Requirement Specification

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PROJECT IDENTITY

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Linköping University, Dept. of Electrical Engineering (ISY)

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Document History

Version	Date	Changes	Sign	Reviewed
0.1	2016-09-15	First draft	KG	KG,LF
0.2	2016-09-21	Fixed CM:s comments.	KG	KG,LF
1.0	2016-09-23	Updated version and history.	KG	KG,LF

1 Introduction

The following requirement specification concerns Massive Audio Beamforming - version II, a project carried out at Linköping University, Department of Electrical Engineering (ISY). The project is implemented by a group of six students in the course TSKS05 and is commissioned and supervised by ISY. The aim of this project is to create a testbed capable of demonstrating the powers of massive MIMO in an intuitive and convincing manner using sound waves.

The testbed uses a number of loud-speakers that also function as microphones (L/M units) for antennas. To demonstrate the powers of MIMO, the testbed will be placed in a room and the L/M units will be used to transmit one sound to one corner of the room and another sound to another corner of the room. This requires the system to estimate the channel and then preprocess the desired signal for desired effect.

The purpose of this document is to specify all requirements of the product. All requirements are specified using a table row as shown below. The numbering increases throughout the document. The second column specifies if the requirement is an original one or has been modified. If it has been modified there will be a reference to the decision that forced the modification. In the third column, the requirement is described and, in the last column, the priority is stated. Priority Base means that the requirement is mandatory and priority Extra requirements should be fulfilled if there are resources available for it.

Req.nr X	**Change**	Description of requirement nr.X	**Priority**

1.1 Who is involved

The parties of the project as well as all the group members with specified responsibilities is defined in the section called "Project Identity" on page ii. They are also stated here for clarity. The group members are: Linnea Faxén, Klas Gudmundsson, Eskil Jörgensen, Stefan Lundström, Ema Becirovic and Javier Preciado. The customer is Mikael Olofsson. The examiner is Danyo Danev and the supervisor is Christopher Mollén.

1.2 Goals

The first part of the goals is to deliver a MAB that can demonstrate massive MIMO. The customer also wants a MAB that can be used in other projects for implementing different kinds of demonstrations.

The second part of the goals is simply to educate the project group on a few subjects such as massive MIMO, communication systems, electronics, project management, collaboration and problem solving.

1.3 Usage

The testbed is to be used by students and researchers at the Division of Communication Systems of ISY for studies, research, experimentation and demonstrations on the possible applications of Massive MIMO systems.

1.4 Background Information

The idea of Massive MIMO is well known and has been around since early 2010 [4]. Theoretical results, such as channel capacity, have been established and the technology has been proved to have a huge potential. The technology of 5G will likely be based on massive MIMO for example.[3]

Physical experimentation, however, requires construction of equipment which is expensive. Radio testbeds have been built in a few places, e.g. Lund University. [2]

An approach that is easier to illustrate, because a direct experience is given to the user through hearing, is using an audio system for proof of concept and demonstrations. This is reasonable because the wavelengths used in modern radio communication systems is similar to the wavelengths of audio in the human hearing range.

1.5 Definitions

The abbreviations used in this document are specified in Table 1

Table 1: Abbreviations used in the document

Abbreviation	Definition
A/D	Analog to digital
API	Application programming interface
D/A	Digital to analog
GUI	Graphical user interface
L/M	Loudspeaker/microphone unit
LED	Light-emitting diode
MAB	Massive Audio Beamformer
MIMO	Multiple input multiple output

2 Overview of the System

The system consists of two subsystems: hardware and software. Software is further divided into an application programming interface (API) and an Application. The user interacts with the Application which use methods from the API to control the hardware. The hardware contains all L/M units and the necessary electronics to control them. This is illustrated in Figure 1.

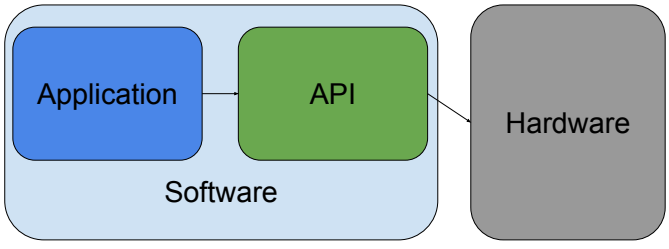

Figure 1: System overview

Controlling the hardware should be simple and the API will handle this. The idea is that later projects run on the MAB should not need to communicate directly with the hardware. Those projects can focus on implementing different demonstrations.

Req. 1	**Original**	The system should have a clear subdivision according to figure 1.	**Base**
Req. 2	**Original**	The Application shall communicate with the hardware through the API.	**Base**

2.1 Description of the System

The system consists of 64 L/M units that are connected to a system of hardware that can be controlled by the user through an API on a Windows computer. The L/M units are used for transmission and recording of signals to make a testbed for Massive MIMO. An example of the finished product can be seen in Figure 2.

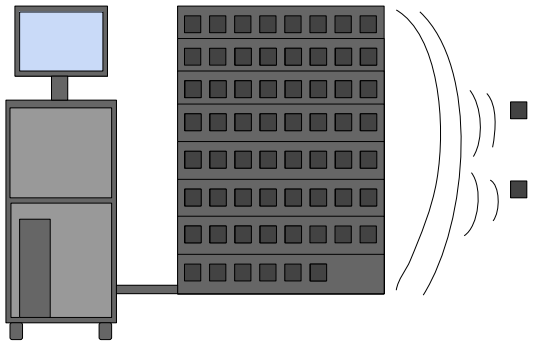

Figure 2: Example of finished product

2.2 General Requirements of the System

Req. 3	**Original**	The system should be able to transmit specified sound at specified L/M units.	**Base**
Req. 4	**Original**	The sound's frequency is in the interval 300 - 3000 Hz.	**Base**
Req. 5	**Original**	The system should be able to record signals at specified L/M units.	**Base**
Req. 6	**Original**	The system should be operable in a Windows environment.	**Base**
Req. 7	**Original**	The system should be able to direct sound so that it is heard loudly at a specified point in space while being much lower around it.	**Base**

3 Hardware

The hardware consists of a computer, expansion boxes, a distribution box and L/M units. The main purpose of the hardware is to control the L/M units in the system. This chapter will further describe the requirements on these entities. An overview of the hardware system is depicted in figure 3. A detailed explanation of the figure can be found in [5].

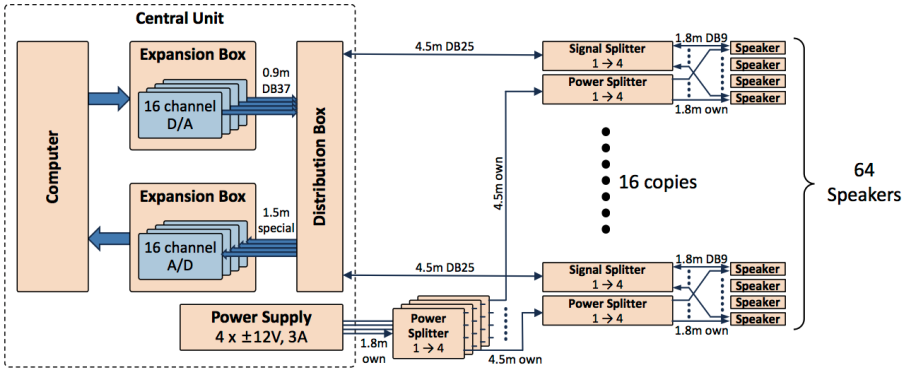

Figure 3: Hardware overview

3.1 Interfaces

The Hardware is interfaced to the API through the expansion boxes. The expansion boxes contain the A/D- and D/A-converters. After the expansion boxes comes the distribution box that contains the Arduinos used to control if the L/M unit:s are transmitting or receiving.

Req. 8	**Original**	The API should be able to send digital signals to the D/A-converters.	**Base**
Req. 9	**Original**	The API should be able to receive digital signals from the A/D-converters.	**Base**
Req. 10	**Original**	The operation mode of the L/M units (transmit or receive) should change when requested through the API.	**Base**

3.2 Design Requirements

For this project, the customer has provided designs for the hardware that describe how it should be implemented.

Req. 11	**Original**	The system should be built according to the design provided by the customer	**Base**

3.3 Functional Requirements

These requirements describe the functional requirements on the hardware.

Req. 12	**Original**	The speakers should be able to both send and receive sound and should be individually controllable	**Base**

4 Software

The software used to control the system is divided into API and Application. The API handles all communication with the hardware while the Application performs required signal processing for directed sound transmission. A user interacts with the user interface in the Application to run the demonstration.

Req. 13	**Original**	The software is written in MATLAB	**Base**

4.1 API

The API is used to control the hardware. This consists of: transmitting the signal requested by the Application at the desired L/M unit, receiveing signals at desired L/M units, assigning L/M units to the array or terminals and controlling when the L/M unit transmits or receives. The API is an interface between the Application and the Hardware. The interface between the Application and API is described in the following section. The interface between the Hardware and the API is described in the Hardware section under Interfaces.

4.1.1 Interfaces

The API connects the Application to the Hardware making them able to communicate with each other. The API itself is a collection of MATLAB methods that the Application runs to communicate with the hardware.

Req. 14	**Original**	Given what L/M units to be used as receivers, the API should return the received signals from these receivers to the Application	**Base**
Req. 15	**Original**	The API should be able to send the requested data from the Application to the desired L/M units	**Base**

4.2 Application

The Application of this project is directive sound transmission, see [5]. In principle, the user will choose what L/M units that should belong to the array (which will be most of them) and what L/M units to use for the terminals. Two terminals will be supported. Thereafter the user chooses what sound to play at what terminal. All choices are made through a GUI. The MAB will then

beamform the two chosen sounds from the array to the two terminals. The sounds will only be heard at the respective terminal.

4.2.1 Interfaces

The Application will have a user interface that can be used to run the demonstration. The user interface should meet the following requirements:

Req. 16	**Original**	L/M units in array and at terminal can be chosen in the user interface.	**Base**
Req. 17	**Original**	The user should be able to choose what sound to transmit and which terminals these sounds will be directed to	**Base**
Req. 18	**Original**	The system shall support two users	**Base**
Req. 19	**Original**	The system shall support more than two users	**Advanced**

4.2.2 Functional Requirements

To actually perform directive sound transmission, the system will estimate the channel using pilots and then with help of this estimation precode the sound. The precoding will direct the sound to the desired position.

Req. 20	**Original**	The software shall be able to precode the signals that will be sent to the L/M units such that the sound is heard at the specified L/M unit but not at the other L/M units.	**Base**
Req. 21	**Original**	The software shall be able to produce pilot signals for channel estimation	**Base**
Req. 22	**Original**	The software shall perform channel estimation for each path between array L/M unit and terminal L/M unit	**Base**

5 Performance Requirements

Under this title, demands on the performance of the product are stated.

Req. 23	**Original**	The two sounds should be distinguishable from each other at each user. It should be clear that the two users receive different sounds.	**Base**
Req. 24	**Original**	Two songs should be easily recognised and distinguished from each other at each user.	**Extra**

6 Possibility of Upgrading

The product is divided into three subsystems. This is to simplify upgrading of one of the subsystems without changing the others. This especially holds true for the Application, it should be easy to implement a new Application that performs a different kind of demonstration while keeping the API and hardware intact.

Req. 25	**Original**	The system should be divided into subsystems to support easy upgrades of each.	**Base**

7 Economy

The hardware budget is handled by the customer. Much money has already been invested here. The human resource budget for the implementation is specified in this section.

Req. 26	**Original**	There are 240 hours per group member for disposal.	**Base**
Req. 27	**Original**	No more than 15 hours of supervision from the supervisor shall be used.	**Base**
Req. 28	**Original**	No more than 25 hours of expert consultancy from the customer and the PhD students at the Division of Communication Systems shall be used.	**Base**

8 Delivery

This section summarizes the deliveries of the project.

Req. 29	**Original**	All items in table 2 should be delivered according to dates specified in table 2 and described in table 3	**Base**

9 Documentation

Table 2 contains details on the documents, reports and other media that should be delivered. The due dates for the documents are specified in Table 3.

Table 2: Deliverables

Name	Purpose	Due date	Due form	Approved by
Documents				
Requirement Specification	Specifies all features and interfaces	TG2	pdf	KG
System Design Sketch	Initial sketch of the system	TG2	pdf	KG
Project Plan	How the project will be executed	TG2	pdf	KG
Time Plan	Schedule of all activities	TG2	pdf	KG
Design Specification	Detailed description of the planned system	TG3	pdf	KG
Test Plan	Describes testing of product	TG3	pdf	KG
Test Protocols	Protocols for each test	TG5	pdf	KG
User Manual	Easy-to-understand description of how to use product	TG5	pdf	KG
Technical Report	Explains how product works in detail	TG6	pdf	KG
Afterstudy	Retrospective discussion about the project	TG6	pdf	KG
Poster	Presentation of project	TG6	pdf	KG
Meeting Protocols	Protocols for each executive meeting	TG6	pdf	KG
Protocols from Milestones	Protocols from meetings where milestone fullfilment is evaluated	TG6	pdf	KG
Reports				
Weekly report	Report of progress, plans and problems	Weekly, Mon.12.00	email	LF
Individual and Collective Time Reports	Weekly reports about who has spent time on what	Weekly, Mon.12.00	ods	LF
Other				
Project Web Page	Presentation of project	TG6	webpage	LF
Oral Presentation	Present to the Communication Systems Group	Project conference	orally	LF

Table 3: Description of due dates

Description	Date	Deliverables
TG2	23/9	Requirement Specification, System Design Sketch, Project Plan
TG3	10/10	Design Specification, Test Plan
TG5	12/12	Product, Test Protocols, User Manuals
TG6	15/12	Technical Report, Afterstudy, Poster, Webpage
Project Conference	20/12	Oral Presentation

10 Education

This section describes requirements on the educational material produced in the project.

Req. 30	**Original**	The user manual shall be enough to teach a new user how to run the MAB for demonstration.	**Base**
Req. 31	**Original**	The technical documentation shall contain all information needed for a non-project member to continue the development of the MAB.	**Base**
Req. 32	**Original**	The customer shall be given the opportunity of a guided instruction on the MAB.	**Base**

References

[1] T.Svensson and C.Krysander, in *LIPS*, Version 1.0, Compendium, LiTH, 2002.

[2] A.Wennberg.(2016, Sep.16). *Redo för världens vassaste mimo*, Elektronik-Tidningen. [Online] Available: http://etn.se/index.php/59642

[3] E.G.Larsson. (2016). Intoductory lecture on massive MIMO.

[4] S.Yang, L.Hanzo, "Fifty Years of MIMO Detection: The Road to Large-Scale MIMOs" in *IEEE Communications Surveys & Tutorials*, vol. 17, no. 4, pp. 1941-1988, Sep. 2015.

[5] K.Gudmundsson et al. (2016). *Design Sketch v0.2*