PUJA VACATION TRAINING CUM PROJECT

Project Report on

"POWER LEVEL MONITORING DEVICE FOR GMRT RECEIVER"

Submitted to

GMRT LIBRARY, GMRT

NCRA. TIFR

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CERTIFICATE

This is to certify that Mr. Surjya Neogy student of institute of Radio Physics & Electronics, C.U. have carried out the project entitled "POWER LEVEL MONITORING DEVICE FOR GMRT RECEIVER" satisfactorily under my guidance during the puja vacation 2006 and submitted the project report as per the requirement of GMRT.

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My cordial thanks to all those who have contributed this sincere cooperation directly and indirectly and material help in works or deeds for the preparation of this period.

Surjya Neogy

<u>**POWER LEVEL MONITORING DEVICE FOR GMRT RECEIVER**</u>

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Abstract

The RF power detector has been developed to monitor the RF power level at various stages of the GMRT receiver chain. This project is then further extended to build a general purpose power meter which is capable of measuring RF power in circuit or in transmission cable. The later has been designed especially for on site applications and is also very useful in tests and troubleshooting of any RF circuits. The equipment is capable to measure the RF power level varying from -50 dBm to 0 dBm. The frequency of the input RF signal should be between 50 MHz to 2.5 GHz. The main component for this RF power level detection system is a multistage demodulating logarithmic amplifier (LT-5534) which provides a dc voltage proportional to the input RF power. The measured value of the RF power is displayed in dBm on a LCD based digital display. The equipment also has a data acquisition interface has also been incorporated into this equipment to read the output of the detector voltage and transfer the data to a PC through a serial port. The necessary program for transferring the data through serial port has been developed and verified.

Contents

1. GMRT
   - 1.1 Brief Introduction of GMRT.
   - 1.2 GMRT Receiver Chain.
2. RF Power Detection
   - 2.1 Introduction.
   - 2.2 Performance Specification.
   - 2.3 Principle of RF Power Detection.
   - 2.4 Operation of RF Power Monitor.
3. Construction
   - 3.1 Detector Prototype.
   - 3.2 PCB Layout.
   - 3.3 Monitoring Subsystem.
   - 3.4 PCB Layout.
   - 3.5 Voltage Conditioning Circuit.
4. Related Instruments & GMRT Modules
   - 4.1 Signal Generator.
   - 4.2 Spectrum Analyzer.
   - 4.3 Network Analyzer.
   - 4.4 Digital MultiMeter.
   - 4.5 Power Meter.
   - 4.6 Monitoring & Control Module (MCM).
   - 4.7 Front End Simulator (FE Simulator).
5. Characterization & Calibration
   - 5.1 Detector Prototype Unit
     - 5.1.1 Single Tone Characterization.
     - 5.1.2 Broadband Characterization.
   - 5.2 Power Detector Module
     - 5.2.1 Single Tone Characterization.
     - 5.2.2 Broadband Characterization.
   - 5.3 Calibration.
6. Antenna Base Measurements
   - 6.1 Wave Shape at ABR.
   - 6.2 Response of RF Power Detector System
     - 6.2.1 Antenna Base C2.
     - 6.2.2 Antenna Base C5.
7. Project Extension: General Purpose RF Power Meter
   - 7.1 DPM Interfacing.
   - 7.2 ADC Interfacing.
8. Summery & Further Scope of Work.
9. References.

1. GMRT [1]

1.1 Brief Introduction to GMRT[1]

The Giant Meter wave Radio Telescope (GMRT) in India is a major international facility in the field of Radio Astronomy. It is a versatile instrument for investigating a variety of astrophysical problems concerning the Sun, radio stars, pulsars, HII regions, supernova, galactic centre, nearby galaxies, radio galaxies, quasars and cosmology. One of the important scientific objectives of GMRT is to search for neutral hydrogen clouds prior to the formation of galaxies and clusters in the universe. GMRT is being currently used by scientists from India and abroad for various scientific experiments. This radio telescope utilizes highly sensitive feeds to collect radio signals from the cosmic sources and processes the signals using state of the art electronic receivers.

1.2 GMRT Receiver Chain[2]

GMRT consists of 30 fully steer-able parabolic dish antennas of 45 meter diameter each. Fourteen of these dishes are located in a central array of about 1Km x 1Km in area and the remaining eighteen along three arms of an approximately Y- shaped array providing a maximum baseline of about 25 Km. The total collecting area of these antennas is about 30,000 square Km. GMRT operates in the frequency bands protected for radio astronomy in India e.g. 150Mhz, 235Mhz, 325Mhz, 610Mhz and in the “L” bands. Independent feeds are used to collect the signals at these frequencies and the signals are then passed through extremely low noise front end electronics. The front end electronics includes low noise amplifiers, band pass filters and band selection switches. The front end electronics is located at the prime focus of the dish antenna just behind the feeds to reduce losses in the cable. The amplified RF signals are then brought to the dish base where the signals are down converted to Intermediate Frequencies (IF). IF circuits includes switchable band width filters and ALC circuits. IF signals are then transmitted to the central laboratory using optical fibre link. At the central lab signals are further down converted to base band frequencies and then digitized, processed and correlated. The study of these signals provides information about the source being observed. All frequency conversions at dish base are done using local oscillators which are coherent with the master LO reference at the Central Electronics Building (CEB), so that phase information in the received signals is not lost. This is very important for an interferometer type receiver like GMRT.
A simplified block diagram of GMRT receiver chain is shown in figure below.

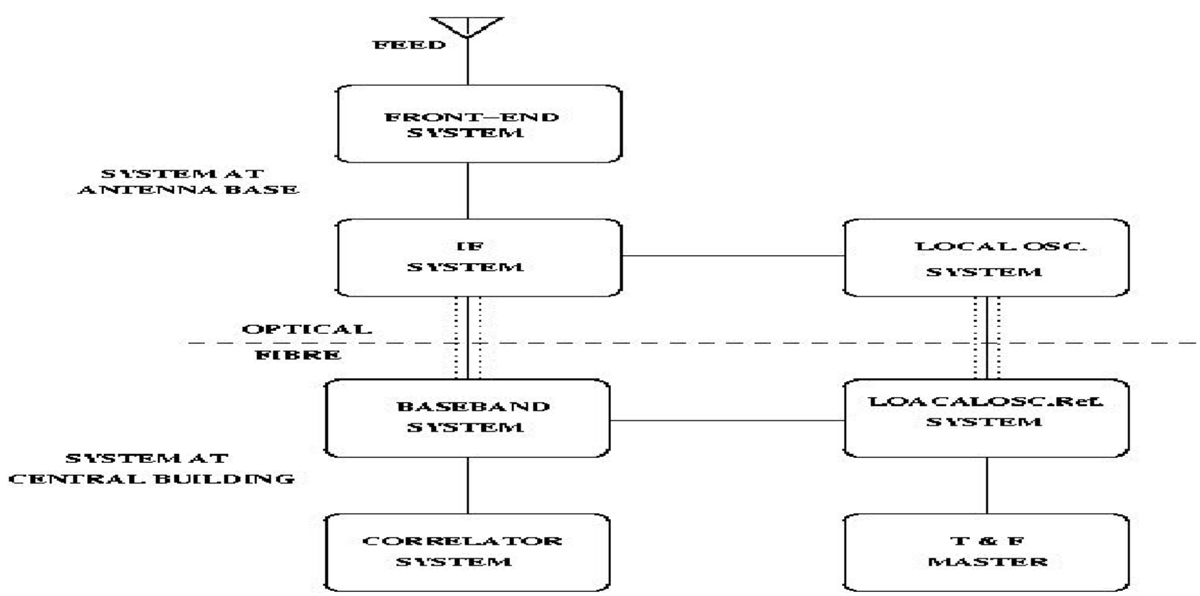

Fig 1.1 Block Diagram of GMRT Receiver Chain

2. RF Power Detection

2.1 Introduction

The RF power monitor is intended to measure the RF power remotely at different stages of the GMRT receiver chain. The main component for this monitoring subsystem is a monolithic logarithmic power sensor (LT-5534). Using this, the monitor can detect the RF power fed to the input port and displays the corresponding count on a console display.
The main parameters for the RF power sensor are the frequency range and the dynamic range of the input signal for which it will give an accurate & faithful measurement.

2.2 Performance Specification

Frequency Range: 50 MHz to 2.5 GHz can be upgraded up to 3GHz
Maximum Input Power: +2 dBm
Input Power Range: -60 dBm to 0 dBm
Dynamic Range: 60 dB
Display: On Console.
DC Power requirements: +5 V,± 12 V
Operating Temperature: -65°C to 125°C

2.3 Principle of RF Power Detection

The LT®5534[3] is a 50MHz to 3GHz monolithic Log Amp RF power detector, capable of measuring RF signals over a 60dB dynamic range. The RF signal in a decibel scale is precisely converted into DC voltage in a linear scale. This large 60dB input dynamic range is achieved using cascaded RF detectors and RF limiters. Their outputs are summed to generate an accurate log-linear DC voltage proportional to the input RF signal in dBm. The output is buffered with a low output impedance driver. The LT5534 delivers superior temperature stability (typical output variation within ±1dB over the full temperature range). The output responds in less than 40ns to a large RF input signal.

General Description of Log Amp Power Detector[4]

Logarithmic Amplifier uses the progressive compression (successive detection) technique to provide a dynamic range of up to 95 dB to a ± 3 dB law conformance or 90 dB to a ±1 dB error bound up to 100 MHz. A functional block diagram shown in the figure bellow

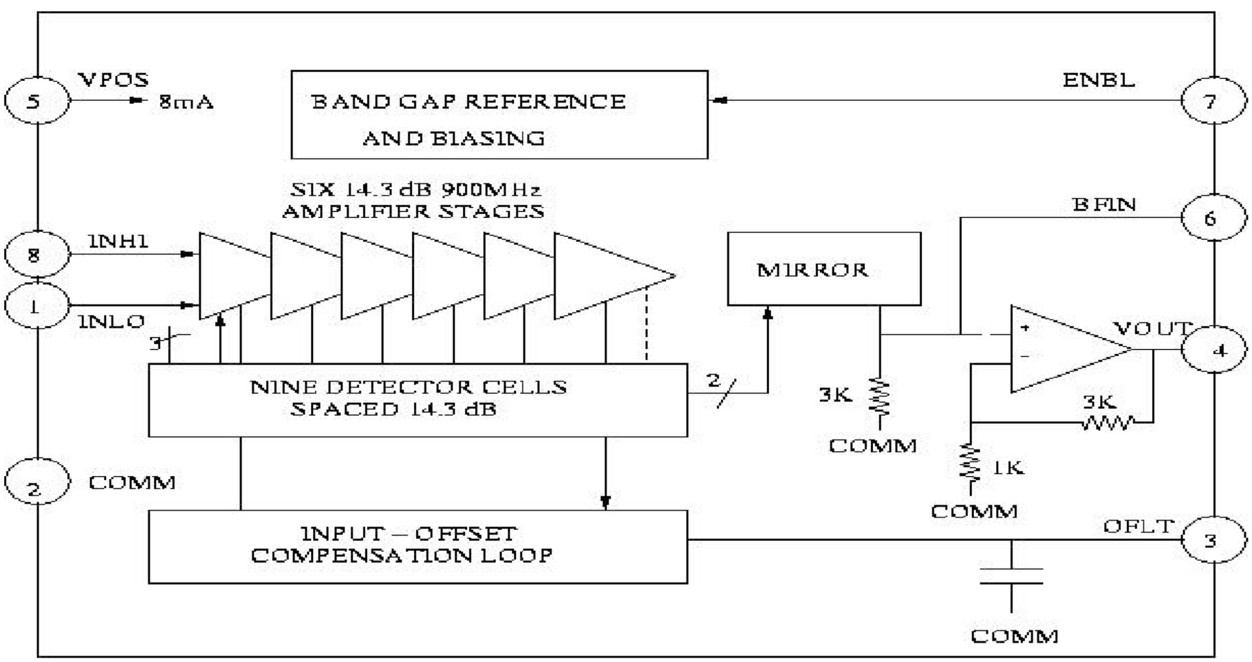

Fig 2.1 Functional Block Diagram of Logarithmic Amplifier Power Detector

The essential purpose of a log amp is not only to amplify but to compress a signal of wide dynamic range to its decibels equivalent. It is, therefore, a measurement device. An even better term might be logarithmic converter, because the function is to convert a signal from one domain of representation to another via a precise nonlinear transformation. The output of it is given by,

$$V_{OUT} = V_Y \log (V_{IN} / V_X)$$

Where: V_{OUT} is the output voltage. V_Y is the slope voltage. V_{IN} is the input voltage & V_X is the intercept voltage.

Log amps implicitly require two references (here V_X and V_Y) that determine the scaling of the circuit. The accuracy of a log amp cannot be any better than the accuracy of its scaling references.

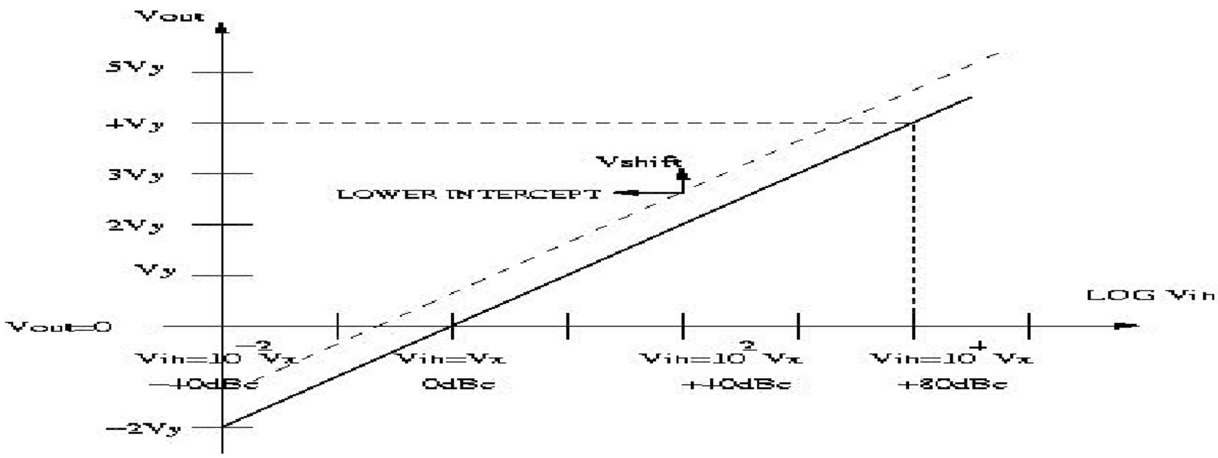

Fig 2.2 General Form of the Logarithmic Function

2.4 Operation of RF Power Monitor

Connect the DC supply to the unit. Switch on the main switch. Connect the input. Wait for some time to stabilize the monitor. Make the RS-232 interface with PC. Run "mcmprnn.exe" from the command prompt. Check the matrix element 04-01 on the console.

DATA OUTPUT FILE

START DATE: 12/09/2006 START TIME: 14:55:25

PRIMARY FILE DETAILS: c44acq.nop 12/9/2006 16:10 DELAY = 1 sec
----

SEC.FILE NAME	MCM ADDR	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25	C26	C27	C28	C29	C30	C31
M00	0A	247	132	000	255	247	128	000	255	134	131	128	128	128	129	128	128
M01	0A	161	149	161	164	000	000	000	000	000	130	128	128	129	128	129	128
M02	0A	000	000	000	000	000	000	000	000	077	130	129	129	128	128	170	128
M03	0A	128	132	128	119	128	128	129	115	129	131	129	128	129	170	170	128
M04	0A	027	132	000	173	128	128	000	170	129	130	129	128	129	128	170	128
M05	0A	130	212	130	212	210	131	131	000	128	131	128	128	128	129	128	128
M06	0A	000	000	000	000	000	000	000	000	128	131	128	128	128	128	128	128
M07	0A	249	241	252	132	129	129	129	128	129	131	129	128	128	170	170	128
M08	0A	128	132	128	132	129	128	128	128	128	131	128	128	128	128	128	128
M09	0A	128	132	128	132	128	129	129	128	128	131	129	128	128	128	170	128
M10	0A	128	132	128	132	128	129	128	128	128	131	128	128	128	128	170	128
M11	0A	169	173	169	173	170	170	170	170	128	131	129	128	129	129	128	128
M12	0A	169	173	169	173	170	170	170	170	128	131	128	129	128	128	170	128

Fig 2.3 Specimen to read the count from the console

The digital count and its position in the console output after execution of the “mcmprnn.exe” is shown above. Here the count “027” corresponds to input RF power of power level of “-15 dBm”. The primary file in this case is the “c44acq.nop” which is responsible to write the data onto the data file “rfdet.dat”. Once the data file is been activated, the acquired data get stored in destination folders starting from M00 to M12, and after completion of the total 12 round of counting, the data are printed on the console automatically. The marked location on the matrix of the above figure is the location of the count corresponding to the analog voltage output of the detector.

3. Construction

3.1 Detector Prototype

Figure 3.1 shows the connection[3] details of the Detector prototype unit.

Input Interface: The RF port is internally biased at (V_{CC}-0.18V). The pin should be DC blocked when connected to ground or other matching components. A 47Ω resistor (R1) connected to ground will provide better than -10dB input return loss up to 2.5GHz. An additional 2nH inductance in series with R1 will provide improved input matching up to 3GHz. The approximate linear RF input power range of the LT5534 is from –60dBm to +2dBm with a 50Ω source impedance. By simply inserting an attenuator in front of the RF input, the power range is shifted higher by the amount of the attenuation. Moreover, due to the high RF input impedance of the LT5534, the detecting range can be moved downward for better detection sensitivity by using a narrow band L-C matching network

Output Interface: The output currents from the RF detectors are summed and converted into an output voltage, V_{OUT}. The maximum charging current available to the output load is about 200µA. The internal compensation capacitor C_C is used to guarantee stable operation for a large capacitive output load. The slew rate is 133V/µs, and the small-signal output bandwidth is approximately 30MHz when the output is resistively terminated or open. The fastest output transient response is achieved when a large signal is applied to the RF input port. A capacitive load may result in output voltage overshoot, which can be minimized with a series compensation resistor R_2. The optional RC network at the output (R_2 and C_5 on the board) can also provide further output filtering, if needed. The output bandwidth is primarily dictated by the RC constant of this low pass filter when its corner frequency is less than 30MHz. When a large signal (e.g., –2dBm) is present at the RF input port, the output voltage swing can be as high as 2.4V. To assure proper operation of the chip, the minimum resistive load at the output termination should be greater than 18kW.

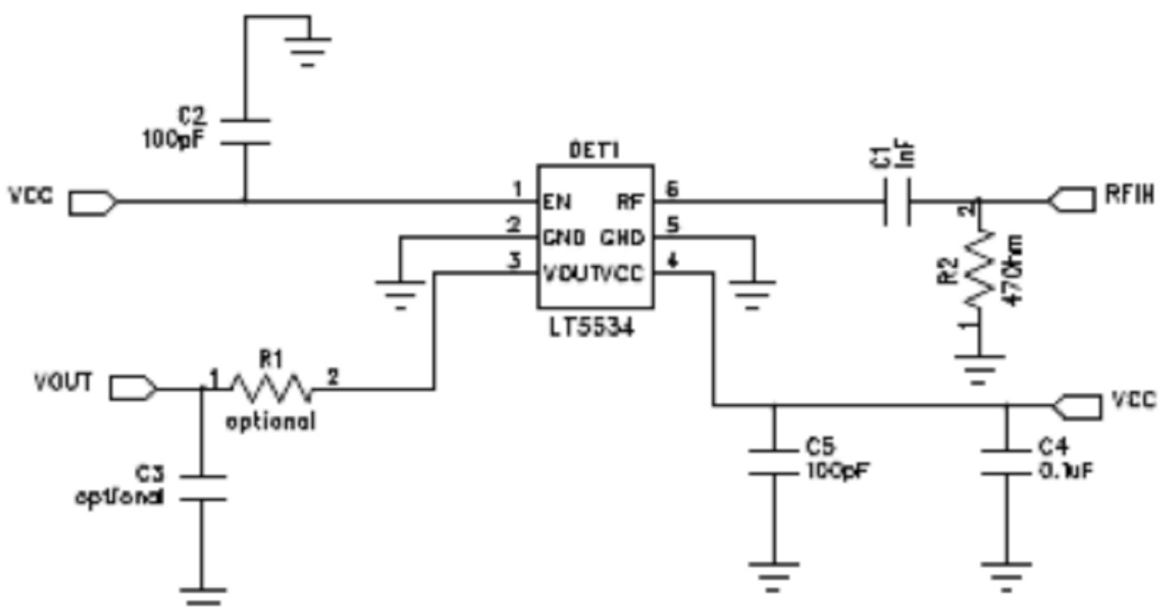

Fig. 3.1 Circuit Diagram for the detector prototype.

3.2 PCB Layout

The PCB Layout for this circuit is shown in the next page.

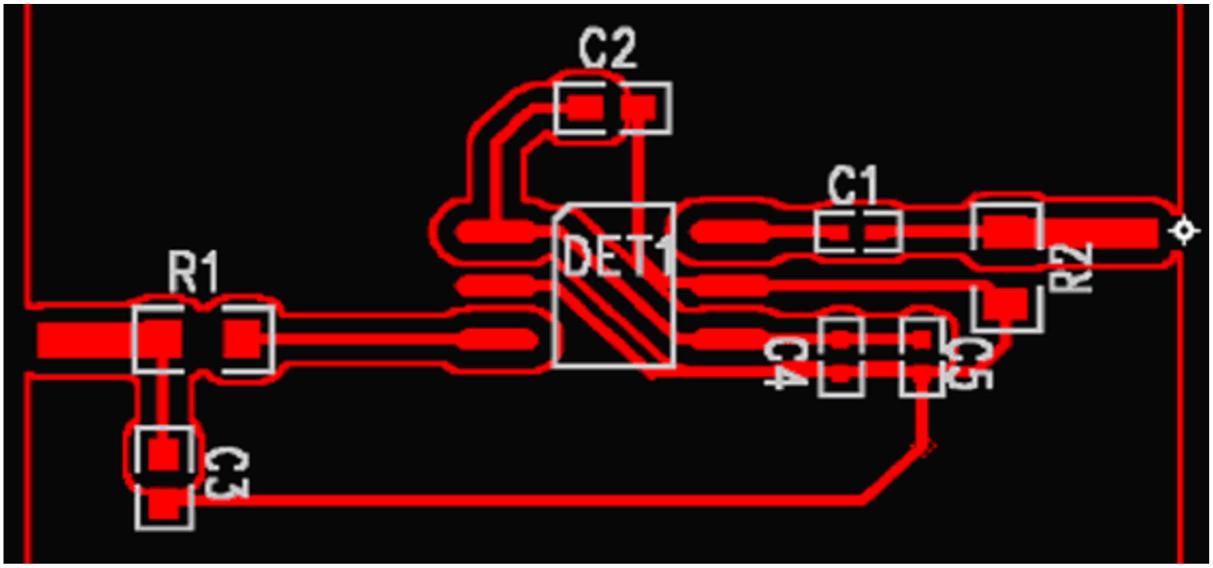

Fig. 3.2 PCB Layout of the Detector Prototype

3.3 Monitoring Subsystem

Figure 3.3 shows the connection details of the power level monitoring unit. To monitor the RF power level at various stages of the GMRT antenna base, a directional coupler is needed in order to bypass a detectable amount of power to the input of the detector without affecting the purpose of the signal. For the coupling purpose PDC-10-5 is used. This further introduces a loss of 10dB. The specified output RF power level at the Front End receiver is found to be the minimum and it is bellow -50dBm. So in order to amplify the input signal strength of the detector IC, a MAR-6+ is also employed. These two are the main elements that are used in addition to the Detector IC in completing the power monitor.

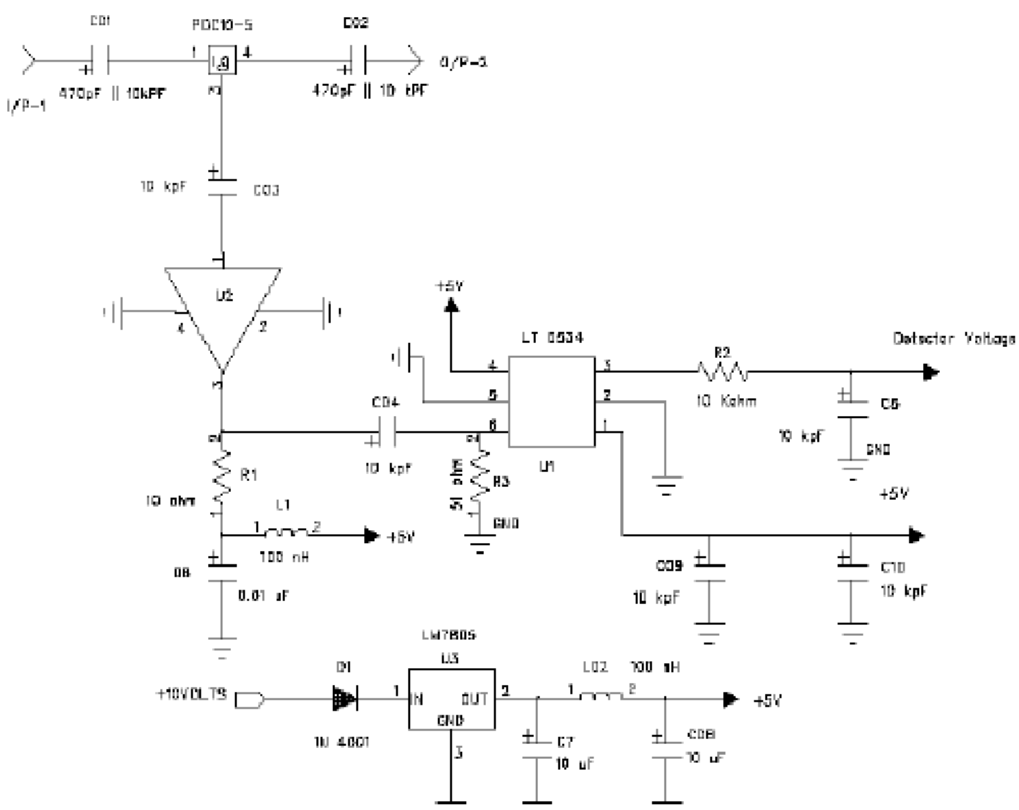

Fig. 3.3 Circuit Diagram for the Monitoring Subsystem

3.4 PCB Layout

The PCB Layout for the detector module is shown bellow

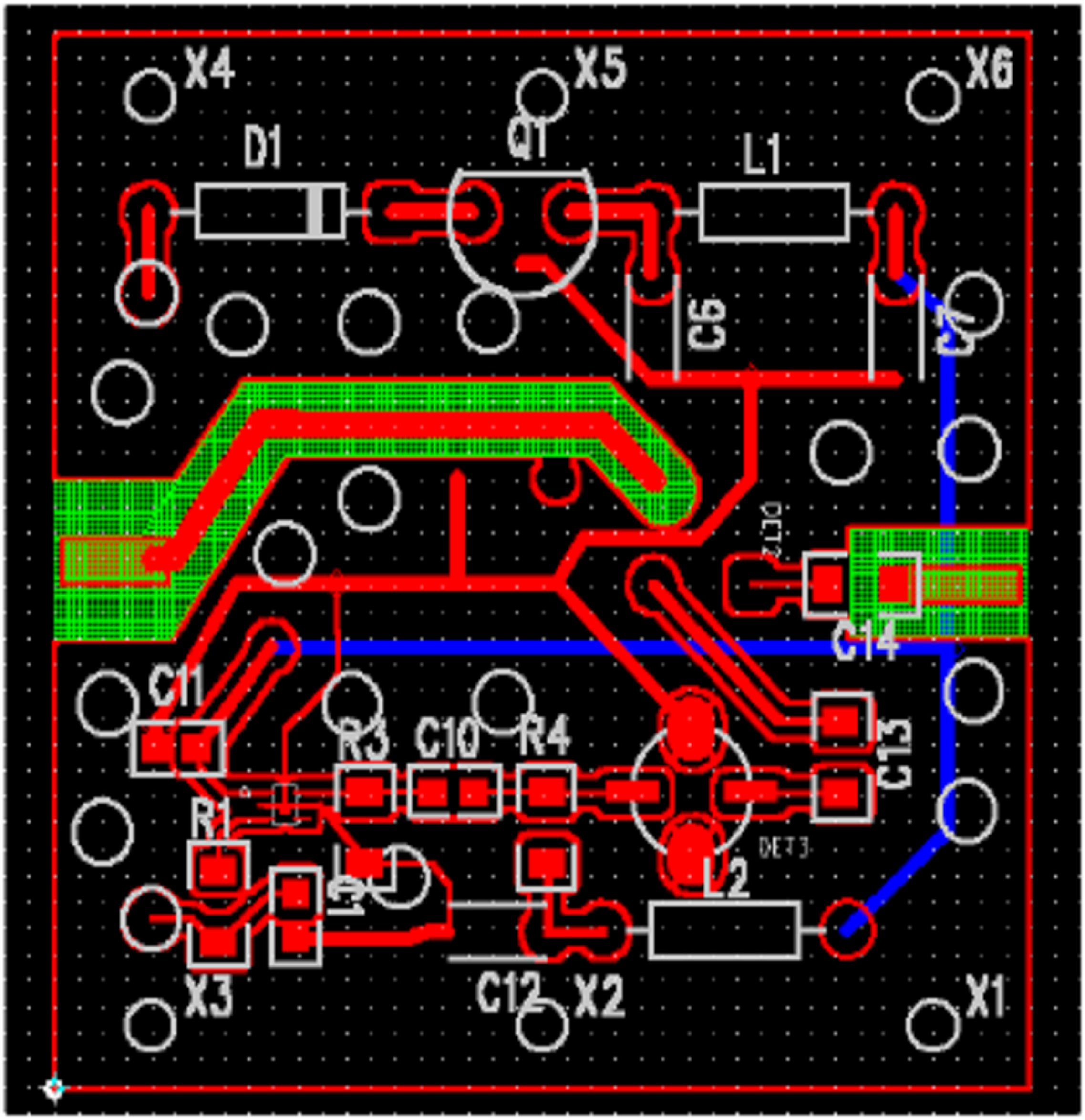

Fig 3.4 PCB Layout of the Detector Subsystem

3.5 Voltage Conditioning Circuit(5)

The output voltage of the detector is not compatible with the Monitor & Control Module (MCM). The ADC used in the MCM has fixed input of -5 volt to +5 volt. To ensure the use of full dynamic range of the MCM a voltage conditioning circuit shown in the fig 3.5 is employed to interface the detector output with the MCM. The circuit is a simple differential amplifier circuit. The aim of this circuit is to shift the voltage reference by a desired amount and then provide the necessary gain to the input voltage.

Due to the severe loading effect with IC741, a buffer circuit is also employed after the detector voltage output. The circuit is completed on a general purpose Vero board. The reference is drawn directly from the +12 volt of power supply by a voltage dividing circuit. The output of this circuit is get connected to Personal Computer using RS-232 connector cable.

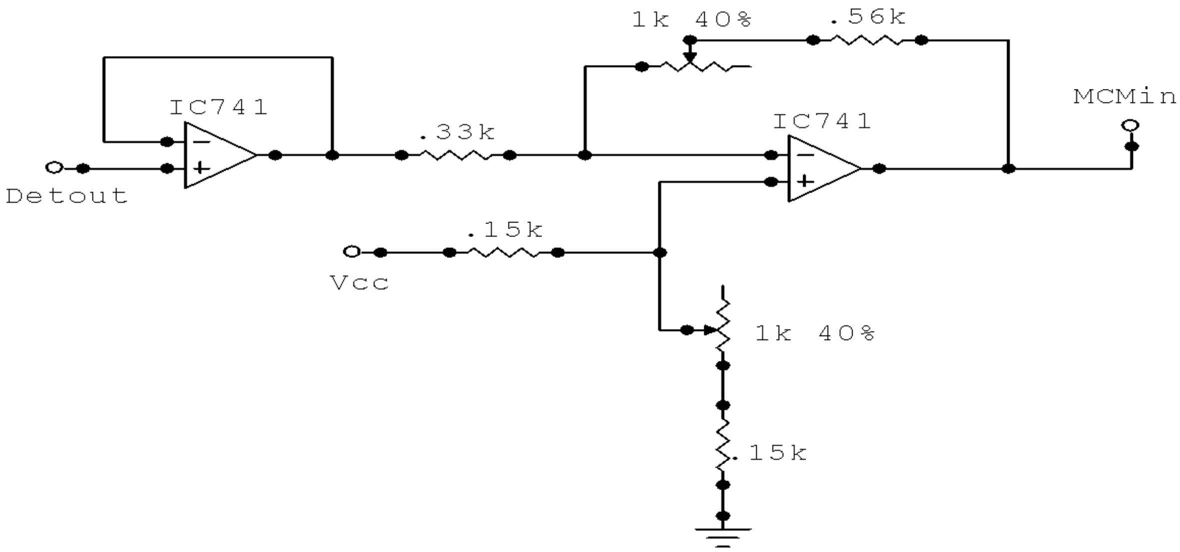

Fig 3.5 Circuit Diagram of the Voltage Conditioning Circuit

The detailed analysis for the circuit is well described in the article by A.B. Adoni[(5)], which is kept in the library. Interested persons can also go through this in the following link of the GMRT web site.
http://www.gmrt.ncra.tifr.res.in/~lib/gmrt/techrep/reports.html
It is also included in the reference chapter of this report.

4 Related Instruments

To characterize the power detector many instruments are used, among them the most important instruments are discussed in brief bellow.

4.1 Signal Generator

Marconi 2031 10KHz to 2.7GHz Synthesized Signal Generator[6]

Fig 4.1 Marconi 2031 Signal Generator

The Marconi /IFR 2031 Signal Generator, operates in the frequency range from 10 kHz to 2.7 GHz with a resolution of 0.1 Hz. The 2031 RF output can be exactly adjusted from -144 dBm to 13 dBm with a resolution of 0.1 dB.
The 2031 offers a built-in modulation oscillator with a frequency range 0.1 Hz to 500 kHz and Broadband-FM with 10 MHz bandwidth. All data can be entered via keyboard and incremental encoder, fully remote controllable via GPIB. Easy to read LCD display.

4.2 Spectrum Analyzer

Rohde & Schwarz 9 KHz to 7GHz FSP Spectrum Analyzer[7]

Fig 4.2 Rohde & Schwarz FSP Spectrum Analyzer

The Rohde & Schwarz 9 KHz to 7GHz FSP Spectrum Analyzer has the wonderful features of 21 cm TFT color display, 1 Hz to 10 MHz RBW, RMS detector for fast and reproducible

measurements on digitally modulated signals ,Measurement routines for TOI, ACPR, OBW, amplitude statistics, multi carrier ACP and finally it has EMI bandwidths and quasi-peak detector.
This FSP possesses 2.5 ms minimum sweep time in frequency domain, 1 µs sweep time in time domain, Up to 55 GPIB measurements/s in frequency domain (including trace transfer), Up to 80 GPIB measurements/s in time domain (including trace transfer), Fast ACP measurement routine in time domain. It has got total measurement uncertainty of 0.5 dB, Displayed average noise level of –155 dBm, Phase noise of -113 dBm at 10 kHz and the Dynamic range of RMS detector is 100 dB.

4.3 Network Analyzer

HP/Agilent 8714C, 300 kHz to 3 GHz Economy Network Analyzer(8)

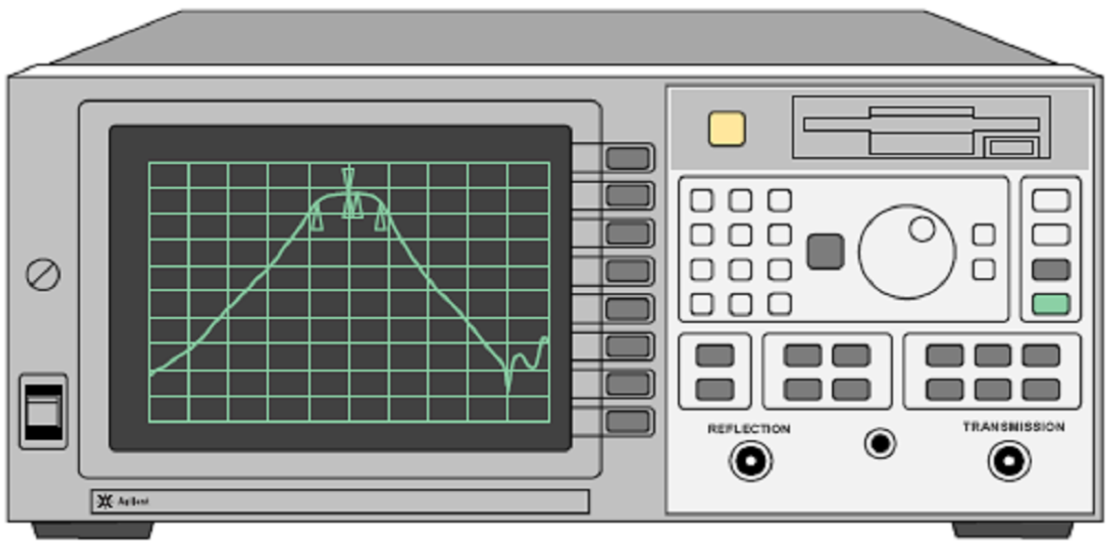

Fig. 4.3 HP/Agilent 8714C Network Analyzer

The 8714C is an economy Scalar Network Analyzer with an integrated transmission/reflection test set. It operates from 300 KHZ TO 3 GHz. The 8714C is suited for production testing of components, networks, and cables. An internal 3 1/2 disk drive simplifies data collection and test setup.
Its features integrate transmission/reflection test set with narrowband and broadband detection "Real time" sweep speed (50 ms/sweep), synthesized 1 Hz resolution source, and 100 dB of system dynamic range Internal 3.5-inch disk drive (LIF/DOS formats) and VGA interface Internal Agilent Instrument BASIC (IBASIC) capability TCP/IP-compliant Ether twist LAN interface option AM delay and fault location/SRL options.

4.4 Digital MultiMeter

3.5 Digit High Accuracy Digital MultiMeter
Modern multi meters are exclusively digital and identified by the term DMM or Digital Multi Meter. In such an instrument, the signal under test is converted to a digital voltage and an amplifier with an electronically controlled gain preconditions the signal. Since the digital display directly indicates a quantity as a number, there is no risk of parallax causing an error when viewing a reading.
The used mid sized handheld meter is really packed with functions. Among all the other features listed below this little gem has a data hold option. Its main features include Data Hold, Back Light, Audible Continuity Test, Temperature Meter, 200 hour battery life, Diode Test and Transistor Test.

4.5 Power Meter
Boonton 4232A Dual Channel, GPIB, 10 kHz - 100 GHz RF Power Meter[9]

Fig. 4.4 Boonton 4232A Dual Channels, GPIB RF POWER METER

The 4232A series is an extremely accurate two channel RF power meter that provides the high measurement speed required in production test with the simplicity of operation required on the bench. It can measure power levels from -70 dBm to +44 dBm and is exceptionally fast. Its 4-line display is easy to read and provides simultaneous display of dual channels with a bar graph display proportional to its numeric display.
The 4232A series is compatible with every Boonton diode, thermocouple and wave guide sensors from 10 KHz to 100 GHz. The 4232A series also integrates smoothly with ATE systems, via its standard IEEE-488 or optional RS-232 interface.

The *Monitoring & Control Module (MCM) and the Front End Simulator Module (FE Simulator)* are also used frequently. Among them, to get desired broad band noise the FE Simulator Module is slightly modified. These two modules are also discussed here.

4.6 Monitoring & Control Module (MCM) of GMRT[10]
MCM is a general purpose Micro-controller based card which provides 16 TTL Control O/Ps and monitors 64 analog signals. Antenna Computers communicate with MCM through RS485 communication link @ 9.6K baud rate and sets various FE, LO and IF system parameters and monitor the ABR parameters. The C44/116 MCM is used in this project. The basic block diagram is shown in the figure 4.5. With the help of the program “mcmprnn.exe” the data can be directly acquired from the voltage conditioning circuit output. Each antenna base has 16 MCMs. The MCMs run a control program which gets inputs from the ABC serial port. These inputs concern the various switch settings and the selection of analog channels which are to be monitored. All the 16 MCMs communicate to the ABC on a common bus. To avoid cross-talk, the ABC polls data from the MCMs as and when required.
This Control and Monitor System of a Radio Telescope is required to provide the necessary co-ordination between the various building blocks of the receiver system. This module is used for controlling the activities of the various building blocks of GMRT like

FE,LO,IF,BB,SERVO and FPS etc and Monitor the healthiness of the same in each of the antenna shells and CEB. It also provides the human interface to persons like Telescope Observers, Scientists and maintenance personnel for operating all the antennas from CEB. It has to monitor all parts of the telescope system for correct operation and alert the operator in case of any anomalous behavior, and in the case of severe fault conditions, safety procedures have to be initiated locally. It has also to prevent human error from placing the telescope in a dangerous situation.

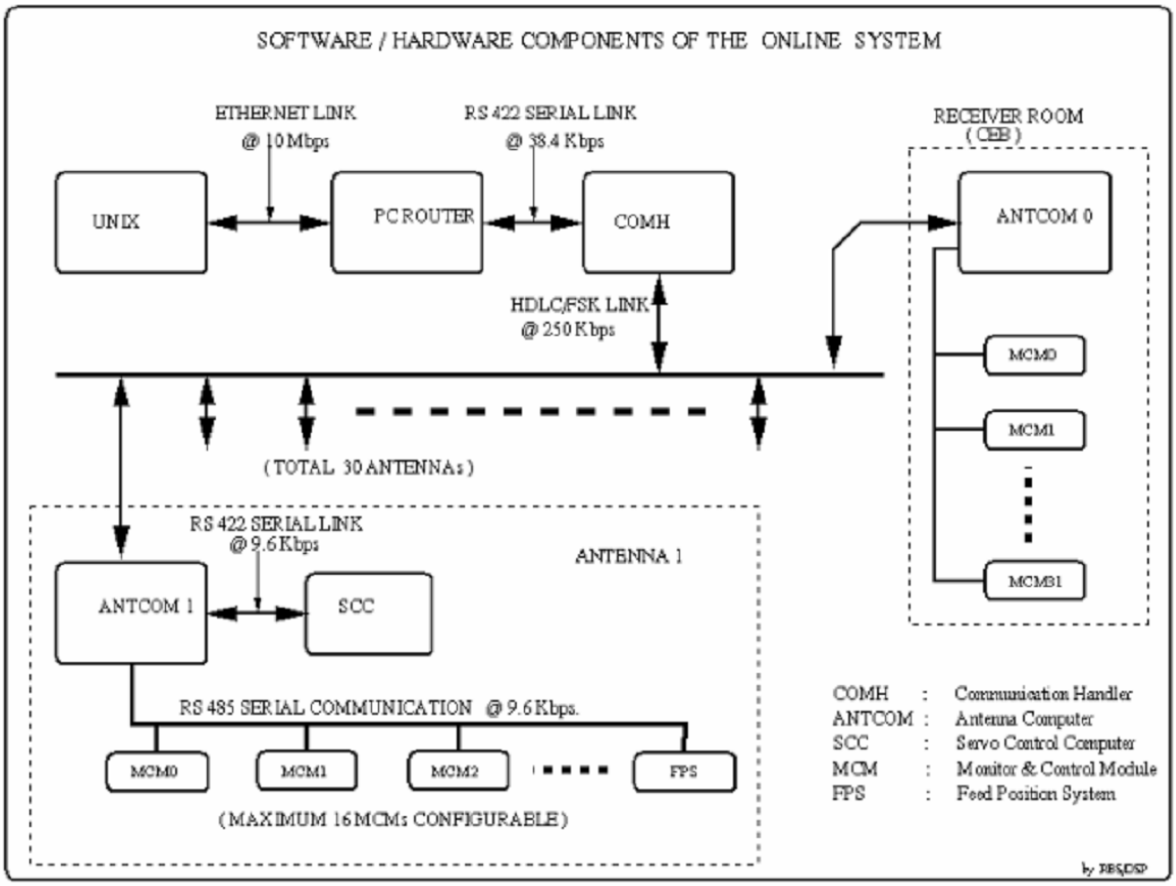

Fig 4.5 Monitoring & Control Module (MCM) of GMRT

4.7 FE Simulator[11]

A wideband noise generator is used to develop the Front End system simulator which provides noise power levels similar to the ones available at the dish base from the front end system at lower frequency bands. This unit is useful in testing the response of the IF system and also for the characterization of the ABR systems. This simulator is used to simulate 150MHz, 235MHz, 325MHz and 610MHz FE outputs.

In this system a wide band noise source using NC-501 is used to generate the noise which is further amplified and passed through a filter bank to generate the noise at each desired FE band. The simulator also has the facilities to vary the power by ± 30 dB from the normal operating power levels in steps of one dB. A two way power splitter provides signals to both channels of TF system thereby reducing the testing time.

In order to characterize the power detector such a source is needed which is capable to deliver variable broad band power starting from 0 dBm to -60 dBm. But the FE simulator can deliver output power no more than -20 dBm, as seen from the table 4.1 and table 4.2. Here two extreme bands are tested the rests are included in the datasheet.

Table 4.1 Experiment with FE Simulator Noise centered at 150 MHz & of BW 6 MHz

1. FE Simulator Settings: Gain = 30 dB Attenuation = 31 dB 2. Spec. Analyzer Settings: Resolution BW = 3 MHz Video BW = 10 MHz Sweep Time = 150 ms Span = 300 MHz / 7 GHz Reference = -10dBm Attenuation = 10dB 3. Marker: Marker Power = -63.33 dBm @ 150 MHz 4. Noise Signal Data: 3dB BW: Theoretical = 40 MHz, Measured = 36.8 MHz Channel Power = -52.57dBm For Channel BW = 80 MHz Channel Power = -43.25dBm For Full Span = 6.8 GHz	1. FE Simulator settings: Gain = 30 dB Attenuation = 0 dB 2. Spec. Analyzer Settings: Resolution BW = 3 MHz Video BW = 10 MHz Sweep Time = 150 ms Span = 300 MHz / 7 GHz Reference = -10dBm Attenuation = 10dB 3. Marker: Marker Power = -32.75 dBm @ 150 MHz 4. Noise Signal Data: 3dB BW: Theoretical = 40 MHz, Measured = 39.2 MHz Channel Power = -21.37dBm For Channel BW = 160 MHz Channel Power = -21.06dBm For Full Span = 6.8 GHz

Table 4.2 Experiment with FE Simulator Noise centered at 610 MHz & of BW 32 MHz

1. FE Simulator Settings: Gain = 30 dB Attenuation = 31 dB 2. Spec. Analyzer Settings: Resolution BW = 3 MHz Video BW = 10 MHz Sweep Time = 150 ms Span = 300 MHz / 7 GHz Reference = -10dBm Attenuation = 10dB 3. Marker: Marker Power = -69.68 dBm @ 610 MHz 4. Noise Signal Data: 3dB BW: Theoretical = 45 MHz, Measured = 73.5 MHz Channel Power = -56.08dBm For Channel BW = 100 MHz Channel Power = -43.58dBm For Full Span = 6.8 GHz	1. FE Simulator settings: Gain = 30 dB Attenuation = 0 dB 2. Spec. Analyzer Settings: Resolution BW = 3 MHz Video BW = 10 MHz Sweep Time = 150 ms Span = 300 MHz / 7 GHz Reference = -10dBm Attenuation = 10dB 3. Marker: Marker Power = -39.20 dBm @ 610 MHz 4. Noise Signal Data: 3dB BW: Theoretical = 45 MHz, Measured = 71.0 MHz Channel Power = -23.94dBm For Channel BW = 100 MHz Channel Power = -23.89dBm For Full Span = 6.8 GHz

So to boost up its output power level a RF amplifier is used just before the power divider. Also the out of band noise from the simulator is getting more prominent for the lower power levels, which is not the actual Front End characteristic. To suppress this unwanted out of band disturbances, A Low Pass filter of cutoff frequency of 800MHz is also employed between the Noise Generator and the Filter Bank. The modified block diagram of the FE Simulator is shown in the fig 4.6.

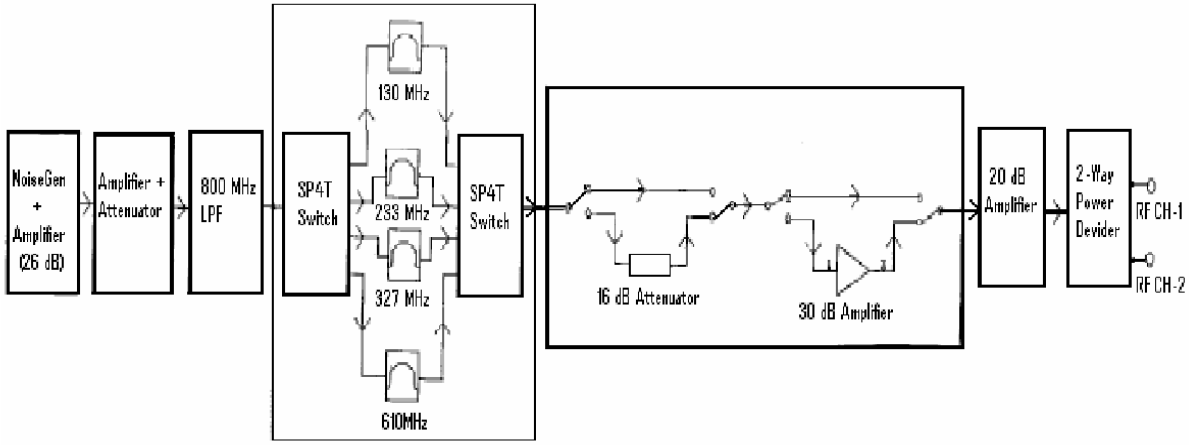

Fig. 4.6 The modified Front End Simulator

Proper RF amplifier was readily available in the Analog Laboratory using MAR-6+ which is utilized directly. But the LPF was not available, so a 5th LPF filter was designed, fabricated and then used in the FE Simulator. The circuit diagram and its transfer function are shown in the fig 4.7. This has been completed using the well known software “GENESYS™”.

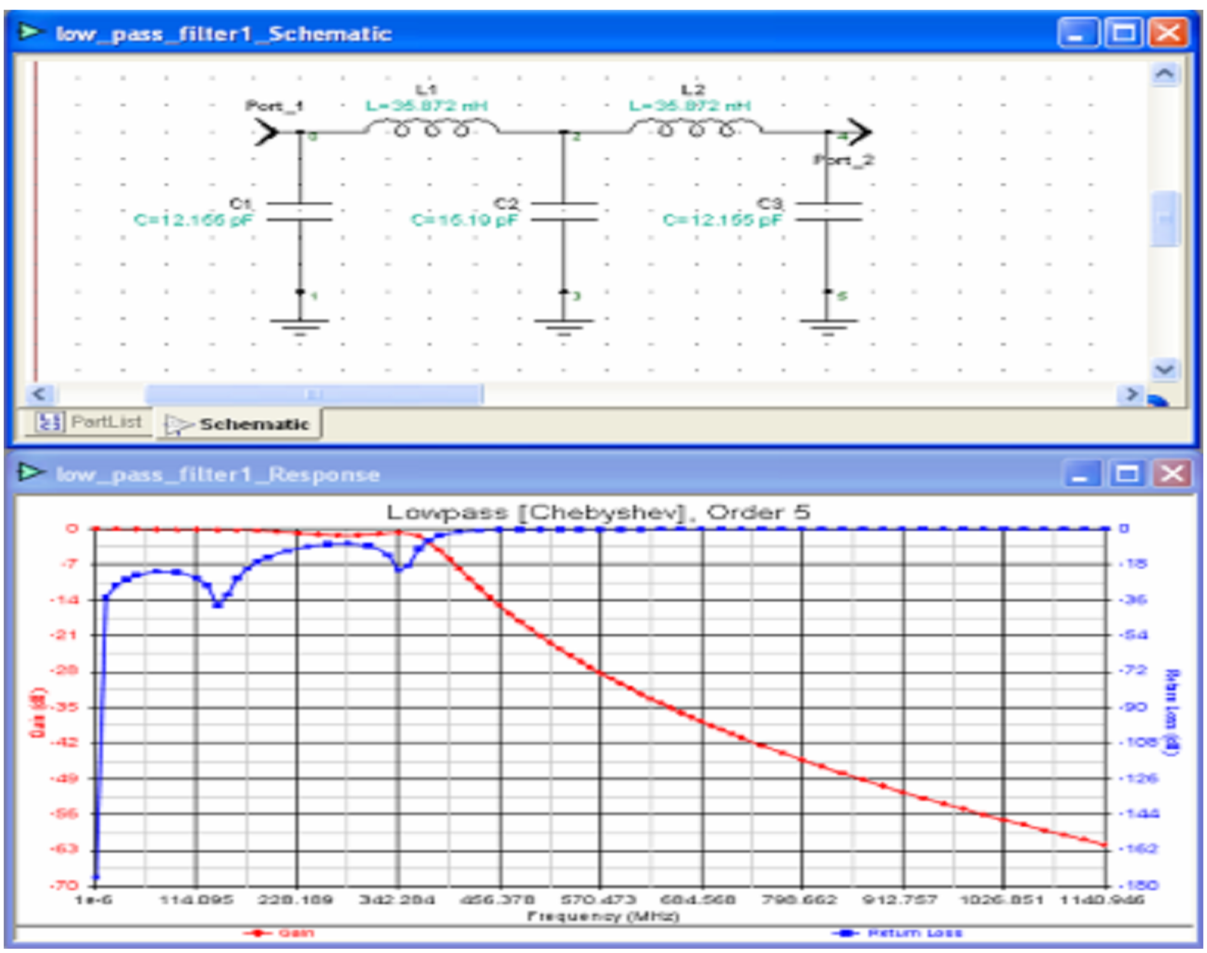

Fig 4.7 LPF and its Characteristics Curve.

These two modifications are fitted with the original FE Simulator. After that there was quite satisfactory result and the module was ready to start the measurements of characterizing the Detector. The improved output wave form of the modified FE Simulator is shown bellow.

327 MHz

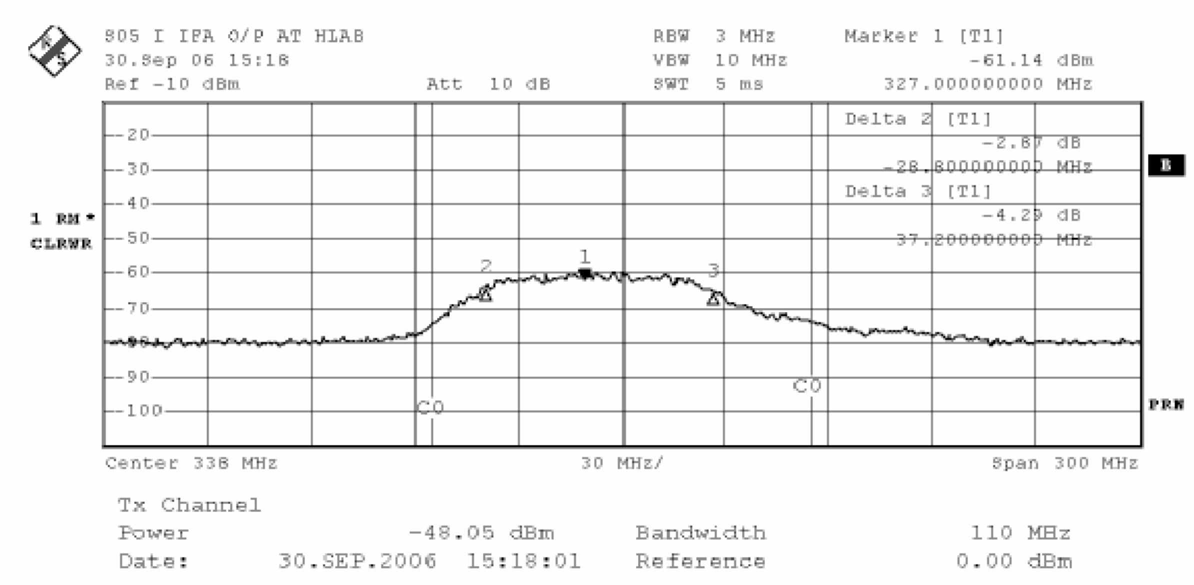

Fig. 4.8 Improved wave shape around the band 327 MHz (Small-Span View)

327 MHz

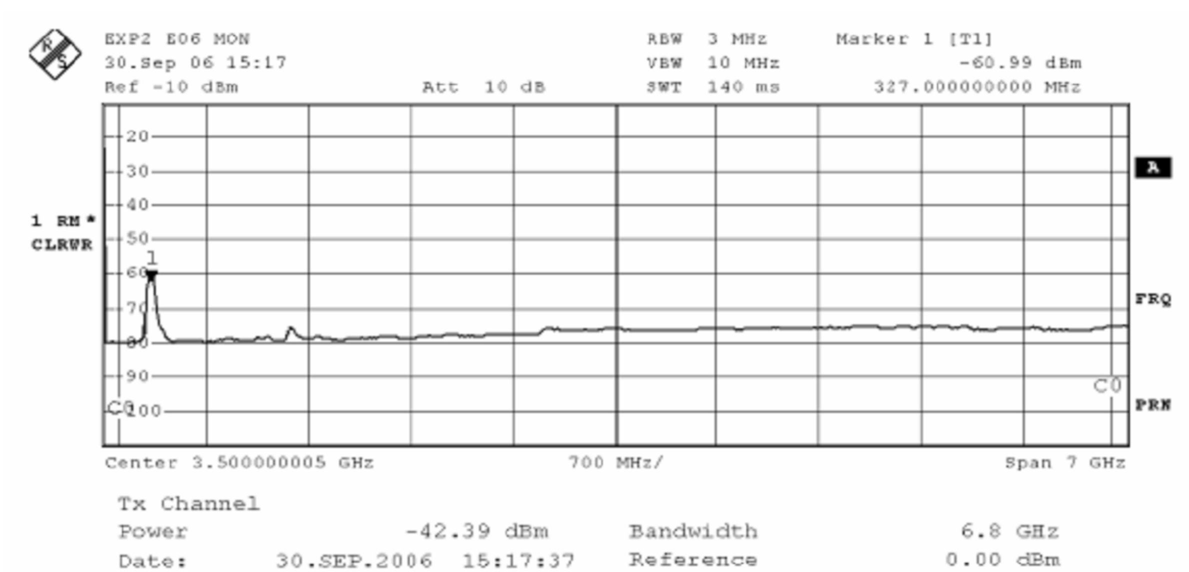

Fig. 4.9 Improved wave shape around the band 327 MHz (Full-Span View)

5. Characterization & Calibration

Every newly designed system should be thoroughly characterized and perfectly calibrated using some predefined instruments. The instruments mentioned in the previous chapter are extensively used in these purposes. The characterization part is done mainly using the R&S Spectrum Analyzer and Boonton Power meter is used for final calibration of the system.
A number of measurements are done with both the detector prototype as well as detector system; among those the most important results are included here. Most of the plots are included while in each case only one sample datasheet is provided and the rests are available as datasheet. Interested persons are referred to the full documentation of the measurements done which are enclosed as datasheet at the end of this report.

5.1 Detector Prototype Unit

5.1.1 Single Tone Characterization of Detector Prototype

Table 5.1 Single Tone Characterization

DATA FOR DETECTOR PROTOTYPE CHARACTERISTICS PART I								
I/P in dBm	Detector Output Voltage in Volt							
	50Mhz	100Mhz	150Mhz	235Mhz	325Mhz	400Mhz	500Mhz	610Mhz
00	2.54	2.53	2.53	2.52	2.49	2.48	2.44	2.43
-01	2.52	2.51	2.51	2.50	2.48	2.46	2.43	2.42
-03	2.48	2.47	2.46	2.45	2.43	2.41	2.38	2.38
-05	2.41	2.40	2.40	2.39	2.37	2.35	2.32	2.32
-07	2.33	2.32	2.31	2.31	2.28	2.27	2.24	2.24
-09	2.23	2.22	2.22	2.21	2.19	2.17	2.15	2.15
-11	2.13	2.12	2.12	2.11	2.09	2.08	2.06	2.06
-13	2.04	2.03	2.03	2.02	2.00	1.99	1.97	1.97
-15	1.96	1.95	1.94	1.94	1.92	1.91	1.89	1.89
-20	1.74	1.73	1.73	1.73	1.71	1.70	1.69	1.69
-25	1.52	1.51	1.51	1.51	1.50	1.49	1.48	1.48
-30	1.31	1.30	1.30	1.29	1.29	1.28	1.28	1.28
-35	1.08	1.07	1.07	1.07	1.07	1.06	1.06	1.07
-40	0.88	0.87	0.87	0.87	0.86	0.86	0.87	0.87
-45	0.67	0.66	0.65	0.65	0.64	0.64	0.65	0.66
-50	0.47	0.46	0.45	0.45	0.44	0.44	0.45	0.46
-52	0.40	0.38	0.37	0.37	0.37	0.37	0.38	0.38
-54	0.33	0.31	0.31	0.30	0.30	0.30	0.31	0.31
-56	0.27	0.26	0.25	0.25	0.25	0.25	0.26	0.26
-58	0.23	0.22	0.21	0.21	0.21	0.21	0.21	0.22
-60	0.19	0.19	0.18	0.18	0.18	0.18	0.18	0.19
-62	0.17	0.17	0.16	0.16	0.16	0.16	0.17	0.17
-64	0.16	0.15	0.15	0.15	0.15	0.15	0.15	0.15
-65	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15

The corresponding plots are given in the next page.

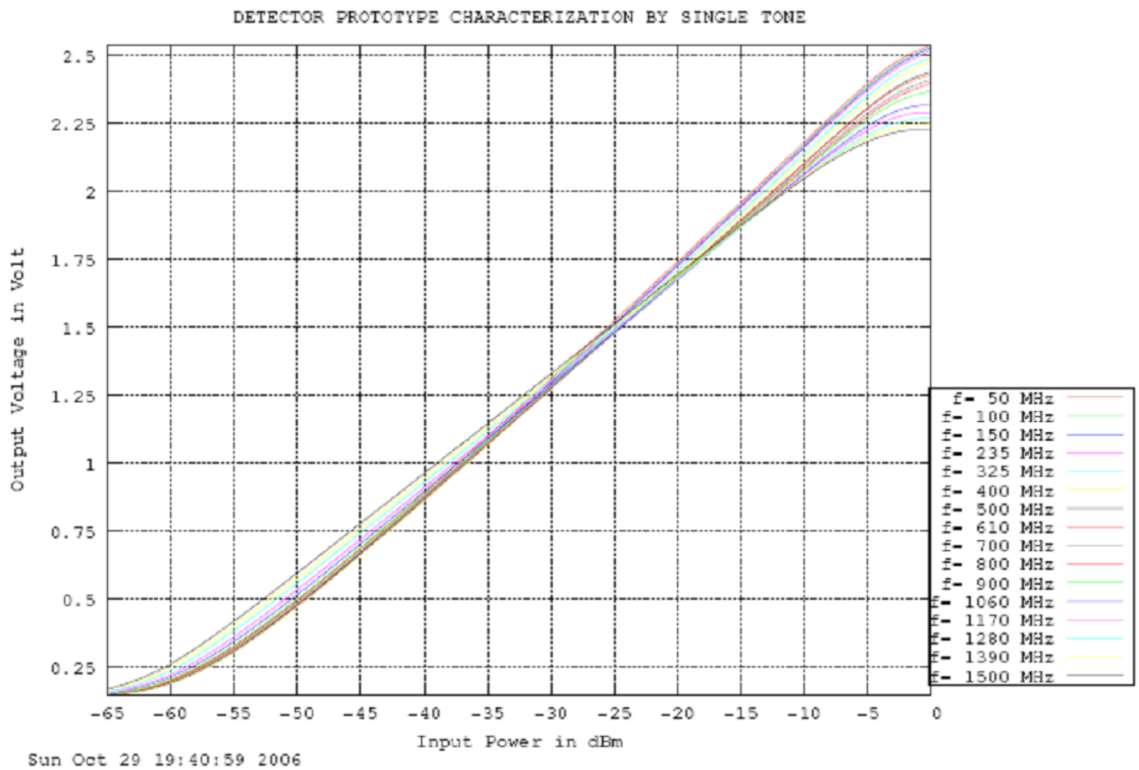

Fig. 5.1 Single Tone Characterization of Detector Prototype

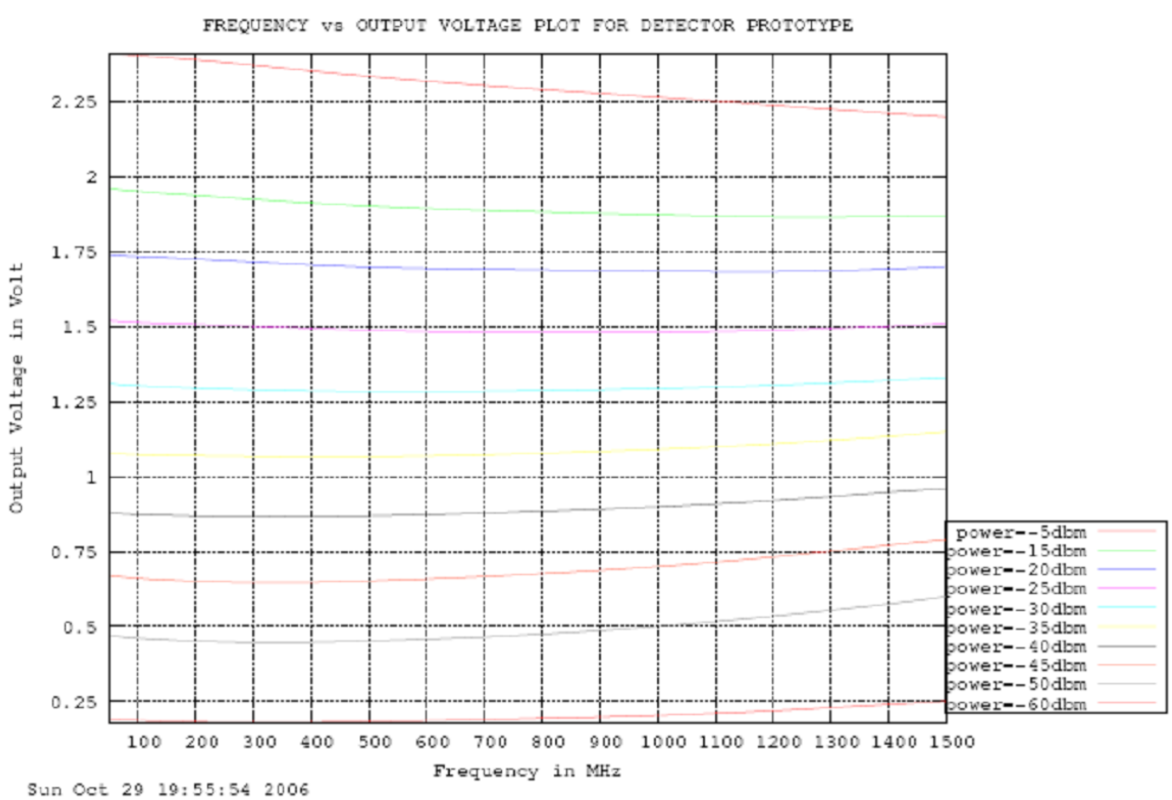

Fig. 5.2 Frequency Vs Voltage Plot for Detector Prototype

5.1.2 Broadband Characterization of Detector Prototype

Table 5.2 Broad Band Characterization for the Band 150 MHz

DETECTOR CHARACTERISTICS WITH NOISE					
Resolution BW = 3 MHz	Video BW = 10 MHz				
Reference = -10 dBm	Attenuation = 10 dB				
Frequency = 150 MHz	Sweep Time = 150 ms				
Gain in dB	Input power level in dBm				O/P in V
	BW = 30 MHz	BW = 3 GHz	Full Span	Marker	
30	-1.48	-0.09	-0.41	-10.48	2.386
28	-3.40	-1.95	-2.38	-12.35	2.320
26	-5.25	-3.96	-4.27	-14.22	2.247
24	-7.26	-5.85	-6.19	-16.21	2.166
22	-9.46	-7.93	-8.44	-18.43	2.075
20	-11.4	-9.84	-10.21	-20.29	1.992
18	-13.27	-11.84	-12.20	-22.51	1.912
16	-15.25	-13.70	-14.11	-24.15	1.830
14	-17.35	-15.93	-16.33	-26.29	1.727
12	-19.34	-17.81	-18.09	-28.53	1.646
10	-21.28	-19.83	-20.13	-30.26	1.565
8	-23.22	-21.71	-21.96	-32.22	1.483
6	-25.24	-23.75	-24.32	-34.28	1.398
4	-27.24	-25.74	-26.00	-36.21	1.316
2	-29.14	-27.64	-27.93	-38.38	1.235
0	-31.05	-29.56	-29.84	-39.97	1.154
-2	-34.97	-32.89	-33.03	-43.99	1.048
-4	-36.87	-34.77	-34.73	-46.00	0.969
-6	-38.78	-36.64	-36.38	-47.89	0.890
-8	-40.82	-38.59	-38.11	-49.97	0.805
-10	-42.76	-40.29	-39.49	-51.84	0.727
-12	-44.68	-42.01	-40.68	-53.60	0.652
-14	-46.65	-43.42	-41.6	-55.70	0.580
-16	-49.10	-44.77	-42.31	-58.29	0.535
-18	-51.09	-45.97	-42.87	-60.16	0.465
-20	-52.92	-46.88	-43.28	-62.06	0.402
-22	-54.86	-47.61	-43.53	-63.73	0.347
-24	-56.76	-48.16	-43.72	-65.83	0.295
-26	-58.61	-48.51	-43.84	-67.63	0.256
-28	-60.36	-48.73	-43.89	-69.36	0.225
-30	-62.13	-48.89	-43.93	-71.47	0.201

The corresponding plots are given in the next pages.

150 MHz

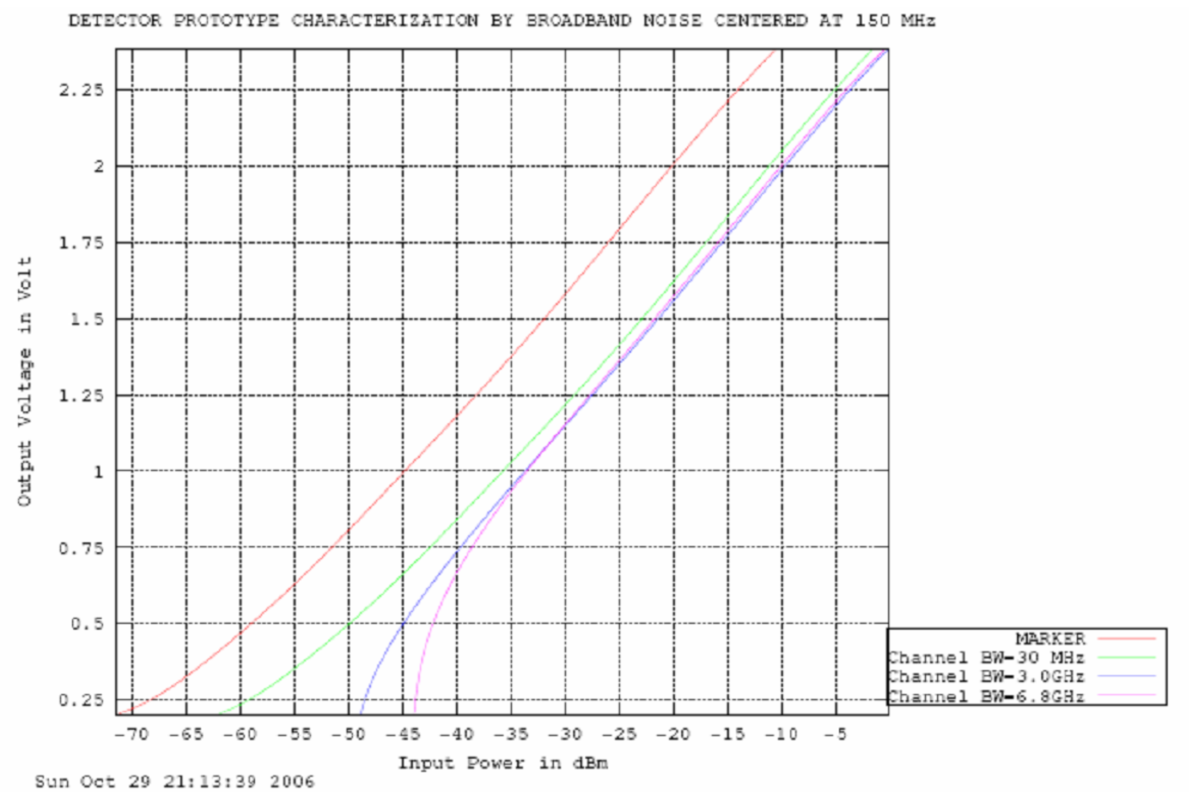

Fig. 5.3 Broad Band Characterization for Detector Prototype for 150 MHz band

233 MHz

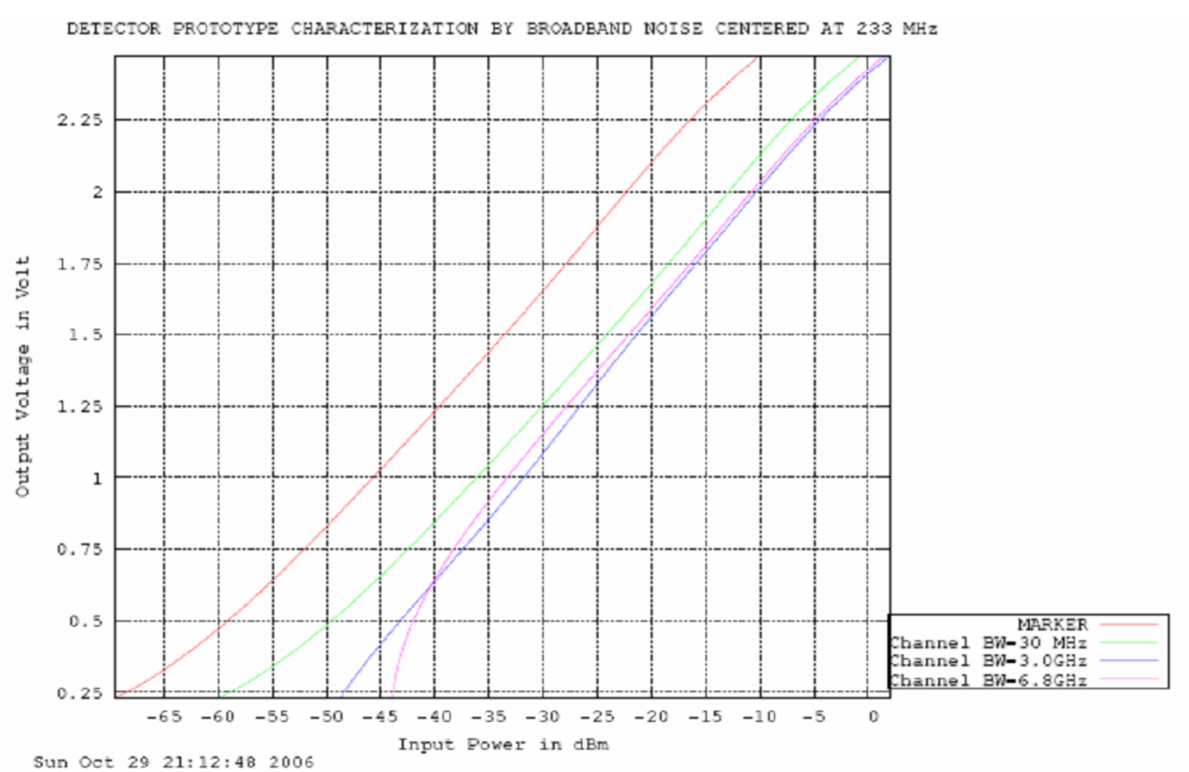

Fig 5.4 Broad Band Characterization for Detector Prototype for 233 MHz band

327 MHz

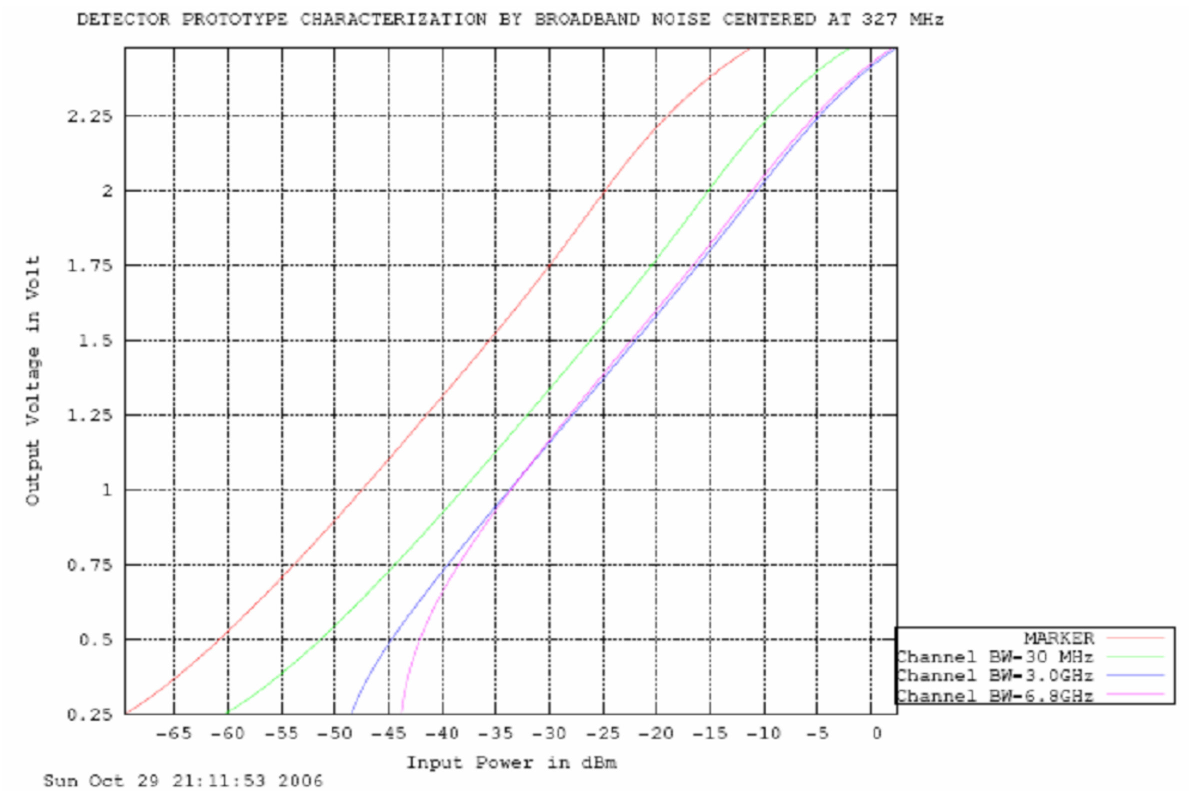

Fig 5.5 Broad Band Characterization for Detector Prototype for 327 MHz band

610 MHz

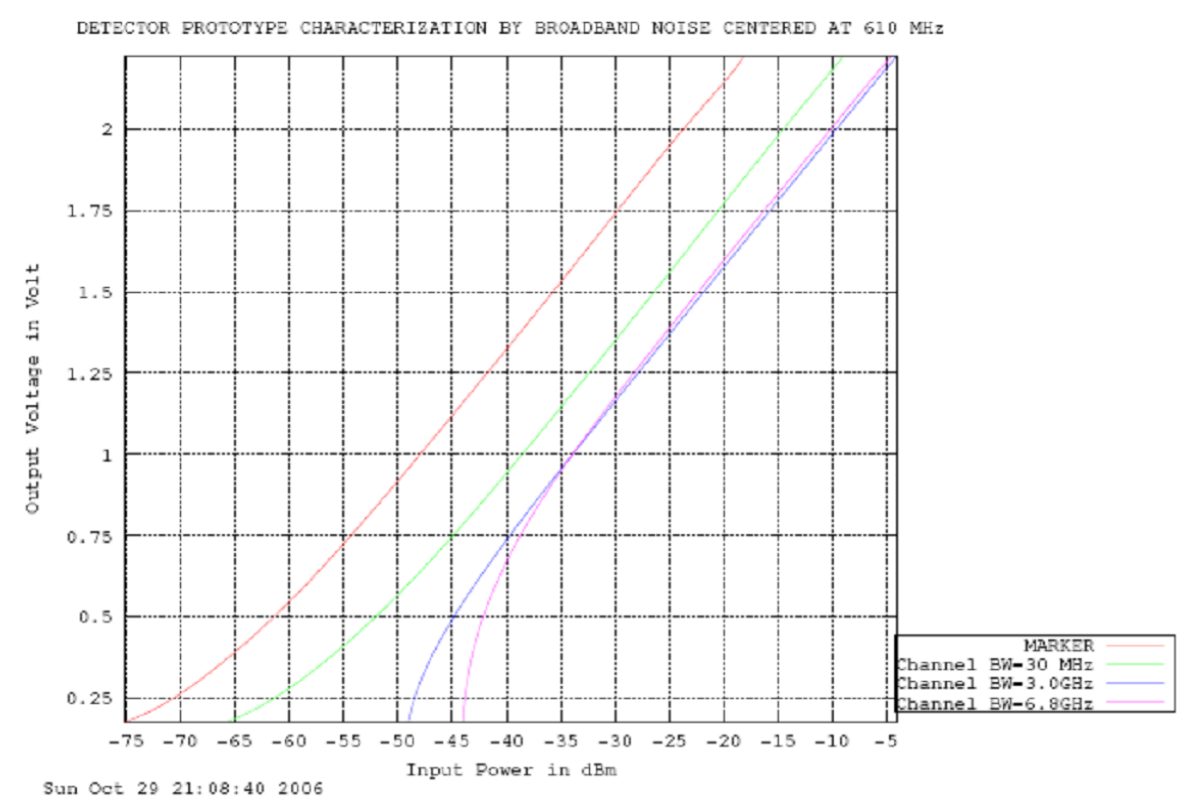

Fig 5.6 Broad Band Characterization for Detector Prototype for 610 MHz band

5.2 Power Detector Module

5.2.1 Single Tone Characterization of the Detector Module

Table 5.3 Single Tone Characterization

SINGLE TONE CHARACTERIZATION OF COMPOSITE SYSTEM								
	Frequency= 150 MHz		Frequency= 233 MHz		Frequency= 327 MHz		Frequency= 610 MHz	
Ref. Gain in dB	I/P in dBm	O/P in Volt	I/P in dBm	O/P in Volt	I/P in dBm	O/P in Volt	I/P in dBm	O/P in Volt
-15	-15.02	2.45	-15.01	2.44	-14.98	2.42	-15.06	2.33
-18	-18.02	2.37	-18.01	2.36	-17.97	2.34	-18.05	2.24
-21	-21.02	2.25	-21.01	2.25	-20.96	2.23	-21.02	2.12
-24	-24.02	2.11	-24.01	2.10	-23.96	2.08	-24.01	1.98
-27	-26.98	1.97	-27.00	1.96	-26.95	1.95	-26.99	1.85
-30	-29.95	1.84	-29.94	1.84	-29.91	1.82	-29.96	1.73
-33	-32.92	1.70	-32.89	1.70	-32.86	1.68	-32.94	1.60
-36	-35.83	1.56	-35.79	1.56	-35.77	1.55	-35.85	1.47
-39	-38.64	1.44	-38.67	1.44	-38.63	1.42	-38.70	1.35
-42	-41.33	1.30	-41.32	1.31	-41.31	1.30	-41.39	1.22
-45	-43.84	1.17	-43.79	1.17	-43.79	1.16	-43.86	1.09
-48	-45.99	1.03	-45.95	1.04	-45.94	1.03	-46.01	0.97
-51	-47.69	0.90	-48.09	0.87	-47.64	0.90	-47.70	0.84
-55	-49.14	0.73	-49.32	0.69	-49.09	0.73	-49.14	0.67
-60	-50.01	0.53	-50.01	0.50	-50.02	0.50	-50.01	0.49

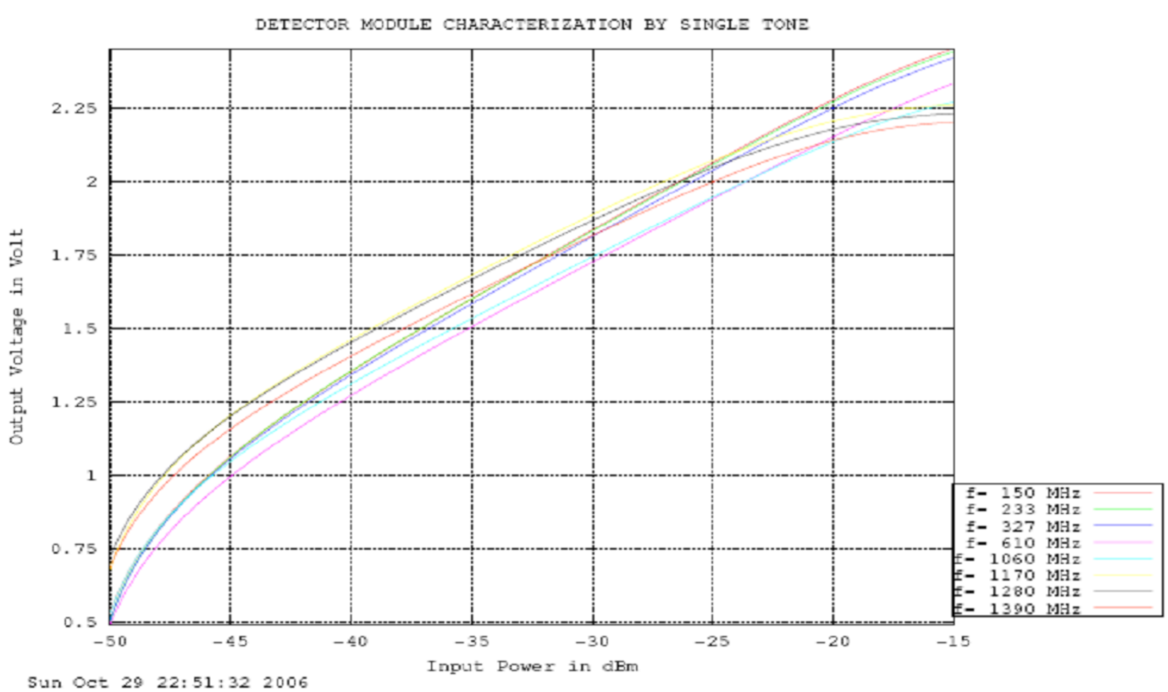

Fig. 5.7 Single Tone Characterization of Detector Subsystem

5.2.2 Broadband Characterization of the Detector Module.

Table 5.4 Broad Band Characterization of Detector Subsystem

Broad Band Characterization of Composite System								
	Frequency= 150 MHz		Frequency= 233 MHz		Frequency= 327 MHz		Frequency= 610 MHz	
Ref. Gain in dB	I/P in dBm	O/P in Volt	I/P in dBm	O/P in Volt	I/P in dBm	O/P in Volt	I/P in dBm	O/P in Volt
-15	-15.48	2.34	-15.40	2.32	-15.01	2.31	-14.87	2.24
-18	-18.14	2.23	-18.40	2.23	-17.96	2.22	-17.74	2.15
-21	-21.20	2.12	-21.22	2.12	-20.91	2.11	-20.72	2.03
-24	-24.10	1.99	-24.20	1.99	-23.90	1.98	-22.80	1.95
-27	-27.08	1.86	-27.11	1.85	-26.79	1.85	-25.69	1.82
-30	-29.96	1.73	-29.55	1.74	-30.28	1.69	-29.77	1.65
-33	-34.20	1.54	-31.51	1.66	-33.15	1.57	-33.69	1.48
-36	-37.09	1.41	-34.38	1.53	-36.07	1.44	-36.47	1.36
-39	-39.90	1.28	-37.19	1.40	-38.85	1.31	-39.39	1.23
-42	-42.47	1.16	-39.98	1.27	-41.55	1.18	-42.09	1.10
-45	-44.88	1.04	-48.60	1.14	-42.70	1.13	-44.58	0.97
-48	-46.92	0.92	-45.28	0.99	-44.30	1.04	-46.59	0.86
-51	-48.36	0.80	-47.18	0.87	-46.38	0.92	-48.51	0.71
-55	-49.40	0.68	-48.54	0.75	-48.03	0.79	-49.49	0.60
-60	-50.00	0.57	-49.50	0.64	-49.16	0.68	-50.32	0.44
-80	-50.42	0.45	-50.19	0.50	-50.03	0.54	-50.58	0.36

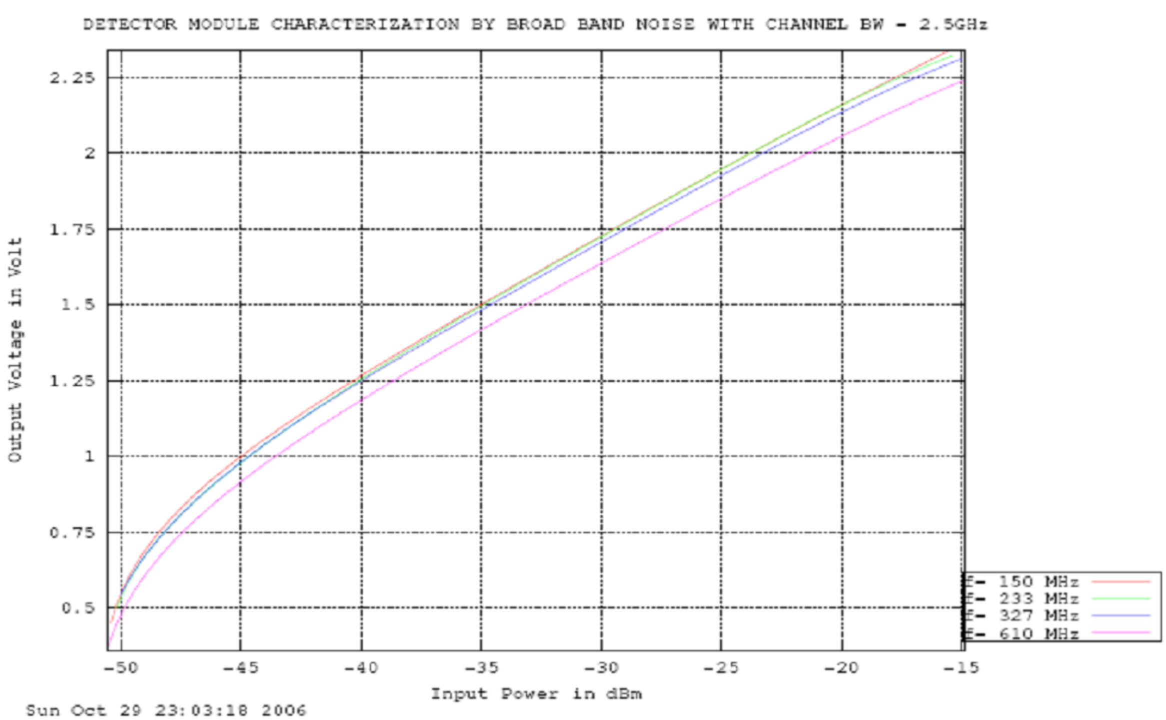

Fig 5.8 Broad Band Characterization for Detector Module

5.3 Calibration

There are four available measuring instruments namely R&S Spectrum Analyzer (Cal & Uncal), HP Spectrum Analyzer and Boonton Power Meter to calibrate the Detector Subsystem. To choose the most efficient one, the following measurements are done.

Table 5.5 Comparison of the Measuring Instruments

COMPARISON BETWEEN THE POWER MEASURING INSTRUMENTS							
R&S SA UNCAL		R&S SA CAL		HP SA		Boonton PM	
I/P in dBm	O/P in V	I/P in dBm	O/P in V	I/P in dBm	O/P in V	I/P in dBm	O/P in V
-34.34	1.47	-26.79	1.85	-34.55	1.55	-35.01	1.57
-37.58	1.34	-30.28	1.69	-38.50	1.38	-37.53	1.46
-40.14	1.21	-33.15	1.57	-41.08	1.21	-40.52	1.33
-42.88	1.08	-36.07	1.44	-43.34	1.13	-43.45	1.21
-45.19	0.96	-38.85	1.31	-46.60	0.87	-46.75	1.08
-47.02	0.83	-41.55	1.18	-48.45	0.58	-49.80	0.95
-48.39	0.73	-42.70	1.13	-48.82	0.37	-52.75	0.84
-49.34	0.61	-44.30	1.04	-49.01	0.27	-53.95	0.80
-49.88	0.51	-46.38	0.92			-55.62	0.73
-50.22	0.43	-48.03	0.79			-60.89	0.58
-50.54	0.28	-49.16	0.68				
-50.56	0.27	-50.03	0.54				

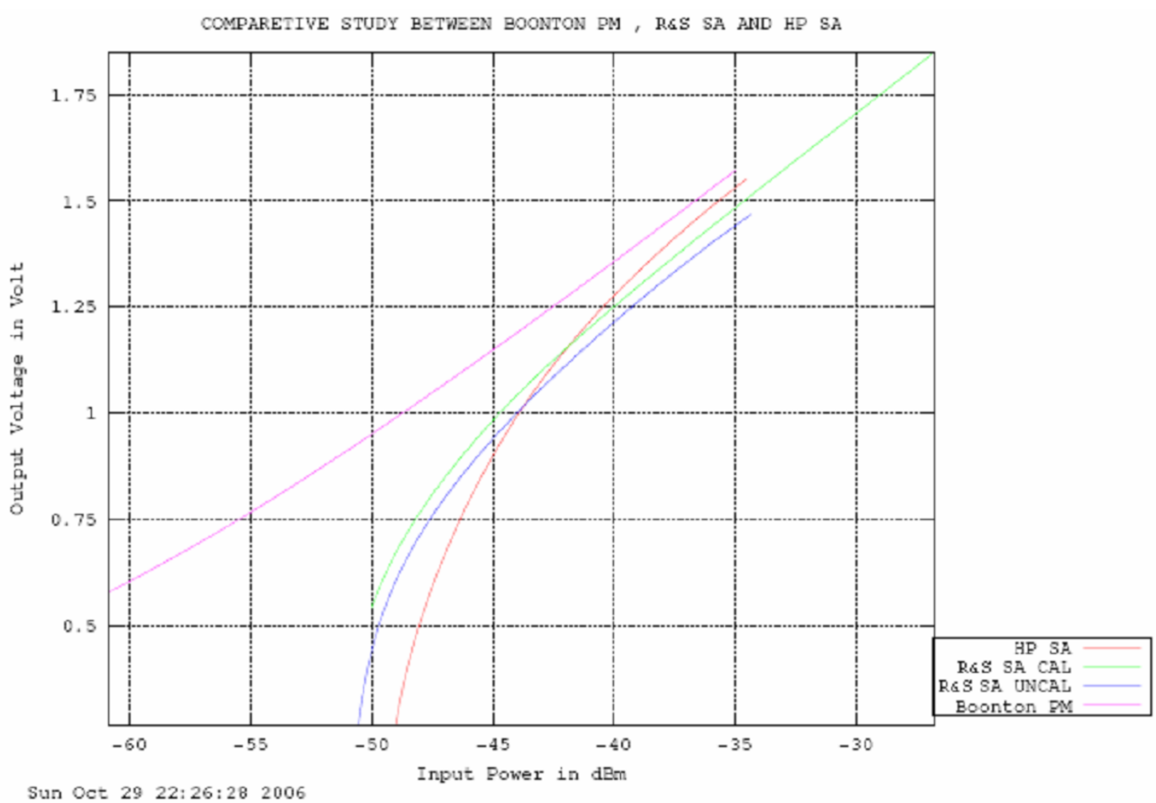

Fig. 5.9 Comparison between the measuring instruments

According to the plots above, it is found that the Boonton Power is found to be more appropriate for this purpose, so the final calibration is done considering this as reference.

Table 5.6 Calibration by Boonton Power Meter

FINAL CALIBRATION OF THE DETECTOR SUBSYSTEM								
	Frequency Band = 150 Mhz		Frequency Band = 233 Mhz		Frequency Band = 327 Mhz		Frequency Band = 610 Mhz	
Ref. Gain in dB	I/P in dBm	O/P in Volt	I/P in dBm	O/P in Volt	I/P in dBm	O/P in Volt	I/P in dBm	O/P in Volt
-15	-14.61	2.377	-15.19	2.346	-15.39	2.324	-15.79	2.208
-20	-19.81	2.223	-20.72	2.184	-19.84	2.198	-21.79	2.088
-25	-25.02	2.024	-24.83	2.020	-25.07	1.992	-24.96	1.964
-30	-30.00	1.805	-29.82	1.800	-30.75	1.741	-30.13	1.745
-35	-35.49	1.559	-35.19	1.563	-35.71	1.526	-35.11	1.535
-40	-40.49	1.346	-40.09	1.348	-40.62	1.313	-40.47	1.310
-45	-45.40	1.140	-45.05	1.133	-45.01	1.127	-45.75	1.093
-50	-50.75	0.937	-50.56	0.904	-50.03	0.917	-49.80	0.928
-55	-55.73	0.739	-55.87	0.704	-55.29	0.715	-55.74	0.694
-60	-59.02	0.553	-59.12	0.529	-59.08	0.540	-59.69	0.548

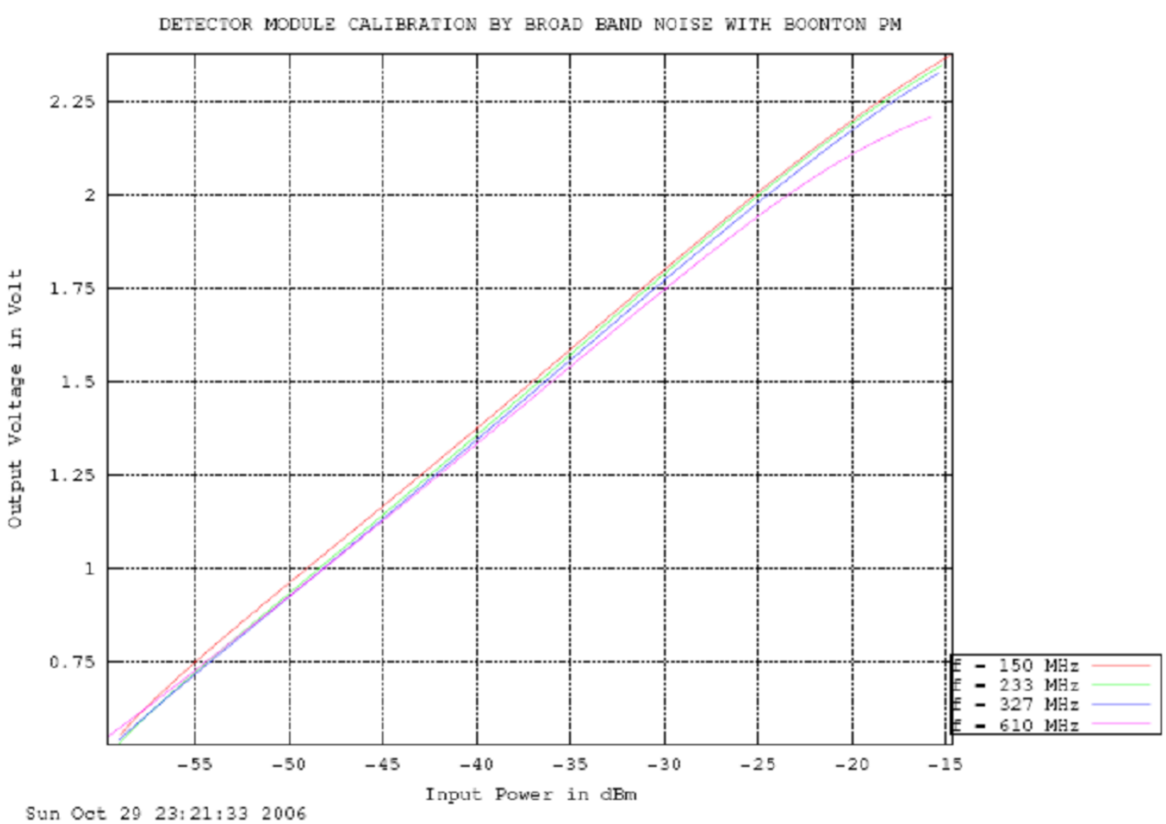

Fig. 5.10 Calibration Curve for the Detector Subsystem

6 Antenna Base Measurements

This detector module is to be installed at the Front End[13] of the ABR as shown by the arrow in the figure 6.1. The monitor suffers an extra RF cable loss as compared with the Front End receiver.

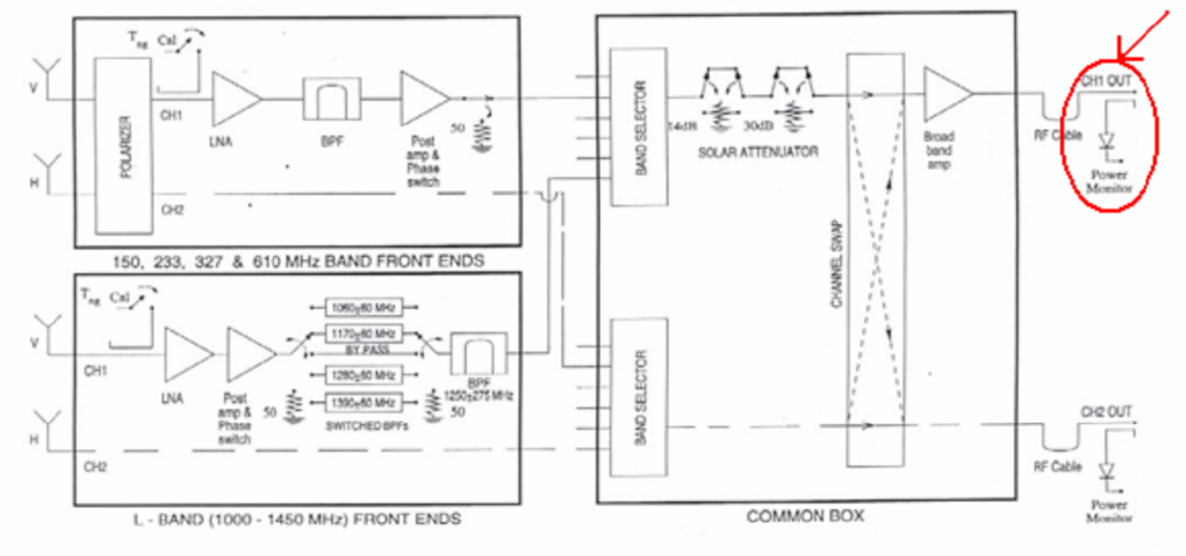

Fig 6.1 Installed Power Monitor

6.1 Wave Shape at ABR

At the ends of the front, the wave shapes of the received signals are shown bellow. The 150 MHz band is in general noise prone at the ABR so it is not been considered in measurement purpose. Instead the L-band signal, 1060 MHz band is included here.

233 MHz

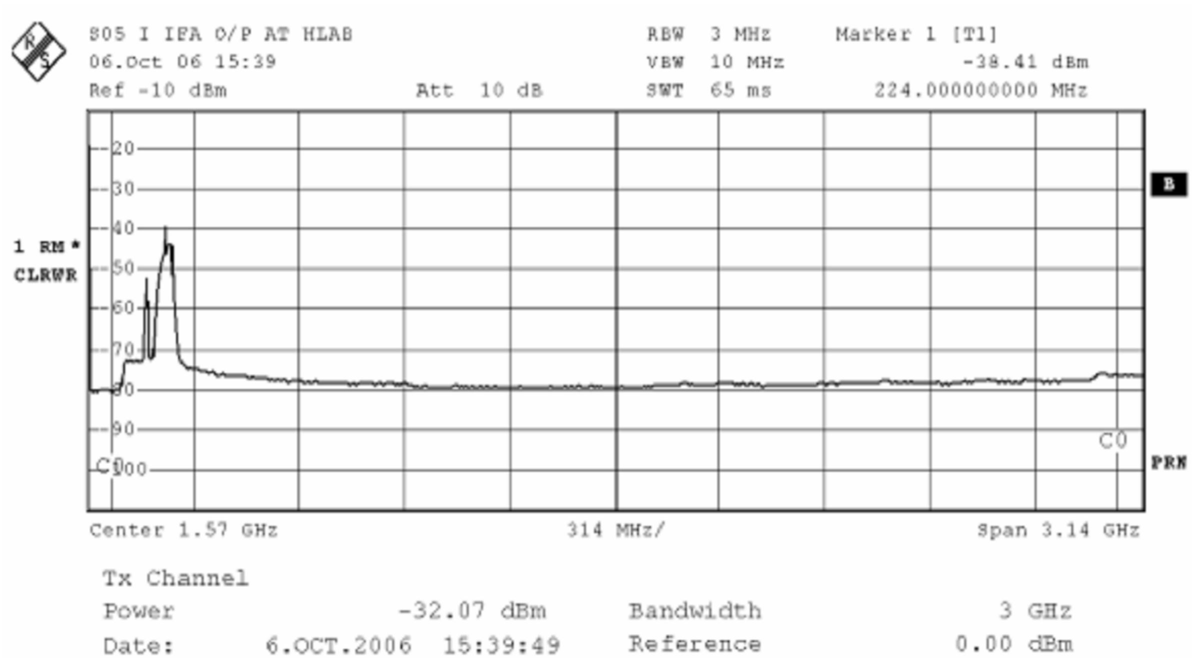

Fig. 6.2 Wave Shape for 233 MHz

327 MHz

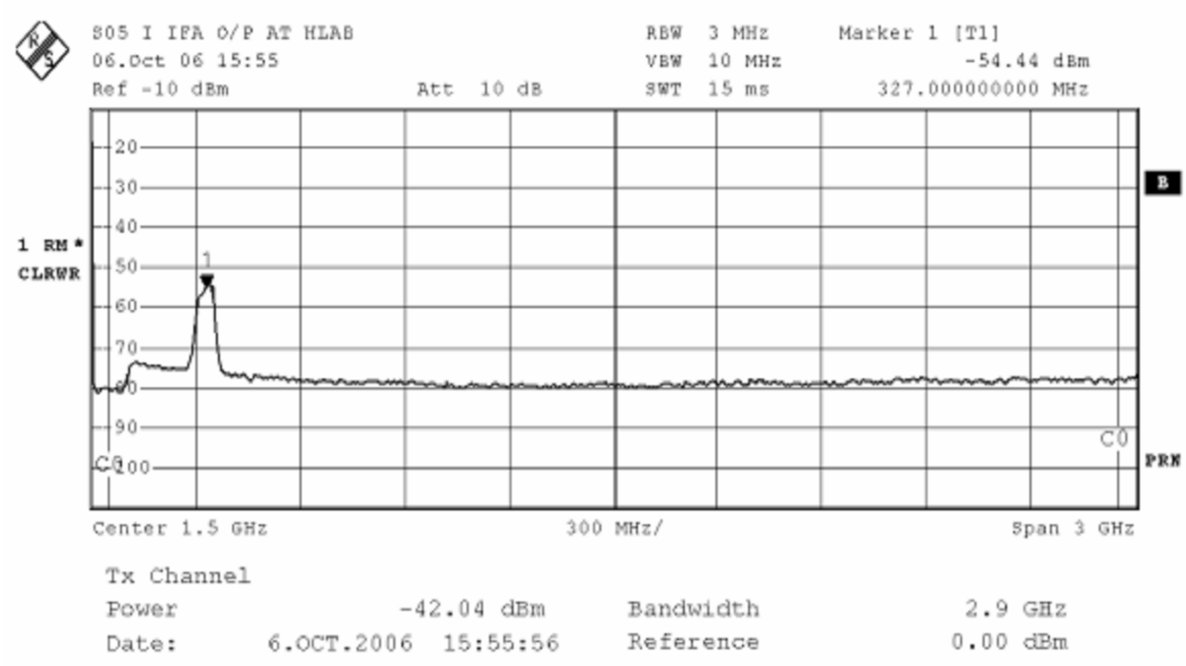

Fig. 6.3 Wave Shape for 327 MHz

610 MHz

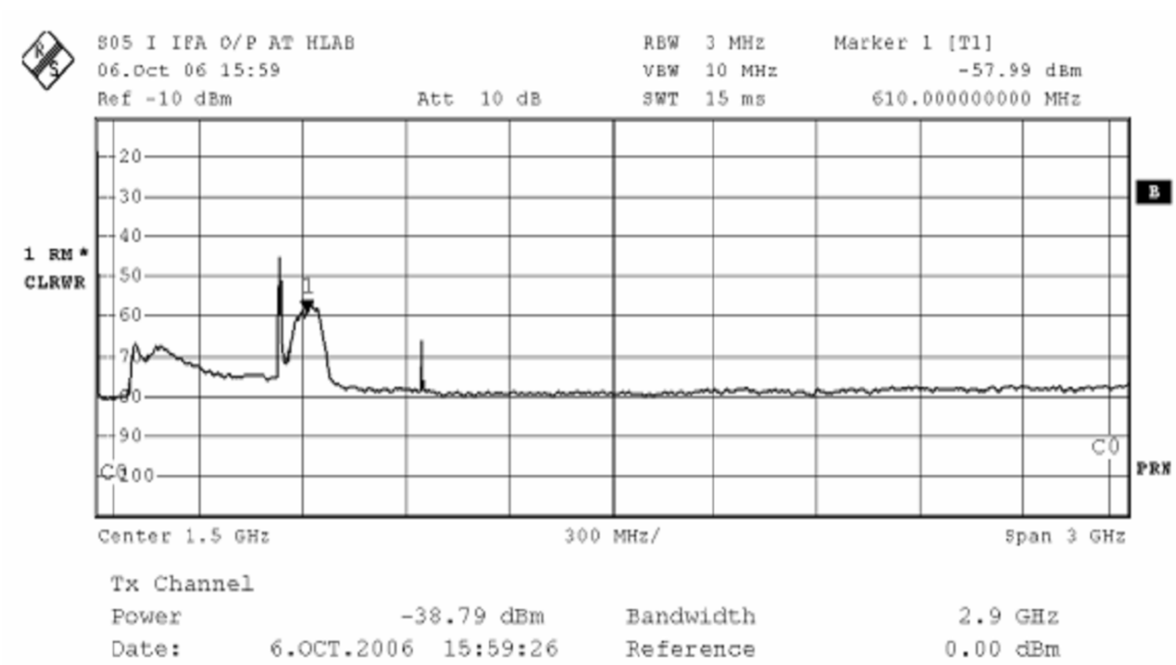

Fig. 6.4 Wave Shape for 610 MHz

1060 MHz

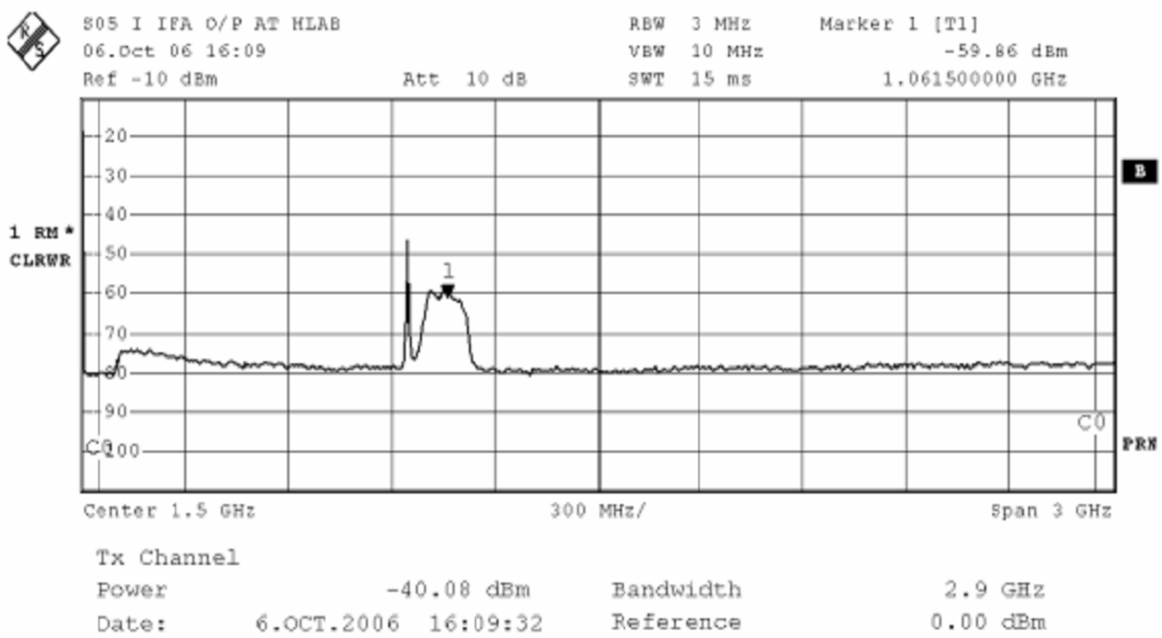

Fig. 6.5 Wave Shape for 1060 MHz

6.2 Response of RF Power Detector System

Among the 30 antennas of GMRT the antenna C2 is the nearest to CEB and hence very important for measurement purpose. So the first set of measurement at ABR is done with C2. Afterward in order to crosscheck the data, the set of measurements are done with C5 also. Both the data are given in the following table. Here also only relevant data are given interested persons are referred to datasheets, for more elaborate measure provided at the end.

6.2.1 Measurement with C2

Table 6.1 ABR Measurement at C2

C2 ANTENNA BASE MEASUREMENT CH-I							
Reference		Frequency = 233 MHz		Frequency = 327 MHz		Frequency = 610 MHz	
Noise Generator	Solar Attenuator	I/P in dBm	O/P in Volt	I/P in dBm	O/P in Volt	I/P in dBm	O/P in Volt
OFF	0	-37.02	1.36	-40.1	1.11	-43.01	1.06
OFF	14	-46.82	0.84	-47.55	0.72	-48.36	0.71
OFF	30	-48.95	0.65	-48.9	0.64	-48.99	0.64
OFF	TERMIN.	-49.03	0.64	-48.94	0.64	-43.00	1.09
LC	0	-36.44	1.37	-40.00	1.12	-42.04	1.11
MC	0	-35.9	1.41	-40.01	1.16	-41.48	1.14
HC	0	-34.52	1.48	-40.39	1.10	-38.83	1.26
EHC	0	-34.01	1.46	-35.62	1.38	-38.13	1.36

6.2.2 Measurement with C5

Table 6.2 ABR Measurement at C5

C5 ANTENNA BASE MEASUREMENT CH-I							
Reference		Frequency = 233 Mhz		Frequency = 327 Mhz		Frequency = 610 Mhz	
Noise Generator	Solar Attenuator	I/P in dBm	O/P in Volt	I/P in dBm	O/P in Volt	I/P in dBm	O/P in Volt
OFF	0	-42.10	1.27	-44.88	1.10	-48.67	0.97
OFF	14	-54.44	0.74	-55.34	0.66	-56.62	0.60
OFF	30	-58.64	0.55	-60.71	0.55	-58.85	0.54
LC	0	-42.03	1.26	-42.82	1.13	-48.55	0.97
MC	0	-41.56	1.28	-42.01	1.14	-47.89	1.00
HC	0	-40.77	1.32	-41.13	1.16	-47.30	1.03
EHC	0	-38.25	1.43	-42.14	1.14	-44.65	1.14

7 Project Extension: General Purpose Power Meter

The basic interfacing scheme is shown in the diagram bellow. These two interfacing are done temporarily on a breadboard and tested successfully.

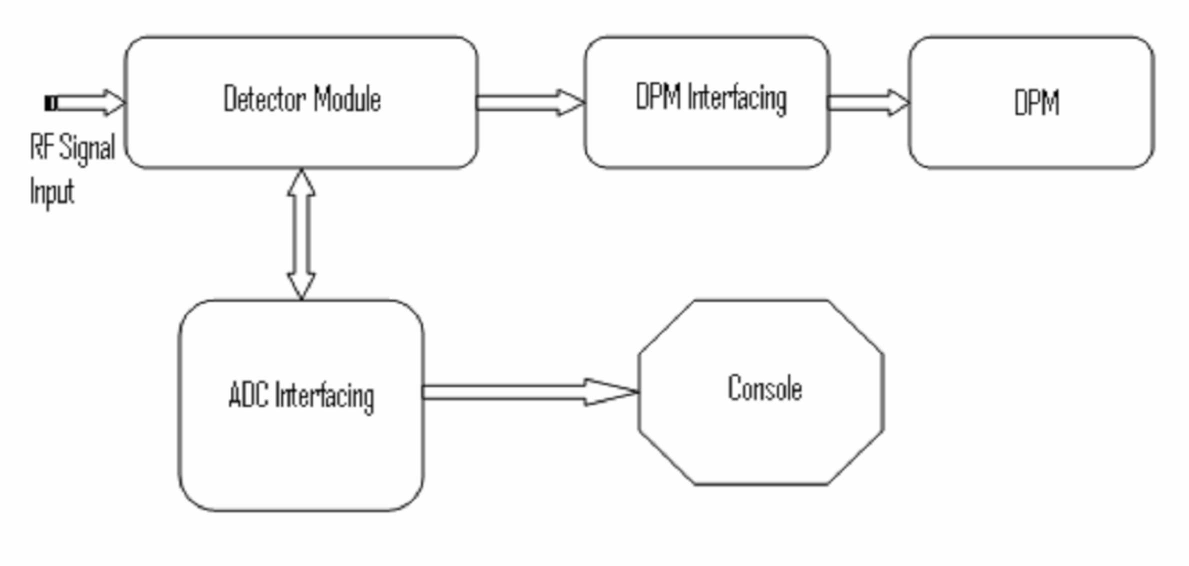

Fig. 7.1 Interfacing Scheme

7.1 DPM Interfacing

The DPM interfacing is necessary for any general purpose power meter to display the input power directly on the Digital Panel Meter (DPM).
The main idea behind the DPM interfacing is to scale the output voltage of the detector with the DPM counts. The DPM has an input voltage range of 1999 unit corresponding to that there is 1999 count at its display.
The circuit diagram for the core interfacing is shown bellow. This circuit is basically a level shifting or voltage conditioning circuit using OP-AMP[14] which is capable to shift the DC output voltage level of the detector module in accordance with the calibrated power level, such that at the DPM display the power in dBm can be directly displayed without any further modification.

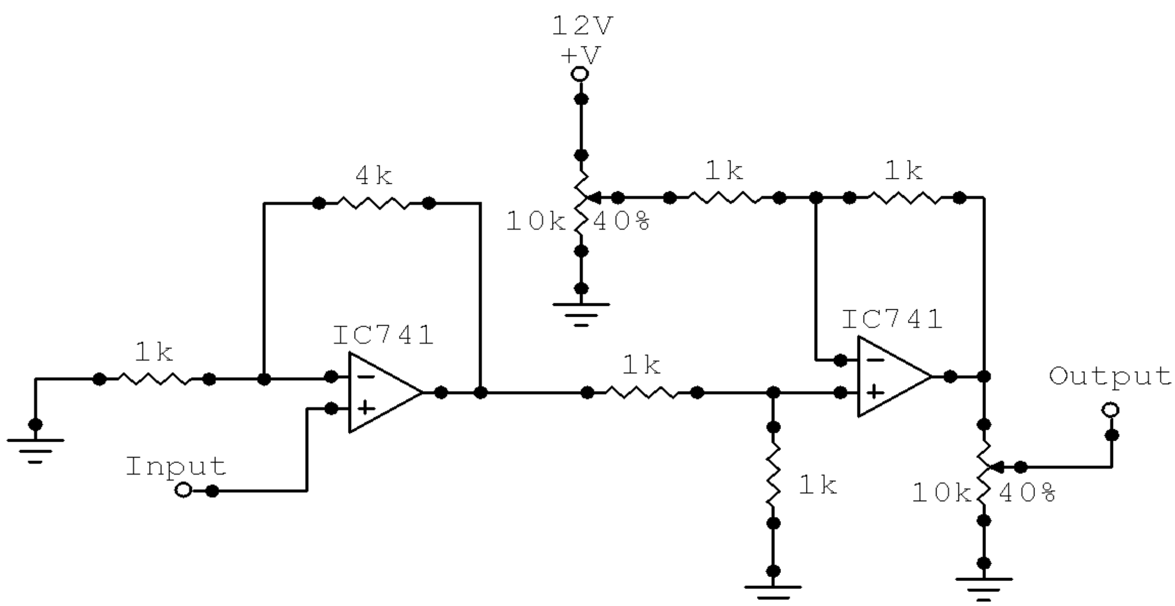

Fig. 7.2 Circuit Diagram for DPM Interfacing

7.2 ADC Interfacing

The ADC Interfacing is necessary to have the facility of displaying the power level onto any Personal Computer console, to store data in removable media and to manipulate data for further signal processing.

The heart of this ADC interfacing is IC MAX132[15] ADC with serial interface.

The MAX132 is a CMOS, 18-bit plus sign, serial-output ADC. Multi slope integration provides high resolution conversions in less time than standard integrating ADCs, allowing operation up to 100 conversions per second. Low conversion noise provides guaranteed operation with ±512mV full-scale input range (2μV/LSB). A simple 4-wire serial interface connects easily to all common microprocessors, and two's complement output coding simplifies bipolar measurements.

Typical supply current is only 60μA and is reduced to 1μA in sleep mode. Four serially programmed digital outputs can be used to control an external multiplexer or programmable gain amplifier. The circuit is shown in Figure 7.3.

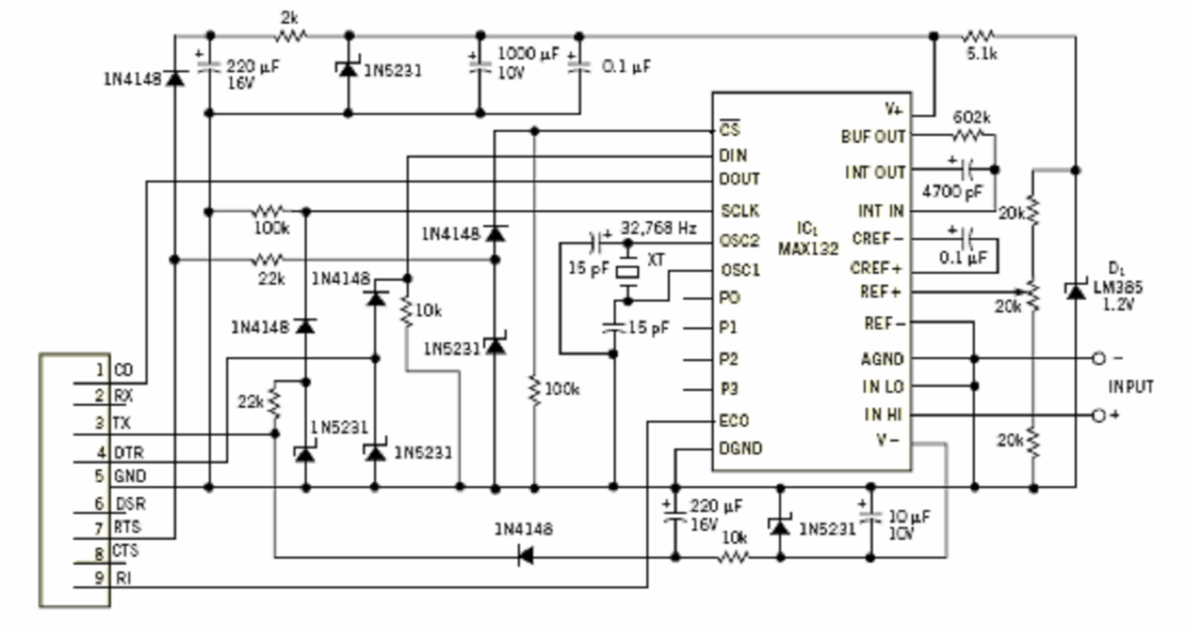

Fig. 7.3 Circuit Diagram for ADC Interfacing

A PC can communicate[16] with an 18 bit ADC through its serial port. The port provides both positive and negative power supplies as well as control signal. IC U1 is the 18 bit MAX132 ADC. It requires input control signals, D_{IN} and S_{CLK} and emits serial data D_{OUT} and E_{OC} signals. An RS-232 port has three output lines. Pin3 (Tx), Pin 4 (DTR) and Pin 7 (RTS), Tx generates the clock signal for the MAX132 and provides the negative power supply, DTR transmits serial data and RTS provides the CS signal and the positive power supply. Both the positive and negative supplies use large capacitors for energy storage. When Tx generates a clock signal or DTR sends a CS logic low signal. The capacitor provide power to the MAX132, the MAX132 integrates every thing except a reference that comes from a 1.2 V LM385 voltage reference diode. The input voltage range from the MAX132 is -512 to +512 mV.

Also for data acquisition and to display it onto console a small screen display routine is developed in C language. This can be further modified to process the data. The program is given in the next page.

The ADC Interfacing Program[16]

```
#include <stdio.h>
#include <dos.h>
#include <time.h>
#include <conio.h>
#include <bios.h>
#include <conio.h>
#define COM1    0
#define MCR     4                               /* control register */
#define MSR     6                               /* status register  */

int i, j, base_add1=0x3f8, base_add2=0x2f8, out_data=0x03, in_data[4];
float data;

void send_clk(void)
{
        delay(1);
        outportb(base_add1, 0x00);
        delay(3);
}

void read_port(void)
{
        int control[4], out_control;
        data=0;
        for (i=0; i<4; i++)
        in_data[i]=0;
        control[0]=0x82;
        control[1]=0x04;
        control[2]=0x00;
        control[3]=0x00;
        out_data|=0x02;
        outportb(base_add1+MCR, out_data);              /* CS high      */
        delay(10);
        out_data&=0x01;
        outportb(base_add1+MCR, out_data);              /* CS low  */
        delay(10);
        out_control=control[0];
        for (i=0; i<8; i++)
        {
            if (out_control>=0x80)
                out_data|=0x01;
            else
                out_data&=0x02;
            outportb(base_add1+MCR, out_data);
            send_clk();                                 /* clock out */
            out_control&=0x7f;
            out_control=out_control*2;
         }
         out_data|=0x02;
         outportb(base_add1+MCR, out_data);             /* CS high      */
         delay(10);
```

```
            do{
            }while((inportb(base_add1+MSR)&0x40)==0);     /* waiting for EOC=high */
            for (j=1; j<4; j++)
            {
                  out_control=control[j];
                   in_data[j]=0;
                  out_data&=0x01;
                  outportb(base_add1+MCR, out_data);              /* CS low       */
                  delay(10);
                  for (i=0; i<8; i++)
                  {
                      if (out_control>=0x80)
                     out_data|=0x01;
                     else
                     out_data&=0x02;
                     outportb(base_add1+MCR, out_data);
                     in_data[j]=in_data[j]*2+(inportb(base_add1+MSR)&0x80)/0x80;
                     send_clk();                                  /* clock out    */
                     out_control&=0x7f;
                     out_control=out_control*2;
                  }
                out_data|=0x02;
                outportb(base_add1+MCR, out_data);                        /* CE high      */
               delay(10);
         }

           if ((in_data[1]&0x08)==0)
           data=(float)(in_data[1]&0x07)+(float)(in_data[2])*2048+(float)(in_data[3])*8;
           else                                                /* reading is negative  */
           {
               in_data[1]=in_data[1]&0x07;
               in_data[1]=(8-in_data[1])&0x07;
               in_data[2]=(256-in_data[2])&0xff;
               in_data[3]=(256-in_data[3])&0xff;
               data=-((float)(in_data[1])+(float)(in_data[2])*2048+(float)(in_data[3])*8);
           }
      }
void dis_data(void)
{
            float show_data;
            show_data=0.000002*data;
            gotoxy(1,1);
            printf("%.5f  ", show_data);
            gotoxy(1,1);
}
void init(void)
{
           bioscom(0, 255, COM1);                                 /* set up COM1         */
            out_data=0x02;
            outportb(base_add1+MCR, out_data);        /* CS=high, DIN=low     */
            delay(100);
}
```

```
void main(void)
{
        clrscr();
        init();
        gotoxy(60,24);
        printf("Hit any key to quit");
        do{
                read_port();
                dis_data();
                delay(500);
          }
         while(!kbhit());
 }
```

The program reads the RS-232 serial[17] COM1 or COM2 port using well known indatab() command and sends the necessary output control commands using outdatab() command. In the process it also does some logical and arithmetic operations. The control statements are mentioned in tabs.

8. Summery & Further Scope of Work

With proper schedules and planning, the project is completed within the stipulated time. After integration of power monitor and later the power meter it is checked for proper operation in the lab environment as well as in the antenna base. All necessary tuning of the equipment is completed so as to achieve the specifications required. The instrument is also thoroughly calibrated and characterized. At the end it can be concluded that the detector device is working satisfactorily.

There is still some nominal job is remaining to finish up the whole module. They are listed bellow:

1. The voltage conditioning circuit is made temporarily for testing purpose. It is yet to be finished.
2. The ADC interfacing routine can be modified to get the facilities of data storage and signal processing.
3. The outer chassis of the power meter is yet to be built.
4. The power monitor should be tested for other two or three antennas.
5. The power monitor is yet to be installed at the ABR rack.
6. While designing the differential amplifier, there was incident of loading problem, so an extra OPAMP is used. Care should be taken to redesign the circuit with minimum number of active device.
7. A variable attenuator can be incorporated at the input of the power monitor so as to measure the higher power level e.g. more than 0dBm.
8. For the lower power level, e.g. bellow -60 dBm, the characteristics curve remains no longer straight line. So to measure the power level of -60 dBm, a lookup table can be incorporated which is expected to be program driven.

If time is allotted in solving these shortcomings the power monitor and the power detector can be demanded successful.

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