AIP

PHYSICS TODAY

Acoustics of multiuse spaces FREE

David L. Klepper

Physics Today **74** (8), 10 (2021);
https://doi.org/10.1063/PT.3.4804

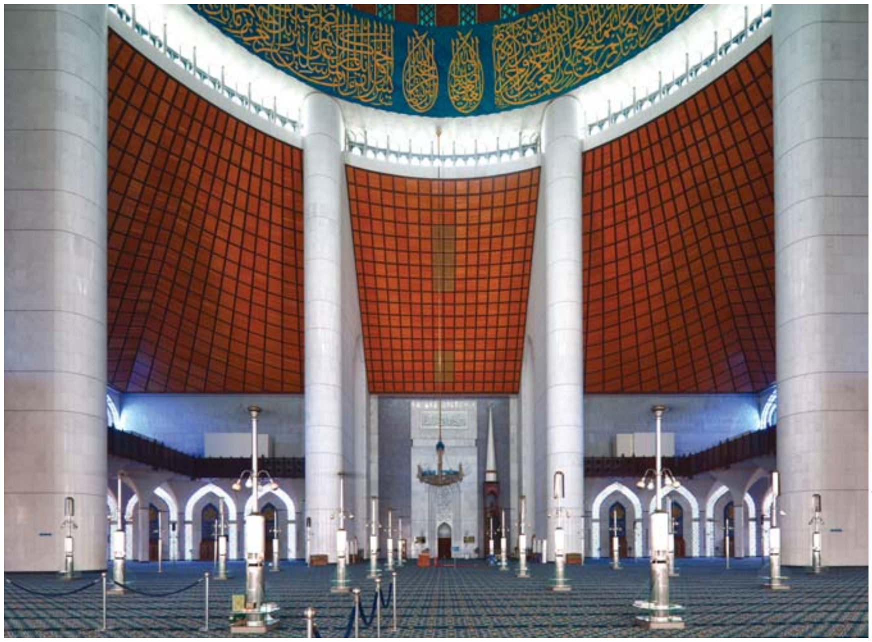
Acoustics of multiuse spaces

The article "Exploring cultural heritage through acoustic digital reconstructions" by Brian Katz, Damian Murphy, and Angelo Farina (PHYSICS TODAY, December 2020, page 32) gives an excellent review of the state of the art in computer simulation of room acoustics. However, the authors seem unfamiliar with the revolution in concert-hall, theater, and worship-space design that started with Peter Parkin and J. H. Taylor's work in London's St Paul's Cathedral[1] in 1952. Beginning with that pioneering effort, room-acoustics designers have found that the ratio of early-arriving sound energy to reverberant sound energy at the listener's ears is at least as important as reverberation for speech and music acoustics.[2,3] The usual division between early and reverberant sound is 50 ms for speech and 80 ms for music. "Usual" is an important word.

At one extreme, an acoustically "dry"—that is, nonreverberant—thrust-stage or in-the-round theater needs special electroacoustic or sound-reflecting surfaces to ensure enough early sound energy reaches a listener who is seeing the back of someone speaking rather than his or her face. Otherwise, with no real departure from previous practice, echoes usually reduce intelligibility.[4]

A more relevant and frequent application is the reconciliation of speech and music in the same space. A multiuse auditorium can, of course, have variable acoustics, but moving drapes, curtains, and sound-absorbing panels in the middle of worship services is hardly practical. Thus the greatest value of the early-to-reverberant energy-ratio concept has been for houses of worship, particularly large Christian churches and cathedrals, and for places where sound-absorbing treatments are not suited architecturally.[4]

Perhaps the best demonstration of the concept is the Sultan Salahuddin Abdul Aziz Shah Mosque, known as the Blue Mosque, in Shah Alam, Malaysia. It has the largest dome—more than 51 m in diameter, rising 75 m above the prayer hall—of any religious building. It also has the largest and most complex sound-reinforcement system. Designed by Larry Philbrick, the system uses the directional properties of loudspeakers rather than sound-absorbing treatments to control echo and reverberation and to increase clarity. Two large, central loudspeaker clusters—one for close worshippers, one for middle and far worshippers—cover the main prayer area under the dome. Additional line-source loudspeakers are built into the interior and courtyard columns. The mosque can accommodate 24 000 worshippers at one time.



B.O'KANE/ALAMY STOCK PHOTO

THE SULTAN SALAHUDDIN ABDUL AZIZ SHAH MOSQUE in Shah Alam, Malaysia, has the largest dome of any religious building. Behind the two sets of tan tiles in the central section of the sloped ceiling seen here are large clusters of loudspeakers that together cover the main prayer area under the dome.

References

1. P. H. Parkin, J. H. Taylor, *Wireless World*, February 1952, p. 54, and March 1952, p. 109, reprinted in *J. Audio Eng. Soc.* **54**, 67 (2006).
2. See, for example, M. Long, *Architectural Acoustics*, 2nd ed., Academic Press (2013), p. 748; M. D. Egan, *Architectural Acoustics*, McGraw-Hill (1988), p. 98.
3. D. L. Klepper, "An autobiographical assessment of the importance of the early-to-reverberant sound-energy ratio, 'clarity,' in speech acoustics," Pro Audio Encyclopedia (1 September 2016), www.proaudioencyclopedia.com/?p=363; L. G. Marshall, *J. Acoust. Soc. Amer.* **96**, 2251 (1994).
4. See, for example, D. L. Klepper, *J. Audio Eng. Soc.* **43**, 599 (1995), reprinted in *An Anthology of Articles on Sound Reinforcement . . .*, Audio Engineering Society (1996), p. 392; Clayton Acoustics Group, "St. Paul's Episcopal Church, Rock Creek Parish, Washington, DC" (2005), www.claytonacoustics.com/pages/portfolio/houses%20of%20worship/project%20profiles/St.%20Paul's.html.

David L. Klepper
(daveklepper@yahoo.com)
Yeshivat Beit Orot
Jerusalem, Israel

▶ **Katz, Murphy, and Farina reply:** Please note that our article was an overview of research in virtual heritage acoustics, not a presentation of modern acoustical design methods. The letter by David Klepper focuses on electroacoustic solutions to difficult acoustic situations.

Contrary to assumptions by the letter writer, we are very familiar with energy-ratio metrics in room acoustics,[1] including their limitations.[2] Although not relevant for our introductory article, we have used energy ratios—together with other measures—not only for characterizing acoustic spaces but also for calibrating and validating acoustic simulations and auralizations.[3] In particular, characterizations of Venice's La Fenice theater[4] and Paris's Notre Dame Cathedral[5] before