Chapter – Two

Acoustical Values and Functions of Tablā

ACOUSTICS

INTRODUCTION

Acoustical phenomena have been an obligatory part of man's surroundings since the initial moment. 'Acoustics, not only of music of India, but also of music of all civilized countries of the world is mainly concerned with the nature of sound and its vibrations and also with its relationship to music[1].'

The study of the materials of a Tablā, where acoustics deals, with the study of the production, propagation and preparation of sound, is an import part of music. It is further deals with the study of motives which create music. In acoustics here we also may study the mechanism of perceiving Tablā sound out of a set of tones, etc.

Music is an emotional presentation of sounds or succession of sounds. The actual material out of which music is produced, that is sound. And the

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[1] A Historical Study of Indian Music, by Swami Prajnanananda, Page – 243.

study of sound in all its aspects is mainly the function of acoustics. 'Though the scientific analysis and study is not available in ancient text of music, but the basic principles of acoustics of music were existed since a long time, though these principles were not explained in scientific language. But in modern time it has become necessary to understand in a scientific way to know the solid base of our music through Acoustic[1].'

Acoustics is one of the youngest classical sciences[2]. But the concept of musical acoustics is both old and young. Scientific view-point in music and acoustics is not new in our country, though it has been sadly neglected. Our ancient scholars had extraordinarily logical concepts about sound and music. It could be observed in the development of musical instruments.

Our grand musicologists like, Bharat Muni, Narad Muni, Matang Muni, Sarangdeva, etc, has made

[1] Sitar As I Know, by Ravi Sharma, Page – 1.
[2] Music, Acoustics & Architecture, by John Wiley & Sons, INC, Page – 4.

an enormous contribution to the science of music by their works Natya Shastra, Naradiya Shiksha, Brihaddashi, Sangit Ratnakar, accordingly. They had written gigantic information about sound on their enormous books, from where we can enrich ourselves by the knowledge of sound. The above scholars were beyond doubt, great scientists in our music.

The findings of acoustics have been made it possible to use a scientific move toward in the study of speech and music. And by this way great advances have been made in reducing speech and music to a scientific basis. The knowledge of hearing universally includes all that relates to the physical basis of sound on which the art of music rests. Therefore, the characteristics of our sense of hearing are an important part of music acoustics.

Hermann Helmholtz, was a immense German scientist of the nineteenth century, paying attention in the physiology of the eye and ear, and his book, 'the Science of Tone' explored the mystery of structure of musical sounds and their intervals , nature of voice production and hearing, and development of musical scales, pitch colour, etc.

Keenig, a scientist and instrument maker in Paris Lord Reyleigh, an English mathematician and physicist, C V Raman a physicist in India, contributed much to the early modern development of acoustics in its musical aspects. Raman dealt not only for the western instruments but Indian drums like Tablā, Pakhāwaj, etc. also, and developed theories for several musical instruments that explained how they work.

MEANING OF ACOUSTICS

There are two very similar words acoustic and acoustics. According to 'The Shorter Oxford English Dictionary' the meaning of 'acoustic' is[1] –

[1] The Shorter Oxford English Dictionary on Historical Principles, Prepared by William Little, H. W. Fowler, J. Coulson.

"Pertaining to the science of hearing' and for 'acoustics' is – "The science of phenomena of hearing". There are very few differences in meaning, between acoustic and acoustics, but overall meaning is same. But, when we look at the 'Britannica Concise Encyclopedia' we can see the meaning of acoustics that, 'of, relating to, or being a musical instrument whose sound is not electronically modified[1]'.

The word Acoustics is derived from the Greek verb àkouotlkóv, pertaining to hearing from ākoúelv, to hear[2]. And such the acoustics of music means the science of auditory nerve, including the qualities or characteristics of a room, music hall, music recording room, auditorium, stadium, etc.

About acoustics, Grove's Dictionary of Music says- 'the science of hearing commonly includes all that relates to the physical basis of sound on

[1] Britannica Concise Encyclopedia, Version: 2008.00.00.000000000
[2] Introduction to Musicology, by Glen Haydon, Page – 21.

which the art of music rests.' The expression has however at various times been used to cover up the following three meanings:

(i). the branch of physics called sound,
(ii). the science of hearing, and
(iii). the physical basis of music[1].

The term acoustics itself has two well defined meanings namely –

(a). The science of the phenomena of hearing, and
(b). The acoustics properties of a building[2].

According to Music Professor, Glen Heydon, 'modern practice more commonly uses the term to refer to the physical aspect of sound. Thus, in physics, acoustics is defined as the study of the laws of sound, or as the science of sound, including the production transmission and effects of sound. In architecture the term is used chiefly

[1] A Guide to Musical Acoustics, by H. Lowery, Page – 9.
[2] The Shorter Oxford English Dictionary on Historical Principles, Prepared by William Little, H. W. Fowler, J. Coulson.

to describe the characteristics of an auditorium with regard to sound. In psychology the emphasis is required placed upon the process of hearing itself, upon the perception of sound. Here the study considers psycho-physical and psycho physiological features[1].

Heydon added again and said, other distinctions, more or less well defined such as musical acoustics or physiological acoustics. In musicology it seems advisable to consider acoustics as a branch of physics dealing primarily with the production and transmission of sound, emphasizing especially phenomena of more or less clearly defined musical import[2].

DEFINITION OF ACOUSTICS

By the above discussion it is understood that in the branch of science where acoustics is discussed scientifically may call acoustical science, and in short we may say that, what is

[1] Introduction to Musicology, by Glen Haydon, Page – 21.
[2] Introduction to Musicology, by Glen Haydon, Page – 21.

discussed by science about sound is acoustics. Or what science discusses about sound is acoustics.

Acoustics is an intimate part of human's everyday life. About its definition, in short it may be said that acoustics is a science where sound classified scientifically.

The modern musicologist, Dr. Ravi Sharma, with his opinion acoustic is defined by the following way, 'in short 'acoustic' is the science, concerned with the production, control, transmission, reception and must concerned with the understanding of sound is called 'acoustic'[1].

BRANCHES OF ACOUSTICS

The science of music has been advanced along with acoustics, electrical engineering, electronics, psychology and physiology. 'In recent years, the content of acoustics has been greatly widened through the development of numerous electrical devices for the production, reproduction and

[1] Sitar As I Know, by Ravi Sharma, Page – 3.

radio transmission of sound, all of which have considerable hearing on the practice of music[1].'

Acoustics may be alienated generally into more than a few branches like, Architectural acoustics, Environmental acoustics, Physical acoustics, Musical acoustics, Engineering acoustics, Physiological acoustics, Biological acoustics, etc. All the terms are too much familiar in our every day life. But, we need not think about that when we come to close of that.

ARCHITECTURAL ACOUSTICS

The first major advances in application of acoustics to architecture were made by Wallace Clement Sabine in the period between 1898 and 1950. It was not until the second quarters of the twentieth century, following the development of the vacuum-tube-amplifier, loudspeakers, and noise free microphones that acousticians began to amass the accurate data that would make of acoustics an effective engineering science[2].

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[1] A Guide to Musical Acoustics, by H. Lowery, Page – 9.
[2] Music, Acoustics & Architecture, by John Wiley & Sons, INC, Page – 4.

PHYSICAL ACOUSTICS

Sound as a stimulus- i.e., the physical sound. The mechanism of production (musical instrument), the propagation of sound the measurement of sound the acoustics of a room or auditoria, etc., fall within this group which is usually called physical acoustics[1].

MUSICAL ACOUSTICS

Musical acoustics, which deals with the principals governing the operation and design of 'musical instruments' and the way musical sounds effect listener[2].

ENGINEERING ACOUSTICS

Which is concerned chiefly with the development of fidelity sound recording and reproduction system is called engineering acoustics[3].

PHYSIOLOGICAL ACOUSTICS

The sensation of sound – i.e., the mechanism of

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[1] Psychoacoustics of Music and Speech, by B. Chaitanya Deva
[2] Sitar As I Know, by Ravi Sharma, Page – 2.
[3] Sitar As I Know, by Ravi Sharma, Page – 2.

receiving sound by a living organism of hearing, etc. This branch is called physiological acoustics[1].

PSYCHOLOGICAL ACOUSTICS

Where we may study the perception of sound, as well as the motives for creation of music, the integration of sound, etc. All these may come within the category called psychological acoustics[2].

And ultrasonic, which involves research into acoustical phenomena whose vibration rate is above the audible range and their application and biomedical science[3].

But, according to 'New Encyclopedia Britannica', acoustics is divided mainly into two branches, Architectural acoustics and Environmental acoustics. And musical acoustics, physical acoustics physiological acoustics, psychological acoustics, etc. are the significant branches of acoustics[4].

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[1] Psychoacoustics of Music and Speech, by B. Chaitanya Deva.
[2] Psychoacoustics of Music and Speech, by B. Chaitanya Deva.
[3] Sitar As I Know, by Ravi Sharma, Page – 2.
[4] New Encyclopedia Britannica, Ready Reference, Volume – 1, Page – 67.

SOUND PRODUCTION

INTRODUCTION

Sounds are established as a fundamental theory of music. The elementary phenomena of sound are very well familiar to us in everyday life. Thus, it is a matter of common observation that many sounding bodies are in a state of vibration, that is, their parts are moving rapidly to-and-fro.

Sound is perceived by all living beings, suggesting that it underlies an inter-wovenness with nature, i.e., sound is the principle means of communication and expression and the pulse of all. Until recently it was widely believed that plant life grew silently but today it has been proved that sound is also an integral part of vegetation. Using photo-acoustic spectroscopy, it has been discovered that rose plants, for example, make sound quite audible when the bud bursts into blossoms. In short, all biological beings are surrounded with sound, be it wind, water, fire, cries and chirpings of other animals/birds/humans[1].

[1] Dhvani, Nature and Culture of Sound, Edited by S. C. Malik, Page – 3.

'The two organs of man - namely the ear and the retina of the eye are the most useful things of life because the sense of hearing through the ear and the sense of sight through the eyes are the two attributes of life which give us the most beautiful and enjoyable things - namely music, painting and other one arts. The study of sound and the study of light reveal that they are so similar and akin to each other in their intrinsic nature and manifestations that it is impossible to ignore their ultimate oneness; because the present theory says that both are simple harmonic vibrations at the source, the former propagated in air and the latter propagated in the Ether[1]'.

Therefore, according to Weaver and Lawrence, 'sound, as every one knows is a vibratory motion. Many physical objects when energy is imparted to them will give up this energy in the form of back and forth movements. Thus a tuning fork when struck a sharp blow, or a violin string when bowed

[1] Melody Music of India, How to learn it, by Rao Bahadur Adyanyhaya N. M., Page – 17.

or a bottle when we blow a stream of air across its mouth, all have the special physical properties that cause them to convert the simple applied energy to a new form, that constitutes a sound and when of suitable frequency and intensity stimulates our ear[1].'

If we touch the edge of a large bell or the diaphragm of a dreem while it is sounding, the tremolos movement can actually be felt. Again the strings of a violin may be seen to perform motions backwards and forwards when bowed. And a membrane of a Tablā instrument or any other percussion instrument starts up and down when it is sounded.

ESSENCE OF SOUND

There are two types of things in universe – one is material and the other is power or energy. It is well known that the ability of working is called power and we are well familiar with many types of power;

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[1] Physiological Acoustics, by Earnest Glen Weaver and Merle Lawrence Page – 16.

like – Heat, Light, Magnate, Electricity, etc. in our everyday life. There is one another type of power, which is known as sound. Like other powers sound is also a power, that can not be seen, but we can feel it, hear it by our sensational organ.

Sound is the very background of music. 'More specifically it is the sensation experienced when vibrating air particles touches our eardrums. Naturally, therefore, three things are needed to produce sound:

(1). an instrument to produced vibrations;

(2) a medium (usually though not necessarily, the air) which conveys these vibrations away from the source to the receiver; and

(3) a receiving instrument, the ear, which transforms these vibrations into a sensation called sound[1]'.

The basic element of music is sound. 'The word sound conveys a double meaning; it refers to (i)

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[1] Acoustics of Music, by Wilmer T. Bartholomew, Page – 2.

the mental sensation perceived by the ears, and (ii) the cause responsible for the perception, namely, the physical phenomenon external to the ear –the wave motion which excites the auditory nerves[1].'

It is already said that, our ancient scholar had an extraordinarily logic concept about sound and music. According to them sound is a quality of air. This vibration of air particles is called sound as well as nāda.

In music sound is called nāda and we are always surrounding with this phenomena. All kinds of sound, whatever it may be musical or non-musical, first emerges from the navel base (muladhara) as a result of rubbing of the air (prana-vayu) and the heat-energy (agni). In this respect Sarangdeva said,

नकारं प्राणनामानं दकारमनलं विदुः ।
जातः प्राणाग्निसंयोगात्तेन नादोऽभिधीयते ।।६।।

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[1] A Text Book of Sound, by D. K. Khanna, Page – 1.

-Sangīt Ratnākar, Swargataddhay, Verse no. – 6.

The meaning is,

'It is understood that the syllable na (of nada) represents the vital force and da represents fire; thus being produced by the interaction of the vital force and fire it is called nada[1].'

'The medium with which the musician works is the sound wave; his works of art take the form of artistically built sound structure. The painter creates his works of art through the medium of physical paints; the sculptor models his creation in clay or chisels, hews, and molds in metal or stone. The musician has but one medium the physical sound[2]'.

Nada is an invisible powerful material which prevails everywhere in the universe and man feels this sensation by their ear. Not only in music but also the whole universe is depends on this unseen nāda. And, so, it is said that the universe

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[1] Sangeeta-Ratnakara, by Sarangadeva, English Tr. by Dr. R. K. Shringy.
[2] Psychology of Music, by Carl E. Seashore, Page – 13.

hangs on nāda. In this respect Damodar Pandit said,

धर्मार्थकाममोक्षाणामिदमेवैकसाधनम् ।।२६।।[1]

It means,

Dharm, Artha, Kām, and Moxsha are the four fundamentals in the world, can be achieved by nāda only.

This above aspect has also been explained by our ancient scholar from the very ancient time. And, the enough knowledge about this aspect is preserved by our modern scholars also.

Human life is studded with different rhythmic phenomena like music, singing, rituals, festivals, carnivals, etc in their every day life. And it is possible as because of nāda. So, nāda has an intricate relation with man's daily life. We can also say that nāda is the fundamental ground of music and upon this primal ground all the phenomena of Indian music are built.

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[1] Sangit Darpan, by Damodar Pandit, Page- 12.

WAVE MOTION

The idea of wave motion is very fundamental on physics as well as music, as it is one of the most significant methods of convey of energy. Musician works with a medium, that is sound wave and this works of art get the shape by sound structures which is built imaginatively.

Wave motion is one of the really significant conceptions in physics and sound provides a useful one – dimensional introduction to it. Sound is transmitted through a medium by means of pulsations. A medium such as air or water is necessary for the propagation and transmission of sound waves. No sound is heard is due to the nonexistence of a medium suitable for transmitting sound waves.

According to Rao Bahadur, 'A simple harmonic vibration in mathematical language is a type of motion, or oscillation of a body to and fro a central position by means of which alternate pressures, or compressions and rarefactions are propagated or transferred from particle to particle, of the medium thus creating waves, like the waves on the surface of a lake when a public is dropped in the centre[1].'

The movement of a wave distinguishes carefully between the motion of the medium and the motion of the wave itself. 'When a wave is propagated in a medium, each particle on the medium vibrates simple harmonically about its mean position. The energy of vibration is imparted to the succeeding particles which also starts vibrating. Thus energy is transferred from one particle to another. This is termed a wave motion[2].'

All waves convey energy without permanently displacing the medium through which they take a trip. According to D. S. Mathur, 'Since there is an onward progression of the wave motion through

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[1] Melody Music of India, How to learn it, by, Rao Bahadur Adyanyhaya N. M., Page – 17.

[2] On the Sensations of Tone as a Physiological Basis for the Theory of Music, by Hermann L. F. Helmholtz Translated by Alexander J. Ellis, Page – 7, 8.

the medium, it is also referred to as progressive wave motion[1].

In a progressive wave motion, a disturbance or a condition that travels onwards through a medium due to the repeated periodic motion of its particles about their mean position, each particle repeating the movements of its predecessor a little later than it and handling it on to its successor, so that there is a regular phase difference between one particle and the next.

It will be readily seen that for a wave motion to be produced and propagated through any medium, that medium must convince three autonomous circumstances which may be stated by this way[2]:

(i) 'The medium must possess 'Elasticity' i.e., there must be a tendency for the medium to return to its original condition after being disturbed.

[1] Sound, by D. S. Mathur, Page – 22.

[2] A Text Book of Sound, by D. R. Khanna and R. S. Bedi, Page – 36.

(ii) The medium must be capable of storing up energy. I.e. , it must have property of inertia.

(iii) The frictional resistance must not be so great as to damp the oscillatory movement.

TWO TYPES OF WAVE MOTION

There are two distinct type of wave motion. These are:

1. Transverse wave motion, and

2. Longitudinal wave motion.

TRANSVERSE WAVE MOTION:

'If the particles vibrate in a direction at right angles to the direction of wave propagation, then the wave is called transverse wave[1]'. Or 'in which the particles of the medium oscillate simple harmonically up and down about their meal position, i.e., at right angles to the direction of propagation of the wave motion, itself. This type of wave motion, therefore travels is the form of crests and troughs, e.g., water waves or the wave

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[1] A Text Book of Sound, by M. M. Srinivasan, Page – 18.

traveling along a stretched string[1].' Vibrations of strings are known as a transverse wave. Light waves are also transverse waves.

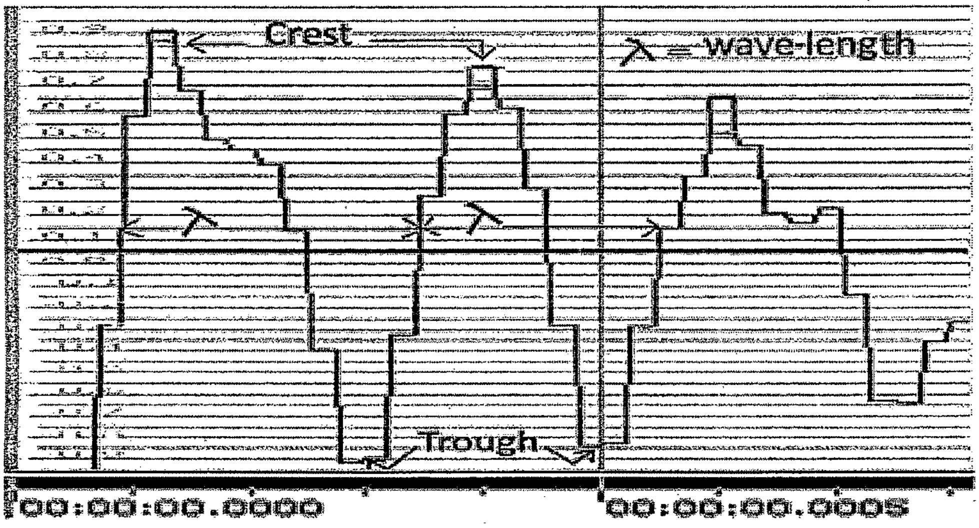

Figure 2.1, Transverse wave motion; the above picture is built on 00.0005 second after playing 'Ta' syllable on Tablā.

LONGITUDINAL WAVE MOTION:

A longitudinal wave motion is that on which the particles of the medium oscillate simple harmonically to and fro about their mean position along or parallel to the direction of propagation of the wave motion itself. This type of wave motion thus travels in the form of compressions and rarefactions, e.g., the waves produced in air by a standing body or those produced on a helix or a

[1] Sound, by D. S. Mathur, Page – 22.

spring when one end of it is compressed or pulled out a little and then released[1].

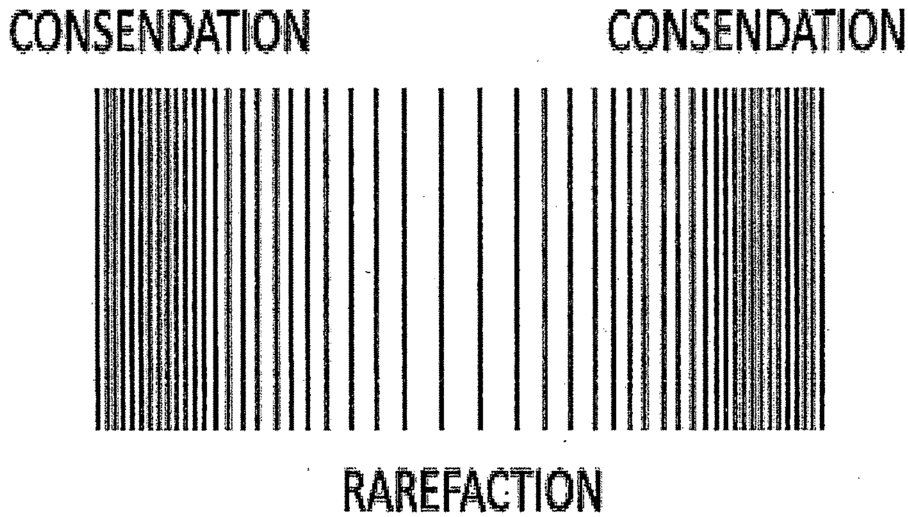

Figure 2.2, Longitudinal wave motion.

CHARACTERISTICS OF WAVE MOTION

Both transverse and longitudinal wave motions exhibit the following three characteristics[2]:

(i) It is only a disturbance, a condition or a state of motion that travels onwards through the medium and nothing material, i.e., there is no transfer of any part of the medium from one place to another. For as we have seen, the particles of the medium simply oscillate up and

[1] Sound, by D. S. Mathur, Page – 23.
[2] Sound, by D. S. Mathur, Page – 23.

down or to and fro about their mean positions and do not travel onwards with the wave motion itself.

(ii) Each particle of the medium receives the disturbance a little later than its predecessor, repeats its movements and hands the disturbance on to the next succeeding particle. In other words, there is a definite phase lag between one particle and the next.

(iii) The velocity of the particles of the medium or the particle velocity, as it is called, is entirely different from the velocity of wave motion or the wave velocity.

PERIODIC AND SIMPLE HARMONIC MOTION

'All kind of motion which repeats itself after a definite period is known as periodic motion. The vibration which produces sounds is also a kind of periodic motion. The simplest kind of periodic motion is the simple harmonic motion[1].

[1] Sitar As I Know, by Ravi Sharma, Page – 7. Based on Acoustics-Waves and Oscillations by S. N. Sen, Page -4.

According to Dr. Ravi Sharma, "A motion which repeats itself over and over again, after regularly requiring intervals, called simple harmonic motion or their vibration consists of a combination of two or more simple harmonic motions[1]".

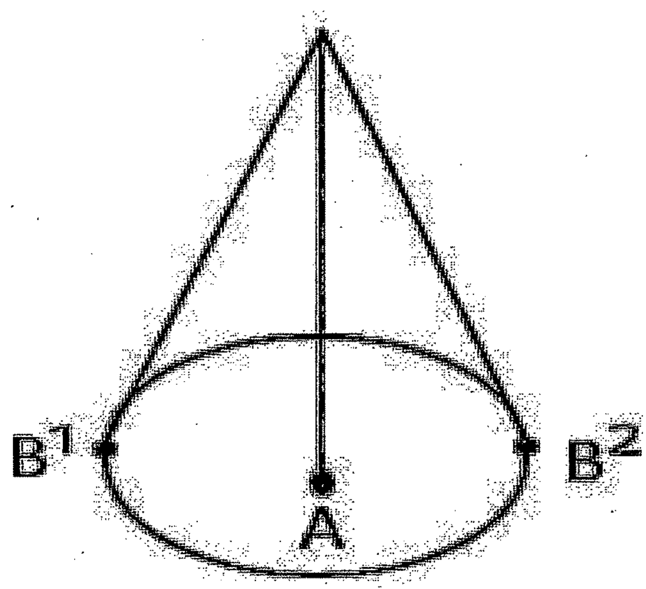

Fig. 2.3, A simple harmonic motion may be under stood by above Pendulum, where A suspended from its centre point to B^1 and then B^2 and finally back again to centre, is created one periodic motion.

The moon rounds to the earth and the earth rounds to the sun are very common examples of periodic motion. The fan rounds in a circle; it is also a common example for our everyday life, which we can observe practically.

[1] Sitar As I Know, by Ravi Sharma, Page – 7.

DEFRACTION

'The theory of wave interference and diffraction in particular, may be discussed with perfect generality for any type of wave – longitudinal or transverse, mechanical or electromagnetic. A comparison of the interference effects in acoustics with those accruing in light is therefore logical. The subject of diffraction is of much greater practical importance in acoustic then it is in light[1]'.

DIFFRACTION ON TABLĀ

Diffraction can be felt by a Tablā player on his playing moment each and every time also to Tablā listener. For example, when a listener is directly in front of a Tablā player while he is playing, can hear sound properly. But when he goes to one side then sounds are somewhat barely audible and demands more loudness. Again, when listener goes to around the corner, even though he is out of the direct line of Tablā player, diffraction makes it possible for a loud sound for the listener. The

[1] An Introduction to Acoustics, by R. H. Randall, Page – 74.

above consequence is connected mostly with the distribution of the sound diffraction pattern. Even though, reflection created by the walls of the room, area if a room, properties of wall, etc. also plays an important roll to make diffraction.

So many examples might be cited to illustrate the importance of diffraction.

RESONANCE

'Resonance, a phenomenon part of sound plays an important part in the construction and operation of most, if not all, musical instruments as exemplified in the soundboard of the piano, the body of the violin, the tube of the clarinet, and the sound box of the mounted tuning bar, not to mention the 'head cavities' in connection with the human voice[1]'.

Glen Haydon also emphasis this fact and added that, 'there are two general methods of applying

[1] Introduction to Musicology, by Glen Haydon, Page – 29.

the resonance principal to musical instruments. One is illustrated by the increase of the rate of flow of energy from a fork in the presence of an air column, in the jar or tube of appropriate length. The other is exemplified by the increase of the vibrating surface exposed to the air, as when a vibrating fork is placed on a table top in such a way that the top of the table acts as a resonator, thus communicating more acoustic energy per unit of time to the air than could the fork alone[1]'.

RESONANCE ON TABLĀ

Resonance is used to the stimulation of vibrations in a body by a sound wave from another source. We may take example for the demonstration of this principle is the experiment with two Tablās of the same frequency and same scale. If the one is sounded and then dampened with the hand, the other clashes up the sound and continue to vibrate. If the Tablās are not on tune, the second one does not respond.

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[1] Introduction to Musicology, by Glen Haydon, Page – 29.

The observation of the principle of resonance may be seen more perfectly in string instruments, like sitar, sarod etc. When we strike on the upper strings of a tuned sitar then it starts sounding. The next moment when the upper strings is dampened with the hand then it also continues to vitiate by the lower strings, which is called jowadi strings. But when we do the same thing with an untuned siter we can not see the same thing.

THE NATURE OF MUSICAL SOUND

MUSICAL SOUND AND NON-MUSICAL SOUND

Sounds are typically classified as tones or as noises. So, there is obsequiousness between a musical sound and a noise and this dissimilarity can generally be unwavering by conscientious acoustic surveillance without artificial assistance.

According to 'Random House Webster Unabridged dictionary', 'Sound, Noise, Tone refers to something heard. SOUND and NOISE are often used interchangeably for anything perceived by means of hearing. SOUND, however, is more general in application, being

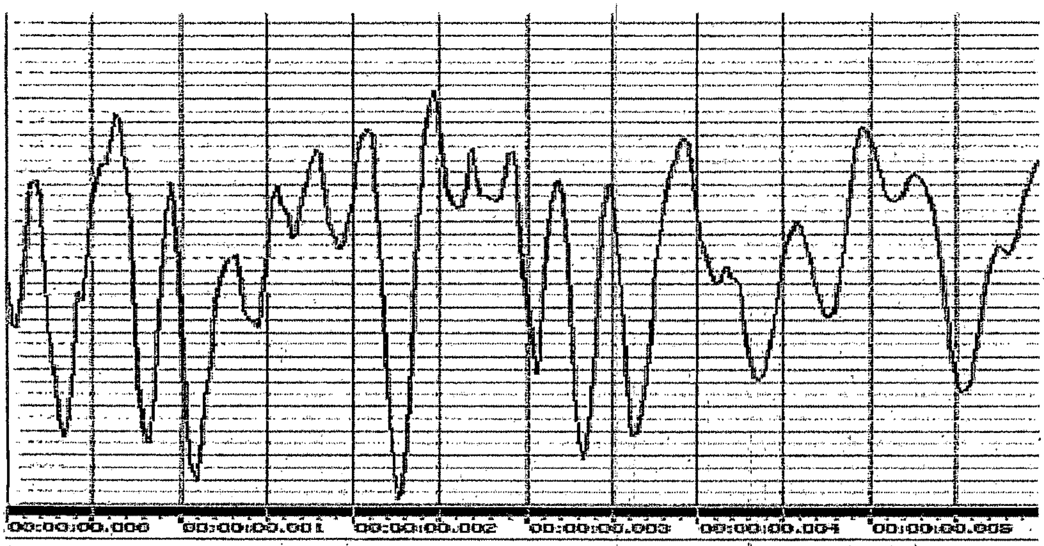

Figure 2.4, Musical Sound, the above picture is shown for 00.005 second's image.

used for anything within earshot: *the sound of running water.* NOISE, caused by irregular vibrations, is more properly applied to a loud, discordant, or unpleasant sound: *the noise of shouting.* TONE is applied to a musical sound having a certain quality, resonance, and pitch[1].'

Harmann Helmholtz has also defines the difference between musical tones and noises and said,
"The first and principal difference between various sounds experienced by our ear, is that between

[1] Random House Webster Unabridged dictionary, by CD version, 1999.

noises and musical tones. The soughing, howling and whistling of the wind , the splashing of water, the rolling and rumbling of carriages are examples of the first kind, and the tones if musical instruments of the second[1]".

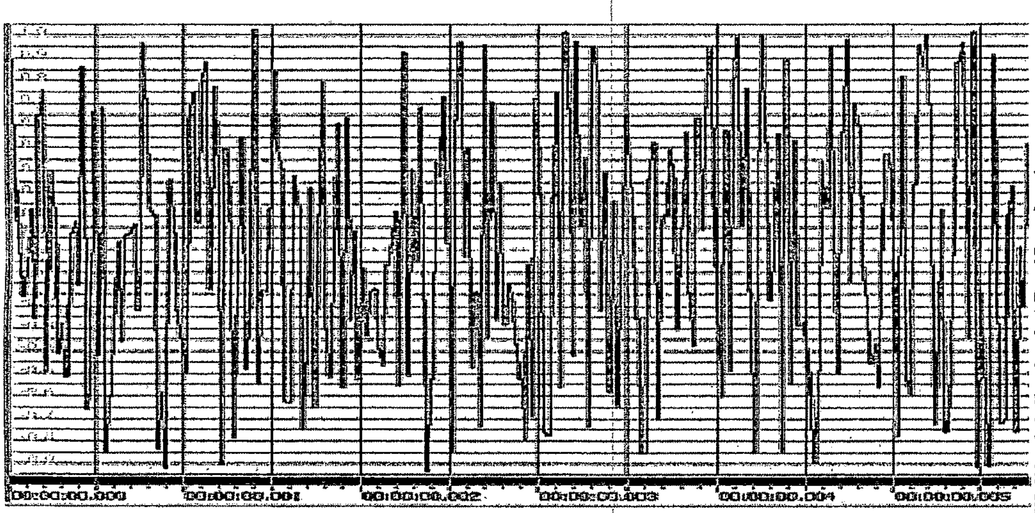

Fig. 2.5, White Noise, the above picture is shown for 00.005 second's image.

The universal difference between tone and noise is clear, but the actual separating line between them is not so pointed. 'Noises and musical tones may certainly intermingle in very various degrees and pass insensibly into one another, but their extremes are widely separated[2].' It is always marked in a noise have more or less musical

[1] On the Sensations of Tone as a Physiological Basis for the Theory of Music, by Hermann L. F. Helmholtz, Translated by Alexander J. Ellis, Page – 7.
[2] On the Sensations of Tone as a Physiological Basis for the Theory of Music, by Hermann L. F. Helmholtz, Translated by Alexander J. Ellis, Page – 7.

characteristics and also some musical sounds are not completely free from noise.

If we analyze the musical sound we find that it consists of a certain number of pulsations per second, with certain extensity, displacement, or amplitude and that the disturbance as an entire experience for a definite length of time. According to Olson,

'In general, musical sounds are smooth, regular, pleasant, and harmonious. Certain tones when sounded together or immediately following one another produce a pleasing effect, while other combinations of tones lead to an unpleasant sensation[1].'

The great German scholar Harmann Helmholtz stresses the fact by this way, 'A noise is accompanied by a rapid alteration of different kind of sensation of sound. On the other hand, a musical tone strikes the ear as a perfectly undisturbed, uniform sound which remains unaltered as long as

[1] Musical Engineering, by Harry F. Olson, Page – 25.

it exists, and it prevents no alteration of various kinds of constituents[1]'.

Musical sound are of definite pitch, where as noises are non-definite. 'A musical co-ordinated sound or tone is intelligible when it is possessed of recognizable pitch and noise is a complex of frequencies, an assembled more or less at random and having no recognizable pitch[2]'.

By the above discussing it is well understood that the sounds are of definite pitch with the quality of its regularity, smoothness and able to make a pleasant environment is a musical sound, whereas non musical sound, in their turn are rough, irregular, unpleasant and therefore, are possessed of no definite pitch.

In brief, we can say that, a note, which is pleasing to the ear, is called musical sound. It is characterized by its periodical, promptness and

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[1] On the Sensations of Tone as a Physiological Basis for the Theory of Music, by Hermann L. F. Helmholtz, Translated by Alexander J. Ellis, Page – 7, 8.

[2] A Historical Study of Indian Music, by Swami Prajnanananda, Page – 246.

continuous nature. And sound which is jarring to the ear is called noise. It is known by its non-periodical, non-promptness and broken properties.

CHARACTERISTIC OF MUSICAL SOUND

Sound it may be musical or non musical, regular or irregular vibrations, definite pitch or indefinite pitch, so long as they last for a longer time one cycle of oscillation or vibration, possess the three qualities of a sound. But, as noise is not directly related to music, here, we will consider only musical sound.

As we know the sensation of musical tone is due to a rapid periodic motion of the sonorous body and the sensation of noise to non periodic motions. Where, about sound's characteristic Hermann Helmholtz said, "Those regular motions which produce musical tones have been exactly investigated by physicists. They are oscillations, vibrations, or swings, that is up and down, or to and fro motions of sonorous bodies, and it is necessary that these oscillations should be regularly periodic. By a periodic motion we jean one which constantly returns to the same condition after exactly equal intervals of time. The length of the equal intervals of time between one state of the motion and its next exact repetition, we call the length of the oscillation vibration or swing, or the period of the motion[1].

THREE QUALITIES OF MUSICAL SOUND

Musical sound is produced by any percussion instrument like Tablā, Pakhawaj, etc. or any vocal cord which clearly emphasizes a fundamental and certain of its partials. Musical sounds may differ from one to another by their loudness, by their quality, and also by their pitch. According to R. L. Saihgal, Musical sounds may differ from one another in three important respects, namely in:

i. Loudness (intensity)

ii. Pitch, and

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[1] On the Sensations of Tone as a Physiological Basis for the Theory of Music, by Hermann L. F. Helmholtz, Translated by Alexander J. Ellis, Page – 8.

iii. Quality or Timbre[1]

Music creates for the above three qualities which is performed by musicians and lastly it fascinates the audience.

LOUDNESS

Loudness is a feature of musical sounds and according to Dr. Swatantra Sharma, which depends on the extent of the vibrations, regulates the loudness or softness of a sound. Where the vibrations of the generating agent of a note are extensive, we get an immense sound, where the vibrations of the generating agent of that same note are small, we get a subdued sound. Amplitude of the vibration is the principal factor which determines intensity[2].

The intensity of the sound waves is a purely physical quantity and according to Swami Prajnananandaji, 'the loudness of a sound depends

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[1] A Text Book of Sound, by R. L. Saihgal, Page – 161, 162.
[2] Bharatiya Sangeet Vaignanic Vishleshion, by Dr. Swatantra Sharma, Page – 13.

upon the intensity of the waves producing it, and decreases with the intensity for a sound of given frequency, but in a way difficult precisely to define, and scarcely susceptible of strictly quantitative statement[1].'

'Loudness of a sound, on the other hand, is just an aural sensation and is, therefore a physiological rather than a physical phenomenon. Infact, intensity and loudness refer respectively to the external or the objective and the internal or the subjective aspects of the same phenomenon[2].'

In short, 'since loudness increases and decreases with intensity, it depends upon the same factors as the intensity, which is -

(i) directly proportional to the square of the amplitude of vibration of the source

(ii) directly proportional to the area of the vibrating body

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[1] A Historical Study of Indian Music, by Pragnanananda, Swami, Page – 244.

[2] Sound, by D. S. Mathur, Page – 180.

(iii) Inversely proportional to the square of the distance from the sounding body of the source of the sound.

(iv) Directly proportional to the density of the medium in which the sound originate.

In addition it is also depends upon

(v) the presence of reflectors or resonators near about the sounding body and

(vi) the motion of the air which increases and decreases the rate of flow of energy to the ear according as its direction of motion is the same as or opposite to, that of the sound itself[1].'

LOUDNESS ON TABLĀ

Loudness is a feature of musical sounds and may be distinct as the amount of sensation formed upon the ear, being familiarly interrelated to the intensity of the sound or the rate of flow of energy to the ear.

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[1] Sound, by D. S. Mathur, Page – 180.

As early stated sound have three characteristics, namely, the loudness, the pitch, and the intensity. Normally, the loudness is not indicated in the musical notation. It is left to the judgment of the performer. The performer after obligatory training develops automatically where to perform loudly and where to softly.

The loudness of the tone of a percussion instrument, determined by the amplitude of vibration, depends on the force used in striking and of course also on the manner of reinforcement of the sound, and on the strength of the materials to withstand the tensions and the displacing forces.

The modern Tablā is largely due to the improvements made during the last century in the length of stretched membrane and the total body length also. The manner of striking on stretch membrane on which the sound is reinforced also has its effect on the tonal loudness. Softer tones may be produced from a Tablā pūdi (membrane) by the use of the mute, by touching a finger (normally used ring finger) on the shyāhi (black-patch) when it is struck.

PERCEPTION PROCESS OF LOUDNESS

As we know, loudness is not indicated in the musical notation and it is a matter of performers thinking so, it is purely a psychological fact. And as loudness is a psychological fact then it is also immeasurable. But, loudness depends on its frequency which is measurable.

According to Alexander Efron, 'the normal ear responds to sounds with an intensity as low as 10^{16} watts/cm^2 at a standard frequency of 1000 cps, and reacts to even fainter sounds at frequencies between 2000 and 3000 cps(the range in which the ear exhibits its maximum sensitivity). The loudest sound that can be tolerated by the ear represents an intensity of 10^{-4} watt/cm^2.'[1]

Now we will see the happiness in the ear as sound rises in intensity while remaining fixed in

[1] Sound, by Alexander Efron, Page – 30.

frequency. Where Efron also referred, Referring to fig. 2-6, note that the region of maximum stimulation no longer shifts along the length of the basilar membrane, but that the extend or magnitude of this stimulation increases with

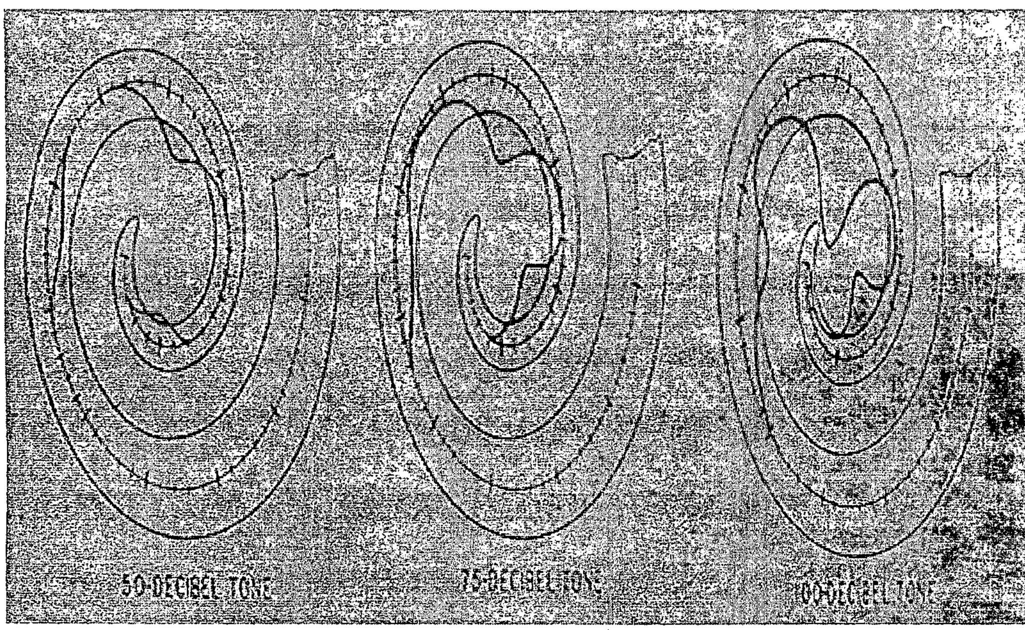

Fig.2.6, Cochlear response patterns for a constant-frequency tone at three different intensity levels.

intensity. It can say that the more intense the sound, the greater the sensation of loudness. The spreading of the response area toward the outer end of the cochlea causes the apparent change in the pitch of the sound as it grows louder[1].

[1] Sound, by Alexander Efron, Page – 30.

PITCH

Pitch as a sensory processes, depends upon the response of the organ of hearing to the physical stimulus which affords us the data for classification of musical sounds in a series running from low to high. According to D S Mathur, 'the pitch of a musical sound is that characteristic of it which distinguishes it from another musical sound is that characteristic of it which distinguishes it from another musical sound of the same intensity (or loudness) and quality. It is infect a sensation depending upon the frequency of the note and is practically wholly independent of intensity and quality. The higher the frequency of a note the higher its pig h and vice versa, so that it is taken to be almost synonymous with determine its frequency[1]'.

Harry Olson describes pitch by a well note and according to him, 'Pitch is that attribute of auditory sensation in terms of which sounds may be ordered

[1] Sound, by D. S. Mathur, Page – 184.

on a scale extending from low to high, such as a musical scale. Pitch is primarily dependent upon the frequency of the sound stimulus[1].'

So, it is found that a pitch depends upon the frequency, where an intensity upon the amplitude of the vibration. It can be also said that pitch is one of the important factor of music and a property according to which musical notes appear to be 'high' or 'low' in relation to each other.

PITCH IN TABLĀ

The peculiar characteristic of Tablā of being adjustable with the pitch of the main performer is helpful to the performer in the sense that he need not adjust himself with the Tablā. Tablā possesses a quality of being adjustable with any kind of music.

Tablā is being tuned in accordance with the main singer or principal 'swara instrument' which are

[1] Musical Engineering – An Engineering Treatment of the Inter Related Subjects of Speech, by Harry F. Olson Page – 25.

being played, like harmoniam or sarangi. A particular note is being played constantly on the harmonium and the pitch of the Tablā is being then adjusted in accordance with that constant note and then it is played whether as an accompaniment or even a solo Tablā recital.

In accompaniment with music, Tablā of different pitches is required. Generally in vocal, Tablā with lower pitch is used while in instrumental music, Tablā with higher pitch is used. Normally the pitch which is used in vocal recital, the same pitch is used in Tablā. In vocal, the normal pitch used are B, B flat, C, C sharp, where G, A, D, are used very rarely and accordingly the pitch of Tablā is being set.

Unlike in vocal music Tablā of higher pitch is used when it is used as an accompaniment in instrumental music, the reason being in instrumental music, the higher pitch is generally used. Mostly in instrumental music C, C sharp and D pitches are used.

Just like vocal and instrumental music, Tablā is an indispensable accompaniment instrument in dance. These days, Tablā is also used as an accompaniment instrument with other dance styles apart from Kathak and also in dance styles of South India. Apart from Tablā, in dance the other accompanying instruments are harmonium, sarangi, violin, sitar etc. and also there in vocal accompaniment. Thus in dance the pitch of Tablā is being adjusted according other swara instruments or vocal accompaniment. Normally in dance the pitch of Tablā is between B and D.

In the past, Tablā was used only as an accompanying instrument, but now it also has a privilege of being able to have a solo recital. Unlike in past, Tablā players and Tablā have achieved such a privileged position which is envious for other percussion instruments. Even in solo Tablā recital, the pitch of Tablā is adjusted according to the main swara instrument which is used as an accompaniment in the Tablā recital. Mostly, the pitch used in solo Tablā recital, range from C to D sharp.

Generally Tablā player does not give attention to pitch in their personal practice session. Most Tablā player firstly gives their attention on the Tablā Pudi by striking, and which side of the pudi is sounded well they adjust the same pitch around the all side of the pudi. Some always practice only by using the well sounded portion of the Tablā-pudi.

During practice, more attention is given to prepare the bols only then pitch. Some practitioners who practice with lehra or nagma by harmonium or sarangi or using by other instruments, the pitch of Tablā are adjusted with the above instrument which is used for accompanying. Recently so many players are using electronic lehra machine during practice. Electronic lehra machine is naturally tuned with standard pitch and player can easily adjust their instrument with it.

PERCEPTION PROCESS OF PITCH

According to Alexander Efron, a definite period of time, usually about 1/50 second is required to form a perception of pitch..... Experiment conducted at the Bell Telephone Laboratories show that, the element of the fundamental frequency from a complex sound wave (accomplished by the use of filters) does not alter the sensation of pitch. Another curious fact that, at very low and very high audio frequencies the apparent pitch is significantly affected by the sound intensity[1].

Alexander efron also added that, it is believed that

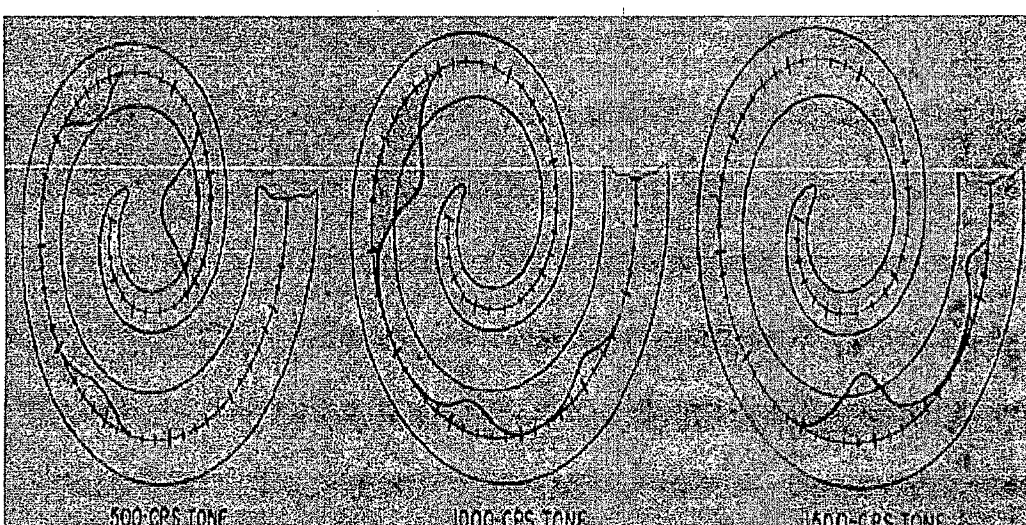

Fig. 2.7, Cochlear response patterns for three tones of different frequency but of the same intensity.

[1] Sound, by Alexander Efron, Page – 29, 30.

different portions of the basilar membrane respond selectively to notes of different frequency. Figure 2-7 is a –series of three patterns of cochlear response to tones of the same intensity, drawn in accordance with this theory. There is a general shift of the area of maximum nerve stimulation toward the open end of the cochlea, as the frequency of the impinging sound rises in value[1].

STANDERD PITCH FOR TABLĀ

'For musical purposes, pitch values are judged in relation to the tones of musical scales. For scientific purposes, pitch values are judged in terms of their relation to a given relation tone[2]'.

The pitch at which music is performed has varied very considerably at different periods. But, still now no standard pitch is set separately for Tablā instrument.

We know that Tablā is mainly used as an accompaniment instrument. So, at some stage in

[1] Sound, by Alexander Efron, Page – 30
[2] Introduction to Musicology, by Glen Haydon, Page – 69.

accompaniment, whether in vocal or instrumental or even in dance, the pitch of the Tablā is adjusted in accordance with the main performer.

Generally, Tablā, the right hand drum is tuned with the note in the madya-saptak (or middle octave) – with *sa*, *ma*, or *pa* mainly, and some times also in mandra-saptak (or lower octave) – with the same above swaras, in their accompaniment. On the other hand, in a solo performance Tablā is normally tuned to the note C-sharp or 'black-five'. And, the bayan Tablā or left drum is tuned with the note in mandra-saptak with *sa* tune. Even it is varied by person to person, but, the above settings are known as a standard permutation for tuning Tablā.

QUALITY

The tonal attribute of sound also called 'timber', is also often referred to as tonal quality, to distinguish it from the attributes of pitch and loudness. Timbre is that aspect of a tone that gives it its richness.

Musical instruments differ in their qualities, and it is by means of quality that we can perceive differences when the same tone is played on the trumpet, piano, violin, oboe, or French horn. Each of these instruments has its own characteristic tonal quality or timbre[1].

QUALITY OF A TABLĀ

The tonal quality of a Tablā-pūdi or any stretched membrane determined by the manner of vibration is dependent on such factors as the following:

(a) Type of membrane displacement, when it is struck by hand or by any other way.
(b) Material and shape of the instrument used for striking.
(c) Striking process on the membrane
(d) Tension, length, thickness and elasticity of the membrane
(e) Characteristics of shyāhi (black patch) materials, and

[1] An Objective Psychology of Music, by Robert W. Lundin, Page – 52.

(f) The characteristics of reinforcing materials, such as the body of a Tablā and baddi (stripes).

PERCEPTION PROCESS OF QUALITY

There remains the sensation of quality whose physical counterpart is mode of vibration or waveform. The quality of sound is determined by the number and relative intensities of the overtones present in the sound.

The pitch of a complex sound is almost always determined by the frequency of its fundamental, although the presence of the fundamental itself is not required. In any case, pitch discrimination is made easier by the presence of overtone.

IMPORTANCE OF LOUDNESS, PITCH AND TIMBER FOR TABLĀ

It is a general rule for every percussion instrument that, when a membrane of that instrument will vibrate slowly then it will produce a low frequency sound. As frequency depends on their vibrations. In this respect a renowned scholar said that, 'Not all vibrations, however, are alike. A long string or a long pipe or a large drum vibrates slowly and produces a sound of low frequency, a low – pitched sound. If a string or pipe is made shorter – for example, when a violinist presses a string against the fingerboard of his instrument the vibrations are more rapid and produce a sound of higher pitch. Size has a similar effect on the pitch of a drum. Vibrations differ from each other also in the intensity of their motion. A performer may cause a string, a pipe or a drum of size, and hence of any pitch, to vibrate with greater or smaller amplitude, and by so doing he produces a louder or fainter tone. And finally, a string or a membrane that is made to vibrate in several different ways will radiate several sounds simultaneously, which results in a sound of a particular timbre. We can say, therefore, that musical sounds have pitch, loudness, and the quality that makes it possible to distinguish one instrument from another, timber[1].

[1] Music, Acoustics & Architecture, by John Wiley, Page – 13, 14.

FREQUENCY

As we know that, sound is produced cause of frequency from any sounding body. Each and every musical instrument is made for producing frequency under controlled conditions. The frequency must be under certain limits of, intensity, transmitting medium etc.

According to Barthholomew frequency being defined as the number of cycles per second, meaning the number of complete vibrations to-and-fro per second. And the term cycle is commonly used to signify one complete vibration per second[1].

From the above definition it is easily understandable that, the number of complete vibrations which occur in a second is called the 'frequency' of the vibration. Vibrations that are too slow, too weak or too fast do not produce sound. Bodies vibrating very slowly do not produce

[1] Acoustics of Music, by Wilmer T. Bartholomew, Page – 5.

sensation of sound, but when their frequency reaches about 20 or more per second, we begin to hear very low sound, and as the frequency continues to reset we hear higher and higher pitch, until finally at a point roughly 20000 vibrations per second we cease to hear sound.

FREEQUENCY ON TABLĀ

A number of conditions are required to perception a sound. The matter of frequency is an important one. To be heard, the vibratory disturbance must have a frequency.

The physical characteristic of musical sounds to which our experience of pitch is most closely related is that of frequency. Therefore in a sense, we may say that pitch depends upon frequency.

By the frequency, Tablā's pitch goes up and down. The pitch of a Tablā instrument is determined by the frequency created on its membrane. It is also depend by its vibrating body. Vibrations succeeding from a membrane slowly create low sound and succeeding rapidly creates high sounds.

And again, if a membrane of a Tablā-pudi is made heavier, its frequency will go for lowers. If the length, tension and weight of a Tablā-pudi are kept constant, the amplitude has little if any effect of the frequency. As it was learned in our school education that, a tight membrane vibrates at a much higher frequency than a lose one, so that the sound produced with tight membrane has a higher pitch.

VIBRATION

Vibrations are very important in the field of music. Or it may say that, vibration is one of the must unavoidable parts of music, as, musical sound is made by regular vibrations.

Physically, sound is produced by vibrations. Every musical instrument is designed to produce vibration of one type or another under control condition. A new dictionary of music describes, 'Vibration the side to side motion of a string, a. struck surface, or air column, by which musical sound are produced. A vibration, as measurement in acoustics as the tonal distance of movement from one side to the other and back[1].'

Sound can be produced by so many ways, like by striking on Tablā pūdi or other percussion instrument, by plucking a sitar or from any stretch string, flicking the end of a steel ruler which has its other end gripped under the lid of a desk and so on, but in whichever way the sound is produced, it is well known that it is a result of vibrations.

The sound is due to the vibratory movement of some body, in every case the body producing is in a state of vibration. According to the Concise Oxford Dictionary, "Vibration is a rapid motion to and fro especially of the parts of a fluid or an elastic solid, where equilibrium has been disturbed[2].

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[1] A New Dictionary of Music, by Aurthur Jackob, Page – 404.
[2] The Concise Oxford Dictionary, by R. E. Allen, Page – 1367.

The vibration must be within certain limits of frequency, intensity, transmitting medium and so forth, in order to be characterized as musical sound, or as the cause of musical sound. As that are too slow, too fast or too weak do not produce musical sound.

VIBRATING PROCESS OF A TABLĀ PUDI

The fundamental pitch of a Tablā, determined by the frequency, depends on its length (area of pudi), its tension, and its weight.

As the area of the pūdi is shortened, its frequency rises proportionally. Stated mathematically, the frequency is inversely proportional to the length of a pudi. In string instruments it is very easy to short their vibrating lengths. Like the strings of a violin have their lengths shortened by stopping them with the fingers. It is also possible in sitar, sarod or and other string instruments. But in percussion instrument vibrating lengths are fixed when the main body is made.

If a membrane is tightened, as for example by tuning a Tablā pūdi or by tuning of a Pakhāwaj, its frequency rises also, varying as the square root of its tension. There is no any fixed highest pitch in percussion instrument. The pitch of a stretched membrane is raised up when its tension also raised up till the membrane has been broken down. When heat expands slightly of a body of a percussion instrument and its membrane also, increasing the tension. So it is looked always that, Tablā pūdi sounded slightly sharp in hot weather and flatted on cold.

There is a big difference between string instruments and percussion instrument. As in string instrument, we can see the reverse work. In string instrument the tension of a stretched string are slightly flatted on hot weather and sharp on cold, unless compensating changes occur through expansion of the frames which hold the strings.

HEARING PROCESS OF MUSICAL SOUND

INTRODUCTION

The principal ornament of hearing any music or any kind of sound is the ear. The ear is described by many psychologists, physiologists and medical scientists as one of the most extraordinary appendage. Scientists are well familiar about its apparatus, manner of action and the hypothetical basis as well as musicians.

Without going any details it may say that, the anatomical structure of the human ear is an exceptionally complex, which is capable receiving the sound wave from the source of vibration. The ear is also capable of analyzing them and making its own contribution to the resulting mental consequence.

Since, we need not to think at the time of hearing that sounds how is working on ear but still its construction is a complicated mystery. To know the process of hearing well, it has a necessity to know its construction first. Here a short depiction of different parts of ear is being presented.

THE CONSTRUCTION OF EAR

'Modern physiologists tell us that sound has an integral relationship with man's hearing sense; that the ear is the first organ which is formed in the womb and within the womb the ear is the most important organ because it is with the ear that the consciousness of the child begins to be aroused. The child in the womb, for instance, hears its mother's heart-beat, and later of course sounds from the outside world. This means that man perceives the world first with his ears and then with the other senses[1].'

The ear consists of three main portions,

1. The outer ear,
2. The middle ear, and
3. The inner ear.

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[1] Dhvani: Nature and Culture of Sound, by S. C. Malik, Page – 3.

THE OUTER EAR

Normally, the outer portion of an ear is known as the outer ear. 'The outer ear is merely a conical opening several centimeters long terminating in a membrane – the tympanum of drum – which completely closes the passage. In the human ear the pinna – the external structure which forms the visible part of the ear – is of little use in hearing. The waves fed to the drum cause it to vibrate and this vibration is thin transmitted to the middle ear which is an almost closed chamber[1].

THE MIDDLE EAR

The ear drum (tympanic membrane) is stretched tightly across the inner end of the auditory canal and separates the outer from the middle ear. The middle ear contains three levers like bones that serve to transmit the motion of the eardrum to the oval window, a second membrane which, in part, separates the middle from the inner ear. The first of these bones, the hammer, is attached to the

[1] The Physics of Musical Sound, by Taylor C. A., Page – 48.

eardrum and to the second bone, the anvil, which in turn is pivoted to the stirrup. One side of the stirrup is attached to the oval window (It is interesting to compare the mechanical structure of the middle ear to the linkage system employed on the pickup head of the old-style acoustical phonograph.) the structure of the middle ear, taken as a system of closely coupled parts, has very broad resonances, due partly to the damping effect of tissue at the joints and partly to the loading supplied by the liquid on the inner ear side of the oval window[1].

THE INNER EAR

The inner ear in which the auditory nerve terminates and which is contained on a cavity in the massive part of the temporal bone consists of three parts, the semi-circular canals, the vestibule, and a long chamber coiled up like a snail shell and hence known as the cochlea. The inner ear communicates with the middle ear through two openings-

[1] An introduction to Acoustics, by R. H. Randall, Page –209.

(i) Feanstra Rotundus (round window) closed by a membrane, and

(ii) Fenstra ovals (oval window) closed by the foot of the stirrup bone. The interior of the inner ear is filled with a watery fluid, the Endolymph[1].

MUSICAL SOUND HEARING

Music is purely an aural sensation which can be perceived and appreciated through auditory nerve. 'The auditory mechanism of the ear has more power than the purely physiological and it can distinguish 5 to 10 or more sounds from each other[2].

The ear is capable of converting vibrations in the air surrounding the subject into a recognizable signal on the brain over a wide angel of frequencies and intensities. According to RH Randall the process of hearing may be said to take place in three stages. A

[1] A Text Book of Sound, by D. R. Khanna, Page – 289.
[2] On the Sensations of Tone as a Physiological Basis for the Theory of Music, by Hermann L. F. Helmholtz, Translated by Alexander J. Ellis, Page – 25.

portion of the wave front is first intercepted by the opening of the outer ear, which funnels the energy through the auditory canal to the eardrum, separating the inner from the outer ear. At the eardrum, the acoustical energy is transformed (partially) to the mechanical energy of vibration of the membrane. The second stage consists of the transmittal of this vibrational energy, through the interconnection of several levers, to a second membrane which lies at the entrance to the liquid-filled cochlea, a complex structure within which lie the sensation detectors. The final stage is the translation of the physical stimuli of these detectors, brought about indirectly by the pressure variation set up within the cochlear fluid, onto a definite nerve massage to the brain[1].

In short we can say that, when a sound wave enters into the ear canal, it impinges upon the eardrum. The eardrum vibrates with a motion corresponding to the undulations in the sound wave. The motion

[1] An introduction to Acoustics, by R. H. Randall, Page – 208.

corresponding to the undulations in window of the cochlea by the lever system of the middle ear. The vibrations of the oval window are transmitted into the fluid of the cochlea back of the oval window.

THE CAPABILITY OF HUMAN EAR

The ear is a great excellence of a human body for which we can hear the sound and can distinguish the different type of sounds. The human ear has the ability to separate musical tone weather it is come from a same type of instruments or from the different types of instrument.

In this respect Helmholtz, the noted musicologist has found that,

'the human ear is capable, under certain conditions, of separating the musical tone produced by a single musical instrument, into a series of simple tones, namely, the prime partial tone, and the various upper partial tones, each of which produces its own separate sensation. That the ear is capable of distinguishing from each other tones producing from different sources, that is, which do not arise from one and the same sonorous body, we know from daily experience[1].'

If we give our attention to a group Tablā solo performance where five to six players are performing with lehrā by harmonium, we will attach with the following affair. During this performance we do not get difficulty in following the melodic progression of each individual instrument which are plying by individual lehrā performer. According to Helmholtz, "If we direct our attention to it excusably; and, after some practice, most persons can succeed on following the simultaneous progression of several united parts. It is true, indeed, not merely for musical tones but also for noises, and for mixtures of music and noise[2].

So many examples also we can see on our daily life experiences.

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[1] On the Sensations of Tone as a Physiological Basis for the Theory of Music, by Hermann L. F. Helmholtz, Translated by Alexander J. Ellis, Page – 25.
[2] On the Sensations of Tone as a Physiological Basis for the Theory of Music, by Hermann L. F. Helmholtz, Translated by Alexander J. Ellis, Page – 25.

THE ADVANTAGE OF TWO EARS

The following advances are found generally from our two ears -

(a) It is an able to hear sounds from all directions except from back side.

(b) It respond more stimulation of sound

(c) It responds the source of vibrating body from where the sound generate[1].

VARIOUS INFLUENCES ON SOUND PERCEPTION

After the sound has been generated by the Tablā instrument or any other musical instrument or any group of instruments or any vocal cord, there are still several stages through which the sound wave must pass before becoming the sensation of sound on the mind of the hearer. According to C. A. Taylor, the three principle steps are there[2]:

(1) First one, 'The acoustical properties of the room' on which the performer and observer are placed.

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[1] A Text Book of Sound, by A Board of Scholars, Page – 10.
[2] The Physics of Musical Sound, by C. A. Taylor, Page – 5.

(2) Secondly, it is useful to consider 'Perception via electrical reproducing systems'. Both broad – casting and recordings make up a very large proportion of our source of music, and the study of the requirements and performance of modern electronic systems is really a suitable subject for several books rather than for a section of one chapter; a brief outline only will be presented.

(3) And finally, the third one is, 'the fascinating and complicated mechanism of hearing'. In which –physiology, psychology and physics are very closely interwoven-is discussed, and we shall see that there are still many unanswered questions on this field.

PERCEPTION VIA ELECTRICAL REPRODUCTION

In the recent world far more people listen to music through some form of electrical reproduction- either 'live' through broadcasting television, radio and public address systems, or after recording on disc, tape and film- than by direct sound transmission through the air.

Generally, a sound reproduction system means a process where sound is picked up in a position and again reproduced either at the same position or at some other position by the listener's choice. The advent of sound reproduction system has made it possible for music and musical instrument to cross the threshold upon a new era. The most widespread sound re-producing systems are the mobile phone, the television, the telephone, the radio, the phonograph, etc. The telephone is the widely used oldest sound reproducing system. Since, to hear any music in a mobile phone is a very simple matter but in recent times, so many countries have started to broadcast musical songs also on telephone by people's demand. However, the television, the radio, etc. all reproduction systems have made it possible for getting the world in so close.

The four basic essentials of any sound reproduction system are[1]:

(i) A converter to change the sound waves in the air into a corresponding electrical wave form (a microphone)

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[1] The Physics of Musical Sound, by C. A. Taylor, Page – 144.

(ii) an amplification system to increase the amplitude of the electrical signal,

(iii) A transmission system (which may involve of a carrier wane as in radio, conversion into variations if light and shade as in film recording or conversion into variations in magnetization as on a tape, and on each case reconversion into electrical signals), and

(iv) Reconversion into sound waves (by aloud speaker). The ideal system should obviously be one in which the final sound wave produced by the loud speaker is identical in every detail with that produced by the original sound. With so many stages of inter conversion and transmission, however, considerable deviations inevitably occur.

LIMITS OF AUDIBILITY

In order to be just audible, a sound must possess a certain minimum intensity and a certain minimum frequency, respectively called the threshold of audibility and the lower pitch limit of audibility. Similarly, there is a maximum intensity beyond which the ear experiences a feeling of pain, as also a maximum frequency beyond which the sound is inaudible to the ear. These maximum values of intensity and frequency are referred to as the threshold of feeling and the upper pitch limit of audibility respectively[1]. The range extends from about 20 complete cycles or full vibrations per second to a maximum of about 20000 cycles per second are known as ultra sonics. Neither group can be detected as audible sound, though the sane as that accompanying their audible counterparts[2].

The following interesting points emerge from a close of the audiogram[3]:

(i) At a frequency of 1000 cps the threshold of audibility occurs at the rms value 0.0002 dynes/cm^2 of the pressure amplitude which as we know, corresponds to an intensity, of 10^{-6} watts per cm^2, or 10^{-10} microwatts/cm^2.

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[1] Sound, by D. S. Mathur, Page – 182.
[2] Sound, by Alexder Efron, Page – 4.
[3] Sound, by D. S. Mathur, Page – 183.

(ii) The least values of intensity audible to the ear lie in the frequency range 500 to 7000. In other words, the ear has its maximum sensitiveness in this range of frequency which corresponds to ordinary speech sounds, the peak sensitive ness being for frequencies within 2000 to 2500 cps.

(iii) The threshold intensity rises both for low and high frequencies, to a much greater extent in the case of the former than in that of the latter.

(iv) The intensity producing a painful sensation on the ear is the highest at a frequency of about 800 cps for which the threshold audibility is fairly low. And at a frequency of 1000 cps, the ratio between the pressure amplitudes at the threshold of feeling and the threshold of audibility works out to 10^{-7}:1, which corresponds to an intensity ratio of 10^{14}:1, an impressively high range of intensities, indeed, to which the ear can respond.

(v) The lowest audible frequency is about 30 cps and the highest, in the neighborhood of 20000. The musical sounds can, however, be heard only within the frequency range 400 to 4000, which too comprises eleven octaves as against the only one octave to which the eye responds in the case of light. And what is more, of these eleven octaves, as many as seven are available for the musical purposes.

The sensitivity of the average human ear varies person to person. 'The upper limit of frequency according to different experimenters varies within wide limits with advancing age, at 20 it is about 20000, at 35 about 16,000 and at 47 about 13,000 vibrations per second. The elderly people can not hear such sounds as chirping of crickets and squeals of bats[1]. The ear is much more sensitive to changes in frequency variations as small as 2 cps in certain ranges. Near the upper and lower limits of audibility, the ear loses its power of pitch discrimination. The acoustic response of dogs extends to 40,000 cps and the bat is sensible to 'sounds' or rather, ultrasonic vibrations of 50,000 cps[2].

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[1] A Text Book of Sound, by D. R. Khanna, Page – 291.
[2] Sound, by Alexander efron, Page – 29.

GOOD ACOUSTICS

The auditorium derives from the Latin word for 'hearing'. Too often, auditoriums gave been designed with solicitude for every aspect that of how well the auditors can hear. The term good acoustics, when used to describe any room, large or small, in which one must hear, should apply:

(i) A size of room fitted to the music or speech to be performed;

(ii) An even distribution of sound (no curved walls or ceilings with foci near source of or audience unless treated with absorbent material, except possibly around the stage).

(iii) An "optimum reverberation time" throughout the frequency range (not too much nor too little absorption of sound at any frequency, and of course no separate echoes), and

(iv) Freedom from transmitted noise from other rooms or out doors (secured by right construction, and using materials differing greatly in density).

BEHAVIOR OF SOUND IN A ROOM

HOW SOUND FILLS A ROOM

When a speaker addresses an audience, the sounds he utters proceed out ward on spherical waves

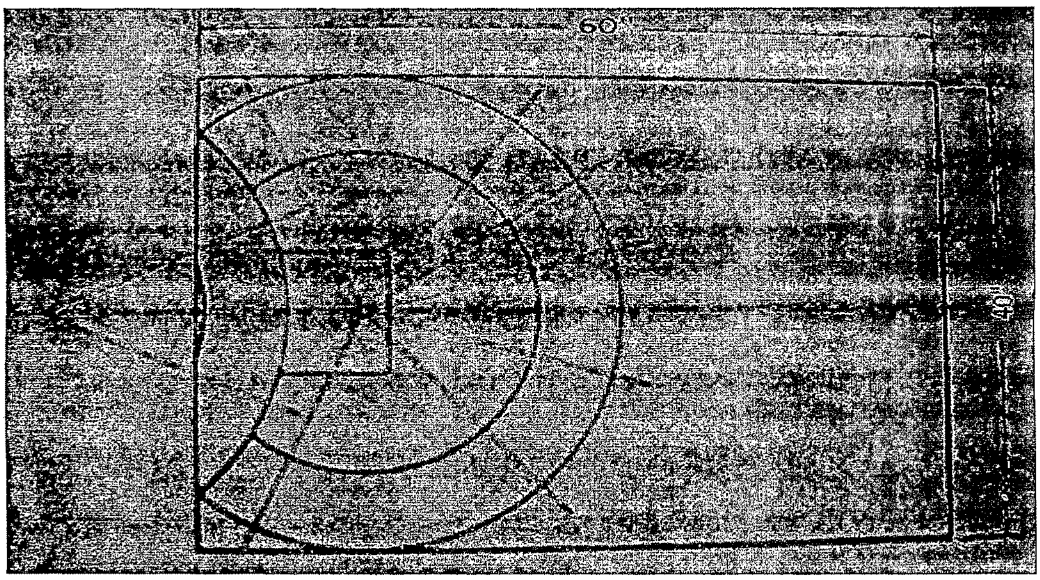

Fig. 2.8, Pulse of sound in a room $^1/_{60}$ second after leaving the source, *S*.

until they strike the boundaries of the room, where they are reflected, transmitted and absorbed in varying amounts, depending on the character of the walls.

Figure 2.8 pictures a pulse of sound in a room 60 feet long and 40 feet wide, $^1/_{60}$ second after it has started from the speaker at S. The pulse travels rapidly, about 1120 feet per second at ordinary temperatures, so that, by successive reflections, it rapidly fills the room, In the mean time, the energy of the pulse is diminished at each reflection by the absorption of a fraction of the incident sound, with the result that it gradually dies out.

Figure 2.9 shows the pulse of sound $^{1}/_{60}$ second later than in fig. 2.8, and indicates the increasing reflections and interference of the waves. the imagination readily supplies the details after $^{1}/_{10}$ seconds has elapsed, when sound has been

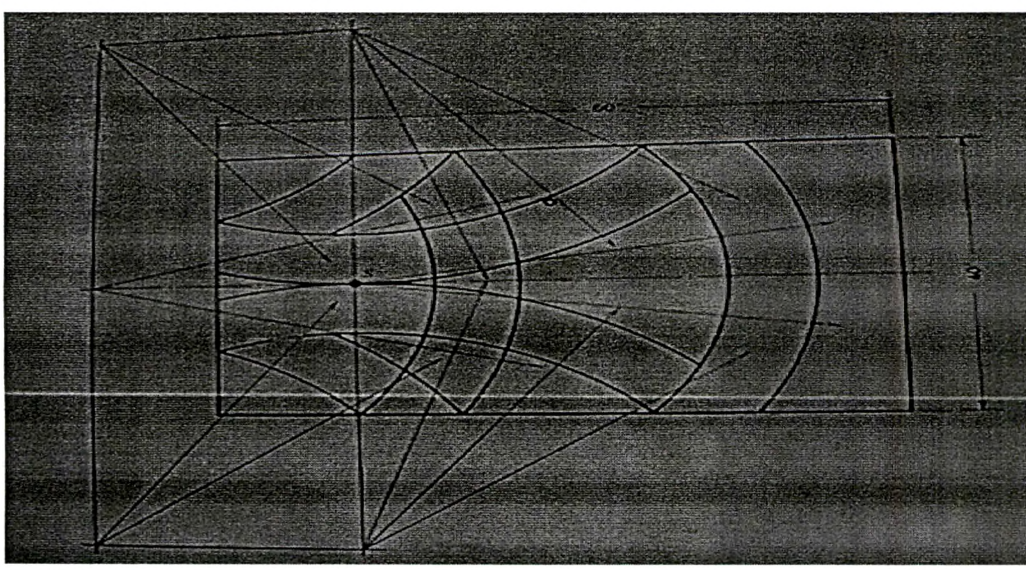

Fig. 2.9, Pulse of sound, $^{2}/_{60}$ second after leaving the source, *S*.

reflected many times, not only from the walls, as pictured, but also from the ceiling and the floor so that every element of volume in the room is filled with waves proceeding on every direction.

GOOD ACOUSTICS FOR TABLĀ IN A ROOM

There are more than a few reasons for acquiring good acoustics in a room for Tablā instrument. Among them some important features are being mentioned here:

⇒ There should be no perceptible echoes in a room

⇒ There should be adequate sound in everywhere of a room

⇒ There should be clear and distinct sound for successive syllables of Tablā, without excessive overlapping.

⇒ There should be maintained appropriate comparative loudness of the several components of a complex sound

⇒ There should be preserved 'quality' for Tablā sound

GOOD ACOUSTICS FOR TABLĀ IN AN AUDITORIUM

A number of requirements are to be maintained by Tablā to reach a good position. The important features of good acoustics for Tablā sound in an auditorium are:

⇒ The auditorium's walls should be sufficiently sound proofed

⇒ The loudness should be sufficient and unvarying through out the auditorium

⇒ There should be sufficient resonance for Tablā sound and should not be excessive reverberation

⇒ There should be no perceptible echoes in an auditorium

⇒ There should be as uniformly reverberant as possible for Tablā sounds of all pitches

⇒ There should be preserved 'quality' for Tablā sound in an auditorium.