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Room sizing for uniform room modes distribution based on fibonacci series

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We propose a new method for uniform distribution of room resonances to eliminate coloration and excess reverberation of small rooms. Uneven distribution of these room modes gives rise to these problems. Different room ratios proposed in the literature are compared with the ones derived in this work from the Fibonacci series.The results show that the proposed method accommodates the construction constraints and variations which the previous fixed ratios failed to address.

Introduction

It is common knowledge that singing in shower, elevators, tub or any small room has a very satisfying and enjoyable experience to the singer or atleast a nearby listner. This is due to the fact that the voice in these locations is rich, full and more powerful than in large rooms. This illustrates the effect of room modal frequencies that reinforced the singer's voice at certain frequencies related to the dimensions of the room. The hard walls of such enclosures are reflecting and the characteristic frequencies associated with the room's length, width and height coincide and thus interfere constructively to strengthen the voice of the singer in the room. These resonance frequencies are welcome here compared to their presence in sound recording rooms where they tend to unnecssarily mask recorded sound.

The work of Bolt (1939) showed that even rooms with irregular shapes possess discrete normal modes and standing wave patterns as pronounced as those which occur in simple regular shapes such as rectangular or cube rooms. These modes in small rooms often lead to prolong reverberation and coloration; uneven frequency responses. Tonal balance and timbre of a sound in rooms are very important qualities of sound for recording and reproduction purposes. Thus proper studio designs most eliminate these objectionable problems. (Knusden and Harris, 1950)

Two most common ways of reducing the nodal ringing at low frequency are proper room sizing and appropriate placement of absoptive materials in the rooms after considering the locations of both the speakers and microphones.The first remedy which results in uniform distribution of the room resonance frequencies in the design has economic advantage over the seond method. It does not allow the problem to exist at all. Various room dimensions' ratioswere proposed in literature that would lead to uniform distribution of these resonance frequencies (Bolt, 1939, Knudsen and Harris, 1950, Louden, 1971 and Gilford, 1979). But these fixed ratios do not allow construction variations and changes. Computerized advanced methods of obtaining uniform room modes distibution are currently being proposed (Papadopoulos, 2000, Trevr e.tal 2001). They optimized several options and arrived at an apropriate one for a given room size.

In this work, we propose an itermediate method of room sizing usinga simple and easy to remember series, the Fibonacci series (Moss, 1961) in selecting appropriate room ratio for a given room size that would spread the room modes evenly and thus avoid the colaration and the excessive reverberation. This series provides several options to accommodate the construction changes and is easy to remember. It does not consider the locations of the speakers, the micropohones and absorptive materials in the room as in the some methods

Theoretical Considerations

The fact that enclosures behave like resonators leads to the existence of the resonant frequencies in rooms. As resonators of different sizes resonated at different frequencies, rooms of different dimensions possess different room resonant frequencies. The distribution of these acoustic modes, the resonant frequencies, of a room in a low frequency range is an issue of great importance (Leo, 1996). These frequencies can be calculated from dimensions of the given by the following equation; (Vigran, 2008)

$$f(Hz) = \frac{v}{2}\sqrt{\left(\frac{n_x}{L}\right)^2 + \left(\frac{n_y}{W}\right)^2 + \left(\frac{n_z}{H}\right)^2}$$

Where$n_x, n_y and\ n_z$ are integers and L, W and H are the length, width and height of the room and v is the speed of sound in air. The room ratio is computed as H:W:L. This ratio controls the density of a particular mode for a given room.

It is observed that at low frequencies, the sound field may be described interms of a superposition of sound fields correspondingto each normal mode in the frequency range of interestas well as modes immediately outside the frequencyrange of interest (Hansen, 2007). Bolt (1939) produced design charts that enabled him to determine preferred room ratios. He arrived at two fixed ratios; 1:1.5:2.5 and1:1.25:1.6. While Louden (1971) obtained a well known room ratio of 1:1.4:1.9 when he considered starndard deviation of the intermode spacing for uniforn distribution of the modes. Two modern methods today make use of computer in optimization processes; Gilford's (1979) method computrized by Trevor et al (2004) and Papadopoulos's (2001). While the first searched for optimum ratio the last proposed modification on the walls of the room to remove point of high nodal densities or reinforce weak modes. Such modification involves creating cavities and 'bumps'on the walls to suppresse some modes as well as enhance some.

Methodology

The method adapted here is comparing the frequency distribution plots at low frequencies of several ratios proposed by various researchers with those ones from any three consecutives elements of the Fibonacci series starting from the begining. The ratios start with a cube; 1:1:1, (for comparison purpose since 1 1 1 is not in the series) then 1:1:2 then 1:2:3 and so on. A MATLABcode is developed to generate the frequencies and plot them against their number of occurences.

The ratios of Bolt, Knusden, Louden and those of the two standard rooms recommended by the British Standard Institute and the International Electrotechnical Commisssion (EBU R22, 1998) were computed and plotted.

Results

Appearance of peaks with different heights, such as in figures 1,2 and 3, indicates existance of uneven distribution of the room modal frequencies within a given band and the corresponding rooms would have nodal ringings. However, if the modes exist but are of equal strengthes (number of occurences) their nodal and reverberation effects are insignificant as in figures 4 through 15.

Fig. 1. Modes Distribution for Room with Ratio 1:1:1

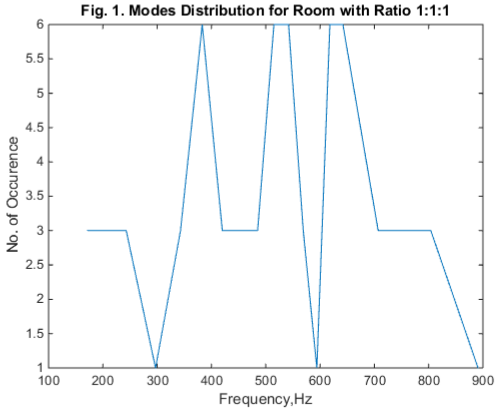


Fig.2 Modes Distribution for Room Ratio 1:1:2

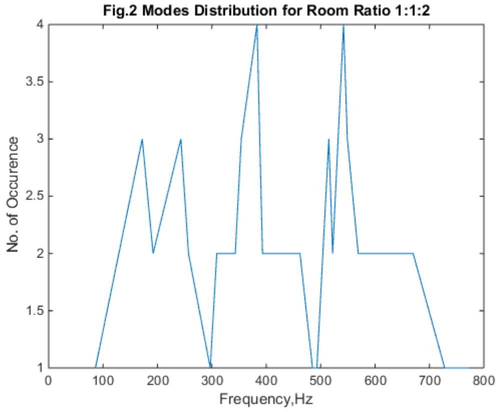


Fig.3 Modes Distribution for Room Ratio 1:2:3

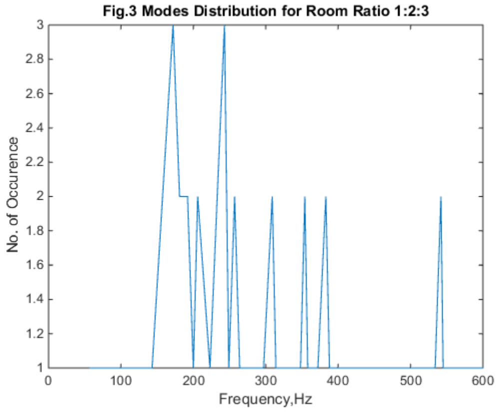


Fig.4 Modes Distribution for Room Ratio 1:1.5:2.5

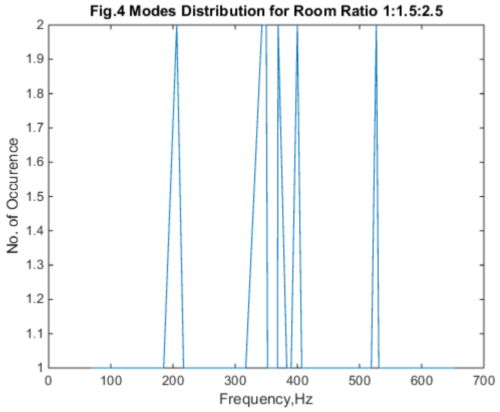


Fig.5 Modes Distribution for Room Ratio 1:1.67:2.67

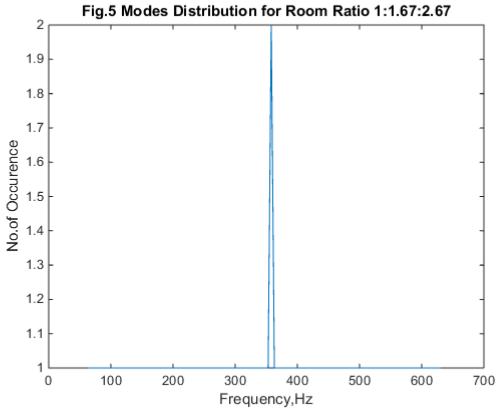


Fig.6 Modes Distribution for Room Ratio 1:1.6:2.6

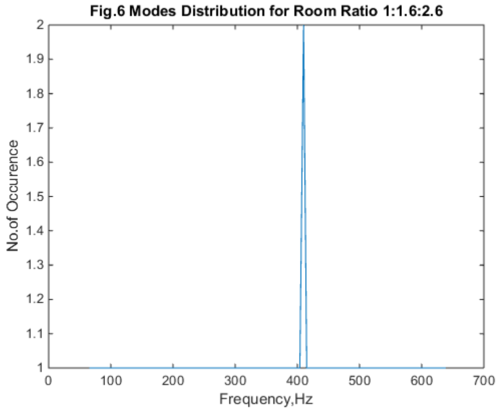


Fig.7 Modes Distribution for Room Ratio 1:1.625:2.625

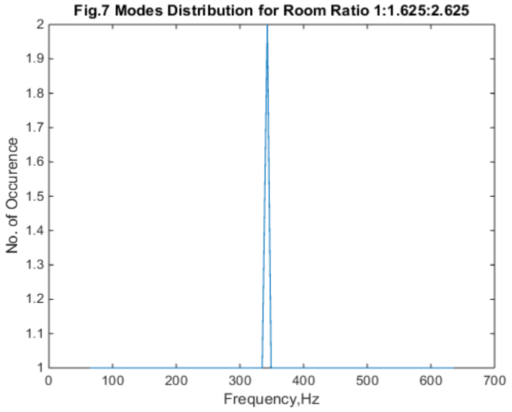


Fig.8 Modes Distribution for Room Ratio 1:1.619:2.619

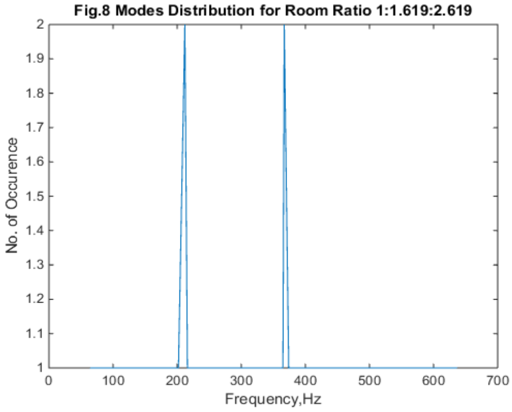


Fig.9 Modes Distribution for Room Ratio 1:1.617:2.617

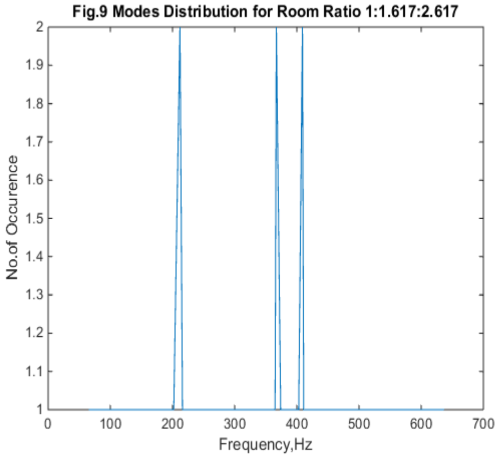


Fig 10 Modes Distribution for Golden Ratio (1:1.618:2.618)

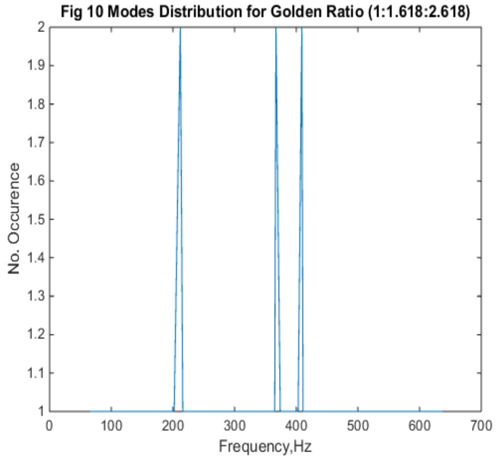


Fig.11 Modes Distribution for Room Ratio 1:125:1.6 Bolt's 2

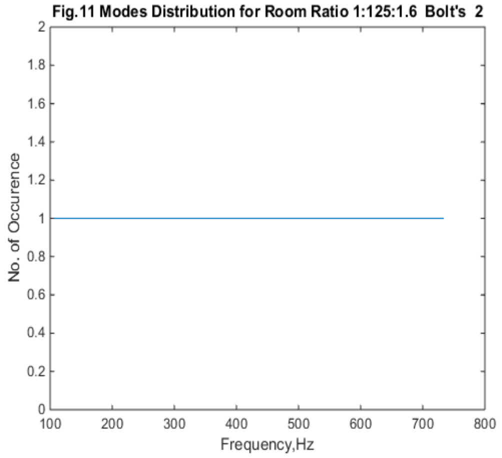


Fig.12 Modes Distribution for Room Ratio 1:1.5:1.9 Lauden Ratio

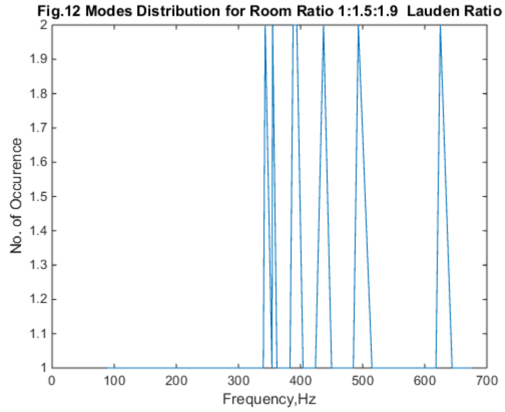


Fig.13 Modes Distribution for Room Ratio 1:1.5:2 Knudsen Ratio

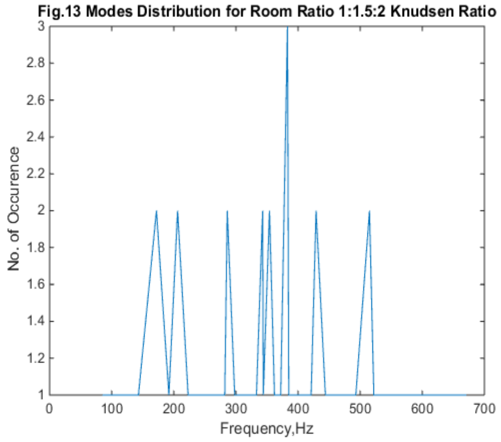


Fig.14 Modes Distribution for Room Ratio 1:1.5:1.59 BSI 1 Ratio

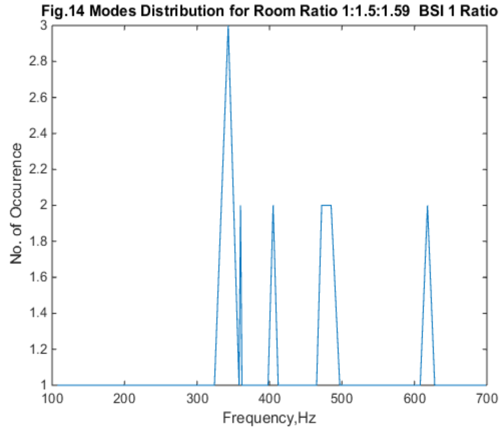
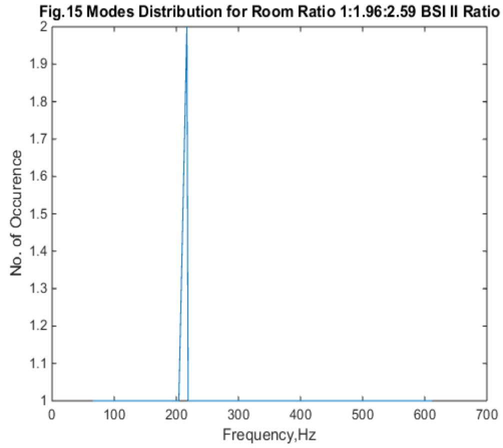


Fig.15 Modes Distribution for Room Ratio 1:1.96:2.59 BSI II Ratio



The qualities of rooms with ratios made from Fibonacci series are clear; Figures 4 through 10. The second room ratio due to Bolt, 1:1.25:1.6 (Fig 11) could be seen to have the best frequency distribution. However, it does not accomodate construction changes and constraints. The last recommended room ratio based on the recommendation in Trevor et.al (2001) has similar distribution as those from ratios derived from the Fibonacci seris (Figs 4-10). Figures 13 and 14 could be seen to have some poor responses due to peaks and with large number of occurrences.

Conclusion

We found that the room sizing for the unifrom distribution of room resonance frequencies could be easily achieved using the simple Fibonacci series. The best practice today is through the use of computer program that would consider additional information about the contents of the room in arriving at the most appropriate ratio of the room dimensions (Trevo, 2004). However, for quick and fairly accurate ratio, the fibonacci series provide the most flexible and more convenient options compared to the fixed ratios which cannot accommodate building constraints. It also worth mentioning that any three consecutive elements of the proposed series satisfy all the conditions put to rooms'measures for uniform room modes'distribution in Bonello(1981) and EBU(1998).

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