Directivity is an important characteristic of any sound source or receiver. In the case of the sources, it states how loud is the sound emitted in different directions, while in the case of the receivers it describes sensitivity to sound coming from different directions. A special type of sound receiver is our hearing system, whose directivity is commonly called head-related transfer function (HRTF). HRTF depends on the shape of the ear, head and torso and thus it is slightly different for each person. Accurate representation of individualized HRTF is crucial for efficient spatial sound rendering, for example in virtualy reality.

The directivity is varying heavily with frequency. In general, for lower frequencies the levels (understood as sensitivity for receivers or volume for sources) are mostly the same for all the directions, while for higher frequencies they start to vary more and more depending on the direction. The 3D directivity is usually expressed in spherical coordinate system, where the levels are depicted as the distance from the center for different directions. The directivity plot can be then imagined as a 3D shape (a solid) - for the lower frequencies it is close to a perfectly round ball, while for the higher frequencies the shape becomes more and more distorted.

The directivity can be measured only at discrete directions around a sound source or receiver, which means that we can get information on levels only at a set of specific directions. Currently there is a popular method of deriving from these discrete data an approximated continuous directivity by expressing it as a sum of simple 3D shapes (described by functions called spherical harmonics). This has to be done for each frequency band separately, since the directivity patterns are different for different frequencies. The goal of this project is to develop a method of directivity represention, where instead of multiple 3D shapes (different for each frequency band) the directivity is expressed as a single 4D shape using a mathematical model where frequency is considered the fourth spatial dimension.

One of the benefits of such approach is infinite resolution in both space and frequency. What is more, including both these dependencies simultaneously might result in more reliable reproductions of the original characteristics. The main drawback is a large increase in required computational resources. However, with the development of more an more powerful computers, this problem becomes less and less significant.

The research will focus on comparison of the accuracy of the currently popular method based on multiple 3D shapes and the novel one based on a single 4D shape. The most important research question is whether or not the 4D approach is better than the 3D one and should replace it. To answer this question, different methods for defining the 4D shape will be tested and compared. Furthermore, all the pros and cons of both approaches will be taken into account.

Preliminary research showed that the 4D directivity representation is indeed possible and can pose an alternative to the 3D one based on spherical harmonics. Depending on the detailed results of the research, the new method might prove to be superior and contribute to more efficient spatial sound processing in applications such as virtual reality or room acoustics simulations.