. The sound signal was recorded using a microphone simultaneously with the body vibration signal using an accelerometer. These signals were then analyzed in MATLAB to obtain the fundamental frequency from the frequency spectrum. It was found that for high and medium string tension, the fundamental frequency of both the body vibration and sound of the sape give similar values. However, when the string tension is low, the fundamental frequency of the sound produced was higher compared to body vibration. This could be because string at higher tension modifies the vibrational mode of the sape body according to its frequency.

**KEYWORDS:** Sape; traditional musical instrument; fundamental frequency; string type musical instrument; tension effects.

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## INTRODUCTION

Due to the increase in awareness to preserve and protect local cultural, over the past, several researches have been carried out on local traditional musical instruments in Malaysia, and most of them were started from the frequency characteristics of the sound production. In the Peninsular of Malaysia, for example, Ismail *et al.* (2006) has studied the properties and characteristics of sound produced by kompang, a Malay traditional musical instrument. Computer music synthesis was used for the analysis of the sound produced. Kompang is noted as a pitch less musical instrument and it is similar to other vibrating circular membrane instruments.

In Sabah, Ong & Dayou (2009) initiated the study on Sabah traditional musical instrument called *sompoton*. They studied the frequency spectrum produced by the sompoton and managed to compare the sound produced by sompoton with open-end pipe model. Further research on sompoton was carried out by Wong *et al.* (2013) on the vibrator of the sompoton. They excited the vibrator of sompoton using a wind jet to produce sound, and the sound production mechanisms were analysed using cantilever beam model. Vibrator made from different type materials were used to facilitate a better understanding the importance of the vibrator. Theoretical and experimental results were compared and they managed to prove that the experimental result complied with the theoretical result with some deviation. A correction factor was then added to the theoretical formula.

In a different development, Batahong & Dayou (2002, 2003) performed investigation on *Kulintangan*, Sabah traditional musical instrument. The authors studied the fabrication process of the instrument, vibrational modes and sound frequency produced by the instrument. Batahong *et al.* (2014, 2016) also did a similar study on another type of Sabah traditional musical instruments which is *Sundatang*. The research was carried out to understand the vibrational properties of the sundatang soundboard. The measurements were carried out by obtaining the FRF and modal parameters of the top plate and back plate of sundatang. The outcome of the research provides important information about the study of the quality development of sundatang.

Sarawak is blessed with local musical arts and musical instruments from different ethnics. Despite the efforts of these studies on local musical instruments, the research on local Sarawak musical instruments remains untouched. Among them, sape or sapeh is one of the most popular traditional musical instruments among local residents in Sarawak. Sape is categorized as stringed type instrument and in general, has a shape similar to a guitar. It is carved from a single bole of soft wood, usually from *meranti* or *merdang*. The elongated body is hollowed out and is said to function as a resonator. The strings were made from the sago tree originally, but now these have been replaced by nylon or steel strings. The common sape usually has three or four strings. Figure 1 and Figure 2 show the schematic drawing and the actual photo of a sape that used in this study, respectively.

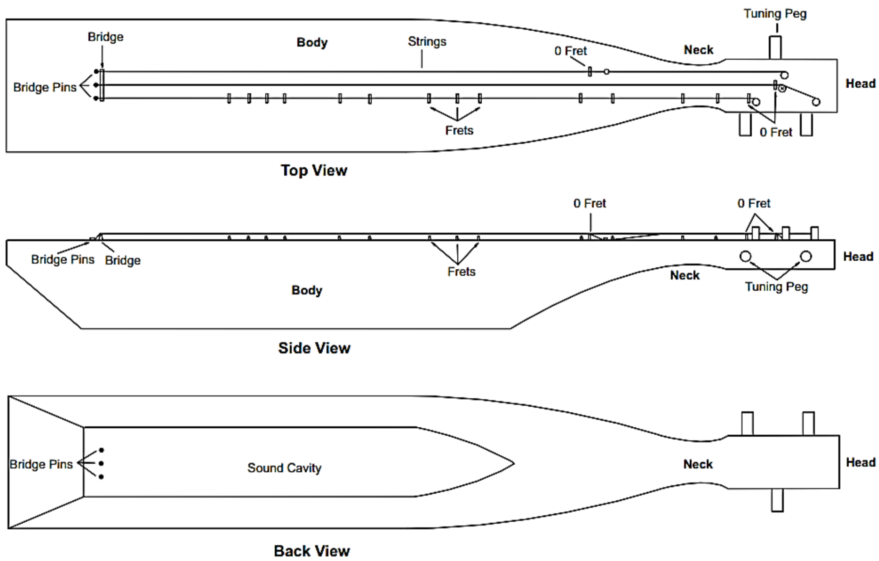


**Figure 1**: Schematic Drawing of sape

**Figure 2:** Traditional Musical Instrument, Sape.

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To shed light on this traditional musical instrument, sape, this study presents the empirical findings on the effects of string tension to the sound frequency and body vibration produced by the sape. These findings suggest the need for further research development on this local traditional musical instrument.

## BACKGROUND THEORY

*Wave Velocity in String*

The wave velocity of a traveling wave, $c$ in a string, is proportional to the square root of the tensional force, $T$ of the string and inversely proportional to the square root of the linear density, $\mu$ of the string.

$$c = \sqrt{\frac{T}{\mu}} \tag{1}$$

The wave velocity is also equal to Eq. (2)

$$c = f\lambda \tag{2}$$

where $f$ is the frequency and $\lambda$ is the wavelength.

*Fundamental Frequency of String*

The fundamental frequency is obtained from the lowest frequency mode where the length of the string, $L$ is equal to the half of the wavelength. Combining Eq. (1) and Eq. (2), gives

$$f = \frac{1}{2L}\sqrt{\frac{T}{\mu}} \tag{3}$$

## METHODOLOGY

A laboratory experiment was conducted on three different sizes of sape, and the setup is as shown in Figure 3. The sape was fixed at both ends on a holder to minimize the movement of the instrument and is allowed to vibrate freely when the string was plucked. The microphone was placed above the instrument, and the accelerometer was attached to the body of the instrument. The strings was tuned into three different notes, note C5 for high tension, A#3 for medium tension and note F4 for low tension. The tuned string was then plucked using finger with constant plucking force to generate the sound. The sound generated was recorded using the microphone and the response of the body vibration from the plucked string was captured using an accelerometer. All of the data obtained from the experiment were analyzed using MATLAB.

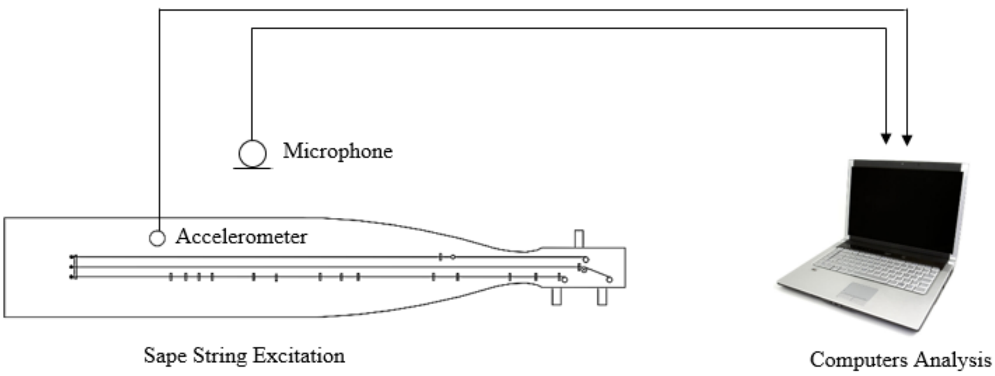


**Figure 3:** Experimental setup for the sound and vibration recording, and data analysis.

## RESULT AND DISCUSSION

The fundamental frequency of the sound generated by the three sapes when the string at different tensions was plucked is shown in Table 1, 2, and 3. The tables also show the corresponding fundamental frequency of the vibration of sape's body as the string was plucked. It can be seen that in general, the fundamental frequency of the sound generated by the sape and the corresponding body vibration increases as the string tension increase as stipulated in Equation (3).

**Table 1**. Fundamental frequency of sound and vibration of big size sape at different string tensions

| Tension | Sound/vibration | Fundamental Frequency, $f_0$, (Hz) | Amplitude, (dB) |
|---|---|---|---|
| High, C5 | Sound | 519.6 | 326.5 |
| | Vibration | 519.7 | 309.5 |
| Medium, A#3 | Sound | 346.0 | 24.29 |
| | Vibration | 346.0 | 40.3 |
| Low, F4 | Sound | 240.4 | 4.49 |
| | Vibration | 237.8 | 2.71 |

**Table 2.** Fundamental frequency of sound and vibration of medium size sape at different string tensions

| Tension | Sound/vibration | Fundamental Frequency, $f_0$, (Hz) | Amplitude, (dB) |
|---|---|---|---|
| High, C5 | Sound | 516.1 | 44.66 |
| | Vibration | 516.2 | 88.39 |
| Medium, A#3 | Sound | 350.2 | 83.84 |
| | Vibration | 351.2 | 9.26 |
| Low, F4 | Sound | 248.6 | 14.08 |
| | Vibration | 238.4 | 3.07 |

**Table 3.** Fundamental frequency of sound and vibration of small size sape at different string tensions

| Tension | Sound/vibration | Fundamental Frequency, $f_0$, (Hz) | Amplitude, (dB) |
|---|---|---|---|
| High, C5 | Sound | 521.5 | 85.93 |
| | Vibration | 521.9 | 134.4 |
| Medium, A#3 | Sound | 352.3 | 28.78 |
| | Vibration | 353.4 | 12.92 |
| Low, F4 | Sound | 239.7 | 7.38 |
| | Vibration | 229.3 | 4.48 |

Detail examination of the fundamental frequencies given in the table shows that at higher string tension, the fundamental frequency of sound generated by the sape is almost the same with the body vibration, regardless of its size. However, as the tension reduced, there are some deviations between the value of the fundamental frequencies of sound generated by the sape and the corresponding body vibration, in the range of 3 Hz to 10 Hz. This difference could be due to the fundamental free vibration of the sape body which is different from any given frequency of a musical note.

As in every engineering structure, the sape body alone (without string) has its own fundamental vibration mode that occurs at certain frequency. When the string is fitted on the sape, the vibrational mode is gradually rearranged as the string tension is increased to a point where the frequency of the body's fundamental vibrational mode is synchronized with the whole instrument so that its frequency is coincides with the frequency of sound produced. At this point, the instruments is said to be tuned to a certain musical note, and not before.

## CONCLUSION

The present study was carried out to determine the effect of the string tension to the frequency of sound produced by the sape, and its relationship with its body's vibration. In general, the fundamental frequency of the sound produced by the instrument increases as the tension of the string increased. In particular, it was found that at the low string's tension, the fundamental frequency of the body's vibration is different from the sound produced by the instrument as a whole. However, as the string's tension increased, the frequency of the body's vibration gradually increases and getting closer to the sound produced, until to a point where they coincide. At this point, the instrument is said to be correctly tuned to a certain note (or frequency) where a clear tonal sound is heard from the instrument. This would correspond to a narrower peak of sound frequency in its spectrum at the frequency where it is tuned.

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