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An Isodynamic High Fidelity MRI Compatible Headphone

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Introduction

We have developed high fidelity MRI compatible headphones for fMRI experiments. Scanner manufacturers, and several small companies, produce MRI compatible headphones which operate under various physical principles including air tubes, magnet-less electrodynamic (http://www.mr-confon.de/) and electrostatic transducers (http://www.nordicneurolab.no/). These systems are often intended for communicating with and for providing diversion to subjects, and typically have a restricted, uneven frequency response.

Our headphones have a smoothly varying and wide frequency response. The new headphones operate electrodynamically, like those of Confon but, in contrast to Confon, use an isodynamically (see reference) (iso – uniform, dyn - force) driven lightweight membrane.

Methods

The transducer, shown in the figure, comprises a frame constructed from synthetic resin bonded paper (SRBP) board, with equally spaced parallel windings spanning the aperture. A Mylar film membrane is glued over the wire and the frame. Porous paper is placed 2 mm behind the membrane to dampen acoustic resonances. The transducer is mounted in non-magnetic hearing defenders (3M, model 1440) and driven via a twisted-pair resistive lead. The principle of operation is that, with respect to the figure, with the main magnetic field running horizontally, an audio current flowing vertically through the aperture-spanning wires causes a force on these wires and attached membrane in and out of the page. Overall, the coil is wound as a balanced, second order gradiometer (arrows show relative direction of current flow). This minimises pick up and transduction as acoustic noise of gradient switching interference. Another advantage of the gradiometric configuration is a reduction of possible longer range image distortion due to audio frequency currents flowing in the transducer. The transducer was driven using a standard hifi amplifier through r.f. filters supplied with the Confon headphones. The headphones were tested at a field of 1.5T, with the headphone cup detached from the headband, placed over sound absorbing visco-elastic foam and weighed down by a sand bag. Sound was measured using two non-magnetic electret microphones approximately centrally positioned under the headphones and spaced 1 cm apart. We compared our new headphones to Confon OPTIME 1 headphones. Swept frequency chirps were played through the headphones, recorded and analyzed to produce frequency response plots.

Results

The two plots in the figure show measured frequency responses from the two microphone sites; new headphone (thick line), Confon headphone (thin line).

Conclusions

The frequency response of our new headphone is relatively smooth over a bandwidth of approximately 14kHz, exhibiting a broad resonance centred on approximately 7.5 kHz. The Confon headphone response extends over an overall wider bandwidth but shows several deep dips in responses, which are clearly audible and a problem for tonotopic mapping studies, for example. A similar, but shallower, dip is seen in the new headphones at 7.6 kHz or 8 kHz. In both headphones the dip frequencies depend markedly on the microphone position suggesting that the cause is a spatially varying interference phenomenon. However, our headphones have, overall, a far smoother and more position-independent frequency response, as expected given the straightforward dynamics of an isodynamically driven membrane.

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