

Some Investigations on the Sound Field (Sound Propagation) Measurement in a Rectangular Room

P.K. Singh¹ and S.J. Pawar²

¹*Mechanical Engineering Department, K. N. G. D. Modi Engineering College, Modinagar, UP.-201204, INDIA.*

²*Applied Mechanics Department, M. N. National Institute of Technology Allahabad, UP -211004, INDIA.*

Abstract

Sound propagation in a room is a combination of a direct and indirect sound. This work illustrates the sound pressure level (SPL) measurement in a rectangular room by commonly available equipments (ported-box-loudspeaker, microphone, amplifier, and laptop). Sound signal (single tone, sine wave, 4000 Hz, continuous) is fed to the loudspeaker via amplifier, is detected by microphone and fed to laptop. Measurements have been performed in a room (3.96 x 3.35 x 3.35 m) having a window and door. The 4 planes (P1 – P4) located at 0.3, 0.91, 1.52, and 2.13 m from ground divides the room. In each plane, 30 measurements points are taken. The loudspeaker is placed at 1.07 m from ground. Measurements at two different loudspeaker positions are reported. For position A, at P1, below loudspeaker, SPL drops to minimum and at extreme corner along y-axis, SPL rises symmetrically. At 2-3 m along x-axis, SPL drops due to interaction of direct and reverberant sound. At centre of front side, SPL drops, whereas at extremities it rises. At P2, maximum SPL is observed near loudspeaker which drops at 2-3 m along the x-axis, and at all corners, SPL raise to maximum. The effect of reverberation from ground surface is observed in readings of P1 and P2. At P3 and P4, smooth transition in SPL along x and y axes are seen. For position B, at P1 and P2, similarities in measurements with P1 and P2 of position A are observed with striking difference. Complex sound pattern is observed in the middle of room and minor rise in SPL is observed towards opposite side. At P3, monotonously undulated SPL is observed. At P4, slightly different sound field is seen. This work concludes that the

source and receiver position is significantly affecting the sound reception, which can be measured with ease as reported.

Keywords: Loudspeaker; microphone; sound reflection; room; sound pressure level.

1. Introduction

Room acoustics is concerned with sound propagation in enclosures and rooms. In most environments, a sound is heard as a combination of direct sound straight from the source/sources and indirect sound (reflections) from surfaces and other objects. If acoustics of a space is examined, both the direct and the reflections are keys to a sound field in the space along with the position of listener with reference to the sound source. Common problems in room are echoes, excess ambience, too much or too low bass response, poor stereo imaging & localization, unclear dialog, and muddy sound. Low frequencies are often the biggest problem, with wide response variations, especially in a smaller room.

First and most remarkable approach to describe the acoustic characteristics of an enclosure was found by W.C. Sabine around 1900. J.S. Bradley (2011) reviewed parameters from room acoustic measures and future needs in room acoustic. Acoustic design of small rectangular rooms is discussed by M.A. Blaszak (2008). X.Y. Zeng (2005) carried out simulation and measurements on small room and predicted that the diffuse reflections in room acoustic prediction is good, however it is cautiously noted that more diffused sound field should not always be promoted. Some reported contributions for measurement of sound field in a room owed to Russell (2001) and Ueda et. al. (2005).

This work attempts to measure sound pressure level (SPL) in dB in a typical rectangular room by commonly available electroacoustic equipments. As aforementioned, the position of speaker in the room plays a significant role in the propagated sound in the room; hence two positions of loudspeaker in room are identified for reporting in this work.

2. Measurement Scheme

Measurement of SPL in a rectangular room is reported in this work. Commonly available equipments, like loudspeaker, amplifier, microphone, and Laptop along with common software for signal processing have been used for sound generation and measurement. Sound pressure level across source and a receiver establishes an acoustic system between the two specific locations. The situation of sound source and location of receiver has a definite effect on the sound pressure level generated. Measurements have been performed in a room of size 3.96 x 3.35 x 3.35 m with all hard (cemented) surfaces. The room is also having a window and door of dimension 1.22 x 0.91 m and 1.83 x 1.07 m respectively which are located adjacent to each other. Four different

planes are designated for measurement in room, located at a distance of 0.3, 0.91, 1.52, and 2.13 m from the ground surface as shown in Fig. 1. In each plane, 5 measurement points are taken along small (y -axis) dimension of room and 6 along large (x-axis) dimension of room. Hence total 30 measurements are carried out at each plane. For convenience these 4 planes are designated as P1 – P4.

Typical measurement schematic is shown in Fig. 2. A single tone, continuous sound signal of frequency 4000 Hz is generated by Laptop. This signal is fed to the ported-box-loudspeaker system consisting of 5 inch woofer and 1.5 inch piezo-tweeter with the port to the rear side of loudspeakers. The amplifier is used to amplify sound signal from Laptop to the loudspeaker. The microphone detects the sound generated by loudspeaker. The signal from microphone is finally fed to the laptop to measure sound pressure level. The measurements were carried out during night to avoid interference and disturbance from noisy activities. It is significant that sound generated by loudspeaker is spread to all directions and subsequently reflected after striking ground, ceiling, and walls. Thus, the sound detected by microphone is a combination of the direct sound and successively reflected sounds. During this study five various positions of loudspeaker are considered, however, only two are reported in this work. These two positions are shown in Fig. 3 (a) and (b).

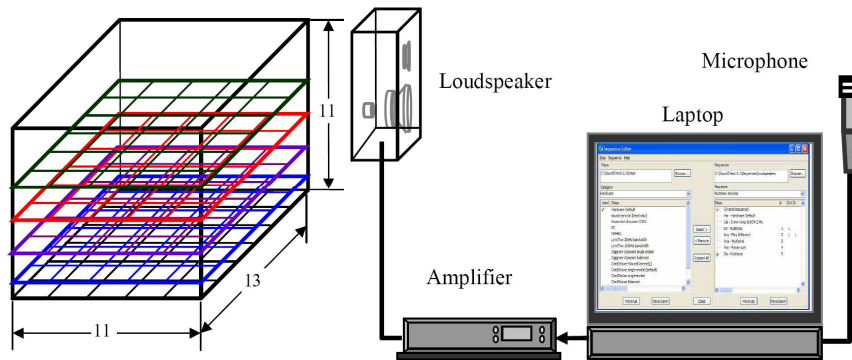


Figure 1: Room showing 4 planes. **Figure 2:** A schematic of measurement setup.

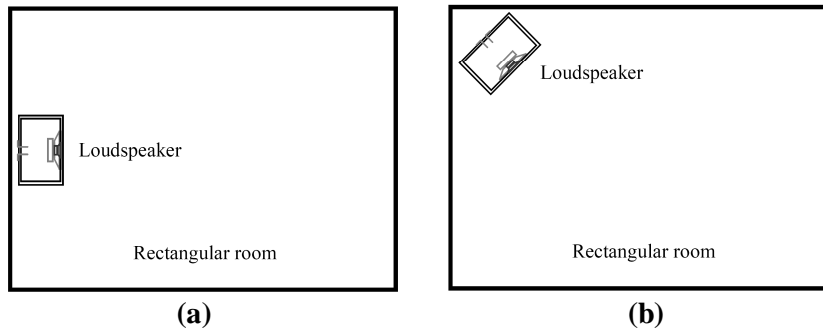


Figure 3: Schematic of placement of Loudspeaker at (a) Position A and (b) Position B.

3. Result and Discussion

Fig. 4 shows the SPL measurement for loudspeaker position A at all planes (P1-P4). One can observe that the sound propagates in three dimensional spaces in a room as pressure fluctuations over ambient atmospheric pressure. Normally, the SPL diffuses away from the source. Once, sound strikes walls, floor and ceiling, it undergoes transmission, absorption, and reflection which depends on the properties of surfaces under consideration. Since, the continuous sound is propagated from the source and reflected from the surfaces, the constructive and destructive interferences cause complex sound field in room. The plane P1 (0.3 m) is located below the plane in which loudspeaker is located. It shows ups and downs in SPL along x and y axes. It is significant that in front of the loudspeaker, SPL tends to be high and away from it along y-axis, SPL drops and then finally rises at the corner of room. Along x-axis, between 2.13-2.74 m, SPL drops to minimum due to strong interactions between direct and indirect sound. Finally, at the other end of loudspeaker, SPL shows maximum rise. At plane P2 (0.91 m), irregularities are observed in the SPL between 0.61-1.52 m. However, at opposite side of loudspeaker, rise in SPL is observed. Just near the loudspeaker, high SPL is found which diminishes symmetrically towards corner. It is significant that the loudspeaker is placed at a height of 1.07 m from the ground and P2 is nearly a plane on axis to the loudspeaker. Result for P3 (1.52 m) and P4 (2.13 m) are moreover similar. At Plane P3, exactly above loudspeaker SPL rises and then drops symmetrically towards corners. Along x-axis, initially SPL drops slowly and then at a faster rate. Since the room height is 3.35 m, the effect of reflection from ceiling is viewed in the SPL of P4. The effect of reverberation from ground surface is observed in readings of P1 and P2. At P3 and P4, smooth transition in SPL along x and y axes are seen.

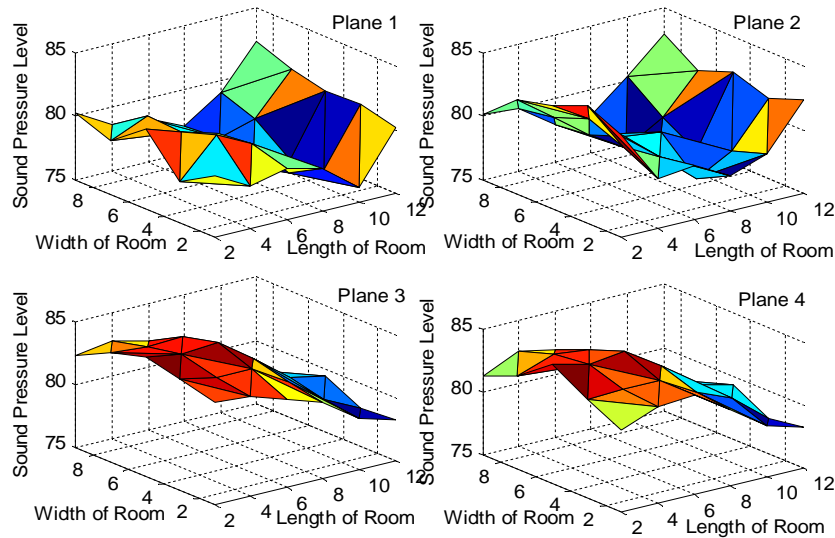


Figure 4: Sound pressure level at various planes for loudspeaker at position A.

Analogous to Fig. 4, the SPL measurement for loudspeaker position B is shown in Fig. 5. At plane P1, exactly below loudspeaker a drop in SPL is observed and towards the opposite corners of room, SPL rises along y-axis, however along x-axis, SPL found to be undulating. As one move exactly opposite to the loudspeaker (near front wall), excessive rise in SPL is observed this is typical characteristic of room under consideration. Significantly different SPL response is observed at P2. However, this response has a striking similarity with response of P1. High SPL is observed in the vicinity of loudspeaker. The effect of door and window are clearly visible at 1x6 and 1x10 measurement positions. Along y-axis, SPL response slightly drops from left side to right side. The results obtained for plane P3 and P4 are nearly same. Highest SPL is observed above loudspeaker. Based on analogous observation for P1, one can conclude that loudspeaker radiate uniformly along top and bottom side; however the platform on which loudspeaker is placed, plays a key role in dropping of SPL. It is concluded that the variation in SPL is observed due to presence of door and window opposite to the loudspeaker. For comparison, results are also shown in Fig. 6 (a) for all planes when loudspeaker is placed at position A. One can observe clear distinction between measured SPL at different locations. Smooth decay in SPL and reverberation effects are clearly illustrated in this figure. Similarly, when the loudspeaker is at position B, the superimposed results are shown in Fig. 6 (b). Based on findings one can conclude that the effect of room surface and topography of room have a significant effect on SPL in room. Thus, one can conclusively state that the sound perception at different position in room would be different.

4. Conclusions

It is concluded from this brief measurement report that the sound generated from single source in a small room has significant effect on the sound propagation in the room. It is also concluded that the sound propagation have been dominantly affected by the placement of loudspeaker in the room. Type of materials (materials absorption coefficient) from which sound is reflecting also shows significant effect on the reverberation. It is also found that, at the two locations of measurement point one can find maximum SPL different upto 2.5-3.5 dBSPL. Sound perception by an individual is highly subjective issue. 3 dBSPL sound pressure difference is not easy to percept by human being, however, human ear can easily detect it. Above 80 dBSPL, daily limit of sound/noise exposure reduces by half for every 3 dBSPL sound pressure level increase. It is also found from the response that objects in room are also playing significant role in the created sound field in the room. It is mentioned, earlier that bass response is more prone to the variations in SPL, however, one can conclusive state that at mid and high frequency, SPL variation can also be observed which could affect sound perception. Finally, this work concludes that the simple procedure with easily available electroacoustic equipment can leads to fairly good estimate of sound propagation in a room.

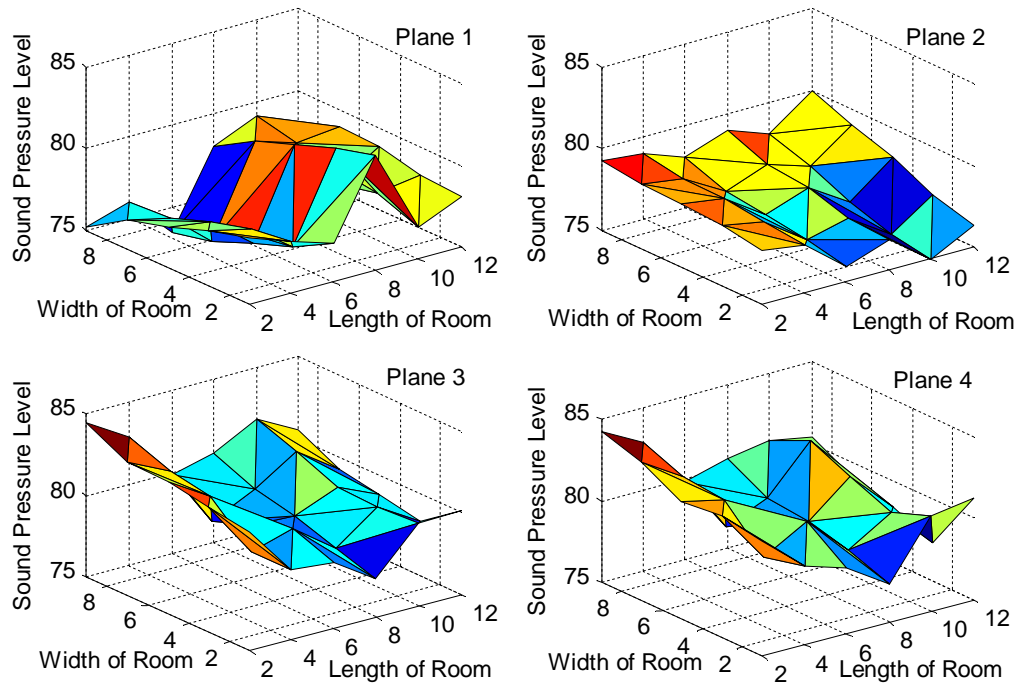


Figure 5: Sound pressure level at various planes for loudspeaker at position B.

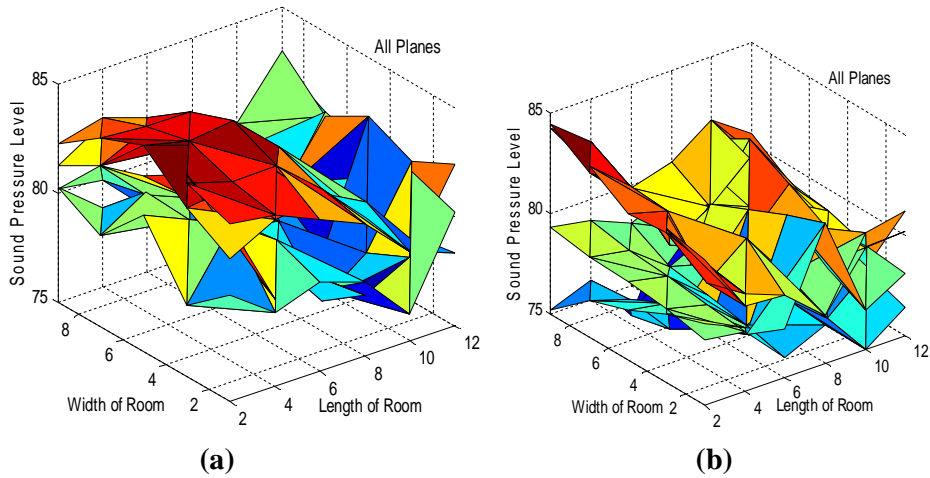


Figure 6: Superimposed SPL at all planes for loudspeaker at (a) position A and (b) position B.

References

- [1] D.A Russell (2001), Reverberation in a small room, Graduate Program in Acoustics, The Pennsylvania State University, USA.
- [2] J S Bradley (2011), Review of objective room acoustic measures and future needs, *Appl. Acoust.*, 72, 10, pp. 713–720.
- [3] L K Ueda, F L Figueiredo, F Iazzetta, and F Kon (2005), A user-friendly graphical system for room acoustics measurement and analysis, *Proc. 10th Braz. Symposium Comp Music*, pp. 118-129 (gsd.ime.usp.br)
- [4] M A Blaszak (2008), Acoustic design of small rectangular rooms : Normal frequency statistics, *Appl. Acoust.*, 69, 12, pp. 1356–1360.
- [5] X Y Zeng (2005), An improved broad-spectrum room acoustics model including diffuse reflections, *Appl. Acoust.*, 66, 11, pp. 1309–1319.

