Sound control in windy weather

Master Thesis

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Will come later

Preface

This report is composed by Jonas Buchholdt during the 10th semester of Electronic Engineering and IT at Aalborg University. The general purpose of the report is *Signal Processing and Acoustics* .

For citations, the report employs the Harvard method. If citations are not present by figures or tables, these have been made by the authors of the report. Units are indicated according to the SI standard.

Aalborg University, February 14, 2019

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Glossary

AC Air Conduction. 3, 4, 17

ACE Air Conduction Earphones. 17

BC Bone Conduction. 3, 4, 17

BCT Bone Conduction Transducer. 3, 4, 17

HINT Hearing in Noise Test. 17

Chapter 1

Introduction

Human sound perception has typically been based on airborne sound for a majority of situations. However, bone conducted sound has been extensively used for diagnostic purposes [**?**]. The main application of Bone Conduction (BC) is to perform pure-tone audiometries in subjects with hearing loss. In conjunction, with Air Conduction (AC) audiometry, it can be assessed, where the damage is situated. It has been established that BC circumvents the outer and the middle ear, which allows for conclusions based on a difference between AC and BC audiometry.

This medical use leads to the question of whether the use of BC could be extended further to day-to-day applications. This expansion of usage could range from leisure activities, such as music playback, to specialised usage, such as communications systems, that do not block the user's ears or conversely, that are used in noisy enviroments, where hearing protection is an imperative. With this objective in mind, the project at hand is proposed by RTX A/S, as foundational research for the usage of BC in communication systems.

The focus of the project is testing the feasibility of incorporating Bone Conduction Transducer (BCT) in communications equipment by comparing its performance with classic AC-based systems. However, there are different applications within this research area, such as utilising a BCT in order to not block the ear canals and maintain environmental awareness in high-risk situations (e.g. firefighters and law enforcement). Another possible application is to substitute AC transducers in equipment used in high noise level environments, adding the possibility to isolate the user's ears with both earplugs and protective headphones and thus reducing the risk of hearing damage (e.g. helicopter pilots and F1 mechanics). For any of these situations, the main concern is the assessment of intelligibility of the transmitted signal.

1.1 Problem Statement

It has been decided to constrain the scope of the project and focus on BCT use in noisy environments. Comparing its performance to the one of an AC-based system

in terms of a subject-based speech intelligibility test. In the course of doing so, the following aspects will be investigated:

- How does BC differ from AC in terms of speech intelligibility?
  - Which intelligibility test method is suitable for the task at hand?
  - Can it be ensured that the perceived level is the same for AC and BC?
- What types of BCT are available at the moment?
- Where should the BCT be placed?

Part I

Problem Analysis

Chapter 2

Analysis of sound propogation in outdoor venue

2.1 Live venue sound challenges

The aim of this section is to explore the challenges of producing live concert in a outdoor venue. The challenge of producing a good sound experience for the audience will be analysed from the calibration of the system to the end of the concert. What is affection the sound doing the concert and does the calibration change over time.

2.2 Wave propagation in temperature change

2.3 Wave propagation in humanity change

2.4 Wave propagation in wind

2.5 Calibration of sound system

This section analysis the calibration method, which is used by a selection of some Danish sound company. By expirence of the athor of this master projet, the hypothisis is that the sound system is calibrated in one point and the microphone is placed just in front of the Front Of House (FOH). The FOH is often a little tent, where the sound engineer control the sound system. The tent is only open in the direction of the stage and reflection might occore from the tent celling to the calibration microphone.

2.6 Sound pressure level measurement doing the concert

Part II

Test Design

Chapter 3

Design

Part III

Results

Chapter 4

Results

Chapter 5

Discussion and conclusion

5.1 Conclusion

As stated in section 1.1, the main objective of this study is to assess the performance of a Bone Conduction (BC)-based communications channel, as compared with an Air Conduction (AC)-based one, in terms of intelligibility. In order to do so, it has been decided to design and perform a subject-based perceptual intelligibility test to obtain relevant data. However, extensive literature research about the matter of BC sound and the state of the art in transducers was needed beforehand. During the course of the project, the questions presented in section 1.1 have mostly been answered, and all relevant data for the final intelligibility evaluation has been extracted. Based on relevant literature, the RadioEar B81 Bone Conduction Transducer (BCT) was chosen for all subsequent applications placed on the condyle. A key point of the project has been finding a way of linking the perceived levels from both the BCT and the Air Conduction Earphones (ACE) for the intelligibility test. In order to do so, a level matching routine has been developed, and although it does not provide exact data about excitation of the basilar membrane caused by the BCT, it provides a framework in which the inter-subject assessment of intelligibility can be performed by looking at the relative performance difference for each individual subject. The final decision has been made on the type of test to perform. Based on the potential application and the background of the project proposal, the Hearing in Noise Test (HINT) was deemed to be most suitable both in terms of obtainable results as well as practical feasibility. This test is based on short sentences, that are unknown to the test subjects.

After analyzing the results from the HINT, it can be concluded that there is a tendency, that the performance of BCT regarding intelligibility might be worse than the performance of ACE-based systems. With the obtained data, this tendency could not be shown to be statistically significant. A higher variance of the performance of subjects could be observed for the BCT. However, the difference in performance appears not to be so drastic, so that the difference does not render BCT as an invalid option for communication applications. The performance could likely be further

increased by flattening the frequency response of the BCT with signal processing. Also a possibility of combining AC and BC in hybrid systems in order to increase the overall performance seems feasible as a subject of future research.

Part IV

Appendix