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Comparative Study of Harmonics to Noise Ratio of Closed Organ Pipe at First and Second Resonance

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Abstract

A sound wave has two components as periodic and non-periodic whose ratio is known as harmonic to noise ratio (HNR). HNR is an important parameter to analyze the voice. It also measures the degree of hoarseness. The measure of this parameter can be done with the help of Praat software. This paper compares the HNR of a closed organ pipe at first resonance and second resonance. HNR has varied from 10.95 dB to 27.87 dB at the first resonance and 7.3 dB to 23.87 dB at the second resonance. The average values at first and second resonance are 15.69 dB and 11.99 dB respectively. From the observation table and graph, it was found that HNR is greater at first resonance than second resonance for closed organ pipe.

Keywords harmonic, noise, periodic, resonance, hoarseness

1. Introduction

In a closed organ pipe, one end of the pipe is closed. At first, the air is blasting through a vibrating tuning fork at the open end of the pipe then a sound wave travels through the pipe and is reflected from the closed end. Due to the superposition of the incident and reflected wave a new resulting wave is formed which is called a stationary wave.

The sound wave consists of two components: one is periodic and another is noise components. The relation between the periodic and non-periodic components of voice sound can be established by the harmonic-to-noise ratio (HNR). This ratio parameter gives information of the periodic and non-periodic components of the speech signal. The quality is determined with help of the acoustic parameters of amplitude, signal periodicity, and spectral compositions (Teixeira et al., 2018; Al-nasheri et al.,2017).

Some parameters like autocorrelation, harmonic to noise ratio and noise to harmonic ratio are measured by the harmonics of the sound. The value of harmonic to noise ratio also varies due to different amplitudes of harmonics (Fernandes et al., 2018).

The acoustic parameter harmonic to noise ratio also conveys the information of shimmer and jitter on the voice sounds (Murphy and Akande, 2006). Yumoto et al. (1982) study the measure of the degree of hoarseness with the help of the ratio of harmonic to noise. Among the different approaches, Cestrum is also used to measure the harmonic and noise components (Murphy et al., 2005).

The ratio of the energy of the harmonic to the noise component is also measured by HNR.

The mathematical form of the voiced signal in term of noise and harmonic can be represented by the equation

$$S(\omega) = N(\omega) + H(\omega) \quad (1)$$

Where the frequency domain function $S(\omega)$, $H(\omega)$ and $N(\omega)$ are represented speech signal, harmonic and noise components.

When analyze the equation (1) by autocorrelation then speech signal is equal to the sum of its articulation parts.

For zero lag, we have

$$r_S(0) = r_H(0) + r_N(0) \quad (2)$$

The local maximum at a lag τ_{max} = with a height

$$r_S(\tau_{max}) = r_H(T_0) = r_H(0) \text{ analyzing} \quad (3)$$

The normalized autocorrelation at τ_{max} represents the relative power of the harmonic component of the signal and its complement represents the relative power of the noise component:

$$r'_S(\tau_{max}) = \frac{r_H(0)}{r_N(0)} \quad (4)$$

$$1 - r'_S(\tau_{max}) = \frac{r_N(0)}{r_S(0)} \quad (5)$$

The harmonics-to-noise ratio in logarithmic scale is defined as

$$\text{HNR} = 10 \log_{10} \frac{r'_x(\tau_{max})}{1 - r'_x(\tau_{max})} \text{ (Murphy et al., 2005)} \quad (6)$$

To calculate HNR first calculate autocorrelation function of speech signal to find the first local maxima that provide the harmonic component and equation (3) determine the noise components.

2. Method

A vibrating tuning fork is held slightly above the free end of the tube, then the water level is adjusted till an approximate resonance is obtained. The length of the air column is adjusted properly by raising or lowering the water level till maximum resonance is obtained. The sound is recorded at first and second resonance. This recorded sound is analyzed with the Praat software.

3. Results and discussions

Using aforementioned method, HNR at first and second resonance in a closed organ pipe for tuning fork having different frequencies were measured and the values are as given in Table 1. Statistical analysis of the obtained data is presented in Table 2.

Table 1: Measurement of HNR at first and second resonance in a closed organ pipe for tuning fork having different frequencies.

S. N	Frequency (Hz)	First resonating length (cm)	HNR of First resonance (dB)	Second resonating length (cm)	HNR of Second resonance (dB)
1	256	33	10.95	98	7.75
2.	288	30	14.89	91.2	11.81
3	320	26.5	13.61	82	9.23
4	341	25	13.10	76.5	9.17
5	362	22.5	11.41	71	7.30
6	384	22	11.42	69	8.47
7	405	21	27.87	65	23.87
8	426	19.5	20.40	61	16.19
9	480	17.5	15.01	54	12.94
10	512	16	18.23	50	13.15
	Avg.		15.69		11.99

Table 2: Statistical analysis of HNR at first and second resonance in a closed organ pipe for Tuning fork having different frequencies.

S. N	Frequency (Hz)	HNR of First resonance (dB)	Standard deviation (S.D)	HNR of Second resonance (dB)	Standard deviation (S.D)	Ratio of first to 2nd	T-test value
1	256	10.95	1.45	7.75	1.02	1.40	
2.	288	14.89	3.35	11.81	3.33	1.26	
3	320	13.61	3.76	9.23	2.05	1.47	
4	341	13.10	2.85	9.17	1.31	1.43	
5	362	11.41	2.97	7.30	1.42	1.56	
6	384	11.42	2.79	8.47	2.26	1.35	3.17
7	405	27.87	2.36	23.87	2.17	1.17	
8	426	20.40	3.31	16.19	2.42	1.26	
9	480	15.01	2.75	12.94	2.43	1.16	
10	512	18.23	4.66	13.15	3.04	1.39	
	Avg.	15.69		11.99		1.31	

HNR are 10.95, 14.89, 13.61, 11.41, 11.42, 27.87, 20.4, 15.01, 18.23 dB at first resonance and 7.75, 11.81, 9.23, 9.17, 7.3, 8.47, 23.87, 16.19, 12.94, 13.15 dB at second resonance cross ponding to respective frequencies 256, 288, 320, 341.3, 362, 384, 405, 426, 480 and 512 Hz of the different tuning fork.

The minimum and maximum value of HNR at first resonance are 10.95 dB and 27.87 dB hence HNR varies from 10.95 dB to 27.87 dB and S.D also varies from 1.45 to 4.66 at this condition.

At the second resonance, the minimum and maximum values of HNR are 7.3 dB and 23.87 dB respectively so that HNR varies from 7.30 dB to 23.87 dB. The value of S.D variation from 1.02 to 3.04.

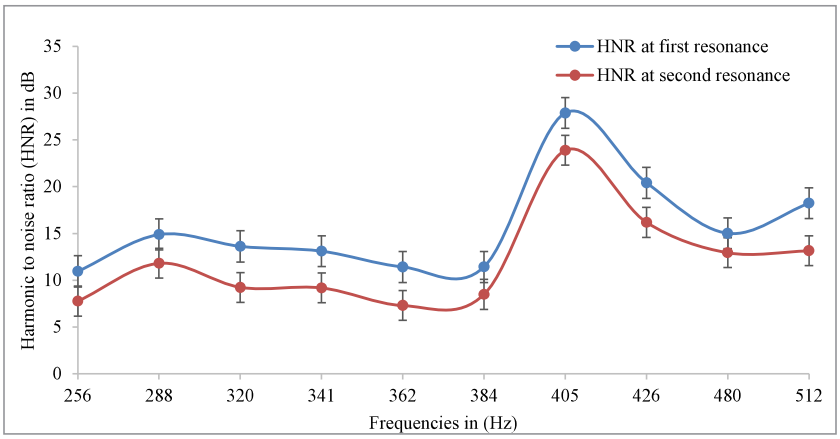

Fig.1. The graph between HNR and frequency at first and second resonance of closed organ pipe.

The ratio of HNR at first to second resonance varies from 1.16 to 1.56. The average value of the ratio of the HNR at the first resonance to the HNR at the second resonance is 1.31.

The tabulated value of 0.002 level of significance is 3.61 which is greater than the calculated value of 3.17. This shows that there is a connection between HNR at the first resonance and the second resonance.

From table 1 and graph (Fig.1), it found that HNR is greater at first resonance than second resonance for closed organ pipe. HNR measures the degree of hoarseness which is greater at first resonance than second resonance at the closed organ pipe.

4. Conclusions

HNR has varied from 10.95 to 27.87 at the first resonance and 7.3 to 23.87 at the second resonance at different frequencies for the same open organ pipe. The average value of HNR at first and second resonance is 15.69 dB and 11.99 dB respectively. The ratio of HNR at first to that of second resonance is 1.31. From the table and graph, it was found that HNR is greater at first resonance than second resonance for closed organ pipe.

That means the degree of hoarseness decreases from the first resonance to the second resonance at the closed organ pipe.

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