Using a bubble to alleviate post implantation hearing loss – a new model of the cochlea.

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The work is the subject of a PhD research project supervised by Steve Elliott and Carl Verschuur at the Institute of Sound and Vibration Research, University of Southampton

Introduction

Cochlear implantation can cause significant loss of residual hearing; this impairs both speech recognition and the appreciation of music. The implant is normally inserted through the round window, which becomes stiffened because the flexible area is reduced; recent work has shown this can be a major cause of post implantation hearing loss, see Elliott et al (2016). The stiffening is often exacerbated by the formation of callous tissue on the round window around the implant. The function of the round window is to release the acoustic pressure in the cochlear fluid that is caused by the action of the stapes and the oval window; the pressure release allows movement of the almost incompressible cochlear fluid from the stapes to the round window, via the basilar membrane and the organ of Corti, where the auditory nerve is stimulated. As described below, a new mathematical model has been developed to show that the inclusion of a bubble in the implant will avoid hearing loss from this cause.

Aim

The aim is to improve the quality of life of patients with a cochlear implant, by understanding the cause of impairment of their acoustic hearing and proposing a remedy to manufacturers of implants. Preservation of residual hearing allows access to low frequency cues, which enhance perception of music, speech in ambient noise, and supra-segmental features of speech, particularly pitch, intonation and stress.

Method

To achieve the aim, a suitable finite element model of the cochlea has been developed, and it will be made available to others to facilitate implementation of a proposed remedy. The model contains default values for the physiological parameters of the human cochlea, which have been obtained from the published work of others; these can be easily altered by the user, as can the physical properties of the implant. In particular, the stiffness of the implanted round window has been taken from Elliott et al (2016), and their illustration of the effect of the implant on the pressure distribution on the cochlear side of the round window is shown in figure 1, below.
As an indicator of perceived sound intensity, the model computes the velocity of vibration of the basilar membrane.

Results

The model has been used to compute the BM velocity with and without an implant, and to calculate hearing loss as the difference. It can also simulate the effect of including a bubble within the implant, to act as a pressure-release and hence a remedy, as shown graphically in figure 2, below. To validate the model, the graph also includes the hearing loss in 105 patients of USAIS, as measured by Verschuur et al (2016).

Conclusion

A two-chamber finite element model of the cochlea has been developed that can be used to predict acoustic hearing loss caused by the mechanical effect of implantation on the round window. The model has been validated by comparison of its results with measured values. The model has also been used to show that such loss of hearing can be almost completely alleviated by manufacturing the implant so that it contains a small bubble, located suitably near the round window. Preservation of low frequency acoustic hearing will be valuable to more patients now, as a result of the NICE criteria for implant candidacy have been relaxed in accordance with BCIG recommendations.

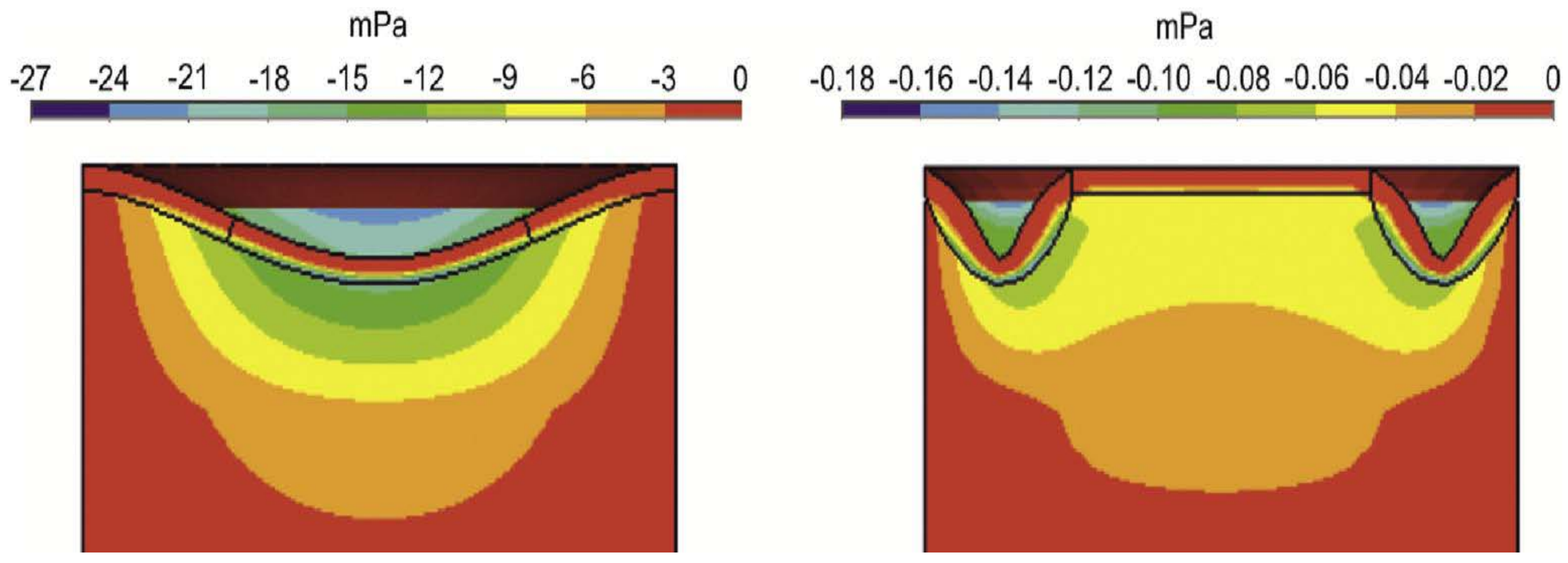

Figure 1: Pressure distribution in cochlear fluid near the round window, with and without an implant. From Elliot et al (2016). (Note colour scales differ by a factor of 150.)

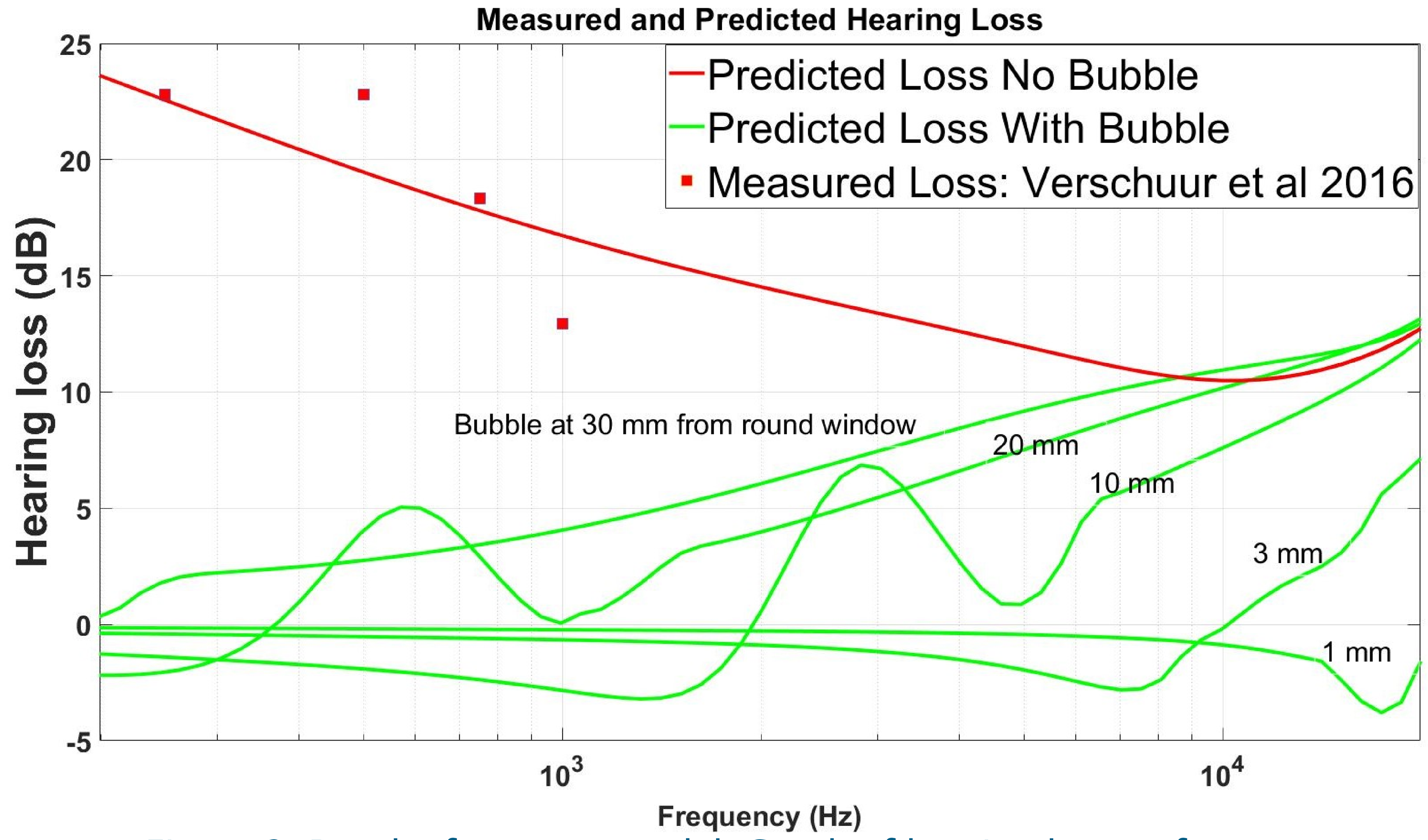

Figure 2: Results from new model: Graph of hearing loss vs frequency, with implant but no bubble, and with bubble in different positions.

References: Elliott, S.J. Ni, G. Verschuur, C. (2016). Modelling the Effect of Round Window Stiffness on Residual Hearing after cochlear Implantation. Hearing Research, 341, pp155-167. Elsevier, North Holland.

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