PREDICTING TRANSMITTED LEVELS AND AUDIBLE EFFECTS FOR MEETING ROOM SPEECH SECURITY

J.S. Bradley, M. Apfel and B.N. Gover

Institute for Research in Construction, National Research Council, Montreal Rd., Ottawa, K1A 0R6

Introduction

The term 'speech security' is used to describe very high levels of speech privacy sometimes required for closed meeting rooms. A room is said to be completely speech secure when persons outside the room are not able to understand conversations from within the meeting room, or in more extreme cases are not able to detect any speech sounds from the meeting room. The audibility and intelligibility of transmitted speech sounds are related to the level of speech sounds relative to existing ambient noise levels (i.e. signal-to-noise ratios) at locations outside the meeting room. The levels of speech sounds from adjacent meeting rooms will depend on the loudness of the speech in the meeting room and the sound transmission characteristics of the room boundaries.

The conventional approach to measuring sound isolation between rooms is from the differences in space-average sound levels in each room. This is not appropriate for many situations where speech security must be verified. A new method is proposed in which attenuations between room-average sound levels in meeting rooms to spot-receiver positions near the outside of these rooms are used to evaluate the speech security of the room. The new method avoids problems with ill-defined receiving spaces, and spaces that do not have even approximately diffuse sound fields. It also provides assessments of speech security for more sensitive locations where an eavesdropper is more likely to be found.

The new approach

The sound transmission characteristics of room boundaries are usually measured using standard tests in terms of room-average sound levels in the source and receiving room (e.g. ASTM E336 standard). (See also Fig. 1) According to such procedures, one can predict expected levels as a function of the $^1/_3$ octave band frequency, f, in an adjacent space as follows,

$$L_R(f) = L_S(f) - TL(f) + 10\log\{S/A(f)\}, \text{dB} \qquad (1)$$

$L_S(f)$ is the average source room sound level,
$L_R(f)$ is the average receiving room sound level,
$TL(f)$ is the sound transmission loss of the wall,
S is the common wall area of the two rooms, m^2,
$A(f)$ is the sound absorption in the receiving space, m^2.

This equation is derived assuming that the sound fields in both rooms are ideally diffuse. Although this may be approximated in the meeting room, the adjacent space could be anything from a broom closet to an atrium or an open-plan office area. It is often difficult to apply equation (1) because the spaces are not diffuse and/or because it is not possible to define the dimensions of the receiving space. It is also more likely that an eavesdropper would be located close to the room boundary rather than in the middle of the receiving spaces. Therefore, the new method predicts transmitted sound levels 0.25 m from the outside of the meeting room,

$$L_{0.25}(f) = L_S(f) - TL(f) + k, \text{dB} \qquad (2)$$

If the receiving space is a free field, $k \approx -3$ dB [1]. For conditions typical of meeting rooms, values of k were determined empirically.

Experimental results

Even 0.25 m from the test wall, reverberant sound in the receiving space has a small effect on the measured $L_{0.25}(f)$ values. Test walls were constructed between a pair of reverberation chambers and ASTM E90 sound transmission loss tests were first performed to obtain $TL(f)$ values. The walls included wood and steel stud constructions and had STC values of 46, 53, and 56. Next, values of $L_{0.25}(f)$ and $L_S(f)$ in equation (2) were determined for varied amounts of sound absorption in the receiving space. A total of 3 different walls have been tested with 4 different amounts of absorption to give 12 estimates of k. These are plotted versus the reverberant sound level, L_{RV}, in Fig. 2.

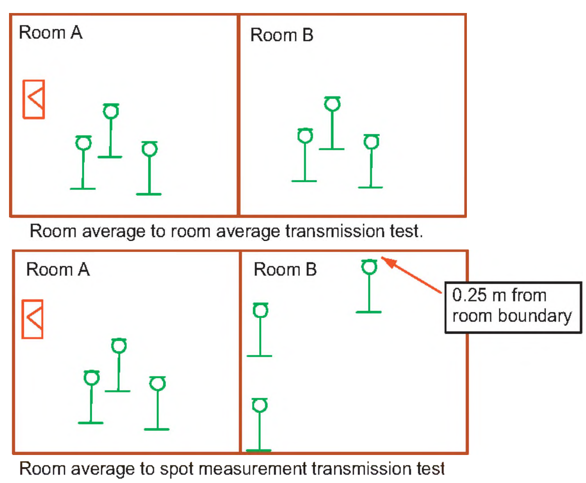

Fig. 1 Conventional room-average to room-average measurement approach (upper) and the new room-average to spot-receiver position approach (lower).

Using equation (2) and an estimate of *k* from Fig 2, one can predict received sound levels, $L_{0.25}(f)$. Fig. 3 compares measured and predicted $L_{0.25}(f)$ for the three test walls. For the speech frequency range from 160 to 5,000 Hz, the average differences between measured and predicted $L_{0.25}(f)$ were 0.24, 0.17 and -0.19 dB.

Predicting the degree speech security

From a design meeting room speech level, we can predict transmitted speech levels at points 0.25 m from the outside of the meeting room using equation (2). Combining these speech levels at points 0.25 m from the outside of the meeting room with the ambient noise levels at those positions, we can estimate the degree of speech security in terms of previously determined signal-to-noise ratio speech security measures [2]. These indicate the fraction of listeners that would: understand at least one word, hear the cadence (or rhythm) of the speech, or hear any speech sounds at all. When mean subjective ratings are plotted versus the uniform weighted signal-to-noise ratio, SNR_{UNI32}, as illustrated in Fig. 4, 50% of listeners can understand at least one word for an SNR_{UNI32} of –16 dB, but for 50% of the listeners some speech sound is audible at or above SNR_{UNI32} = -22 dB.

Conclusions

The new procedure makes it possible to reliably rate the speech security of meeting rooms, even when adjacent spaces do not have diffuse sound fields and are difficult to define. The degree of speech security can be given in terms of signal-to-noise ratio measures that have been calibrated against subjective ratings in extensive previous work.

Acknowledgements

This work was jointly funded by Public Works and Government Services Canada, the Royal Canadian Mounted Police and the National Research Council.

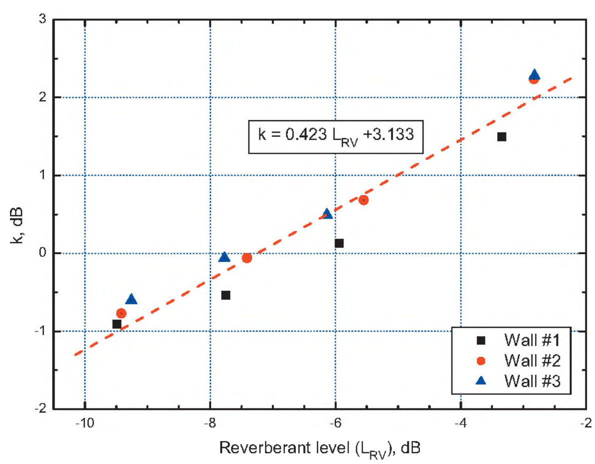

Fig. 2 Value of k versus reverberant level in the receiving space.

References

1. Pierce, A.D., "Acoustics", McGraw-Hill (1981).
2. Gover, B.N. and Bradley, J.S., "Measures for assessing architectural speech security (privacy) of closed offices and meeting rooms", J. Acoust. Soc. Am. vol. 116, no. 6, pp. 3480-3490 (2004).

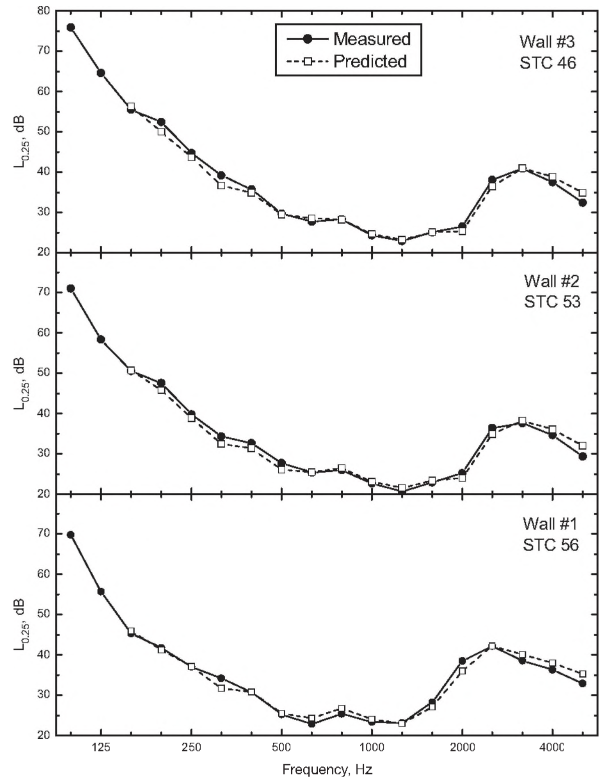

Fig. 3 Comparison of measured and predicted $L_{0.25}$

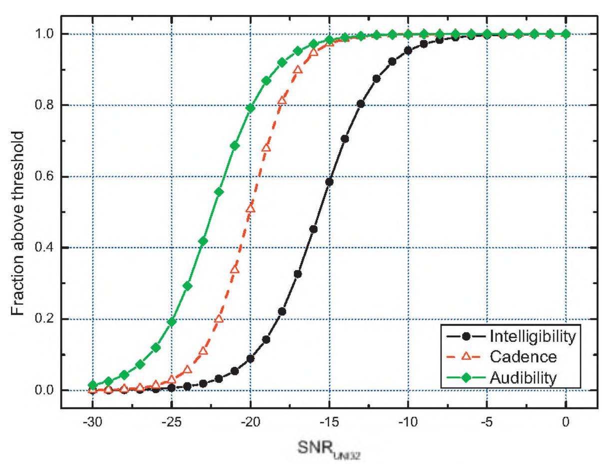

Fig. 4 *Mean trends for the fraction of subjects above the thresholds: of the audibility of speech, of the audibility of the cadence of speech, and of the intelligibility of speech [2].*