A New Method for Elevation Panning Reducing the Size of the Resulting Auditory Events

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Abstract

Panning between two vertically arranged loudspeakers results in an auditory event that can cover almost the whole spanned angle. Additionally, these vertically arranged loudspeakers cause audible comb filtering if listeners are not equally spaced from each loudspeaker (some centimetres displacement is sufficient). Usually, these effects are reduced by increasing the number of loudspeakers. The present method diminishes the spatial extent of the auditory event to a great degree without increasing the number of loudspeakers. Also, the comb filter effects occurring with misplaced/moving listeners are equally reduced.

1 Introduction

Natural 3D sound fields consist of sources at different heights. Assuming uniformly distributed sources in closed rooms, about a third of all reflections (two out of six boundaries in a rectangular room) reach the listener from the floor or the ceiling. Therefore, elevation reproduction is necessary to fully immerse listeners in auditory virtual environments.

Different reproduction methods are used for rendering audible 3D sound fields over loudspeakers, e.g. Ambisonics, Wave Field Synthesis or Amplitude Panning. First order Ambisonics has been shown to perform worse with regard to amplitude panning concerning localisation accuracy and localisation blur [6]. Wave field synthesis today still needs a substantial amount of processing power and hardware resources even when just reproducing sound sources in the horizontal plane. Therefore, we investigate Amplitude Panning for elevation reproduction.

Elevation localisation of an auditory event depends on the listeners' pinnae and the sound signals [1, pp. 44,104,310,312; 2]. Panning between a pair of vertically arranged loudspeakers results in an auditory event that can cover almost the whole spanned angle [2,3,4]. Confronted by these problems, loudspeaker installations with height reproduction and amplitude panning consist today either of a high number of loudspeakers to keep the spatial extent of the resulting auditory event small, or they don't address the problem at all.

2 Elevation Localisation

Humans form auditory events in the median plane just by help of the pinna filtering cue. There are no strong interaural time and level differences. Blauert describes in [1, p.106] the localisation experiment with sine pulses made by Roffler/Buttler in 1968 (Setup: 4 loudspeakers in the median plane between -15° and +20° elevation). They found that listeners do <u>not</u> locate a sine pulse according to the angle of elevation of its presentation. Rather, the <u>frequency</u> of the sine pulse specifies the elevation angle of the auditory event: pulses that are based on a low frequency sine are perceived below, those based on a high frequency sine above the 0° elevation angle.

A similar effect has been recognized in informal listening tests at our institute (*signals*: frequency filtered pink noise or music, different broadband signals; *reproduction method*: amplitude panning; *setup*: two loudspeakers at +/- 25° elevation and 2m distance). Elevation positions of the auditory events varied with the frequency band that was reproduced. Even with broadband signals, the listener indicated frequency dependent auditory events similarly as in figure 1. The tests also showed that the more energy above 5 kHz is present in the test signals the bigger the spatial extent of the auditory event will be (see figure 2). These findings support the ones in [2,3, 4].

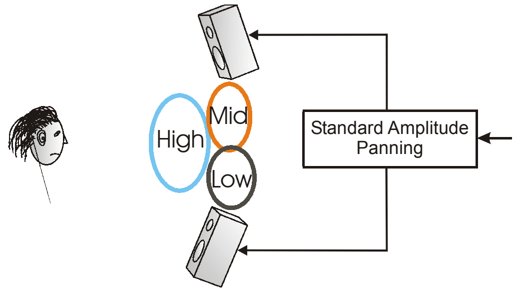

Figure 1: Frequency dependent elevation of auditory events with standard broadband amplitude panning

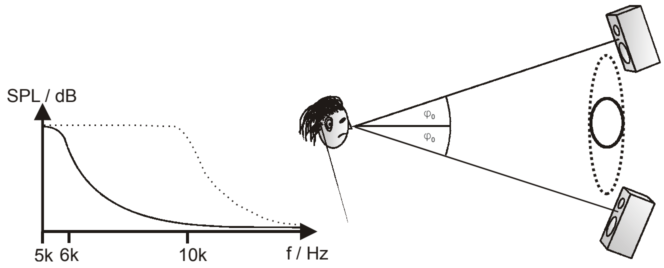

Figure 2: The higher the amount of high frequency energy that is present in the signal, the bigger the spatial extent of the auditory event (**solid curves:** less high frequency energy, **dotted curves:** more high frequency energy)

3 Comb Filter Effects

Two vertically arranged loudspeakers cause audible comb filtering. Already a vertical displacement by 2 or 3 centimetres out of the symmetry point (at which the loudspeaker above and below has the same absolute elevation) will change the comb filtering and thus make it more audible (informal listening tests by the authors). The same comb filter effect occurs with horizontally placed loudspeakers (e.g. the standard stereo placement), but it is nearly not audible because of the binaural processing/ head shadowing.

Informal listening tests showed that the comb filter effects lead to false localisation for all listener positions except the position at the symmetry point.

4 New Elevation Panning Method

The algorithm proposed to improve elevation reproduction of standard amplitude panning consists of a decomposition of the signals in sub-bands and application of different panning laws for each sub-band, see figure 3 (details in [5]). Panning laws for sub-bands up to 5 kHz were adjusted perceptually (elevation localisation to same angle for all sub-bands) by expert listeners in a listening room and in an anechoic chamber by using different sound signals. As a result, the energy of the sub-bands is spatially separated between the loudspeakers and can no longer interfere as before. Thus, the comb filter effects in the frequency bands up to 5 kHz are reduced.

To reduce the comb filter effects also in frequency bands higher than 5 kHz, a special filtering method was developed. In the listening tests we found a very inconvenient effect of the comb filtering at higher frequencies: when the listener positions himself in an interference notch, he mostly perceives the upper and lower speaker and a “hole” in-between. To compensate for this, a special ladder filter structure was chosen, which pre-combs the signals. As preliminary listening tests by the two authors showed, this filtering method leads to a perception of not only reduction of the comb filter effects but also reduction of the spatial extent of the auditory event.

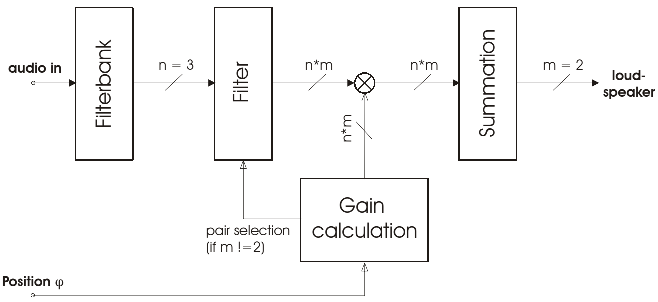

Figure 3: Signal flow graph of the new elevation panning method

5 Subjective Evaluation

Two listening tests were performed for a preliminary evaluation of the new algorithm. The tests took place in a listening room in order to test the algorithm in a reflective environment (T_{60} =0.5 s from 80Hz to 4kHz, loudspeakers at -40° and +45° elevation, hidden by an acoustically transparent curtain, loudspeaker-listener distance 1.7 m). Figure 4 presents the results.

6 Conclusion

Broadband amplitude panning between elevated loudspeakers induces problems based on audible comb filter effects, false localisation and vertically extended auditory events. An improved algorithm (ElPan, **El**evation **Pan**ning) involving frequency-dependent amplitude panning was introduced: The comparison with broadband panning shows preference of listeners for the new algorithm concerning the spread of the auditory event. The results indicate nevertheless signal dependence of the absolute location of elevated auditory events and, for some signals, a relatively high inter-individual variance. The proposed panning method has been implemented in the auditory virtual environment simulator “IKA-SIM”. An overview of this system is given in [7].

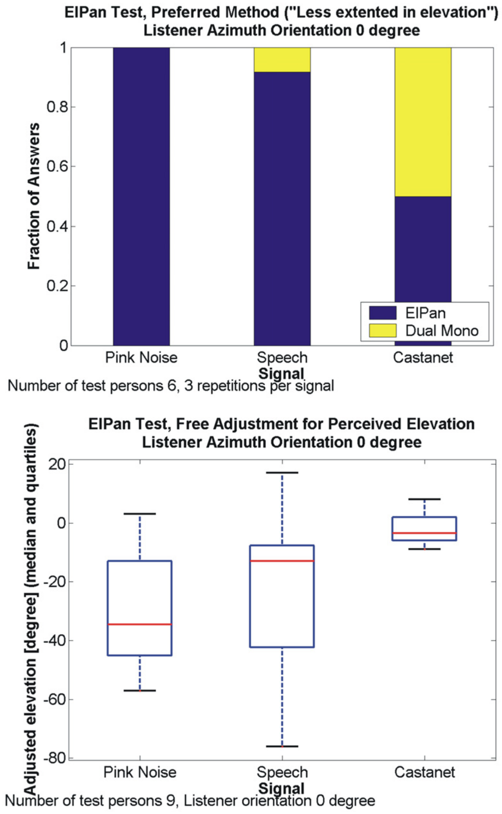

Figure 4: Results of the subjective evaluation with three test signals. Above: Preference of the 6 subjects for either of the two panning methods in terms of spatial extent of their auditory event (broadband panning is "dual mono"; "ElPan" is the new **El**evation **Pan**ning method). Below: Free elevation adjustment of subjects to get their auditory event to a 0° elevation (line in middle of box: median, upper and lower end of box represent upper and lower quartile, whiskers show deviation for remaining answers)

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