Audibility of Edge Diffraction in Auralization of a Stage House

Rendell R. Torres and Mendel Kleiner

Chalmers Room Acoustics Group, Chalmers Univ. of Tech., S-41296 Gothenburg, Sweden

Abstract: This investigation determines the audibility of edge-diffraction when used in auralization of a stage house. Computed impulse responses with varying orders of diffraction are auralized and compared via listening tests. These impulse responses are also compared with measured, auralized impulse responses from a scale model. Results indicate that, for the positions studied, first-order diffraction is significantly more audible than second-order diffraction. Thus, higher-order edge diffraction calculations can possibly be neglected in auralization programs.

INTRODUCTION AND APPROACH

A numerical model to calculate first- and second-order edge diffraction has been developed by Svensson, following work by Biot, Tolstoy, and Medwin (1). The questions pursued here regard the model's use in auralization of a scale-model stage house (see Fig. 1): Is the inclusion of diffraction audible (i.e., necessary) in the auralized room impulse response (IR)? If so, must one include more than first-order diffraction? Finally, does the computed IR sound more "realistic" when diffraction is included?

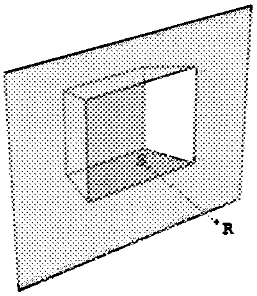

FIGURE 1. Geometry of the stage house. The source "S" and receiver "R" represent measurement positions.

Three listening tests are constructed, wherein impulse responses are convolved with various anechoic signals: a Dirac pulse, pink noise, speech, and organ music. The first test, to determine whether the computed diffraction is audible, compares computed IRs without diffraction ("specular") to IRs with up to second-order diffraction. The listening-test format "ABX" requires the test person to choose which of sound "A" or "B" is actually "X"; the perceived difference between A and B is determined from the percentage of identifications. The second test, to determine whether an audible difference exists between IRs with first- or second-order diffraction, also uses ABX format. The final test uses pair comparisons to rate the similarity of the computed IRs to the measured IRs.

The computed IRs correspond to measurements on a 1:20 scale model of a baffled stage house, with source-receiver positions depicted in Fig. 1. The response of the scale-model's spark source is "equalized" (inverse filtered) to obtain a flat frequency response up to 2 kHz (the "full-scale" range allowed by the measurement). For the third listening test, the equalized spark response is convolved with the computed IRs to allow comparison with the measured responses. Most of the significant frequency effects of diffraction typically occur in this lower region.

For this initial investigation, computed IRs are compared with omnidirectionally measured IRs. Binaural head-related transfer functions (HRTF's) are not used, which leaves the frequency content uncolored. Binaural measurements and computations will later be conducted to determine effects on spatial perception, although diffraction is generally considered to be a low-frequency effect.

CURRENT RESULTS AND CONCLUSIONS

Frequency responses for three computed IRs (specular; first- and second-order diffraction) are plotted and averaged over third-octave bands in Fig. 2. For the positions studied, diffraction seems to have little effect (~ 1 dB), and addition of second-order diffraction is nearly indistinguishable from first-order in the frequency domain.

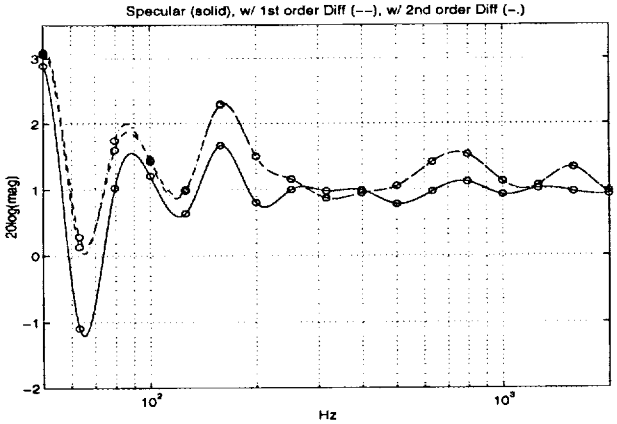

FIGURE 2. Frequency responses with zero, 1st-order, and 2nd-order diffraction; circles = third-octave center frequencies.

Differences are more audible in the time domain, particularly when listening to "bare" IRs (convolved with a Dirac pulse), for which their time-decay characteristics are most apparent. In this case, the two ABX-tests results indicate (1) a significant difference between the specular IR and the IR with diffraction (Q(r) ≈ 0.002), and (2) *no* significant difference between IRs with first- or second-order diffraction. Schematically shown in Fig. 3, preliminary results from pair comparisons (Test 3) between four IRs suggest that adding diffraction to the specular IR increases its perceived similarity to the measured IR. The values shown are normalized ratings of "similarity to the reference," where the reference is the scale-model IR. (Note: The "reference" is not always given the value 1.0 when compared to itself.) One may conclude that first-order edge diffraction is useful for auralization, while second-order diffraction may generally be neglected. Although the computed IRs are still relatively "distant" from the measured IR, the diffraction model is nonetheless a perceivable improvement over the image source method. Diffraction under balconies ("shadow zones"), furthermore, likely has greater audibility and significance. Future study will investigate these effects and extend the computational model to handle closed geometries.

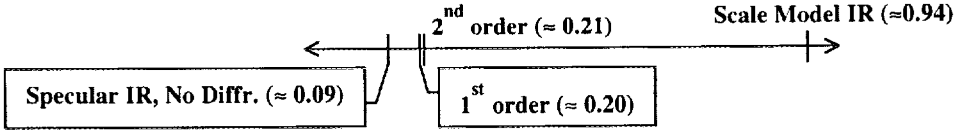

FIGURE 3. Pair comparisons with the "bare" IRs suggest that inclusion of first-order diffraction increases similarity to the measured IR and is virtually (audibly) identical to second-order diffraction for the source-receiver combination studied.

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1. Svensson, U. P.; Andersson, R.; Vanderkooy, J. "A new interpretation of the Biot-Tolstoy edge diffraction model," Submitted July 1997 to *J. Acoust. Soc. Amer.*