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Intraoperative Stimulation and Measurement System with Distance Compensation

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Introduction

Over the past decades transcutaneous bone conduction implants such as the Bonebridge (Med-EL, Austria) have been established as a treatment for patients [1] with moderate to severe conductional mixed hearing loss and single sided deafness (**Fig. 1**). For quantitative measurements such as intraoperative testing it is required to transmit a well characterized stimulus to the implant.

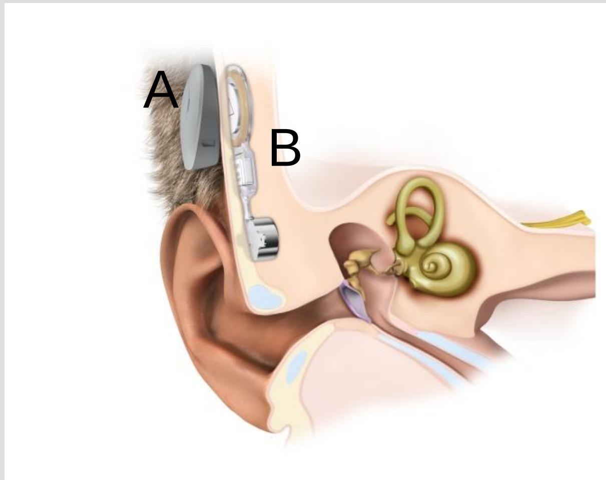

Fig.1: The Bonebridge consists of two parts: An external audio processor (A) and the implant (B) with a receiver coil, a demodulator and a bone conduction floating mass transducer (BC-FMT) to stimulate the skull.

However, using the audio processor as a mean during surgeries to transmit the stimuli to the implant is different in terms of distance between the transmitter and the receiver coil compared to the patients' daily use, as the distance is often > 10 mm. As a consequence of the large distance (**Fig. 2**), an uncalibrated stimulus is being transmitted to the implant. Therefore, the interpretation of the measured signals is unreliable and an undesired inter-individual variability is added. Hence, a transmission system with increased transmission accuracy for intraoperative measurement purposes is needed.

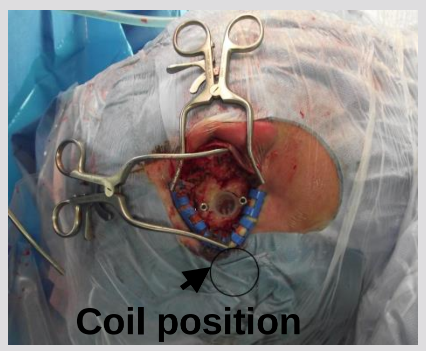

Fig.2: Surgical view of Bonebridge implantation.

Method

We developed an inductive link to transmit a calibrated stimulus signal to the Bonebridge implant. AM signals were synthesized and signal measurements were performed using a National Instrument multifunctional data acquisition device in combination with a custom written program in LabVIEW 2015 (National Instrument, USA) program. The AM signal was buffered with a low noise amplifier (LF-353N) to drive the original transmission coil of the sound processor.

Estimation of the coil-coil distance

The voltage across the transmitter coil (**Fig. 3**) in the primary loop due to coupling coefficient changes with distance (see **Tab. 1**) was used to estimate the distance between the transmitter and receiver coils.

Method

Distance compensation

The distance influence on the change in measured output (acceleration on an artificial mastoid) was minimized by adjusting the input driving voltage according to the distance estimate (**Tab. 2**).

Table 2: The calculated input voltages to obtain -20 dB(m/s²) average acceleration amplitude at 6 different distances.

Dist. [mm]	-20 dB Est. V. [V]
2	1.50
5	1.53
8	1.812
11	2.67
14	3.73
17	4.73

Table 1: Average voltages measured across the V_{L1} and the corresponding distances.

Distance	Mean V_{L1}± (min+max)/2
2 mm	0.0142± 0.01
3 mm	0.0674±0.04
4 mm	0.138±0.07
5 mm	0.208±0.11
6 mm	0.278±0.14
7 mm	0.346±0.18
8 mm	0.409±0.21
9 mm	0.460±0.23
10 mm	0.507±0.26
11 mm	0.542±0.27
12 mm	0.573±0.29
13 mm	0.599±0.30
14 mm	0.622±0.31
15 mm	0.641±0.32
16 mm	0.658±0.33
17 mm	0.672±0.34

Output comparison of the implant

A Bonebridge implant was used to verify the functionality of our transmission system. For this purpose an artificial mastoid (type 4930, B&K, Denmark) was used to measure and compare the output.

In this configuration a modified older processor AP304 (MED-EL, Innsbruck, Austria), where the modulator is separate and can be driven electrically was compared to the developed transmission system with different distances from 2 – 17 mm between the transmitter and the implant coil. The measurement setup is illustrated in **Fig. 3**.

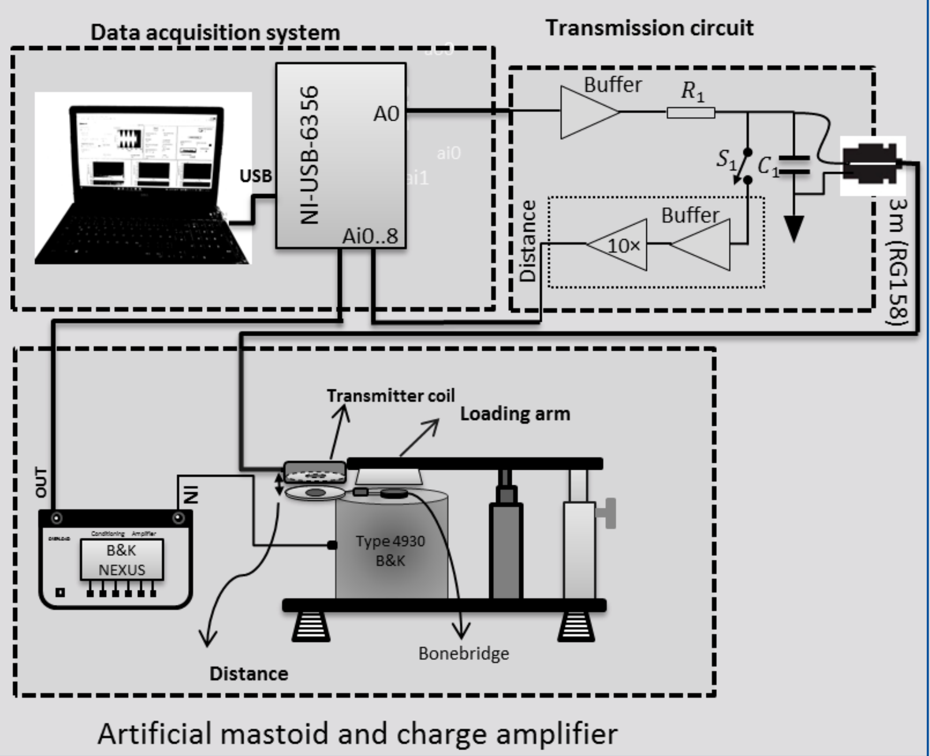

Fig.3: Transmission and measurement system setup.

Results

The acceleration output amplitude of the Bonebridge driven with the AP304 showed 10 to 20 dB drop in the frequency range between 0.1 and 10 kHz when the distance between the AP304 and receiver coil was increased from 2 to 17 mm (**Fig. 4**). On the other hand the acceleration amplitude of the Bonebridge when driven with the developed transmission system without any adaptation of the input amplitude to the distance showed up to 17 dB drop in the same frequency range.

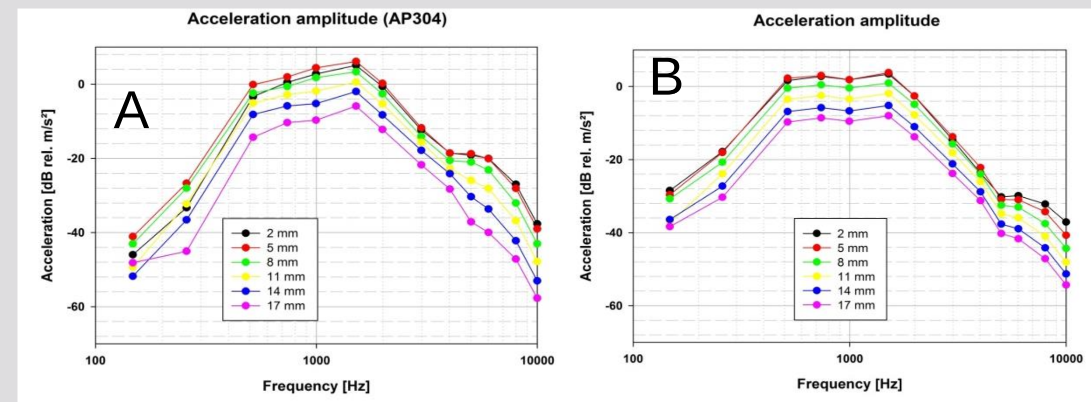

Fig. 4: (A) Acceleration amplitude of Bonebridge measured on the artificial mastoid A: driven with the AP304 at distances from 2 to 17 mm. The input voltage to the AP304 was 100 mV_p. **(B)** :driven with our transmission system at the same distances. The input voltage was $2V_p$.

In contrast the compensated acceleration amplitude of BC-FMT driven with our developed system showed 4 dB variations to obtain -20 dB re. m/s², while increasing the distance from 2 to 17 mm (**Fig. 5**).

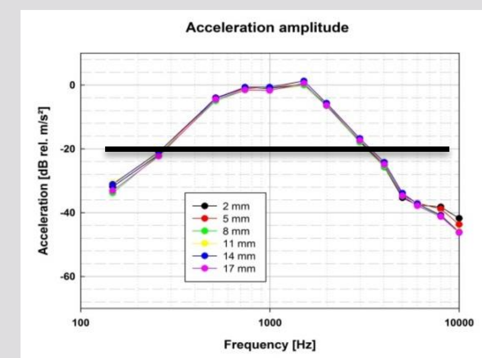

Fig. 5: Compensated acceleration amplitude using the estimated distances based on voltages across the primary coil to obtain -20 dB re. m/s².

Conclusion

The new transmission system provides a well-characterized stimulus to the Bonebridge for measurement purposes by estimating the distances between the transmitter and receiver coils and applying a compensation.

Reference

[1] Huber, A.M., Sim, J.H., Xie, Y.Z., Chatzimichalis, M., Ullrich, O., Roosli, C. 2013. The Bonebridge: preclinical evaluation of a new transcutaneously-activated bone anchored hearing device. Hearing research 301, 93-9.

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