The interaural coherence of physically widened sound sources

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Introduction

The apparent source width (ASW) is one of the key perceptual attributes of a sound and is usually investigated for decorrelated point sources (e.g. Käsbach, 2016, Whitmer et al., 2013). The radiation patterns of spatially extended sound sources are generally less coherent than those of point sources, and depend on their physical properties (Goriely, 2011). The relation between the geometric dimensions of sound sources, the ear signals and perception are, however, not yet understood. Here, we present an analysis of the interaural coherence, i.e. the maximum of the interaural cross-correlation function, elicited by spatially extended sound sources as a function of their azimuthal position and spatial extent.

Methods

Spatially extended sound sources were approximated as the superposition of adjacent point sources. A set of HRTFs was measured at a spatial resolution of 0.5 degrees using an artificial head (HEAD Acoustics HMS II.3 with an anatomically formed pinna according to ITU-T P.57).

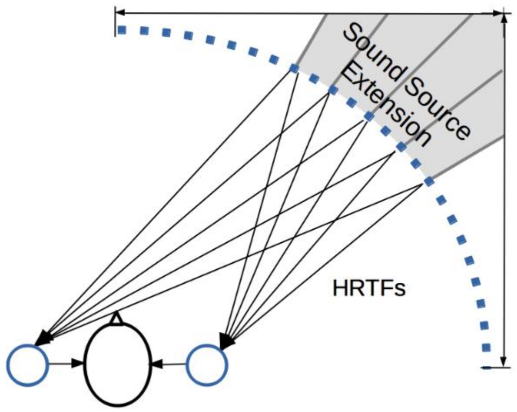

Figure 1: The approach to extending sound sources. White noise is convolved with all head-related transfer functions (spaced at 0.5 degrees) within a given incidence angle. The binaural signal is retrieved via summation of the resulting signals.

For a specific physical source width, white noise was convolved with all HRTFs within the incidence angle of the sound towards the listener. The binaural signals were then retrieved as the sum of all left ear and right ear HRTFs, respectively. The approach is illustrated in Figure 1.

Results

The resulting binaural signals were bandlimited from 200 to 4000 Hz and their coherence was evaluated. The interaural coherence depends on the azimuth, already for single pairs of HRTFs.

In Figure 2, the frequency-dependent coherence is exemplarily illustrated for an azimuthal sound source position of 120 degrees. The decrease in interaural coherence at angles beyond about 100 degrees is largely caused by low coherence in the frequency range from 1080 to 3050 Hz.

Similarly, the maximum aperture angle of the HRTFs does affect the interaural coherence, albeit not necessarily in a monotonic fashion.

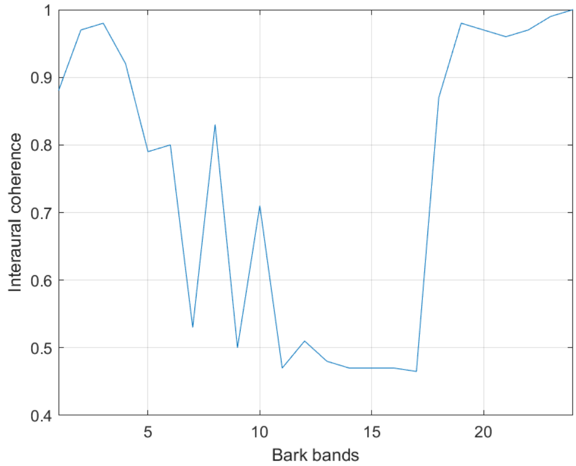

Figure 2: The interaural coherence per bark band for a sound source center of 120degrees and a spatial extent of 240 degrees. Bark bands 10 to 16 correspond to frequencies from 1080 to 3050 Hz

For frontal sound sources (up to an azimuth of about 20 degrees) the interaural coherence remains beyond 0.96 for all frequency bands. Sources extending further than about 200 degrees yield coherent signals.

The interaural coherence of lateral sound sources decreases largely monotonically for increasing spatial extents. The precise physical source width for which the interaural coherence reaches its minimum again depends on the azimuth of the sound source. Further increases in spatial extent restore binaural coherence. Sound sources centered at azimuthal angles beyond 90 degrees generally elicit a lower interaural coherence than those centered at smaller angles.

For sounds with theoretical centers from 160 to 180 degrees, increases in spatial extent yield an increase in coherence. The maximum degree of coherence is reached for extents of 90 to 100 degrees.

Discussion and Summary

The results suggest that both, the physical width of a sound source, and the relative source position are likely to affect the ASW. The minimum and maximum interaural coherence that can be elicited by a spatially extended sound source, and whether a relative increase in spatial extent leads to a more or to a less coherent binaural signal, depend on its lateral position in regards to the listener. The front-back asymmetry of the head and outer ears might influence the interaural coherence, thus contributing to the perception of widened sound sources at lateral positions.

References

[1] J. Käsbach, Characterizing apparent source width perception, PhD thesis, DTU, 2016

[2] W.M. Whitmer, B.U. Seeber & M.A. Akeroyd The sensitivity of hearing-impaired adults to acoustic attributes in simulated rooms. J. Acoust. Soc. Am. 133, 3493, 2013

[3] A. Goriely, Vibrations of a Rectangular Membrane. Wolfram Demonstrations Project, http://demonstrations.wolfram.com/VibrationsOfARectangularMembrane/, 2011 (ass.22.03.2019)