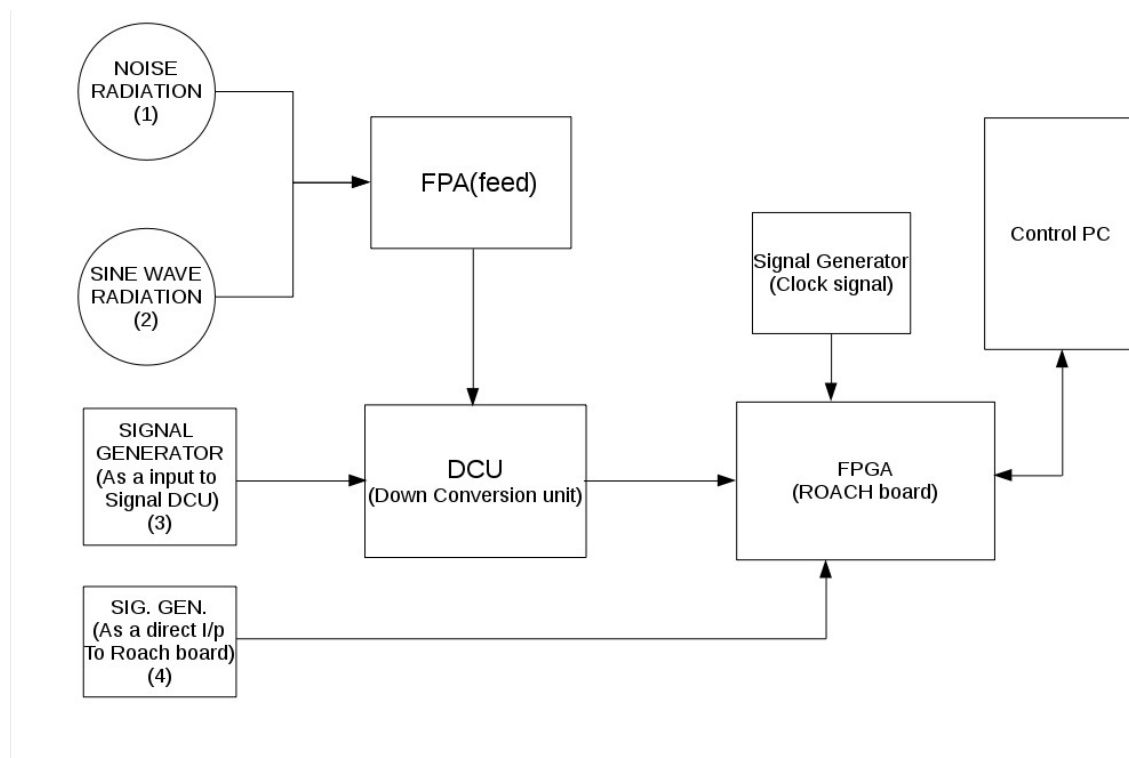# SOP for Four-Element Two-Beam FPGA based Wideband Beamformer

[CTRL_PC]   : 10.144.151.25
[USER_CTRL_PC]   : siddhesh
[CTRL_PC_PASS]   : egmrt@1994
[PYTHON_DIR]   :/home/siddhesh/siddhesh_testing/mdf_inc_cw3_scripts

TEST SETUP :

- This is general test set-up for doing experiments using LOFAR-FPA system with FPGA based beam-former system.

- To do the basic test, we can use any one of above method as shown in test set-up block-diagram.

1. Power ON and instrument settings :

(a) Power on Distribution boards , AC distribution boards in the RACK
        (verify : PC , ethernet swithces & ROACH Units are powered ON).
(b) Now Switch ON the instruments and do the following settings -
        (i) Signal generator settings as CLOCK to ROACH boards : Freq = 600MHz , Power

= 0dbm, Set "Mod to OFF and RF to ON"

      (c) Power "ON" the ROACH boards by pressing the switch at front panel. All Roach boards will boot through NFS (Network File System) on control PC {192.168.100.12}.

2. Interconnections :

1. Connect the clock signal to ROACH unit clk_i input of iADC.
2. We can make set-up based on experiments. Total Power over BW between -14dbm to -17dbm to iADC's inputs.
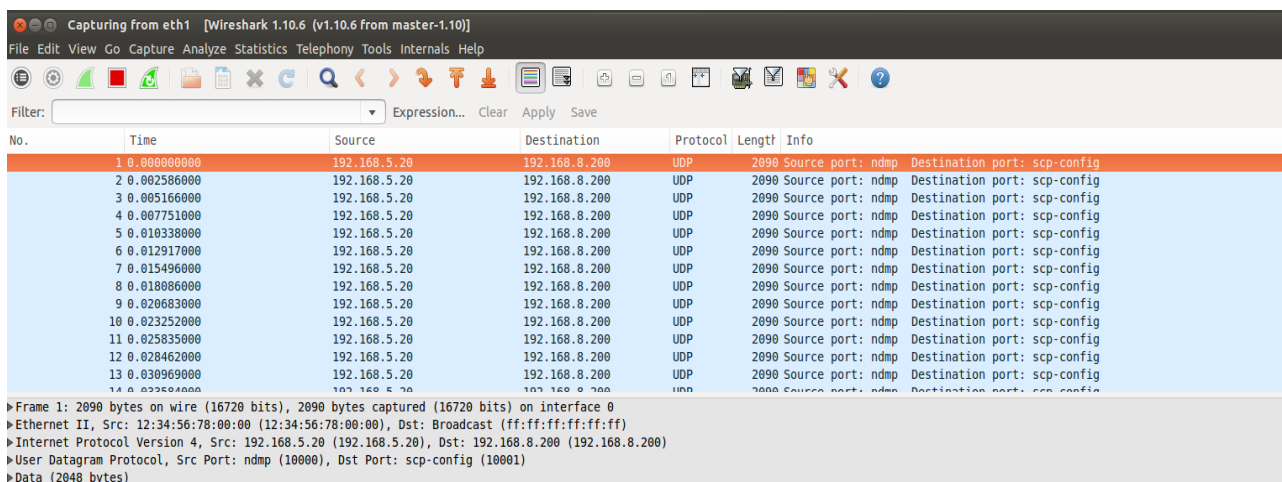
3. Initialization :

      Follow these steps to initialize the ROACH board and load the design :

```
root@siddhesh-OptiPlex-7040:~/siddhesh_testing/mdf_inc_cw3_scripts# ./ini_4ant_2beam.py
```

1. In this step we initialize ROACH board and load .bof file through python script.
2. Also this scripts will set the parameters.

4. Check packets :

"root@siddhesh-Optiplex-7040:~/siddhesh_testing/mdf_inc_cw3_scripts# sudo wireshark"

  # To check whether packets are reaching the PC from ROACH. "The Wireshark Network Analyser" window opens !

    # Select Capture/Interfaces in the Menu. Another window "Wire-shark: Capture Interfaces" opens!

    # Observe at Packets and Packets/sec. Counts here show that packets are being   received (0 for no packets received).

    # Select File/Quit to exit !

5. Record cross phase value :

1. Record the phase value, we record the phase values by selecting different elements.
2. By using python scripts we select different pairs of elements and record cross phase values of them.
3. After recording cross phase values, copy that files into a another file with different names and we use that files for further operations.

Following are the steps to record cross phase values :

- Step 1 : First step is selection of pair of elements, for that run the following command

"root@siddhesh-Optiplex-7040:~/siddhesh_testing/mdf_inc_cw3_scripts# vi corr_selection.py"

```
root@siddhesh-OptiPlex-7040:~/siddhesh_testing/mdf_inc_cw3_scripts# vim corr_selection.py
```

- Step 2 : Select the pair of elements in that python script. Make change and save the file and run it.

```
#!/usr/bin/python

#from katcp import BlockingClient, Message

#import katcp,numpy,pylab,time,corr,sys
import corr,numpy,time,katcp,sys,pylab


#data = int(sys.argv[1])

print"connecting to ROACH......."
#device_host = "192.168.100.245"


device_host = "192.168.100.176"

device_port = 7147

#data = input()

my_corr=corr.katcp_wrapper.FpgaClient(device_host)

while not (my_corr.is_connected()):
        pass
my_corr.write_int("cr_s13",0) #use 1 antenna 1 and 0  antenna 3
print "cr_s13= %i" %my_corr.read_int("cr_s13")
                                              Replace : either 0 or 1 or 2
my_corr.write_int("cr_s24",1) #use 0 antenna 2 and 1  antenna 4 and 3 for antenna 3
print "cr_s24= %i" %my_corr.read_int("cr_s24")
~
~
```

Reference table for selecting elements,

Registers	Correlation between 1 and 2 element	Correlation between 1 and 3 element	Correlation between 1 and 4 element
s13	0	0	0
s24	0	2	1

[Note : Do not change the value of register 's13', it is our reference element]

- Step 3 : Save and run the corr_selection file after selecting elements,

```
root@siddhesh-OptiPlex-7040:~/siddhesh_testing/mdf_inc_cw3_scripts# ./corr_selection.py
connecting to ROACH.......
cr_s13= 0
cr_s24= 1
root@siddhesh-OptiPlex-7040:~/siddhesh_testing/mdf_inc_cw3_scripts#
```

- Step 4 : Now the Following command to record the cross phase values between selected elements and also it shows the correlator data of selected elements.

```
root@siddhesh-OptiPlex-7040:~/siddhesh_testing/mdf_inc_cw3_scripts# ./stp_4pobe_plot_dump.py 192.168.100.176
```

After run above script one window pop-up to monitor screen, it show the plot of correlator data, of input signals which we have provided.
- In this plot sub-plot 1st and 2nd show the self-power of two input elements.
- 3rd sub-plot show cross-power of two input elements, and 4th sub-plot show cross-phase of two input elements
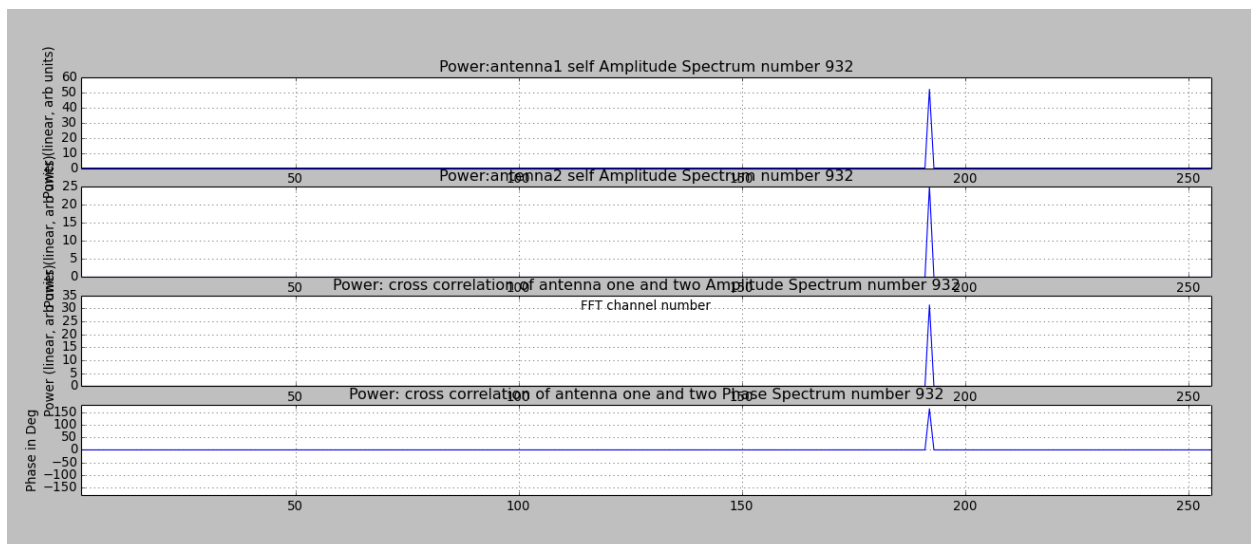

Fig. Correlator plot

In our directory 'cross_angle' named file appears, this file contains cross phase values, we copy that file into another file and use for further operations. [Note:Power level check with the help of correlator output]

```
-rw-r--r-- 1 root     root      1536 Apr 21 10:39 cross_angle
-rw-r--r-- 1 root     root      1286 Apr 21 10:39 antenna1auto_real_sine
-rw-r--r-- 1 root     root      1285 Apr 21 10:39 antenna12cross_real_sine
-rw-r--r-- 1 root     root      1286 Apr 21 10:39 antenna12cross_img_sine
-rw-r--r-- 1 root     root      1285 Apr 21 10:39 antenna2auto_real_sine
root@siddhesh-OptiPlex-7040:~/siddhesh_testing/mdf_inc_cw3_scripts# mv cross_angle cross_angle_21april2017_14
root@siddhesh-OptiPlex-7040:~/siddhesh_testing/mdf_inc_cw3_scripts# ▮
```

- Step 5 : Follow all above steps to record the cross phase values for different pair of elements.

6. Dump phase values externally :

Dumping phase values externally is needs to provide weights externally via python scripts. Following the steps :

- Step 1 : Create taper(amplitude) files, run following commands, "root@siddheshOptiPlex7040:~/siddhesh_testing/mdf_inc_cw3_scripts# ./taper_txt_file_creator.py taper_element1_beam1 taper_element2_beam1 taper_element3_beam1 taper_element4_beam1 taper_element1_beam2 taper_element2_beam2 taper_element3_beam2 taper_element4_beam2"

Example :
"root@siddheshOptiPlex7040:~/siddhesh_testing/mdf_inc_cw3_scripts#./taper_txt_file_creator.py 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0" we create 8 taper files of amplitude 1, we change it up-to 1 to 7.

- Step 2 : For dumping phase values, run the following command "./phase_add_four_ant_two_beam_argv.py phase1.txt taper1.txt phase2.txt taper2.txt phase3.txt taper3.txt phase4.txt taper4.txt phase5.txt taper5.txt phase5.txt taper5.txt phase6.txt taper6.txt phase7.txt taper7.txt phase8.txt taper8.txt"

Example : "./phase_add_four_ant_two_beam_argv.py zero.txt taper1.txt cross_angle_12 taper2.txt cross_angle_13 taper3.txt cross_angle_14 taper4,txt zero.txt taper5.txt cross_angle_12 taper6.txt cross_angle_13 taper7.txt cross_angle_14 taper8.txt."

[Note : We can select any one baem and correct only the phase of that beam, also without changing another beam's phase]

7. Capture packets using Gulp :

- Change the directory : 'cd /home/siddhesh/off_line_corr'

For capturing packets run the following command

```
root@siddhesh-OptiPlex-7040:/home/siddhesh/off_line_corr# ./gulp -i eth1 > 20dec2016_before
```

- "gulp -i eth1 >" gulp is 'c' programme to capture the packets.
- "20dec2016_before" is the output file name. Give name to file as we want for understanding purposed.
  [NOTE : If we want to changes number of packets open gulp.c file change line number 295 of program. If changes are made, run 'make' around to compile the changes.]

8. Depacketize the data :

Following steps used for depacketize the data :

- Step 1 : First we extract two beam data from record file, separate it with proper names. We get four files, namely "Real of Beam 1" "Imaginary of Beam 1" "Real of Beam 2" "Imaginary of beam 2".

```
root@siddhesh-OptiPlex-7040:/home/siddhesh/off_line_corr# ./test_p11_1 20dec2016_after r_20dec16_b1_af i_20dec16_b1_af r_20dec16_b2_af i_20dec16_b2_af a h 2090 1
```

"root@siddheshOptiplex7040:~/siddhesh_testing/mdf_inc_cw3_scripts#./test_p11 _1 "Recorded File Name""Real of Beam_1" "Imaginary of Beam_1 " "Real of Beam_2" "imaginary of Beam_2" a h 2090 1

- Step 2 : After successful extraction of data we get four files namely as per the names provides by us. Now we get data of two beams.

- Step 3 :

```
root@siddhesh-OptiPlex-7040:/home/siddhesh/off_line_corr# ./Int.o r_20dec16_b1_be4 i_20dec16_b1_be4
```

After running above command system gets provide the following inputs,
"spectral channels = 256"
"Base Integration = 1"
"Number of packets = 1000"

- Step 4 : We find out intensity of beam data by selecting real and imaginary file of any one beam. To find out intensity run the following command :

- Step 5 : "./Int.o" is a program to find out intensity values from selected beam data. The output sets stored into another file which have default name 'intensity2.txt'

- Step 6 : Intensity2.txt is a simple text file which contains ASCII values which we can used to read and plot the beam data.

9. Plot the Depacketized OUTPUT_file using Matlab.

- Now for reading the ASCII values from intensity2.txt file and plotting use following Matlab commands in Matlab command window :

clc;

a=dlmread('New named intensity2.txt file ');

b=dlmread('New named intensity2.txt file');

plot(a);hold on;plot(b,'m');xlim([0,250]);xlabel('Spectral channels-->');ylabel('power ------>');legend('single element','two elements') ;title('Focal Plane Array Beam data');saveas(gcf,'FPA_beam');saveas(gcf,'FPA_beam.jpg');

10. Beam Steering :

After recording cross phase values(up-to 5th step of SOP do same operations) run following steps,

1. Add phase(steering angle) into the existing cross-phase values, for that run the following command,
   ./read_file1.py <recorded cross phase file> <modified cross phase file for steering> <steering angle>
   eg:for 30 degree steering
   - /read_file1.py <recorded cross phase between element one and two file> <modified cross phase file for steering between element one and two file> 30
   - /read_file1.py <recorded cross phase between element one and three file> <modified cross phase file for steering between element one and three file> 60
   - /read_file1.py <recorded cross phase between element one and four file> <modified cross phase file for steering between element one and four file> 90
2. For further operations go through step number 6th onwards up-to 9th step.

11. Element selection for beamforming:

Before capture packets there is provision to select elements for beamforming.
run following steps to select elements

　　　1. open python script:

　　　　　　vi element_select_beam.py

2. Set register value 0 for select element for beamforming other wise set 1
Reference table for selecting elements,

Register name	Element number
Subsystem_Subsystem_po1 and Subsystem_Subsystem_po5	1st
Subsystem_Subsystem_po2 and Subsystem_Subsystem_po6	2nd
Subsystem_Subsystem_po3 and Subsystem_Subsystem_po7	3rd
Subsystem_Subsystem_po4 and Subsystem_Subsystem_po8	4th

12.Results :

1. Correlator output without phase correction :

Fig12.1. Correlator output at 5th step(In this plot sub-plot 1st and 2nd show the self-power of two input elements.3rd sub-plot show cross-power of two input elements, and 4th sub-plot show cross-phase of two input elements)

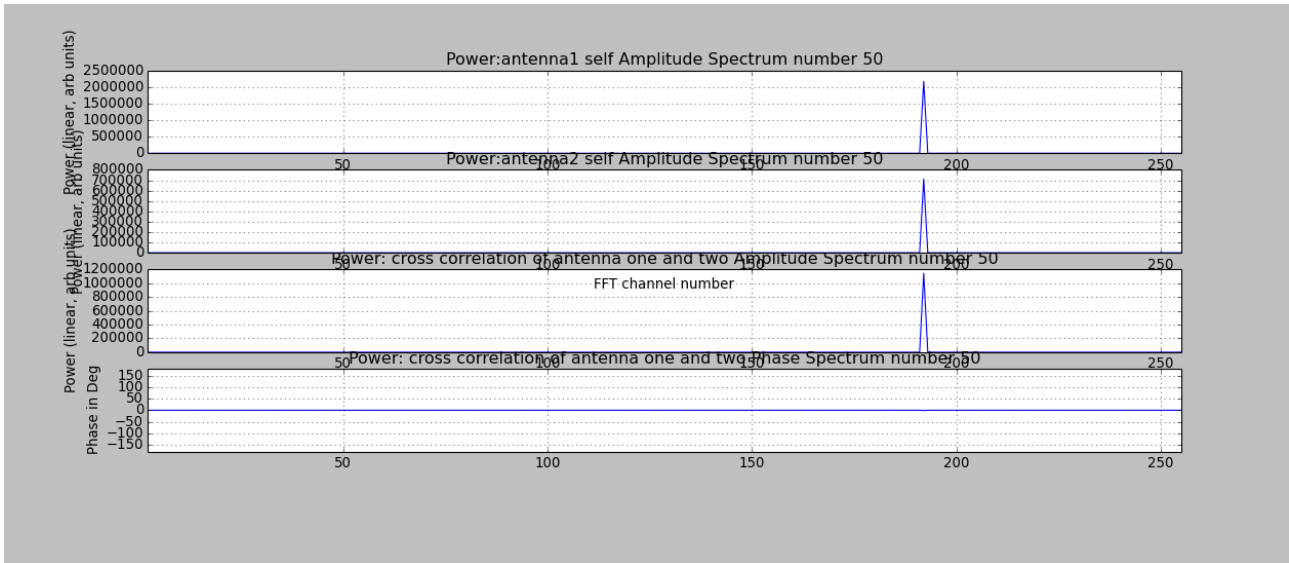## 2. Correlator output with phase correction :

Fig.12.2 Correlator output at 6th step(In this plot sub-plot 1st and 2nd show the self-power of two input elements.3rd sub-plot show cross-power of two input elements, and 4th sub-plot show cross-phase of two input elements)
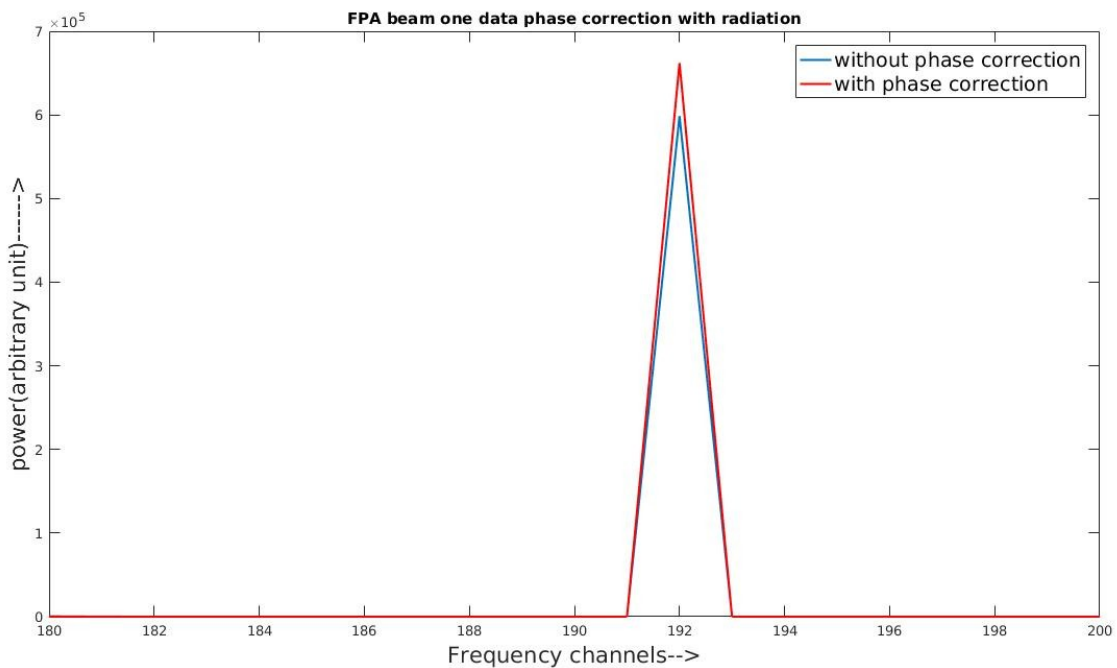
3. Beam output with and without correction :

Fig12.3. Beamformer output at 9th step
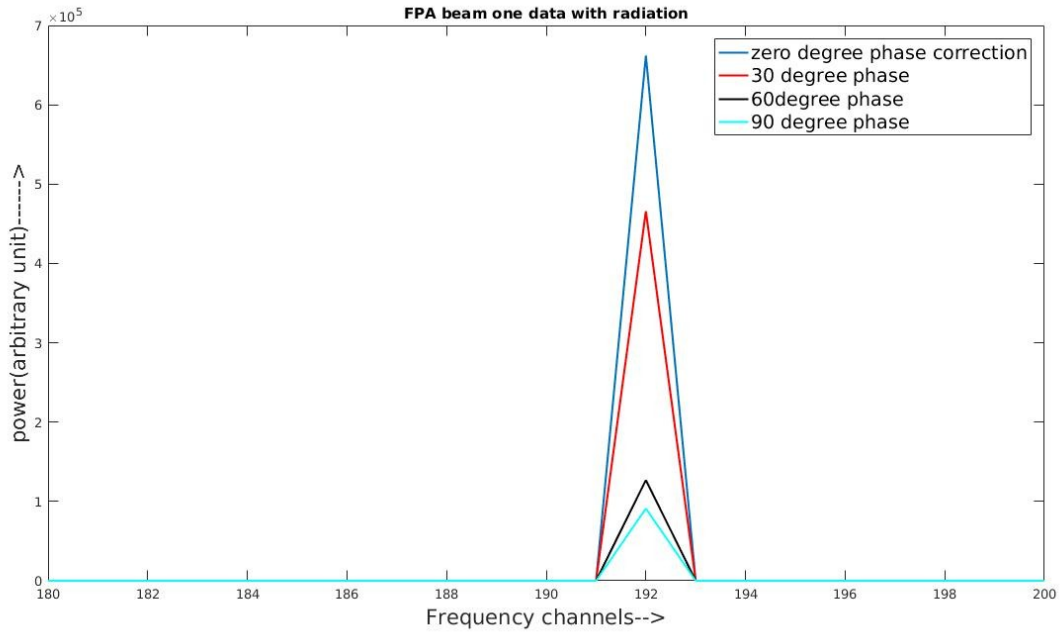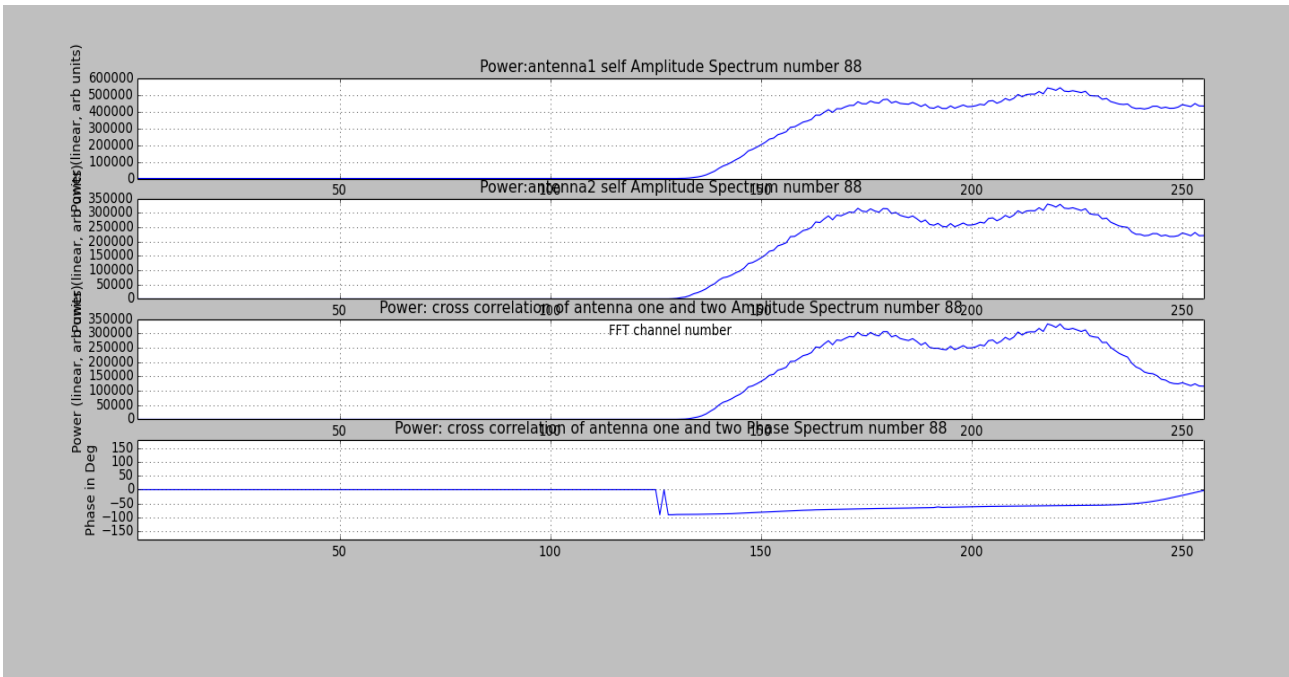
4. Beam steering with different steering angle:

Fig12.4. Beamformer output at 10th step

5. Correlator output without phase correction :

Fig12.5. Correlator output at 5th step(In this plot sub-plot 1st and 2nd show the self-power of two input elements.3rd sub-plot show cross-power of two input elements, and 4th sub-plot show cross-phase of two input elements)
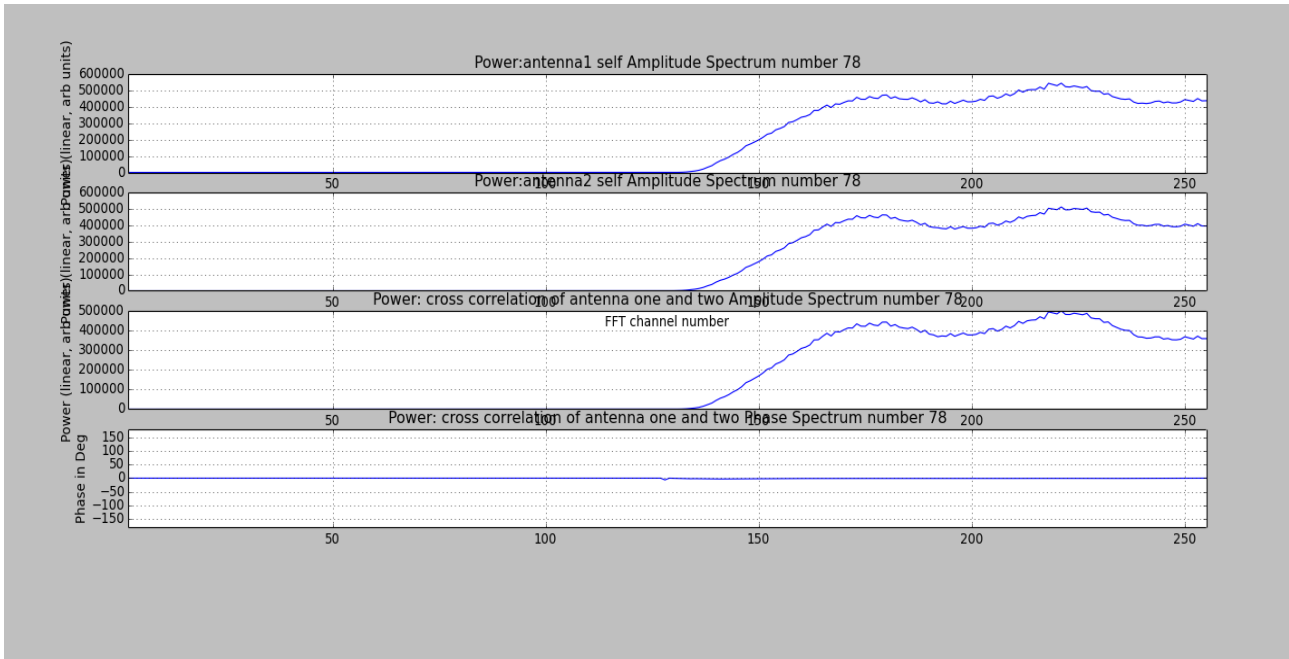
6. Correlator output with phase correction :

Fig.12.6 Correlator output at 6th step(In this plot sub-plot 1st and 2nd show the self-power of two input elements.3rd sub-plot show cross-power of two input elements, and 4th sub-plot show cross-phase of two input elements)

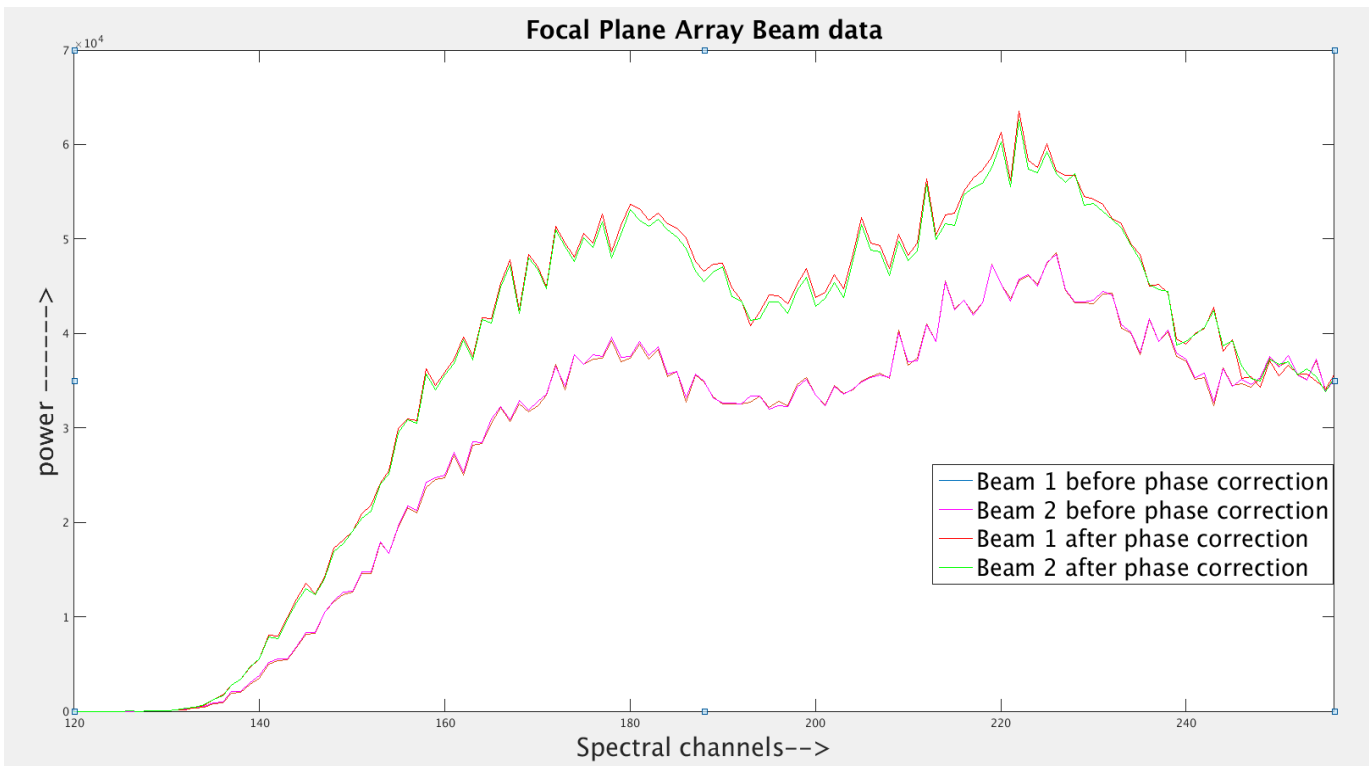## 7. Beam output with and without correction for Noise source :

Fig12.7. Beamformer output at 10th step