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ACOUSTICAL STUDIES OF WORSHIP SPACES IN HINDU TEMPLES

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Sound plays a major role in Hindu worship practices at homes, community halls and traditional Hindu temples. This work presents acoustical studies carried out in a traditional Hindu temple. In a Hindu temple, Garbha-Griha (like a Sanctum-sanctorum) is an important space (room) where the deity is consecrated for worship. In front of the Garbha-Griha, there is a space called Ardha-Mantapa. In front of the Ardha-Mantapa, a large hall called Maha-Mantapa is located where large number of devotees assemble to offer worship through priests. Only priests can enter and conduct the worship in Garbha-Griha and Ardha-Mantapa. In a Hindu temple, priests through Vedic chants and instruments such as conch-shells, bells and gongs conduct worship on behalf of devotees. Throughout the worship rituals, the Vedic chants are recited in the Garbha-Griha and the assisting priests would be in Ardha-Mantapa joining in the chorus of Vedic chanting along with playing the instruments during certain stages of the rituals. Acoustically the coupled space of the Garbha-Griha and Ardha-Mantapa is highly reverberant. The reverberant sound of the Vedic chants and instruments emanating from the priests enhance the spiritual perception and experience of devotees. The intonations of the collective Vedic chants and the tonality of the instruments bring out the acoustical quality of the sacred space to the devotees. The completion of the worship ritual is marked by offering a lamp along with Vedic chants and all instruments played simultaneously. It is interesting to note that the sound from the Vedic chants would get embedded into the sounds from the instruments. Worship in a Hindu temple is a celebration in which reverberant sound in coupled space plays an important role. This paper presents the analytical and experimental studies carried out in two Hindu temples in USA.

Keywords: Worship Spaces, Hindu Temples, Garbha-Griha,Ardha-Mantapa, Reverberant

1. Introduction

Worship is the pinnacle of communication between God and human beings in many religions. Worship can be individualistic or communal. Individual worship can happen anywhere and anytime. However, the communal worship usually requires dedicated spaces such as temples, gurdwaras, churches, synagogues and mosques. Communication during the worship can take several forms. Praying mentally and contemplation can be silent whereas other forms of worship such as chants, songs and music all will involve sound[1]. Acoustics plays an important role in worship spaces in all cultures and religions. In Hinduism, acoustics is of major importance in various aspects of life namely spirituality, religion, culture, science, art etc. It is also well known that sound plays a very important role in Hindu worship spaces namely homes, community halls and temples. The Vedas, which are the foundational literature of Hinduism, are the collection of mantras chanted with precise acoustical characteristics[2]. The effectiveness of Vedic chants in Hindu worship is well known. In addition to Vedic chants (vocal), conch-shells, bells and gongs are also very commonly used to enhance the spiritual experience of the devotees during the worship.

Sound plays a very important role in Hindu worship spaces. In Hindu temples the two coupled chambers that have reverberant acoustic characteristics are the Garbha-Griha where the deity is consecrated and the Ardha-Mantapa which is a chamber in front of Garbha-Griha. The Vedic chants and prayers are recited and the sacred instruments such as conch-shells, bells, and gongs are played in these chambers. The sounds from these acoustically well designed instruments are considered as sacred when they are used during worship. These sacred sounds help devotees in their concentration during worship. The sounds of conch-shell, bell and gong are used at various times during the worship. However, all of these sounds are simultaneously used at the end of the worship when camphor flame is offered to the deity. This acoustical experience is significant to the devotees in the worship.

The conch-shell is generally used to announce the beginning of the worship. Given the tonal quality of its sound, it captures the attention of the devotees and helps in focusing their mind to the worship. Similarly the bell is also used at the beginning of the worship. The sound of well-designed bell has a ringing sound that sustains for considerable duration. It is also noted that both the conch-shell and bell sounds acoustically resembles the chant of sacred sound of 'OM'. The gong is generally played during the end of the worship along with bell and conch-shell. When all these three instruments are played together at the end along with the chanting, one can experience the synergy of the various sounds adding to the spiritual experience of the devotees. The Hindu worship is seen as a celebration of the devotees having communion with God. Figure 1 shows typical Conch-Shell, Bell and Gong instruments used for this study. The paper discusses the importance of these instruments and their contributions to the acoustics of the Hindu worship spaces.

Figure 1: Typical Conch-Shell, Bell and Gong intruments used in Hindu worship spaces.

2. Vedic perspectives on sound

Vedas are categorized into four namely Rig, Yajur, Sama and Atharvana-Veda. Vedas refer to the body of the knowledge that deals with physical, psychological and spiritual aspects of life and cosmos. It is well known that Vedas are collection of very large number of "mantras", which are referred as Vedic chants. These chants have phonetic characteristics such as pitch, duration, emphasis, uniformity and juxta-position.These chants are orally transmitted with extraordinary acoustic precision from master to disciples from ancient times to present times. It is well known that the acoustic precision in the oral transmission of Vedic chants, music and speech cannot be surpassed through writing. The art and science of acoustics have received high importance in the Vedic literature. The chants along with both vocal and instrumental music are playing major role in Hindu tradition from ancient times to the present.

In Vedic literature the production of human speech is emphasized. This could be due to the importance of acoustical aspects of Vedic chants. The speech production according to Vedic view can be described through four stages. These four stages are called as Paraa, Pashyantee, Madhyamaa and Vaikharee. These four stages are integrally connected to the yoga aspects of Vedic tradition. Among these four stages the last stage namely Vaikharee refers to fully manifested speech sounds from the human speaker propagated to the listener. The other three stages namely Paraa, Pashyantee and Madhyamaa refers to the stages internal to the human speaker. The fourth stage of Vaikharee encompasses various types of acoustic expressions in human life. These expressions can be represented by speech, music, literary readings and spiritual recitations. This model for four stage development of speech

sounds can also be generalized conceptually to production of sound[3]. It is interesting to note that the commonly referred five basic elements in Vedic literature namely space, air, fire, water and earth are related to corresponding senses of perception.The subtle to gross order of correspondence according to the Vedic tradition is shown in Table 1.

Table 1: The order of correspondence according to the Vedic tradition.

Space	Sound
Air	Touch and Sound
Fire	Form, Touch and Sound
Water	Taste, Form, Touch and Sound
Earth	Smell, Taste, Form, Touch and Sound

3. Acoustical aspects of Hindu worship spaces

Temples as worship spaces have been an integral part of Hindu religion from ancient times. Hindu temples in India and around the world are marvels of art and architecture. Hindu temples play a major role in not only performing various sacraments and celebrating festivals but also a resource for spiritual development. In addition to Hindu temples as worship spaces, Hindus also use spaces such as community halls and a specified space in their homes as spaces of worship. The worship practice in a Hindu temple or in a community hall generally consists of a priest performing the worship on behalf of the congregation. However, at some stages of worship, devotees chant together mantras and recite prayers along with the priest. Devotees also sing together songs as prayers and they are known as bhajans and kirtans. In addition to the mantras and bhajans, instruments such as bells, gongs and conch-shells are also used during the worship.

The most important space in a Hindu temple is the space where the deity is installed. This space is known as “Garbha-Griha” in Sanskrit, which means a “womb-chamber”. This is also referred as sanctum-sanctorum. The dimensions of this chamber are based on the size of the deity. This chamber has only a door and no windows. Only the priest is allowed in this chamber for worship through chants and prayers. Generally the priest also rings a hand-bell during the worship along with chants. Generally this chamber is built of walls made of stones. The interesting acoustical fact is that this chamber is highly reflective and has a high reverberation time. In addition, this womb-chamber is connected to another space through its door opening. This attached second space is called as “Ardha-Mantapa” which means “half-chamber” to indicate that this space is about half the floor size of the Garbha-Griha. The Ardha-Mantapa is also made of stones and is highly reflective with high reverberation time. The scriptures called Agama Shastras on temple design prescribe that the whole temple is designed based on the size of the deity installed in the Garbha-Griha. The acoustical importance of Ardha-Mantapa is that a number of priests in addition to the main priest in the Garbha-Griha chant in unison and also the instruments such as conch-shells, bells and gongs are sounded. Generally the Ardha-Mantapa leads to a “main hall” referred as “Maha-Mantapa”. It is in this Maha-Mantapa where a large number of devotees assemble and participate in the worship[4]

The two temples in which acoustical measurements were made for this study are Sri Venkateswara Temple of the Hindu Temple and Cultural Society (HTCS) in the Bridgewater, New Jersey, USA shown in Fig. 2a and The Sri Lakshmi- Sri Narayana Temple of the Hindu Temple Society of Capital District in Albany, New York, USA is shown Fig. 2b. Figure 2a also includes the details of Ardha-Mantapa and Garbha-Griha of both the temples. In both temples there are many other deities. In both temples the sound pressure level (SPL) recordings were made outside but near the Ardha-Mantapa in the main hall. The priest chanted in the Ardha-Mantapa and also the conch-shell, bell and gong were sounded in the Ardha-Mantapa. Similar sound recordings were also made in a community hall environment and an anechoic chamber. The sound recording indicates that the SPL values increases at the position outside the Ardha-Mantapa of each temple. This is due to reverberation effects of combined Garbha-Griha and Ardha-Mantapa in comparison with the corresponding position in the

free field. The increase in sound pressure level can be predicted using the following room acoustic equations. (a) If we model the entire Garbha-Griha and Ardha-Mantapa space as a highly reflective and diffuse field then the sound pressure level (SPL) at any given point,

$$L_{P1} = L_w + 10log\left[\frac{4}{R}\right] \tag{1}$$

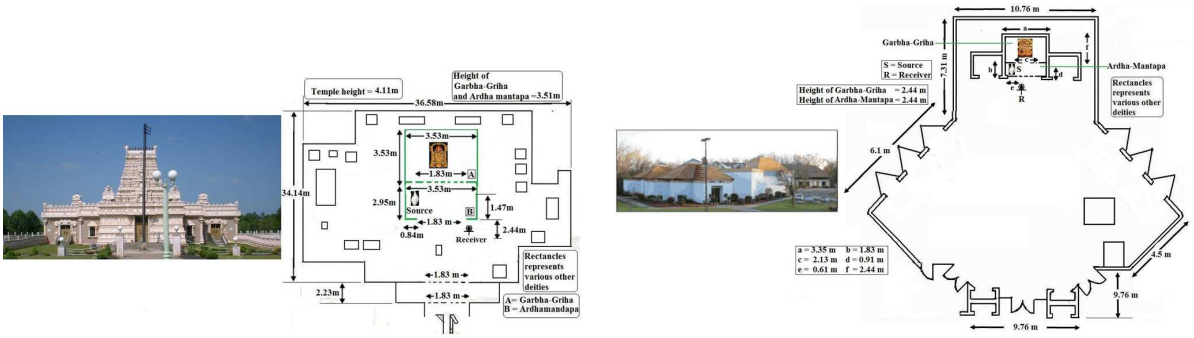
(b) However, If we assume the room (such as Garbha-Griha and Ardha-Mantapa) space as an entirely free field then the sound pressure level at the corresponding point, close to Ardha-Mantapa for a given source of sound power level (L_w) can be written as,

$$L_{P2} = L_w + 10log\left[\frac{1}{4\pi r^2}\right] \tag{2}$$

Subtracting Eqn. (2) from (1), we can obtain the increase in SPL of the room space as,

$$\Delta L = L_{P1} - L_{P1} = 10log\left[\frac{16\pi r^2}{R}\right] \tag{3}$$

Where, $R = S\bar{\alpha}/(1-\bar{\alpha})$ is the room constant, S is the surface area of the room and $\bar{\alpha})$ is the average absorption coefficient of the room. Here, '*room*' represents Ardha-Mantapa, Garbha-Griha as well as combined space of Ardha-Mantapa and Garbha-Griha. The volume (m^3), theoretical estimation of reverberation time T_{60} (in sec) and increased sound pressure level (ΔL in dB) calculated using the Eqn.3 for all these two temples are given in Table 2. The estimated reverberation times T_{60} for the combined Ardha-Mantapa and Garbha-Griha for the Bridgewater temple and the Albany temple are 1.12 sec and 0.63 sec respectively. The theoretically estimated reverberation times for the Maha-Mantapa (total space) for the above two temples are 1.25 sec and 1.1 sec respectively. The reverberant field in this highly reflective combined space and its propagation to the Maha-Mantapa can be pictorially represented in Figs. 3 for the cases of sound sources in Garbha-Griha and Ardha-Mantapa respectively.



(a) Sri Venkateswara Temple, Bridgewater, NJ, USA.

(b) The Hindu Temple Society of Capital District, Albany, NY, USA.

Figure 2: Floor sketch view of two Hindu temples in USA.

Table 2: Estimated reverberation time and SPL of two Hindu temples in USA.

	Temple (Bridgewater, NJ)			Temple (Albany, NY)		
	Volume	T_{60}	ΔL	Volume	T_{60}	ΔL
Ardha-Mantapa	36.18	1.09	22.93	10.87	0.58	13.9
Garpha-Griha	43.86	1.14	22.32	19.93	0.68	14.5
Combined space	80.02	1.12	19.62	30.8	0.63	11.2

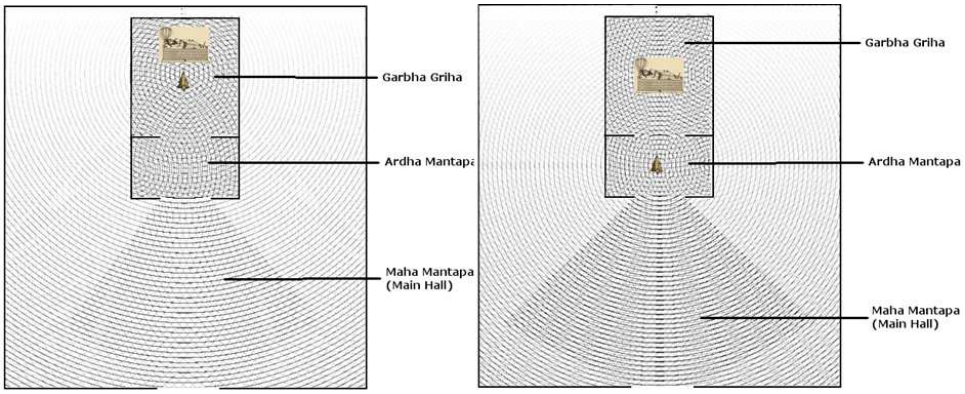


Figure 3: Reverberant sound fields with sound source in Garbha-Griha (left) and in Ardha-Mantapa (right).

4. Chanting the mantras in Hindu worship spaces

Vedas, the foundational literature of Hinduism refers to infinitely large collection of mantras. These mantras describe the various facets of knowledge dealing with life and cosmos.The chants from Vedas are extensively used in worship and sacrament rituals at homes and temples. Sounds of the Veda mantras chanted in Hindu worship spaces would carry the listeners to spiritual experiences. The acoustical characteristics, in addition to the clear phonetic articulation of chants, have deep impact on the devotees. The Vedas are recited by a single priest or a number of priests collectively throughout the rituals or worship. Sometimes devotees also join the recitation of Vedas. In this study, a single priest recitation is measured and sound spectral analysis is carried out for an anechoic room, a community hall and an Ardha-Mantapa of a Bridgewater temple. The observed frequencies of the vocal (Vedic chanting) are given in Table 3. It is noted that the observed fundamental frequency of the Vedic chanting spectra is 147 Hz.

5. Sounding of Conch-shells in Hindu worship spaces

Conch-shell is a musical wind instrument that is made from a seashell, one of several different kinds of very large sea snail. It is also sometimes referred to as “conch-shell trumpet” and it is thought to have been the original horn-trumpet. The clear and hauntingly beautiful sound when blowing the conch-shell trumpet was an integral part of daily life in many societies, where it was used for communication and religious rituals. In Hindu religion, conch-shell is of great importance and symbolizes luster, brilliance and purity. Its tonal sound provides auspicious beginning of an event. In many Hindu temple rituals, conch-shells are sounded to announce the beginning and the ending of a worship and also arrival of the deity. It is used both as a musical instrument and as a container for holy water. It is also used to drive away the evil spirits. It is interesting to note that sound from conch-shell has a loud and sharp tonal quality due to it very high Q-factor that can be easily recognized while listening. It is not possible to sound or play the naturally available conch-shell in their original form. In order to play the conch-shell, a pointed tip of its closed end is cut off to open the cavity, and then it is played by blowing into that end through vibrating lips. When the frequency of the lip vibrations matches a resonance frequency of the conch shell cavity, a clear tone is produced. By adjusting lip tension and blowing speed, different frequencies can be produced by skilled players, as like on any brass wind instruments. The spectrum of sound produced on an end blown Indian conch-shell trumpet was studied initially by Bhat et al[5, 6]. In this study a conch-shell was blown in an anechoic chamber, a community hall and in the Ardha-Mantapa of the two of the Hindu temples. The corresponding spectral analyses of the sounds were carried out.The observed fundamental tones of conch shell are given in Table 3. The measured frequencies of the tested conch-shell in an anechoic

chamber are 327.5 Hz as its fundamental and its harmonics.

6. Sounding of Bells in Hindu worship spaces

According to *Agama-Shastra*[7], which is the text for temple design and rituals, ringing of bells in temples and in other Hindu worship spaces during rituals is to ward off evil spirits. A verse in Sanskrit is recited when ringing the bell at the beginning of the worship. The meaning of the verse is that the bell is rung to invite the sacred vibrations and to drive away the evil vibrations. A well designed bell is an indispensable and an important part in most Hindu worship (pooja) and prayers. It is also observed that a well-designed bell would produce long strains of the sound 'OM'. Usually the bell is sounded before the actual pooja begins. A bell is also rung in a Hindu worship, during the waving of camphor light in front of the deity, while bathing the deity and while offering food. The sound made from a well-designed bell is uninterrupted, reverberating, deep and sonorous. The bells used in Hindu temples are usually made of five metal alloys or panchaloha. The five metals used are gold (Au), silver (Ag), copper (Cu), iron (Fe) and lead (Pb). A typical hand-bell used in Hindu worship rituals is shown in Fig. 1. The observed frequencies of the hand-bell are given in Table 3. It is noted that the fundamental frequency of the bell analysed for the study is 1262 Hz and it also noted that the next higher tone is not an integer multiple unlike conch-shell.

Table 3: Observed frequencies of Vedic chants, Conch-Shell, Bell and Gong.)

Type of Instrument	Observed Frequency (Hz)
Vedic chant (alone)	147.5, 302, 440
Conch-Shell (sounding alone)	327.5, 655, 980, 1302.5, 1637, 1965, 2292.5
Bell (sounding alone)	1262.5, 2877.5
Gong (sounding alone)	392, 762, 1437, 1792, 2070, 2350, 2675, 3002
Simultaneous sounding of Vedic chant, Conch-Shell, Bell and Gong	147, 302, 327.5, 392, 440, 655, 762, 980, 1262.5, 1437, 1792, 2070, 2350, 2675, 2877.5, 3002

7. Sounding of Gongs in Hindu worship spaces

A gong is a musical instrument that takes the form of a flat, circular metal disc which is struck with a mallet. Gongs are broadly of three types. Suspended gongs are more or less flat, circular discs of metal suspended vertically by means of a cord passing through holes near to the top rim. Bossed or nipple gongs have a raised center boss and are often suspended and played vertically. Gongs are made mainly from bronze or brass but there are many other alloys also in use. Gongs are fabricated through impacting by a metal (iron) or wooden hammer after repeated intervals to get sound of same pitch.The earlier studies[8]indicates that the vibrational properties of gongs will depend on the point of actuation. In Hindu temples, gongs are sounded during the worship and they are sounded along with other musical instruments such as conch shells and bells. The sizes of the gongs are usually small and they are sounded using wooden mallets. They are made of brass and circular in nature. For this study the gong is excited at the center and the spectral analysis of excited sound is carried out. The measured fundamental frequency is at 392 Hz. It is noted that unlike the conch-shell, the higher frequencies observed in gong are not exact integer multiples. The measured sound spectra are given in Table 3. It is also observed that the fundamental frequency and its higher tones are not shifted when the measurement is taken at reflective room which is similar to the observation made for Bell ringing.

8. Simultaneous sounding of conch-bell-gong and chanting in Hindu worship spaces

In worship rituals at a Hindu temple, in a community hall and in a worship room at individual homes, usually all the instruments described above are simultaneously sounded along with Vedic

chanting during the pooja. In this study we have measured the sound spectra of all the three instruments played along with Vedic chanting. The measurement was carried out in anechoic chamber, community hall and Ardha-Mantapa of HTCS temple, Bridgewater, NJ, USA. The measured frequencies are given in Table 3 and the sound spectra are shown in Fig. 4. It is observed that the measured spectra of all the three instruments and vocal chanting are combination of individual frequencies of the Conch-Shell, Bell, Gong and Chanting frequencies.

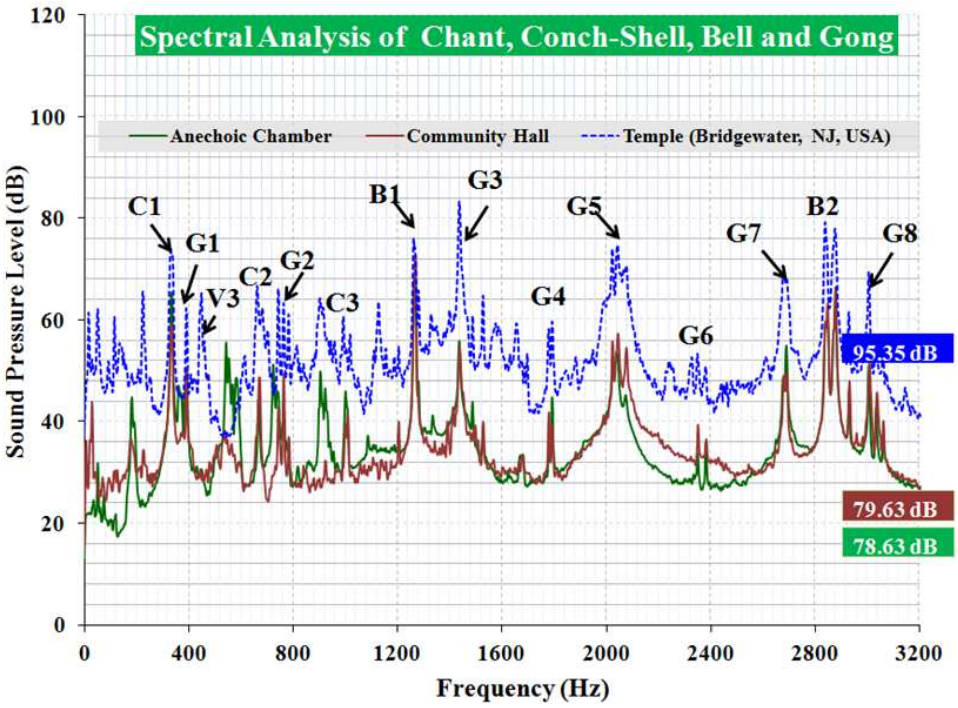


Figure 4: Spectra of Chant (V), Conch-Shell (C), Bell (B) and Gong (G) when simultaneously sounded.

9. Results and Discussions

It is seen from the Table 2 that the theoretically estimated sound pressure level increase ($\sim$19 dB) of the combined coupled space agree well with the sound pressure level ($\sim$17 dB) measured (refer Fig. 4) at the main hall just outside the Ardha-Mantapa of the HTCS temple, Bridgewater, NJ, USA. Generally a traditional Hindu temple has both a Garbha-Griha and an Ardha-Mantapa. Thus the acoustically reverberant environment in the Garbha-Griha and the Ardha-Mantapa not only enhances the spiritual experiences for the devotees but also it adds to the devotional environment of the temple. Figures 3 shows the sound propagation due to the placement of the acoustical source in Garbha-Griha and Ardha-Mantapa respectively. The acoustical enhancement of the environment is seen clearly in both cases.

However during the celebrations of the festivals in a temple, the priests will be in both Garbha-Griha and Ardha-Mantapa. This will further amplify and enhance the acoustical environment in the temples. The perception of pitch is known to depend on both spectral and temporal characteristics[9]. The presence of sharp tones in chants and various other musical instruments have deep impact on devotees in Hindu worship spaces. It is to be noted that chants and musical instruments are also commonly used in worship spaces of other religions[10]. Althoughit is observed that there are positive and beneficial effects of chants and music on human beings[11, 12, 13]further research is needed in this interesting field. Prasad et al[14] studied in detail on acoustics of conch, bell and gong on worship spaces and its comparison with community halls and anechoic chambers. The readers who are interested in more on spectral analysis of individual instruments on Hindu worship spaces can refer to this[14] paper.

10. Conclusions

In Vedic Hinduism sound has received major emphasis through mantras, music, religion and spirituality. It is well known that sound plays a very important role in Hindu worship spaces both at homes, community halls and temples. It is observed that both Garbha-Griha and Ardha-Mantapa as a coupled space significantly contribute to the acoustical enhancement of the spiritual experience of the devotees. The effects of Vedic chants in Hindu worship are well known. In addition to Vedic chants musical instruments such as conch-shells, bells and gongs are also very commonly used to enhance the spiritual experience of the devotees during the worship. It is known that the tonal sounds of these instruments along with Vedic chanting during the prayer would enable the wandering mind of the devotees to focus on the worship rituals. In this study, evaluations of acoustical characteristics of these instruments have been carried out by sounding individually as well as collectively. Measurements are carried out in an anechoic chamber, community worship hall and temple. The observed sound spectra indicate that the measured frequencies are collection of all individual frequencies. Also the frequencies are distinct and are spread across from low to high frequencies in the active hearing range, which contribute to the spiritual experience of the devotees.

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