



USER MANUAL

Fredrik Stenmark

Version 1.1

Status

Reviewed	Christoffer Ring	2014-12-03
Approved with rest list	Christopher Mollén	2014-12-05



PROJECT IDENTITY

HT 2014
Linköping University, ISY

Name	Role	Phone	E-mail
Anton Eriksson	Hardware Designer	0736143063	anter@592@student.liu.se
Christoffer Ring	Documentation Manager	0738133863	chrri226@student.liu.se
Dimitrios Bakogiannis	Test Manager	0707395508	jbakogia@gmail.com
Fredrik Stenmark	Project Manager	0703823561	frest522@student.liu.se
Magnus Thalén	Chief of Design	0705190977	magth371@student.liu.se

Customer: Christopher Mollén, christopher.mollen@liu.se, 013 – 28 26 43

Examiner: Danyo Danev, danyo@isy.liu.se, 013 – 28 13 35

Supervisor: Antonios Pitarokoilis, antonios.pitarokoilis@liu.se, 013 – 28 13 40



Table of Contents

1 Introduction.....	1
2 System Components.....	1
2.1 The Computer.....	2
2.2 The Distribution Box.....	2
2.3 Power Supply Unit.....	3
2.4 L/M-Pair.....	4
2.5 USB Power Adapter.....	4
2.6 Connection Cables.....	4
3 Setting up the system.....	5
4 Using the system.....	5
4.1 Specifying User Defined Parameters.....	5
4.2 Displaying Data.....	6
4.3 Running a Demonstration.....	6



Document History

Version	Date	Changes	Performed by	Reviewed
1.0	2014-12-03	First version	All group members	Christoffer Ring
1.1	2014-12-08	Changes according to rest list	Christoffer Ring	Fredrik Stenmark



1 INTRODUCTION

The purpose of this document is to provide a user guide for how to use the massive MIMO beamforming system. The system is designed to demonstrate one of the powers of massive MIMO beamforming, namely that signal energy can be focused to a specific point of interest and at the same time be suppressed essentially everywhere else.

2 SYSTEM COMPONENTS

The massive MIMO beamforming system consists of the following parts, which can also be found in Fig. 1:

- One computer with A/D card Contec AD12-64 (PCI), D/A card Contec DA12-16 (PCI) and installed massive MIMO beamforming software (1).
- One Distribution Box (2).
- One power supply unit that can generate -11 V , $+11\text{ V}$, $+5\text{ V}$ and ground, where the ground for $\pm 11\text{ V}$ and 5 V are common. The power supply, used in this user guide, is named University Power 3535 (3).
- Eight L/M-pairs (4).
- Four USB power adapters (5).
- One 37-pin D-sub connector cable (6).
- One 96 pin PCA connector cable (7).
- Eight 9-pin D-sub connector cables (8).

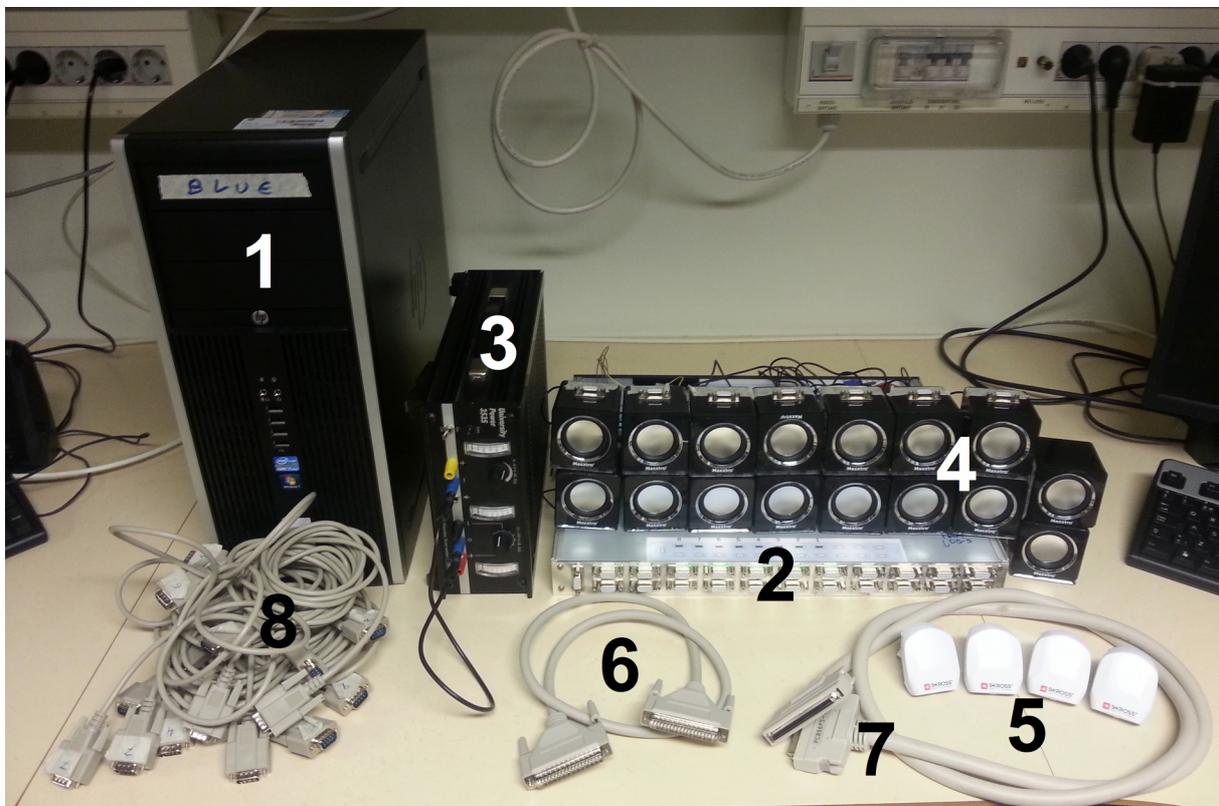


Figure 1: Presentation of components in the system.



2.1 The Computer

Except ordinary computer components, the computer consists of the A/D card of type Contec AD12-64 (PCI) and a D/A card of type Contec DA12-16 (PCI). Connections to these cards are found at the backside of the computer, see Fig 2. The top slot in the picture is the D/A connection and the slot under it in the picture is the A/D connection. The computer runs Windows 7 and has MATLAB installed in order to run the software programs. Also a library called ML-DAQ is installed in order to fetch and send data, from and to the D/A and A/D card.



Figure 2: The computer back panel with A/D and D/A slots.

2.2 The Distribution Box

The Distribution Box provides connections between the computer and the L/Ms. On the front panel, there are connections for the L/M-pairs, see Fig. 2. There are 23 connections, but only 8 out of these are used. This means that the remaining connections can be used for future extensions. A picture on top of the box specifies which connections that are active.

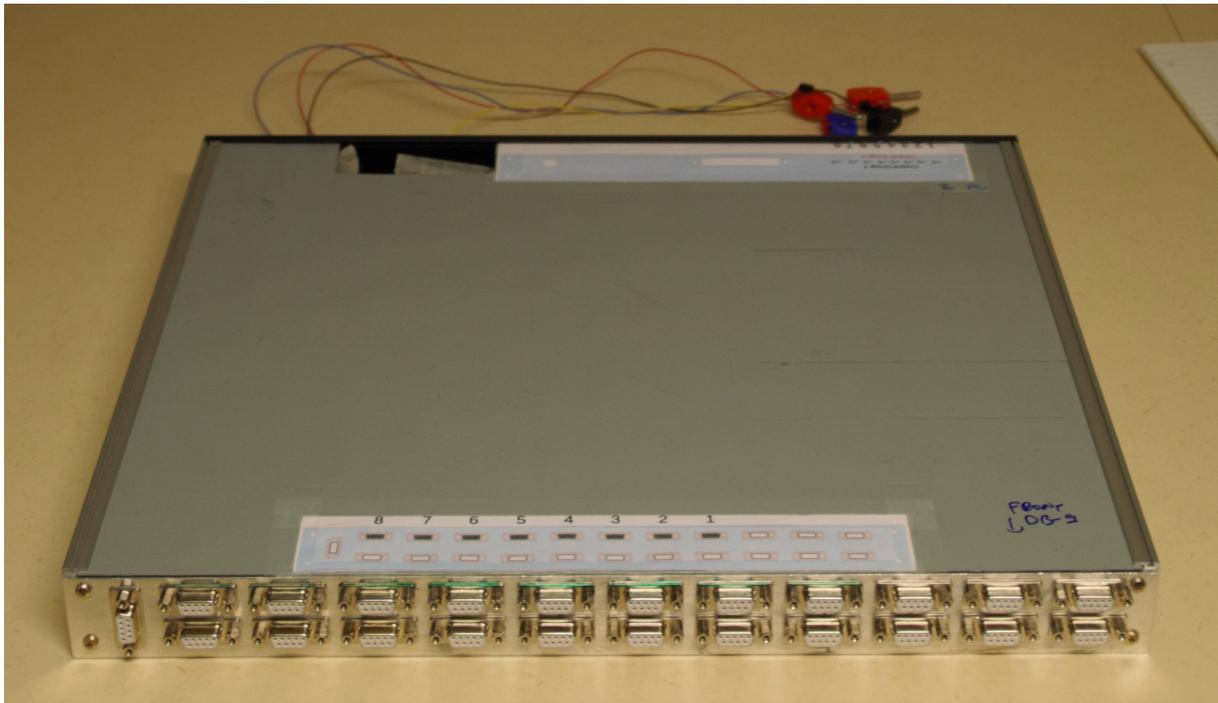


Figure 3: The distribution box. The figure shows the front panel, containing the D-sub connectors for the L/M-pairs.



On the backside, there are eight switches, one connection for the D/A card and four cables for power supply, see Fig. 3. The switches control whether an L/M-pair belongs to Control Group 1 or Control Group 2, where one of these groups corresponds to the group that is situated in the point of focus and the other group belongs to the MIMO array. Which one of the two groups that is situated in the point of focus must be set in the software. All L/M-pairs in the same group will always have the same mode of operation. That is, all L/M-pairs belonging the same control group will always be in either microphone mode or loudspeaker mode, at the same time. On top of the box, there is a picture showing which switch that controls which L/M-pair. The picture also tells that an L/M-pair belongs to Control Group 1 if its corresponding switch is switched upwards and that an L/M-pair belongs to Control Group 2 if its corresponding switch is switched downwards. On top of the box, there is also a hole for the connection to the A/D card.

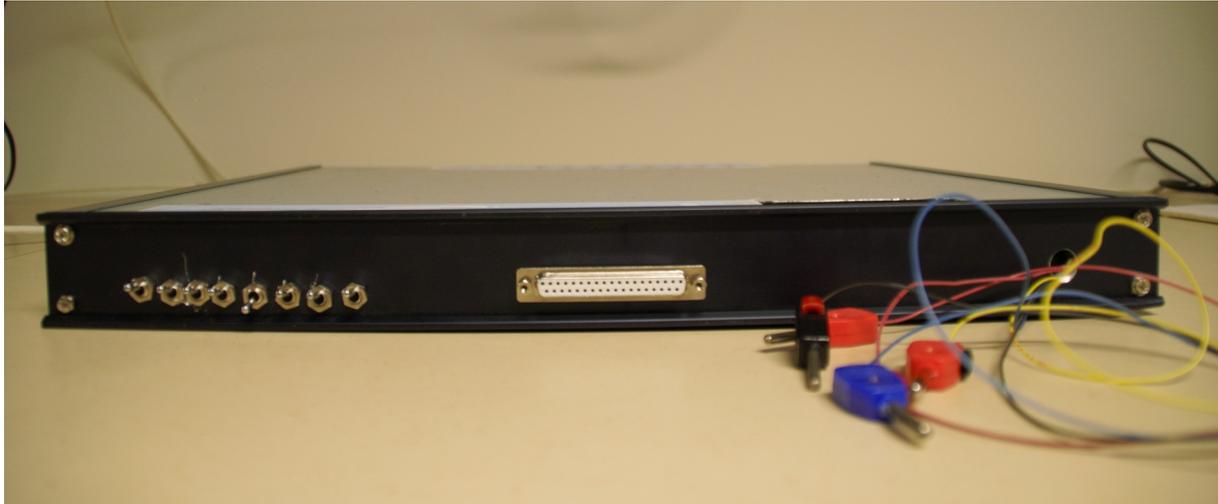


Figure 4: The back panel of the Distribution Box.

The mapping between color and voltage for the power supply cables is listed in table 1.

Table 1: Mapping of color and voltage for the power supply cables.

Color of power supply cable	Voltage
Yellow	+5 V
Black	Ground
Blue	-11 V
Red	+11 V

2.3 Power Supply Unit

The power supply unit for the Distribution Box is named University Power 3535 and has a total of five connections. Two belong to the output channel with output range [4, 6] V DC, where one connection is positive and the other is ground. The other three connections belong to the second output channel consisting of one negative and one positive connection, with ranges [-11, -16] V DC and [11, 16] V DC respectively. The voltage outputs are relative to the ground of this channel, which constitutes the third connection. In the system setup, the ground of the two channels are connected, so that all voltage levels of the power supply unit is relative to the common ground of the entire system.

The Power Supply Unit has two controls, controlling each channel output level individually. The minus and plus pole of the second channel are hence simultaneously adjusted by the second control. Fig. 5 shows the power supply unit in more detail.



Figure 5: The Power Supply Unit.

2.4 L/M-Pair

L/M stands for Loudspeaker/Microphone, since the loudspeakers are able to operate as both. One L/M-pair consists of two L/M-units, one master and one slave. The master loudspeaker has a 9-pin D-sub connector on top of it. The L/M-pair is powered through its USB cable and shines blue from the bottom, when it is powered. The master loudspeaker has a volume control on the backside and this control alters the volume of both the master and the slave, when the pair operates in loudspeaker mode. Fig. 6 Shows the L/M-pair.

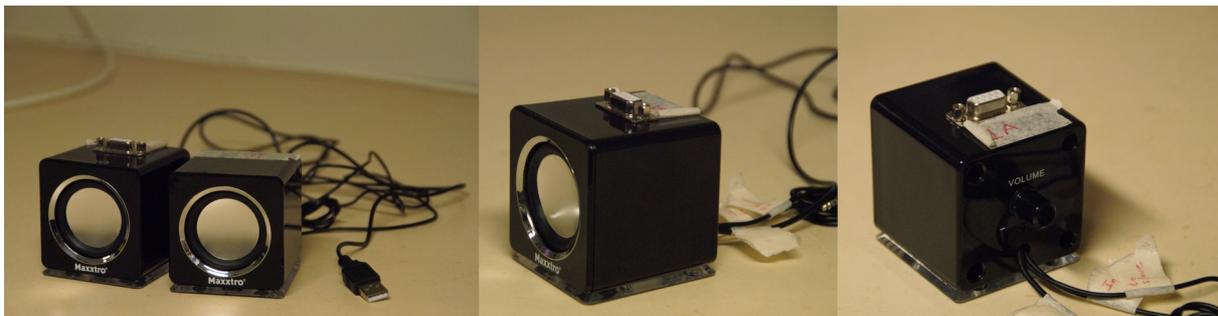


Figure 6: The L/M-pair and the master L/M from different angles.

2.5 USB Power Adapter

The USB Power Adapter for the L/M-pairs is a simple Skross USB travel charger with two outputs. It is connected to a wall outlet and delivers an output DC voltage level of 5 V per output.

2.6 Connection Cables

The connection between the L/M-pairs and the Distribution Box consists of D-sub cables with a 9-pin plug on both ends, each of length 1.8 m. The cable between the Distribution Box and the D/A converter of the computer is a D-sub cable with a 37-pin plug on both ends. The connection between the Distribution Box and the A/D converter of the computer consists of a 96 pin PCA connector cable.



3 SETTING UP THE SYSTEM

In order to get the system to work, the following steps must be carried out.

1. Connect the computer and the Distribution Box by connecting the A/D card with the connector inside the Distribution Box, using the 96 pin PCA connector cable.
2. Also connect the computer and the Distribution Box by connecting the D/A card with the connector on the backside of the Distribution Box, using the 37-pin D-sub connector cable.
3. Connect each L/M-pair to the Distribution Box, using the 9-pin D-sub connector cables. L/M-pair number one shall always be connected to connection number one on the Distribution Box, using the 9-pin D-sub connector cable labeled number one. The numbering of the connections on the Distribution Box are specified in the picture found on top of the Distribution Box.
4. Connect the power cables of the Distribution Box such that the yellow cable is connected to the yellow connection on the power supply unit, the black cable is connected to one of the blue connections on the power supply unit, the blue cable is connected to the black connection on the power supply unit and the red cable is connected to the red connection on the power supply unit. Also make sure that the blue connections on the power supply unit are connected in order to have the same ground in the system.
5. Connect the USB cables from each L/M-pair to the USB power adapters.
6. Power the system by connecting the power cable of the computer, the power cable of the power supply unit and the USB power adapters to power plugs.
7. Decide which L/M-pairs that will be in which group by using the switches on the backside of the Distribution Box. All L/M-pairs in the same group will have the same mode of operation at the same time, i.e. there is one group for the *point-of-focus* (PoF) and one group for the MIMO array.

It is recommended that L/M-pair number 5 is used at the PoF as mentioned. This means that this pair is not included in the MIMO array, but instead placed in front of it. This pair should therefore be switched to the group that is, in the software, latter chosen to be in the PoF. The system is developed and tested for a system configuration where the L/M units are placed in a half circle with radius 1-1.5 m and individually spaced at least 20 cm from each other. The future use of the system will include other setups, but the functionality and hence also the strength of the demonstration may then be limited. A more detailed instruction of how to use the system is delivered in the following section, section 4.

4 USING THE SYSTEM

The interaction with the system is enabled through the software installed on the computer. To start the massive MIMO beamforming software, start MATLAB and run `Controller_Main.m`. The program will prompt for user defined setup or standard setup, where standard setup means the recommended setup described in section 3.

4.1 Specifying User Defined Parameters

In order to specify user defined parameters, choose the user defined setup alternative when being prompted at the start up of the program. This will start a parameter initialization procedure. The parameters that can be user defined are:

- The amount of L/M-pairs – This means the amount of L/M-pairs that will be used in the system. It can take all scalar integer values from 1 to 8. The default value is 8.
- The number of L/M-groups – This means how many groups there will be for L/M-pairs to be put in, either 1 or 2. The default value is 2, one group at the PoF and one group for the MIMO array. This is actually also the only configuration for which the system, at this point, will work



at all. The other configuration is for using only one group of L/M-pairs, i.e using an external source of sound emitting from the PoF.

- The L/M-group in the PoF – This parameter can only be set when the number of L/M-groups is 2 and it specifies which L/M-group that will be in the PoF. It can take the values 1 or 2. The default value is 2.
- The L/M-pair to be in the PoF. It can take all integers from 1 to the chosen amount of L/M-pairs. Default value is 5.
- Which one of the L/M-units to be verifier and which one to be the one at the PoF. The input is either number 1 for master or 0 for slave. Default number is 1.
- The signal frequency – This means the frequency of the tone that will be generated as pilot signal, in Hertz. It can take positive scalar integer values from 300 to 3000 Hz. The default value is 502 Hz.
- The signal duration – This means for how long time the signal will be transmitted from the MIMO array, in seconds. It can take values from 1 to 30 seconds. The default value is 1 second, recommended values are values in the interval [1,2] seconds. It should in this context be mentioned that the time the PoF transmits sound is locked to 1 second.
- What to plot – This means the mode of plotting operation? It can take the values 0, 1, 2, 3 or 4 (default value 4) where:
 - 0 – No data is displayed.
 - 1 – Difference in power in dB between received signal of L/M-unit in the PoF and verifier is displayed in the command window.
 - 2 – Power spectral densities of the received signals of L/M-unit in the PoF and verifier are displayed.
 - 3 – The received signals of L/M-unit in the PoF and verifier are displayed in one plot.
 - 4 – All of the above is displayed.

4.2 Displaying Data

The result is displayed as MATLAB plots according to the user defined parameter regarding the plotting of data. All other signal data that the system is handling is displayed in the workspace to the right in the MATLAB window. There are several ways of displaying this data if the user wishes, although it may require some knowledge of the MATLAB syntax.

4.3 Running a Demonstration

After inputting the user parameters, the system will run a demonstration based on those parameters. The user is then prompted to run the same demonstration again using the same parameters, or to quit.

To effectively demonstrate the effects of massive MIMO, it is desirable to be able to see a clear difference between the signals received in the PoF and somewhere around it. Therefore, the L/M unit intended to be in the PoF should always receive a signal of greater power than the verifier. This could be shown by using some of the optional data displayed. If for example display alternative 1 or 4 is used, the difference in dB between the received signal power will be printed, which is a quick way of verifying the MIMO effects.