



REQUIREMENT SPECIFICATION

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PROJECT IDENTITY

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Document history

Version	Date	Changes	Performed by	Reviewed
0.1	22/09/2015	First draft	All group members	MA, SS, HM
1.0	28/09/2015	First version	SS	SS



1 Introduction

In this project, which is part of the course TSKS05 – Communication Systems CDIO, the students are to construct a system which demonstrates parallel data transmission of massive MIMO. Massive MIMO is a hot topic in wireless communications and there is a vision of it being part of the future of wireless communications.

This project is a continuation of a former project in the same course. The former project group achieved building the hardware of an array of loudspeakers and microphones and developed the software for transmitting and receiving audio signals with this array. This project aims to further develop this system into transmitting digital data to several terminals in the same time and frequency by the use of the existing hardware.

The purpose of this document is to specify the requirements of the system and the project. The requirements are listed as in table 1. The first column contains the requirement number. The second column specifies if the requirement is original or has been modified. The third column contains the wording of the requirement. The last column contains the priority of the requirement. Priority 1 implies that the requirement must be fulfilled, priority 2 & 3 implies that the requirement is fulfilled if resources allows.

Table 1: Formatting of a requirement.

Req. No. x	Original/Changed	Description of requirement x	Priority
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1.1 Parties

The parties of the project are listed in table 2.

Table 2: List of the parties of the project.

Name	Role
Danyo Danev	Examiner
Mikael Olofsson	Customer
Antonios Pitarokoilis	Supervisor
The students (see project identity)	Project Group

1.2 Aims and goals

The aim of this project is to demonstrate the capability of massive MIMO to communicate with several terminals at the same time instant and in the same frequency band. The project members should also learn to use their acquired knowledge of communication systems in a practical implementation.

1.3 Use

The usage of this project is to demonstrate the capability of massive MIMO to communicate with several terminals at the same time instant and in the same frequency band.



1.4 Background information

Massive MIMO is a wireless communication technique consisting of an array of multiple antennas. By making use of constructive and destructive interference the transmitter can increase the signal strength at the terminal and at the same time suppress it at other terminals to prevent co-channel interference. One can view this as the base station in a cellular mobile network beam-forms the signal to the terminal. It is possible to serve several terminals by transmitting an individual beam to each terminal.

1.5 Definition of terms

In table 3 below, abbreviations used throughout the document is listed and explained.

Table 3: Definitions of terms in the document

Word	Definition
A/D	Analog to Digital
BER	Bit Error Rate
D/A	Digital to Analog
GUI	Graphical User Interface
L/M	Loudspeaker/Microphone
MIMO	Multiple Input Multiple Output



2 Overview of the system

The complete system consists of both hardware and software implementations. However this project will only focus on the software part of the complete system as the hardware that will be used was created during the last year's project. The software will be divided into three subsystems, the channel estimator, the modulator and the channel coder. The hardware consists of a computer, 8 L/M pairs, A/D and D/A converters and a distribution box, as described in last year's project documentation (Stenmark, 2014). A simple overview of the entire system is shown in figure 1, where the actual system is in the large bold square. Things outside of this square are the material of the project from the previous year.

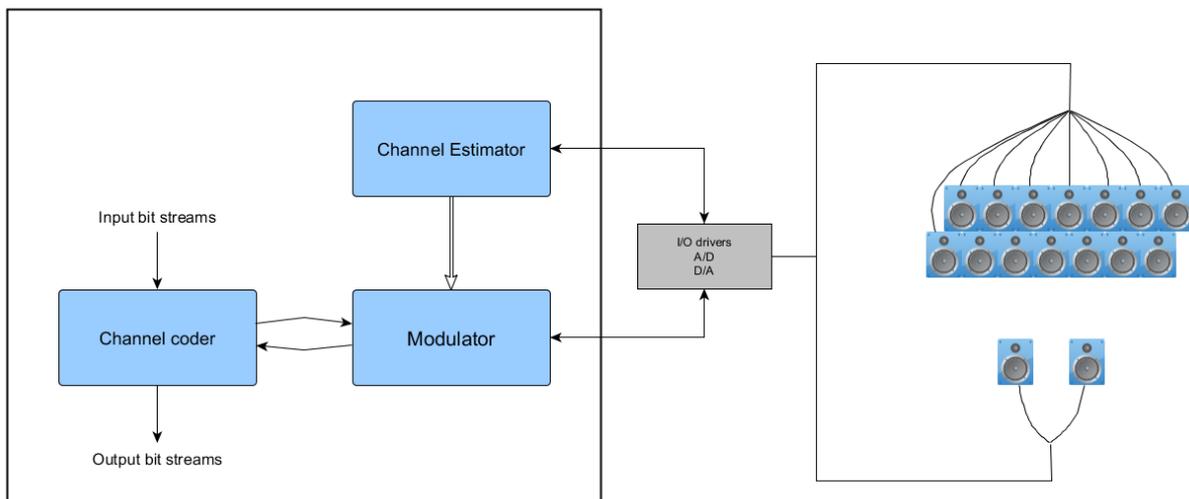


Figure 1: An overview of the system.

2.1 Description of the product

The product will enable an array of 14 loudspeakers/transmitters to parallel send digital data to 2 different microphones/terminals with the use of sound waves. The parallel sound wave signals will be sent in the same time and frequency, but differ in space at the 2 microphones. The microphones are referred to as terminals throughout the rest of this document.

2.2 Product components

The following deliverables are included in the product.

- Software fulfilling the requirements
- Technical documentation
- User manual



2.3 Dependency of other systems

For this system to work it is dependent on the existing hardware. The hardware was made by the group who took this course the last year and consists of the following entities:

- A computer with Windows 7 and required drivers installed.
- A/D converter Contec AD12-64 (PCI).
- D/A converter Contec DA12-16 (PCI).
- 8 L/M pairs
- Distribution box
- Required cables and connectors

For more information about this hardware, read last year's user manual (Stenmark, 2014).

2.4 Included sub-systems

The system is divided in the following three sub-systems:

1. Channel estimator
2. Modulator
3. Channel coder

2.5 Delimitations

The main delimitation of this project is that the system will always use a setup of 2 receiving terminals and 14 transmitters in the MIMO array.

2.6 General requirements on the system

The following requirements are general for the entire system.

1.	Original	The system shall support an array of 14 transmitters in the MIMO array.	1
2.	Original	The system shall support two terminals.	1
3.	Original	The system shall be applied to the hardware made by the 2014 year's project group who took the course TSKS05.	1
4.	Original	The transmitter shall be able to transmit different information to each terminal in parallel.	1
5.	Original	The parallel data transmissions shall be able to occur in the same time instant.	1
6.	Original	The parallel data transmissions shall be able to occur in the same frequency band.	1
7.	Original	The transmitted information shall be a bit stream.	1



8.	Original	The terminals shall be able to receive and decode the information transmitted and intended for them.	1
9.	Original	The terminals shall be able to transmit a training sequence (pilot) to the array.	1
10.	Original	The communication link shall adapt to changes in the channel.	2
11.	Original	The system shall be able to transmit and receive a text message.	2
12.	Original	The system shall be able to send information in one direction. (MIMO array to terminals)	1
13.	Original	The system shall be able to send information in two directions.	3
14.	Original	The system shall be able to present an estimation of the BER to the user.	1
15.	Original	The system shall be able to present the information bit rate and the coded bit rate to the user.	1
16.	Original	The system shall include a GUI.	3



3 Channel Estimator

The channel estimator will estimate the channel between each transmitter in the MIMO array and both receiving terminals. An overview of this sub-system is shown in figure 2.

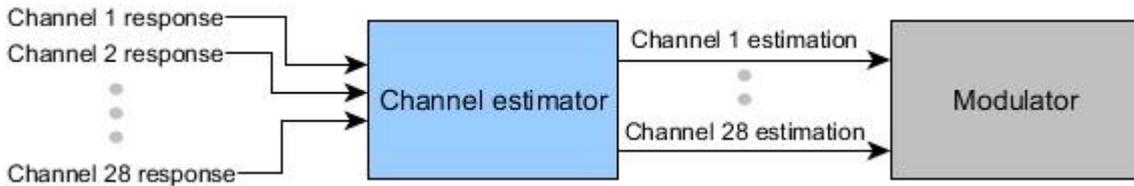


Figure 2: A block scheme of the channel estimator.

3.1 External interfaces

The following requirements define how the channel estimator communicates with other parts of the system.

17.	Original	The channel estimator shall be able to provide the modulator with estimations of the channels.	1
18.	Original	The channel estimator shall be able to receive channel responses from the channels between each terminal and transmitter in the array.	1
19.	Original	The interface of the channel estimator shall be some well-specified functions.	1

3.2 Design requirements

The following requirement defines how the channel estimator shall be designed.

20.	Original	The channel shall be estimated at the transmitter array end.	1
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3.3 Functional requirements

The following requirement defines specific functionalities of channel estimator.

21.	Original	The channel between each terminal and transmitter in the array shall be estimated.	1
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4 Modulator

The main task for the modulator is to, given two specific bit streams, create signals to be transmitted from each transmitter in the MIMO-array. These signals shall be modulated with data from both data streams and shall be generated in such way that each data stream adds up constructively at the intended terminal.

To accomplish this, the modulator will have to use the information about the channels that has been acquired by the channel estimator, along with a proper algorithm.

The modulator sub-system will also be responsible for demodulating the data that the two terminals receive. An overview of the modulator is shown in figure 3.

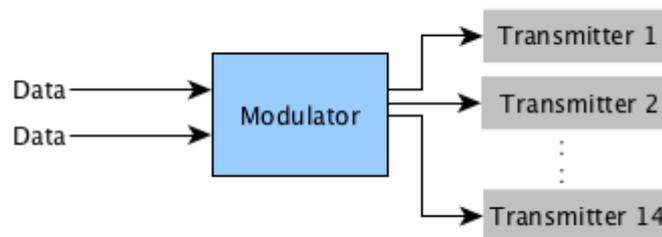


Figure 3: A simple block scheme of the modulator.

4.1 External interfaces

The following requirements define how the modulator will communicate with the other parts of the system.

22.	Original	The modulator shall be able to receive two bit streams as input.	1
23.	Original	The modulator shall be able to output signals in a way that befits the operating systems and the hardware.	1
24.	Original	The interface of the modulator shall be some well-specified functions.	1

4.2 Functional requirements

The following requirements specify the functionality of the modulator.

25.	Original	The modulator shall be able to modulate massive MIMO signals with data.	1
26.	Original	The modulator shall be able to map received data to a chosen modulation constellation.	1
27.	Original	The modulator shall be able to send two data streams to two different terminals at the same time and frequency band.	1
28.	Original	The modulator shall be able to provide signals to all 14 transmitters in the MIMO-array, in a manner such that they add up constructively at the positions of the terminals.	1
29.	Original	The modulator shall be able to demodulate data received by the two terminals.	1



5 Channel coder

To be able to use the system for demonstration of real data transmission, channel coding shall be used to try to minimize errors in the information bits being transmitted. A visual overview of the sub-system is shown in figure 4.

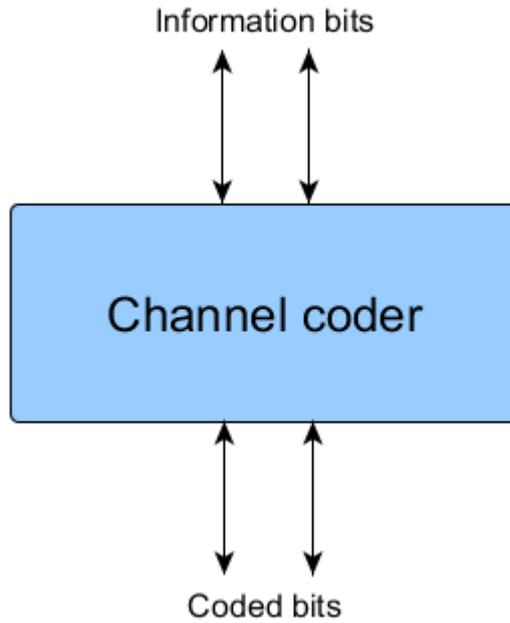


Figure 4: A block scheme of the channel coder.

The channel coder shall be designed to improve the system, meaning that compared to the system without channel coding it shall preserve the information bit rate while decreasing the information BER. To make this possible, the choice of channel coding procedure must be carefully chosen to fit the type of channel that the rest of the system will present.

The channel coder is supposed to input two information bit streams that are to be sent, and output the same number of coded bit streams.

5.1 External interfaces

The following requirements define how the channel coder will communicate with the other parts of the system.

30.	Original	The interface of the channel coder shall be some well-specified functions.	1
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5.2 Design requirements

The following requirement defines how the channel coder shall be designed.

31.	Original	The choice of channel coding procedure shall be motivated by measured characteristics of the channel.	1
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5.3 Functional requirements

The following requirements specify the functionality of the channel coder.

32.	Original	The implemented code shall be used for error correction.	1
33.	Original	The channel coder shall improve the BER while preserving the information bit rate as compared to the system without channel coding.	1



6 Possibilities to upgrade

The product is modularized in the three sub-systems presented above. This design is supposed to make it easy to upgrade a single part of the entire system by only making changes within a single module (sub-system).

34.	Original	The system shall be modularized into at least the three sub-systems, to support easy software upgrades.	1
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7 Economy

This section specifies the budget of the project.

35.	Original	All project members shall put in a maximum of 240 hours work into the project.	1
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8 Delivery

The following requirements specify what is to be delivered by the project. Descriptions of document deliverables can be found in the next chapter.

36.	Original	Requirements specification	1
37.	Original	System Design Sketch	1
38.	Original	Project Plan	1
39.	Original	Time Plan	1
40.	Original	Individual and Collective Time Reports	1
41.	Original	Status Reports	1
42.	Original	Design Specification	1
43.	Original	Software fulfilling the requirements	1
44.	Original	Technical Report	1
45.	Original	User Manual	1
46.	Original	A poster that demonstrates the result of the project	1
47.	Original	A web page presenting the product and its functionality	1
48.	Original	An oral presentation of the project	1
49.	Original	Afterstudy	1



9 Documentation

Table 4 below consists of a list of descriptions for all the required documents that will be produced within the project.

Table 4: Listing of all the documents that will be produced within the project.

Document	Language	Aim	Format
Requirement Specification	English	Defines all requirements on the product.	pdf
System Design Sketch	English	An initial sketch/overview of the design of the product.	pdf
Project Plan	English	Describes how the project shall be performed.	pdf
Time Plan	English	Details when and by whom various activities in the project are planned to be performed.	Excel
Design Specification	English	Describes how the product shall be designed.	pdf
Time Reports	English	Contains the actual used time of different project members and on activities.	pdf
Protocols from tollgates	English	Protocol to describe the tollgates.	pdf
Meeting Protocols	English	Protocol that recount important results from group meetings.	pdf
User Manual	English	Specifies how the user shall use the product.	pdf
Technical Report	English	Details how the product is implemented.	pdf
Afterstudy	English	Presents a retrospective discussion about results and time planning.	pdf

10 Education

This chapter specifies the educational material that is to be accompanied with the product.

50.	Original	The user manual shall be extensive enough to be the only needed educational material for a user to use the product.	1
51.	Original	The technical documentation shall be extensive enough to enable a non-project member to continue development of the system.	1
52.	Original	The customer shall be provided an opportunity for a guided demonstration of the product for educational purposes.	1



11 Maintainability

The following requirement specifies maintainability of the software.

53.	Original	The code shall be well commented.	1
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References

Published references

Svensson, T. & Krysander, C. (2011). Projektmodellen Lips, Upplaga 1:1, Studentlitteratur AB, Lund, ISBN 978-91-44-07525-9

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Stenmark, F. (2014). User Manual Version 1.1 (PDF) Tillgänglig:
<http://www.isy.liu.se/edu/projekt/kommunikationssystem/2014/documents/UM_1.1.pdf>

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(September 7, 2015). The CDIO Project in Communication Systems: Massive Audio Beamforming (PDF)