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RF Power monitoring Scheme for upgraded Front End and Common Box

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Objective: The aim was to design a power detector, capable of detecting power over the large range typically 70 dB linearly. Apart from this it should be capable of detecting 1dB power variations (resolution).

| | | |
|--|-------------------------------|--------------------------------------|
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1.0) Introduction:

Giant Meter wave Radio Telescope (GMRT) has been designed to operate at six frequency bands centered at 50 MHz, 150 MHz, 235 MHz, 327 MHz, 610 MHz, and L-Band extending from 1000 MHz to 1450 MHz. L-band is split into four sub-bands centered at 1060 MHz, 1170 MHz, 1280 MHz and 1390 MHz, each with bandwidth of 120 MHz. The 150 MHz, 235 MHz and 327 MHz bands have about 40 MHz bandwidth and 610 MHz band has about 60 MHz bandwidth. Lower frequency bands from 150 MHz to 610 MHz have dual circular polarization channels (Right Hand Circular and Left Hand Circular) which have been conveniently named as CH1 and CH2 respectively. The higher L-Band frequency has dual linear polarization channels (Vertical and Horizontal) and they have also been named CH1 and CH2 respectively. The receiver system has the flexibility to be configured for either dual polarization at single frequency band or single polarization at two different frequency bands. The polarization channels can be swapped whenever required. For observing strong radio sources like "SUN", the selectable solar attenuators of 14dB, 30 dB, and 44 dB can be used. Any band of the receiver can be switched OFF, whenever not in use, with the RF on/off facility provided in the front end box. The receiver can be calibrated by injecting one of the four levels of calibrated noise viz. Low Cal., Medium cal., High Cal., Extra High Cal.; depending upon the flux density of the source being observed. To minimize cross coupling between channels, a phase switching facility using WALSH function is available at RF section of the receiver.

As a part the GMRT upgrade activity it was decided to design a RF power detector to be fitted at different stages of receiver chain (FE & CB output *which has a combined gain of approximately 70 dB*) *so the desired RF power detector must cater to such high dynamic range along with high sensitivity (can response to low power levels) and should have good resolution.* The main motivation for designing RF power monitoring was to debug the problem online before going to the antenna; also to decide where the problem lies in Front end box or Common box.

The proposed design will have the dynamic range of around 70 dB and resolution of around 40mV/dB. The heart of the design is the Logarithmic Power detector from Analog Devices (ADL5513) which provides linear DC output voltage corresponding to input RF power. The

other supporting devices used are a Directional coupler and RF amplifier from Mini-Circuits. The basic block diagram of RF power monitoring circuit is shown below.

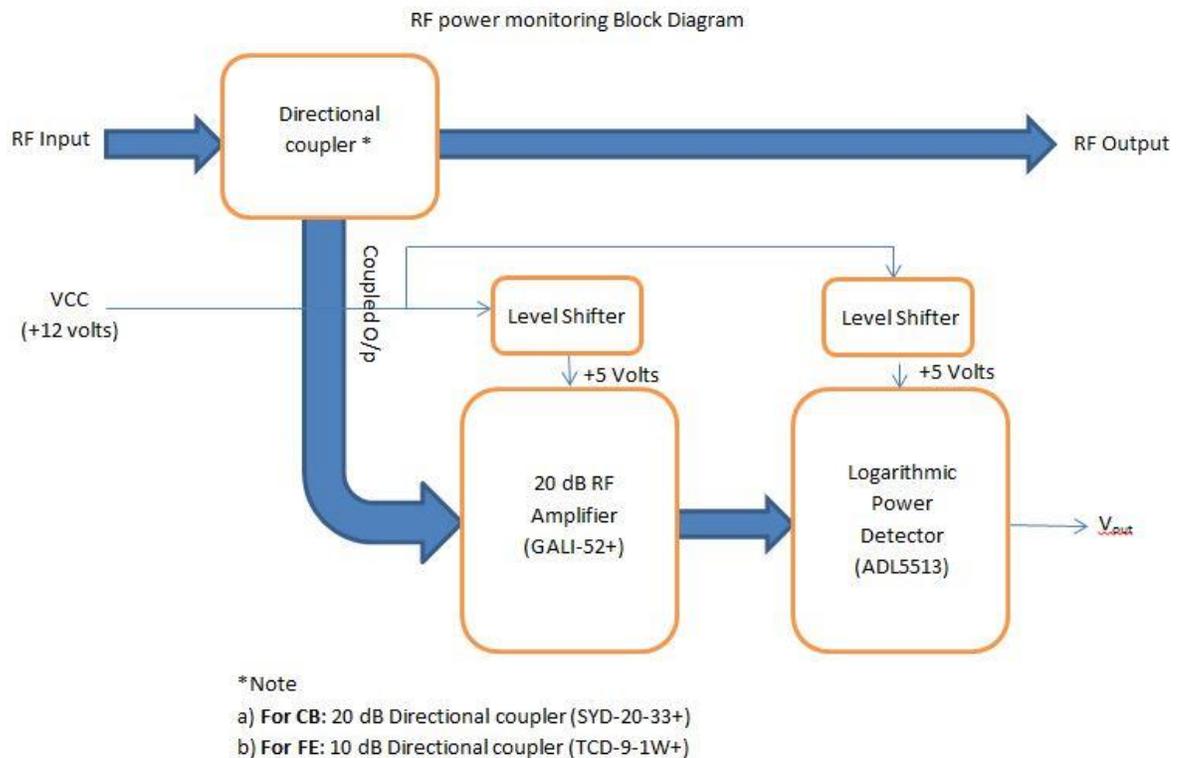


Figure 1: Basic Block Diagram

2.0) Circuit Design For Common Box:

The channel power which is to be measured is coupled to the RF power monitoring circuit by a 20 dB directional coupler from Mini-Circuits (SYD-20-33+). After that, the coupled RF signal is amplified by a 20 dB amplifier from Mini-Circuits (GALI-52). Then the amplified signal is given to the Logarithmic power detector from Analog Devices (ADL5513), which gives a linear DC output voltage corresponding to the input RF power.

Performance Specifications:

- Frequency Range: 30 MHz to 2 GHz
- Input Power range: -60 dBm to +5 dBm
- Dynamic Range: 65 dB
- Maximum Input power: +5dBm
- Operating Voltage (V_{dc}): +12 V
- Operating Current (I_{dc}): 80 mA

- Operating Temperature: -45°C to $+85^{\circ}\text{C}$
- Resolution: $40\text{mV} / \text{dB}$
- Temperature dependence: $< 2\text{mV} / 10^{\circ}\text{C}$

3.0) Principle of RF power Detection:

3.1) *Logarithmic Detector (ADL5513)*

The ADL5513 is a demodulating logarithmic amplifier, specifically designed for use in RF measurement and power control applications at frequencies up to 4GHz. The block diagram is shown in figure 2. It maintains tight intercept variability vs. temperature over 80 dB range. The ADL5513 maintains accurate log conformance for signal up to 4GHz. The input dynamic range is typically 80 dB (referred to 50Ω) with error less than $\pm 3\text{dB}$ and 74 dB with error less than $\pm 1\text{dB}$. The ADL5513 has 20 ns response time that enables RF burst detection to a pulse rate of beyond 50MHz. A supply of 2.7V to 5.5V is required to power the device, with current consumption of 31mA. As a measurement device, VOUT is externally connected to VSET to produce an output voltage, V_{out} that increases linear-in-dB with RF input signal amplitude. The logarithmic slope is 20 mV/dB (can be changed, in our case it is 40 mV/dB), determined by the VSET interface. The ADL5513 is fabricated on a SiGe bipolar IC process and is available in a 3mm X 3mm , 16-Lead LFCSP package for the -40°C to $+125^{\circ}\text{C}$ temperature range.

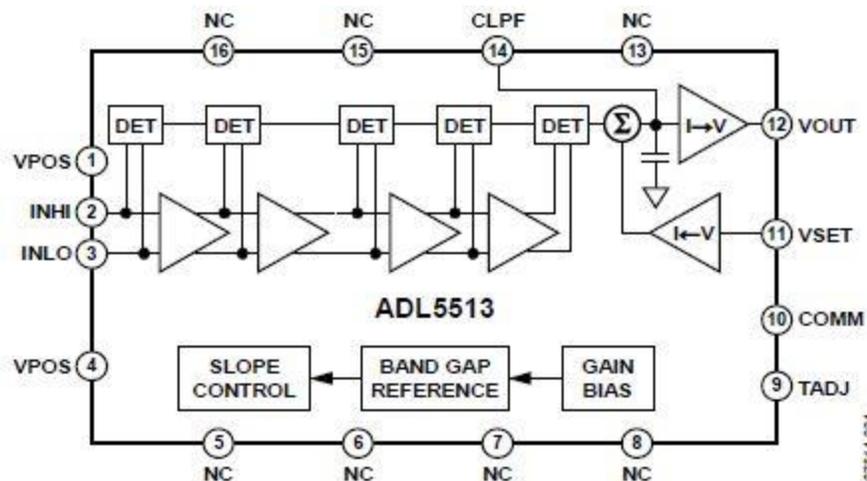


Figure 2: Functional Block diagram of ADL5513

a) Basic connections:

The ADL5513 is specified for operation up to 4GHz, as a result low impedance supply pins with adequate isolation between functions are essential. A power supply voltage of between 2.7V to 5.5V should be applied to VPOS. Connect 100pF and 0.1μF power supply decoupling capacitors close to this power supply pin.

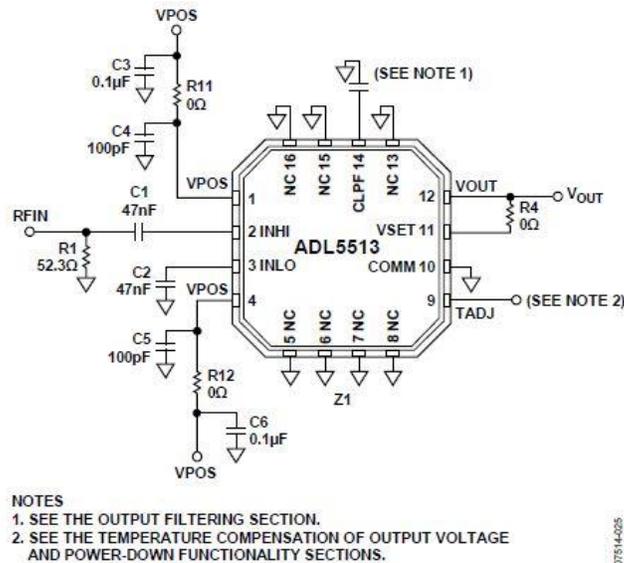


Figure 3: Basic Connections

The expose paddle of LFCSP package is internally connected to COMM. For optimum thermal and electrical performance, solder the paddle to low impedance ground plane. While the input can be reactively matched, in general this is not necessary. An external 52.3Ω shunt resistor (connected to single side of the input coupling capacitor as shown in figure 3.) combines with relatively high input impedance to give an adequate broadband 50Ω match. The coupling time constant $50 * C_C / 2$ forms a high pass corner with a 3 dB attenuation at $f_{HP} = 1 / (2\pi * 50 * C_C)$, where $C_1 = C_2 = C_C$. using a typical value of 47 nF, this high pass corner is approximately 68KHz (in our designed we have used $C_C = 330$ pF, which gives high pass corner approximately equal to 10 MHz). For applications in which maximum video bandwidth and consequently fast rise time are desired, it is essential that CLPF pin be left unconnected and free from any stray capacitance. The slope and output swing can be increased by placing

a resistor divider between VOUT and VSET. The input impedance of VSET is approximately 40kΩ. The slope setting resistors must be kept below 20kΩ to prevent this input impedance from affecting the resulting slope. If two equal resistors are used (in our case 10kΩ & 10kΩ), the slope doubles to approximately 40 mV/dB.

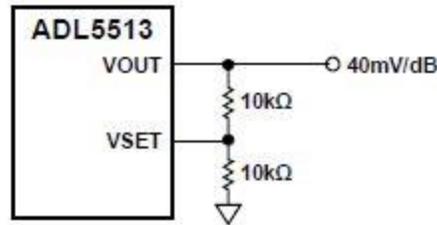


Figure 4: Increasing Slope

The required resistor values needed to increase the slope are calculated from the following equation:

$$\frac{R1}{R2} + 1 = \frac{Slope\ 2}{Slope\ 1}$$

Where: R1 => resistor between VOUT and VSET

R2 => resistor between VSET and ground

Slope 1 => nominal slope of ADL5513

Slope 2 => new slope

It is important to note that R1 and R2 must be properly sized, so that the output current drive capability is not exceeded.

3.2) Directional Coupler

a. **For Common Box (SYD-20-33+)**

It is a unidirectional 20 dB directional coupler from Mini-Circuits. Basically it is used to couple the signal from the main line for RF power measurement, without introducing much attenuation (loss) in the main line. It is the first component that is used in the RF power detector circuit. The electrical specification along with electrical schematic is shown in table 1 and Figure 5.

| FREQ. (MHz) | COUPLING (dB) | | MAINLINE LOSS ¹ (dB) | | DIRECTIVITY (dB) | | VSWR (:1) | POWER INPUT (W) |
|----------------|------------------|----------|------------------------------------|------|---------------------|------|--------------|-----------------------|
| | Nom. | Flatness | Typ. | Max. | Typ. | Min. | | |
| f_L - f_U | | | | | | | Typ. | Max. |
| 30-3000 | 20.8±0.8 | ±1.4 | 1.6 | 2.5 | 15 | 9 | 1.20 | 1 |
| 800-1000 | 21.5±0.5 | ±0.3 | 1.1 | 1.5 | 17 | 14 | 1.10 | 1 |
| 1700-2000 | 21.1±0.6 | ±0.5 | 1.3 | 1.8 | 20 | 15 | 1.15 | 1 |
| 2300-2700 | 20.8±0.7 | ±0.5 | 1.5 | 2.1 | 16 | 11 | 1.20 | 1 |

1. Mainline loss includes theoretical power loss at coupled port.

Table 1: Directional Coupler (SYD-20-33+) Electrical Specifications

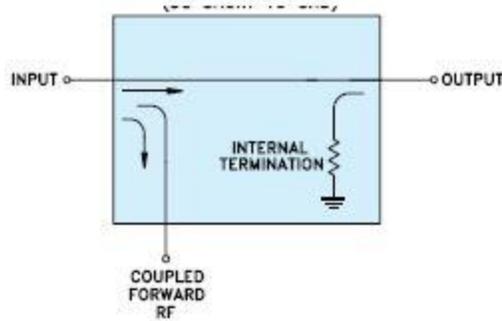


Figure 5: Directional coupler Electrical Schematic

b. For Front-End Box (TCD-9-1W+)

Again like common box directional coupler it is a unidirectional 10 dB directional coupler from Mini-Circuits. The electrical specification along with electrical schematic is shown in table 2 and Figure 5.

Electrical Specifications

| FREQ. RANGE (MHz) | COUPLING (dB) | | MAINLINE LOSS ¹ (dB) | | | | | | DIRECTIVITY (dB) | | | | | | VSWR (:1) | POWER INPUT, W | |
|-------------------------|------------------|----------|------------------------------------|------|------|------|------|------|---------------------|------|------|------|------|------|--------------|-------------------|------|
| | Nom. | Flatness | L | | M | | U | | L | | M | | U | | | Typ. | Max. |
| f_L - f_U | | | Typ. | Max. | Typ. | Max. | Typ. | Max. | Typ. | Min. | Typ. | Min. | Typ. | Min. | Typ. | Max. | Max. |
| 5-1000 | 8.9±0.5 | ±0.6 | 1.2 | 2.1 | 1.2 | 1.8 | 1.5 | 2.1 | 21 | 17 | 17 | 10 | 13 | — | 1.30 | 0.5 | 1.0 |
| 1000-2000 | 8.9±0.5 | ±0.6 | — | — | 2.5 | — | — | — | — | — | 10 | — | — | — | 1.60 | — | 1.0 |

L = low range [f_L to $10 f_L$] M = mid range [$10 f_L$ to $f_U/2$] U = upper range [$f_U/2$ to f_U]

1. Mainline loss includes theoretical power loss at coupled port.

Table 2: Directional Coupler (TCD-9-1W+) Electrical Specifications

3.3) RF Amplifier (GALI-52+)

It is a 20 dB wideband amplifier from Mini – Circuits in a SOT-89 package. The coupled input RF power from the directional coupler is given to this amplifier for amplification. The amplified signal is then given to the RF power detector discussed earlier. The recommended circuit is as shown in Figure 6.

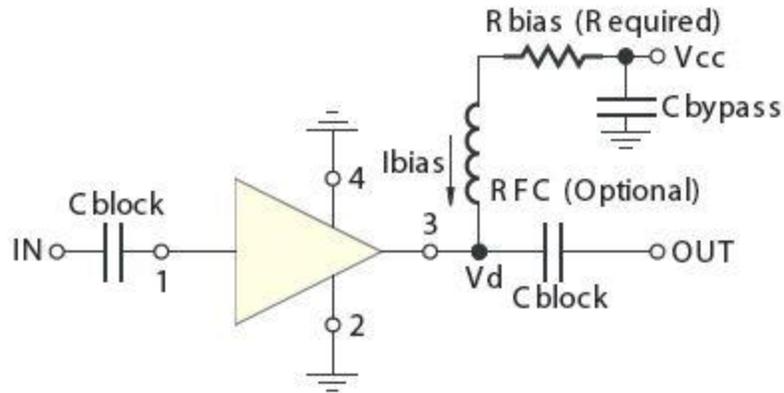


Figure 6: Application circuit for GALI-52+

As per the datasheet, for 12V supply R bias is 150Ω and RFC though optional we are using 1μH inductor as specified.

3.4) Total Integrated Circuit for CB

All the components where assembled, and interconnected as per the circuit diagram shown in figure 7.

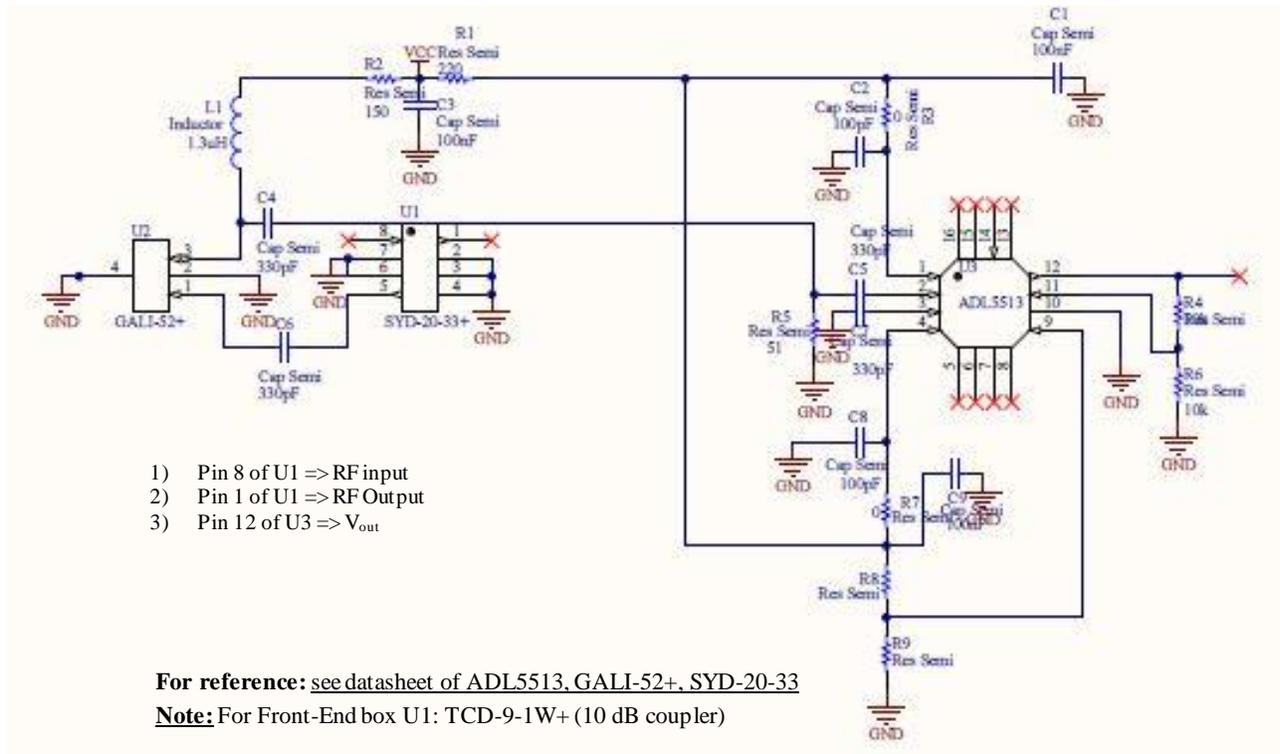


Figure 7: RF power Monitoring Circuit Diagram (Common box)

3.5) *Bill of Materials*

| Description | Designator | Footprint | Make | Value |
|---------------------|-------------|-------------|----------------|---------------------|
| Directional Coupler | U1 | | Mini-Circuits | |
| Amplifier | U2 | | Mini-Circuits | |
| Detector | U3 | | Analog Devices | |
| Inductor | L1 | Axial-0.6 | | 1 μ H |
| Capacitor | C1,C3,C9 | Chip (1210) | | 100 nF |
| Capacitor | C4,C5,C6,C7 | Chip (0805) | | 330 pF |
| Capacitor | C2,C8 | Chip (0805) | | 100 pF |
| Resistor | R1 | Axial-0.6 | | 220 Ω /0.25W |
| Resistor | R2 | Axial-0.6 | | 150 Ω /1W |
| Resistor | R5 | Chip (1206) | | 51 Ω /0.25W |
| Resistor | R4,R6 | Chip (1206) | | 10k Ω /0.25W |

Table: 3

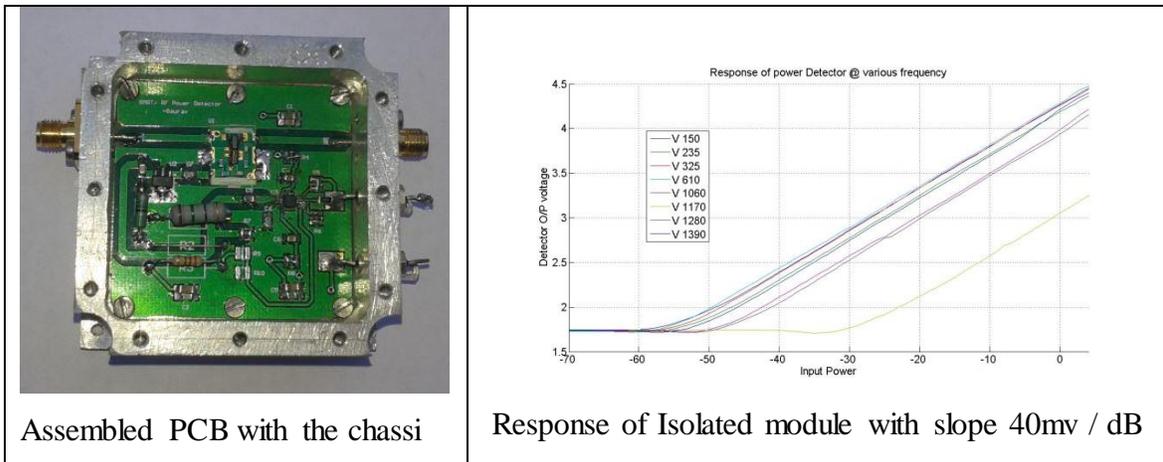


Figure: 8 Assembled PCB with it's response

The following figure show the entire power detector circuit integrated in common box and its response.

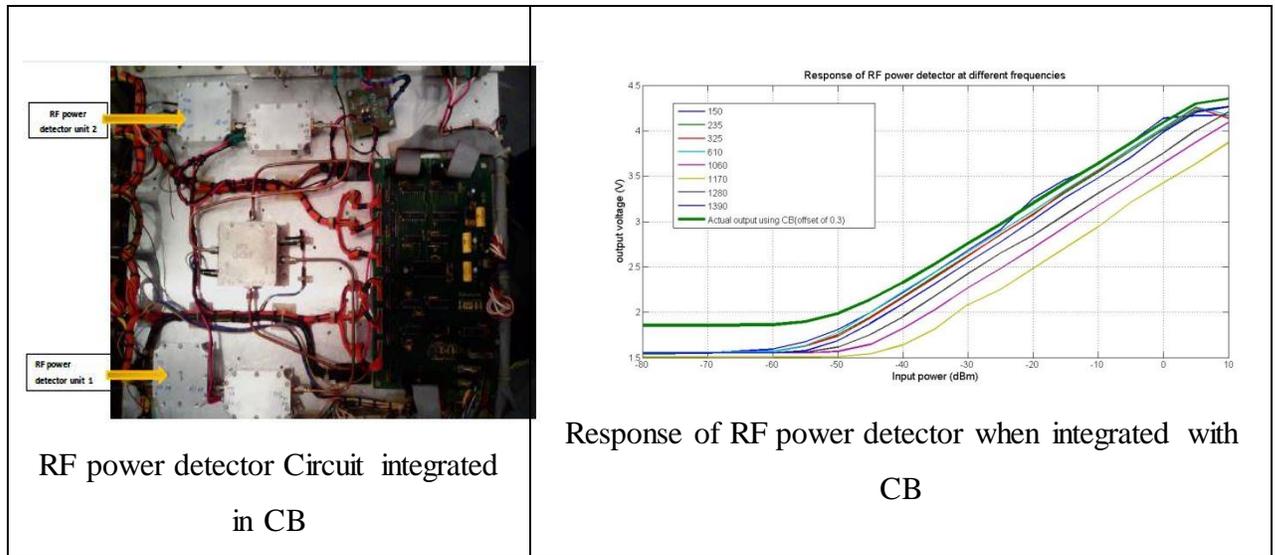


Figure: 9

3.6) Online monitoring of the installed system

The upgraded common box was then installed on antenna E02, after which its online monitoring and experiments were done. In order to find out the monitoring points the lab experiments were conducted and it was found that the data came on data channel number 19 (CH2) and data channel number 47 (CH1). (Please note: to map this data channels output of each power detector CH1 and CH2 was connected to pin 25 and 53 of MCM cards, which were pin 20 of respective BSCTL card).

This is shown in the figure below.

| Channel | Voltages |
|---------|----------|---------|----------|---------|----------|---------|----------|---------|----------|---------|----------|
| 0 | 0.039 | 11 | -3.203 | 21 | -3.242 | 31 | -2.969 | 41 | 0.156 | 51 | -3.203 |
| 1 | -3.281 | 12 | 0.039 | 22 | 3.438 | 32 | -2.969 | 42 | 0.234 | 52 | 2.383 |
| 2 | 0.039 | 13 | 0.039 | 23 | -3.242 | 33 | 0.234 | 43 | -3.203 | 53 | -5 |
| 3 | -3.281 | 14 | 0.078 | 24 | 1.797 | 34 | 0.234 | 44 | -3.203 | 54 | -0.938 |
| 4 | -3.281 | 15 | -3.203 | 25 | -5 | 35 | -2.969 | 45 | 0.156 | | |
| 5 | 0.039 | 16 | -3.203 | 26 | 0 | 36 | -3.008 | 46 | -3.203 | | |
| 6 | 0.039 | 17 | 0.078 | 27 | 0.156 | 37 | 0.195 | 47 | 2.812 | | |
| 7 | -3.281 | 18 | -3.203 | 28 | 0.234 | 38 | 0.234 | 48 | 0.117 | | |
| 8 | -3.281 | 19 | 2.969 | 29 | -2.969 | 39 | -2.969 | 49 | -3.203 | | |
| 9 | 0.039 | 20 | 0.117 | 30 | 0.234 | 40 | 0.195 | 50 | 3.516 | | |
| 10 | 0.039 | | | | | | | | | | |

1. Marked in yellow indicates RF power monitoring voltage.
2. Marked in blue indicates temperature monitoring voltage.

Figure: 10

As we can see that we get detector output voltage, which needs to be mapped to the corresponding input RF channel power (for e.g. as shown in the figure 2.969V corresponds to RF power of -25 dBm). Therefore a way of mapping was required for online monitoring.

3.6.(a) Mapping Methodology

For online monitoring, the output (Voltage) needs to be converted to the corresponding input RF power (dBm). For this the data acquired during monitoring (in the lab) was fitted using MATLAB curve fitting tool. And the equation was extracted. The extracted equation as follows:

$$P(V) = a_1 * e^{-\left(\frac{V-b_1}{c_1}\right)^2} + a_2 * e^{-\left(\frac{V-b_2}{c_2}\right)^2} + a_3 * e^{-\left(\frac{V-b_3}{c_3}\right)^2} + a_4 * e^{-\left(\frac{V-b_4}{c_4}\right)^2} + a_5 * e^{-\left(\frac{V-b_5}{c_5}\right)^2} \quad (i)$$

| | | | | |
|------------------|--------------------------|-------------------------|---------------|----------------|
| $a_1 = 3.613$ | $a_2 = -3.589 * 10^{15}$ | $a_3 = 0$ | $a_4 = 122.1$ | $a_5 = -37.47$ |
| $b_1 = 4.353$ | $b_2 = -8.921$ | $b_3 = 2.454$ | $b_4 = 7.34$ | $b_5 = 2.077$ |
| $c_1 = 0.006815$ | $c_2 = 1.895$ | $c_3 = 2.22 * 10^{-14}$ | $c_4 = 1.898$ | $c_5 = 1.513$ |

Note:

1. $P(V)$ *Input Power (dBm) as a function of Output Channel Voltage (V)*
2. V *Output Channel Voltage (Volts)*

The equation was tested against the curve fitted by the MATLAB software, and the output is as shown below:

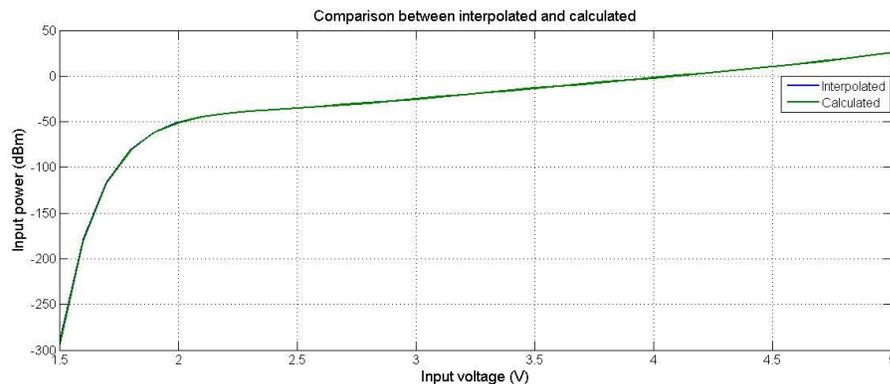


Figure: 11 Mapping function as compared to calculated

The extracted equation is a very good match.

3.6 (b) Final online monitoring

Initially the script was written by Mr. Jitendra of Telemetry dept. in order to validate the power monitoring is working. Once that was done the script was run, using online commands with help of control room staff (Mr. Sachin, Miss Shilpa).

The raw data which was coming at the desired channels were converted to voltage using following equation:

$$Voltage(V) = -5 + 0.001 * (raw\ data) * 39.0625 \dots\dots\dots (ii)$$

This voltage is then mapped to corresponding input RF power using mapping equation (i)

The voltage that was calculated from the raw count (CH1:198 and CH2: 204) corresponds to 2.8V and 2.9V respectively., which corresponds to input RF power of about -25 dBm as measured in the lab. Once this was verified, various other experiments was carried like finding power at other frequency band, noise on-off experiment and finally doing a source on-off experiment (some of the results are shown and analyzed below).

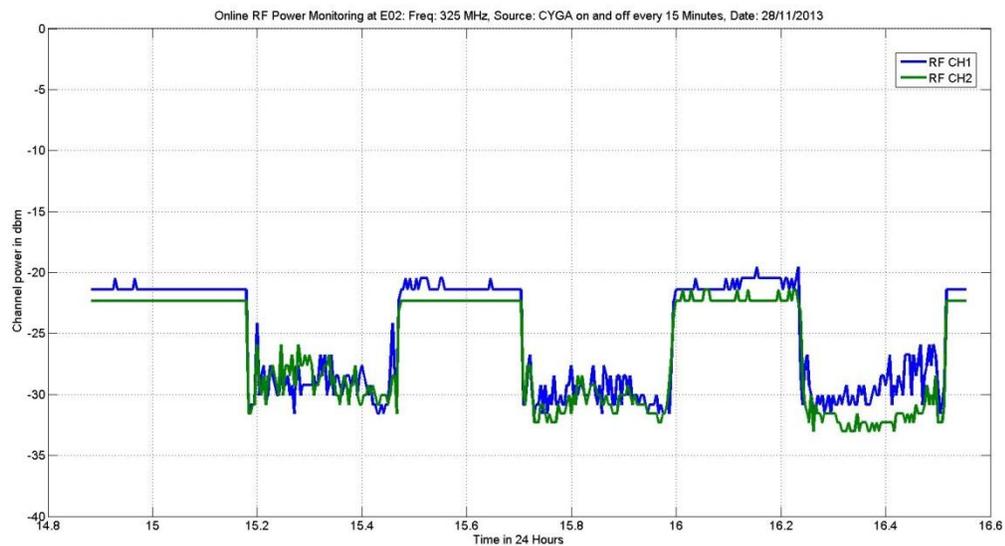


Figure: 12 ON-OFF deflection on CYGA using online power monitoring tool

| Noise Cal used | CH1 (1170 MHz) | CH2 (1170MHz) |
|-------------------|----------------|---------------|
| <i>Noise on</i> | -26.76 dBm | -25.90 dBm |
| <i>Noise off</i> | -33.72 dBm | -33.72 dBm |
| <i>High cal</i> | -30.05 dBm | -29.25 dBm |
| <i>Medium cal</i> | -31.57 dBm | -30.82 dBm |
| <i>Low cal</i> | -33.02 dBm | -31.57 dBm |

Table: 4

4.0) **Circuit design for Front end Box:**

The channel power which is to be measured is coupled to the RF power monitoring circuit by a 10 dB directional coupler from Mini-Circuits (TCD-9-1W+). After that, the coupled RF signal is amplified by a 20 dB amplifier from Mini-Circuits (GALI-52). Then the amplified signal is given to the Logarithmic power detector from Analog Devices (ADL5513), which gives a linear DC output voltage corresponding to the input RF power.

The entire circuitry is same except for the 10 dB coupler. The specifications are also the same.

5.0) Total Intergated Circuit for FE:

The schematic diagram is shown in figure 13.

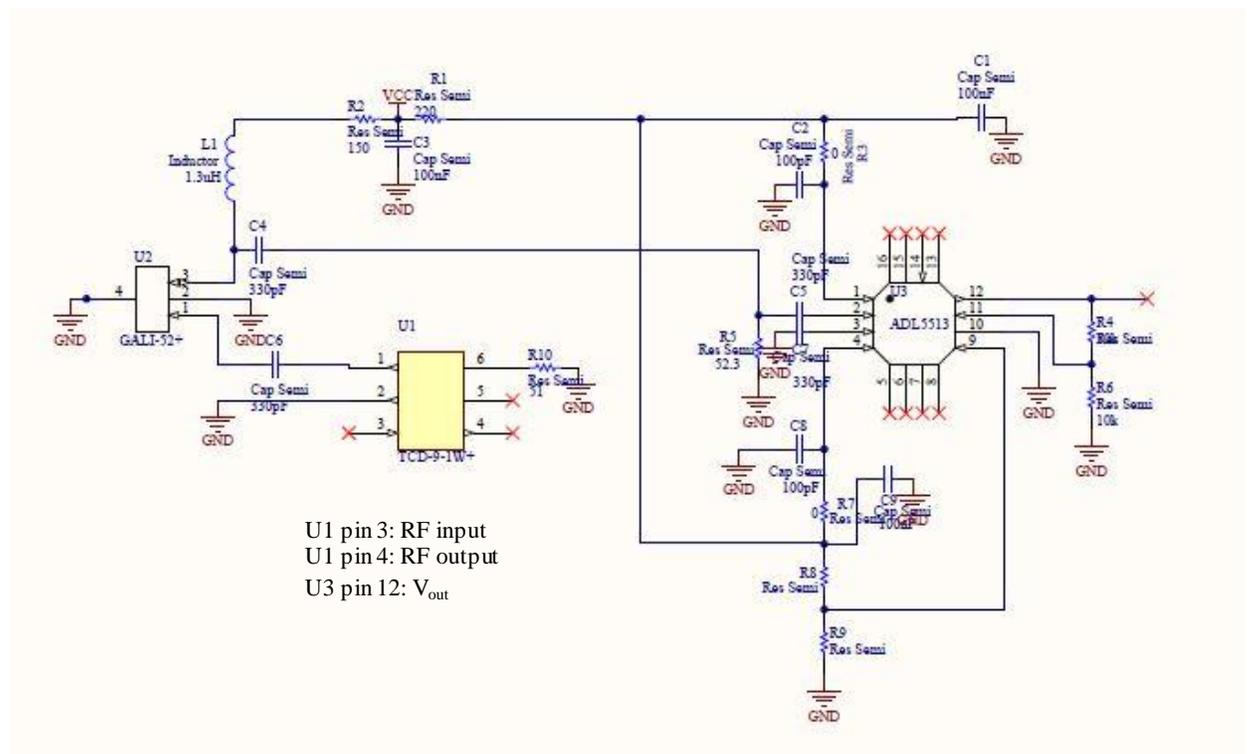


Figure 13: Schematic diagram for FE RF power monitoring

The bill of materials is shown in the following figure 15.

| Footprint | Comment | LibRef | Designator | Description | Quantity |
|--------------------|-----------|---------------------------|----------------------------|-------------------------------------|----------|
| C1210 | Cap Semi | Cap Semi | C1, C3, C9 | Capacitor (Semiconductor SIM Model) | 3 |
| ATC chip capacitor | Cap Semi | Cap Semi | C2, C4, C5, C6, C7, C8 | Capacitor (Semiconductor SIM Model) | 6 |
| Axial 0.6 | Inductor | Inductor | L1 | Inductor | 1 |
| Axial 0.6 | Res Semi | Res Semi | R1, R2 | Semiconductor Resistor | 2 |
| Boums | Res Semi | Res Semi | R3, R4, R5, R6, R7, R8, R9 | Semiconductor Resistor | 7 |
| RES_1206 | Res Semi | Res Semi | R10 | Semiconductor Resistor | 1 |
| ATC chip capacitor | TCD-9-1W+ | 10 dB directional coupler | U1 | 10 dB coupler | 1 |
| GALI-52 | GALI-52+ | Amplifier | U2 | Amplifier | 1 |
| ADL5513 | ADL5513 | Detector | U3 | Detector | 1 |
| | | | | | 23 |
| Approved | | Notes | | | |

Figure: 14 Bill of Materials-FE RF power monitoring

The performance of the isolated FE-RF power monitoring circuit is shown in figure 15.

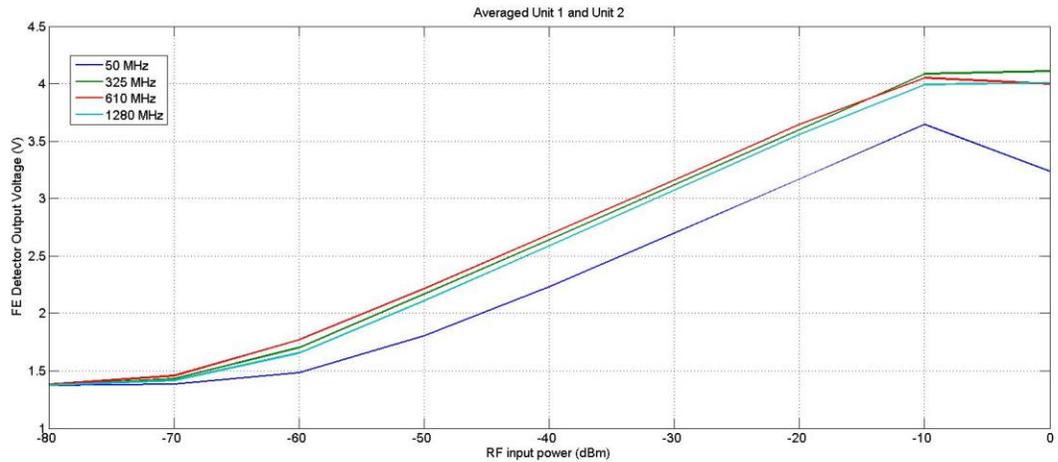


Figure 15: Isolated performance of FE-RF power Monitoring circuit.

6.0) Online Mapping for Frontend box:

For online mapping the detector output voltage is connected to the pin 8 (CH1) and 9 (CH2) of IC U12, Which is mapped to channel no. 28 and 27 respectively from the 32 monitoring points. The mapping formula for converting raw DC voltage to RF power in dBm is given below.

$$RF\ power\ (P) = \frac{(p_1 * V^4 + p_2 * V^3 + p_3 * V^2 + p_4 * V^1 + p_5)}{(V^5 + q_1 * V^4 + q_2 * V^3 + q_3 * V^2 + q_4 * V^1 + q_5)}$$

The coefficients are:

| | |
|----------------|----------------|
| $p_1 = -40.29$ | $q_1 = -11.24$ |
| $p_2 = 326.1$ | $q_2 = 48.01$ |
| $p_3 = -689.6$ | $q_3 = -101.2$ |
| $p_4 = -46.67$ | $q_4 = 114$ |
| $p_5 = 641.7$ | $q_5 = -54.67$ |

The mapping function was obtained using MATLAB, curve fitting toolbox and was tested against the measured one, which is shown in the next figure 16.

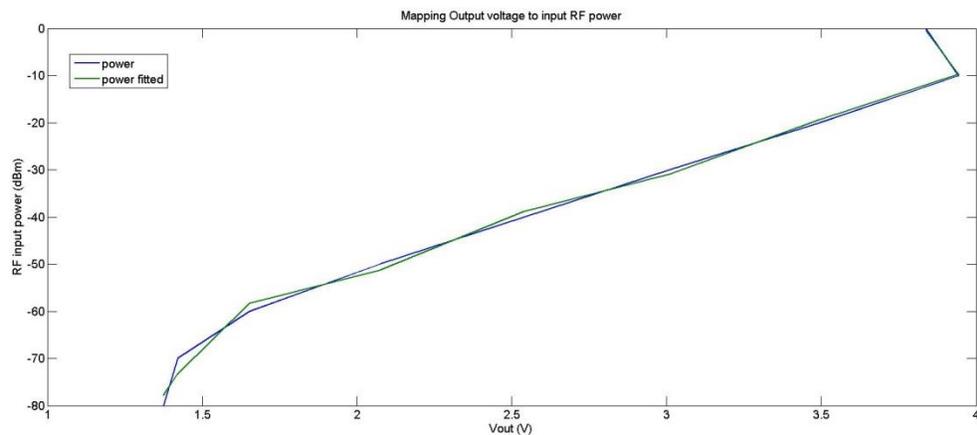


Figure 16: Mapping Function-FE as compared to calculated

7.0) Combined performance of FE and CB RF power detector

Once this both the power detector were ready and tested in the lab, they were installed in few of the antennae, out which C13 has both FE and CB RF power detector installed on it. The result obtained from some of the runs are shown in figure.17

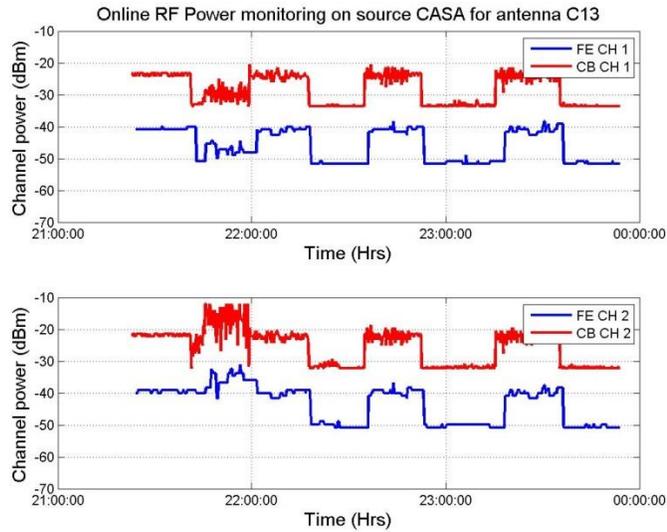


Figure.17

Only FE box performance is shown below

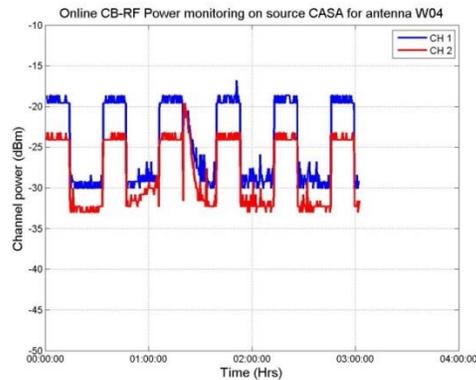
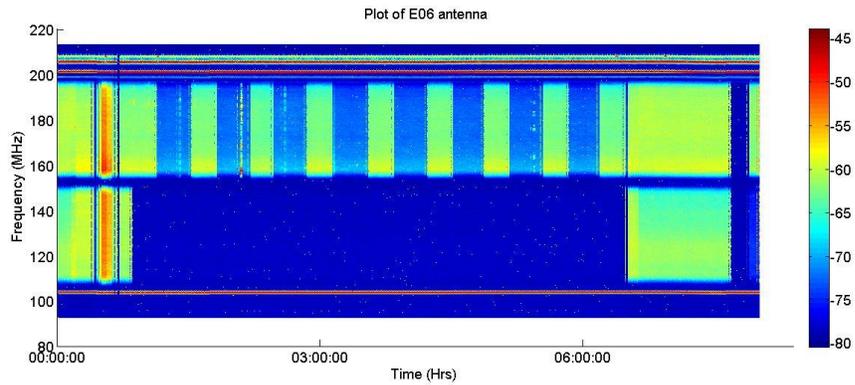


Figure. 18

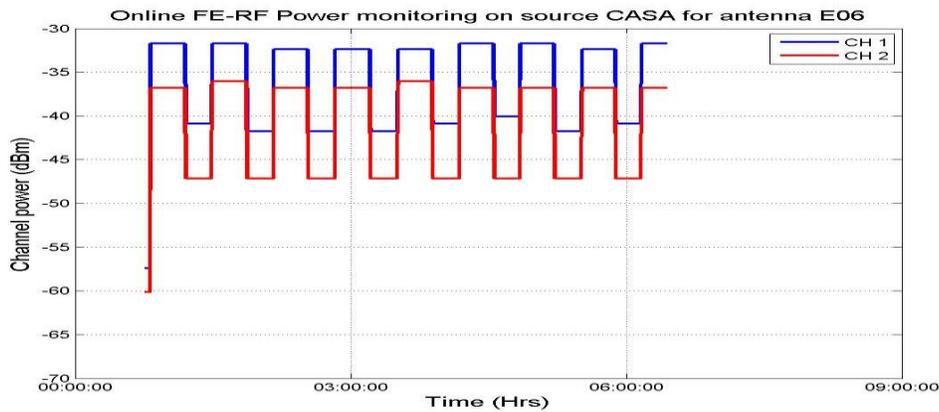
Form both the figure we see that

- I. Theoretically there should be 20dB power level difference between FE and CB. This due to different directional coupler used in both the circuit, as expected (Ref. figure 17)
- II. Whereas in figure 17. The granular type noise is due to quantization error of the ADC, also we see that there is power difference of about 5 db between two channels of same antenna. Thus can also be used as debugging tool.
- III. The unusual shape in 3rd iteration is due to RFI, confirmed using gray scale plot.

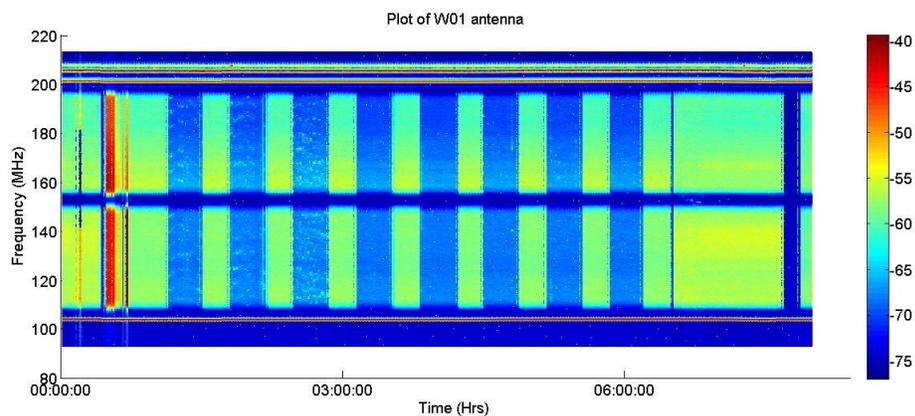
8.0) What kind of analysis that can be done using these detectors



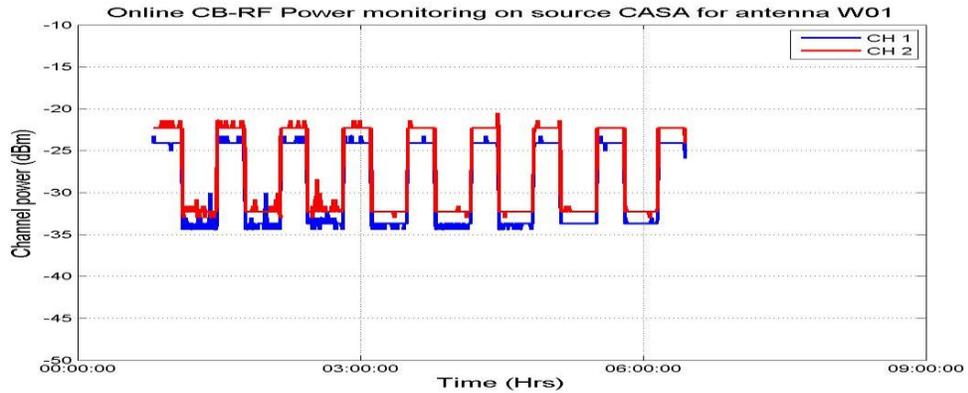
28_08_2014



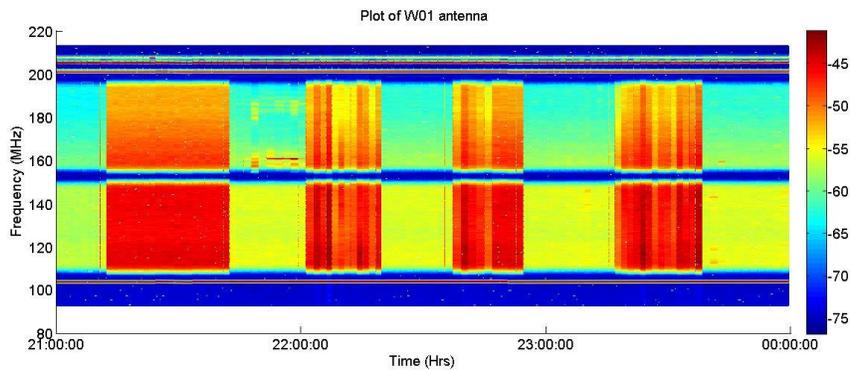
Note: We see that deflection in both channels is Ok, but there is power difference of nearly 5 dB. Also both channels are coming at FE-output, but 30:1 shows only CH2, this may raise a callsheet with CH1 no fringe. But actual problem might be after FE system or cable may be loose.



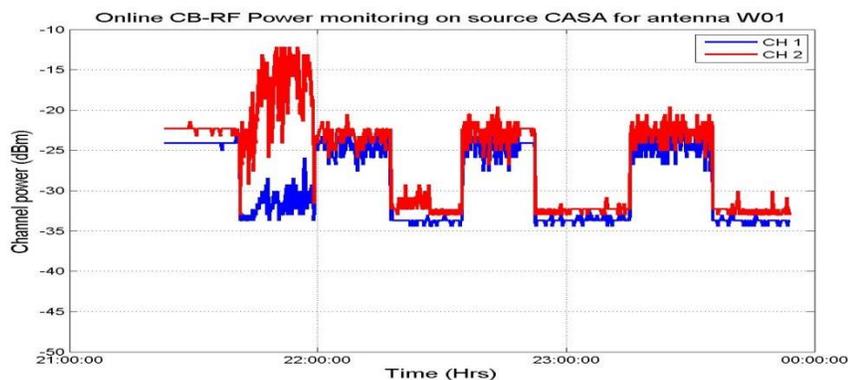
28_08_2014



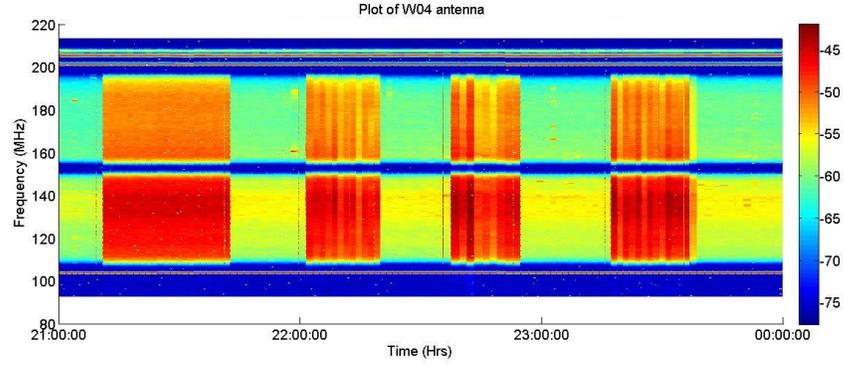
Note: We can see traces of RFI during 2nd and 3rd cycle. The small glitches are due to quantization error of ADC.



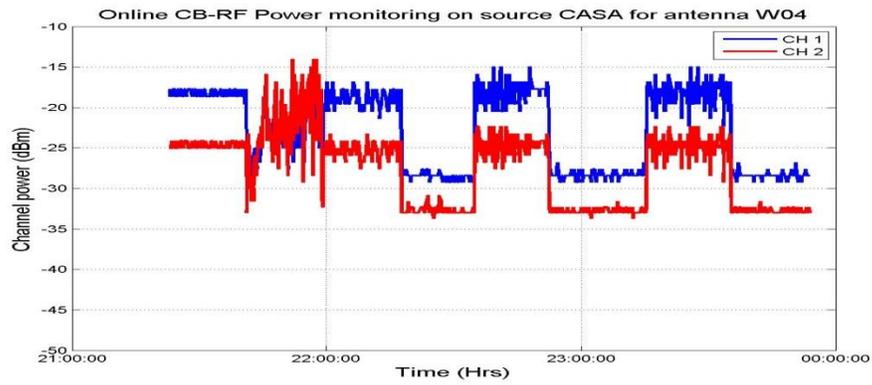
16_09_2014



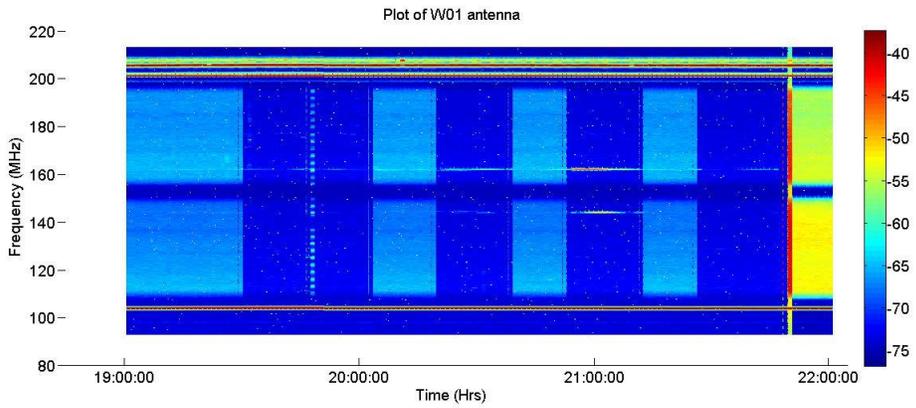
Note: Here at the end of 1st cycle, we see that in CH2 polarization there is some RFI kind of thing, but it is not seen in CH1, this might be internally generated due to leakage. But same phenomenon was observed in all the antennas on which detector was placed, so it might be a polarized RFI.



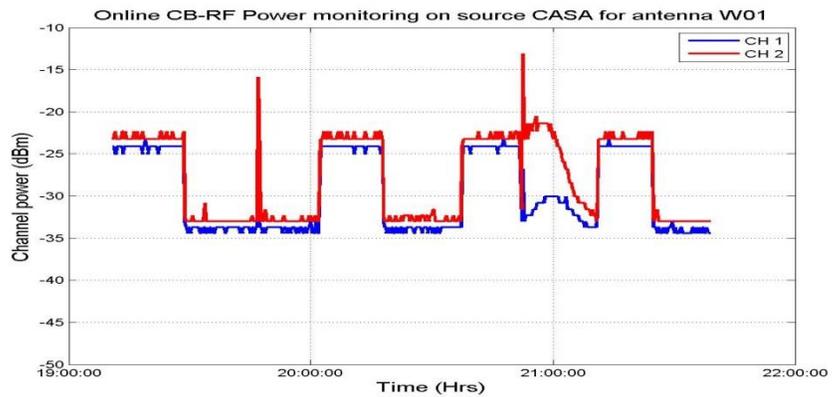
16_09_2014



Note: Same phenomenon is seen here also, as in W01.



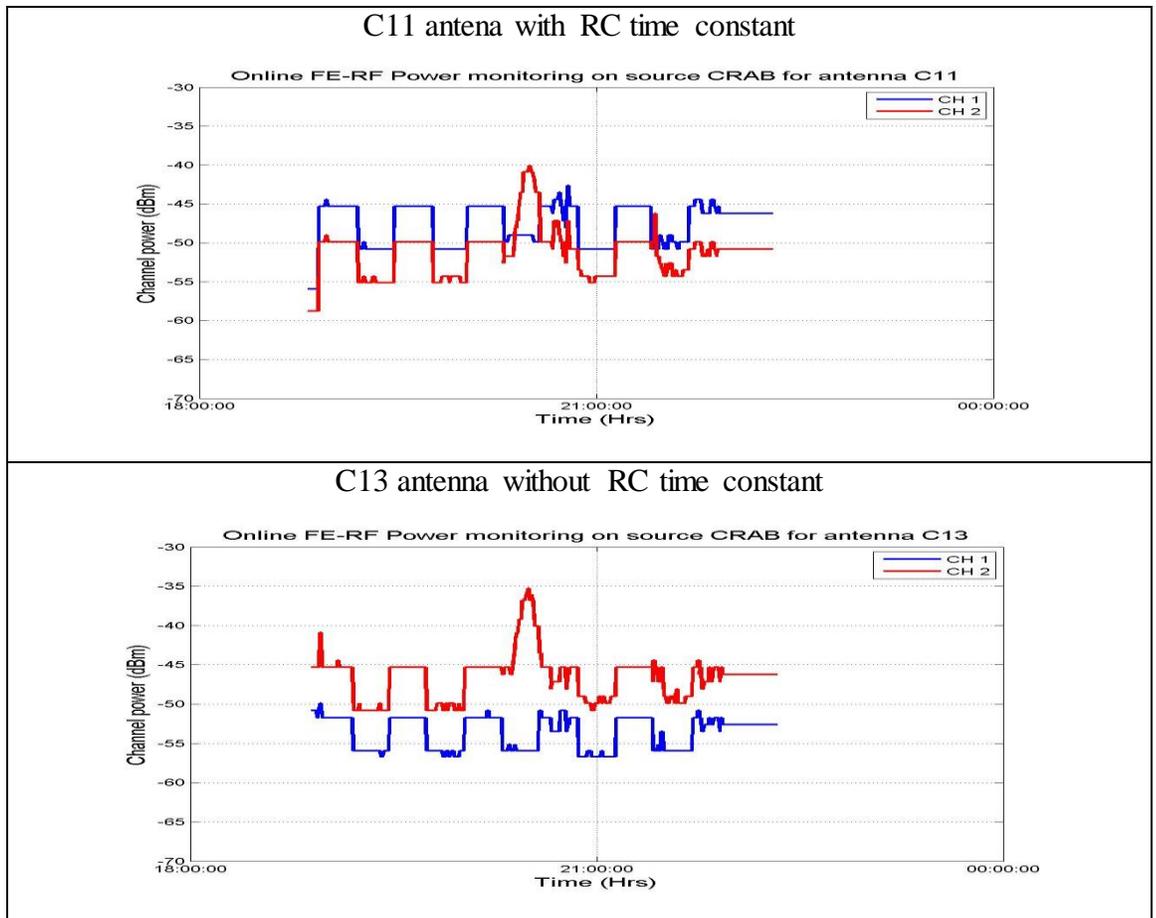
30_09_2014



Note: The sudden spike is due to external RFI and the weak RFI during end of the cycle (strong in CH2 but weak in CH1)

9.0) Conclusion and future scope

- a) Overall power detector is working for both FE and CB satisfactorily. Because of its repeatability and robustness, now it is in a mass production phase.
- b) SOP for online monitoring is tested and verified and already released.
- c) During analysis phase, it was found that the FE data has some memory related issue as it has to be scanned, and then data is acquired, thus not following the CB curve. This is the way the data monitoring system of GMRT is designed; so much can't be done about this.
- d) To filter out some of the noise, RC time constant of 100 msec will be introduced, and its effect will be analysed. After analysis it was found that not much effect is seen in with or without RC time constant.



- e) Ultimate aim is to automate this analysis process by way of making a GUI and this template can be used for other groups/departments

10.0) Reference

- a) Datasheet of analog devices power detector ADL5513, and Directional coupler from Mini-Circuits (SYD-20-33+ for CB and TCD-9-1W+ for FE)
- b) Tools used Altium designer for PCB design, Matlab for Analysis, and Signal generator during validating the performance of the detectors.

11.0) Appendix: A detailed SOP on how online RF monitoring is to be done

While performing online monitoring following steps are to be followed:

1. Select the mentioned antennae in **any of the available sub-array**.
2. Focus the feed for the corresponding frequency mentioned.
3. Set the corresponding RF , IF and respective LO for the mentioned frequency
4. Once that is done, do necessary changes in file named “**fetest.cmd**” stored at the location: **/odisk/gtac/cmd/gaurav/fetest.cmd** and save it with the same name (don't make copies of it) then run this command file.
5. Do the necessary changes in file named “**FECB1.sel**” stored at the location: **/odisk/systest/FE/FECB1.sel** and save it with the same file name.
6. After this start recording the data by using “table” command, note down it's process id (PID) and use the above file i.e **FECB1.sel** as the selection file. Give the file name in which the data needs to be recorded as input to “table” command. The data needs to record for every 15 (or mentioned) seconds.
7. Followed by this to stop recording automatically give this command in background > (sleep time in seconds; kill -9 PID) &

For your reference the command and selection file is given below.

Example: here sub array 2 was selected with 3 antenna in an array i.e C11 (09), C13 (11) and E02 (17) tracking on source CYGA according to this, the command file must be changed. Based on this proper sub-array command must be selected, in this case it is `/(gotosrc 5m 2)` for subarrya 2 . Please note that for which FE box this is to be used. In this case 325 MHz (number to be given as input to ufemon (box number, iteration))

Command file:

```
# Update on 09/NOV/2014 by Gaurav & Jayprakash.
cmode 1

suba 2
goout
gosacout
```

```
addlist'/odisk/gtac/source/cool.list'
```

```
ante 3 9 11 17  
cp 0;defs 2;subar 2  
enafemon
```

```
run mcm5on  
ana 00ff0x 00000x 00f00x 00000x  
stana 5  
stscan 5
```

```
$1
```

```
gts 'CYGA'  
sndsacsrc(1,10h)  
sndsacsrc(1,10h)  
#/(gotosrc)  
/(gotosrc 5m 2) for subarrya 2  
#/(gotosrc 5m 3) for subarrya 3  
#/(gotosrc 5m 5) for subarrya 5  
stabct
```

```
ufemon(3,20)  
#ufemon(1,20)  
#ufemon(2,20)  
#ufemon(4,20)  
#ufemon(5,20)  
# 1 - 150, 2 - 235, 3 - 325, 4 - 610 & 5- Lband
```

```
/bell  
gts 'OFFCYGA'  
sndsacsrc(1,10h)  
sndsacsrc(1,10h)  
#/(gotosrc)  
/(gotosrc 5m 2) for subarrya 2  
#/(gotosrc 5m 3) for subarrya 3  
#/(gotosrc 5m 5) for subarrya 5  
stabct
```

```
ufemon(3,20)  
#ufemon(1,20)  
#ufemon(2,20)  
#ufemon(4,20)  
#ufemon(5,20)  
# 1 - 150, 2 - 235, 3 - 325, 4 - 610 & 5- Lband
```

```

/bell

goto 1

end

```

⇒ Changes that need to be done (if required) before running the command file:

1. Whether the antenna will be **in inner track or outer one** during the course of monitoring.
2. The **number and list of antenna** taken must be mentioned (in this case 3 number of antennas were taken) e.g. ante 3 9 11 17
3. The **source** on which the antennas will be tracking must be changed (if required) by the given source e.g. 'CYGA' and 'OFFCYGA, etc.
4. For selected frequency band corresponding FE box number has to be updated in ufemon (3,20) -> ufemon (FE box number, number of iterations). For FE box number refer:
 - A. 150 MHz -> 1
 - B. 233 MHz -> 2
 - C. 325 MHz -> 3
 - D. 610 MHz -> 4
 - E. 1420 MHz -> 5

Selection File: FECB1.sel

```

# Update on 09/NOV/2014 by Gaurav & Jayprakash
# DO NOT CHNAGE WITHOUT CONSULTING Gaurav.

# 1 - 150 2 - 235 3 - 325 4 - 610 5- Lband
# Selection file:
{
  log_time f Abs_sec_to_date 0
  abcarray { 9 11 17 }
  {
    fe_mon { 3 }
    {
      tp_lna n
      tp_fe n
      detfe { * } n
      data { 24 25 26 27 28 } n
    }
  }
  abcarray { 9 11 17 }
  {
    commn_mon
    {
      new_det { * } n
      tp_cb f No_conversion 0
    }
  }
}

```

```
mcmarray { 5 }  
  {  
    para  
    {  
      scandata { 24 52 57 } n  
    }  
  }  
}
```

Changes that need to be done (if required) before using this selection file:

1. The **list of antenna** taken in an array has to be updated e.g. `abcarray { 9 11 17 }`
2. The **FE box** number has to be given as input to `fe_mon()`, e.g. `fe_mon { 3 }`. For FE box number, refer to the starting comment of the selection file.