

## 4 CONCLUSION

Human ability to perceive differences in sounds due to the modification of the phase spectrum was studied in this article. Formal listening tests were arranged and synthetic harmonic complex signals were used as test signals. The results of the tests confirm that humans are not "phase deaf," the perceived difference due to randomization of the phase spectrum can be larger than the difference due to randomization of the magnitude spectrum with a standard deviation of 4 dB.

In addition, it seems that the mechanisms leading to phase perception are somewhat local in frequency, e.g., phase-spectrum modifications at high frequencies do not affect the perception at low frequencies. Nevertheless, the phase spectrum affects the perception of the neighboring frequencies. According to the tests, the phase of a component at a certain frequency affects the perception of frequencies about one octave lower and higher. Thus, there is interaction between nearby auditory frequency bands but the effect is not global. Furthermore, changes in the phase spectrum in both the narrow and the wide band can cause differences in the perception.

Based on informal listening tests and earlier studies, the signals for which the phase between the harmonics is aligned can be described to have a strong low pitch and a "buzzy" quality, whereas random-phase signals are perceived to be colored, thinner, and absent of the buzzy quality. According to the results of the formal listening tests, the effects of phase modification are perceived to be larger the lower the fundamental frequency is, and for signals with a fundamental frequency above 800 Hz, the differences in the phase spectrum cannot be perceived. In addition, the perceived level of bass frequencies can be affected by the phase spectrum. The difference due to phase-spectrum modification corresponds to amplification of the magnitude spectrum at low frequencies by 2–4 dB on average. However, this effect was found to be greatly dependent on the individuals.

Based on the results, an auditory model to explain these effects was developed. It aims to mimic the firing rate of the neurons in the cochlea. After comparing the output of the auditory model to the results of the listening tests, it was found that the crest factor of the neural firing rate for each frequency band can be used to explain differences in the perception due to phase-spectrum modifications. At the lowest frequencies of the tone, the high crest factor indicates a perception of loud bass, whereas at mid and