Internal Technical Report

Understanding and Debugging LOFAR FPA Setup

Giant Metrewave Radio Telescope

NCRA • TIFR

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Abstract

This report concentrates on the work done on the LOFAR Focal Plane Array beamformer project. Along with this, there were certain areas in which the work was extended Matlab simulations, department of FPA test lab etc.

This work is a part of feasibility study for which comprises of the Expanded-GMRT project. The LOFAR focal Plane Array beamformer System is one possibility of expanding the existing GMRT in terms of field of view, surveying area, multiple observations etc. and various tests, documentation was prepared as a part of this activity.

The relocation of the entire system to the shielded area was achieved. The learning from the department of a shielded lab facility are described.

Acknowledgements

A special gratitude to Prof. Nissim Kanekar, Prof. Jayaram Chengalur and Prof. Y. Gupta for various suggestions and encouragement.

Furthermore we would also like to acknowledge the GMRT backend group for their help in this project. We would also like to thank the Mechanical, Electrical and Civil groups for their help in shielding the glass room for hosting the LOFAR receiver and beamformer. Thanks to Menno Norden, Wim van Cappellen and team at ASTRON for their support in remote debugging.

Contents

Chapter 1

Background

As a part of this activity most of the reverse engineering on tracing the system flow had been done. Since the documentation for the system was feeble, the system was a black box to be tested. Soon the different blocks in the system were cleared, the system changed to grey box. As the correspondence between the GMRT and ASTRON developed, many things got the clarity in terms of understanding of the system, interpretation of the plots, implementing the data in Matlab scripts etc. Some of the Matlab simulations were also carried out during the tenure as a part of learning and capacity building exercise. Matlab 2015 version equipped with phased Array toolbox, RF toolbox, Antenna toolbox were evaluated. The characterization of different ADC's(for FPGA based beamformer) was carried out at output of the down converter unit of LOFAR FPA system.

Chapter 2

Introduction

This provides the information to the LOFAR Focal Plane Array (FPA) beamformer system. This system was procured from the ASTRON (Netherlands Institute for Radio Astronomy) as a part offive year plan of expanding the existing GMRT.FPA beamformer system is a system generating multiple beams. Multiple beams are useful to achieve a large field of view and large field of view means surveying large area of the sky. Image no. 1 shows the LOFAR FPA beamformer system along with its FPA Feed.

2.1 Major components of LOFAR beamformer

1. Focal Plane Array (FPA) : Focal Plane array is a feed of 8*9 Vivaldi elements. The signal frequency coming to the feed is in L-band, ranging from 1 GHz to 1.7 GHz.

2. Down Converter Unit (DCU) : The L-band frequency signal coming from FPA to Down converter unit(DCU). DCU has about 20 dB gain with 7dB equalization across band.

3. Receiver unit (RCU) : It is a part of Digital Processing Board(DPB) which consist of 64 receiver unit. RCU contains inbuilt frequency band selector block along with ADC.

4. Remote Station Processing Board (RSP) : It is another part of DPB. Remote Station Processing board consist of five FPGAs, out of that four are Antenna Processors and One board processor.

5. LOFAR control unit (LCU) : The local control unit is a 19 inch rack PC with Redhat Linux operating system. The LCU controls all the boards in the sub rack, it receives 1PPS time signal from time distribution system.

Image 1: Snapshot of the LOFAR FPA beamformer system (right) and feed(left).

Chapter 3

Debugging of LOFAR FPA System

This section describes more about the reverse engineering that has been done while working with LOFAR FPA[3] beamformer system. It also provides a contextual information developed during understanding of the system.

3.1 Testing of Digital Processing Board(DPB)

As DPB plays a vital role in the beamformer system, information to the DPB and knowing its function became important. In order to that, document [3] was referred to develop more understanding.
Following test checks were carried out in order to know that DPB is in working mode.

- Checking LED's on the Digital Processing Board.
- Checking the connections on the DPB.
- Checking communication between the boards.

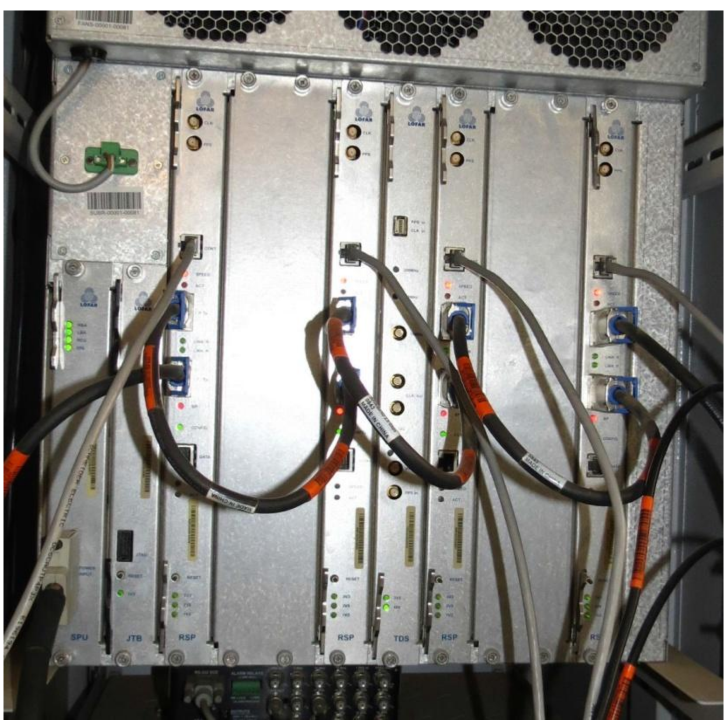

Image 2: Photograph of Digital Processing Board

3.2 Testing of Rubidium Frequency Standard

Testing of the rubidium frequency standard (SRS make fs725) was carried out to test the 1 PPS signals and 10 MHz signals coming out of it. Input from the rubidium was provided to the Time Distribution System (TDS) and the Local Control Unit (LCU). (i.e 2 inputs each of 1 PPS and 10 MHz goes to the two TDS boards of DPB).

Image 3: Front(left) and rare(right) images of Rubidium frequency standard.

Test equipments used: Digital Oscilloscope, SMA-SMA adapter, BNC-SMA cable. Test Procedure: 1 PPS and 10 MHz signal going to the TDS Board were removed

*Settings of CRO :

- Volts/div : 500mV
- Time/div : 25.0ns
- Input Impedance : 1 MΩ ±3% || 16pF ±3pF
- Trigger source : CH1

The powered oscilloscope was used to test the signals by controlling the times/div knob.

Results:

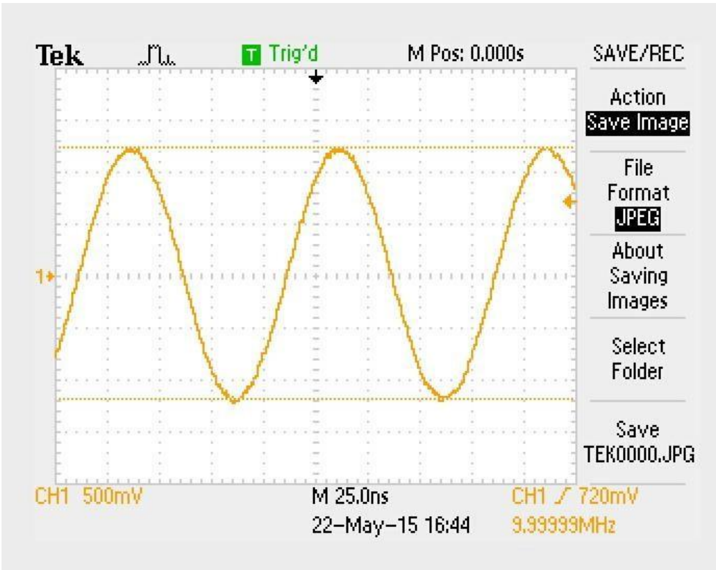

Image 4: Scope output plot for 10 MHz signal

Image 5: Scope output plot for 1 PPS signal

3.3 Understanding shell scripts

LOFAR FPA system consists of different configuration files. (location: localhome/lofarsys/etc) In order to know each configuration file, one needs understanding of shell scripting. A basic knowledge of shell scripting was developed in order to understand the .conf files.

3.4 Working with RSP Control commands

RSP Control commands are the commands that controls the RSP Boards. Documentation [2] gives detail information on how to use the commands and implement a basic beamforing using the RSP control commands. After developing understanding on how to use the commands a detailed document has been prepared.

3.5 Harnessing of RF cables

Harnessing of the RF cables from the FPA feed to the beamformer was carried out by manually connecting the 60 RG6 cables with F-type connector on both sides of the feed and the beamformer.

Image 6: Connecting 60 cables to the FPA feed and routing them

3.6 Inter-rack cabling

Inter-rack cabling was done for the beamformer racks when they were installed in the shielded room. It included cabling from the down converter unit to the receiver unit. Manually the interconnection of the RG6 cable providing IF output from the DCU were connected as input to the receiver unit. Image 7 shows the connected cables.

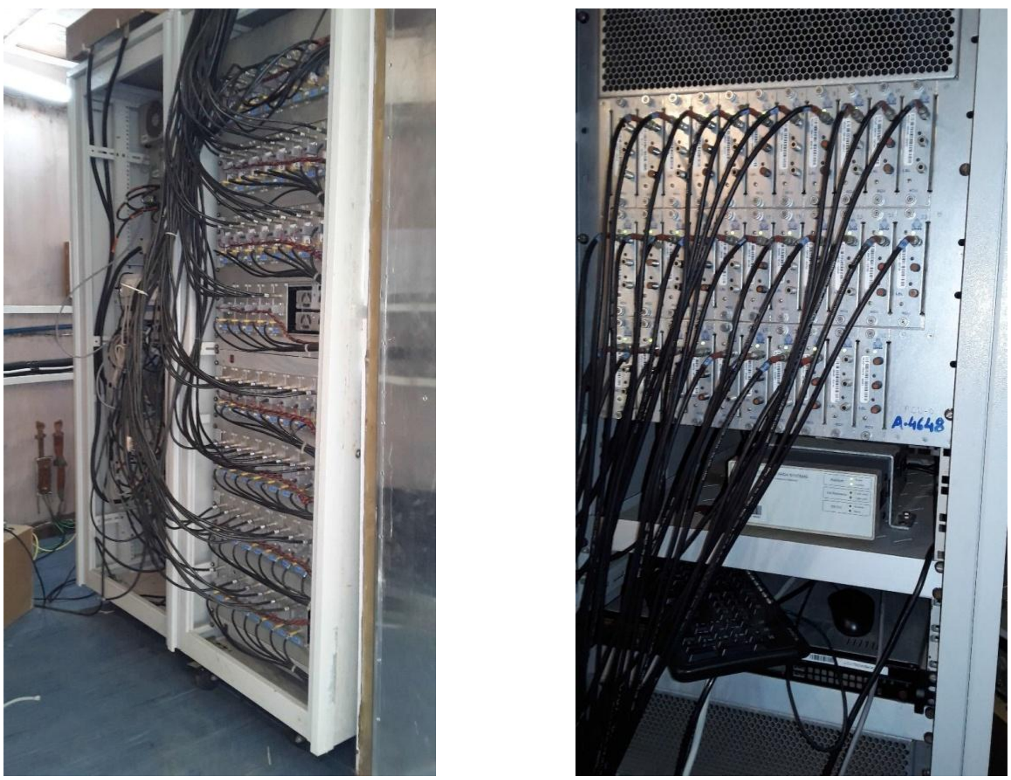

Image 7: Front(left) and rare(right) images of Rubidium frequency standard.

3.7 Basic beamforming with LOFAR FPA beamformer

Testing basic beamforming was the first step. After understanding the commands that are needed to do the signal processing, the basic beamforming was carried out. Using different methodologies like CW signal from external signal generator, CW signal from inbuilt waveform generator, radiated tone signal, noise signal, the beamforming was done. The actual method of performing the beamforming using different sources is documented in the Standard Operating Procedure for performing basic beamforming for LOFAR FPA beamformer[1]. Some of the results of the basic beamforming with different sources are as follows:

Beamforming using external signal Generator:

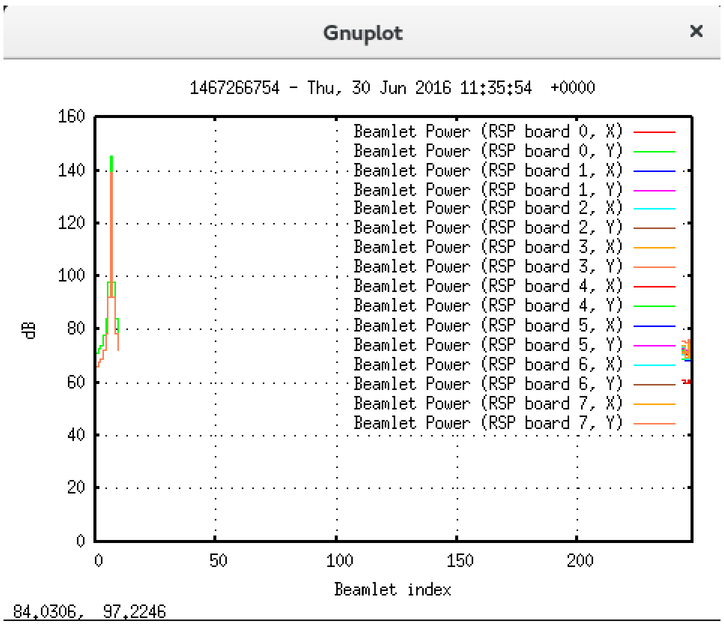

Image 8: Two tone signals added in phase with each other (original tone signal amplitude 139 dB) later increased to 145 dB

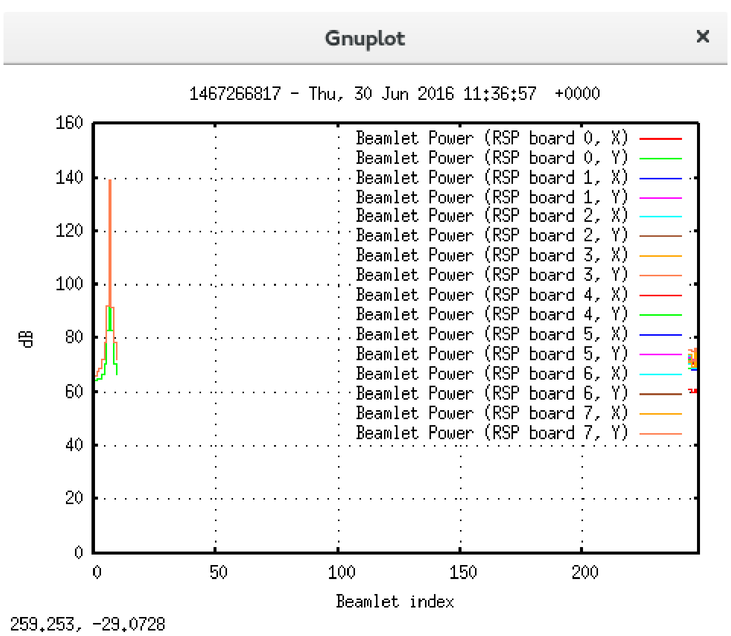

Image 9: Two tone signals provided out of phase (original amplitude 139 dB) later decreased to 133 dB.

Basic beamforming using inbuilt waveform generator:

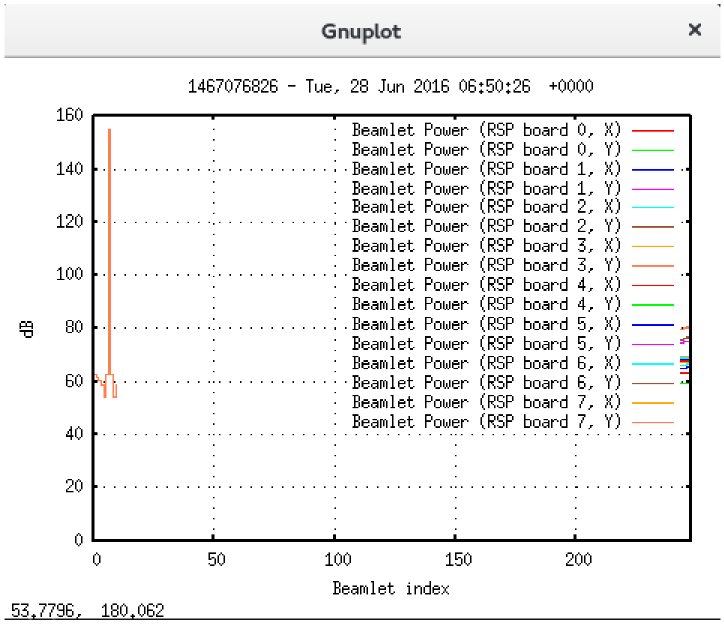

Image 10: Two tone signals added in phase (original amplitude 149 dB) after adding increased to 155 dB.

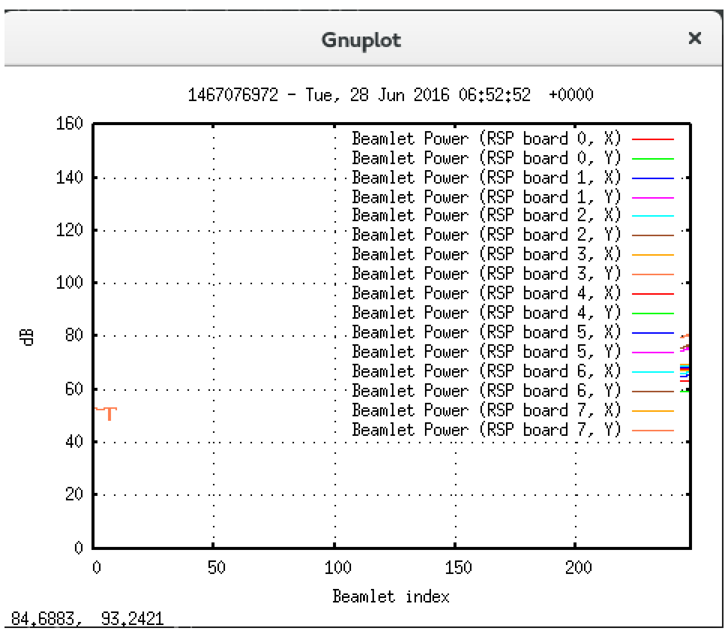

Image 11: Two tone signals provided outof phase input after cancellation they cancelled out fully.

3.8 Cloning of Local Control Unit(LCU)

The Local Control Unit which came along with beamformer from ASTRON that started giving frequent rebooting problems over the period of usage. So to carry out the test smoothly, without any interruption cloning of Local Control unit was decided. To get an LCU which has same hardware as well as software, the original LCU was dismantled from the rack.

Image 12 : Local Control Unit (PC) after dismantling

Hardware cloning

The current LCU had two RS232 serial ports, one USB port, two ethernet ports, a VGA port and mouse and keyboard ports.
Various models having same hardware capabilities as of LCU were searched.

Software Cloning

While cloning the machine software various things were figured out. For e.g the OS, the processor, the memory, the RAM etc. were checked.
Following possibilities were tried:

- Dumping the executables as well as source files directly into the disk.
- Cloning it by taking the full backup of the original disk.
- Installing multi-port serial card from old server to the new test PC.

After cloning the new test PC ,it was not found working as of the original PC. Due to the reason that the whole software tool chain needed 1 PPS to be connected on a serial port and that is to be read by the kernel. To make the kernel read the 1 PPS it needs to be patched with Linuxpps patch or one has to use ”PPSkit”. Linuxpps project initially had given patches for the older kernel and later on it was merged with main linux kernel requiring no patching from kernel 2.6.34 onward. Before Linuxpps the PPS support was provided by PPSkit. So it was not clear that which one of this is currently being used in the system the cloning was not achieved to its fullest.

3.9 Test of Down Converter Unit(DCU)

- Test 1: Checking DCU output power by varying input power.
- Test 2: Checking receiver chain by radiation test using monopole antenna.
- Test 3: Checking receiver chain by radiation test using whip antenna.

In first round of test, unexpected loss at the output of DCU was observed, while as per estimates to give 13dB gain (1.1 GHz input frequency) at the output. On further tests seen that LO power that is expected to be 13 dBm at the LO ports of DCU was lower. Refer fig. no. 1 for block diagram of experimental setup.

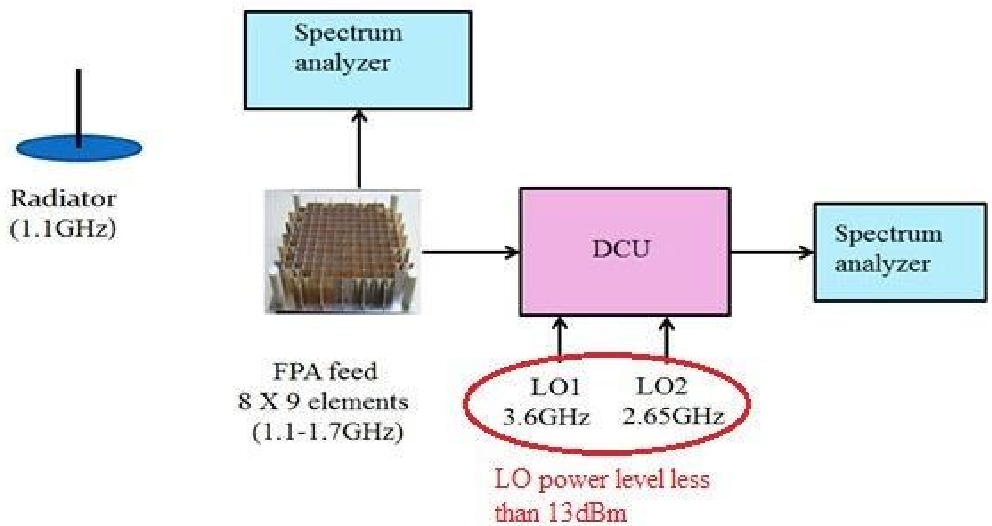

Figure 1: Fault detected in connections of experimental setup

Signal got attenuated because of LO1 power is less than -13dBm. due to faulty cable between LO1 and DCU as shown.By replacing cable and repeating the same experiment 10dB gain at the output of DCU was achieved.

Spectrum analyzer settings:

Fc = 1.1 GHz, Span = 10 MHz, Attenuation = 0 dB, RBW = 300 Khz, VBW= 3 Khz

Test 1: Checking power level at DCU output by varying the input power:

Experimental setup:

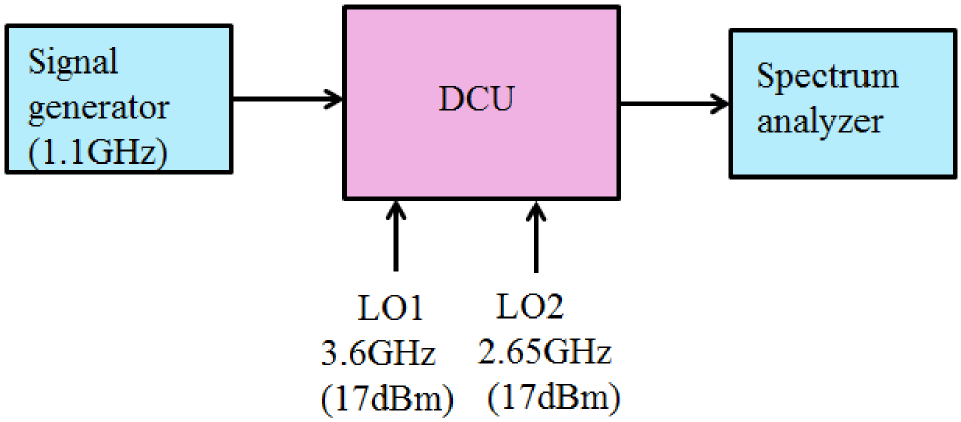

Figure 2: Experimental setup

. **Input Power varied from -30 dBm to -96 dBm and measured the power level at the output of DCU.**
Image 13 showing Output power response of DCU by changing input power.

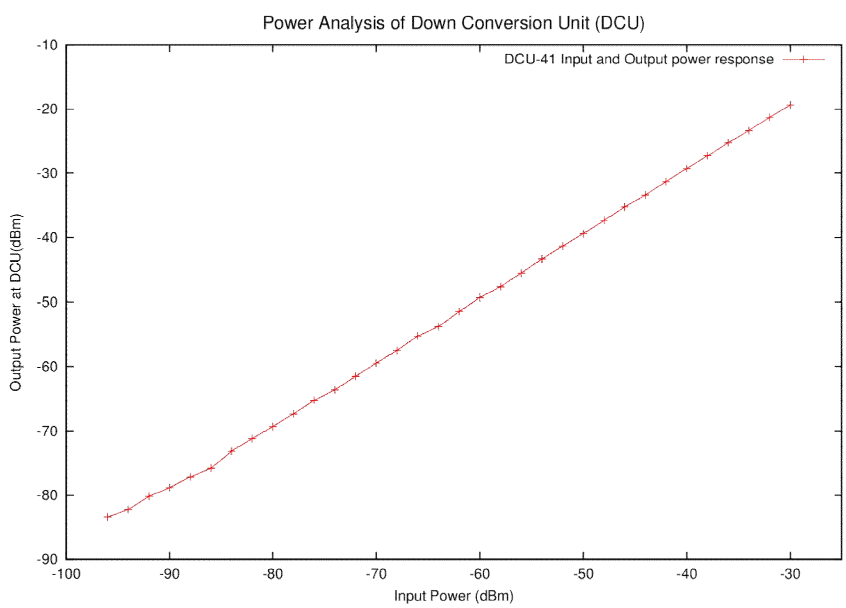

Image 13: Power analysis of Down Converter Unit

Test 2: Check receiver chain by radiation test using monopole antenna:

Experimental setup: Monopole is a antenna having λ/2, long metal rod mounted on ground plane having nearly Omni-directional pattern, experimental setup shown in Fig. 3

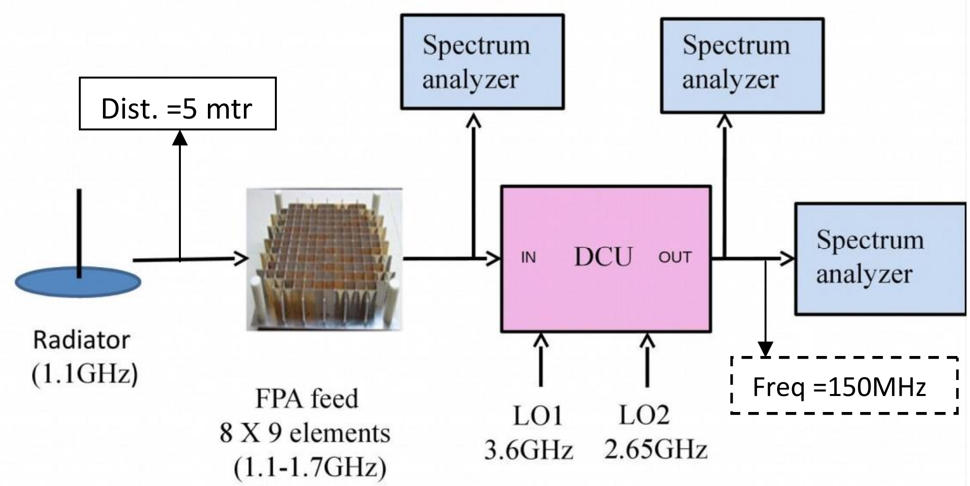

Figure 3:Experimental setup 2

Input Power to the radiator varied from +13 dBm to around -49 dBm and measured the power at input and output ports of DCU.

With Monopole :

Image 14 is a graph showing Output Power measured at input and output ports of DCU by varying the radiated power.

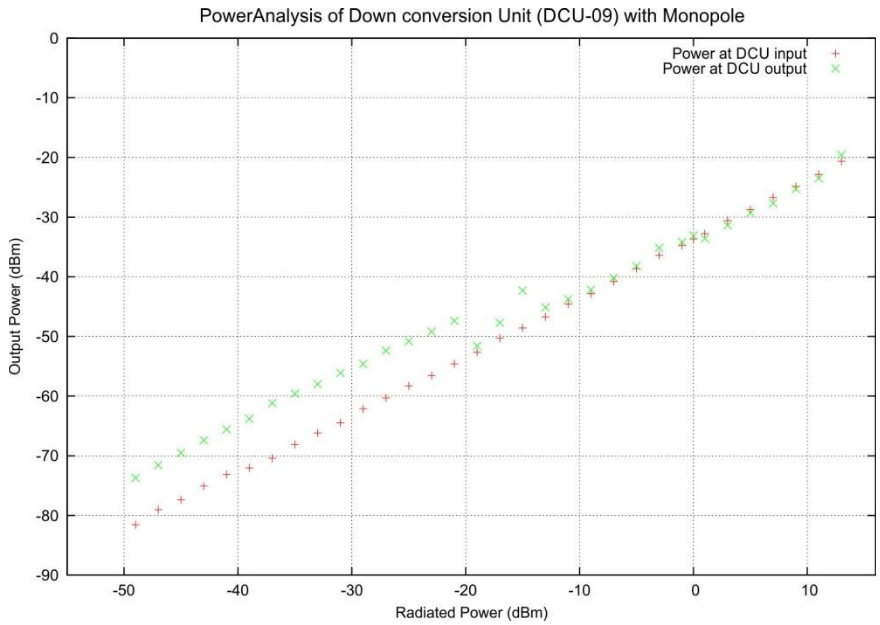

Image 14:Power analysis of DCU with monopole

Test 3: Check receiver chain by radiation test using Whip antenna:

Experimental setup: Whip is a hand held monopole antenna having Omni-directional pattern.

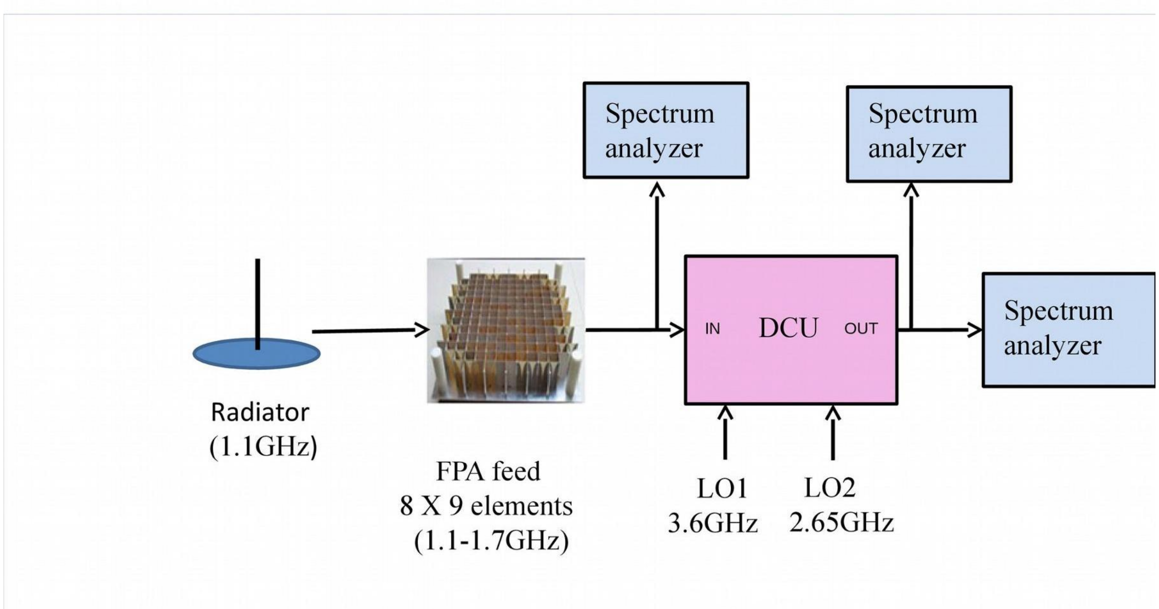

Figure 4: Experimental setup 3

Input Power varied from +9 dBm to around -47 dBm and measured the power at input and

output ports of DCU.

Image 15 is a graph showing output power variation at the input and output port of DCU by varying the radiated power.

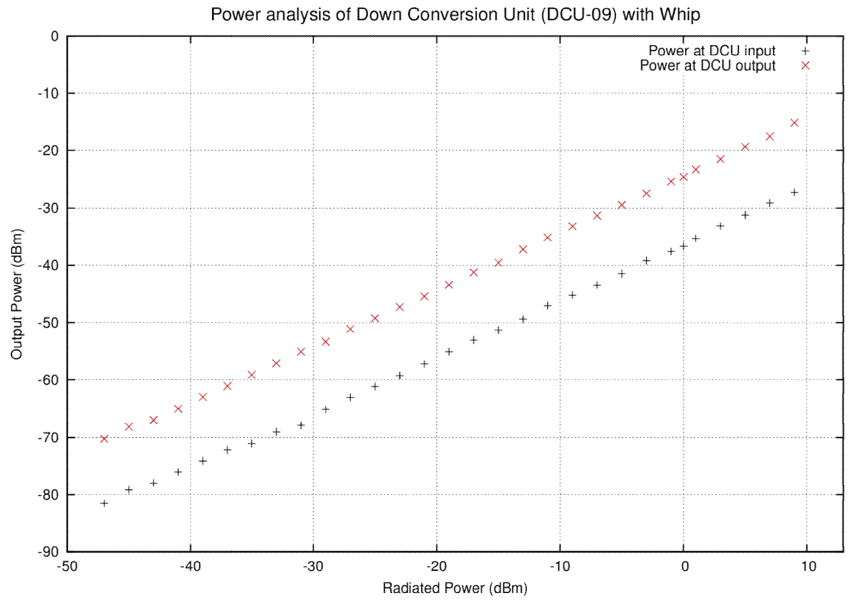

Image 15: Power analysis of DCU with whip antenna

Test Conclusion:

1. DCU Power Analysis: Input Power to DCU (RFin port) : Max : -30dBm Min: -90dBm Output Power to DCU (IFin port): Max : -19.35dBm Min: -78.81dBm
2. For Radiation, use radiation frequency 1.1 GHz power +10dBm, to achieve better power level at input and output port of DCU.

3.10 Noise test with LOFAR FPA beamformer

In order to carry out the test following test setup was made to feed two separate uncorrelated noise inputs to the LOFAR FPA beamformer to execute the noise cancellation test. Test setup for noise test shown in fig. 5

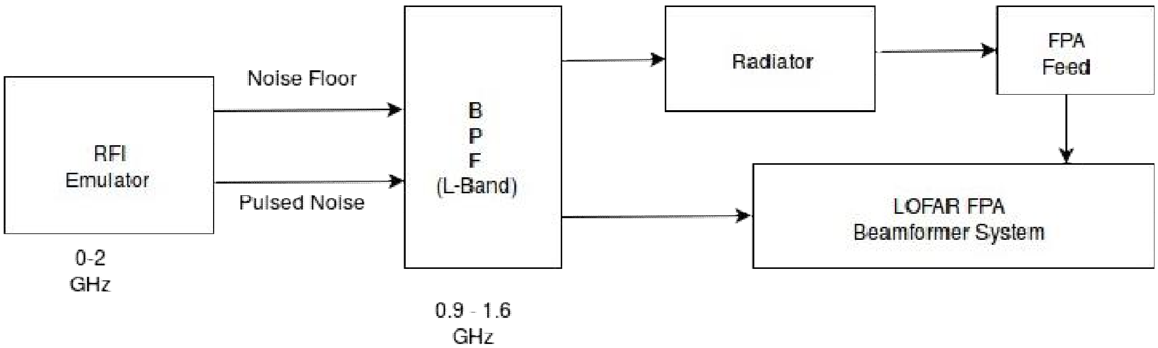

Figure 5: Test setup for noise test

Before getting the result plots out of the test, clean plot with the system was taken. Image 16 shows the snapshot of the clear plot.

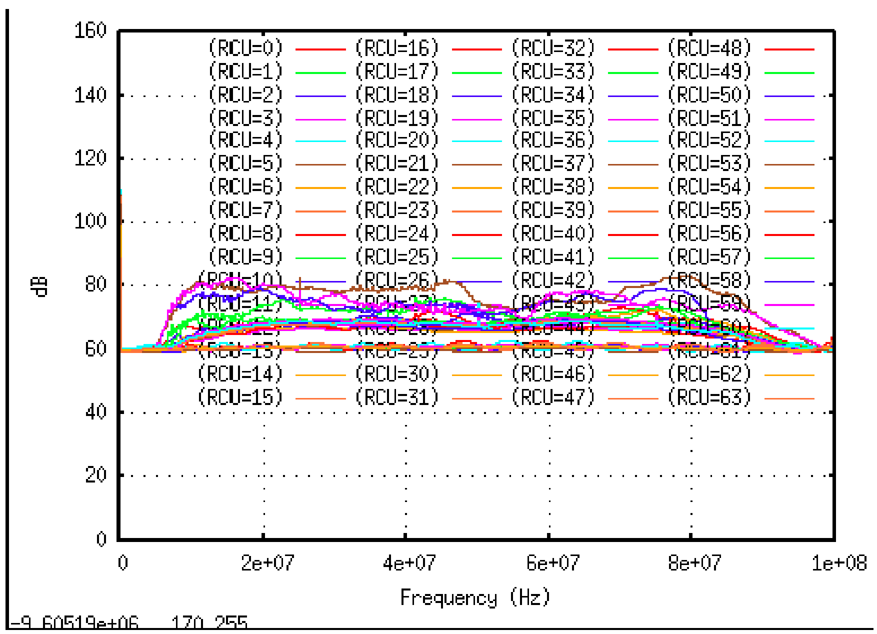

Image 16: Plot before performing the noise test

After running the Remote station processing (RSP) control commands [2] related to signal processing the noise output was observed. Image 17 shows the noise cancellation.

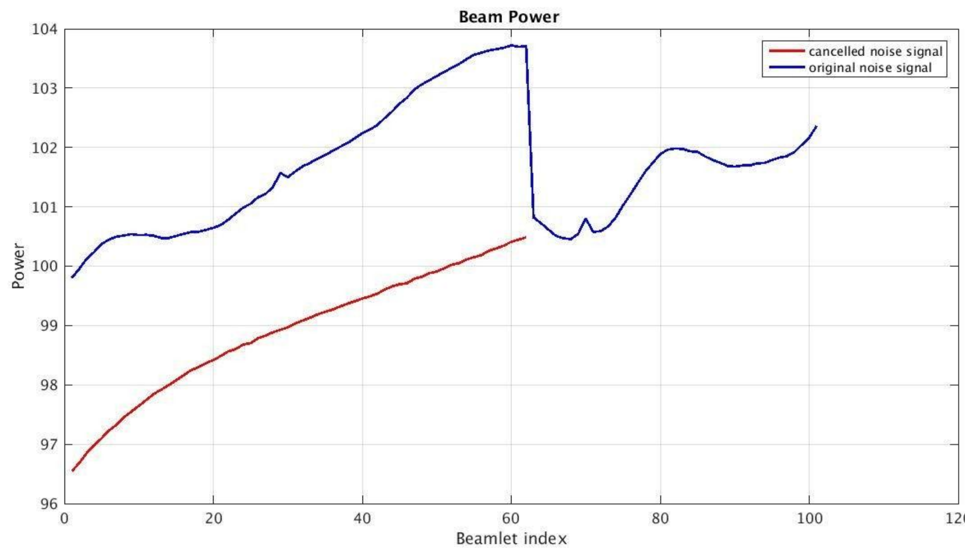

Image 17: Noise cancellation resulting 3dB change after applying the weights for 60 beamlets

In this way the noise cancellation test was carried out on LOFAR FPA beamformer system which resulted in 3dB cancellation of the uncorrelated noise signal.

Chapter4

Shielded room for LOFAR FPA beamformer system

This section describes about the overall development of the shielded enclosure for setting up LOFAR FPA beamformer system.

4.1 Dimensioning rack

First of all, before relocating, dimensioning of FPA racks were done in order to estimate the layout of Glass room. The length, height, width parameters of the rack were measured.

4.2 Designing Layout

After dimensioning the FPA racks, different layouts for setting up the racks were tried. Designing of the layout was carried out taking the exact measurement of the glass room and the FPA racks. Image 18 shows the layout prepared for arranging the racks in the glass room.

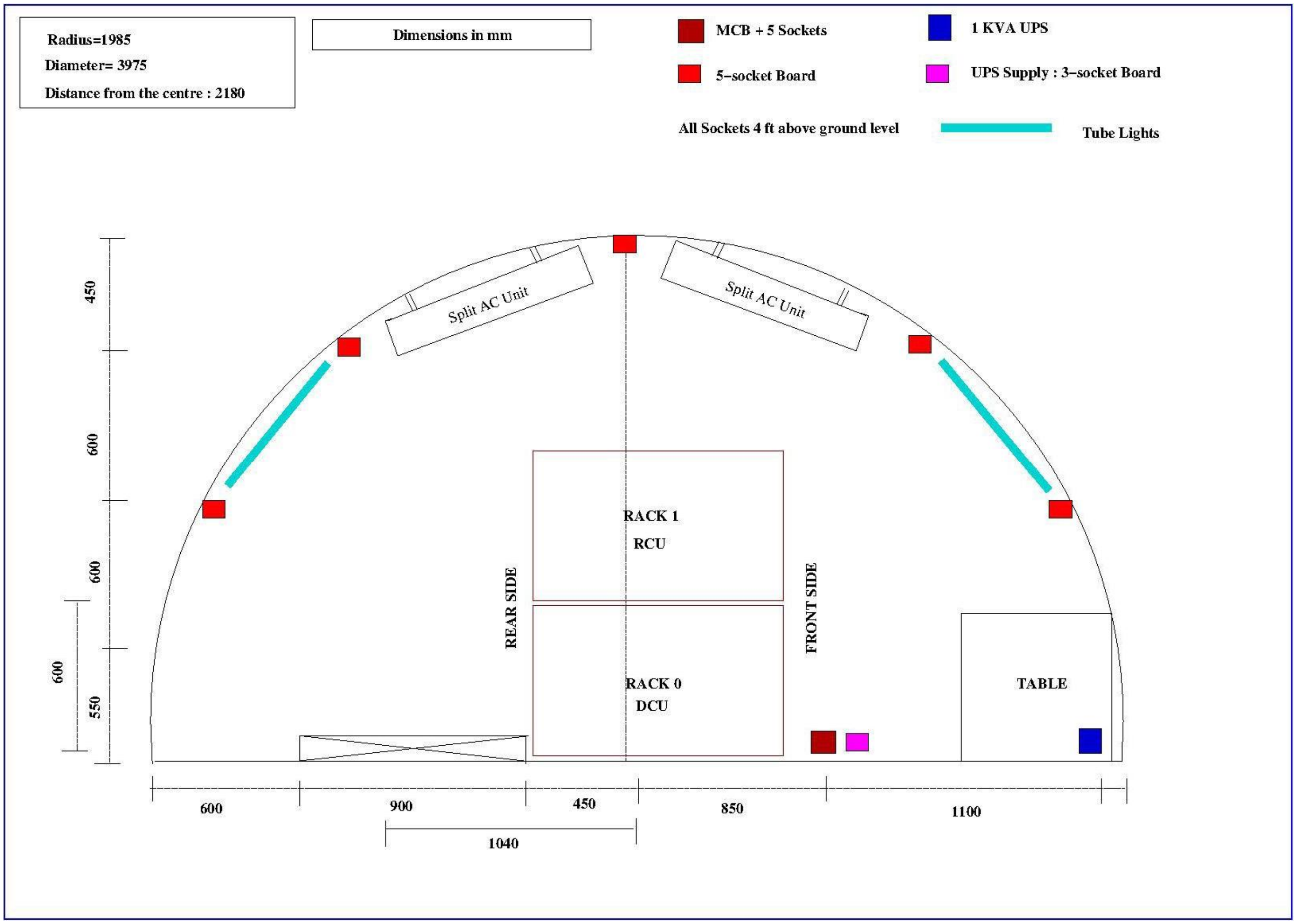

Image 18: Layout for arranging the FPA racks in glass room

4.3 Electrical Layout designing

In order to have supply in the Glass room, distribution of the supply at various locations were estimated. Layout for having distribution boards at specific point and specific layout was designed. Current ratings for each distribution board was designed. Image 19 shows the electrical layout for glass room.

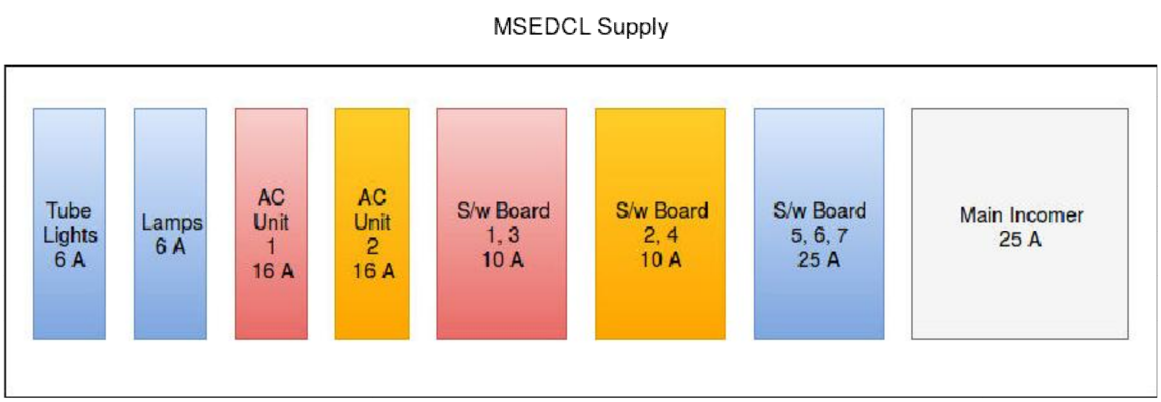

Image 19: Electrical layout for glass room

4.4 Estimation of electrical parameters

To know the exact rating of the power supply needed in the Glass room for the racks and other appliances, power rating of the racks were measured. Power rating for the AC was calculated depending upon the AC tonnage. The racks total power consumption was measured using power meter. Depending upon the application, LCU machine and rubidium system of LOFAR FPA beamformer was estimated to put up on UPS power of 1KVA capacity. The racks of the FPA beamformer were put up on raw power.

The overall electrical load in glass room is balanced through 7 switch boards. Different RF equipments, AC units, FPA beamformer racks, UPS etc are split-up on switch boards that the load is maintained. The three phases (R, Y, B) are managed in such a way that the AC mains don't trip due to overload. Following description shows distribution of the boards and units for balancing the load.

R phase : Used for 1 AC unit and for switch board 1 3.

Y phase : Used for 2 AC unit and for switch board 2 4.

B phase : Used for Tube lights, Lamps and switch board 5, 6 7.

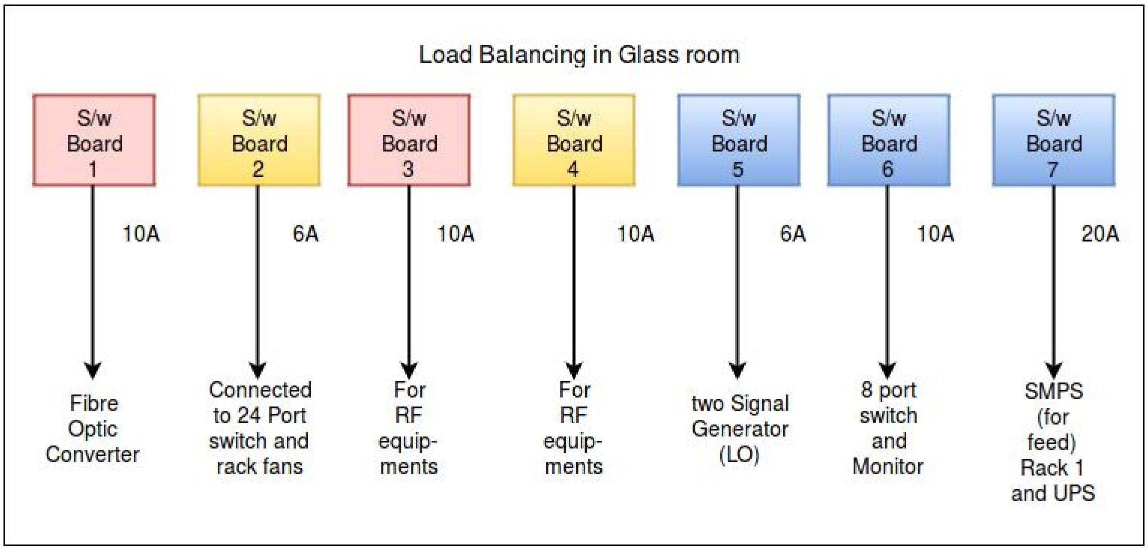

Image 20 Load Balancing in glass room

Estimation of power for Focal Plane Array

Parameters	Rack 2 (With PC)	Rack 1	Rack 0	Rubidium
Frequency	50	50	50	50
Voltage(V)	228.1	228.3	230.8	228.1
Current(A)	5.44	2.2	1.16	0.21
Power Factor	-0.98	1.00	0.8	1.00
Total Power(w)	1200	500	220	47.94

Hence, the total power consumption of the system is 1967 Watts.
Apparent Power: 2.186 KVA
Miscellaneous: 1.5 KVA
Total Raw Power : 3.5 KVA

UPS Power: 1 KVA
Miscellaneous: 2 KVA
Total UPS Power: 3 KVA

4.5 AC tonnage estimation

The AC tonnage estimation was done by calculating the BTUs required per hour. Depending upon the number of BTU's the tonnage was estimated.
For calculating the AC tonnage following ways were tried

- The Area of the Glass room is 6.18 mtr square, so that is equal to 66.52 sq.ft.(approx equal to 100 sq.ft) With reference to energy star chart, 100-150 sq.ft equals to cooling capacity of 5000Btu/h. That means for 5000Btu/h the required AC tonnage is 0.416 RT.
- If we calculate it in terms of heat dissipation than power consumption of racks is 1967.94 Watts equal to 6714.89 BTU/h. So the AC tonnage requirement is 0.55 RT. Overall final AC tonnage requirement with 1 RT is suffice for Glass room.

Finally it was decided to have two 1.5 RT AC's, where one will act as spare unit for half a time.

4.6 Copper Pipe dimensions

Different copper pipe dimensions were surveyed. After measuring the bending radius and diameter of the RG6 cable used for LOFAR application suitable copper pipe dimension were searched. And depending upon that the configuration for incoming 144 cables inside the glass room was prepared. Following CAD based drawing Image 20 shows the implementation of the same.

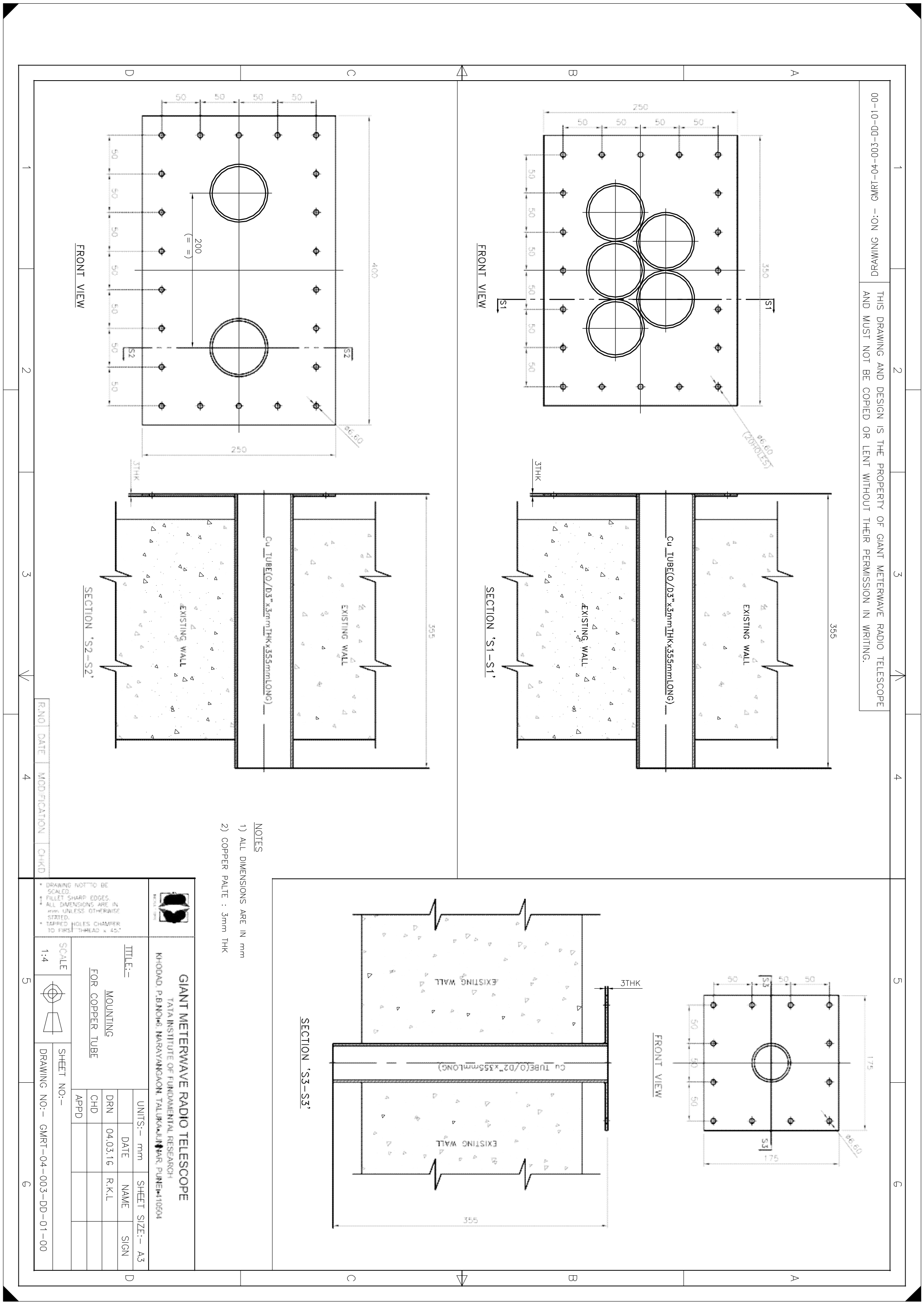

Image 21: CAD drawing for copper pipe configuration

Chapter 5

Simulation and Analysis using Matlab

5.1 Simulation for phased ULA

To simulate phased ULA, a linear array with 10 dipoles with 0.5λ spacing was created.

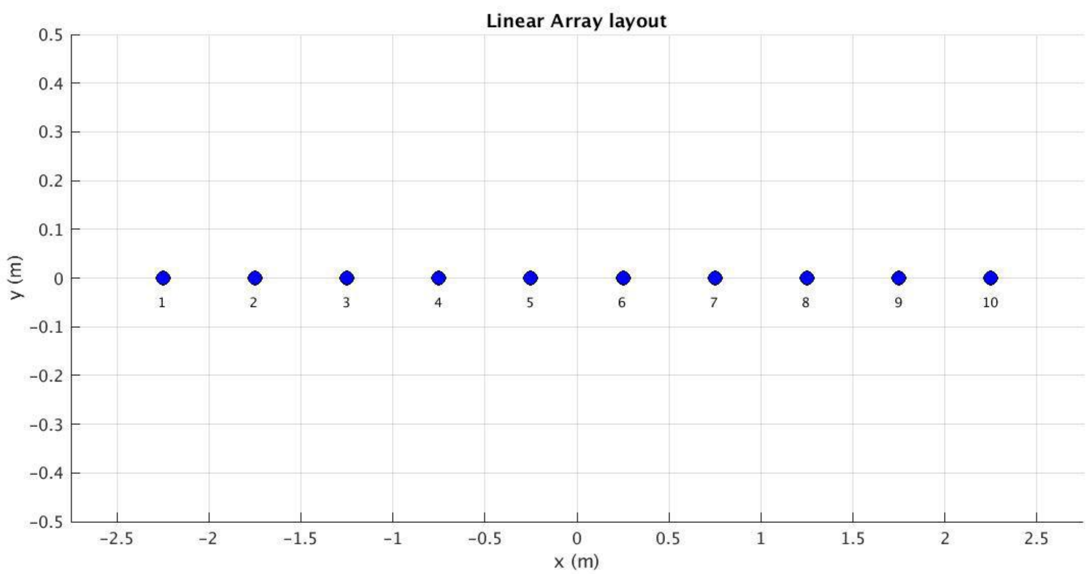

Image 22: Linear array layout for 10 dipole elements

To know how exactly the array layout appears after the simulation, Matlab's view array command was used to know the overall view of 10 dipole elements spaced uniformly.

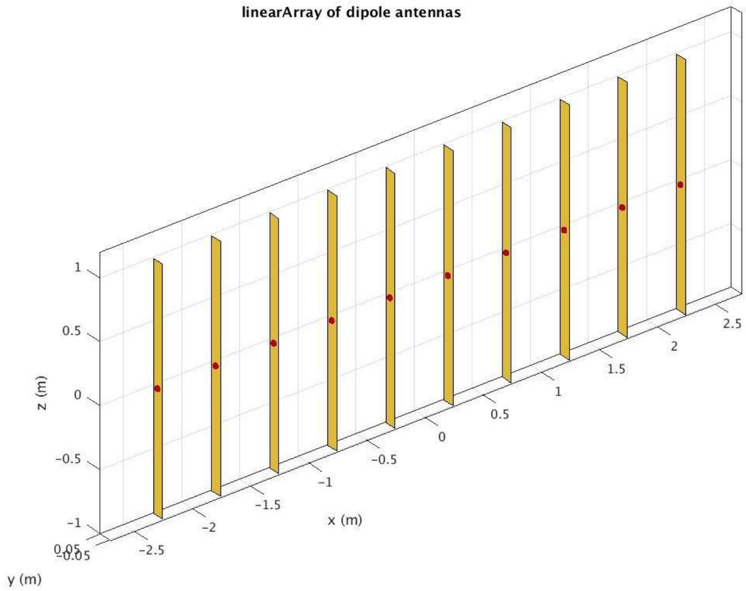

Image 23: View of the linear array

Radiation pattern of the ULA tells about the direction in which maximum radiation of the array appears. Along with that various parameters such as directivity of the array, side lobe level etc are also observed. Radiation Pattern of the linear Array shown in Image 24.

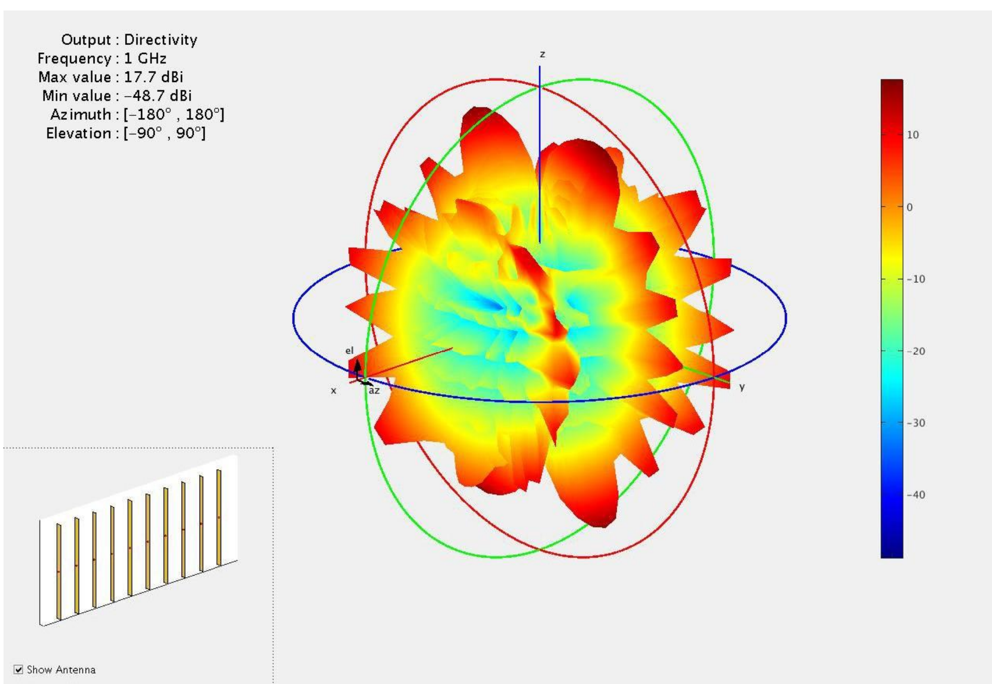

Image 24: Radiation Pattern of the linear Array

5.2 Simulation for phased URA

To simulate phased URA, a rectangular array with 10*10 dipoles with 0.5λ spacing was created.

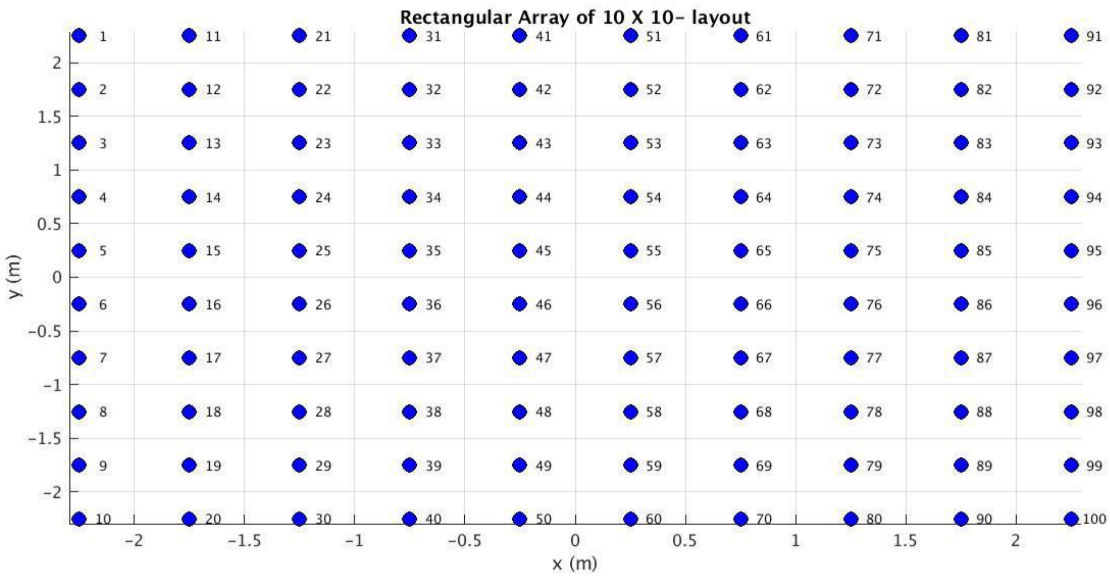

Image 25: Rectangular array layout for 10*10 array of dipole antennas

To know how exactly the array layout appears after the simulation, Matlab viewarray command was used to know the overall view of 10*10 dipole elements spaced uniformly.

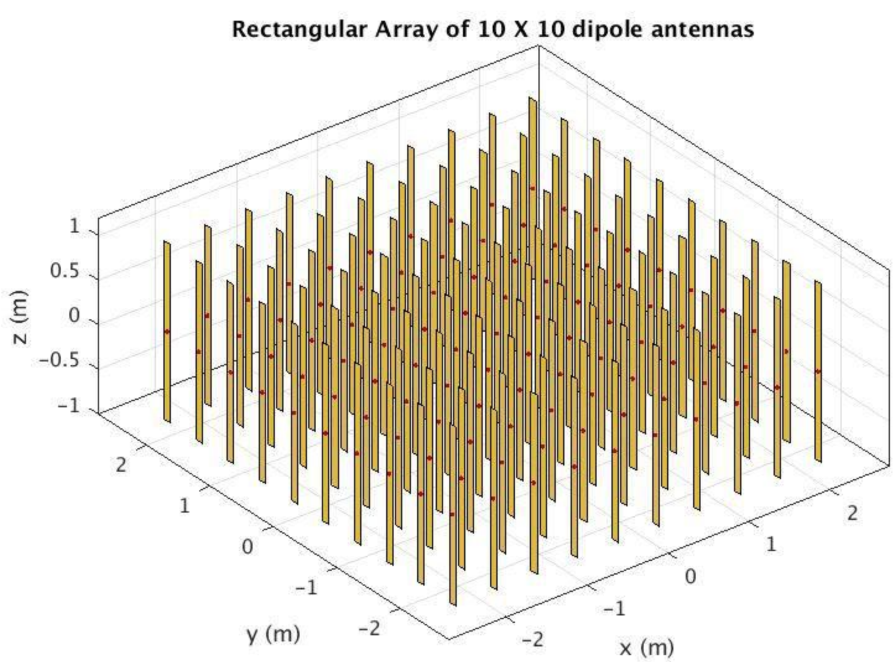

Image 26: View of the rectangular array

Radiation pattern of the ULA tells about the direction in which maximum radiation of the array appears. Along with that various parameters such as directivity of the array, side lobe level etc are also observed.

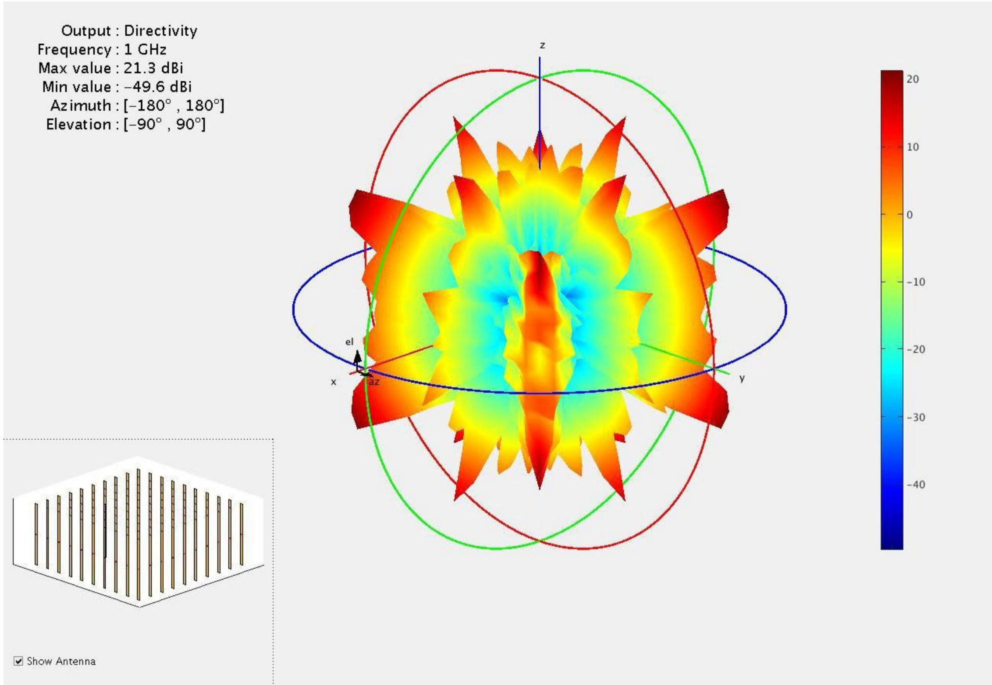

Image 27: Radiation pattern of uniform rectangular array

5.3 Simulating Array factor for Linear Array

5.3.1 Using generic Matlab code

A complete Matlab code without using the toolbox was developed in order to simulate the linear array of cosine elements, spaced 0.4λ at frequency of 1.1 GHz. Image 27 shows the element pattern for cosine distribution antenna.

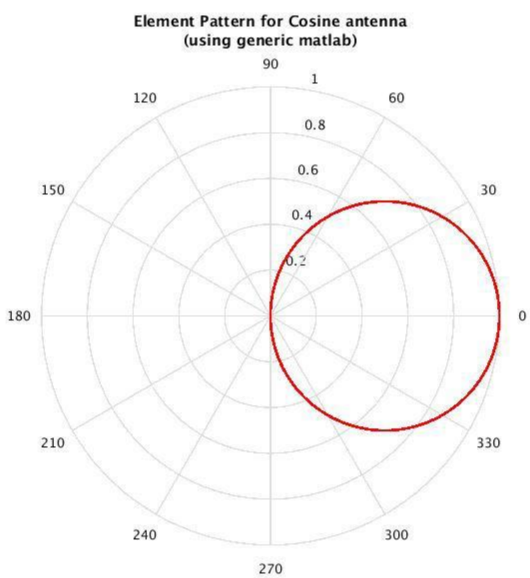

Image 28: Element Pattern for Cosine Antenna

After simulating the element pattern, the whole array factor was simulated using the formula,

$$AF=\frac{1 sin\frac{n\psi}{2}}{n sin\frac{\psi}{2}} \tag{5.1}$$

where,

$$\psi=\frac{2\pi}{\lambda}d sin\Theta \tag{5.2}$$

This provided the whole array factor for 9 cosine elements spaced 0.4λ.

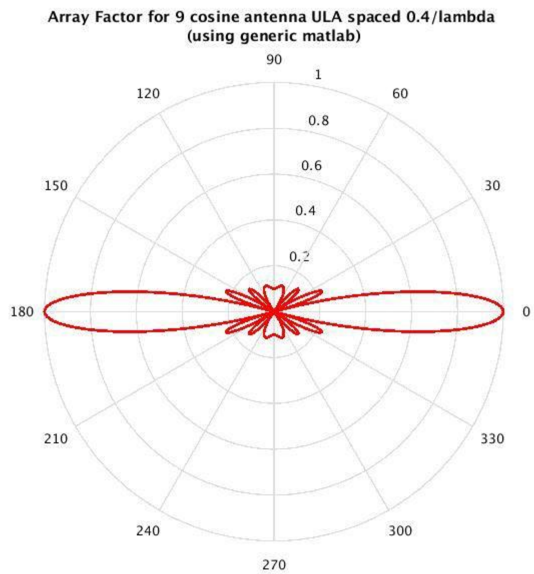

Image 29: Array factor for 9 cosine antenna ULA spaced 0.4λ

Now, to get the whole array pattern, a simple pattern multiplication formula was used which says, Array Pattern = Element Pattern * Array Factor. Hence the finalized Array pattern in sine as,

$$AP=cos\Theta\frac{1 sin\frac{n\psi}{2}}{n sin\frac{\psi}{2}} \tag{5.3}$$

This provided the whole array pattern for 9 cosine antenna elements spaced 0.4λ.

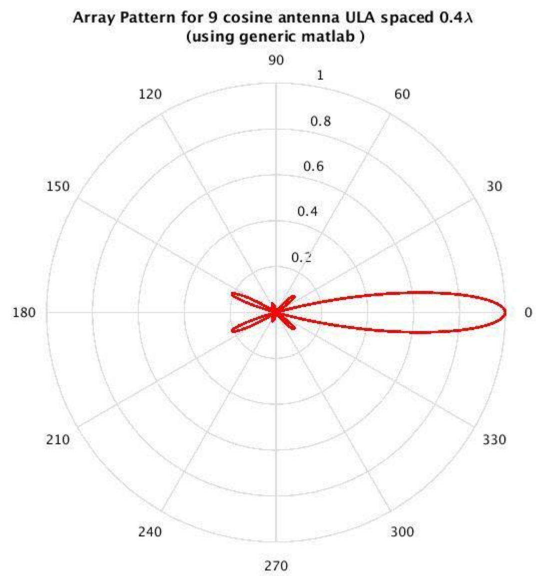

Image 30: Array Pattern for 9 cosine antenna ULA spaced 0.4λ

5.3.2 Using tool box

To cross check the results obtained by developing the Matlab code for uniform linear array having cosine distribution, sensor array analyzer app equipped in phased array toolbox was used. Image 31 shows the directivity plot obtained with same configuration.

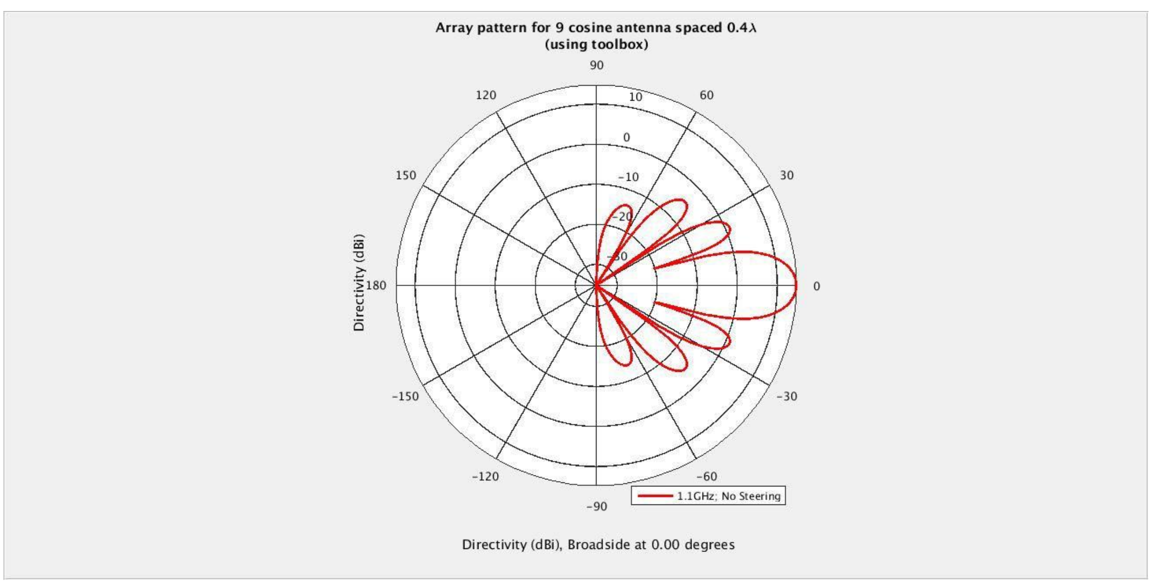

Image 31: Array directivity for 9 cosine antenna ULA spaced 0.4λ using sensor array analyzer app

5.4 Simulating Array factor for Rectangular Array

5.4.1 Use

This toolbox used for the directivity plot for 8*9 array of cosine antenna elements. The parameters were substituted as it is, considering number of elements equal to array of 8*9, spaced 0.4λ and frequency 1.1 GHz.
Image 32 shows the directivity plot for the same.

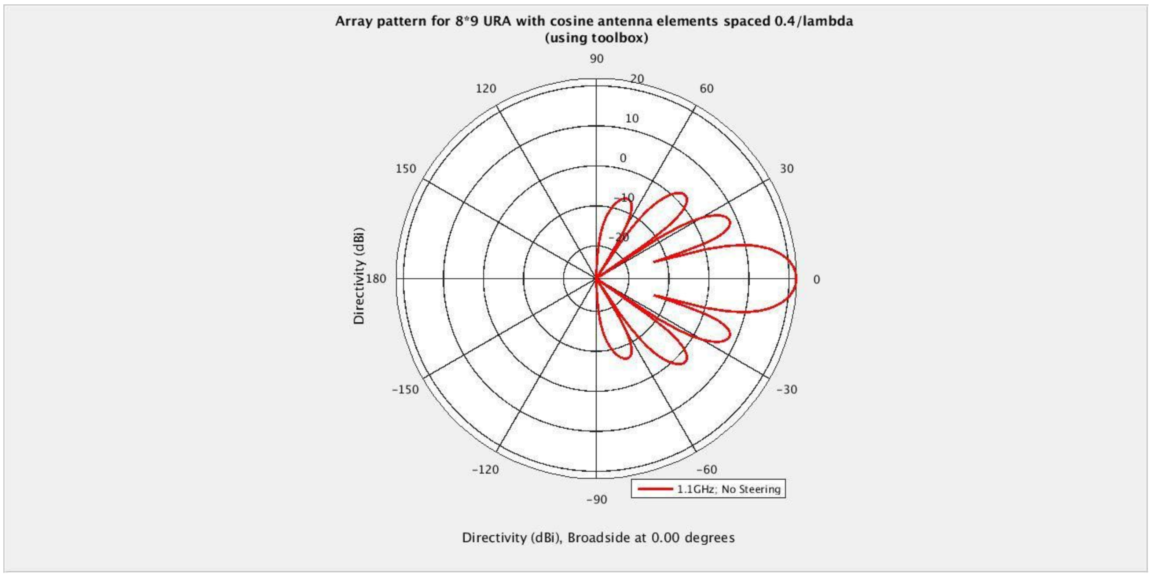

Image 32: Array directivity for 8*9 array of cosine antenna URA spaced 0.4λ using sensor array analyzer app.

5.5 Matlab scripts for the LOFAR FPA beamformer system

One alternate way of getting the beamlet statistics output is by providing the RSP control (rspctl) command in a specified format. The xlabel and the ylabel provided in the output plot doesn't match so to have own interpretation of the data 'beamlet statistics' file is developed in Matlab. In this Matlab file one can dump the beamlet data (actually present in binary format) and get the output out of it with correct labels. The tests done so far were basically for testing the beamforming, hence beamlet statistics file were used to get the plot of cancellation as well as addition of the signal which actually the system provided

```
%Used for plotting the beamlet statistics
clear all; close all;

nch = 4*61; %# subbands for CEP

meet_nr=1;

fid = fopen('20160614_082708_bst_00X.dat', 'r');
data = fread(fid, 'double');
fclose(fid);
duration=floor(length(data)/nch);
acmeet = reshape(data(1:nch*duration), [nch,duration]);

fid = fopen('20160614_082708_bst_00X.dat', 'r');
data = fread(fid, 'double');
fclose(fid);
duration=floor(length(data)/nch);
acmeet = reshape(data(1:nch*duration), [nch,duration]);

figure(1);
plot(10*log10(abs(acmeet(:))),'r');
plot(10*log10(abs(acmeet(:))),'y');

xlabel('Beamlet index');
ylabel('Power');
title('Beam Power ');
grid on;
```

Image 33: Screenshot for the beamlet statistics file

Similar is the case with the cross correlation script. It can be plotted using the RSP control(rspctl) command which also shows a mismatch in the labeling. In order to ensure that a script has been developed with correct labels which plots the cross correlation spectrum for the crosslet data.

One needs to know the correct matrix to be used along with the file, which defines the data dumped with all the receiver units enabled or disabled.

```
[user@matlab2014 beamlet_script]$ cat bst.m
%Used for plotting the beamlet statistics
clear all; close all;

nch = 4*61; %# subbands for CEP

meet_nr=1;

fid = fopen('20160706_092102_bst_00Y.dat', 'r');
data = fread(fid, 'double');
fclose(fid);
duration=floor(length(data)/nch);
acmeet = reshape(data(1:nch*duration), [nch,duration]);

meet_nr=2;
fid = fopen('20160706_092234_bst_00Y.dat', 'r');
data = fread(fid, 'double');
fclose(fid);
duration=floor(length(data)/nch);
acmeet2 = reshape(data(1:nch*duration), [nch,duration]);

meet_nr=3;
fid = fopen('20160706_092428_bst_00Y.dat', 'r');
data = fread(fid, 'double');
fclose(fid);
duration=floor(length(data)/nch);
acmeet3 = reshape(data(1:nch*duration), [nch,duration]);


figure(1);
plot(10*log10(abs(acmeet(:))),'r');
hold on;
plot(10*log10(abs(acmeet2(:))),'b');
plot(10*log10(abs(acmeet3(:))),'y');
xlabel('Beamlet index');
ylabel('Power');
title('Beam Power ');
grid on;
```

Image 34: Screenshot of cross correlation file.

Following Image 34 points out the places in the file to be edited.

```
close all; clear all;

fid = fopen('20160614_121415_xst.dat', 'r');
data = fread(fid, 'double');
fclose(fid);

acc = reshape(data(1:2:end) + 1i * data(2:2:end), [32 32]);

rcu_zero = 10*log10(acc(1,1))
rcu_two = 10*log10(acc(3,3))

angle_zero_two = 180*angle(acc(3,1))/pi
amplitude_zero_two = 10*log10(abs(acc(3,1)))

angle_two_zero = 180*angle(acc(1,3))/pi
amplitude_two_zero = 10*log10(abs(acc(1,3)))
```

Image 35: Screenshot of xst.m file pointing out places to edit

5.6 LOFAR FPA beamformer receiver chain simulation

This exercise was carried out as an experiment to simulate the whole receiver chain. The idea behind executing the experiment was to know the change in the numbers for noise figure, Gain, SNR etc after every block consequently changing the input parameter.

This experiment was done as a part of evaluation to the new toolbox 'SimRF' and 'RFBugetAnalyzer' toolbox which are available in the new version of Matlab (Matlab 2016b onwards).

Image 36 shows the input parameters provided to simulate the DCU Block.

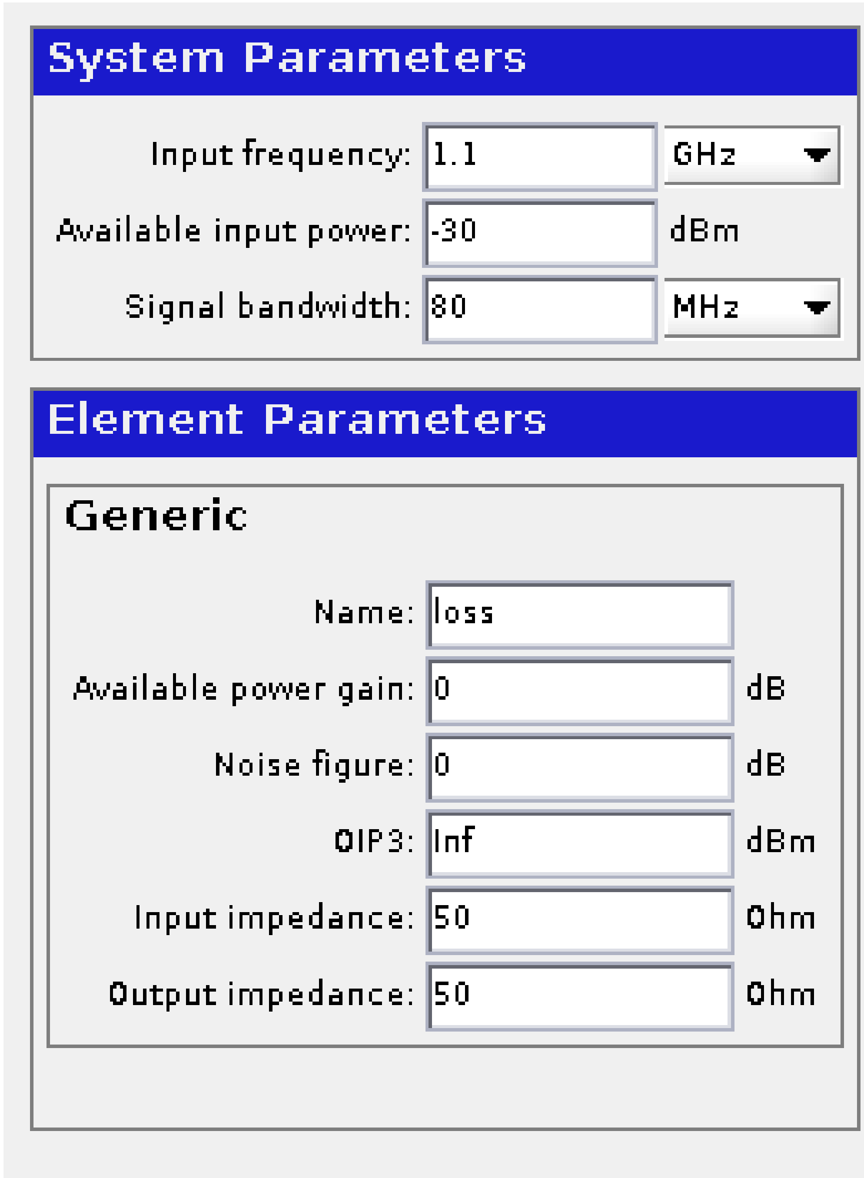

Image 36: System parameter inputs to simulate receiver chain

Each block in the receiver chain is can tested as per the specifications. And matching the output parameters with the one achieved with actual tests with the Unit.

Image 37 shows the screenshot of each block configured.

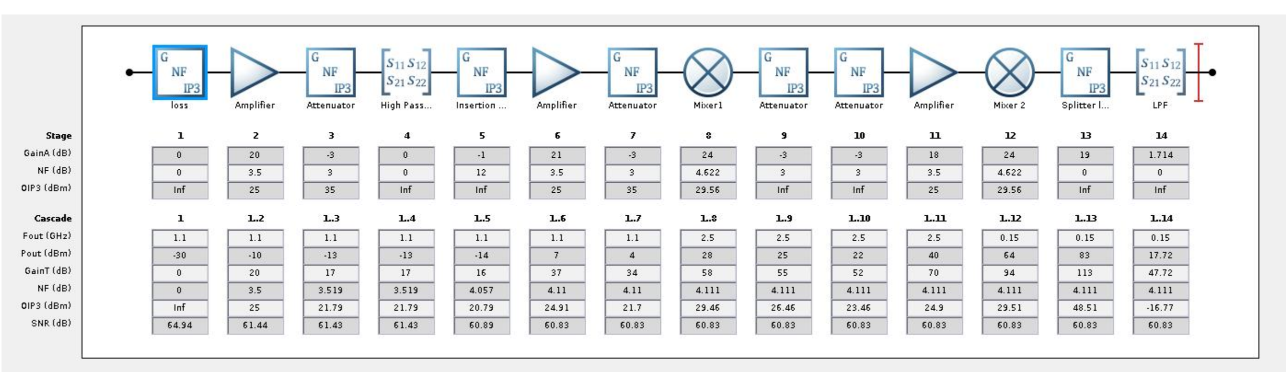

Image 37: Screenshot showing configuration of each and every block of DCU

5.6.1 Exporting to Simulink

The RF Budget Analyzer toolbox provided a functionality to export the simulation done with RF budget analyzer to Simulink, work space, or test bench in order to cross check the results. By exporting to Simulink one can either add additional blocks and modify the chain to achieve the results.

Image 37 and 38 shows the screenshot for the same.

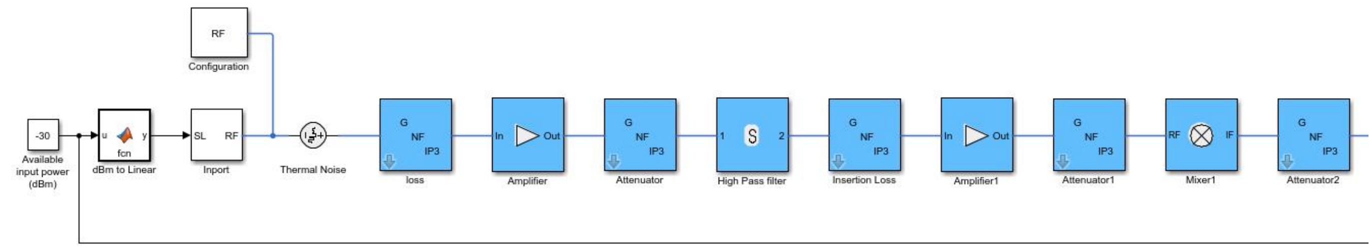

Image 38: Screenshot showing receiver chain exported to simulink environment (first half)

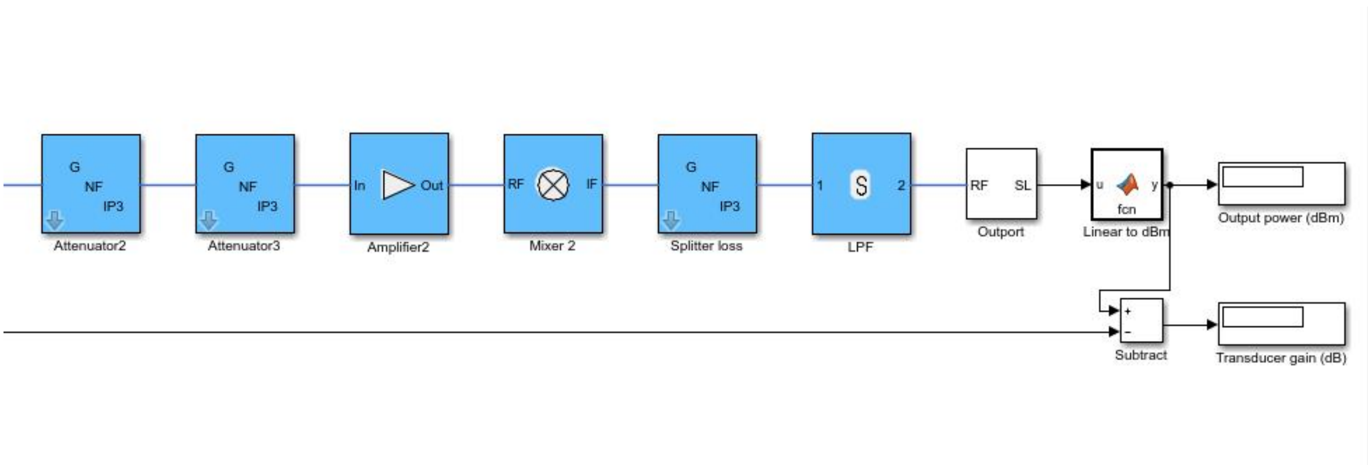

Image 39: Screenshot showing receiver chain exported to simulink environment (Second half)

Chapter6

Designing GUI in a Matlab

Interface for FPA

The focal Plane Array feed has 8*9 dual polarized vivaldi elements. The radiation pattern of the whole array needs to be simulated in order to know HPBW, FNBW, Front to back ratio, polarization effect etc. Hence a interface to analyses the feed behavior user defined elements is simulated using MATLAB GUI. Following images (38 to 42) shows the design of focal plane array feed for analysis of radiation pattern depending upon the selection of the elements and polarization.

6.1 Geometry simulation for FPA

To make the 8*9 array visible to the user was the idea behind implementing the axis 1 in the GUI. The user would get the feel of the overall view of the array geometry. Image 40 shows the actual geometry for the array with specified number of elements and the desired spacing.

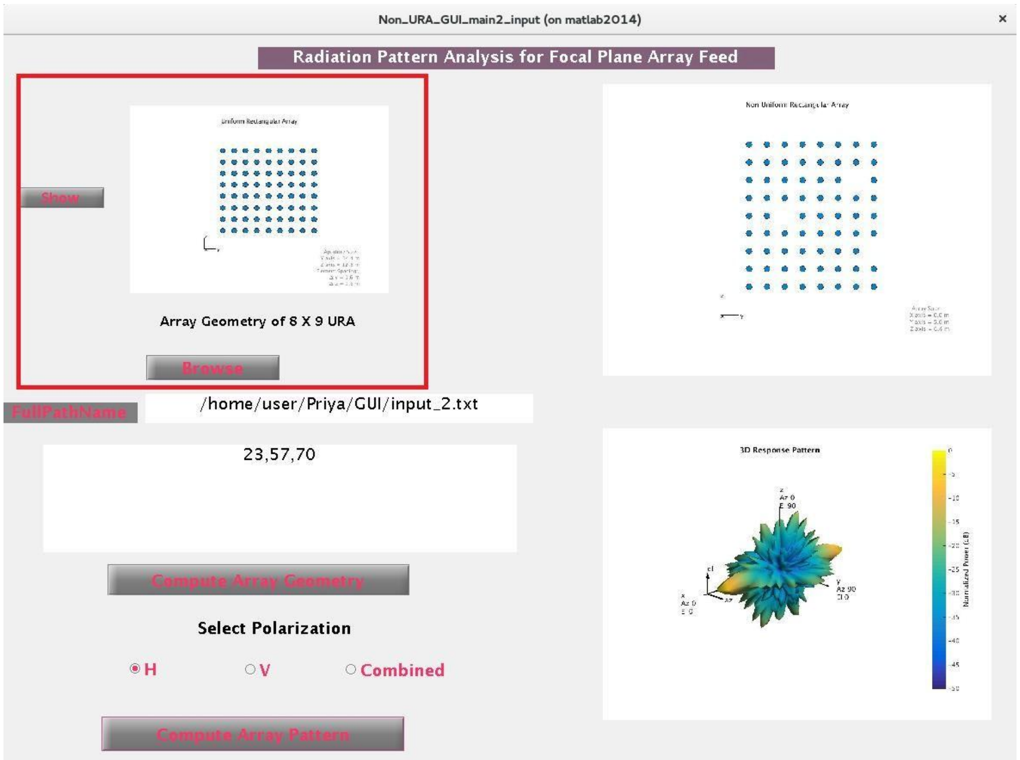

Image 40: Interface showing array geometry

6.2 Reading text file for removing elements from geometry

This provision has been provided the user to input a text file from the file selector to remove the elements from 8*9 array. Radiation pattern can be calculated for a selected set of element of the FPA. This takes in case some of the element have gone bad, or the LNA's are not working properly. The user has been provided control of the unwanted elements in the array. Based on the input file, the elements that are listed would be considered as zeros and the spacing would be adjusted automatically using Phased Conformal Array. Image 41 shows the provision made for removing the elements.

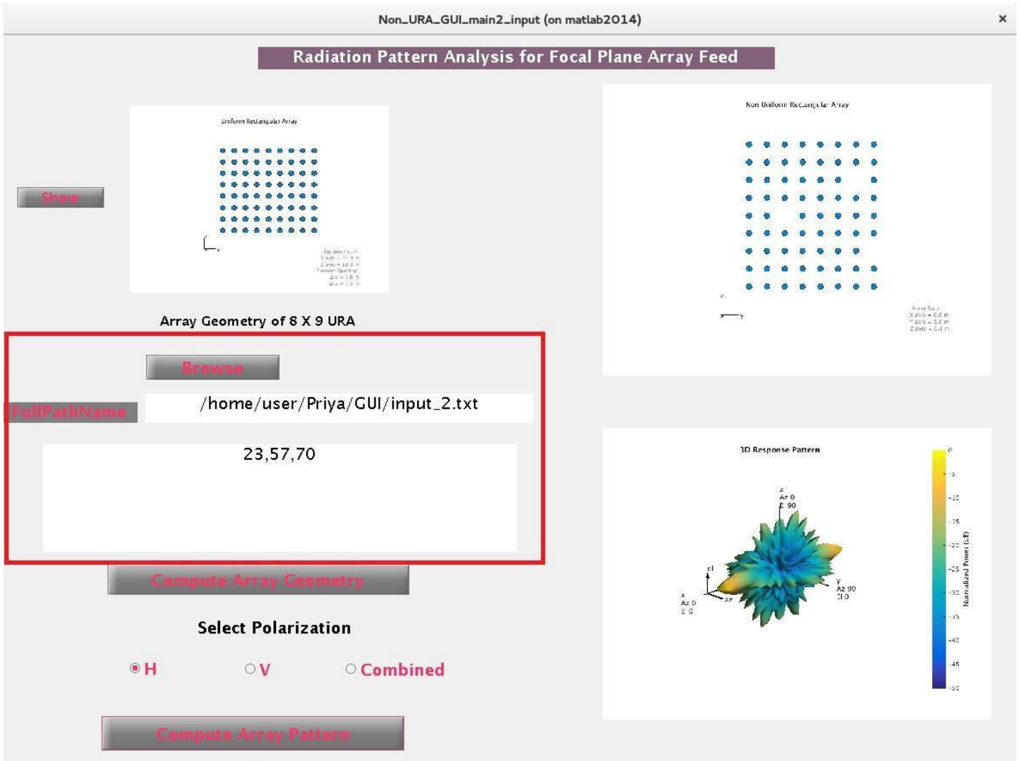

Image 41: Interface showing elements to be removed from array

6.3 Polarization selection for FPA

The radiation pattern of the FPA can be plotted in three different polarizations, one is horizontal polarization, second is vertical polarization, and the third is the combined polarization.

User can plot the radiation pattern of the array by selecting the polarization equipped with the radio buttons in the GUI. A message box would provide a notification of the selected polarization for plotting the radiation pattern. Refer Image 42 Interface showing polarization selection.

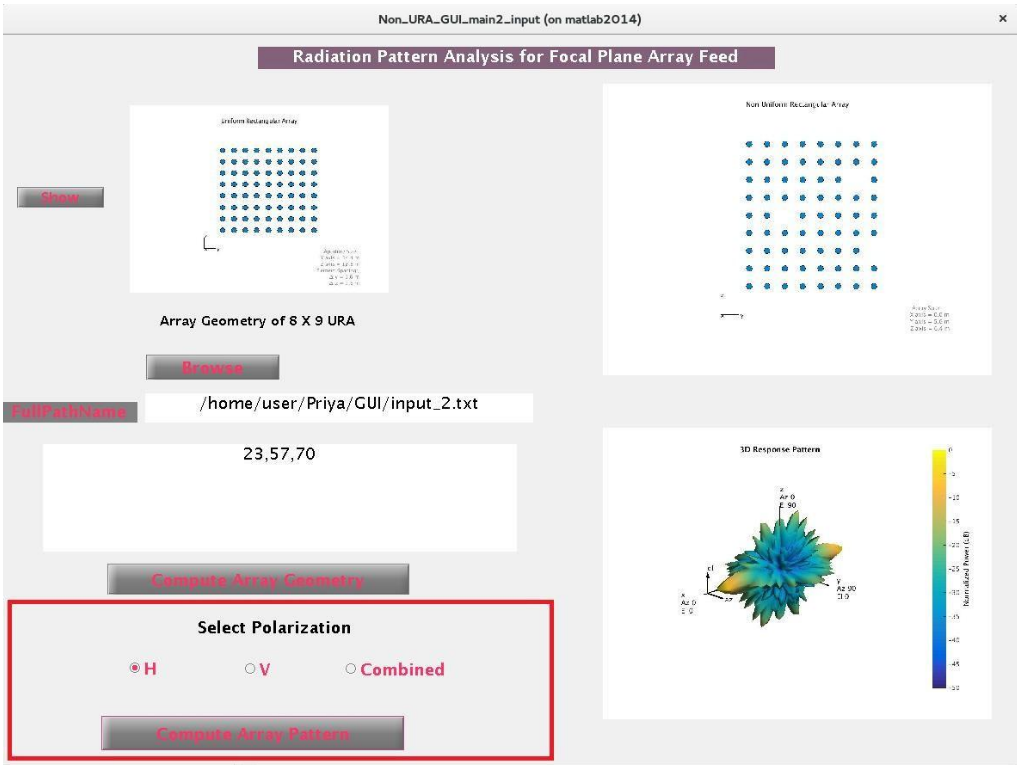

Image 42: Interface showing polarization selection

6.4 Array Geometry with removal of elements

After providing the text file as input, an axis would make the array geometry visible again. This would show the geometry with the listed elements removed. Image 43 shows the array geometry with removed elements.

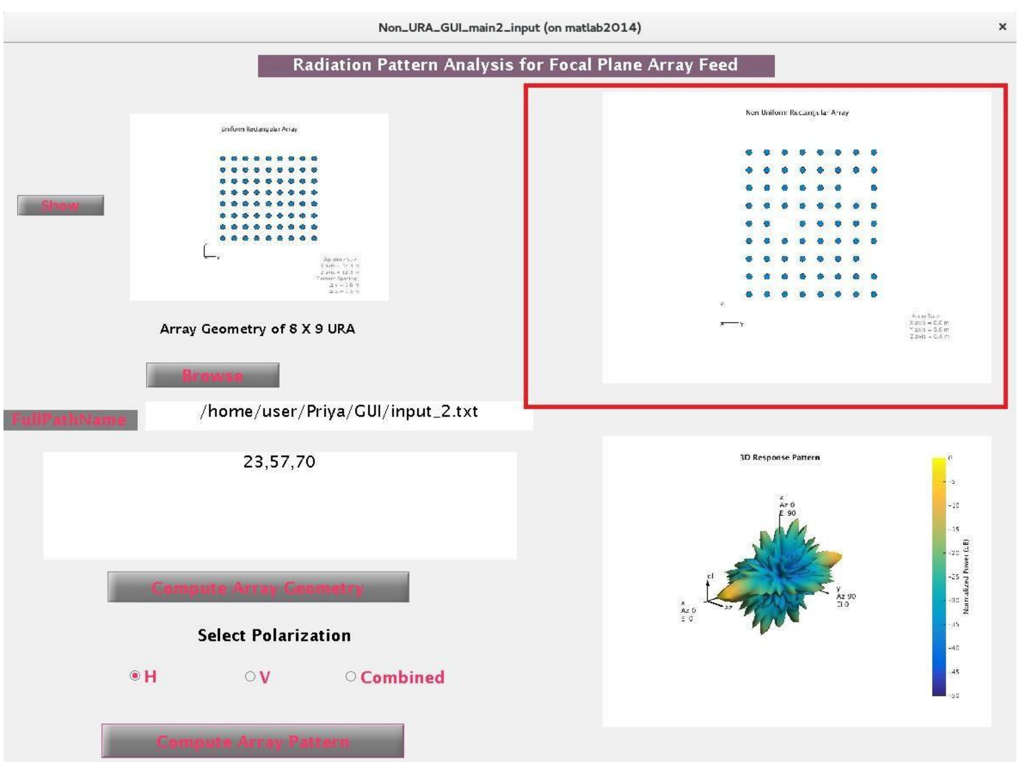

Image 43: Interface showing array geometry with removed elements

6.5 Radiation Pattern with removed elements

The user can plot the radiation pattern based on the elements selection, polarization selection etc. Image 43 shows the radiation pattern of the array after modifications.

If in case user wants an array of 8*9 elements without removing any of the elements, the radiation pattern can be plotted without inputting the text file. Just select the polarization for plotting and the desired radiation pattern would be plotted. Image 44 shows radiation pattern with removed elements

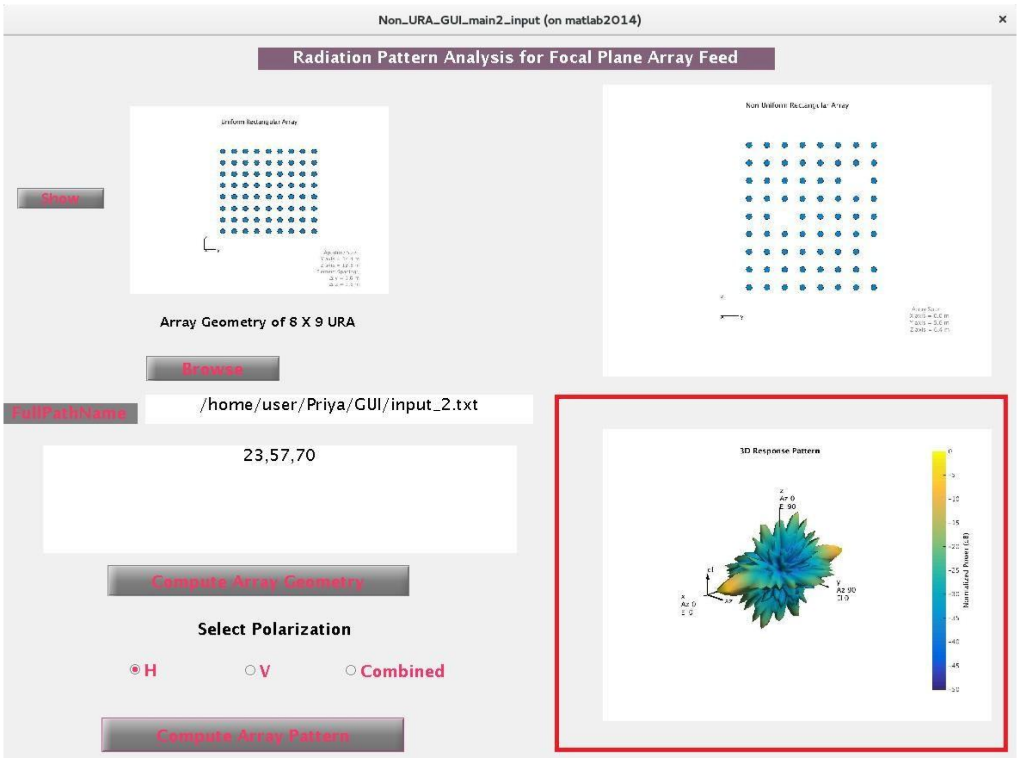

Image 44 Interface showing radiation pattern with removed elements

Chapter 7

Documentation

Following documents were prepared as a part of this activity.

- Troubleshooting document for LOFAR Focal Plane Array (FPA) beamformer:- This document provides the troubleshooting done for LOFAR FPA system till date. The problems encountered and the action taken on it has been explained in detail.
- SOP for Basic beamforming:- In this document, step by step description for carrying out the basic beamforming test with LOFAR FPA beamformer system is provided. Along with that the test results are also appended after each test carried out.
- SOP for Using the command set:- In this document all the commands for Remote Station Processing (RSP) control are listed out. A brief introduction for each command is also provided along with the screenshot.
- Documentation on Glass room shielding:-This document provides the details on building of the shielding enclosure for FPA beamformer system. Starting from the civil work towards the end, everything related to shielding has been covered in detail.
- Student Trainee Project report:- This document is the report for the work done by Priya Hande as a part of Student Trainee Program(STP). This report includes the work done on the LOFAR FPA system and some simulations tried in Matlab.

Conclusion

LOFAR Focal Plane Array beamformer : Various blocks and units inside the system are well understood along with the flow of the signal and control of the data. Tone signal and noise tests have been carried out in order to do basic beamforming. Commands related to RSP control are very much clear.

Matlab Simulations for FPA System For FPA feed interface providing the polarization selection and element selection has been covered up. Simulation of the receiver chain of FPA system is in process. The DCU unit is simulated using the newer version of MATLAB.

Future Scope

LOFAR FPA beamformer system :- Testing the FPA feed with LPDA and analyzing various parameters of the feed. Testing the whole system on 15 meter dish.

MATLAB simulations for FPA System:- For the Matlab interface implementing additional parameters to analyze the feed. for e.g. beam width of the feed, side lobe level, front to back ratio, adding coupling effect etc. For the receiver chain simulation, using simRF toolbox, the DCU output can be digitized to implement RF to bits simulation.

References

[1] *Standard Operating Procedure for Basic Beamforming* Priya P. Hande, Dt: 13/9/2016

[2] *LOFAR FPA Beamformer- Using command sets* Priya P. Hande, Dt: 19/9/2016

[3] *Station Data Cookbook ASTRON, The Netherlands.* I.I. Virtanen