FREQUENCY CHARACTERISTICS OF SOUND FROM *SOMPOTON* MUSICAL INSTRUMENT

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ABSTRACT. *'Sompoton' is one of the most popular traditional musical instruments among local residents in Sabah. The sound generated by the instrument is unique and attractive and its architecture contains a gourd, which had been dried up with eight pieces of bamboo (pipe) inserted into it. A measurement has been carried out to determine the frequency characteristics of sound of the 'sompoton' in its original forms. Frequency values obtained from the measurement were then compared to the frequency predicted by using the closed-end pipe and open-end pipe model. It was found that the generation of harmonic frequency by the 'sompoton' follows the open-end pipe model. However, the generation of the fundamental frequency does not comply with any of the models. This has opened for possibility to the establishment of a new model for 'sompoton'.*

KEYWORDS. Musical instruments, frequency analysis, pipe model, harmonic frequency.

INTRODUCTION

Sabah is rich with local musical arts and instruments from different clans (Williams 1961). Music in Sabah have been an important part of most of the social activities for the indigenous people. Most of the musical instruments in Sabah are made from natural resources, for instance *tongkungon, turali, suling* and *sompoton* are made from bamboo. Musical instruments in Sabah have been categorized as membranphones (e.g. *gendang* and *kompang*), aerophones (e.g. *suling, turali, sompoton* and *kungkuvak*), codophones (e.g. *biola, tongkungon, sundatang* and *gambus*) and idiophones (e.g. gong, *kulintangan, togunggak, bungkau, turuding* and wooden castanet) (Frame, 1982; Pugh-Kitingan, 1992&2000).

The traditional music of the native is slowly dying out (Liew, 1962). Many traditional popular songs which were played half a century ago are slowly being eroded by time and the younger generation prefers modern music such as Hip Hop, Rock, R & B and so on. For this reason, the Kadazan section of Radio Sabah has started taking steps to collect traditional songs (Liew, 1962). Some of the personnel from this section had also visited some villages at urban area to search for suitable broadcasting material especially classic songs which are now only known by older generation.

With the decline in the art of playing these instruments, there is loss of skill in making them too (Liew, 1962). Foreign materials are now being used in making traditional musical instruments such as steel strings for the *sundatang* and the *tongkungon* which would definitely alter the musical quality of the instruments. Another reason for the decline of native instruments is the fact that they are traditionally tuned to a pentatonic or five notes, scale which is unsuitable for playing most western melodies.

Past researches related to *sompoton* are all about its history, ethnics that play the instrument and the making of the instrument. However, none of the research discussed about the acoustics characteristics of *sompoton.* The present investigation is therefore timely right to help in preserving the dying musical instrument. It is our hope that this paper will initiate a more active research on local musical instruments as well as to understand the physics mechanisms associated with them.

Basic Structure Of Sompoton: *Sompoton* consists of eight pieces of bamboo pipe inserted into a dried gourd, which are arranged in two layers of raft-like configuration. Figure 1 illustrates the basic structure of the instrument. Seven of the bamboo pipes are named according to local terminology and they are *lombohon, monongkol, suruk, baranat, randawi, tuntuduk* and *tinangga* as shown in the figure. The eighth bamboo pipe, which is one of the *lombohons* does not produce sound and it serves just to balance the structure.

Lombohon, monongkol and *suruk* are arranged in one layer together with the eighth pipe whereas *baranat, randawi, tuntuduk* and *tinangga* are arranged in the second layer. They are normally tightened up using a cane string and stick together using bee wax, or *sopinit* as it is known locally, at the lower end. The firmly arranged pipes are then inserted into square hole of the dried gourd and the space between them is filled with bee wax to make the structure firm.

Sound Generation Inside A Pipe: As has been mentioned before, *sompoton* consists of bamboo pipes. Basically, sound of the *sompoton* is generated from these pipes, which can be considered as cylindrical pipe. For a cylindrical pipe, there are two basic models to describe the mechanisms of the generation of sound which are opened-end and closed-end pipes.

The opened-end model is shown in Figure 2. For the fundamental frequency, the air flows inside the pipe generates standing waves which has a nodal point at the middle of the pipe and anti-nodal point at both ends. Such pipe generates sound that has fundamental frequency given by (Okamoto & Tanaka 2002), without end correction

$$f_0 = \frac{v}{2l} \tag{1}$$

where v and l are the speed of sound in air and the length of the pipe, respectively. The first and second harmonic can be written in terms of the fundamental frequency as, respectively

$$f_1 = 2f_0 \tag{2}$$

$$f_2 = 3f_0 \tag{3}$$

Therefore, in general, it can be written that for an opened-end pipe,

$$f_m = (m+1)f_0 \tag{4}$$

where m is the harmonic number given by 1, 2, 3 ....

The standing wave of the fundamental frequency inside a closed-end pipe is shown in Figure 3. The wave has a nodal point at the closed-end of the pipe whereas at the open-end is the anti-nodal point. For this configuration, the fundamental frequency is given by (Okamoto & Tanaka 2002)

$$f_0 = \frac{v}{4l} \tag{5}$$

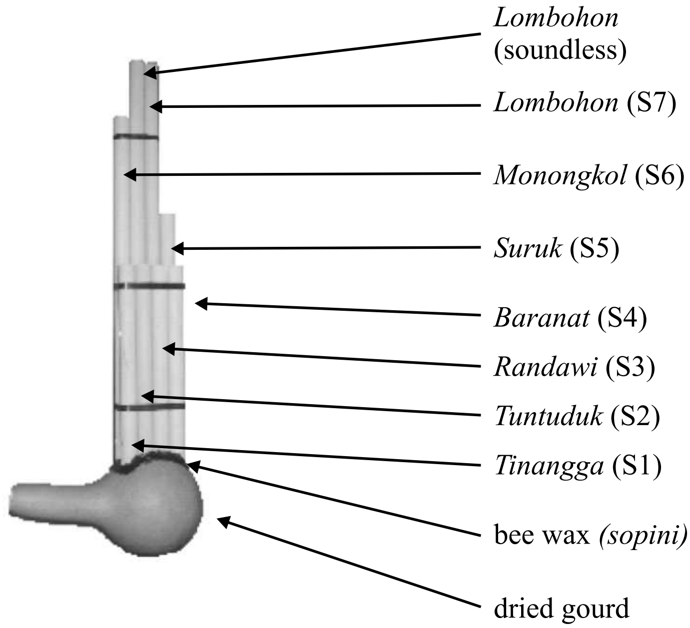


Fig. 1. Basic structure of sompoton

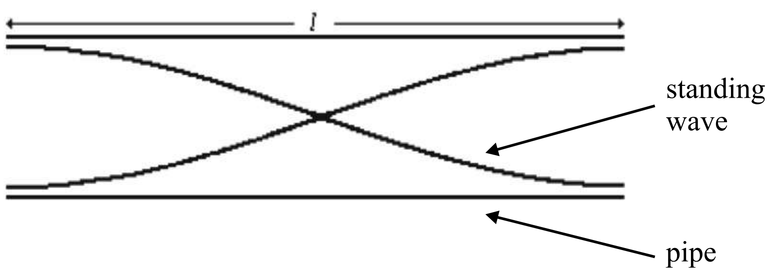


Fig. 2. Standing wave for fundamental frequency inside an open-end pipe

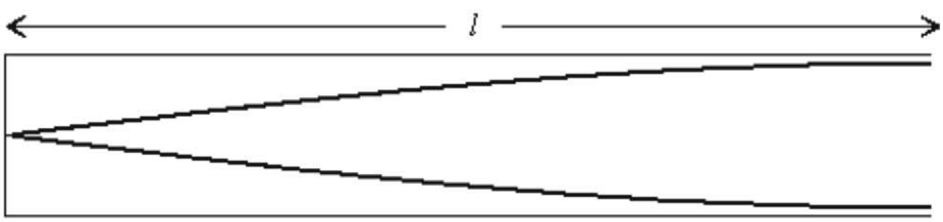


Fig. 3. Fundamental frequency in a closed-end pipe

As a result, the first harmonic can be written as

$$f_1 = \frac{3v}{4l} \tag{6}$$

or

$$f_1 = 3f_0 \tag{7}$$

and second harmonic is given

$$f_2 = 5f_0 \tag{8}$$

Therefore, the higher harmonic number, which is given by

$$f_m = \frac{(2m+1)}{4} f_0 \tag{9}$$

where m is the harmonic number given by 1, 2, 3, ... These two models are used as reference in the investigation.

RESULTS AND DISCUSSION

The sound from *sompoton* was first recorded into a computer using a high quality microphone type 4190 by B&K in the anechoic chamber, Universiti Malaysia Sabah. The microphone was placed horizontally where the cartridge is about 50 cm pointing towards the vertically blew *sompoton.* The microphone, acting as a transducer, converts analog sound signal into electrical signal which later converted into digital form by an analog-to-digital converter (ADC). The digital signal was then analyzed using Matlab software. A Matlab code was written to execute the Fast Fourier Transformation (FFT), to determine that frequency spectrum of the sound.

There are three samples of sompoton used in this investigation labeled as sompoton A, B and C, and their dimensions are given in Table 1. For each *sompoton,* the frequency of sound from each bamboo pipe is determined by closing six pipes so that only the pipe concerned produces sound. The frequency of the pipe is determined from its frequency spectrum for each *sompoton.* Figure 4(a), 4(b) and 4(c) show three examples of the frequency spectrum produced by pipe *tinanga* (S1) for *sompoton* A, B and C, respectively.

Table 1. The dimension for each pipe of the *sompoton.* Refer to Figure 1 for label S1 - S7.

		S1	S2	S3	S4	S5	S6	S7
Sample A	Length/cm	21.0	20.8	21.3	20.7	27.0	35.0	40.4
	Diameter/cm	1.13	1.10	1.11	1.11	1.08	1.09	1.08
Sample B	Length/cm	26.1	24.5	26.3	26.4	31.9	38.1	42.2
	Diameter/cm	1.10	1.17	1.18	1.15	1.17	1.04	1.10
Sample C	Length/cm	24.0	23.4	25.2	25.0	31.3	39.6	45.1
	Diameter/cm	1.39	1.34	1.35	1.26	1.29	1.30	1.28

Table 2. Frequency for each pipe of the *sompoton*

(a). Frequency for each pipe for *sompoton* A

	f_0	f_1	f_2	f_3	f_4	f_5	f_6	f_7	f_8	f_9	f_{10}	f_{11}	f_{12}	f_{13}	f_{14}	f_{15}	f_{16}	f_{17}	f_{18}
S1	791	1582	2373	3164	3955	4746	5537	6328	7120	7911	8701	9492	10284						
S2	704	1407	2111	2814	3518	4222	4925	5629	6332	7036	7740	8443	9146	9850					
S3	587	1174	1761	2348	2934	3521	4108	4703	5282	5868	6456	7043	7629	8216	8804				
S4	523	1047	1571	2094	2616	3141	3664	4186	4709	5234	5756	6280	6802	7326	7849	8373	8896	9418	9942
S5	468	937	1405	1874	2343	2811	3280	3748	4216	4679	5148	5616	6085	6552	7021	7489	7955	8424	8894
S6	382	765	1147	1529	1911	2293	2676	3057	3440	3822	4204	4584	4966	5348	5736	6114	6495	6877	7260
S7	349	698	1047	1396	1745	2094	2443	2792	3141	3491	3840	4189	4536	4887	5235	5583	5934	6282	6630

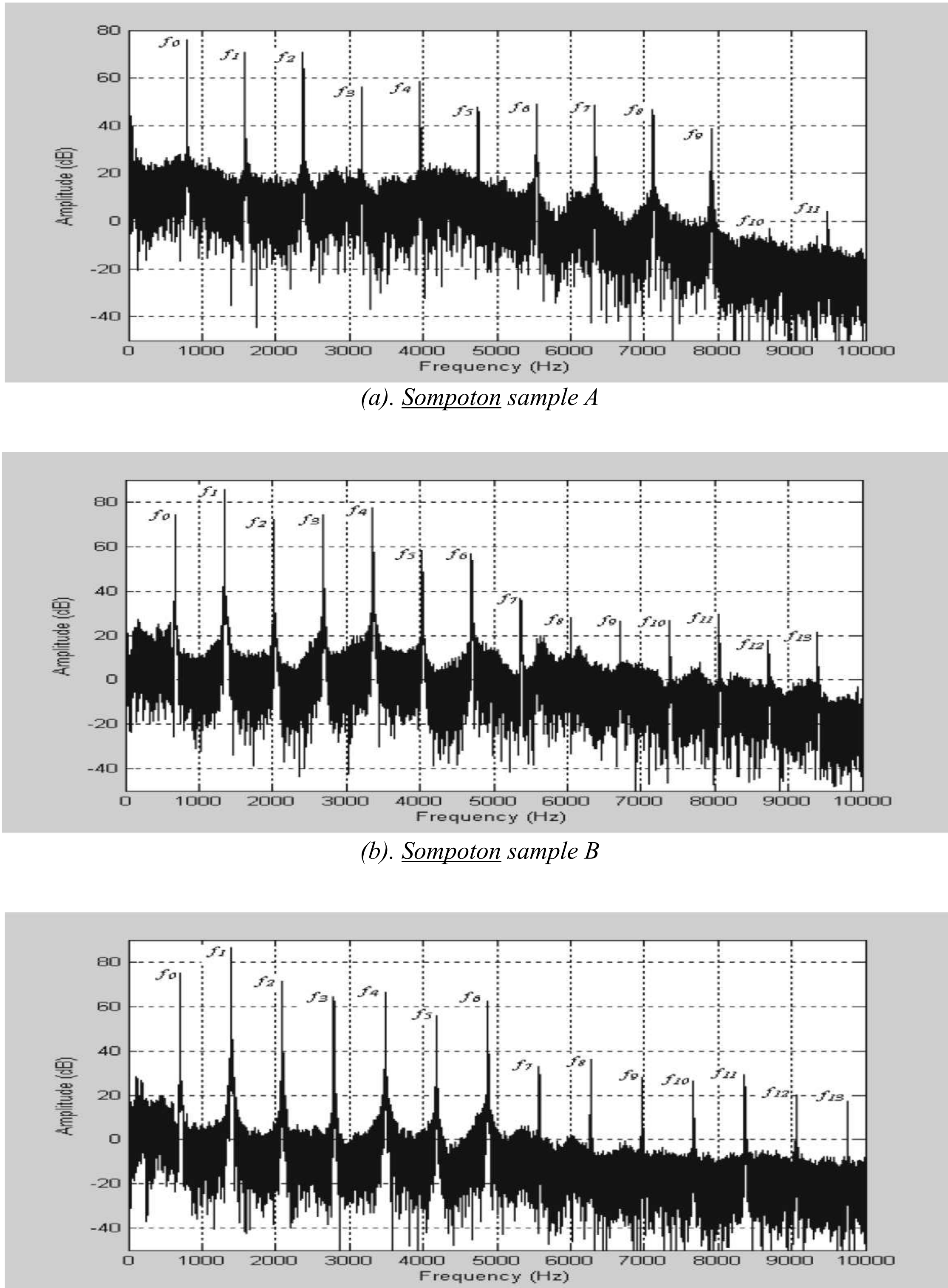
(a). Frequency for each pipe for *sompoton* B

	f_0	f_1	f_2	f_3	f_4	f_5	f_6	f_7	f_8	f_9	f_{10}	f_{11}	f_{12}	f_{13}	f_{14}	f_{15}	f_{16}	f_{17}	f_{18}
S1	671	1342	2013	2684	3355	4026	4697	5368	6038	6712	7380	8052	8723	9394	10065	10734			
S2	593	1187	1780	2373	2966	3559	4152	4745	5338	5931	6526	7117	7710	8303	8896	9489	10085	10676	
S3	498	995	1492	1989	2486	2983	3481	3978	4476	4974	5471	5968	6467	6962	7463	7957	8454	8951	9453
S4	449	897	1346	1794	2243	2691	3140	3588	4038	4487	4935	5384	5836	6281	6729	7182	7626	8083	8528
S5	392	783	1174	1566	1958	2350	2739	3130	3527	3918	4308	4699	5090	5482	5875	6266	6658	7052	7436
S6	332	663	994	1326	1657	1988	2324	2651	2982	3313	3644	3984	4307	4642	4970	5301	5632	5964	6295
S7	297	594	891	1188	1485	1782	2079	2376	2673	2970	3266	3563	3860	4157	4454	4751	5048	5345	5642

(a). Frequency for each pipe for *sompoton* C

	f_0	f_1	f_2	f_3	f_4	f_5	f_6	f_7	f_8	f_9	f_{10}	f_{11}	f_{12}	f_{13}	f_{14}	f_{15}	f_{16}	f_{17}	f_{18}
S1	696	1393	2089	2785	3481	4177	4873	5569	6265	6961	7657	8354	9050	9746	10442				
S2	624	1248	1872	2496	3119	3743	4367	4991	5614	6238	6859	7488	8110	8734	9356	9984	10608		
S3	516	1033	1548	2066	2580	3096	3612	4130	4644	5160	5676	6192	6708	7224	7740	8256	8771	9288	9804
S4	478	956	1435	1913	2391	2869	3347	3826	4304	4782	5258	5737	6215	6693	7171	7650	8128	8606	9084
S5	414	828	1242	1656	2070	2484	2898	3312	3726	4140	4554	4968	5382	5796	6210	6624	7038	7452	7866
S6	338	677	1015	1353	1691	2030	2368	2706	3044	3382	3720	4058	4397	4735	5073	5412	5750	6088	6426
S7	308	617	925	1234	1542	1850	2158	2466	2775	3083	3391	3699	4007	4316	4624	4932	5239	5548	5856

The peaks in the spectrum are the fundamental and harmonic frequencies produced by the pipe and these frequencies are summarized in Table 2(a), 2(b) and 2(c) for all pipes in all three *sompotons*. f_0s in the table are the fundamental frequency of the pipe whereas f_ns are the frequency of the nth harmonic. The frequency measurement in these table shows that each pipe in a *sompoton* produces sound with fundamental frequency together with their harmonics.



(a). <u>Sompoton</u> sample A

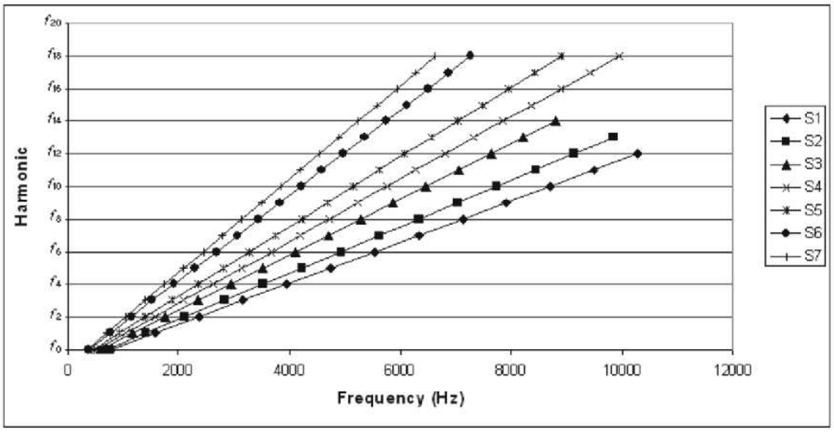
(b). <u>Sompoton</u> sample B

(c). <u>Sompoton</u> sample C

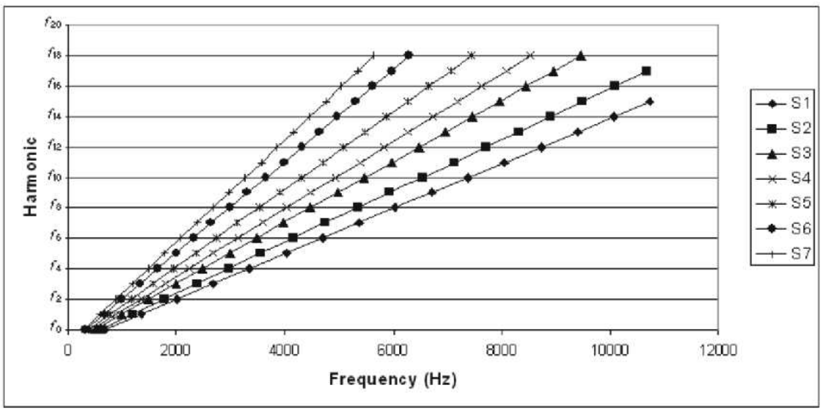
Figure 4. Graph showing the pressure amplitude versus frequency for each sample of <u>sompoton.</u>

These harmonics are in a perfect multiplication between the harmonic number and their respective fundamental frequency. This is clearly shown in Figure 5(a), 5(b) and 5(c). Mathematically, the harmonic frequency can be written as

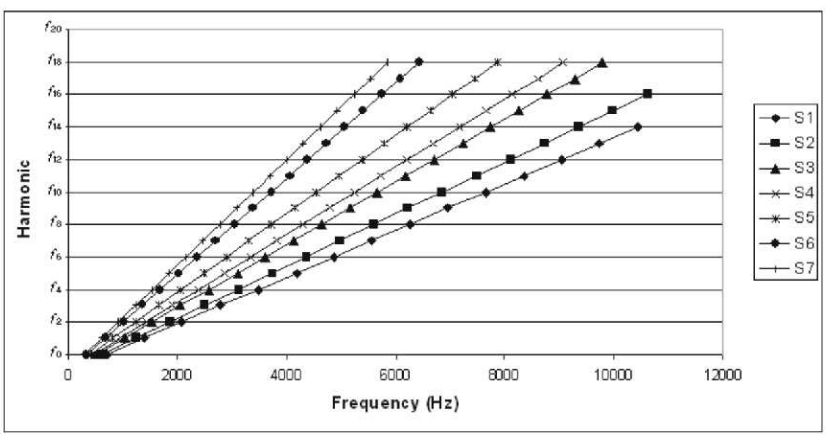
$$f_n = (n + 1) f_0 \tag{10}$$



(a). Sompoton sample A



(b). Sompoton sample B



(c). Sompoton sample C

Figure 5. Graph showing the harmonic number versus frequency for each sample of sompoton.

Comparison between Equation (10) and (4) implies that the harmonic generated by the *sompoton* comply with the open-end pipe model. This relationship is clearly shown in Figure 5 where the slop of the each line in the graph is corresponding to (n+1) with n as the harmonic number for the model. However, there is an interesting fact revealed in this investigation, which is the discrepancy in the fundamental frequency of the pipes in respect to the open-end pipe model.

Table 3 shows the fundamental frequency predicted using opened-end and closed-end model in comparison with the measured frequency for each pipes of the *sompoton.* The table clearly shows that none of these models can be used to predict the fundamental frequency generated by the instrument. For *sompoton* A for example, the measured frequency for pipe S1 was 791 Hz, whereas the predicted frequency was 786 Hz and 393 Hz for open-end and closed-end model, respectively. Similar observation was found for other pipes and *sompotons.* This is very interesting because on one hand, the generation of the harmonic frequency follows one of the models which is the opened-end model. However, generations of the fundamental frequency of *sompoton* comply to non of the models.

Table 3. Comparison between the frequencies predicted using open-end pipes and closed-end pipe model with measurement

(a). *Sompoton* A

Sample	S1 (21.0cm)	S2 (20.8cm)	S3 (21.3cm)	S4 (20.7cm)	S5 (27.0cm)	S6 (35.0cm)	S7 (40.4cm)
f_0 (Opened Pipe)	786 Hz	793 Hz	775 Hz	797 Hz	611 Hz	471 Hz	408 Hz
f_0 (Closed Pipe)	393 Hz	397 Hz	387 Hz	399 Hz	306 Hz	236 Hz	204 Hz
f_0 (Measured)	791 Hz	704 Hz	587 Hz	523 Hz	468 Hz	382 Hz	349 Hz

(b). *Sompoton* B

Sample	S1 (26.1cm)	S2 (24.5cm)	S3 (26.3cm)	S4 (26.4cm)	S5 (31.9cm)	S6 (38.1cm)	S7 (42.2cm)
f_0 (Opened Pipe)	632 Hz	673 Hz	627 Hz	625 Hz	517 Hz	433 Hz	391 Hz
f_0 (Closed Pipe)	316 Hz	337 Hz	314 Hz	313 Hz	259 Hz	217 Hz	195 Hz
f_0 (Measured)	671 Hz	593 Hz	498 Hz	449 Hz	392 Hz	332 Hz	297 Hz

(c). *Sompoton* C

Sample	S1 (24.5cm)	S2 (23.4cm)	S3 (25.2cm)	S4 (25.0cm)	S5 (31.3cm)	S6 (39.6cm)	S7 (45.1cm)
f_0 (Opened Pipe)	673 Hz	705 Hz	655 Hz	660 Hz	527 Hz	417 Hz	366 Hz
f_0 (Closed Pipe)	337 Hz	353 Hz	327 Hz	330 Hz	264 Hz	208 Hz	183 Hz
f_0 (Measured)	696 Hz	624 Hz	516 Hz	478 Hz	414 Hz	338 Hz	308 Hz

CONCLUSIONS

In this paper, the frequency of *sompoton* produced by the bamboo pipe of the instrument was measured. The frequency was then compared with the two models for generation of sound in pipes namely the open-end and closed-end model. It was found that each pipe produces sound with fundamental frequency together with its harmonics. The harmonic frequency of the sound from the instrument was found to be in a perfect multiplication between the harmonic number and their respective fundamental frequency as predicted by using the open-end pipe model. However, none of the models can be used to predict the generation of the fundamental frequency by the instrument. This finding has opened new possibility for new formula specifically for sompoton musical instrument. Fundamental investigation is required in order to explain this *phenomenon.*

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