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The influx of Sound dynamics: A perspective of Music and Physics

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Abstract : Learning sound dynamics of a music piece helps a musician in the pursuit to compose, record and present music of higher quality. The effectiveness to create the most efficient environment to present a music before an audience depends largely on placement of microphones and speakers in an auditorium or a recording studio. In this work, an understanding of concepts of constructive and destructive interference on superposition of sound waves is described which will help a musician to creatively improve his performance. An experiment is conducted to calculate absorption coefficient of different sound absorbing materials. Knowing the physics of sound absorbing materials will help the composers to design their own studios.

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1. Introduction : Music is expressed only through the medium of sound. Sound can be distinguished as musical and non-musical. A musical sound is a perfectly continuous and uniform sensation, while a noise is the result of irregular and distinctly perceptible alternations of various kinds of sounds. [1]. The dynamics of sound is the variation in loudness which occurs in a music passage. Dynamics come into picture at all the stages of production of music, its recording and arrangement.[2]. It plays an important role in mixing when the composers use compression and expansion, limit the range and use noise gates [2]. The study on technical details of compression techniques used in the production of music and its recording is reported in literature [3]. Anders et.al [4] did research in prediction of the perception of performance of dynamics in music with the help of ensemble learning. Lots of research is done on the use of sound dynamics for production of music, effect on acoustical parameters, absorption, loudness etc. [5-7]

In the current research work the different aspect of music is related to basic physics of sound. This will give a knowledge of sound dynamics which is essential for a musician to successfully create an ambience to display beautiful music that can be heard clearly and is soothing to the ear.

2. Experimental

2.1 Experimental observations were taken in a studio. A group of research students visited a studio and listened to the sound coming out of two speakers, placed side by side and then after shifting the position of one of the speakers. The position of the listeners was the same. The students heard different intensity of sound at different angles in the same room. Then the arrangement of two audio sources was kept constant and sound was heard by standing at different positions in the same room. At some points, sound was loud, at some very frail and at some, totally no sound.

Table 1: The observations at different positions of speaker keeping listener at the same place

Situation	Position of speaker 1	Position of speaker 2	Observation
1	A	B (Same phase)	Louder sound
2	A	C (opposite phase)	No Sound
3	A(Blocked)	C (opposite phase)	Sound heard
4	A	D (same phase, Moving back)	Loudness decreased
5	A	E (same phase, Moving back further)	Loudness increased

2.2: To find the absorption coefficient of potential absorbing material for sound waves, an experiment is performed in the laboratory. The block diagram for experimental setup is shown in Fig [1]. A headphone connected to an audio generator worked as a source, while a microphone received the sound after getting reflected from the experimental material. The intensity of out coming sound was noted in decibels keeping amplitude of input signal to be constant. The frequency of sound was varied from 200 Hz to 10 KHz and intensity measurements were done. The experiment is repeated for different materials like cotton, foam, egg shell, egg tray.

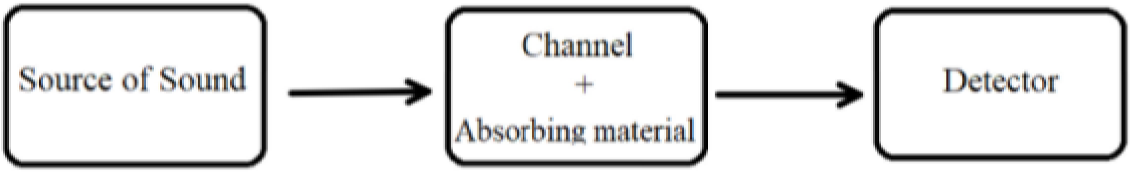

Figure 1: Block Diagram of the experimental setup used for measuring absorption coefficient

3. Results and Discussions

The word Nada is derived from two syllables Na and Da. Phonetically the letter Na indicates life and Da indicates fire. Therefore Nada is the combination of life and fire. There are two types of Nada- Ahat Nada is produced by striking two objects together whereas Anahat Nada is the sound Omnipresent without any external factor and is related to the human ear. [8-9]. The word 'Shruti' comes from the ancient Sanskrit saying "Shruyate iti shruti". This means that when a Nada is heard so clearly that it can be 'identified' it is called as a 'Shruti'. This is possible only if we 'stay' on a Nada (Nyasa) which allows the human ear to recognize it as a specific 'musical' note.

The loudness of sound in human voice is dependent on the structure of vocal cords and its frequency depends upon the vibration and elasticity of vocal cords. Even with riyaz(practice), frequency of the sound of a human cannot be altered. Although the audible range of frequency is 20Hz to 20000Hz, the most soothing sound to our ear is from 400-1000KHz.

Sound waves are a good example of spherical waves. When a body or an object vibrates or oscillates in a medium, a sound wave produces and this wave travels in all possible directions.

The characteristics of musical sound depends on its loudness, pitch and timbre.[8]

Intensity: The magnitude or intensity signifies louder, weak, greater or smaller amplitude of Nada. The force used determines the characteristics of Nada. The amount of sound energy crossing per unit area per unit time is the intensity of sound. Loudness of a sound depends upon intensity and on the sensitivity of the ear. It is proportional to the square of the amplitude and surface area of the sounding body. If the source of sound produces waves in all possible directions, then the intensity of sound can be calculated by inverse of the square of the distance between the source and the listener. [10]

Pitch : The pitch of the sound indicates high or low Nada, depending upon the frequency. A source of high frequency produces a shrill sound, while low frequency produces lower Nada.[10]

Timbre: Different mediums/sources have different sounds. Timbre or quality of sound helps us to distinguish between two sound which are having the same loudness and pitch.[10]

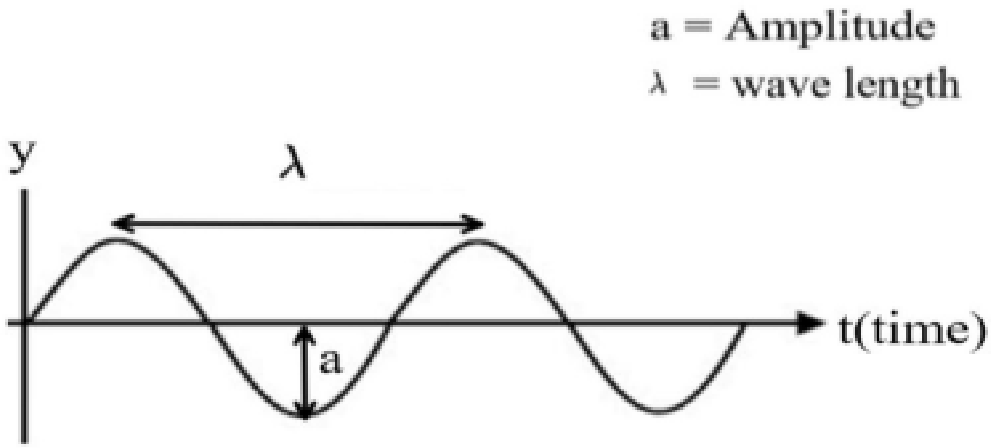

Figure 2: Representation of a sound wave

Figure[2] describes a sound wave showing its amplitude and wavelength. The maximum displacement of a point or the peak is called amplitude. The distance between two peaks of a wave is called wavelength.

3.1: The experimental observations in table 1 are related to basic concepts of physics and sound dynamics. When two or more waves of sound coming from different audio sources interact with each other at the same instantaneous time, they superimpose. A resultant wave is produced which is the sum of all the different waves. This process of Physics is known as interference.[10]

Situation 1: When both audio sources are side by side such as two waves are coming from two different audio sources with the same frequency in the same direction [fig 3a]

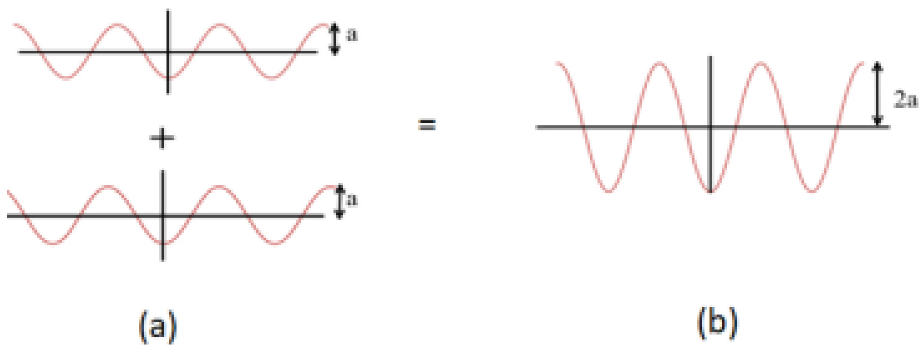

Fig 3: Superposition of two sound waves with zero phase difference

Then the resultant wave reaching us will be of similar characteristics as the original waves. However, its amplitude will be higher fig [3b]. This is called constructive interference. When the path difference between two waves is an integral multiple of wavelength, constructive interference takes place and amplitudes are added up.

The path difference = në, where n is an integer

Situation 2: If two audio waves of the same frequency, moving in the same direction having a phase difference of 180^0 [fig4a] superimpose, they result in destructive interference. The resultant wave, which is the sum of two waves, will give total destructive interference if the phase difference is exactly 180^0 and amplitudes of original waves are the same [fig4b]. The path difference in this case is

Path difference=(2n-1) ë/2, where n is an integer

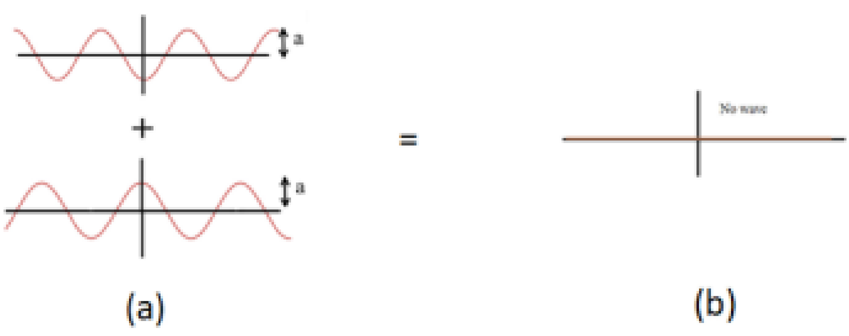

Fig 4: Superposition of two sound waves with 180^0 phase difference

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Situation 3: If one of the speakers is blocked then the resultant wave will be same as the original wave coming from the unblocked speaker [figure 5]

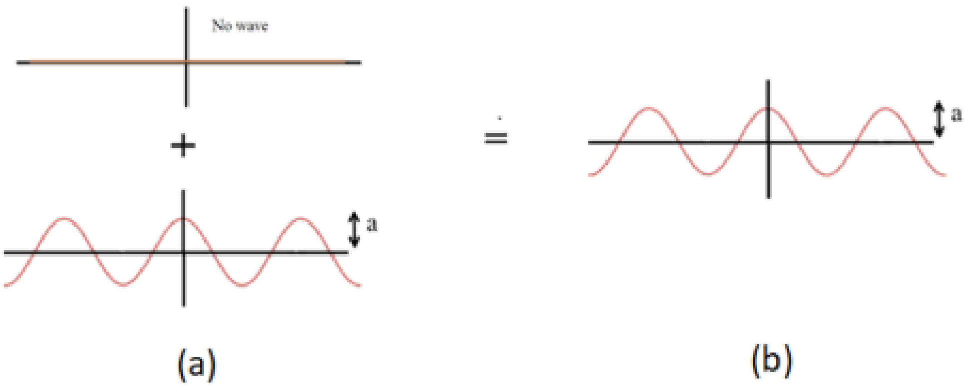

Fig 5: Explanation for situation 3

Situation 4 and 5: If speaker 2 is moved backward keeping position of speaker 1 same, there will be regions of constructive and destructive interference. Whenever, path difference between travelling waves is an integral multiple of wavelength, amplitude of sound will be high, otherwise low in case of destructive interference. The same explanation can be given to the fact that when speakers are at fixed position and listener changes its position in the same room, the amplitude of sound varies depending upon constructive or destructive interference.

The above understanding of the concepts of sound dynamics help a musician to decide the placement of microphones and speakers to give the best presentation of its music.

3.2: To make the performance of the musician most effective in terms of melody, noise free presentation in an auditorium or in a recording studio, depend largely on the design of the walls, roofs, the materials used for sound absorption, sound proofing etc. The sound absorbing materials have the characteristic to absorb reverberant energy. They reduce the reverberations in a space and are called acoustic materials [8]. A sound absorbing material used in auditoriums or recording studios should have a good absorption coefficient. The values of absorption coefficient can be calculated using the formula [11]

$$\textbf{Absorption Coefficient (á)} = \frac{\text{Intensity of sound reflected by the surface}}{\text{Intensity of Incident sound}}$$

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The obtained values calculated by the experiment described in section 2.2 are shown in table 2.

Table 2: The values of absorption coefficients calculated for different materials.

SNO	Frequency(Hz)	Absorption coefficient(á)			
		Foam	Cotton	Egg tray	Egg shell
1	100	0.3405	0.3688	0.6027	0.5735
2	200	0.3550	0.365	0.6301	0.5882
3	300	0.3695	0.3688	0.6438	0.6176
4	400	0.3840	0.3688	0.6712	0.6470
5	500	0.3985	0.375	0.6849	0.6470
6	600	0.4040	0.3711	0.7534	0.6617
7	700	0.4057	0.375	0.8219	0.6911
8	800	0.3913	0.375	0.8493	0.6617
9	900	0.4202	0.4027	0.7534	0.7941
10	1000	0.4557	0.3888	0.6983	0.75
11	2000	0.3913	0.395	0.7671	0.8970
12	3000	0.4202	0.3927	0.6986	0.8235
13	4000	0.4347	0.3888	0.6438	0.6323
14	5000	0.3968	0.3802	0.5890	0.6176
15	6000	0.3967	0.3801	0.5890	0.6617
16	7000	0.3913	0.3800	0.6164	0.5882
17	8000	0.3957	0.375	0.6027	0.6029
18	9000	0.3913	0.378	0.5890	0.5882
19	10000	0.4057	0.3888	0.5890	0.5735

The values of absorption coefficient obtained for foam, cotton, egg tray and egg shell match with the reported values earlier [12]

The optimum value of absorption coefficient 0.8970 is obtained for egg shells at 2000 KHz indicates its application as potential material for sound absorption used in recording studios and auditoriums.

4. Conclusion

The sound experience in an auditorium is highly dependent on placement of microphone and speakers in a room. The placement of the microphone depends on the genre of song, music, instruments used and acoustics of the room. The sound wave coming out of the microphone and speakers suffer interference by waves coming after reflection from walls or different materials. The interference of these waves leads to

a. Constructive interference b. Destructive interference

Whenever constructive interference takes place, amplitude ads up; however, in case of destructive interference, amplitudes get subtracted. Sometimes there is total destruction and net amplitude is zero. Since amplitudes are proportional to intensity of sound or loudness, the placement of microphones and speakers may affect the loudness which may become high, low or zero and may form dead zones in the auditorium.

These interference patterns also depend on the design of the auditorium or studio, its walls, ceiling and various objects present. Hence the placement of microphones and speakers should be done in a way to get maximum sound effects at all the regions of the place avoiding dead zones.

Acoustic of a sound studio depends on sound absorption, soundproofing, reverberation, echo etc. The absorption properties depend on the material's density and surface regularity. As per our result the optimum value of absorption coefficient of egg shells makes them a suitable material to be used in soundproofing. Egg trays, cotton and foam are also potential materials which can be used for sound absorption. It can also be noted that the absorption is maximum in frequency range 800-2000 KHz.

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