National Centre for Radio Astrophysics

Technical Report on

Broadband Analog Backend Receiver System for uGMRT

Compiled By:

Sweta Gupta & N D Shinde

Analog Backend Group

Giant Metrewave Radio Telescope

Khodad-410504.

Author: Sweta Gupta &N D Shinde	Date of issue: 16/12/2015	GMRT/BES/001-Dec2015
Approved by: Ajith Kumar B	Status/ Version: Ver.1	Internal Technical Report No.: R273

ACKNOWLEDGEMENT

We are thankful to Prof. Yashwant Gupta (Dean of GMRT) and Prof. S K Ghosh (Center Director of NCRA-TIFR) for giving constant support during this work.

We would like to say sincere thanks to Telemetry group for help us understanding New MCM card. We are also thankful to RFI group for RFI measurements of newly designed SMPS power supplies. We are also thankful to the Frontend team for providing band pass Filters design used in GAB system. We would also like to thank Digital Backend group, for support during the performance and reliability test of the GAB system. We are very much thankful for all those who helped in completing the assignment successfully. We wish to express our sincere gratitude to all our Analog Backend colleagues.

GMRT ANALOG BACKEND SYSTEM Team Member

1. Shri. Ajithkumar B.
2. Mrs. Sweta Gupta
3. Shri. Shinde N. D.
4. Shri. Phakatkar S. V.
5. Shri. Nanaware D. K.
6. Shri. Hande P. J.
7. Shri. Ganla A. A.
8. Shri. Dhende A. T.
9. Shri. Vishwakarma A.M.
10. Shri. Gadge S. B.
11. Shri. Shigwan R. B.

ABSTRACT

The backend receiver system of the Giant Metrewave Radio Telescope (GMRT) is being upgraded and the modifications being implemented in the analog and digital sections of these receivers cater to the improved specifications of the upgraded GMRT (uGMRT).

The main specifications related to the analog section are the ability to process 30 dual polarized RF signals at the central station for a frequency range from 130 to 1600 MHz with seamless frequency coverage, and an instantaneous maximum bandwidth of 400 MHz.

This report describes the design details, implementation scheme and set-up for testing of the Receiver. It also includes the test results; lessons learned and further possible improvements in this upgrade activity.

List of Figure

1. GMRT Analog Backend System (GAB SYSTEM)

1.1 Introduction:

A versatile Analog Back-end System (GAB) has been developed to process the RF signal received from antennas using high dynamic range circuits. The modifications being implemented in analog and digital backend receivers will improve the overall specifications of the Backend receiver. The major up gradation related to the analog section includes complete processing of the RF signals at the Central Electronic Building (CEB), seamless frequency coverage up to 1600 MHz and an instantaneous bandwidth of 400 MHz (max).

1.1.1 Requirement of GAB system:

As mentioned above, upgraded GMRT frequency bands i.e. seamless frequency coverage from 100 MHz up to 1600 MHz required to bring directly through optical fiber at central electronics building (CEB) for further digitization process. This OFC signal includes the desired band signal as well as other noise from rest of the frequencies. It is not feasible to directly digitize OFC output signal frequencies directly due to limitations of ADC's.
Hence higher RF frequencies are down converted in to lower frequencies and sent to ADC units. To serve this purpose as well as to adjust the input power level to ADC unit, a baseband signal converter system is designed and named as GAB system.

GAB system also provides the facility about wave shaping in different band widths. This is achieved by various types of band pass filter circuits.

GAB system provides noise injection facility at two stages, which is important for the calibration of complete receiver chain.

GAB system also provides better signal amplification, improved signal to noise ratio, improved dynamic range etc.

1.1.2 Analog backend system specifications:

- Input Freq : 30 - 1600 MHz
- Input Power: -24 dBm
- Max Bandwidth : 400 MHz
- Headroom : 27 dB
- Output power : -12 dBm
- Noise Contribution to FE < 0.01 K
- Filter bank – 7 filter selection
- 3 BB converted signal
- Power detector at input and output
- Noise + CW calibration signal at input
- Noise (var corr) calibration at ADC input.

1.1.3 List of components:

- Directional Coupler : SYD-20-33+
- High isolation SPDT switch : M3SWA-2-50DR+
- RF Amplifier : SBA 5089A, GALI-84+, GALI-6+
- Digital Attenuator : HMC472LP4E
- 8-Way Non-Reflective Switch : HMC253QS24E
- Mixer : SYM 2500+
- Directional Coupler : PDC-20A-5+
- Power Splitter : PRSC-2050
- Buffer : LMH6559
- RF detector : ADL5513

1.1.4 RF signal Chain Analysis:

For RF signal chain budget analysis, an Excel spreadsheet has developed to calculate RF parameters like Gain, Noise Figure, P1 dB, IP3, CDR, SFDR, Headroom, Noise Density, Power consumption in the system etc.

Calculations are completed for Freq. 100MHz, 1000MHz and 1500MHz.The summary of the cascade analysis is shown in Table1 below.

Table1: Cascade RF signal channel analysis

	@100 MHz RF	@1000 MHz RF	@1500 MHz RF
Input Power	-24 dBm	-24 dBm	-24 dBm
Output Power	-12.62 dBm	-12.75 dBm	-12.93 dBm
Power Gain	11.38 dB	11.25 dB	11.07 dB
Noise Figure	19.1 dB	19.91 dB	20.31 dB
Output P1 dB	14.9 dBm	14.9 dBm	14.9 dBm
Output IP3	27.09 dBm	29.6 dBm	30.06 dBm
CDR	72.29 dB	71.56 dB	71.36 dB
SFDR	56.32 dB	57.53 dB	57.69 dB
HeadRoom	27.52 dB	27.65 dB	27.83 dB
O/p Noise Density	-143.41dBm/Hz	-142.71dBm/Hz	-142.49dBm/Hz
Noise Temp @FE in	0.0096 K	0.0116 K	0.0127 K
Power Consumption	2.45 Watts	2.45 Watts	2.45 Watts

1.1.5 How GAB design completed?

First a scheme of expected GAB receiver was put considering the RF powers in various bands directly coming to Receiver room. As per scheme primary circuits/units were developed. This development was done using available components. After achieving the expected results of the same, prototype design was started.

For the prototype design, the best suited components/modules were selected. The study of parameters and comparison gave the clear ideas for the final selection of new components/modules. In the initial stage new components/modules were received as samples. Simultaneously, GAB system flow chart was analyzed using the Spectrum microwave CASCADE7.0 simulation software for RF parameter cascade study.

After cascade analysis, prototype units were designed using samples of new components/modules. With this design various tests were carried out and the results of integrated testing were compared with simulated software test results.

At this stage final design concepts were become clear to proceed for mass production. Simultaneously integrated testing results became useful to design and estimate the rack fittings, power supplies, cables etc.

Also during mass production power supplies, cable-connector assemblies to rack, mechanical rack fitting designs were completed.

After mass production of all PCB’s, units were assembled in chassis and characterized individually. The same test method was carried out at PIU and integrated system level. Thus, installation for complete 30 antennas system with spares completed successfully.

1.2 Basic block diagram of GAB System:

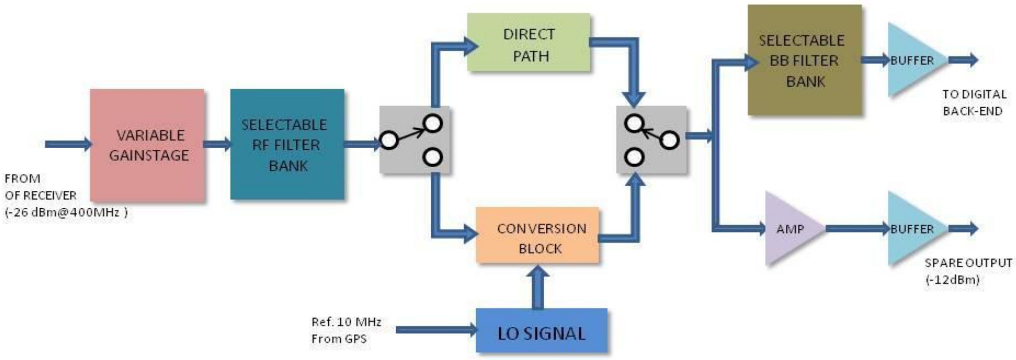


Fig 1.2: Basic block diagram of GAB system

1.2.1 Description of signal processing flow:

The incoming RF signal is passed through a variable gain circuit whose gain can be adjusted in steps of 0.5 dB so that any variation in signal levels between antennas can be corrected at this stage and the ADC will receive same power levels. The RF signals are then passed through a RF filter bank which will have same filter as the one used immediately after the feed being used. This filter is used to improve the out of band rejection and provide a clean signal to the later stages. Since the ADC is operating at 800 MHz sampling rate, we need to down convert all signals above 400 MHz to a lower frequency. So the frequency conversion stage is provided with a bypass stage so that whenever the observation frequency is lower than 400 MHz, one can use the bypass path and the RF signal will be directly given to the ADC circuits.

For RF bands above 400 MHz a suitable LO signal is to be used to down convert the signal to 0 to 400 MHz range. The mixer unit is followed by a 400 MHz low pass filter section to attenuate the high frequency signals due to LO/RF leakage. The baseband signals thus generated are provided as two outputs, one directly as a 400 MHz signal (spare output) and the main output with a baseband filter bank which provides a facility for 100, 200, 400 MHz filter selection based on observation requirements. The power levels are adjusted for the ADC linear range.

The Local oscillator for the mixer is generated from a 10 MHz reference signal provided by the GPS disciplined Rubidium oscillator which is the T&F standard used at the observatory. There are two ways in which the LO signal is generated. A common Signal generator which covers the full frequency range is locked to this 10 MHz reference. The output of this unit is amplified and distributed to down conversion units for all 30 antennas. This provides a facility for setting a common LO for all antennas, but provides facility to vary the set LO frequency in steps of 1 Hz. A second LO generation scheme uses individual Lo signals generated in the range 600 to 1700 MHz in 0.5 MHz steps. Here individual antennas can be set to different LO frequencies as per requirement.

The system also provides complete control & monitor of the parameters and health of the system through online and also facilities to monitor the signal levels at various stages in the receiver. A facility also exists to inject a noise or CW to the circuits to check the gain and other system parameter without removing the units from the rack

1.3 Detailed Block diagram of GAB system:

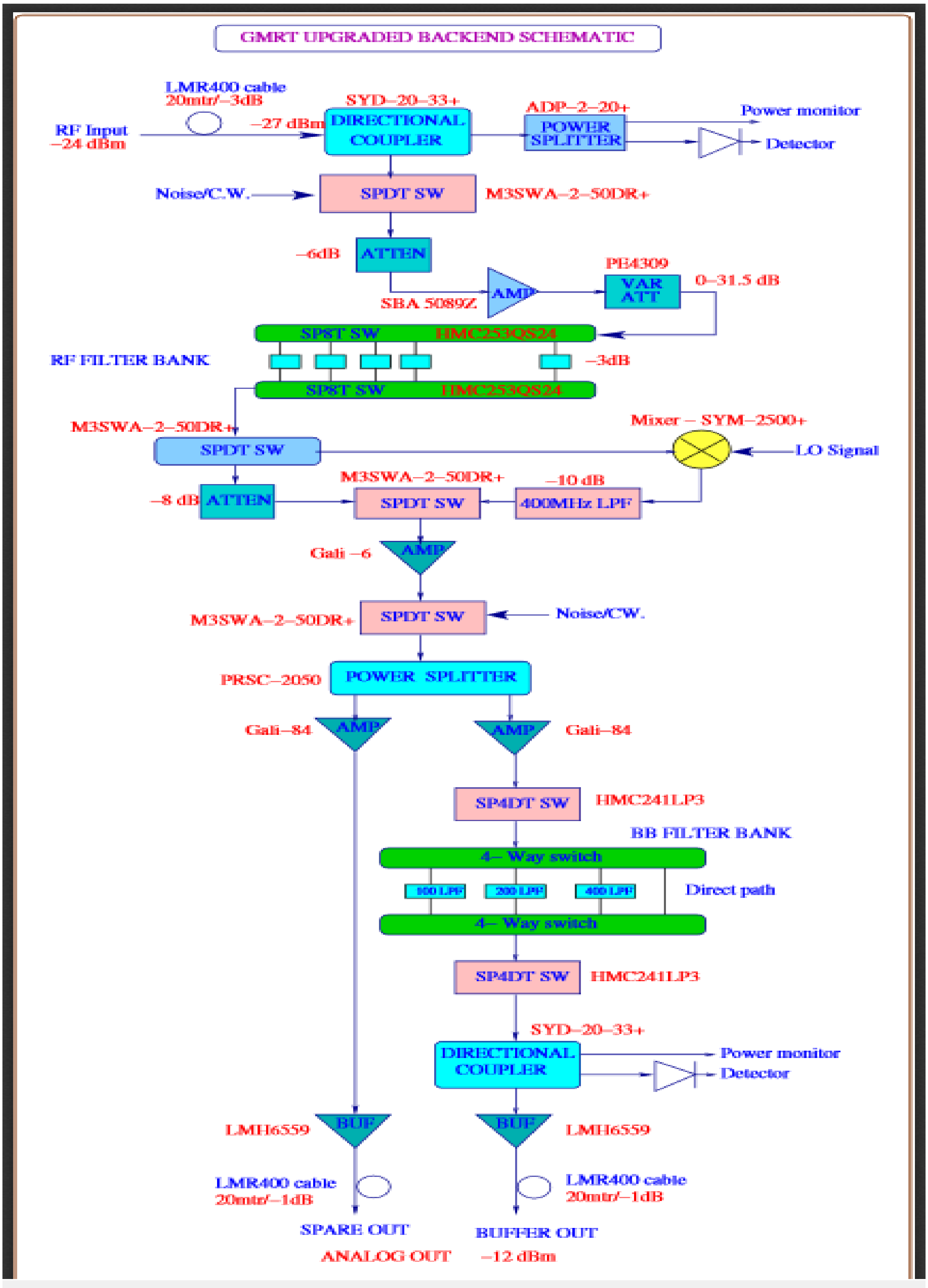


Fig1.3: Detailed Block diagram of GAB system

1.3.1 Description:

The RF signal received from antenna with an input level of -24dBm is first passed through a Mini circuits make directional coupler SYD-20-33. The coupled output is then passed through 2-way power splitter for power monitoring and detection. The direct output of SYD-20-33 then fed through 2-way absorptive RF switch M3SWA-2-50DR+ which is used to provide noise /CW injection facility.

Further, GALI-84+ is used for required RF amplification and PE4309 Peregrine make step attenuator is used to adjust power level variations with 0.5 dB step size.

Then output is fed to RF filter bank unit which includes 8 way switch HMC253QS24E .

For desired filter selection and is used for selecting the various filters i.e. 100 MHz Low Pass Filter, 130-260 MHz Band Pass Filter, 250-500 MHz Band Pass Filter, 550-900 MHz Band Pass Filter, L-Band Band Pass Filter and it also have Direct Path and a facility to connect external filter. After that using M3SWA-2-50DR+ (2-way absorptive switch) there is a provision to select direct path or mixer path for frequency conversion. The converted signal is then amplified and also noise/CW signal injection facility is provided at this stage. This switch is then followed by a 2-way power splitter, from which one of the output is taken as Spare out and another is passed through base band filter bank which incorporates 4way switch following with 100MHz, 200MHz, 400MHz LPFs. It also has a facility to connect external filter if required. Selectable output is connected to a Buffer amplifier. A coupled output is taken for Monitor purpose.

The ADL5513 IC is used as RF detector capable of accurately converting an RF input signal to a corresponding decibel-scaled output.

1.4 Ideal Response of System:

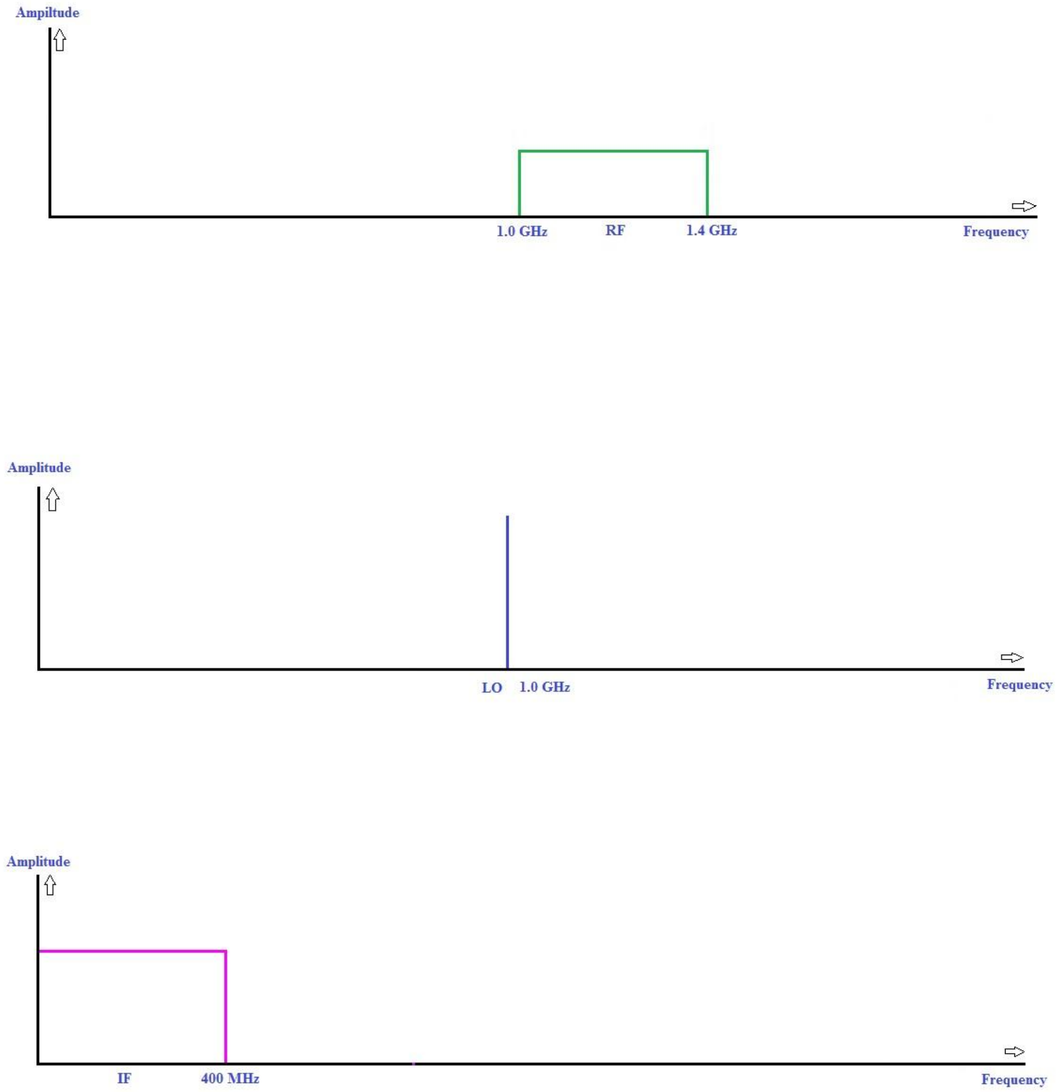


Fig1.4: Ideal response of system

1.5 Measured response of GAB system:

1.5.1 Input Spectrum of Analog Backend system:

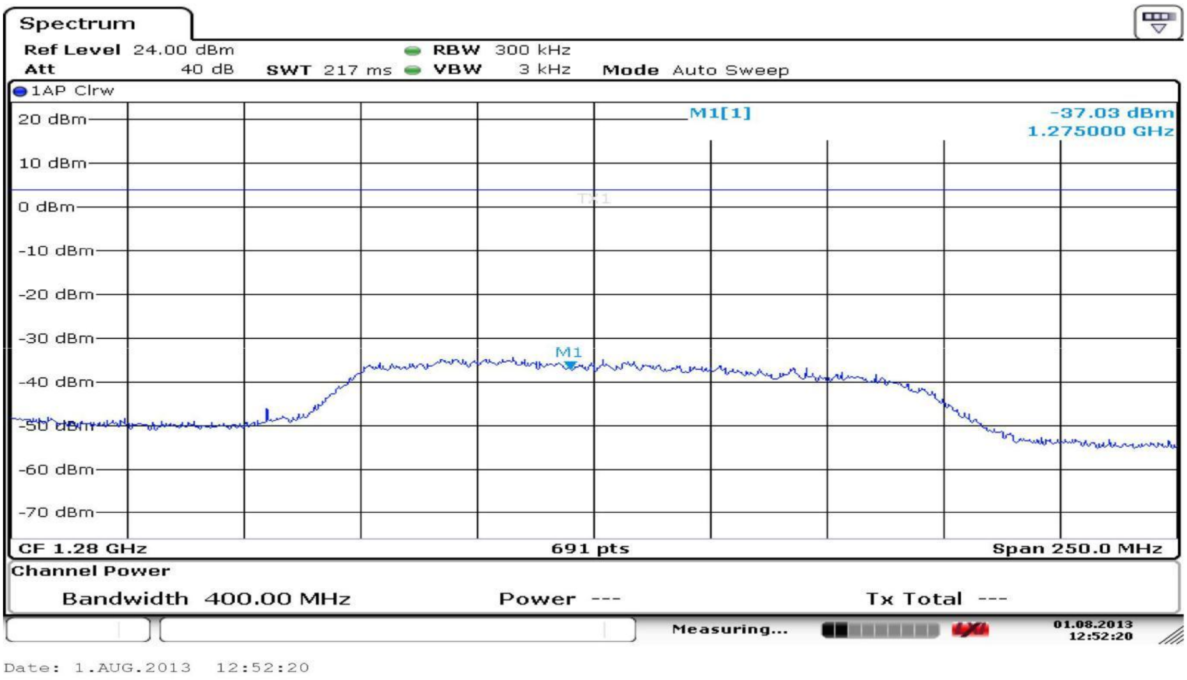


Fig1.5.1: Input Spectrum of Analog Backend system:

1.5.2 Output Spectrum of Analog Backend system:

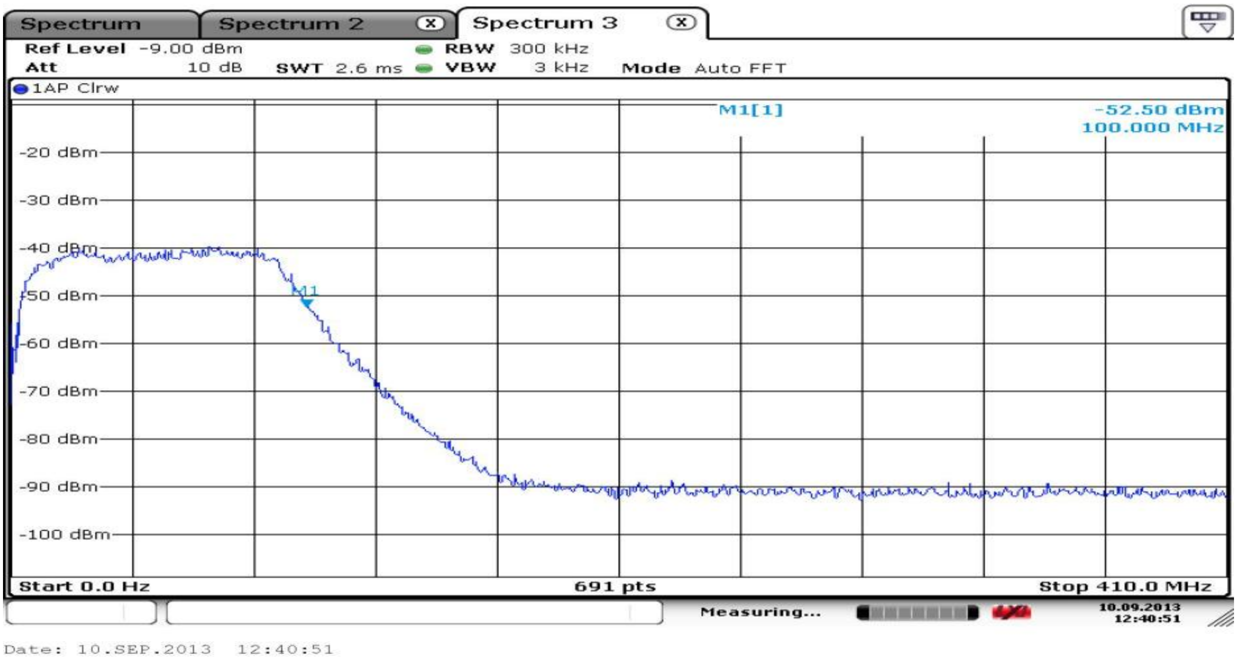


Fig 1.5.2.1: Output Spectrum of Analog Backend system With 100 MHz Bandwidth

Fig 1.5.2.2: Output Spectrum of Analog Backend system With 200 MHz Bandwidth

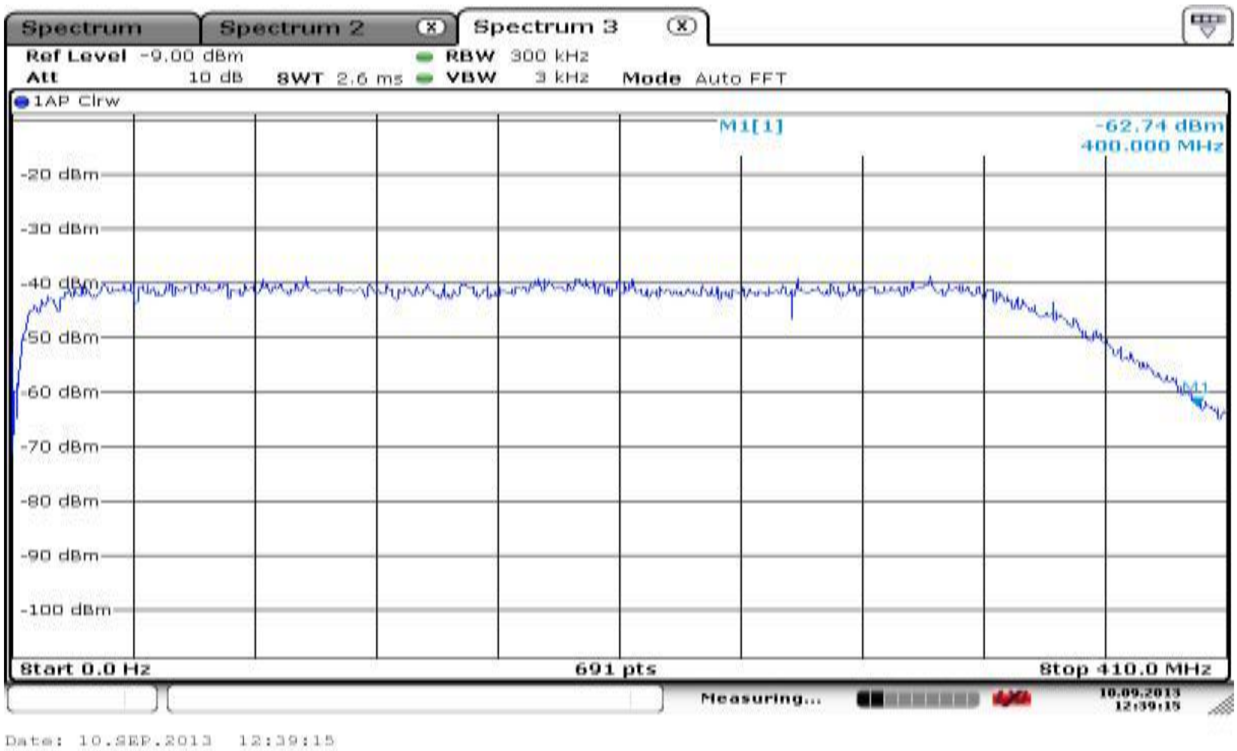


Fig 1.5.2.3: Output Spectrum of Analog Backend system With 400 MHz Bandwidth

2 Analog Receiver PIU

2.1Block diagram of Analog Receiver PIU:

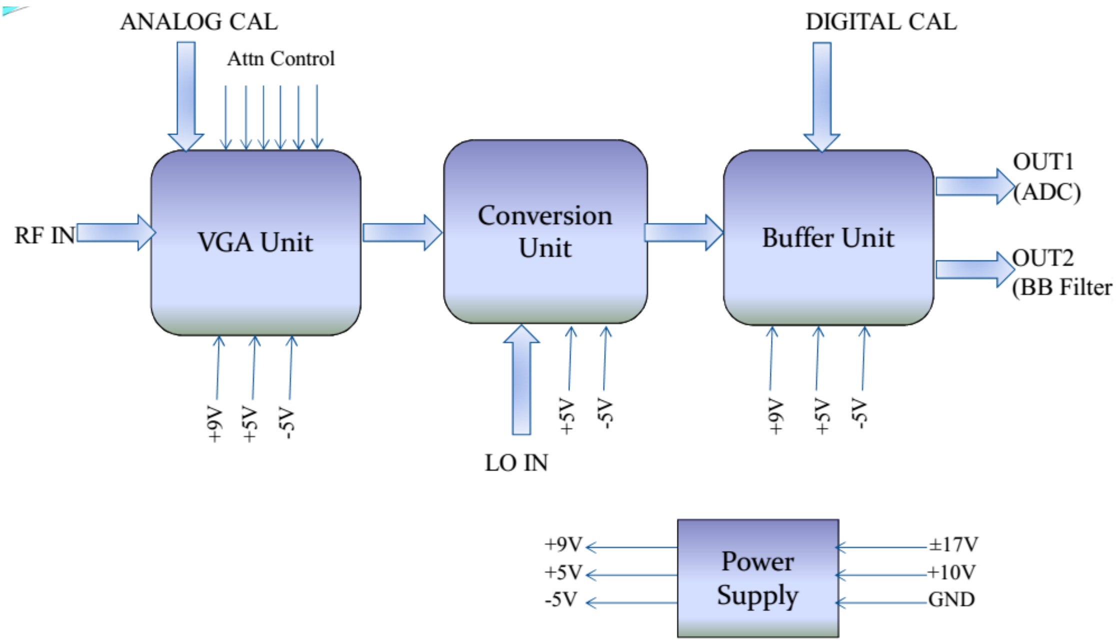


Fig2.1: Block Diagram of Analog receiver PIU

2.2 Description:

At the first, RF signal received from antenna is passed through a variable gain amplifier (VGA) unit whose gain, can be adjusted in steps of 0.5 dB so that any variation in signal levels between antennas can be corrected at this stage. Since the ADC is operating at 800 MHz sampling rate, we need to down convert all RF signals which are above 400 MHz to a lower frequency. For down conversion, frequency conversion unit is provided with a bypass stage so that whenever the observation frequency is lower than 400 MHz, one can use the bypass path and the RF signal will be directly given to the ADC circuits. For RF bands above 400 MHz, a suitable LO signal from 600 MHz to 1700 MHz is to be used to down convert the signal from 0 to 400 MHz range. The mixer unit is followed by a 400 MHz low pass section to attenuate the high frequency signals due to LO/RF leakage. Buffer is used for drive the signal through RF Cable up to ADC input.

2.2.1 VGA unit:

The variable gain amplifier unit includes Minicircuits make directional coupler SYD-20-33+ which is wideband i.e. 30-3000 MHz, low mainline loss of 1.6 dB typ. with excellent VSWR, 1.15:1 typ. at all ports.

It has 2-way absorptive RF switch M3SWA-2-50DR+ with an operating range from DC to 4500MHz and it provides high isolation, 65dB at 1GHz with low insertion loss 0.7dB.

GALI-84+ is used for RF amplification which has operating frequency range from DC to 6 GHz and it provides High gain, 25.6 dB typ. at 100 MHz with 38dBm IP3 and 21.9P1dB.

IC PE4309 Peregrine make step attenuator is used to adjust power level variations.

This product is a high linearity, 6-bit RF Digital Step Attenuator (DSA) covering a 31.5 dB attenuation range in 0.5 dB steps. The Peregrine 50Ω RF DSA provides a parallel CMOS control interface and it operates on 3-volt to 5-volt supply. It maintains high attenuation accuracy over frequency and temperature and exhibits very low insertion loss and low power consumption. To monitor power levels at front panel, 2 way RF divider ADP-2-20 is used which has operating frequency 20 to 2000MHz with low insertion loss, 0.7 dB typ.

The ADL5513 IC is used as RF detector capable of accurately converting an RF input signal to a corresponding decibel-scaled output. The ADL5513 maintains accurate log conformance for signals between DC to 4 GHz. The input dynamic range is typically 80 dB (re: 50 Ω) with error less than ±3dB.

2.2.2. CNV Unit:

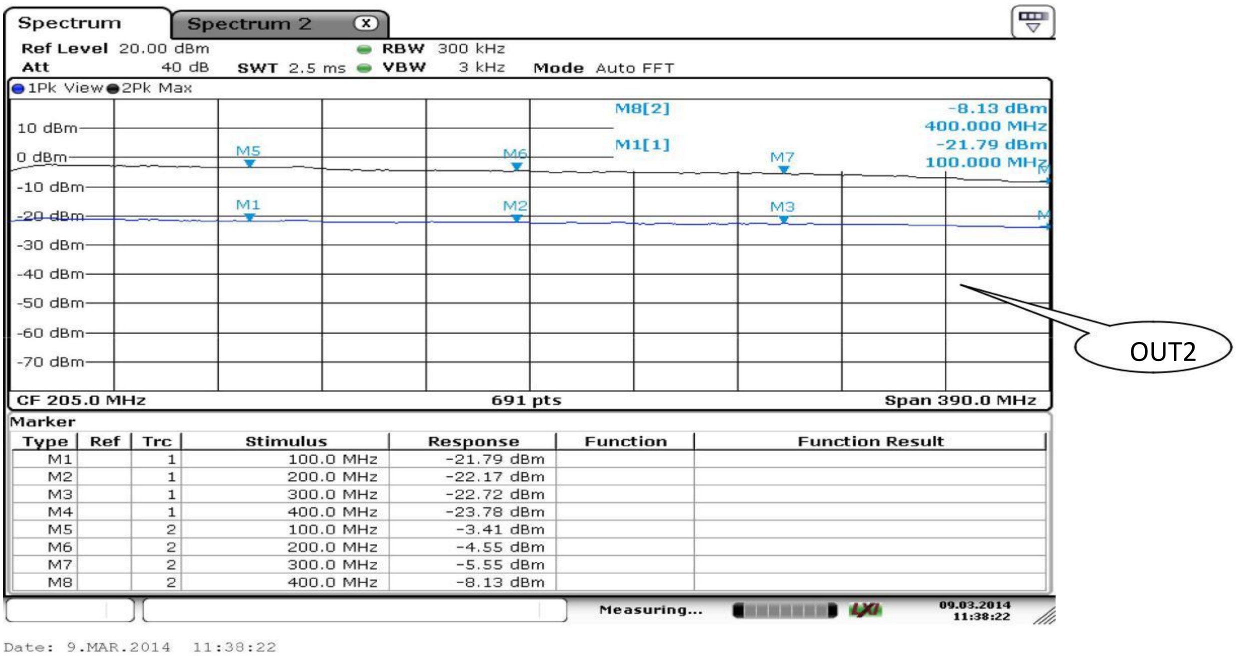
As mentioned above, for the down conversion, frequency conversion (CNV) unit is provided with a bypass stage so that whenever the observation frequency is lower than 400 MHz, can be use through bypass path and the RF signal will be directly given to the ADC circuits. In the conversion path, for RF bands above 400 MHz, a suitable LO signal, from 600 MHz to 1700 MHz is to be used to down convert the signal from 0 to 400 MHz range. The conversion path and direct path is made possible by using two way RF switch M3SWA-2-50DR+ at both ends. SYM-2500 wideband (1 to 2500 MHz) level 7 mixer module is used for frequency conversion which is having low conversion loss 6.5 dB and high L-R isolation 50 dB. The mixer circuit is followed by a 400 MHz low pass section to attenuate the high frequency signals due to LO/RF leakage. A fixed resistive attenuator of 8 dB (Pie type) is put in the direct path to compensate the conversion loss due to mixer module in the conversion path.

2.2.3. BUFFER Unit:

Buffer is used for drive the signal through RF Cable up to ADC input.

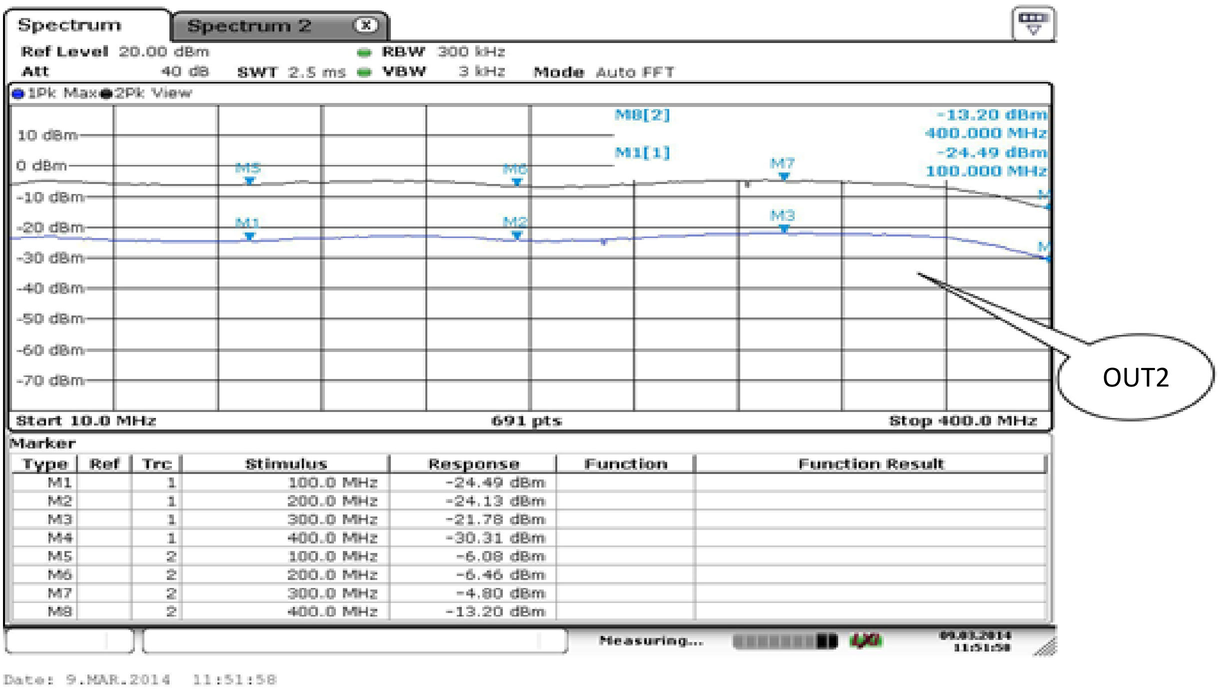
The conversion unit output is given to the buffer unit as an input. Gali-6 amplifier is used for further amplification. After that noise injection facility is provided using M3SWA-2-50DR+ switch for calibration of the digital chain. Using PRSC-2050 power splitter, one output is taken as spare for future backend and another is given as an input to the BB filter PIU.

2.3 Test Results for Analog Receiver PIU:



Type	Ref	Trc	Stimulus	Response	Function	Function Result
M1		1	100.0 MHz	-21.79 dBm		
M2		1	200.0 MHz	-22.17 dBm		
M3		1	300.0 MHz	-22.72 dBm		
M4		1	400.0 MHz	-23.78 dBm		
M5		2	100.0 MHz	-3.41 dBm		
M6		2	200.0 MHz	-4.55 dBm		
M7		2	300.0 MHz	-5.55 dBm		
M8		2	400.0 MHz	-8.13 dBm		

Fig 2.3.1: RF Input to OUT1 & OUT 2 response plot (100-400 MHz) Input@-30dBm.



Type	Ref	Trc	Stimulus	Response	Function	Function Result
M1		1	100.0 MHz	-24.49 dBm		
M2		1	200.0 MHz	-24.13 dBm		
M3		1	300.0 MHz	-21.78 dBm		
M4		1	400.0 MHz	-30.31 dBm		
M5		2	100.0 MHz	-6.08 dBm		
M6		2	200.0 MHz	-6.46 dBm		
M7		2	300.0 MHz	-4.80 dBm		
M8		2	400.0 MHz	-13.20 dBm		

Fig2.3.2: RF Input to OUT1 & OUT 2 response plot (400-800 MHz)Input@-30dBm/LO-800MHz

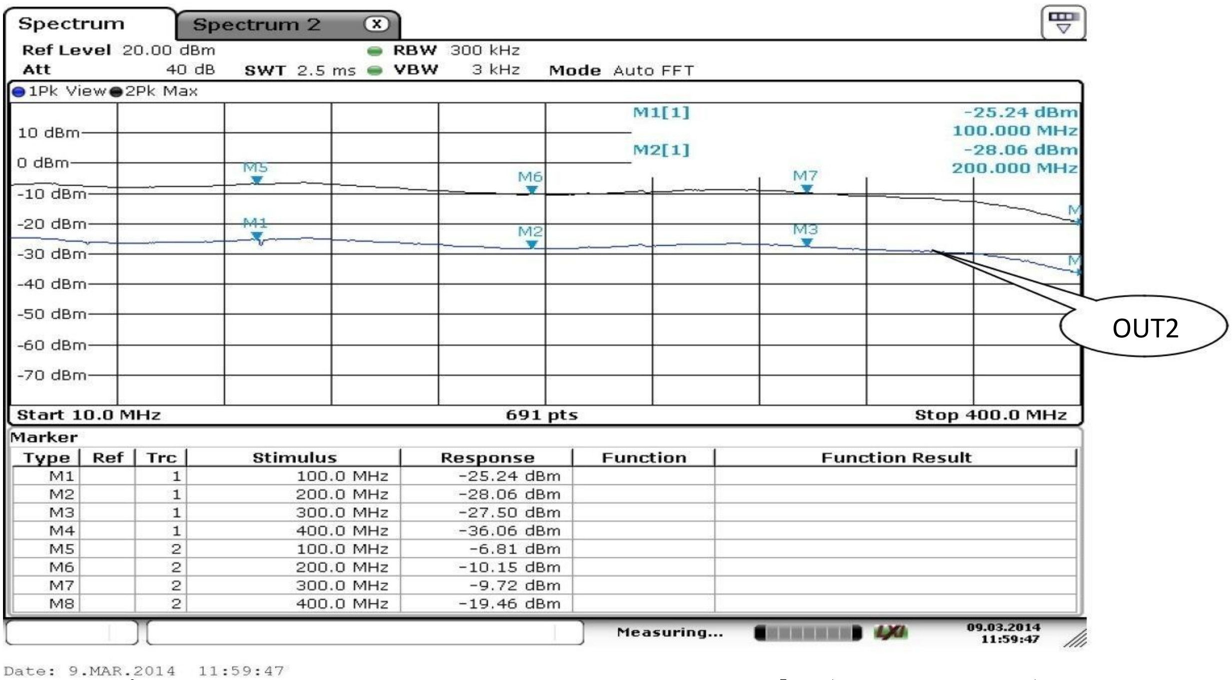


Fig2.3.3: RF Input to OUT1 & OUT 2 response plot (800 -1200MHz) Input@-30dBm/LO-800MHz

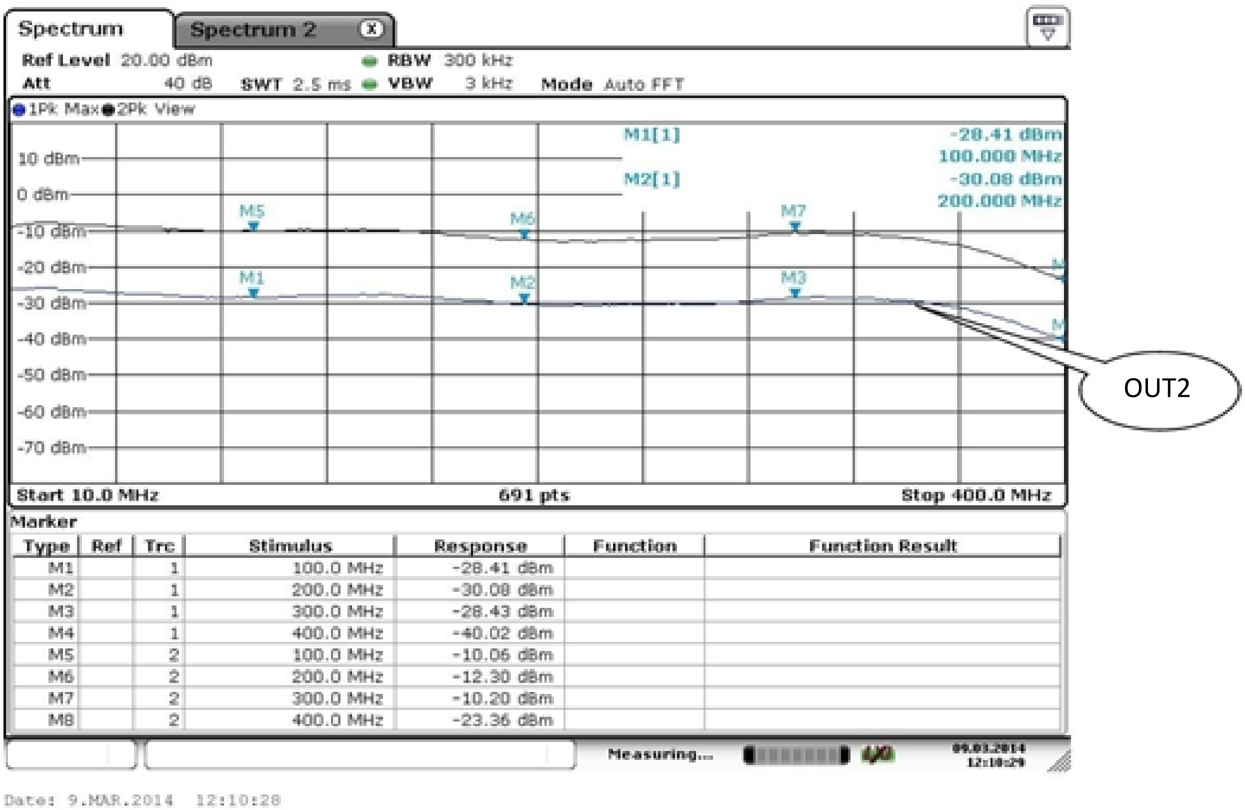


Fig2.3.4: RF Input to OUT1 & OUT 2 response plot (1200 -1600MHz) Input@-30dBm/LO-1200MHz

3.0 LO SYNTHESIZER PIU:

3.1: Block diagram of LO Synthesizer PIU:

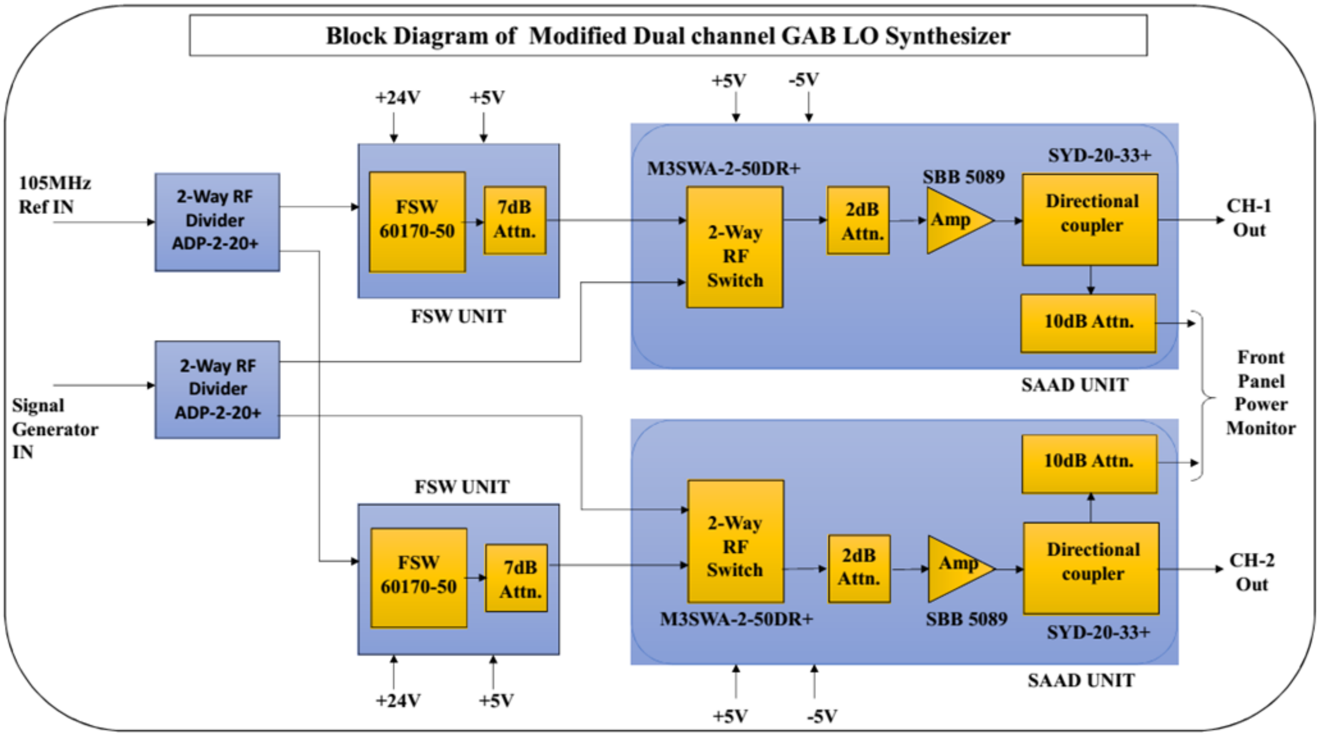


Fig3.1: Block diagram of Lo synthesizer PIU

3.2 Description:

The LO signal for the mixer unit uses 105MHz reference signal .This 105MHz reference signal provided is taken through LO master system at receiver room. There are two schemes for LO signal generation.

A common Signal generator which covers the full frequency range is locked to the 105 MHz reference signal. The output of the signal generator is then amplified and distributed to down conversion units for all 30 antennas.

This scheme provides a facility for setting a common LO frequency for all antennas with the steps of 1 Hz. A second LO generation scheme uses individual LO signals generated in the range of 600 to 1700 MHz in 0.5 MHz steps. With this scheme individual antennas can be set to different LO frequencies as per requirement.

3.3: Test results for LO Synthesizer PIU:

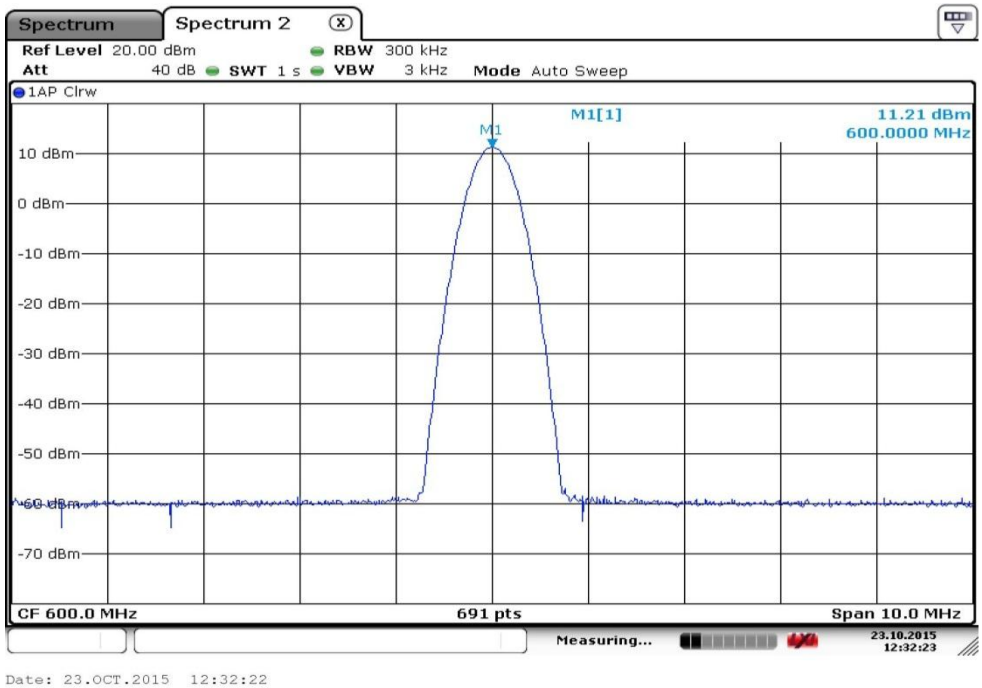


Fig3.3.1: Response Plot of 600 MHz LO Selection@ Minimum Span

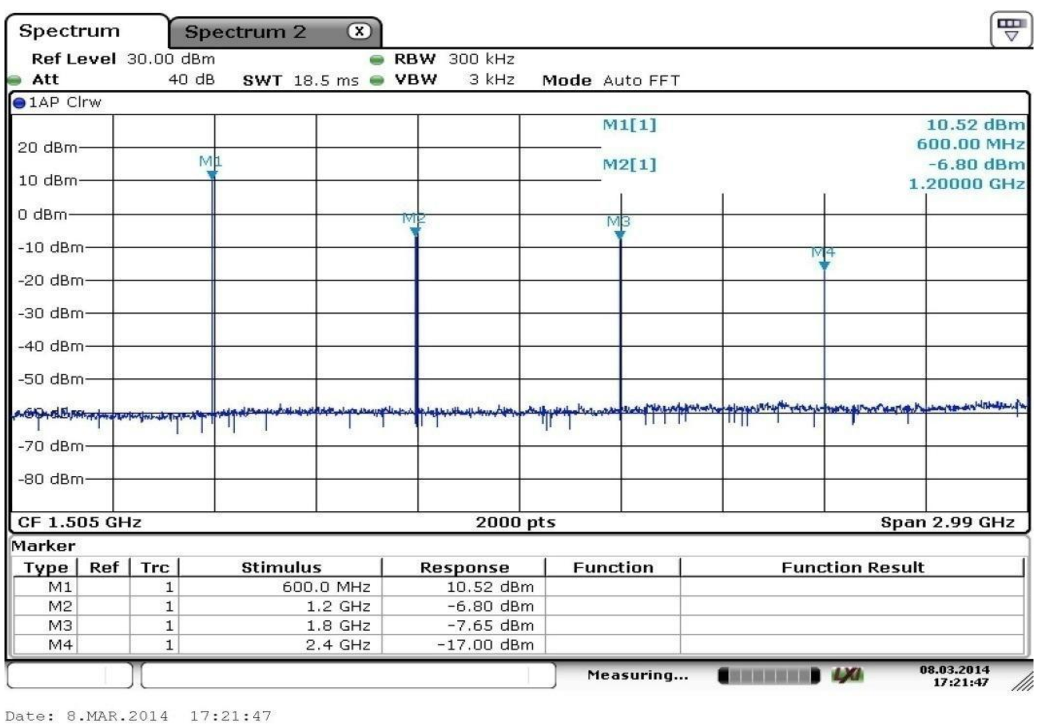


Fig3.3.2: Response Plot of 600 MHz LO Selection@ Maximum Span

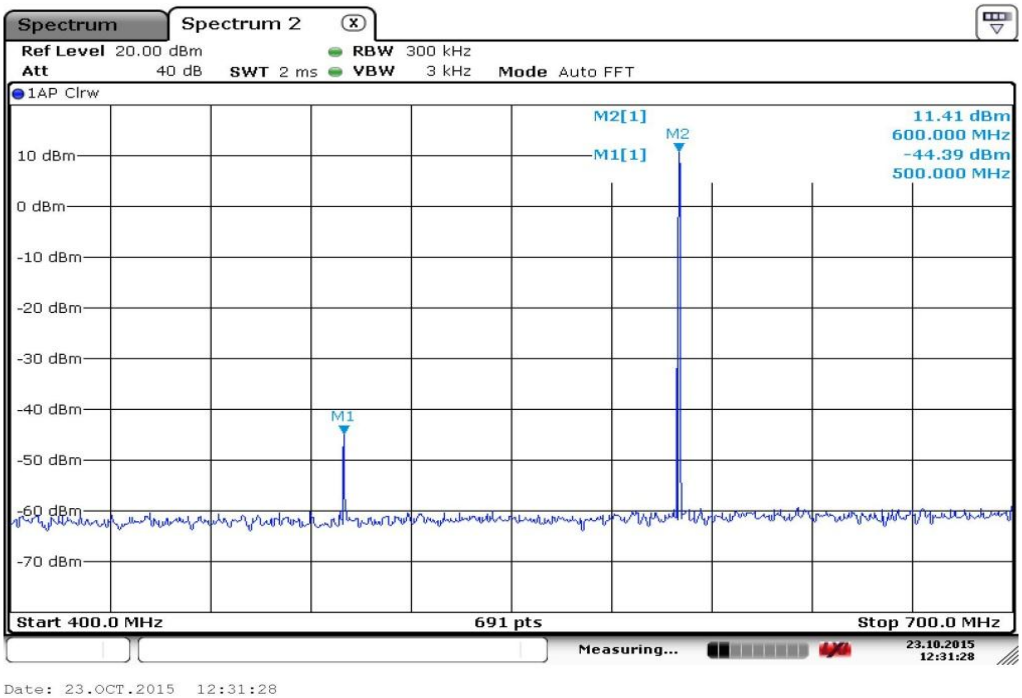


Fig3.3.3: Isolation between CW & FSW with FSW Path ON

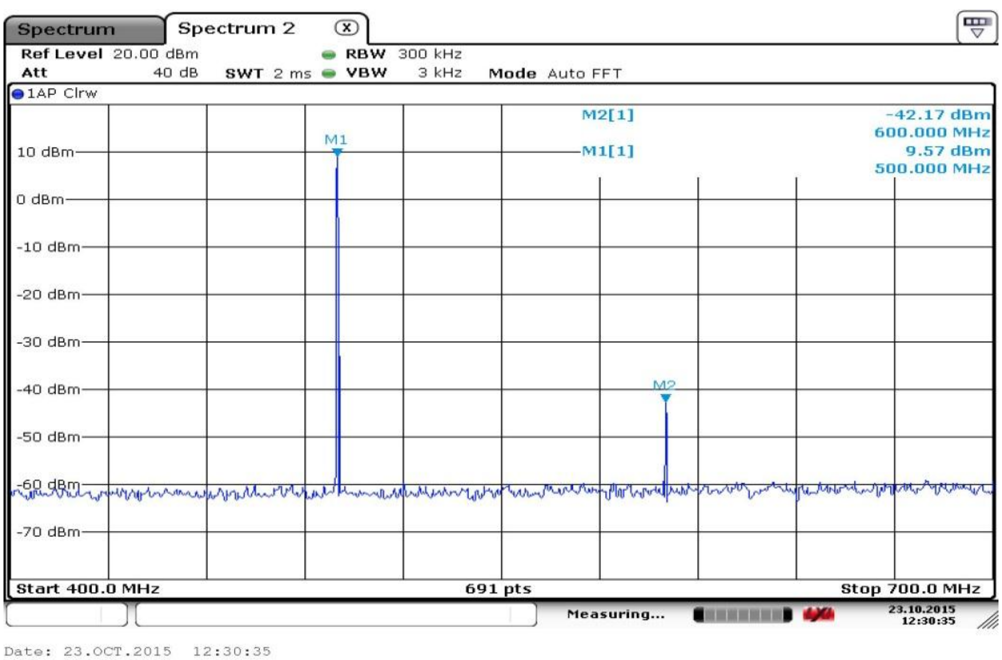


Fig3.3.4: Isolation between CW & FSW with CW Path ON

4.0 REF. Distribution PIU

4.1 Block Diagram

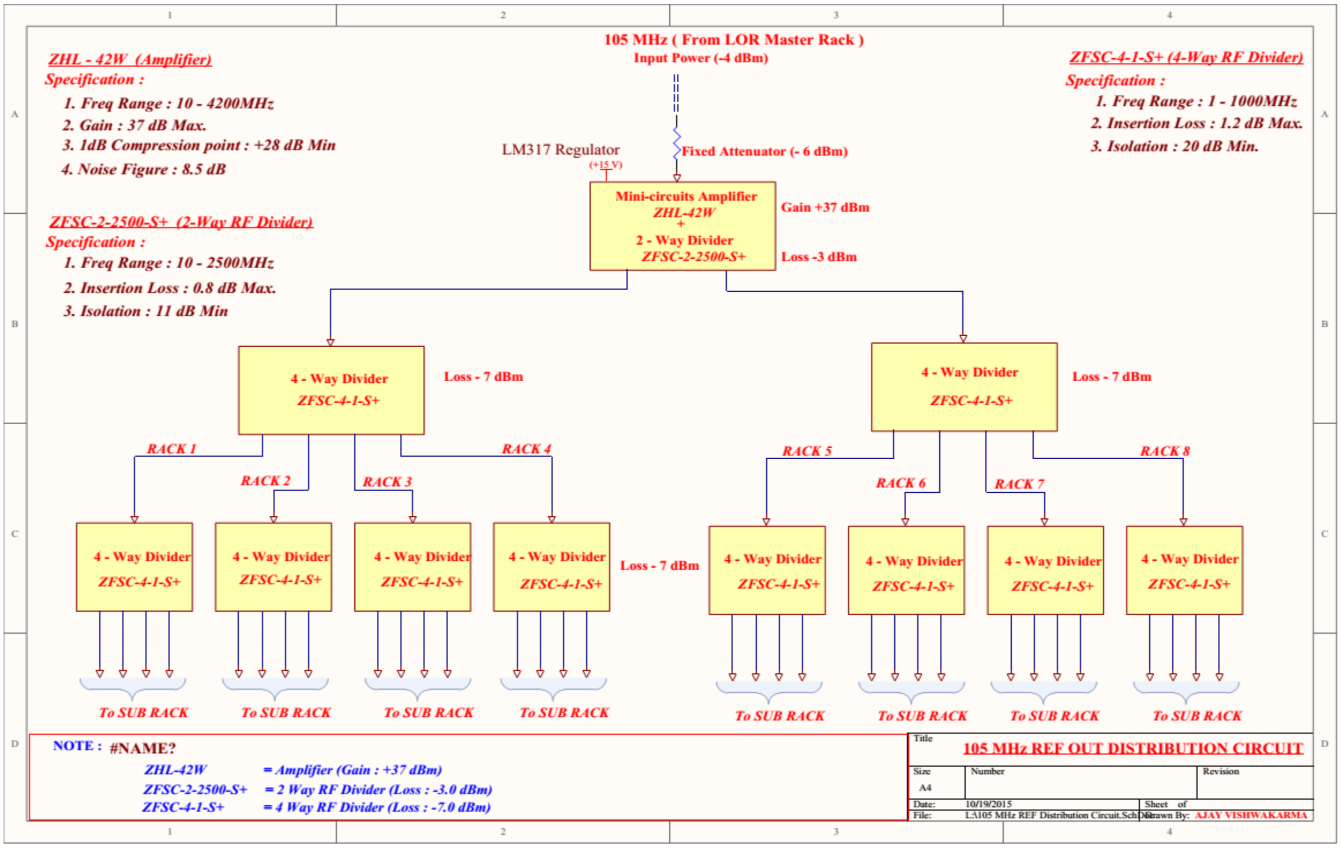


Fig4.1: Block diagram of Reference Distribution PIU

4.2 Description:

The LO reference of 105Mhz is taken from the Freq. & Time Standard (FTS) system amplified using a power amplifier from Minicircuits lab and then distributed to backend system for each antenna using pulsar microwave make 4 way splitter network. The power levels are adjusted using attenuators/amplifiers at every stage.

The circuit has facility to select among 105 MHz signal from one of the two available FTS units. The output reference signal is provided at +3dBm to the LO synth unit. In the LO synth unit, a 2 way switch is used to select the common signal source or the FSW unit as per requirement.

The signal is then amplified and split to two signal for each pol channel in an antenna. A directional coupler with power detector circuits is used for monitoring the signal levels regularly. A high performance signal source i.e. Agilent make N5161A is used as the common LO source for reference distribution as per scheme.

5. RF Filter bank PIU

5.1 Block Diagram:

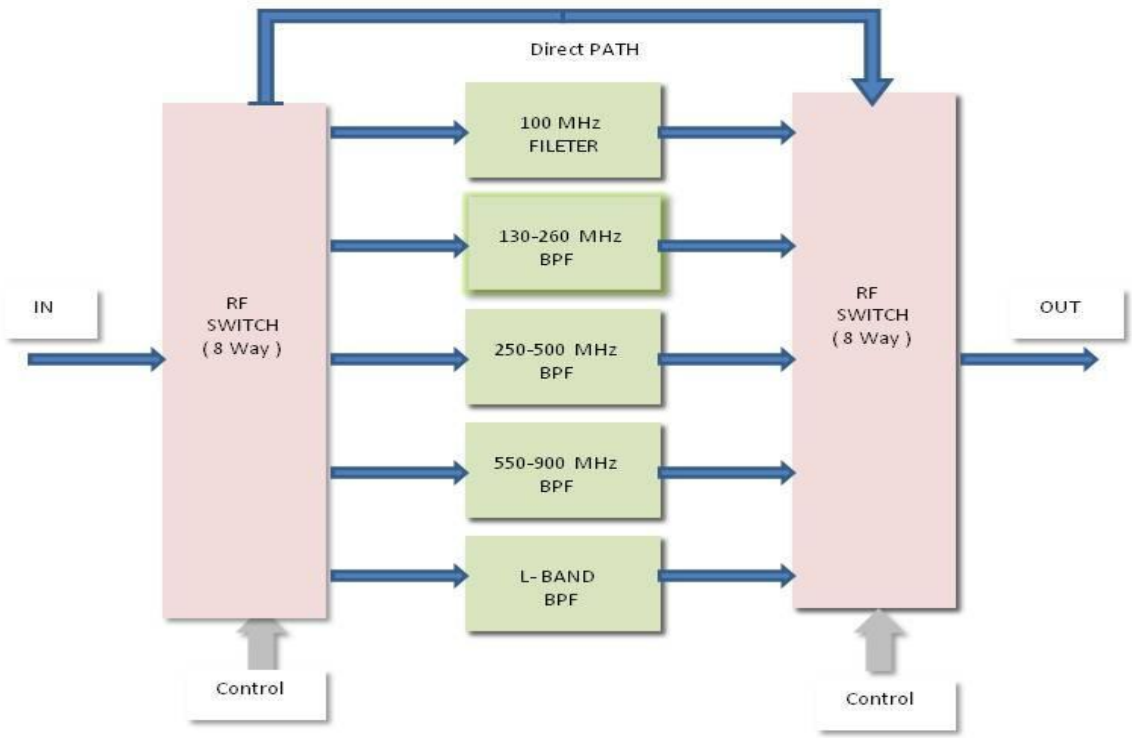


Fig5.1: RF Filter bank PIU

5.2 Description:

RF filter unit is part of a GMRT Analog Backend System and is used for selecting the various filters i.e. 100 MHz Low Pass Filter, 130-260 MHz Band Pass Filter, 250-500 MHz Band Pass Filter, 550-900 MHz Band Pass Filter, L-Band Band Pass Filter and it is also have Direct Path and a facility to connect external filter. The HMC253QS24E are low-cost non-reflective SP8T switches in 24-lead QSOP packages is used in 8 Way RF switch unit featuring wideband operation from DC to 2.5 GHz. The switch offers a single positive bias and true TTL/CMOS compatibility. A 3:8decoder is integrated on the switch requiring only 3 control lines and a positive bias to select each path.

5.3Test results for RF FILTER PIU

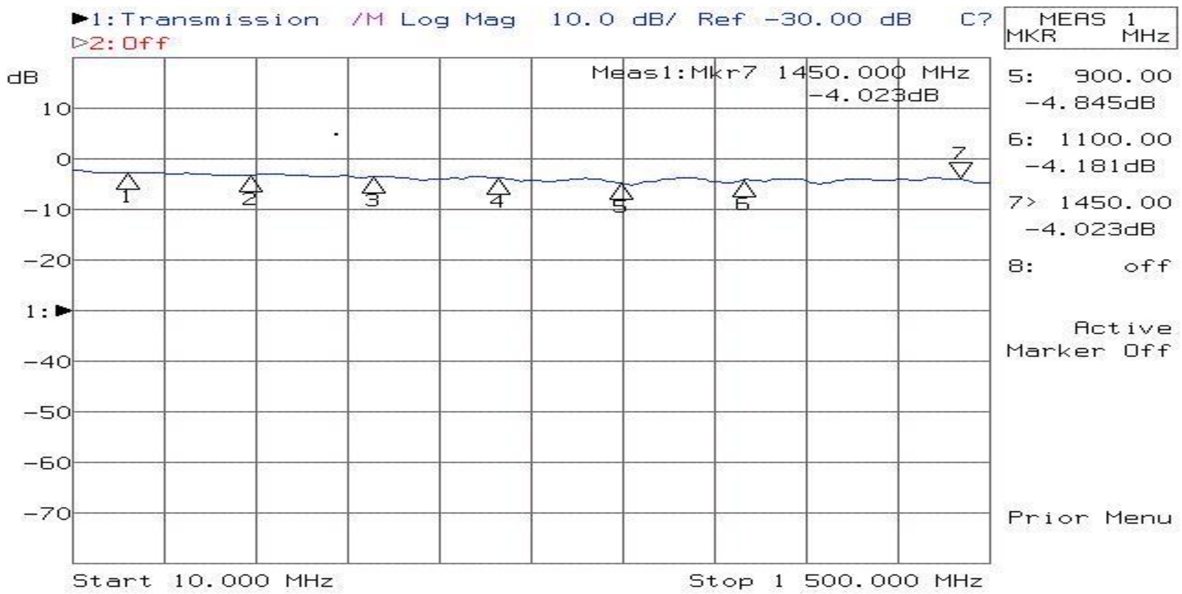


Fig5.3.1: Direct Path

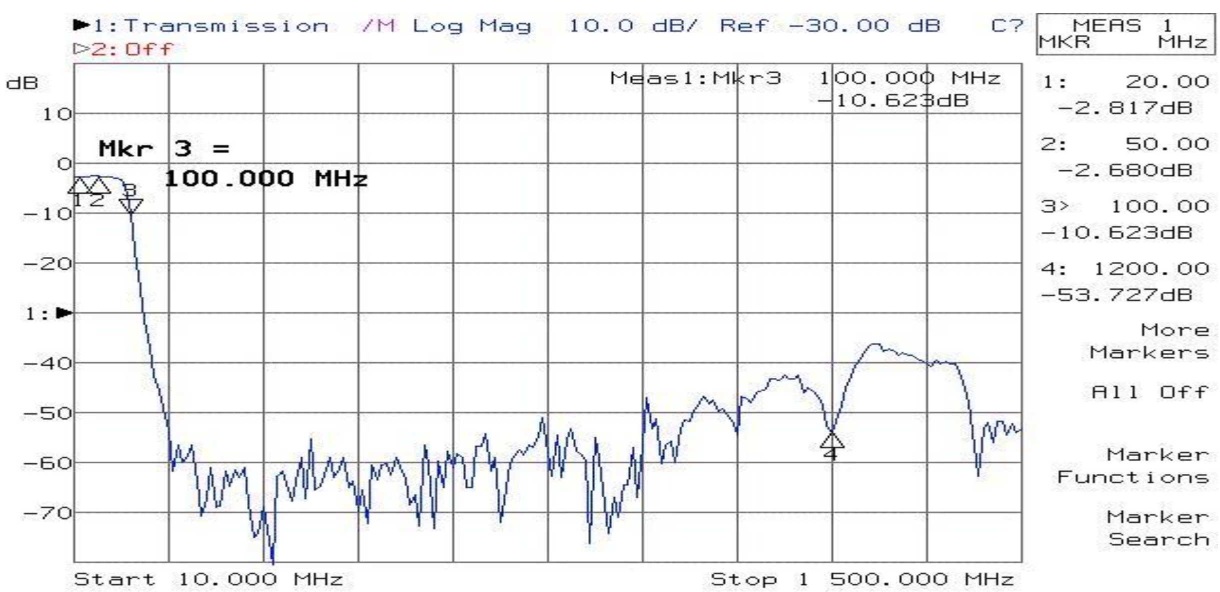


Fig5.3.2: 100 MHz Low Pass Filter

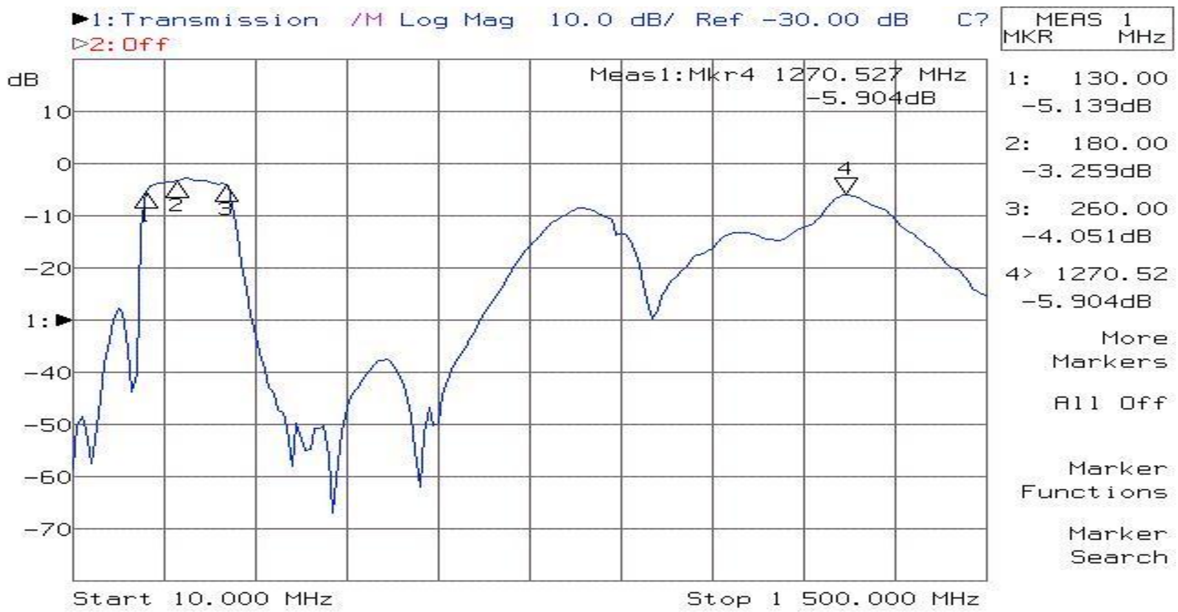


Fig5.3.3: 130MHz to 260 MHz BandPass Filter

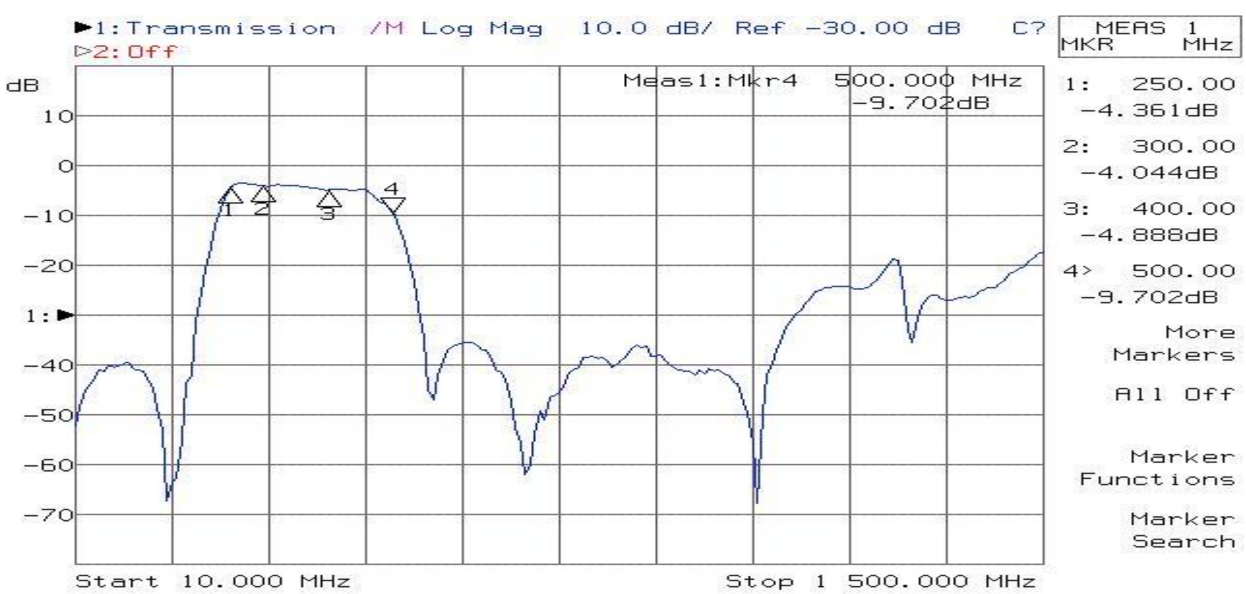


Fig 5.3.4: 250MHz – 500MHz BandPass Filter

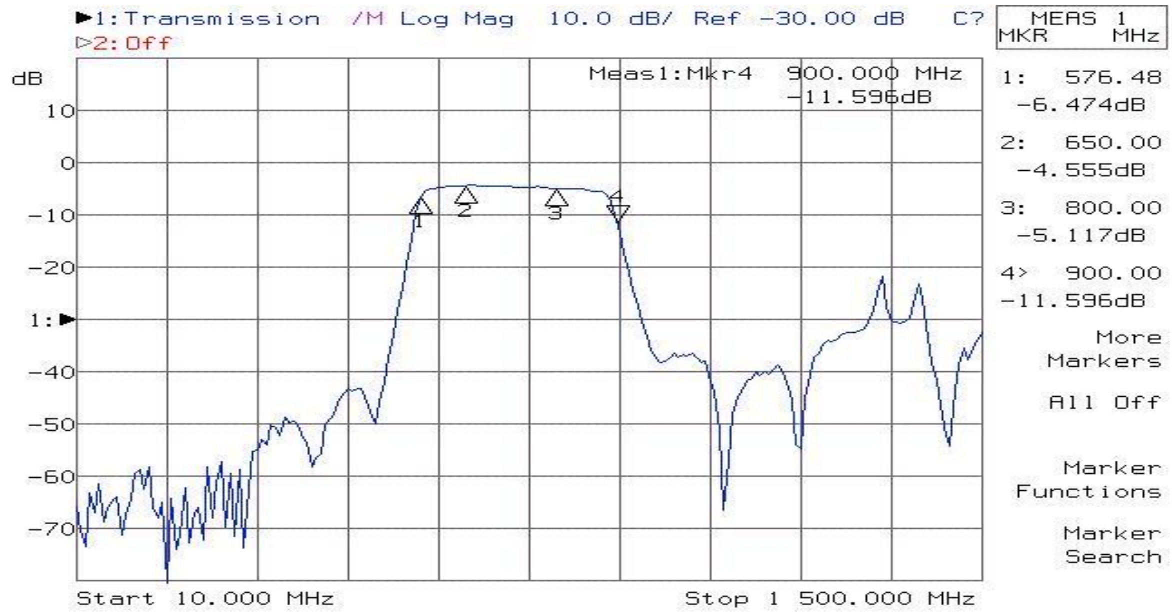


Fig 5.3.5: 550MHz-900MHz BandPass Filter

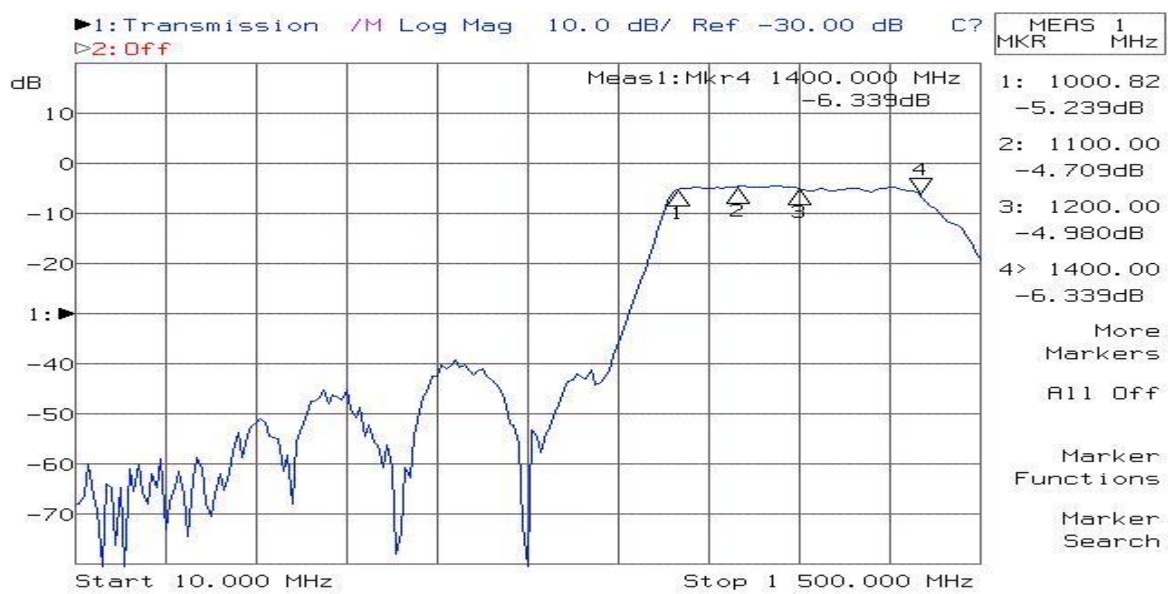
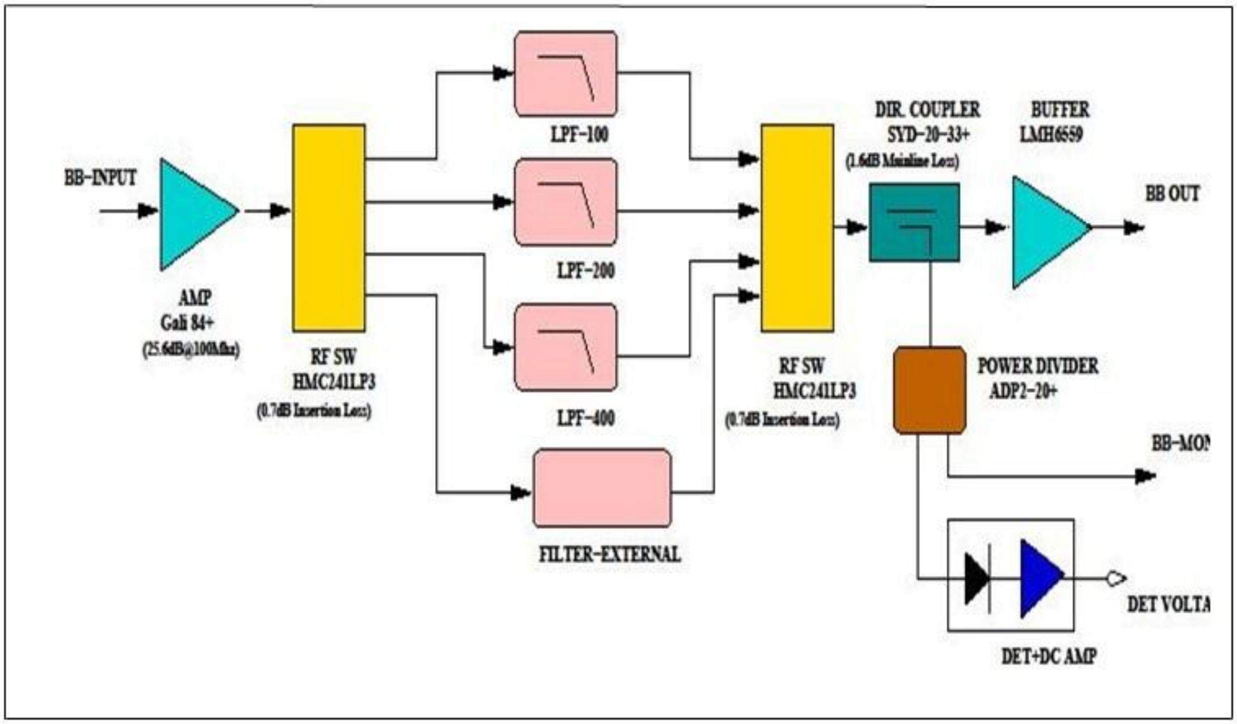


Fig 5.3.6: L-Band Band Pass Filter

6. Base band filter bank PIU

6.1 Block Diagram



6.2 Description

The output of Analog Rx PIU is given to the Base band Filter bank unit. The main function of this unit is to provide the facility to utilize 100MHz, 200MHz and 400MHz LPF’s.

This incorporates 4way switch following with 100MHz, 200MHz, 400MHz LPFs. The LPF’s used are passive filters and been designed using Gensys Software. It also has a facility to connect external filter if required.

Input signals are amplified and fed to Low pass filter bank through a 4 way RF Switch which is controlled through 2 control bits. Selectable output is connected to a Buffer amplifier. A coupled output is taken for Monitor purpose.

All this blocks are divided into a four different RSW, BUF, LPF, DDD& PS units. Where RSW unit consist RF Amplifier followed by a RF Switch. BUF unit consist RF switch followed by Directional Coupler & a Buffer amplifier. DDD unit consist power divider & Detector IC and DC amplifier.

6.3 Test results for BB FILTER PIU:

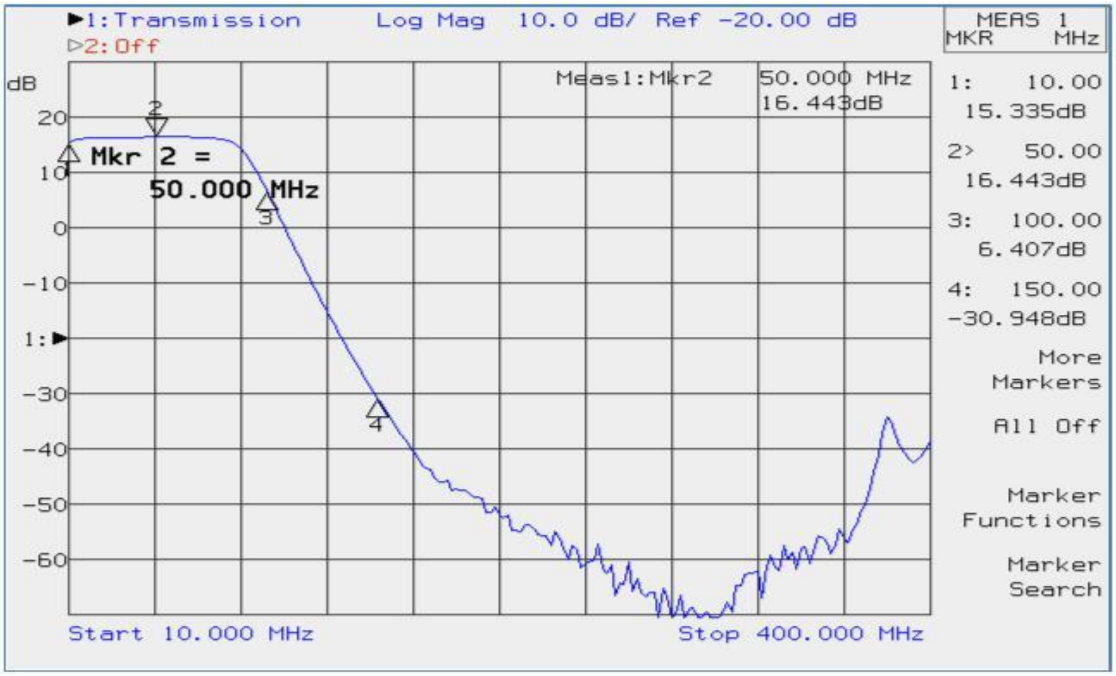


Fig 6.3.1: BB IN to BB OUT Frequency response @ 100MHz Low Pass Filter Selection (Input:-30dBm)

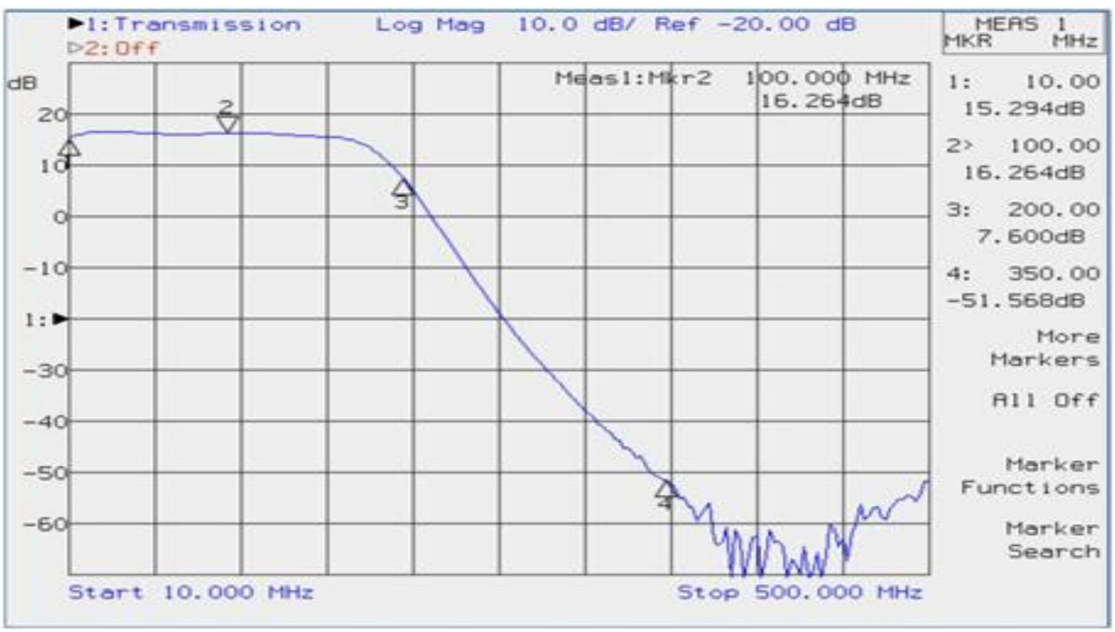


Fig 6.3.2:BB IN to BB OUT Frequency response @ 200MHz Low Pass Filter Selection

Fig6.3.3:BB IN to BB OUT Frequency response @ 400Mhz Low Pass Filter Selection

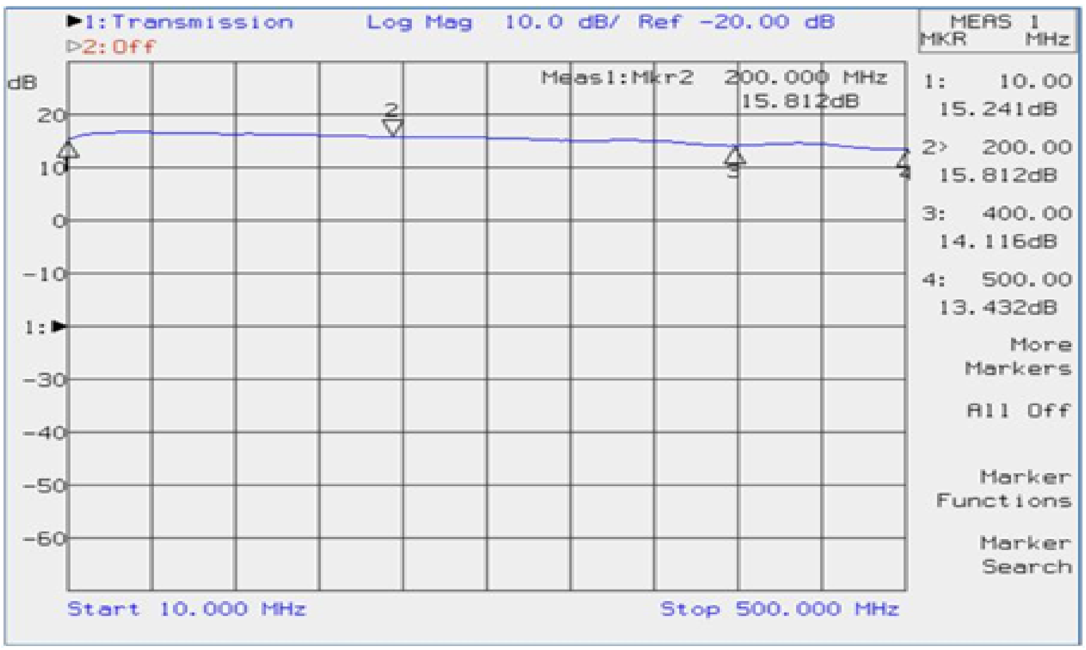


Fig6.3.4: BB IN to BB OUT Frequency response @ Direct Path selection

7.0 NOISE CAL PIU

7.1 Introduction:

Noise CAL PIU unit is used for calibration of the GAB system and GPU correlator system . This unit is sub classified in ANACAL and DIGICAL. ANACAL unit is used for calibration of analog backend chain (GAB) system and DIGICAL unit is used for calibration of Digital backend chain.

Specifications of system:

1. Analog Noise Cal : Broadband Noise of 0 to 2GHz
   Max Output power : -10dBm.
2. Digital Noise Cal : 0 to 400 MHz
   Max Output power : -17 dBm

7.2 Block Diagram of ANACAL and DIGICAL Noise PIU:

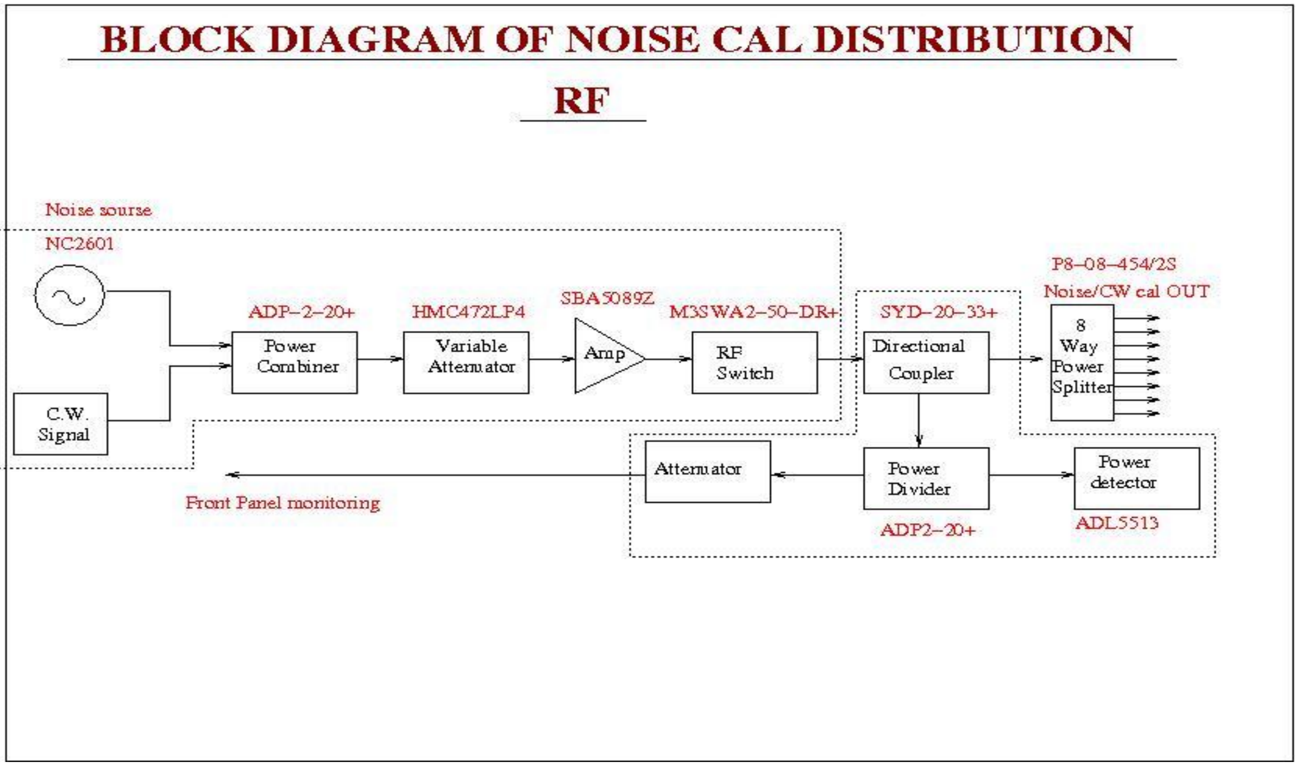


Fig7.2.1: Block Diagram of ANACAL Noise PIU

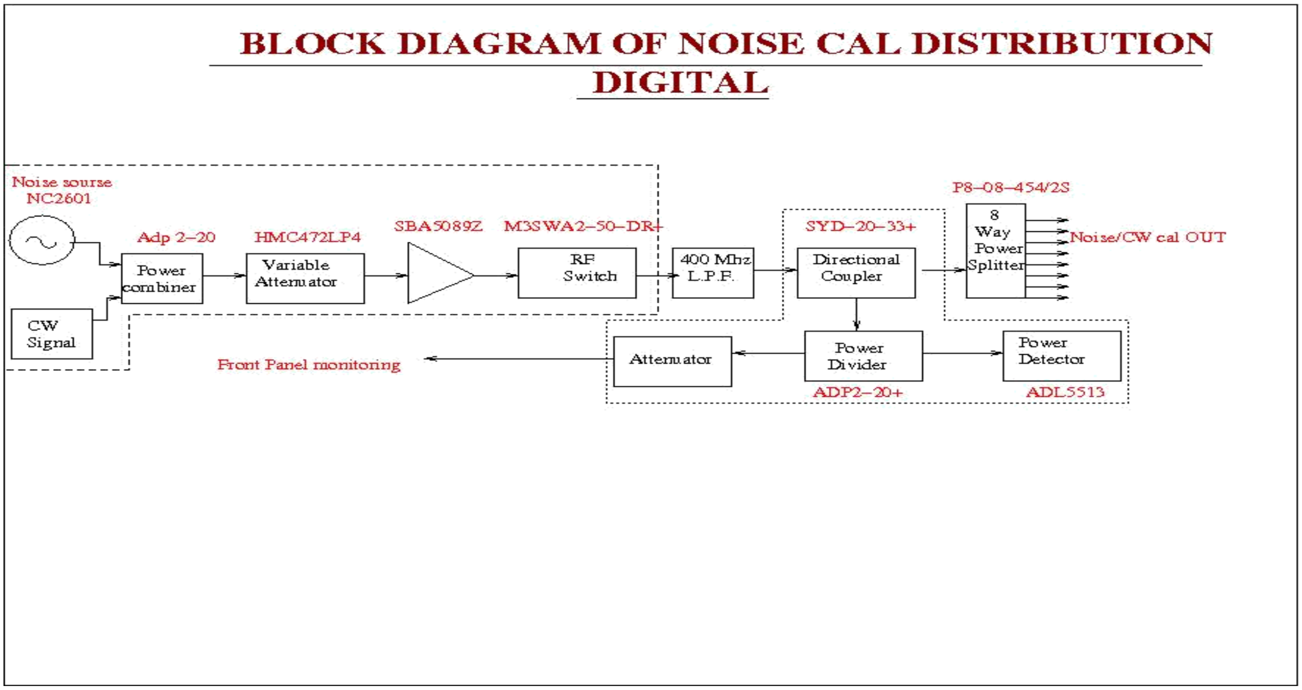


Fig7.2.2: Block Diagram of DIGICAL Noise PIU

Description:

Noise com make source NC2601 is used as Broadband noise source which is followed by power combiner to inject C.W. Signal for calibration of GAB Analog Rx PIU. After this HMC472LP4 variable attenuator is used to adjust the output power level with 0.5dB step size.

After this signal is being amplified using SBA5089Z amplifier with 20dB gain. There is a facility to monitor the power level at front panel and through online by using DDD (Directional coupler, Divider, Detector) chassis. The difference between ANACAL and DIGICAL unit is that DIGICAL has an additional 400MHz LPF included.

7.3: Test results for NOISE CAL PIU:

Fig 7.3.1: Frequency response of Analog Noise Cal

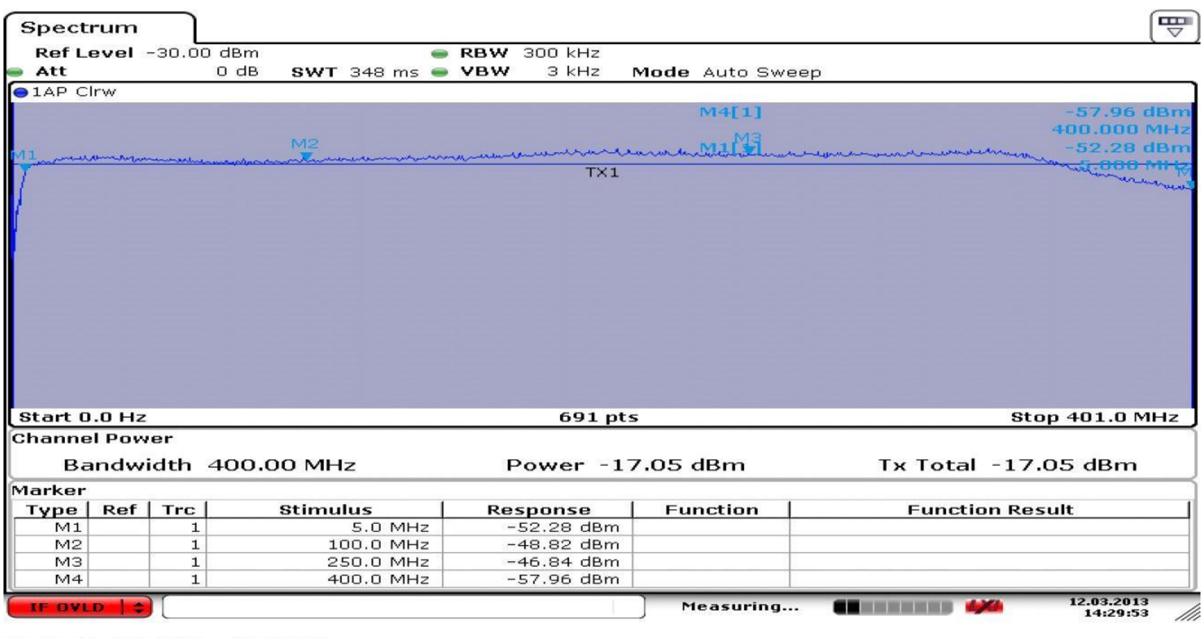


Fig 7.3.2 : Frequency response of Digital Noise Cal

8. Temperature monitoring system

8.1Introduction:

In the upgraded GMRT system some systems and components are critical so it was decided to design a temperature monitoring system that could measure and record temperature at various locations in receiver room, critical components and various sub systems

Design specification of temperature monitoring is as follows:

In the temperature monitoring system we have used National semiconductor make LM35.The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centi-grade scaling. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy. It can be used with single power supplies or with plus and minus power supplies. The LM35 is rated to operate over a -55 degree to +150 degree centigrade temperature range.

How to measure temperature?

Using the LM35 is easy, simply connect the pin no1 to power supply and the pin no 2 to ground pin 3 will have an analog voltage that is directly proportional (linear) to the temperature. The analog voltage is independent of the power supply.

To convert the voltage to temperature, simply use the basic formula: formula: Temp in Celsius = (Vout in mV) / 10

8.2 Block Diagram:

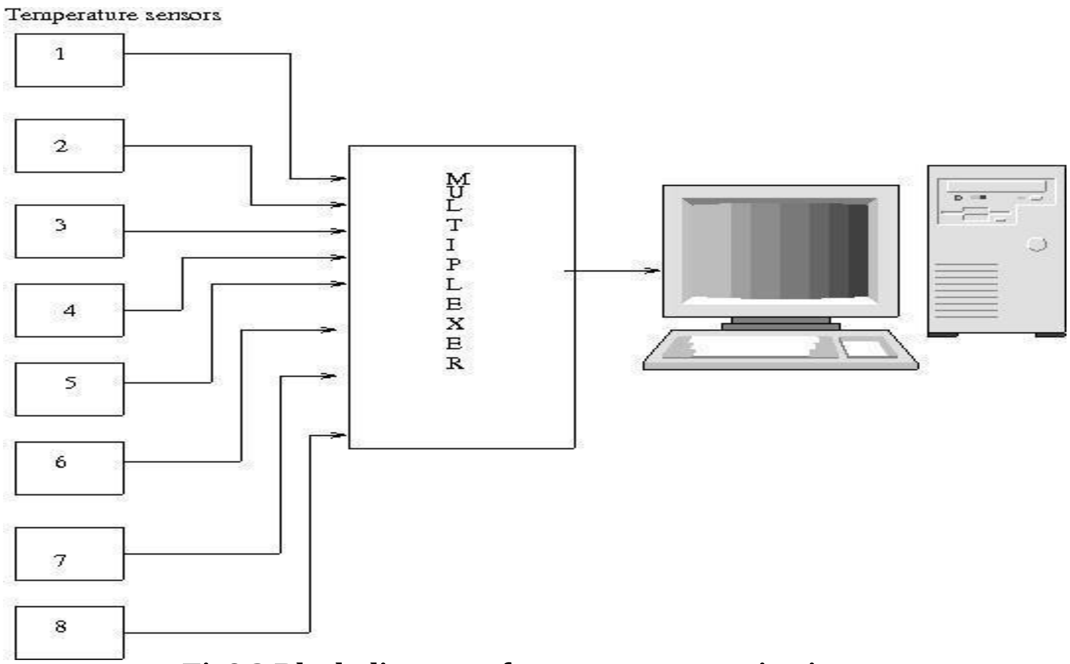


Fig8.2 Block diagram of temperature monitoring system

8.3 Description:

Temperature sensors are connected as an input to analog multiplexer. Maximum 8 sensors can be connected to one multiplexer unit. This multiplexer unit is connected to National instruments make hardware DAQ (data acquisition) NI USB 6008, which is having Analog and digital input and output ports. Control point for multiplexer is connected to digital output of DAQ and the output of multiplexer is connected to analog input of the DAQ.

The DAQ is controlled by national instruments make software called Lab view. The program using Lab view performs following task:

It sends digital data 0000 reads back multiplexer o/p, this will be channel1 displays on to front panel of the program then it will increment digital data 0001 and reads channel2 data and write it into file.

8.4Test Results:

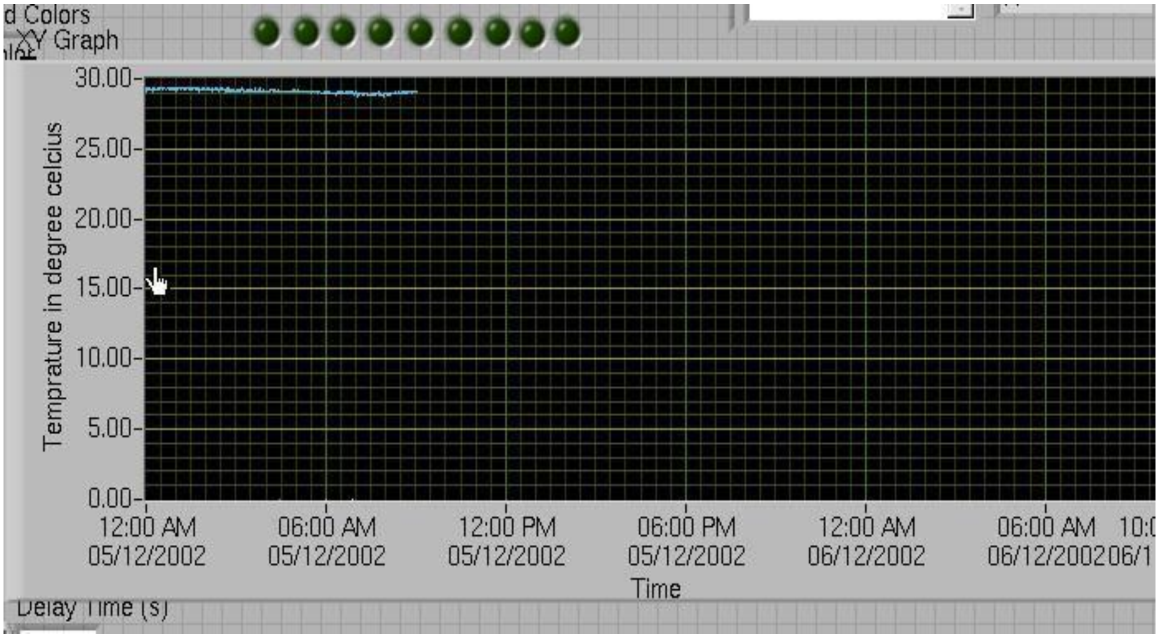


Fig8.4.1 Plot using data recorded in Lab using Labview Software

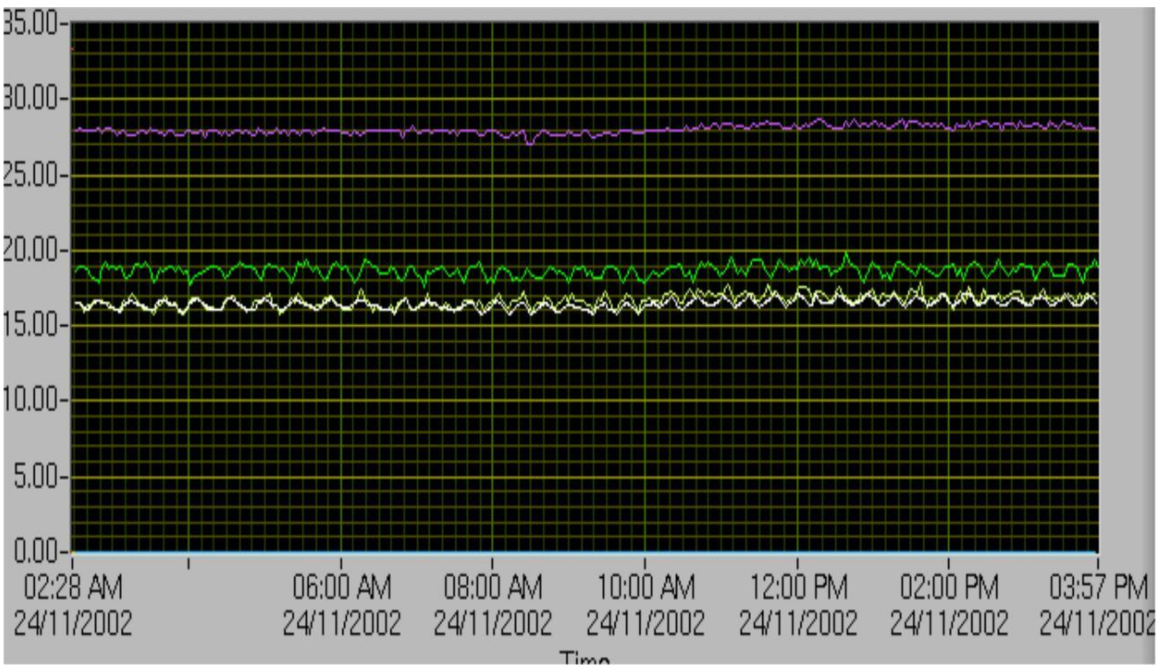


Fig8.4.2 Plot using data recorded in correlator room

9. SMPS based Power supply for GAB system

9.1 Introduction:

The GAB System installed in receiver room needs a power supply for each rack. A new SMPS based power supply instead of linear power supply is designed for GAB system which is also integrated in RFI shielded enclosure.

This unit consist Meanwell make SMPS modules of +9V, +15V, +27 V & - 9V with 100 watt capacity of each. We have carried test for min-max voltage level variation using the potentiometer on the module, ripple at no load and full load.

9.2 Feature of SMPS power supply:

1. 19inch Rack mount arrangement.
2. Independent module that gives you flexibility during maintenance.(easily repairable)
3. Shielded AC power line filter with fuse for AC power input at the back side.
4. Feed through with terminal strip arrangement for temperature monitoring and DC output power supply at the back side.
5. AC power fan arrangement at the bottom for cool air circulation.
6. Hot air out using hole arrangement on the top side.
7. LED monitoring at the front side.

9.3 Technical specifications Lab Measurements:-

1) It is consisting of Meanwell make SMPS modules of +9V, +15V, +27 V with 100 watt capacity of each. In power supply box we used modules listed below

Meanwell SMPS Model NO.	Volt (V)	Current (Amp)	Power (watt)	Min Voltage	Max Voltage
NES-100-9	9	11	100	7.78 V	10.38 V
NES-100-15	15	7	100	12.38 V	17.43 V
NES-100-24	24	4.5	100	20.09 V	27.85 V
NES-100-9	-9	11	100	7.73 V	10.35 V

This output voltage adjusted by independent potentiometer.

2) Ripple

Meanwell SMPS Model NO	Volt (V)	Ripple @ No Load	Ripple @Full Load	Ripple given in datasheet
NES-100-9	9 V	< 50 mv	<100 mv	120mV
NES-100-15	15 V	< 50 mv	<100 mv	120mV
NES-100-24	27 V	< 50 mv	<100 mv	120mV
NES-100-9	-9 V	< 50 mv	<100 mv	120mV

Table 9.3.1 Ripple

3) Over voltage protection:-

Recovers automatically after fault condition is removed , this is Hiccup mode.

4) Output load regulation:-

Meanwell SMPS Model NO	Volt (V)	Output @ No Load	Output @ 10% Load	Output @Full Load	Output load regulation Calculated	Output load regulation in datasheet
NES-100-9	9 V	8.96	8.90	8.46	0.05%	+/- 0.5%
NES-100-15	15 V	14.9	14.86	14.66	0.02%	+/- 0.5%
NES-100-24	27 V	26.9	26.81	26.60	0.01%	+/- 0.5%
NES-100-9	-9 V	-8.9	-8.90	-8.40	0.05%	+/- 0.5%

Table 9.3.2 Output load regulation:

9.4 Temperature variation on SMPS power supply :-

The overall temperature variation seen for the SMPS power supply kept inside the Receiver room is between 21°C to 27°C. The data recorded at every one minute interval on each SMPS unit for 20 days.

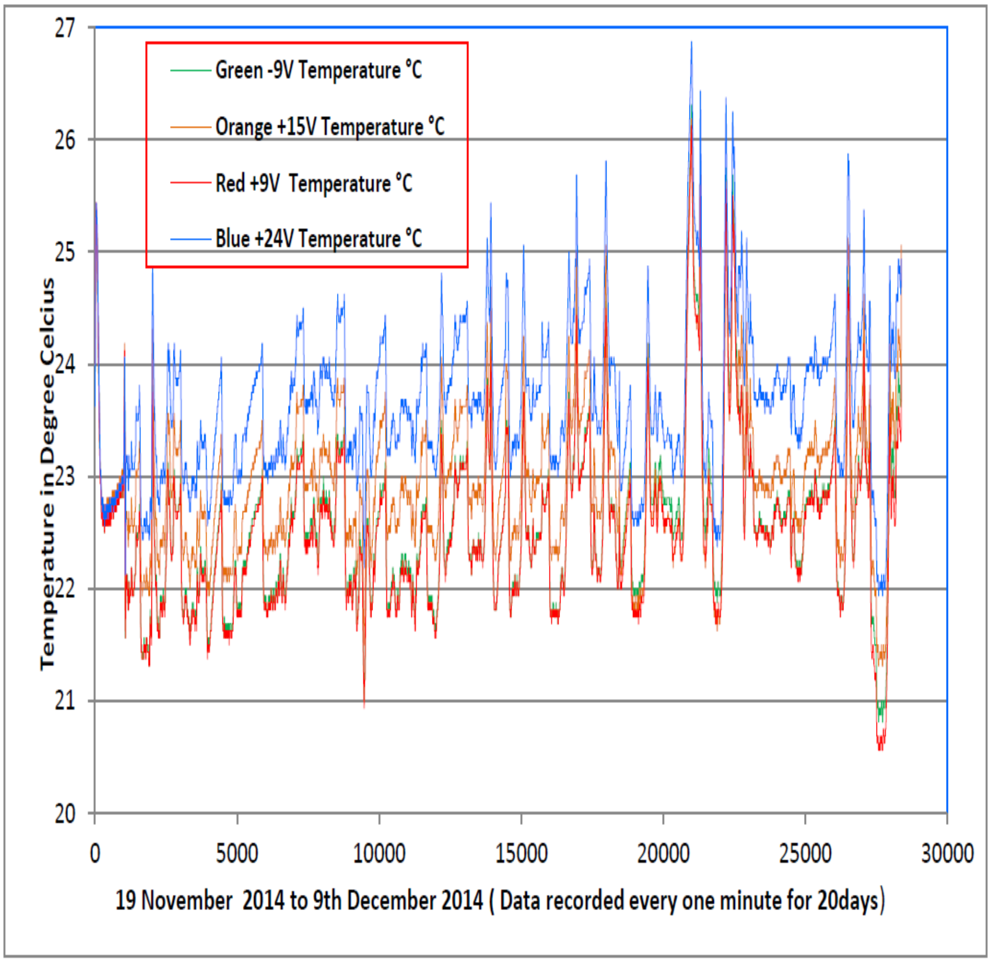


Fig.5:- Temperature variation seen for 20 days at the top layer of SMPS for each SMPS unit between 21°C to 27°C.

Fig9.4 Temperature variation on SMPS power supply

10 Control & Monitor UNIT:

10.1 Block Diagram

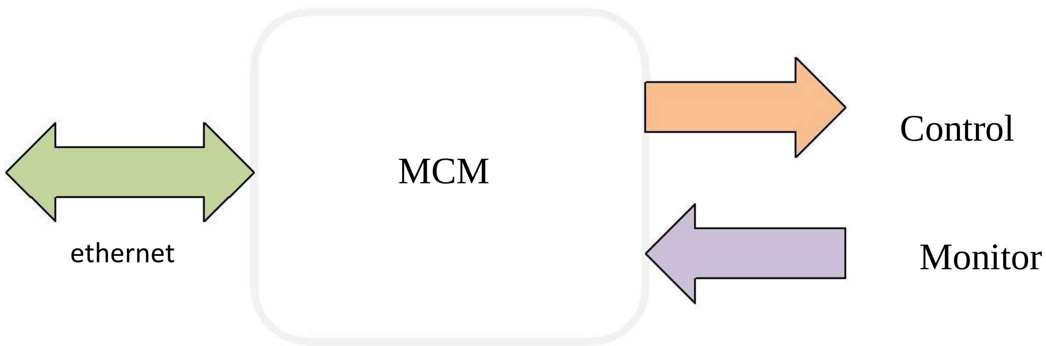


Fig10.1 Block diagram of Control & Monitor PIU

10.2 Description:

GAB control and monitoring does controlling of Analog Receiver system, Baseband Filter, RF filter and Local Oscillator system. To control these systems it use MCM card. MCM card has 32 Output Lines which are used to set GAB subsystems. Out of 32 Output lines 18 lines for set Analog Receiver system channel1 and Channel2.

With these 18 lines we can set Attenuation, Input selection (Antenna input or Noise input), Mixer or Direct path. 6 lines for RF filter selection of channel1 and channel2and 4 lines for baseband filter selection of channel 1 and channel 2. 100 MHz, 200MHz, 400MHz and Direct path. 2 line for source of local oscillator i.e. external (signal generator for LO < 500 MHz) FSW. SPI bus is use to set Local Oscillator frequency.

64 input lines of MCM card are used to monitor various parameters like attenuations, selected path, Power supply and temperature.

BASE BAND FILTER MONITORING-1				BASE BAND FILTER MONITORING-2				
FRC	D37-I	D15-3	Signals	FRC	D37-II	D15-3	Signals	*D-15 TO BB filter X 2*
20	23	1	BBF	52	23	1	BBF	
21	24	9	BBf	53	24	9	BBf	
22	25	2	MON1	54	25	2	MON1	
23	26	10	MON2	55	26	10	MON2	
24	27	3	Power	56	27	3	Power	
	28	15	GND		28	15	GND	
		4				4		
LO MONITORING- 1 &2				Not userd				*D-15 TO LO PIU X 1*
FRC	D37-I	D15-4	Monitoring	FRC	D37-II			
25				57	29	1	CW1	
26				58	30	9	CW2	
27				59	31	2	Lock Det. 1	
28				60	32	10	Lock Det. 2	
				61	33	3	Power Mon.	
29			NC	62	34		Temp. Mon.	
30			NC		35	15	GND	
31			NC	63	36		NC	
32			NC	64	37		NC	
					37			

Table10.3.1 Table for monitoring points

Table10.3.1 Table for monitoring points

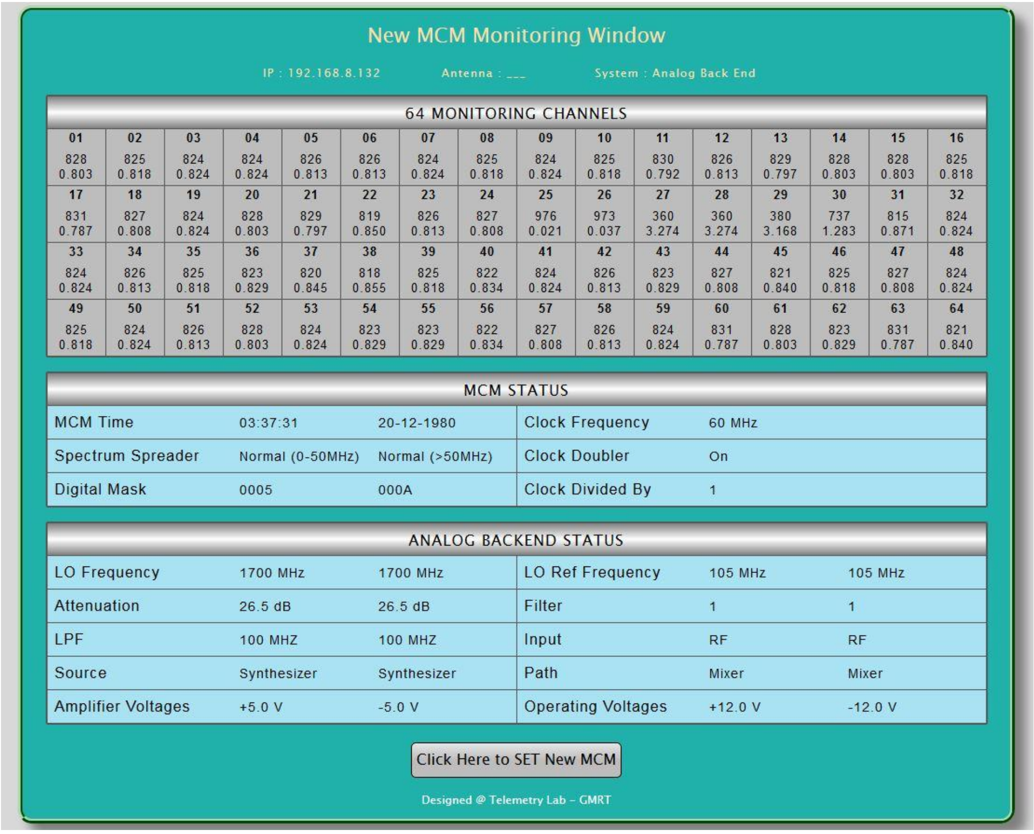
From Connector D37- I & II to D15 connector of Analog Receiver, RF filter ,Baseband and LO PIU's monitoring connector								
RX PIU MONITORING -1				RX PIU MONITORING -2				
FRC	D37-I	D15-1	SIGNAL	FRC-II	D37-II	D15-1	SIGNAL	
1	1	1	0.5 dB	33	1	1	0.5 dB	D-15 TO RX PIU MONITORING X 2
2	2	9	1.0 dB	34	2	9	1.0 dB	
3	3	2	2.0 dB	35	3	2	2.0 dB	
4	4	10	4.0 dB	36	4	10	4.0 dB	
5	5	3	8.0 dB	37	5	3	8.0 dB	
6	6	11	16 dB	38	6	11	16 dB	
7	7	4	VGA	39	7	4	VGA	
8	8	12	Buffer	40	8	12	Buffer	
9	9	5	Conversion	41	9	5	Conversion	
10	10	13	Det VGA	42	10	13	Det VGA	
11	11	6	Det Buffer	43	11	6	Det Buffer	
12	12	14	Power Supply	44	12	14	Power Supply	
13	13	7	Temp Mon.	45	13	7	Temp Mon.	
	15	15	GND		15	15	GND	
	14	8	SP			8	SP	
RF filter monitoring -1				RF filter monitoring -2				
FRC	D37-I	D15-2	Monitoring	FRC-ii	D37-II	D15-2	Monitoring	
14	16	1	RF Filter	46	16	1	RF Filter	ERLTFI D- 15 TO 2 1 X
15	17	9	RF Filter	47	17	9	RF Filter	
16	18	2	RF Filter	48	18	2	RF Filter	
17	19	10	RF Filter MON1	49	19	10	RF Filter MON1	
18	20	3	RF Filter MON2	50	20	3	RF Filter MON2	
19	21	11	Power	51	21	11	Power	
	22	15	GND		22	15	GND	

Table10.3.2 Table for control points

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1 2	LPF		FILTER			S Si	A N	D M	A N	ATTENUATION							LPF		FILTER			S Si	A N	D M	A N	ATTENUATION					

S – Synthesizer, **Si** – Signal generator, **A –** Antenna, **N –** Noise source,
D – Direct, **M** – Mixer,
1 / 2 – Channel select

10.4 Snapshot of New MCM monitoring window



New MCM Monitoring Window

IP : 192.168.8.132 Antenna : ___ System : Analog Back End

64 MONITORING CHANNELS

01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
828 0.803	825 0.818	824 0.824	824 0.824	826 0.813	826 0.813	824 0.824	825 0.818	824 0.824	825 0.818	830 0.792	826 0.813	829 0.797	828 0.803	828 0.803	825 0.818
17	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**
831 0.787	827 0.808	824 0.824	828 0.803	829 0.797	819 0.850	826 0.813	827 0.808	976 0.021	973 0.037	360 3.274	360 3.274	380 3.168	737 1.283	815 0.871	824 0.824
33	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**
824 0.824	826 0.813	825 0.818	823 0.829	820 0.845	818 0.855	825 0.818	822 0.834	824 0.824	826 0.813	823 0.829	827 0.808	821 0.840	825 0.818	827 0.808	824 0.824
49	**50**	**51**	**52**	**53**	**54**	**55**	**56**	**57**	**58**	**59**	**60**	**61**	**62**	**63**	**64**
825 0.818	824 0.824	826 0.813	828 0.803	824 0.824	823 0.829	823 0.829	822 0.834	827 0.808	826 0.813	824 0.824	831 0.787	828 0.803	823 0.829	831 0.787	821 0.840

MCM STATUS

MCM Time	03:37:31	20-12-1980	Clock Frequency	60 MHz
Spectrum Spreader	Normal (0-50MHz)	Normal (>50MHz)	Clock Doubler	On
Digital Mask	0005	000A	Clock Divided By	1

ANALOG BACKEND STATUS

LO Frequency	1700 MHz	1700 MHz	LO Ref Frequency	105 MHz	105 MHz
Attenuation	26.5 dB	26.5 dB	Filter	1	1
LPF	100 MHZ	100 MHZ	Input	RF	RF
Source	Synthesizer	Synthesizer	Path	Mixer	Mixer
Amplifier Voltages	+5.0 V	-5.0 V	Operating Voltages	+12.0 V	-12.0 V

Click Here to SET New MCM

Designed @ Telemetry Lab – GMRT

Fig10.4 Snapshot of monitor window

10.5 Snapshot of New MCM Control window

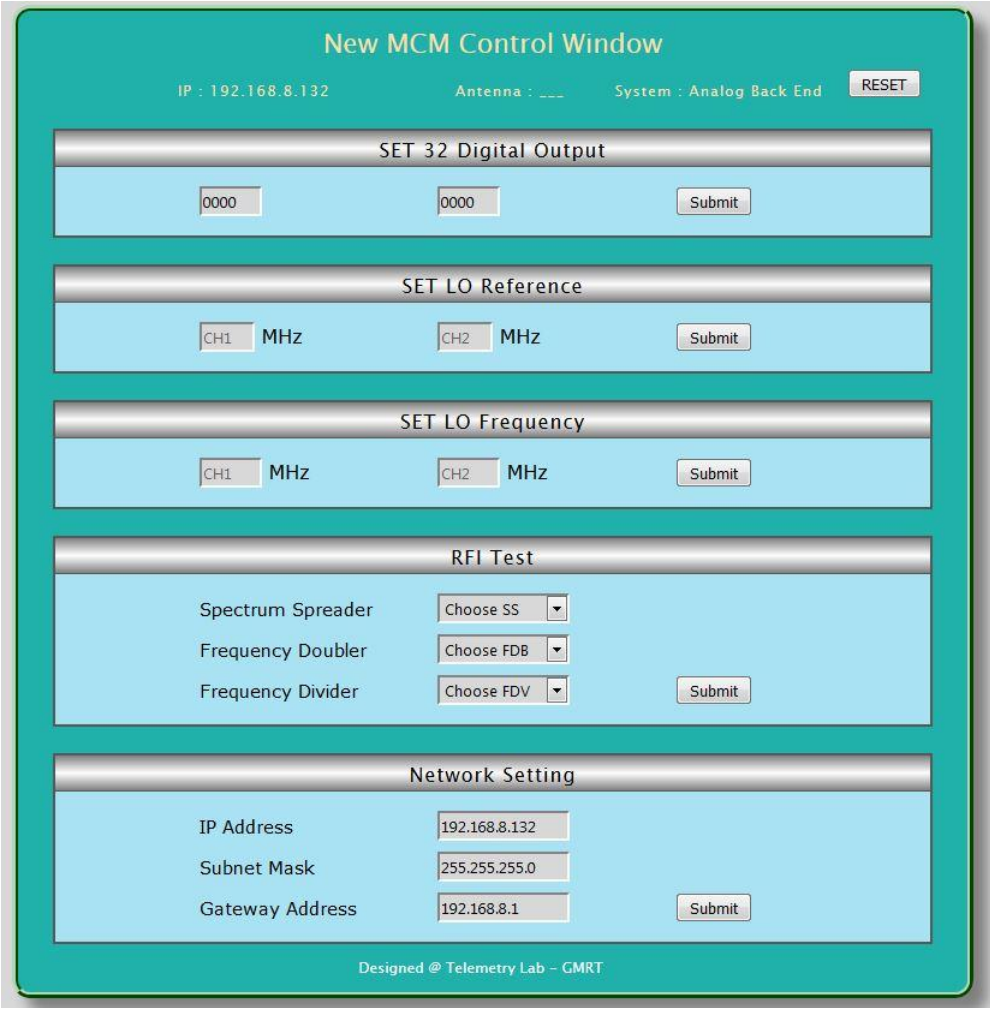


Fig10.5 Snapshot of monitor window

CONCLUSION

The GMRT Analog Backend (GAB) has been upgraded as a part of uGMRT, with seamless frequency coverage of 130 to 1700 MHz, and an instantaneous selectable bandwidth up to 400 MHz.

Dual polarized independent LO synthesizer system has been designed with improved Phase noise specifications to help user to perform the polarized dependent observations.

A computerized based ALC has implemented using RF Power detectors implemented in the system and computed, based on the gain requirements in terms of attenuation setting.

A Frequency and Time standard (FTS) system specifications are improved with help of new instrument i.e. PTS make GPS10RBN model.

The various sub systems are newly developed in house and implemented are such as RFI shield Ethernet Switch, RFI shield SMPS power supply which helped to optimized the overall cost.

Rack wiring and fabrication were also carried in- house under the mass production and units were characterized for the performance test at chassis as well as integrated PIU level. This design provides analog spare output which can be used independently as backend output without disturbing the working chain.

A fully functional 30 antenna GAB system has been released with online interface for control and monitors the system parameter.

Annexure

Cascaded Analysis Result:

Theoretical analysis @100 MHz :

Input power : -24 dBm

Signal Bandwidth : 400MHz

Impedance : 50 ohm

UNIT Description	DEVICE Part	MAKE	Freq (MHz)	Zin/Zout (ohms)	Gain (dB)	Noise Figure (dB)	Output P1 dB (dBm)	Output IP3 (dBm)	Volt s (V)	Curre nt (mA)	Pow @ Device O/P	Cum. Gain (dB)	Cum. NF (dB)	Head room for the	I/P for Device Sat
RF Cable (~20mtr	LMR400	TMS	100	50	-1.00	1.00	40	100	0	0	-25.00	-1.00	1.00	65	41
Directional Coupler	SYD-20-33+	MCL	100	50	-0.9	0.9	27	100.00	0	0	-25.90	-1.90	1.90	52.9	28.9
2-Way RF Switch	M3SWA2-50DR+	MCL	100	50	-0.6	0.6	25	100.00	0	9	-26.50	-2.50	2.50	51.5	27.5
Fixed Attenuator	Home made		100	50	-6	6	100	100.00	0	0	-32.50	-8.50	8.50	132.5	108.5
RF Amplifier	Gali-84+	MCL	100	50	25.6	4.2	21.9	35.50	5.8	100	-6.90	17.10	12.70	28.8	4.8
Digital Attenuator	HMC472LP4	Hittite	100	50	-17	17	18.5	38.50	5	50	-23.90	0.10	12.92	42.4	18.4
8-Way RF Switch	HMC253QS24E	Hittite	100	50	-1.1	1.1	23	100.00	5	50	-25.00	-1.00	12.98	48	24
Band Pass Filter	Home made		100	50	-3	3	30	100.00	0	0	-28.00	-4.00	13.25	58	34
8-Way RF Switch	HMC253QS24E	Hittite	100	50	-1.1	1.1	23	100.00	5	50	-29.10	-5.10	13.39	52.1	28.1
2-Way RF Switch	M3SWA2-50DR+	MCL	100	50	-0.6	0.6	25	100.00	0	9	-29.70	-5.70	13.49	54.7	30.7
Mixer	SYM-2500+	MCL	100	50	-5.17	5.17	1	100.00	0	0	-34.87	-10.87	14.89	35.87	11.87
Low Pass Filter	Home made		100	50	-1	1	30	100.00	0	0	-35.87	-11.87	15.31	65.87	41.87
2-Way RF Switch	M3SWA2-50DR+	MCL	100	50	-0.6	0.6	25	100.00	5	9	-36.47	-12.47	15.59	61.47	37.47
RF Amplifier	Gali-6	MCL	100	50	12.2	4.5	18.2	35.50	5	70	-24.27	-0.27	18.35	42.47	18.47
2-Way RF Switch	M3SWA2-50DR+	MCL	100	50	-0.6	0.6	25	100.00	5	9	-24.87	-0.87	18.36	49.87	25.87
Directional Coupler	PDC-20A-5+	MCL	100	50	-0.3	0.3	33	100.00	0	0	-25.17	-1.17	18.36	58.17	34.17
2-Way Pow Splitter	PRSC-2050	MCL	100	50	-6.05	6.05	30	100.00	0	0	-31.22	-7.22	18.61	61.22	37.22
RF Amplifier	Gali-84+	MCL	100	50	25.6	4.2	21.9	37.60	5.8	100	-5.62	18.38	19.09	27.52	3.52
High-Speed Buffer	LMH6559	Nsem	100	50	-6	6	23	100.00	10	10	-11.62	12.38	19.10	34.62	10.62
RF Cable (~20mtr	LMR400	TMS	100	50	-1.00	1.00	40	100	0	0	-12.62	11.38	19.10	52.62	28.62

Input Power	-24	dBm
Output Power	-12.62	dBm
Power Gain	11.38	dB
Noise Figure	19.09752559	dB
Output P1 dB	14.9	dBm
Output IP3	27.09359892	dBm
CDR	72.28566319	dB
SFDR	56.31950807	dB
Headroom	27.52	dB
O/p Noise Density	-143.41	dBm/Hz
Noise Temp @ FE in	0.0096	K
Power Consumption	2.45	Watts

Theoretical analysis @ 1500 MHz:

Input power : -24 dBm

Signal Bandwidth : 400MHz

Impedance : 50 ohm

UNIT Description	DEVICE Part	MAKE	Freq (MHz)	Zin/Zout (ohms)	Gain (dB)	Noise Figure (dB)	Output P1 dB (dBm)	Output IP3 (dBm)	Volts (V)	Current (mA)	Pow @ Device O/P	Cum. Gain (dB)	Cum. NF (dB)	room for the I/P	I/P for Device Sat
RF Cable (~20mtrs.	LMR400	TMS	1500	50	-3.50	3.50	40	100	0	0	-27.50	-3.50	3.50	67.5	43.5
Directional Coupler	SYD-20-33+	MCL	1500	50	-1.25	1.25	27	100.00	0	0	-28.75	-4.75	4.75	55.75	31.75
2-Way RF Switch	M3SWA2-50DR+	MCL	1500	50	-0.9	0.9	25	100.00	0	9	-29.65	-5.65	5.65	54.65	30.65
Fixed Attenuator	Home made		1500	50	-6	6	100	100.00	0	0	-35.65	-11.65	11.65	135.65	111.65
RF Amplifier	Gali-84+	MCL	1500	50	19.2	4.4	21.2	38.00	5.8	100	-16.45	7.55	16.05	37.65	13.65
Digital Attenuator	HMC472LP4	Hittite	1500	50	-4	4	18.5	38.50	5	50	-20.45	3.55	16.08	38.95	14.95
8-Way RF Switch	HMC253QS24E	Hittite	1500	50	-1.3	1.3	23	100.00	5	50	-21.75	2.25	16.10	44.75	20.75
Band Pass Filter	Home made		1500	50	-3	3	30	100.00	0	0	-24.75	-0.75	16.16	54.75	30.75
8-Way RF Switch	HMC253QS24E	Hittite	1500	50	-1.3	1.3	23	100.00	5	50	-26.05	-2.05	16.20	49.05	25.05
2-Way RF Switch	M3SWA2-50DR+	MCL	1500	50	-0.9	0.9	25	100.00	0	9	-26.95	-2.95	16.24	51.95	27.95
Mixer	SYM-2500+	MCL	1500	50	-8.23	8.23	1	100.00	0	0	-35.18	-11.18	17.26	36.18	12.18
Low Pass Filter	Home made		100	50	-1	1	30	100.00	0	0	-36.18	-12.18	17.53	66.18	42.18
2-Way RF Switch	M3SWA2-50DR+	MCL	100	50	-0.6	0.6	25	100.00	5	9	-36.78	-12.78	17.71	61.78	37.78
RF Amplifier	Gali-6	MCL	100	50	12.2	4.5	18.2	35.50	5	70	-24.58	-0.58	19.71	42.78	18.78
2-Way RF Switch	M3SWA2-50DR+	MCL	100	50	-0.6	0.6	25	100.00	5	9	-25.18	-1.18	19.72	50.18	26.18
Directional Coupler	PDC-20A-5+	MCL	100	50	-0.3	0.3	33	100.00	0	0	-25.48	-1.48	19.72	58.48	34.48
2-Way Pow Splitter	PRSC-2050	MCL	100	50	-6.05	6.05	30	100.00	0	0	-31.53	-7.53	19.92	61.53	37.53
RF Amplifier	Gali-84+	MCL	100	50	25.6	4.2	21.9	37.60	5.8	100	-5.93	18.07	20.31	27.83	3.83
High-Speed Buffer	LMH6559	Nsem	100	50	-6	6	23	100.00	10	10	-11.93	12.07	20.31	34.93	10.93
RF Cable (~20mtrs	LMR400	TMS	100	50	-1.00	1.00	40	100	0	0	-12.93	11.07	20.31	52.93	28.93

Cascaded Analysis Result:

Input Power	-24	dBm
Output Power	-12.93	dBm
Power Gain	11.07	dB
Noise Figure	20.30865344	dB
Output P1 dB	14.9	dBm
Output IP3	30.0625001	dBm
CDR	71.37138283	dB
SFDR	57.68925529	dB
Headroom	27.83	dB
O/p Noise Density	-142.49	dBm/Hz
Noise Temp @ FE in	0.0127	K
Power Consumption	2.45	Watts

Photographs of Final GAB System Installed at Central Electronics Building:

GAB System Rack – Front Side

GAB System Rack – Rear Side