The Indian Sky Watch Array Network (SWAN)

A Hands-On Experience

Raman Research Institute
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Submitted To

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At this juncture I feel deeply honored in expressing my sincere thanks **Ms. Anjana Kudva, VSP** at **Raman Research Institute, Bangalore** for making the resources available at right time and providing valuable insights leading to the successful completion of our hands-on.

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Chapter 1
Introduction

1.1 The Indian Sky Watch Array Network:-

The Indian Sky Watch Array Network (SWAN) is a project led by Raman Research Institute (RRI) Bangalore, with a primary aim of providing exposure to undergraduate students in the field of Radio Engineering and Radio Astronomy. The project plans on setting up Radio Telescopes in educational institutions across India, thus fulfilling the dream of Radio Astronomy pioneer, Dr. Govind Swarup of setting up Very Large Baseline Interferometry (VLBI) in the Indian sub-continent. BITS-Pilani, Pilani Campus, became a part of SWAN project following the visit of Dr. Avinash Deshpande, the father of SWAN project, to the campus in the month of April 2016.

1.2 Purpose:-

The purpose is to design, develop and use a Radio Telescope having baseline spread over thousands of kilometres across India with the following objectives:-

- To facilitate and conduct searches in radio frequency.
- To build a Radio telescope with high resolution.
- To train, involve and provide hands-on experience to a large number of undergraduates through their direct and active participation starting from the design stage to research using the array network.

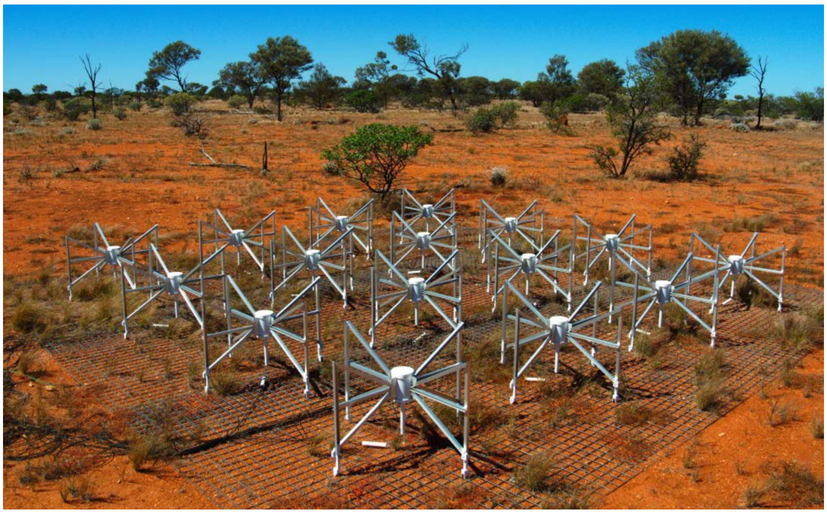
1.3 Scope

- SWAN project would involve more than 20 science and technology institutes across India, thereby facilitating the exchange of technology, ideas and even personnel between institutes of repute in India.
- Once fully functional, the SWAN system with its very high angular resolution can be used to study radio transients.
- To facilitate and conduct high angular resolution imaging of discrete galactic and extragalactic sources at low radio frequencies
- To study structure of the intergalactic gas in our Milky Way galaxy and galaxies beyond
- To study the influence of the Sun on inter-planetary weather close to Earth.

Chapter 2
MWA System

2.1 The 'Pathfinder': MWA

The SWAN system uses an array of **Murchison Wide-field Antenna (MWA)**. The MWA radio telescope located in Murchison Shire in the Australian outback is an array of antennas arranged as square 'tiles' consisting of 16 dual-polarization wide-band 'bow-tie shaped' antennas in a tile that operate in the frequency range 80-330 MHz.



A MWA tile consisting of 16 antennas

The MWA array has 128 square 'tiles', each 'tile' having 16 pairs of antennas. The antenna distribution is designed for precision imaging of a wide field of several hundred square degrees of the sky at any instant and over a wide frequency band. The antennas are connected to digital receivers which process the data before transmitting it to a centralized imaging system located 800 kilometres away at Perth. The digital receivers that take the signals from the antennas and perform complex high-speed signal processing of the data prior to transmission to the central processing unit, which computes the imaging information, were designed and built at RRI.

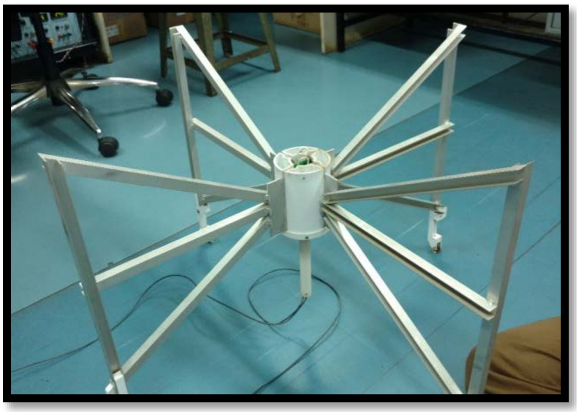
The MWA has already begun gathering weak radio signals from deep space that are being analysed by astronomers at RRI and in the US and Australia using massively parallel computing systems. The data is expected to provide an insight into the dramatic evolution experienced by primordial cosmic gas as the first stars and galaxies formed in the early universe. That apart, MWA data will help study structure of the intergalactic gas in our Milky Way galaxy and galaxies beyond, and the influence of the Sun on inter-planetary weather close to Earth.

Chapter 3
SWAN System @ GBD

3.1 Important Equipments:-

i. A pair of 'bow-tie' antenna

- In this pair of antennas, one axis represents the X pole and other represents Y pole in the form of Vertical (V) and Horizontal (H) polarization.
- Each pair of antenna houses two LNAs, one each for H and V polarization



ii. A tile consisting of 16 antennas

- Each tile has 16 pair of 'bow-tie' antennas which are arranged in the form of a 4x4 matrix.
- The entire dimension of a tile is 5m x 5m, thus having a maximum collecting area of 25m^2.
- The antennas are placed on a wire mesh which acts as reflectors.
- The wire mesh has small squares of dimension 2.5 cm
- The numbering of the individual antennas is done with respect to the position of the Beamformer (as shown).

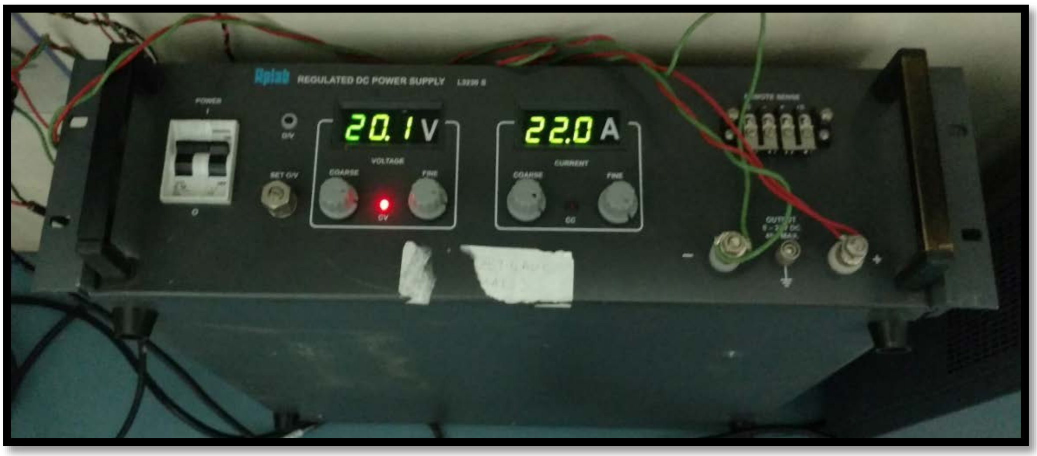
1	2	3	4
5	6	7	8
9	10	11	12
13	14	15	16

Beamformer

iii. Beam-former

- The Beamformer takes two input signals (H and V) from each antenna. Hence one Beamformer has 32 input signals.
- Beamformer also provides power supply of 5 volts (thick wire on the left in photo) to each of the two Low Noise Amplifiers (LNAs) that are present inside an antenna.
- Beamformer does the task of introducing the delays to the signal from the antennas. This helps in pointing the beam in a direction other than zenith and also in tracking the source.
- Finally, all the signals from H and V are combined separately and the signals are sent to the observatory using two cables (the two thick cables in middle show in the photo.)

iv. Beam-former power supply



- The power supply to beamformer is given from the observatory via the coaxial cables that are connected to the beamformer.
- The beamformer must draw a voltage of minimum **15 volts** and a current of at least **4 Amperes**. Every 'bow-tie' antenna must draw a current of 200mA from the beamformer and the beamformer itself draws a current of 800mA.

v. Spectrum Analyser

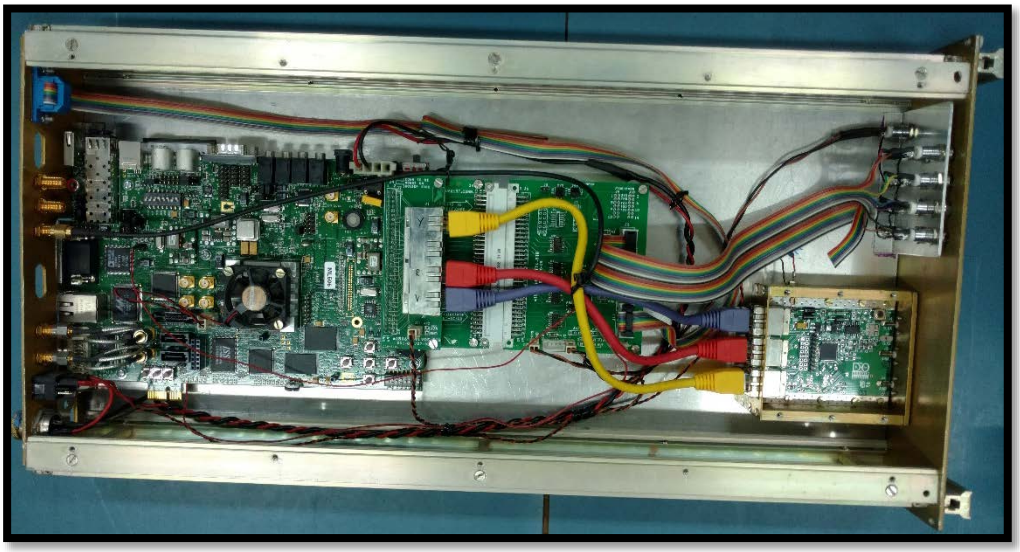
- A **spectrum analyser** measures the magnitude of an input signal versus frequency within a specified frequency range. The primary use is to measure the power of the spectrum of known and unknown signals.
- The spectrum analyser has various other functions like finding the frequency with maximum power, etc.
- Spectrum analyser was used to check the magnitude of RF-input and IF-output signals. If the signal strength were found to be outside specified range (-5dBm to -15dBm for IF-output and -45dBm to 65dBm for RF), the channel power is to be brought in the range by changing attenuator values appropriately.

vi. Data Acquisition System(DAS)

- The Data Acquisition System (DAS) is the computer where data is acquired and analysed.
- Each DAS looks after the acquisition of a single tile.
- The raw voltages that are digitized by the DSP block is stored in binary format with extension as '.mbr' in these machines
- Here all 8 DASes are connected to the Master DAS, which acts as an interface between the user and individual slave DASes.
- The master DAS is linux based and is connected to a monitor, keyboard and mouse for taking inputs from user.
- Various processes related to the SWAN system can be started/ stopped/ changed by giving appropriate commands to the Master DAS.

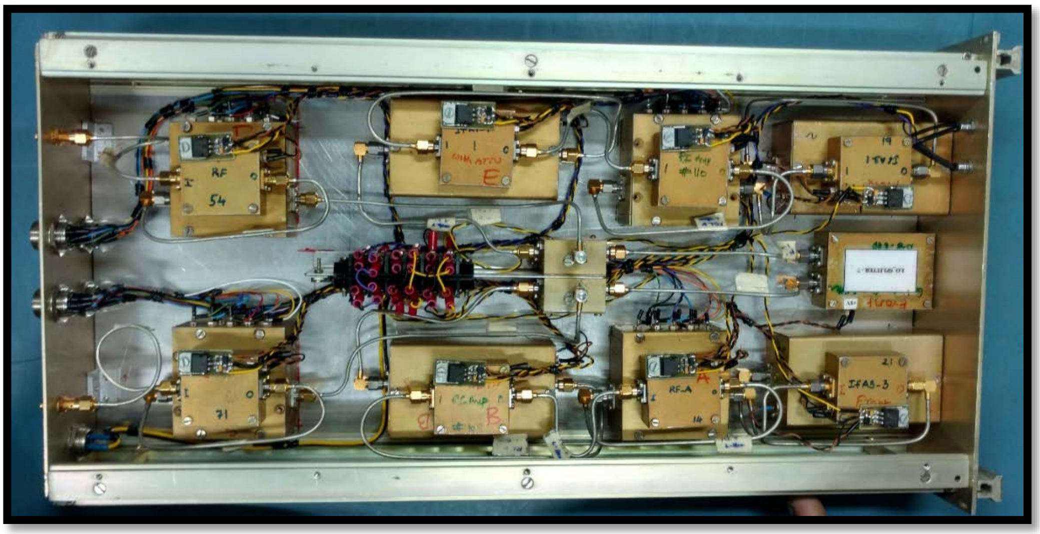
vii. DSP block

- The DSP block comprises of ADC (Analog to Digital Converter), FPGA (Field Programmable Gate Array) and PCB (Printed Circuit Board) board.
- FPGA is a programming device and PCB talks between ADC and FPGA.
- FPGA is a semiconductor device that are based around a matrix of configurable logic blocks (CLBs) connected via programmable interconnects. In contrast to processors that you find in your PC, programming an FPGA rewires the chip itself to implement your functionality rather than run a software application.
- The ADC is a device that converts a continuous physical quantity (usually voltage) to a digital number that represents the quantity's amplitude.



viii. RF-IF block

- The RF-IF block consists of multiple LNAs (Low Noise Amplifier), attenuators and SAW (Surface Acoustic Wave) filter.
- SAW is a filter whereby the electrical input signal is converted to an acoustic wave by so-called interdigital transducers (IDTs) on a piezoelectric substrate such as quartz. The IDTs consist of interleaved metal electrodes which are used to launch and receive the waves, so that an electrical signal is converted to an acoustic wave and then back to an electrical signal.
- LNA is an electronic amplifier that amplifies a very low-power signal without significantly degrading its signal-to-noise ratio. An amplifier increases the power of both the signal and the noise present at its input.

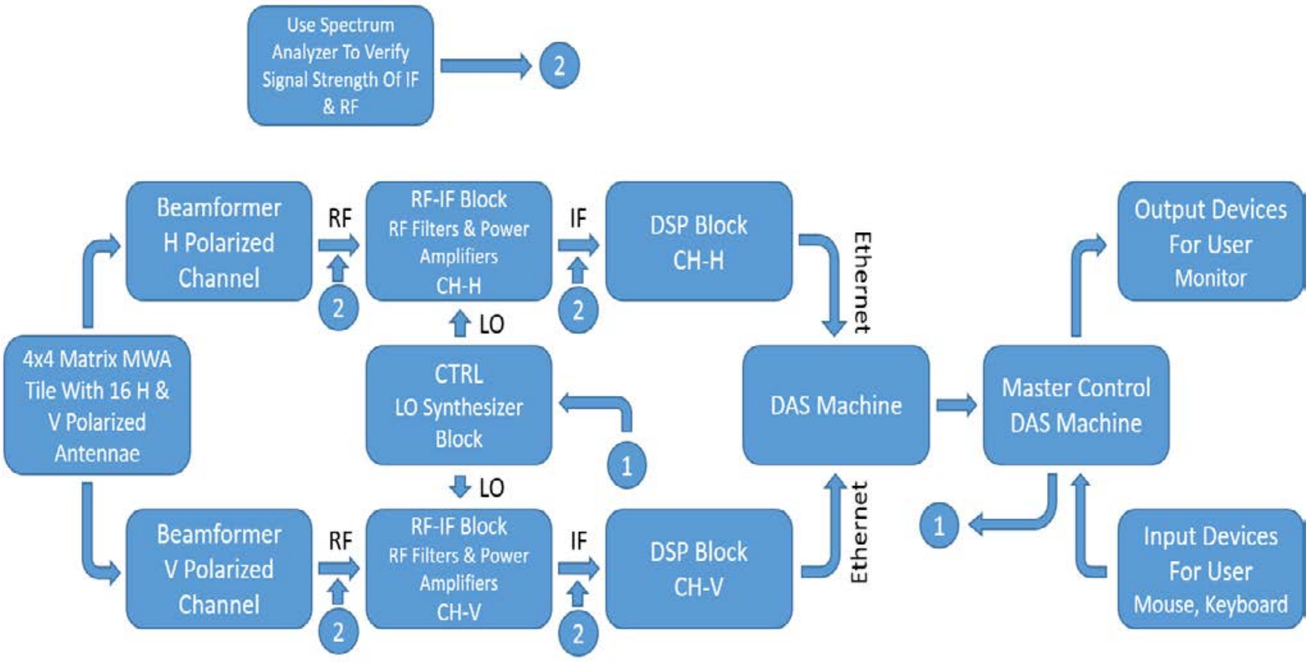


ix. LO block (CTRL) and GPS block(CLK Distributor)

- The CTRL block generates a Local Oscillator (LO) frequency and gives it to the RF-IF block in order to convert the RF signal into the desired IF signal output.
- The CTRL block takes its input directly from the Master DAS, which in turn takes input from the user.
- The GPS block generates and gives a constant clock input of 10 MHz to all of the DSP blocks for proper functioning.

Chapter 4
The Process

4.1 The basic working of the SWAN system



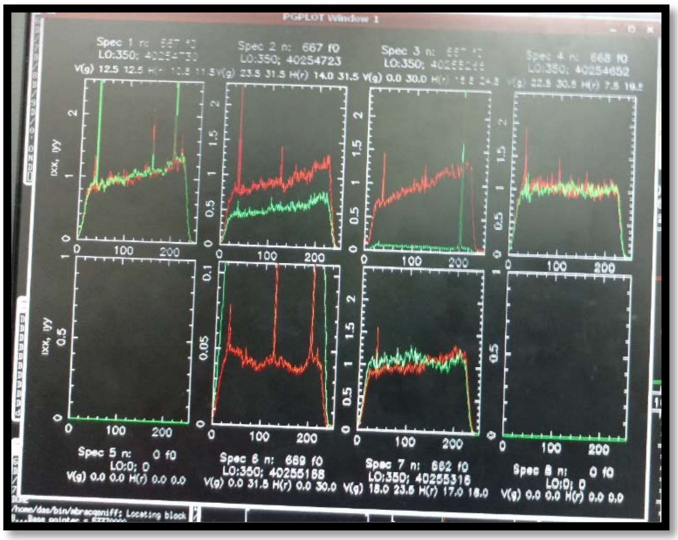
- The eight 4x4 matrix of MWA tiles, each with 16 horizontal (H) and vertical (V) polarized bow-tie antenna, are used to receive low frequency radio waves (below 380 MHz) from space. Each antenna has two LNAs for H and V polarizations respectively.
- Each individual tile has a beam width of 30 degrees solid angle and can scan up to 60 degrees on either side of zenith.
- Each of the H and V channels of the antenna are connected to the Beamformer, which itself acts as a channel between the antenna and the amplifiers, attenuators and signal processors in the laboratory required for generating output. The Beamformer also supplies power to the antennae. The H and V channels have the same process, hence, only one shall be explained here further on.
- The Beamformer is also used to introduce delays in the antenna input, so as to be able to capture any specified portion of the sky. The delays are introduced by varying the lengths of the connecting wires inside the circuitry, thus, varying the total impedance of the circuit.

- The RF input from the antenna goes to the Beamformer and then to the RF-IF block inside the laboratory. The RF-IF block consists of attenuators and amplifiers to increase the signal to noise ratio of the input without greatly distorting the actual signal and also reducing noise. The CTRL block is connected to the RF-IF block which gives a local oscillator frequency to the RF signal in order to convert it into the desired IF signal.
- The CTRL block gets its input directly from the master DAS which in turn gets its input from the user. Hence, the user controls the IF outputs. Also, the user gets to choose the attenuator values which are varied in the RF-IF block by varying the different coloured cables in order to get the required output amplitude.
- There is also a filter amplifier which is being used to cut off frequencies below 100 MHz to reduce the RFIs from the surroundings.
- The RF and IF signals can be externally measured using a spectrum analyser to pinpoint errors and rectify them before they cause damage.
- The IF output from the RF-IF block goes into the DSP block, which consists of an ADC which converts the analog signal into digital signal so that we are able to display it as required on the computer screen and analyse it.
- The DSP blocks are connected to respective DAS machines via Ethernet cables, and each DAS machine takes command from the master DAS, which in turn takes command from the user.
- The master DAS is connect to input devices like keyboard and mouse so as to get input from user and also connected to output devices like monitor so as to display the final output.

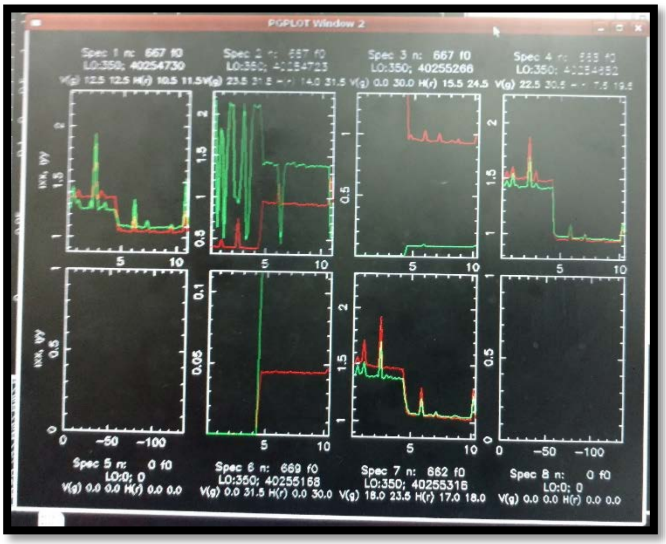
Chapter 5
The Output

5.1 Terminal output

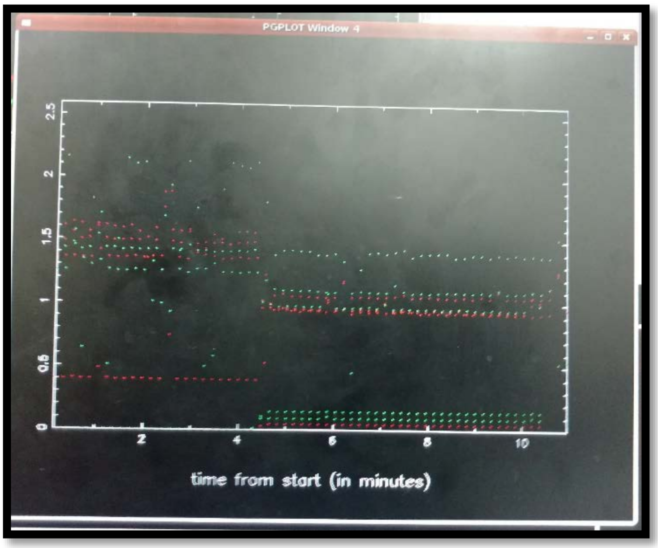
- The amplitude vs frequency graph for each tile, green showing the vertical polarization and red showing the horizontal polarization.



- The amplitude vs time graph at central frequency for each tile, green showing the vertical polarization and red showing the horizontal polarization.

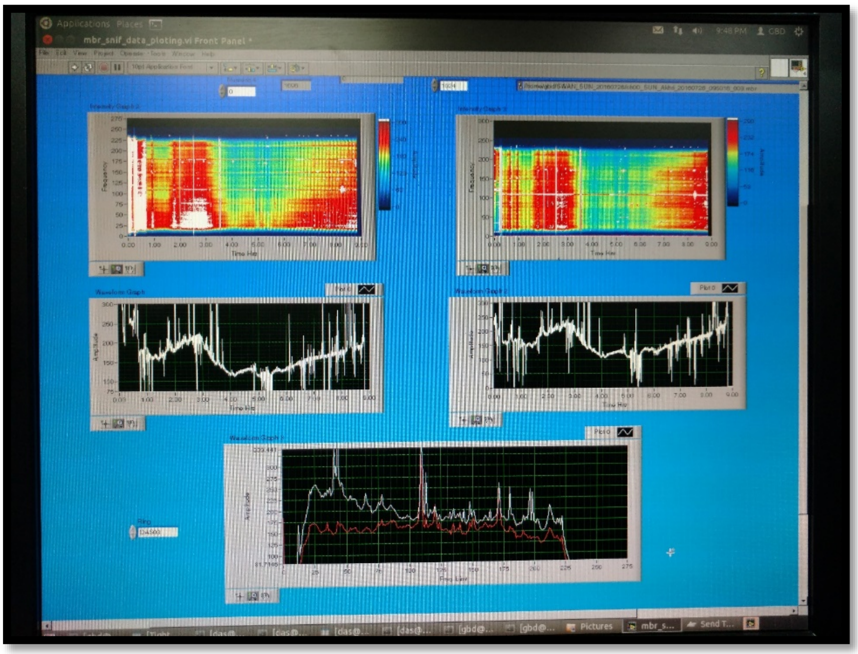


- The amplitude vs time graph for all the tiles in a single graph, green showing the vertical polarization and red showing the horizontal polarization.



5.2 LabView output

- The first graph in the first row shows the frequency vs time vs amplitude for a single polarization for a single tile, where the amplitude is shown by the variation is colour, white being out of range, red being maximum and black being minimum. Similarly the adjacent graph.
- The first graph in the second row shows the intensity vs time at central frequency for a single polarization for a single tile. Similarly the adjacent graph.
- The third row graph shows the intensity vs frequency graph for both polarizations, for a single tile.



Chapter 6
Conclusion

6.1 Final words

- The SWAN hands-on experience has provided us great exposure in the field of radio engineering as well as radio astronomy.
- This hands-on experience has given us a very practical realization of the subject and the vast expanse that it covers.
- This experience has given us a chance to exchange ideas, technology and personnel across premiere institutes all over the country and also the whole world.
- This experience has provided BITS Pilani with an opportunity to be one of the very few institutions in India to excel in radio engineering.
- BITS Pilani would get the chance to house the leading radio technology in India.

Chapter 7
Appendices

7.1 Appendix A: All terminal commands of master DAS control

- To open black terminal window:
  - **mbrrunterms –m**
- To start all the DASes:
  - **start_dasd_on_all_machines_and_mcd**
- To change the name of the source:
  - **mbrset 0 source <*source_name*>**
    [source_name: Enter desired name of source. Change each time before observation to avoid confusion.]
- To start the processes for acquisition:
  - **mbrdo 0 run setup_prepare_for_acquire_in_sniff_mode**
- To start acquisition for desired time interval:
  - **sudo ~/bin/sniff_data_for_<*time*>_shdmem_newacq**
    [time: 1min, 10min, 1hr, 2hrs, 8hrs, 24hrs]
- The proper control to shut down the master control machine:
  - **mbrdo 0 run shutdown –h now**
- To shutdown individual DASes, use command:
  - **> ssh das@das<*dasid*>**
    [dasid: 0,1,2,3…10; 0 is master DAS]
    > sudo shutdown –h now
- To stop acquisition:
  - **mbrdo 0 run killall mbracquire**
- To start plotting the acquired data:
  - **~/bin/first_level_mbr -p A -c 512 -n 10 -a 100 -i <*inputfile*> -o temp.spec -m 1/xs -w 18000**
    [inputfile: Input the name of the file as it is stored in the computer. If input file name is not provided, then the latest file created is taken into use.]
- To change the attenuator value is:
  - **mbrset <dasid> attenuator <vif/hif/vrf/hrf> <value>**
    [value: Enter the desired attenuator value]
- To access the individual DAS window and enter command specifically for that DAS:
  - **mbrrunterms**
- To check which commands have been used till now:
  - **history |grep <keyword>**

[keyword: Enter part of command that you remember to search in history for that command. The history is displayed with serial numbers. Use **!<serial_number>** to run the corresponding command]

- To update the status of the DASes:
    - **mbrlivedas**

      [After using this command, enter the number of DASes that you want down. And then enter the *dasid* of those specific DASes. Use this command before using the 'start_dasd_' command]
- To set the local oscillator frequency:
    - **mbrset 0 lofreq <LO_frequency_value>**
- To run the pointing program:
    - **mbrdo 0 run swan_pointing <RA> <Dec> <reference_epoch> <start_beam_number> <stop_beam_number> <stop_time_in_LST> <pointing_code> <frequency> <null_flag>**

      [RA: Mention the right ascension. Dec: Mention the declination.

      reference_epoch: RA Dec system changes every 50 years. We will be following the J2000 system as reference. Hence we need to write "TODAY"

      start/stop_beam_number: Beam goes from -48 to +48 degrees, with a 6 degrees interval. Put (0 0) to always keep pointing to the meridian. Put (-8 8) to track the source.

      stop_time_in_LST: Input the time when you want to stop the pointing program in Local Siderial Time in "hh:mm"

      pointing_code: The code used to point at the mentioned RA and Dec. In this case, we need to mention "swan_tile_beam_set"

      Frequency: Enter central frequency in Mhz.

      null_flag: "0" will create a phase difference of 180deg between subsequent antennae and "1" will not create any phase difference.]
- To run 1-D scan program (This program scans sky in one dimension to see if the source produces any variations in reading(A Gaussian is expected)):
    - **SWAN_beam_1d_scan.scr** ***<Azimuth> < Zenith-Angle > <scan_type> <offset> <step>***

      [scan_type: Whether Scan along azimuth (s2) or elevation (s1)]
- To kick start the DAS transmission:
    - **~/bin/kickstart_this_das_transmission <dasid>**
- To start/stop an individual DAS:
    - **> sudo ssh root@das<dasid> /etc/init.d/mbrdasd start**

      > sudo ~/bin/mbrrunterms –m – d <dasid> [To write in specific DAS window]

      …

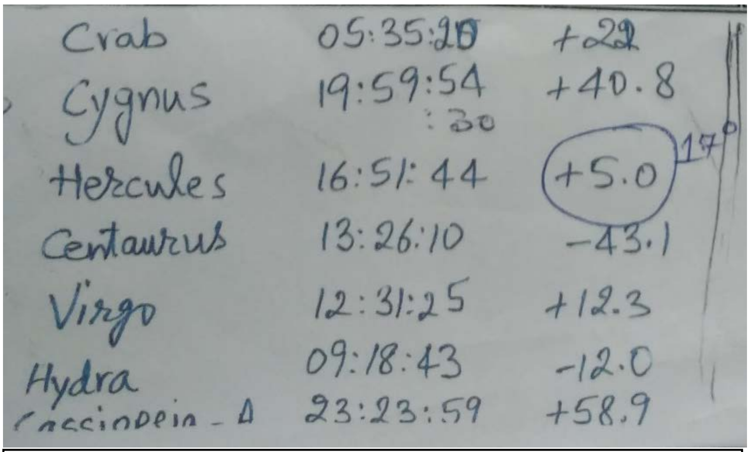
      > sudo ssh root@das<dasid> /etc/init.d/mbrdasd stop [To stop]
- To reboot a single DAS:
    - **mbrdo <dasid> run reboot**
- To restore communication with a DAS:

- **sudo ~/bin/restore_dasd_communication_with_this_das <dasid>**

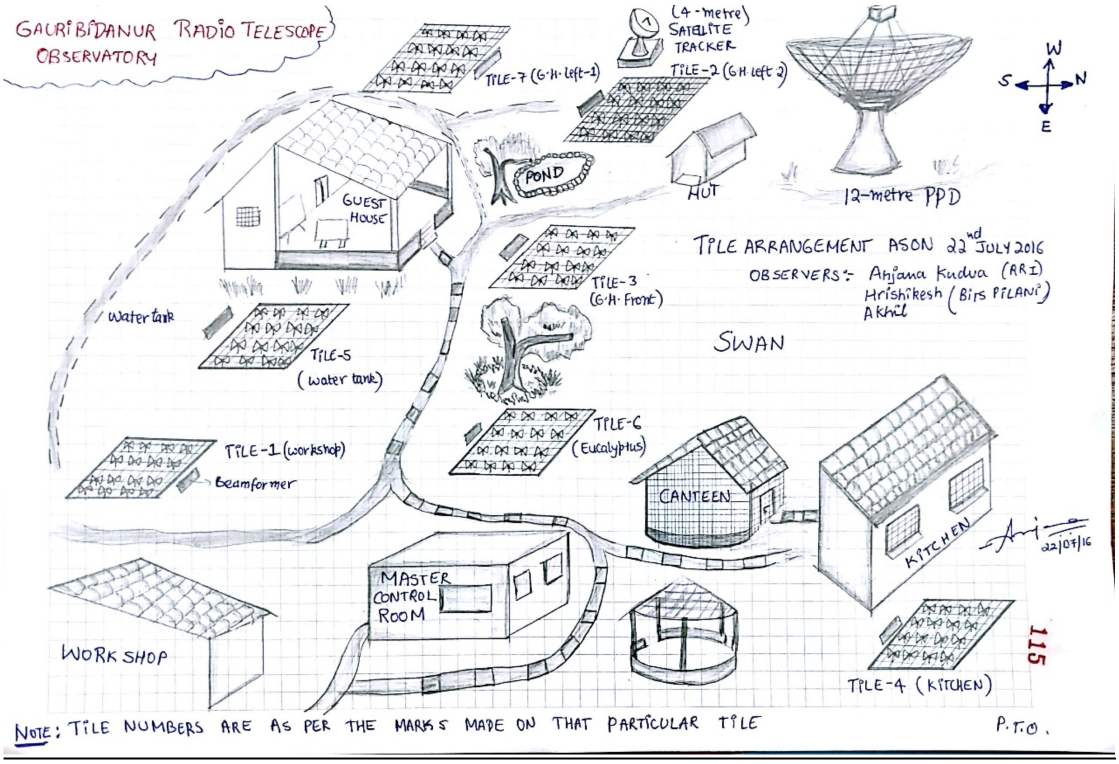
- To kick start and start acquisition:
  - **sudo ~ /bin/kickstart_this_das_transmission_and_sniff_for_this_duration_tag <dasid> <time>**
    [time: 10min, 1hr, 2hrs, 8hrs, 24hrs]

7.2 Appendix B: A few important pictures

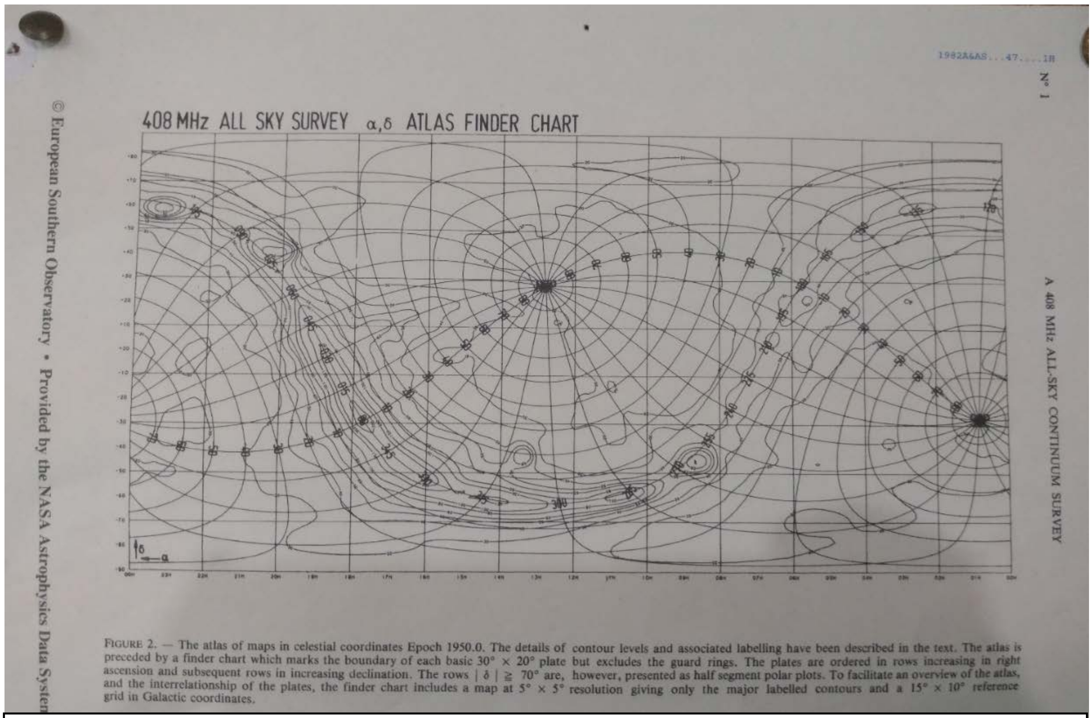
An Astronomical Clock
Local Sidereal Time – Julian Day – Indian Standard Time



A few important radio sources



Tile Arrangement as of 22nd July 2016



All sky survey at 408 MHz

7.3 Appendix C: SWAN log as on 28th July 2016

Day 1 – 18/07/2016

- Went through all the various reports and logs made previously to familiarize ourselves with the different electronic components used and the different programs used to run the antennae.
- Had a survey of the GBD Radio Observatory to familiarize ourselves with the positions of the tiles and their orientations.
- List of logs and reports analyzed:
  - Preliminary_Tests_2016may05.pdf
  - SWAN_single_tile_guide_for_observation_20May2016.pdf
  - SWAN_guide_ason_17June2016_edited_on_8july.pdf
  - A few handy things_ason_8July2016.pdf
  - SWAN_Log for 07 July 2016_by_Arunita.pdf
  - SWAN_Log_by_Vineeth_ason_8thJuly2016.pdf
  - SWAN_log_vineeth_Anjana_Manju_ason_8th&9th_july2016.pdf
  - SWAN_Pointing_Scanning_plotting_ason_29thjune2016.docx
  - Command_Specification. 1.0.pdf
  - quickstart.pdf
  - setting_up_and_acquiring.pdf
  - Data_Acquisition_Quickstart.pdf
- All these documents will be provided as hard copy and soft copy. The guides for quick start will be on the desktop for quick reference.

Day 2 and Day 3 – 19/07/2016 and 20/07/2016

- Tried using the commands given in the logs to the computer and tried observing.
- The commands to be used are:
  - **mbrrunterms -m** [To open black terminal window]
  - **start_dasd_on_all_machines_and_mcd**
  - **mbrset 0 source <*source_name*>**
    [source_name: Enter desired name of source. Change each time before observation to avoid confusion.]
  - **mbrdo 0 run setup_prepare_for_acquire_in_sniff_mode**
  - **sudo ~/bin/sniff_data_for_<*time*>_shdmem_newacq**
    [time: 1min, 10min, 1hr, 2hrs, 8hrs, 24hrs] [Do not use the command: **sudo ~/bin/sniff_data_for_<*time*>_newacq** which is given in the quickstart.pdf. It is an invalid command.]
- Got the error "ERROR: Binding to socket failed!" multiple times.
  - Solutions tried:

        - Checked if Ethernet cables are connected, both lights of Ethernet should blink ideally. If not, then try reconnecting the cables. If the lights still do not blink, it means the internet is not stable. So try after some time.
        - Shut down and restart DAS which is showing the error:
            - If all DASes are showing the error, then shut down and restart all of them. The proper control to shut down the master control machine:
                - **mbrdo 0 run shutdown –h now**
            - To shutdown individual DASes, use command:
                - **ssh das@das<*dasid*>** [dasid: 0,1,2,3…10; 0 is master DAS]
                - **sudo shutdown –h now**
    - A more promising and easy to approach solution was arrived at after much deliberation by Desh sir and us, which will be elaborated at a later stage of this log.

- While starting up the DASes, wait for the red HDD light on the DAS machine to turn off completely. The glowing red LED suggests that booting is going on.
- In morning Vinutha ma'am and Ashwathappa sir replaced the digital box. And beamformers for 1 and 2 were working.
- *** In commands, whenever there is '0' it means the command is being given to the master DAS which in turn will communicate the command with the slave DASes.
- *** Writing 'sudo' before a command implies you are providing administration permission to the respective DAS. So you will need to provide the correct password to proceed. The master DAS has a different password and all of the slave DASes have a different password. Do remember to note down these passwords for future use. And please be careful to not let these passwords go into the wrong hands.

<u>Day 4 – 21/07/2016</u>

- Started 1 hrs acquisition without pointing
    - DASes 5, 6 and 8 were working properly.
    - DASes 2, 3 and 4 weren't accepting any commands.
    - Stopped acquisition:

        - **mbrdo 0 run killall mbracquire**
    - So tried shutting them down individually and then restarting them.
- Got another error "ERROR: Not transmitting data even after reprogramming 25 times"
    - Solution tried:
        - Press RESET switch behind DSP. This would restart the individual DSP.
        - This even works when the TX green light is not glowing, which means the transmission is not going on. So restarting the DSP would do the work.
    - A better solution for this problem was created by Desh sir which shall be explained later on.
- Started plotting the acquired data. The commands used were:
    - **~/bin/first_level_mbr -p A -c 512 -n 10 -a 100 -i <*inputfile*> -o temp.spec -m 1/xs -w 18000**
      [The details of this command have been given in *SWAN_Pointing_Scanning_plotting_ason_29thjune2016.pdf*] [inputfile: Input the name of the file as it is stored in the computer. If input file name is not provided, then the latest file created is taken into use.]
    - While plotting is going on, press ENTER in the terminal used for plotting to pause midway. Then various options will be displayed in the terminal window.
    - Use AUTOCALIB (Auto-caliberation) to change the attenuation values as required to get a plot which has both h and v intensities in the same range.
    - In the **first_level_mbr** command, additionally **–l** and **–u** can be appended to specify the lower and upper limits of the graph.
    - *** Always use this command in a separate terminal window so that you can play with it later on without disrupting other operations.
- If error occurs "segmentation fault → core dumped" then a file named 'core' is created in that same directory. We have to remove this core using command: **rm core**

Important – Remote Access

- Install '**xtightvncviewer**' in your Ubuntu device.
- VNC Server IP Address: 172.17.17.150 (For use within the RRI Network)
- VNC Server IP Address: 14.139.157.120 and Port Address: 2223 (For use anywhere in the World)
- Enter password when prompted.
- To communicate with other users who are accessing the computer at that same time, the terminal window can be used alternatively as a chat window.
    - Command: **echo "message" |wall** [message: Input your message to display it.]
- A proper system needs to be implemented to avoid confusion while multiple users try to remote access the computer at the same time.

Day 5 – 22/08/2016

- The DASes 1, 2, 3, 4, 6 were working properly. DAS 5 had some problem in output values which has been mentioned later on. DAS 7 always had the red HDD light glowing, because it had a problem in its temperature sensor. The problem was in the Beamformer and it has to be replaced. DAS 8 was not connected as the corresponding antenna array was also not connected.

- The RF-IF unit of 3 was replaced with the RF-IF unit of 8 as that of 3 had been sent to Bangalore for repair.
- It is important to check whether all the antenna tiles are following the direction convention properly i.e. the H and V convention. This can be achieved by alternately disconnecting the H and V circuits respectively from the Beamformer. This operation has to be performed in the field to get accurate results.

- The spectrum analyzer was connected to each DSP unit to check the IF and RF outputs respectively. The desired IF output for each tile is **-5 to -15 dBm**. And the desired RF output for each tile is **-45 dBm or more**.

- *** **The RF and IF outputs for any tile should never be greater than 0 dBm**. If such a case ever occurs immediately disconnect the cable from RF-IF block to DSP to avoid damage of the circuitry.
  Then try changing the attenuation values to get the IF output within desired range.
- The H and V outputs for any tile must be close to each other. The lesser the difference between the outputs of a tile, the better the results would look. If the outputs have a large enough difference between them, then change the attenuator values accordingly.
- The obtained results were as follows:

RF-IF 1	Initial Output (in dBm)	Change Attenuator Values (if required)	Final Output (in dBm)
CH-V IF_{OUT}	-5.45	-	-
CH-H IF_{OUT}	-6.20	-	-

RF-IF 2	Initial Output (in dBm)	Change Attenuator Values (if required)	Final Output (in dBm)
CH-V IF_{OUT}	-4.51	-	-
CH-H IF_{OUT}	-6.98	-	-

RF-IF 3 (Using RF-IF unit 8)	Initial Output (in dBm)	Change Attenuator Values (if required)	Final Output (in dBm)
CH-V IF_{OUT}	-8.85	-	-
CH-H IF_{OUT}	-7.55	-	-

RF-IF 4	Initial Output (in dBm)	Change Attenuator Values (if required)	Final Output (in dBm)
CH-V IF_{OUT}	-14.15	-	-
CH-H IF_{OUT}	-8.10	-	-

RF-IF 5	Initial Output (in dBm)	Change Attenuator Values (if required)	Final Output (in dBm)
CH-V IF_{OUT}	**+10.00 (Disconnected)**	-	-
CH-H IF_{OUT}	-15.25	-	-

RF-IF 6	Initial Output (in dBm)	Change Attenuator Values (if required)	Final Output (in dBm)
CH-V IF_{OUT}	-9.55	-	-
CH-H IF_{OUT}	-7.76	-	-

RF-IF 7	Initial Output (in dBm)	Change Attenuator Values (if required)	Final Output (in dBm)
CH-V IF_{OUT}	-39.43 (Too low)	0	-14.89
CH-H IF_{OUT}	-35.03 (Too low)	1	-14.35

RF-IF 1	Initial Output (in dBm)	Change Attenuator Values (if required)	Final Output (in dBm)
CH-V RF_{OUT}	-43.75	-	-
CH-H RF_{OUT}	-44.78	-	-

RF-IF 2	Initial Output (in dBm)	Change Attenuator Values (if required)	Final Output (in dBm)
CH-V RF_{OUT}	-38.78	-	-
CH-H RF_{OUT}	-38.20	-	-

RF-IF 3 (Using RF-IF unit 8)	Initial Output (in dBm)	Change Attenuator Values (if required)	Final Output (in dBm)
CH-V RF_{OUT}	-37.75	-	-
CH-H RF_{OUT}	-31.76	-	-

RF-IF 4	Initial Output (in dBm)	Change Attenuator Values (if required)	Final Output (in dBm)
CH-V RF_{OUT}	-22.80 (Too high)	Changed	No change
CH-H RF_{OUT}	-23.75 (Too high)	Changed	No change

RF-IF 5	Initial Output (in dBm)	Change Attenuator Values (if required)	Final Output (in dBm)
CH-V RF_{OUT}	-28.10	-	-
CH-H RF_{OUT}	-59.06	-	-

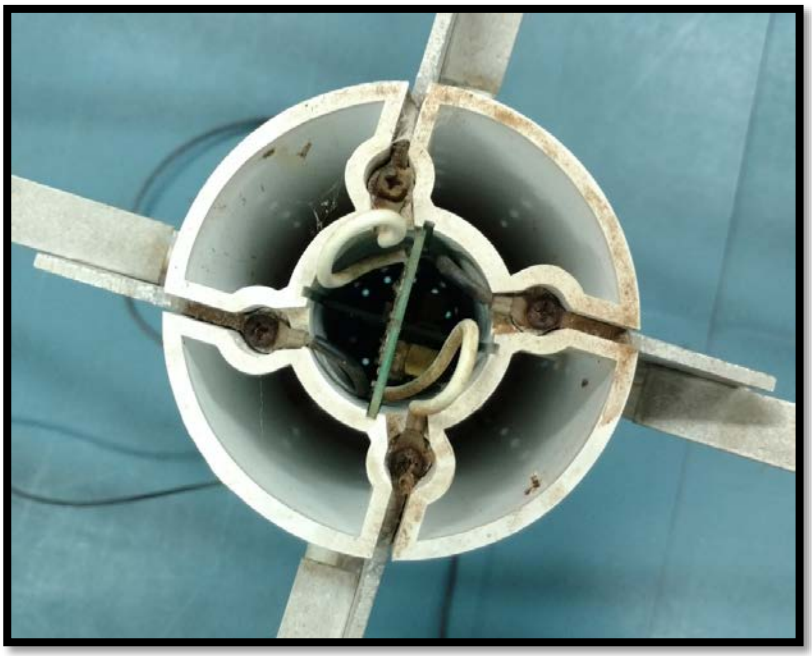
RF-IF 6	Initial Output (in dBm)	Change Attenuator Values (if required)	Final Output (in dBm)
CH-V RF_{OUT}	-38.78	-	-
CH-H RF_{OUT}	-38.20	-	-

RF-IF 7	Initial Output (in dBm)	Change Attenuator Values (if required)	Final Output (in dBm)
CH-V RF_{OUT}	-56.75	-	-
CH-H RF_{OUT}	-54.30	-	-

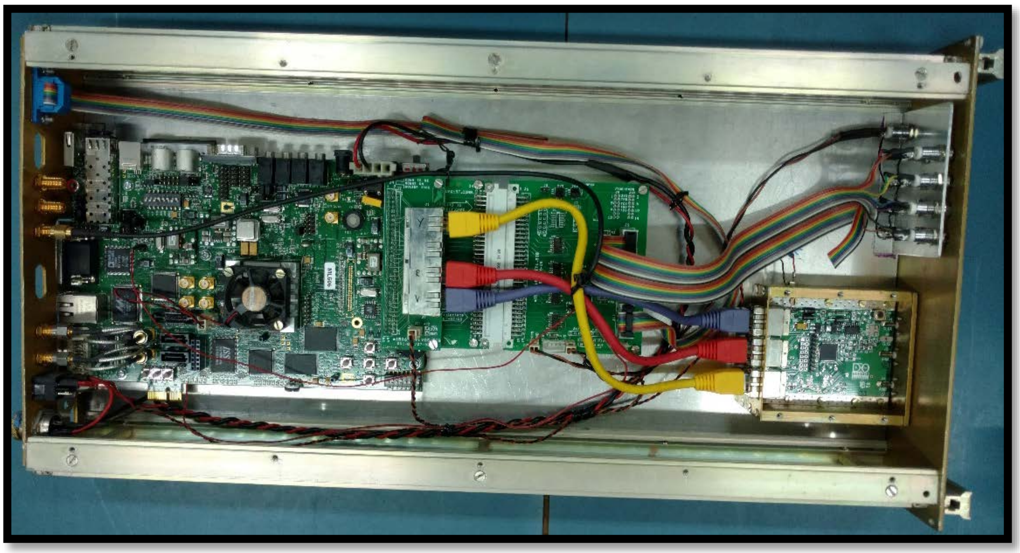
- The RF output for RF-IF unit 4 was higher than desired but change in attenuator values did not change the output values. The output was saturated.
- The attenuator values can be from 0 to 30. The command used to change the attenuator value is:
    - **mbrset <dasid> attenuator <vif/hif/vrf/hrf> <value>**
      [value: Enter the desired attenuator value]
- DAS 5 was continuously rebooting without any known reason (The red LED was blinking continuously suggesting that the HDD was undergoing reboot). It was connected to another monitor to observe the reboot process. The DAS was going into forced disk check, which took about 45 minutes to complete. A detailed solution to this problem has been discussed later on.

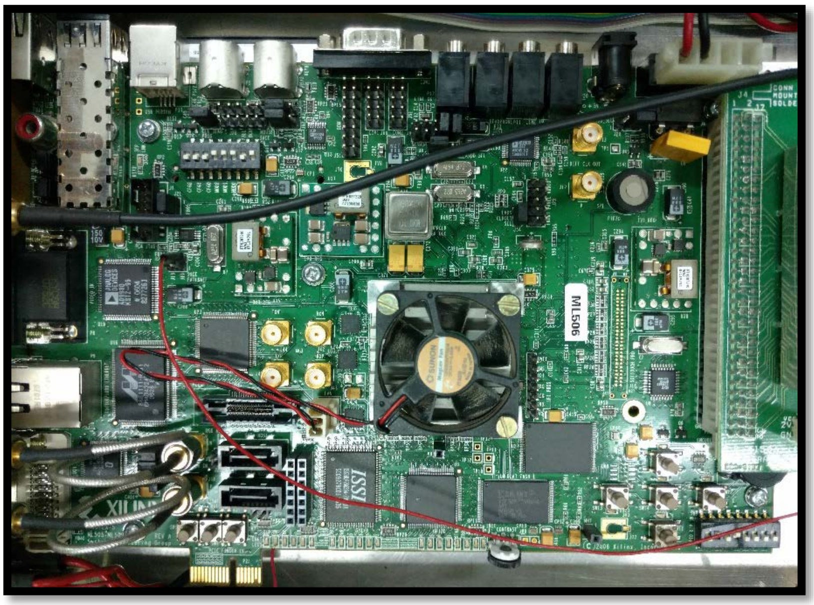
Day 6 – 23/06/2016

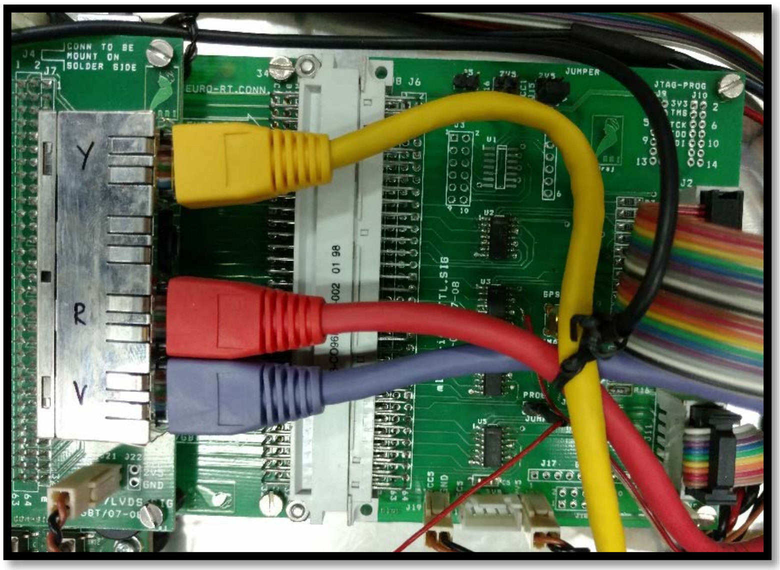
- Opened the spare dipole antenna and learnt about the functioning of two LNAs and other circuitry.

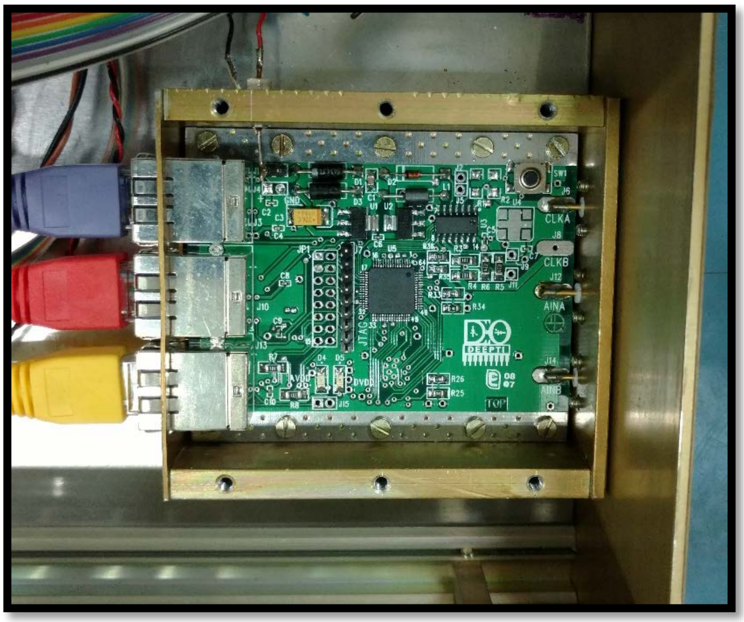


- Opened DSP block and studied about the ADC (Analog to Digital Converter), FPGA (Field Programmable Gate Array) and PCB (Printed Circuit Board) board. FPGA is a programming device and PCB talks between ADC and FPGA.
    - **FPGA:** It is a semiconductor device that are based around a matrix of configurable logic blocks (CLBs) connected via programmable interconnects. In contrast to processors that you find in your PC, programming an FPGA rewires the chip itself to implement your functionality rather than run a software application.
    - **ADC:** It is a device that converts a continuous physical quantity (usually voltage) to a digital number that represents the quantity's amplitude.

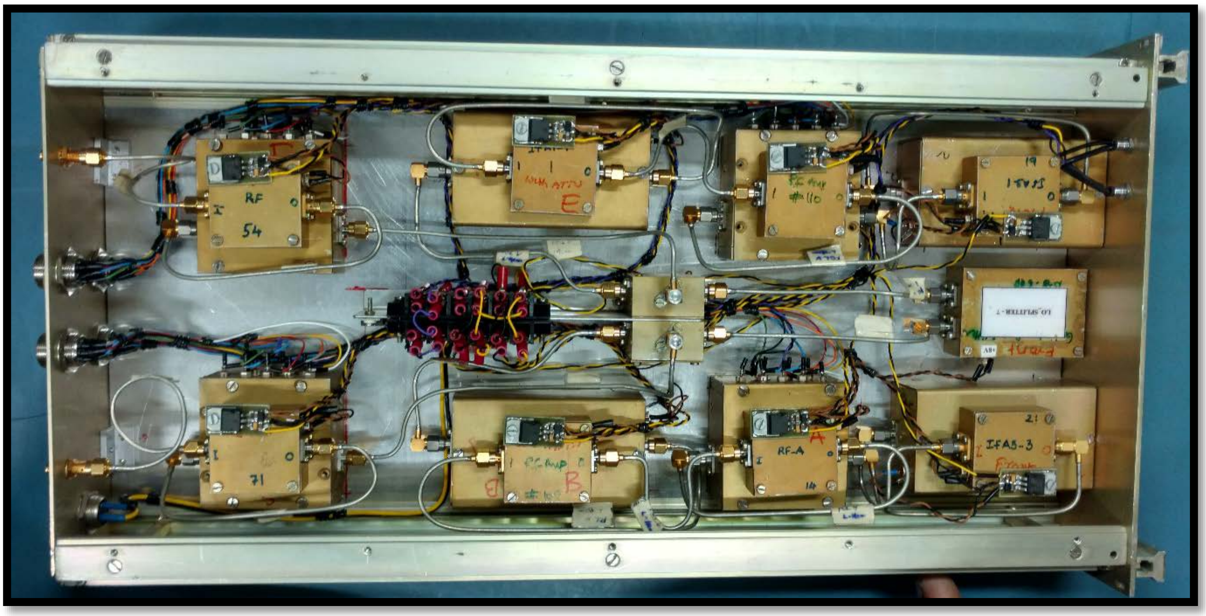




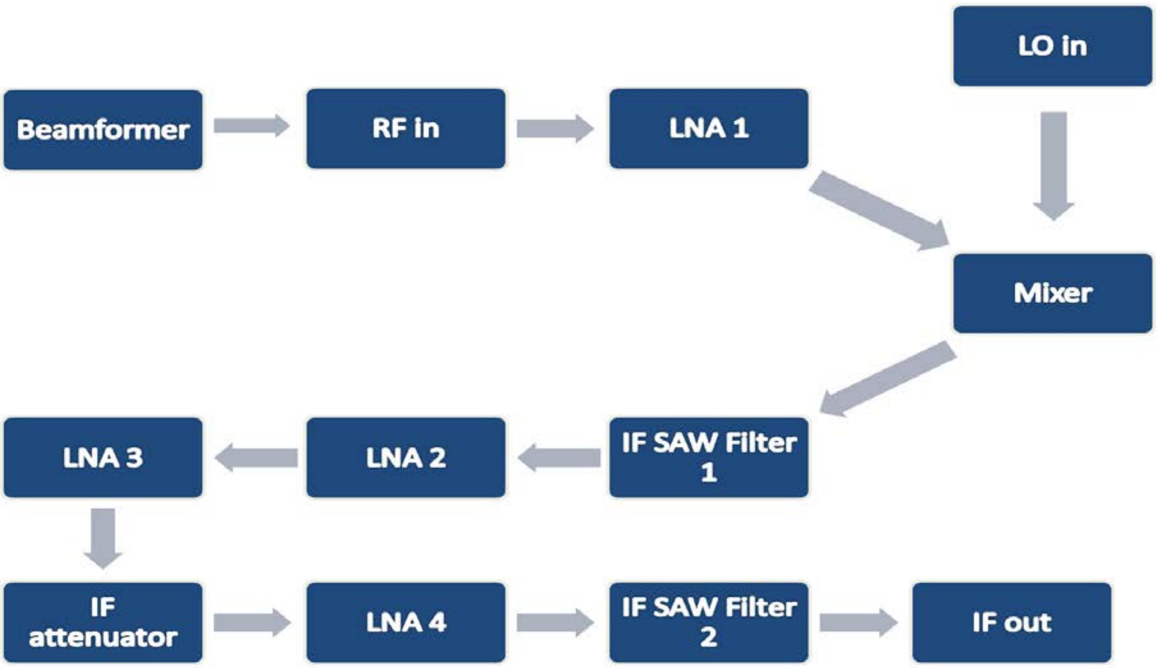




- Further studied the RF-IF block. This block consists of multiple LNAs (Low Noise Amplifier), attenuators and SAW (Surface Acoustic Wave) filter.
    - **SAW:** It is a filter whereby the electrical input signal is converted to an acoustic wave by so-called interdigital transducers (IDTs) on a piezoelectric substrate such as quartz. The IDTs consist of interleaved metal electrodes which are used to launch and receive the waves, so that an electrical signal is converted to an acoustic wave and then back to an electrical signal.
    - **LNA:** It is an electronic amplifier that amplifies a very low-power signal without significantly degrading its signal-to-noise ratio. An amplifier increases the power of both the signal and the noise present at its input.



- The working of the RF-IF block is as follows:



- Later on, the IF output were rechecked again, after Ashwathappa sir made some changes in the Beamformer connections. The obtained results were as follows:

• RF-IF 1	Initial Output (in dBm)	Change Attenuator Values (if required)	Final Output (in dBm)
CH-V IF_{OUT}	-25.1	13 → 0	-11.7
CH-H IF_{OUT}	-16.0	10 → 7	-9.8

RF-IF 2	Initial Output (in dBm)	Change Attenuator Values (if required)	Final Output (in dBm)
CH-V IF_{OUT}	-27.9	20 → 2	-9.7
CH-H IF_{OUT}	-33.0	20 → 0	-10.9

RF-IF 3 (Using RF-IF unit 8)	Initial Output (in dBm)	Change Attenuator Values (if required)	Final Output (in dBm)
CH-V IF_{OUT}	-35.3	25 → 0	-11.8
CH-H IF_{OUT}	-35.0	25 → 2	-10.9

RF-IF 4	Initial Output (in dBm)	Change Attenuator Values (if required)	Final Output (in dBm)
CH-V IF_{OUT}	-30.2	30 → 10	-10.1
CH-H IF_{OUT}	-33.0	15 → 0	-18.5 (Too low)

RF-IF 6	Initial Output (in dBm)	Change Attenuator Values (if required)	Final Output (in dBm)
CH-V IF_{OUT}	-21.3	30 → 20	-12.0
CH-H IF_{OUT}	-25.5	25 → 10	-10.3

RF-IF 7	Initial Output (in dBm)	Change Attenuator Values (if required)	Final Output (in dBm)
CH-V IF_{OUT}	-12.1	0 → 0	-12.1
CH-H IF_{OUT}	-29.0	0 → 0	-29.0 (Too low)

- Even after changing the attenuator values, the output for unit 4 and 7 were lower than desired.

Day 7 – 24/06/2016 – The day when Desh sir set foot in GBD

- A few new commands:
  - **mbrrunterms**
    [To access the individual DAS window and enter command specifically for that DAS]
  - **history |grep <keyword>**
    [keyword: Enter part of command that you remember to search in history for that command. The history is displayed with serial numbers. Use **!<serial_number>** to run the corresponding command]
  - **mbrlivedas**

[Use this command to update the status of the DASes. After using this command, enter the number of DASes that you want down. And then enter the *dasid* of those specific DASes. Use this command before using the 'start_dasd_' command]

  - **mbrset 0 lofreq <LO_frequency_value>**
  - **mbrdo 0 run swan_pointing <RA> <Dec> <reference_epoch> <start_beam_number> <stop_beam_number> <stop_time_in_LST> <pointing_code> <frequency> <null_flag>**

    [RA: Mention the right ascension. Dec: Mention the declination.
    reference_epoch: RA Dec system changes every 50 years. We will be following the J2000 system as reference. Hence we need to write "TODAY"
    start/stop_beam_number: Beam goes from -48 to +48 degrees, with a 6 degrees interval. Put (0 0) to always keep pointing to the meridian. Put (-8 8) to track the source.
    stop_time_in_LST: Input the time when you want to stop the pointing program in Local Siderial Time in "hh:mm" This time should be less than the sniffing time. If it is greater, then the sniff program will override and stop the acquisition. If it is lesser, then pointing will stop at the mentioned stop time but sniffing will continue.
    pointing_code: The code used to point at the mentioned RA and Dec. In this case, we need to mention "swan_tile_beam_set"
    Refer to *SWAN_Pointing_Scanning_plotting_ason_29thjune2016.docx* for further information on this program.
    Frequency: Enter central frequency in Mhz.
    null_flag: "0" will create a phase difference of 180deg between subsequent antennae and "1" will not create any phase difference.]
  - **SWAN_beam_1d_scan.scr** ***<Azimuth> < Zenith-Angle > <scan_type> <offset> <step>***

    [scans sky in one dimension to see if the source produces any variations in reading(A Gaussian is expected)
    scan_type: Whether Scan along azimuth (s2) or elevation (s1)]
- Problem with rebooting of DAS 5:
  - Maybe this is the reason why attenuator of unit 5 was not responding to commands and was unable to bring IF values inside threshold.
  - Solutions tried:
    - Remove connections and check if some loose connection was the reason behind the rebooting.
- Problem with DSP WR light not glowing during acquisition:
  - Solutions tried:
    - Reboot the DSP using the back switch.
    - Use command **mbrdo <dasid> setup_prepare_for_acquire_in_sniff_mode**
    - A proper solution for this was arrived at, which shall be mentioned in detail later on.
- **Never use hardware switch to reboot a machine unless absolutely necessary.**
- On sir's last visit, the swan_pointing code was modified. So the necessary changes were made only on certain DASes which were functional at that time. So today they were downloaded on the rest of the DASes.
- When we tried setting the acquisition for 24 hours, we got an error stating:- **"Number of files must be at least 1 and not more than 999! "**

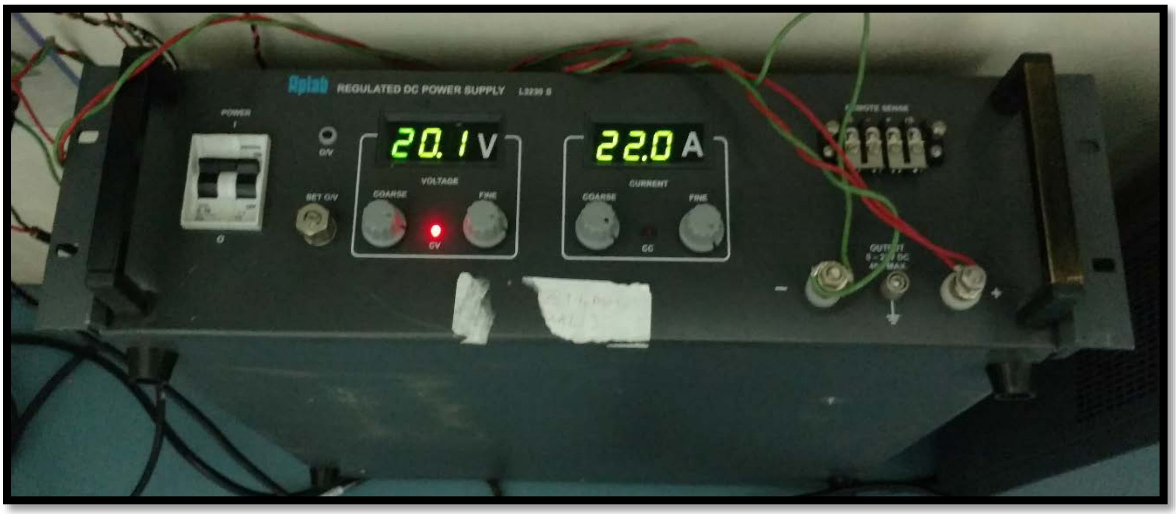
- This was because the some of the programs were directly taken from GEETEE and appropriate modifications weren't made to the code.
- So in the code:
  - **sudo ~/bin/sniff_data_for_24hrs_shdmem_newacq**

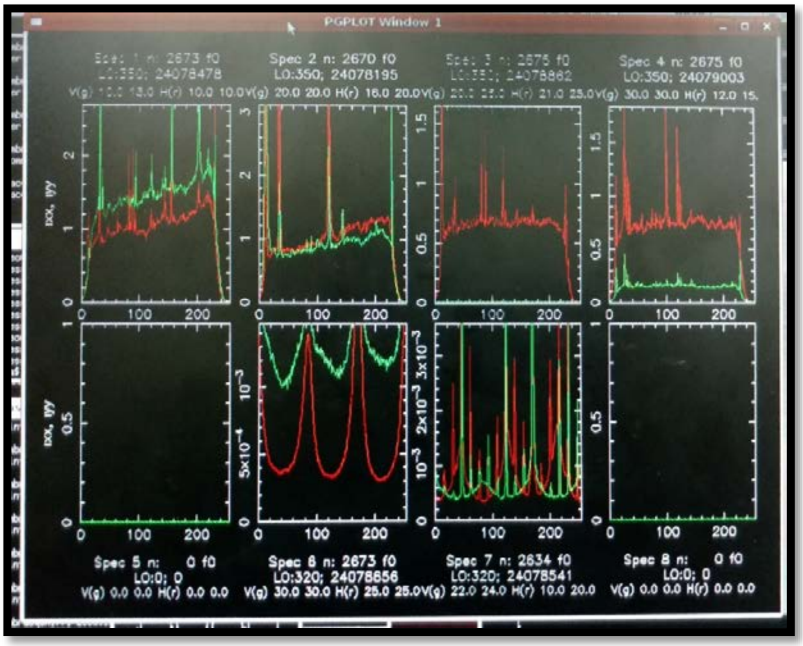
  -f 2880 was changed to –f 999 so as to accommodate sniff mode for 24 hours.

- To know about the current azimuth-elevation values pointed by the telescope look for log in file where the acquisition is going on :
  - LOG → swan_beam_position.LOG

<u>Day 8 – 25/06/2016</u>

- Problem with signal strength of tiles 6 and 7(H and V were very low)
  - Loose connection in Beamformer power supply of 6
  - Beamformer power supply for 7 wasn't connected





- Since DAS 05 was continuously rebooting, we decided to bring in DAS 08 instead of DAS 05. Made required connections.
    - To our dismay DAS 08 too started rebooting continuously.
    - Tried replacing and reinserting the power cable. HDD scan going on.
    - DAS 08 is now on!!!
- To disable file system check (HDD scan) for DAS on accidental shutdown, following steps were performed;
    - **more /etc/fstab**
      sudo vi /etc/fstab
    - change last number to '0'
    - This has been done already on all DASes and need not be done again unless necessary.
- TX and WR lights of DSP 06 went off:
    - Solutions tried:
        1. **> ssh 06**
           > **~/bin/reprogram_fpga_till_transmission**
        2. **> mbrdo 6 reprogram_fpga_till_transmission**
           [in the above code, FPGA reset and FPGA program happen.]
- If you need to copy files from main computer to some other computer for analysis, it can be done using the following commands on the secondary computer (provided both the computers are on the same network.):
    - **ssh –X das@172.12.17.150**
      scp –p 'das@<ip>:/<path_of_required_file>' <path_to_save_file>
- To communicate with a single DAS, use command: **ssh –X das@das<dasid>**
    - To come out of ssh mode while communicating with DAS → **exit**
- A **new code** was written by Desh sir:
    - **~/bin/kickstart_this_das_transmission <dasid>**
      [This code is a combination of two previously devised codes, namely:
      mbrdo <dasid> run killall mbracquire
      mbrdo <dasid> reprogram_fpga_for_transmission]
    - When we use the code **mbrdo <dasid> reprogram_fpga_for_transmission** while the acquisition is going on, the code does not work. So we created this code, which automatically stops the acquisition program, resets the FPGA, reprograms it and then restarts acquisition.
- Then we tried to acquire data in **observation mode.** Till now we were acquiring only in sniff mode, which only acquires data as discrete packets which are collected after specific intervals of time. But in observation mode, data acquisition takes place continuously. Observation mode takes up a lot of disk space and memory, so it should be used only when highly accurate data (or for interferometry) is needed. For all other purposes, sniff mode will suffice.
- Data acquisition in observation mode:
    - **> mbrset 0 acqmode obs**
      > mbrdo 0 run setup_prepare_for_acquire_in_sniff_mode
      > mbrset 0 source <*source_name*>

> sudo ~/bin/sniff_data_for_<*time*>_shdmem_newacq

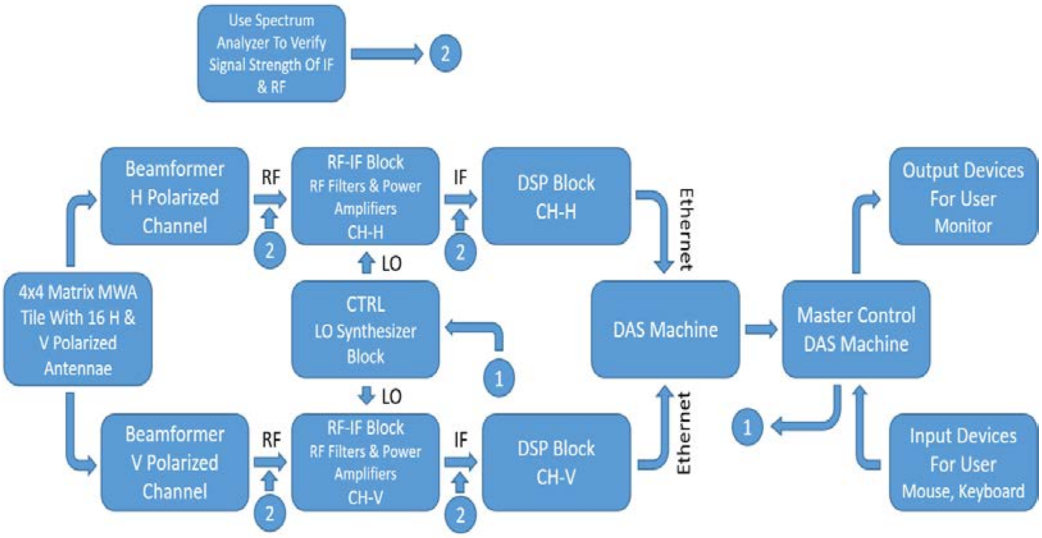
- Using the code mentioned above, we tried acquiring in observation mode for 10 minutes and then compared the data with that of sniff mode for the same time interval. We found that the data size is comparable in both modes. Had the observation mode worked correctly, the data size should have been much larger than that of sniff mode. So we concluded that our execution of the above code was wrong and is yet to be amended.
- To start individual DAS:
    - **sudo ssh root@das<dasid> /etc/init.d/mbrdasd start**
sudo ~/bin/mbrrunterms –m – d <dasid> [To write in specific DAS window]
…
sudo ssh root@das<dasid> /etc/init.d/mbrdasd stop [To stop]
- To reboot a single DAS:
    - **mbrdo <dasid> run reboot**

<u>Day 9 – 26/06/2016</u>

- An extensive research was done today to solve the “Binding to socket error” problem.
- In general, the basic steps to be followed are:
    - Check connections
    - Stop DAS
    - Start DAS
    - Run the usual processes to start acquisition
- We had a problem with DAS 08 rebooting mid acquisition.
    - Solutions tried:
        - Start individual DAS
        - If “binding to socket error” occurs, restart after checking the cables
- If the DAS still does not respond to commands like **~/bin/kickstart_this_das_transmission <dasid>** (→ -1: timeout) then the following steps need to be taken:
    - **> ssh root@das<dasid> reboot**
> sudo ssh root@das<dasid> /etc/init.d/mbrdasd stop
> sudo /etc/init.d/mbrmcd stop
> sudo /etc/init.d/mbrmcd start
> sudo ssh root@das<dasid> /etc/init.d/mbrdasd start
> sudo ~/bin/mbrrunterms –m – d <dasid>
> mbrget <dasid> lofreq
> mbrdo <dasid> run killall mbracqsniff
> mbrdo <dasid> run killall mbracq
> sudo ~/bin/kickstart_this_das_transmission <dasid>
> mbrset <dasid> acquisition off
> mbrdo <dasid> run setup_prepare_for_acquire_in_sniff_mode
> sudo ~/bin/sniff_data_for_<*time*>_shdmem_newacq
> mbrset <dasid> acquisition on
- The above method will eat your brains and test your patience. So desh sir, for the betterment of humanity created a new code that is a combination of all above codes:

- **~ /bin/kickstart_this_das_transmission_and_sniff_for_this_duration_tag <dasid> <time>**
  [time: 10min, 1hr, 2hrs, 8hrs, 24hrs**]**

- If in individual command boxes for DAS, if we get the "creating block ---" after starting the acquisition it is not a good thing. This means that it is creating shared memory blocks. KILL ACQUISITON IMMEDIATELY. Instead, if "Locating block ---" is written, it is normal behavior.
- If there are conflicts with shared memory, STOP ALL ACQUISITIONS (sniff as well as mbracq).
- DAS 08 keeps rebooting uncertainly,
  - Maybe problem with wires or sockets.
  - Solution on software side does not help
  - Solutions by checking cables does not help
  - DAS 8 was shutdown
- A new code: **sudo ~/bin/restore_dasd_communication_with_this_das <dasid>**
  - This code contains the following codes:-
    > ssh root@das<dasid> reboot
    > sleep 90s
    > sudo ssh root@das<dasid> /etc/init.d/mbrdasd stop
    > sudo /etc/init.d/mbrmcd stop
    > sudo /etc/init.d/mbrmcd start
    > sudo ssh root@das<dasid> /etc/init.d/mbrdasd start
    > sudo ~/bin/mbrrunterms –m – d <dasid>
- The kickstart and acquisition command that was created above was modified to solve the problem with DAS 08:
  sudo ~ /bin/kickstart_this_das_transmission_and_sniff_for_this_duration_tag <dasid> <time>
  - This code contains the following codes:-
    > mbrdo <dasid> run killall mbracqsniff
    > mbrdo <dasid> run killall mbracq
    > mbrdo <dasid> run rm –f /home/das/lock/acquire.lock
    > mbrdo <dasid> run /home/das/scripts/rmshm.py
    > mbrdo <dasid> run reprogram_fpga_till_transmission_with_acq_kill_each_time
    > mbrset <dasid> acquisition off
    > sleep 1s
    > mbrdo <dasid> run /home/das/bin/run_sniff_<time>_shdmem_in_dasmachines_newacq
    > sleep 1s
    > mbrset <dasid> acquisition on
- The basic functioning of the whole SWAN system:



Important – LabView

- Copy all transferred files into one folder
- Open LabView script
- Select DAS (dasid)
- Press 'Run'
- Select file (will run all files in the folder one after another sequentially)
- Give index for required frequency
- Wait for LabView to plot the graph