GMRT UPGRADE

RF GAIN BLOCK FOR BROADBAND ANALOG FIBER OPTIC LINK

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Internal Technical Report

(Under the guidance of Shri. S. Sureshkumar)

July-2011

TATA INSTITUTE OF FUNDAMENTAL RESEARCH
NATIONAL CENTER FOR RADIO ASTROPHYSICS

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1.0 Introduction

The Giant Meterwave Radio Telescope undergo major upgrade to provide seamless coverage of all radio astronomy bands from 30 MHz to 1600 MHz. This needs a high dynamic range broadband signal transport system to bring in the noise like radio astronomy signals from remote antennas directly from frontend system to the central processing station (CEB) without any frequency translation. The upgrade to the existing working antennas could lead to non availability of these antennas for radio astronomy observation. The upgraded system co-exist with the existing signal transport system and works in parallel with the broadband link. The broadband link uses optical multiplexing and bi-directional fiber optic link on to the same fiber. The existing forward link operates at 1300 nm carrying telemetry and LO signals to remote antenna. The existing return link carrying IF, LO and return telemetry link is brought over one of the DWDM optical channel on to the same fiber along with the broadband signals directly from the frontend system.

This requires splitting of the RF signals coming from frontend with suitable amplification to compensate the splitting loss and feed one input to the IF system of ABR rack and the other directly connected to broadband analog fiber optic link. Figure 1.0 shows the configuration done at the antenna base. A RF coupler is added at the input for monitoring the incoming RF signal at the antenna base. A variable attenuator is placed in the RF gain block unit to adjust the input RF power level to the fiber optic system. The total power received from the frontend system vary with frequency band and to provide constant input power to the fiber optic system a variable attenuator is included in the RF gain block unit. A single PIU situated at remote antenna base has two independent receiver chain carrying both the polarizations from frontend system.

This report describes the individual blocks of the RF PIU with performance details.

ACKNOWLEDGEMENTS

I wish to thank **Shri. S. SURESHKUMAR** for guiding me all through this project and for making it the final design for the GMRT upgrade. I thank him for understanding my skill and work experience in RF design and have trusted me by assigning this work which is of high interest to me and motivating.

We are very much thankful to **Shri A. PRAVEEN KUMAR** for his support and giving valuable suggestions. We thank **Prof. YESHWANT GUPTA** for assigning this work to us.

We thank our FOC Lab team members who are involved in the design of different sub-systems used in CWDM-DWDM systems.

Shri. ARUN KUMAR HEDDALIKKAR for making PCB layouts using Altium design software and testing/installation of integrated systems**.** He has helped in verifying the system performance through his simulation software. **Shri. PRAVIN RAYBOLE** for designing the front and rear panel of this PIU. He has helped us in providing the Control & Monitoring systems for this PIU. **Shri. SATISH LOKHANDE** for helping during installation of this sub- system in various antennas and for testing with broadband fiber optic system.

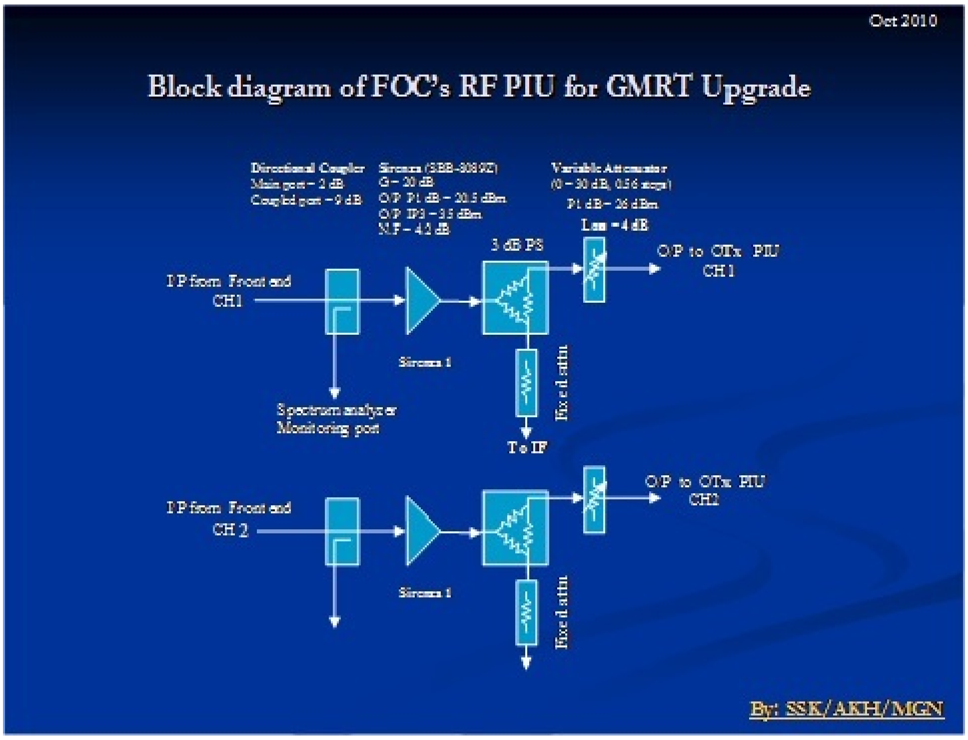
We thank **Shri. GOVIND SHETE** and **Shri. SRIKANT BHUJBAL** for their help during the wiring and installations.

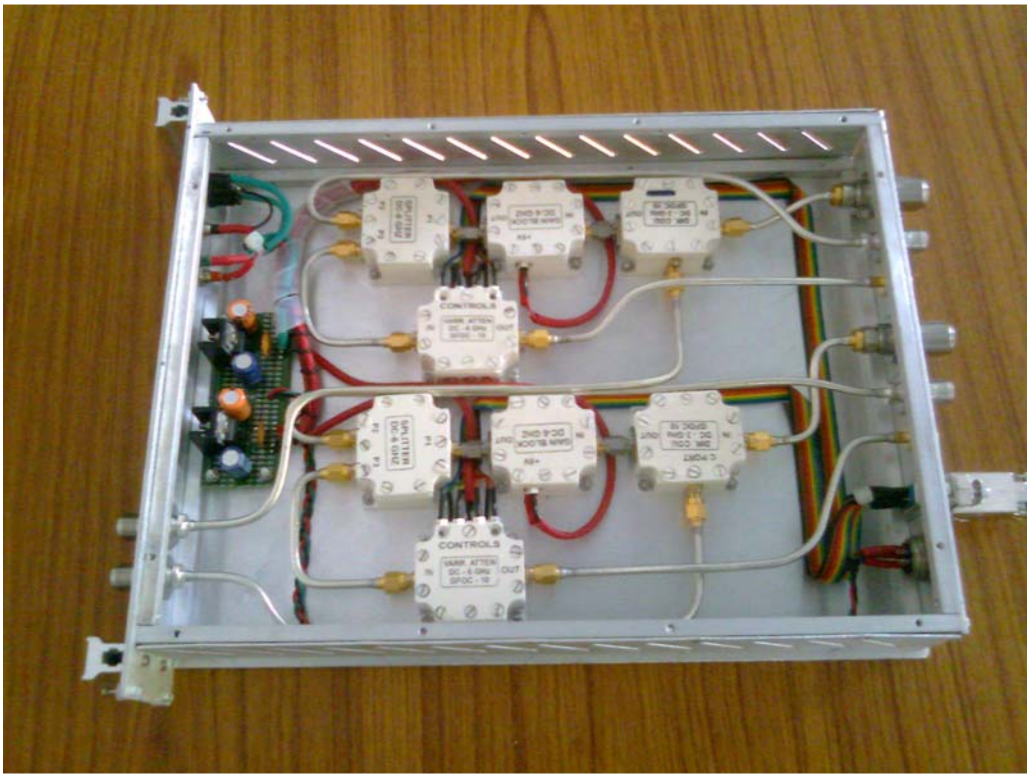
I wish to Thank **Shri. S. Ramesh** for helping me during system assembly and measurements.

Last but not the least, we would like to acknowledge the support rendered by **Shri.S.MURUGESAN** & **Shri. P.D.BHILARE** for designing the chassis for this sub-units which is small and needs high precision. I also thank them for helping us in mass producing these chassis in time at NCRA workshop.

REFERENCES

Mini-Circuits data sheets for directional coupler & power divider devices
Macom/tyco data sheet for digital attenuator device.
Sirenza Microwaves product description for broadband amplifier device.





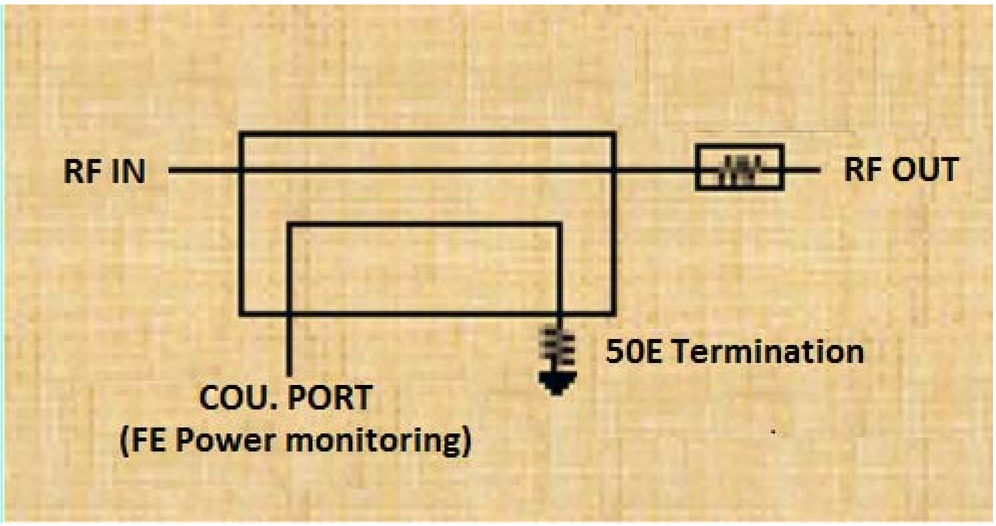
View of RF PIU

2.0 Sub-units of RF Gain Block Unit

The RF gain block unit consists of Directional coupler for RF monitoring at antenna base, Broadband RF amplifier, RF power splitter and variable RF attenuator. Figure 2.0 shows the various sub-units inside the RF PIU for two RF channels connecting to frontend system.

2.1 Directional Coupler

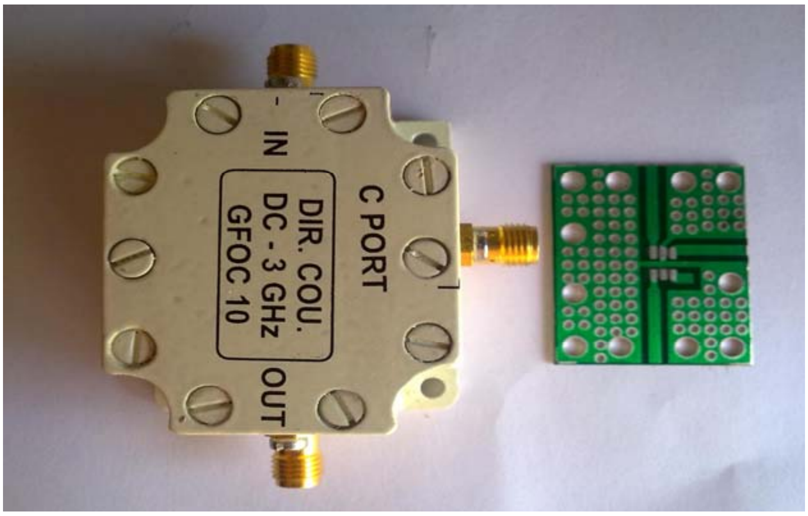
The broadband directional coupler is designed using Mini-circuits module (TCD-9-1W+) covering 5 to 2000 MHz with 50 Ω input and output impedance. The input port of this device is connected to frontend system using Type 'N' RF connector (Huber + Suhner 24_N_50-3-51/19-NE). The coupled port is 9 dB down from the main port and it is terminated with removable TNC 50 Ω load to avoid reflection from open port. The output port is provided with 4 dB fixed attenuator to provide better match with the following broadband RF amplifier input port. The insertion loss for the main line is 1.2 dB over the band. The unit used Rogers Ultralam board for PCB and the card is placed inside a small milled aluminum chassis with SMA connectors at input and output port of this sub-unit.



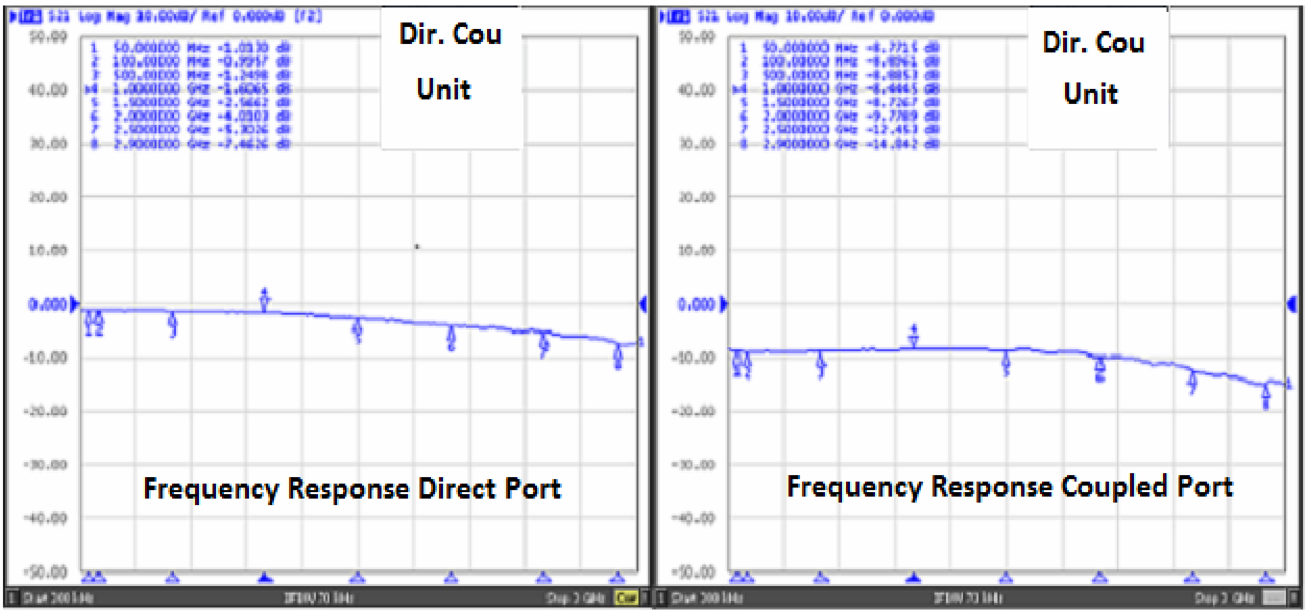
TCD-9-1W+ (CASE STYLE: DB714)

PIN CONFIGURATIONS	
INPUT	3
OUTPUT	4
COUPLED	1
GROUND	2
50E TERMINATION	6
NOT USED	5

Typical Performance			
Frequency In MHz	Mainline loss (dB)	Coupling (dB)	Input Return loss (dB)
	Measured/Mini-Circuits	Measured/Mini-Circuits	Measured/Mini-Circuits
50	**-1.01**/-1,13	**8.75**/8.96	**-30.1**/-27.80
100	**-0.99**/-1.14	**8.81**/8.97	**-28.5**/-30.00
500	**-1.24**/-1.25	**8.73**/8.65	**-22.1**/-22.87
1000	**-1.60**/-1.54	**8.24**/8.48	**-22.7**/-22.07
1500	**-2.56**/-2.31	**8.22**/8.57	**-23.9**/-21.45
2000	**-3.78**/-3.07	**9.18**/8.76	**-12.4**/-22.33



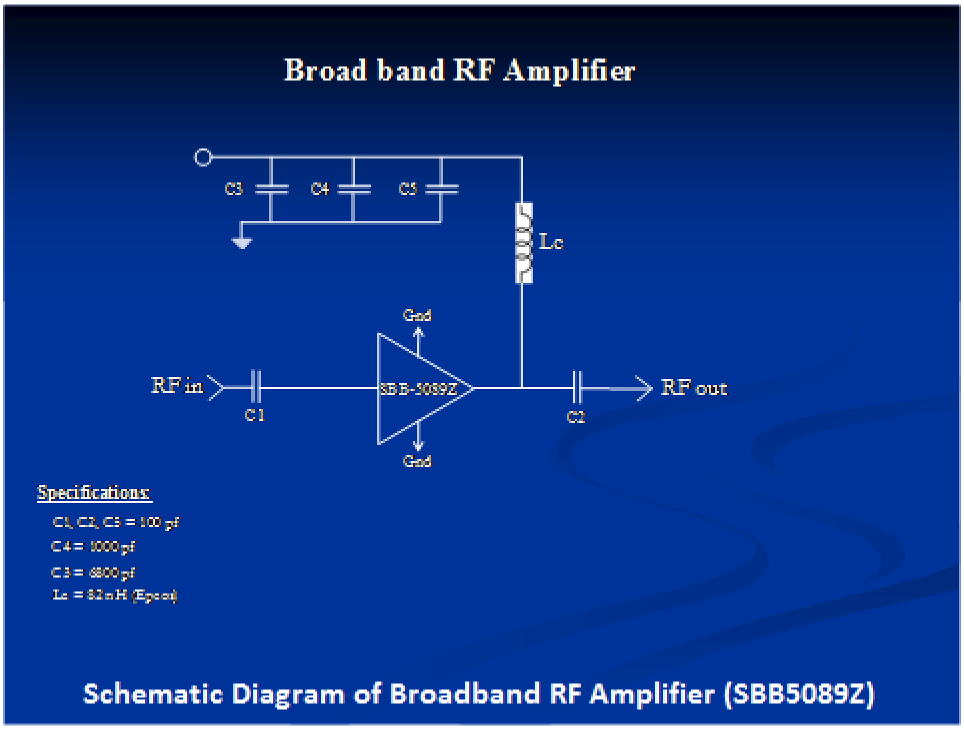
View of Directional Coupler Unit and it's PCB



2.2 Broadband RF amplifier (50 MHz - 6 GHz)

The broadband RF amplifier used as gain block is an InGaP HBT MMIC amplifier (SBB5089Z) with Darlington configuration using an active bias network. The active bias network provides stable current over temperature and process Beta variations. The RF amplifier works on + 5V Dc and does not require a dropping resistor as compared to typical Darlington amplifiers. The device is highly linear with flat frequency response over large bandwidth suitable for broadband fiber optic system and used minimum external components. Both input and output port is internally matched to 50 ohms.

The manufacturer specification is given in Table 2 for reference. The schematic and performance is given in figures below.



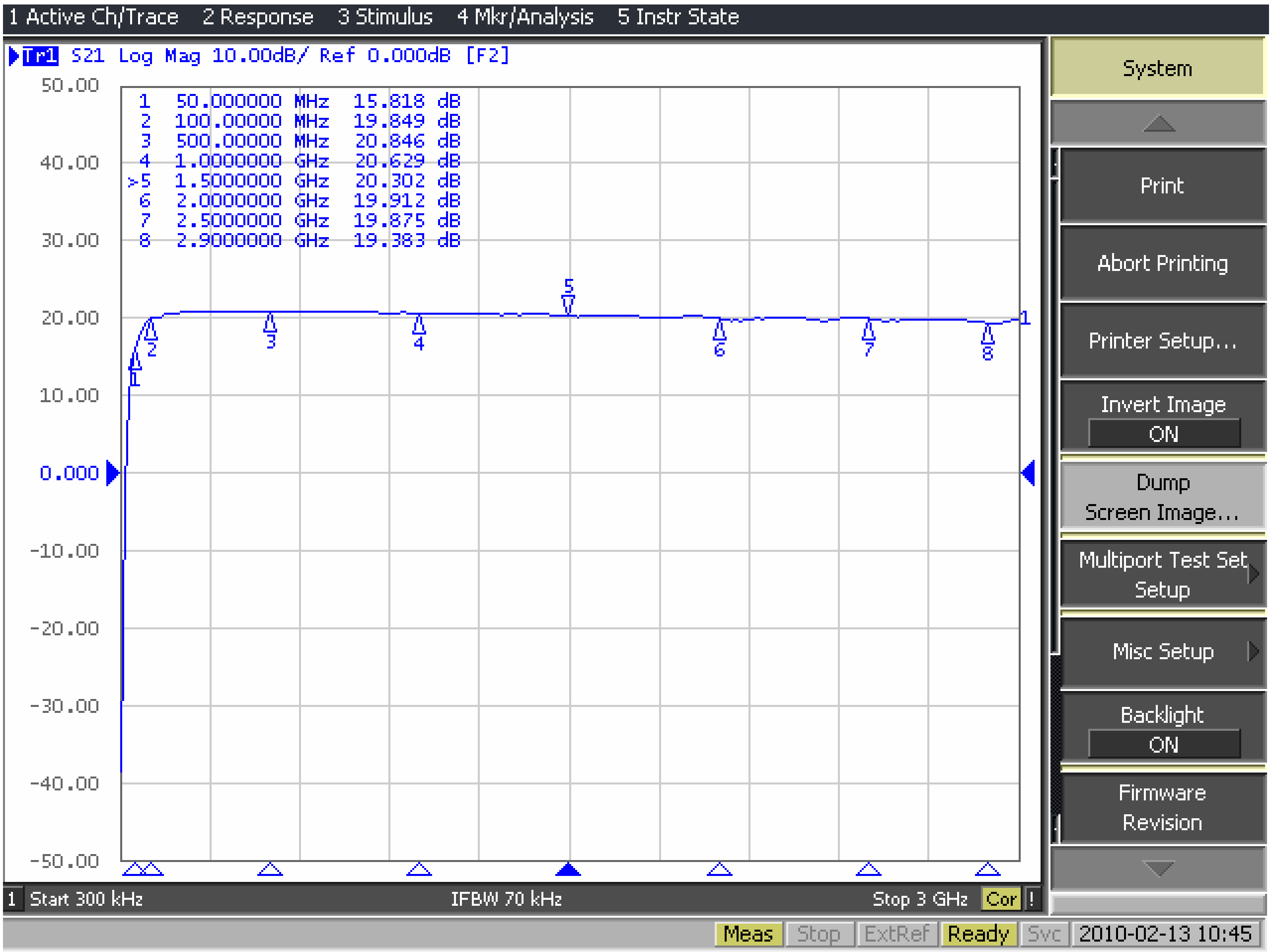
Manufacturer Specifications (SBB5089Z)

Frequency Range (Min) (MHz):	50
Frequency Range (Max) (MHz):	6000
Signal Gain (dB):	20
Noise Figure (dB):	4.2
Output Power at 1 dB Compression (dBm):	20.5
Third Order Intercept Point (dBm):	35
Device Operating Voltage (Vcc) (V):	+5
Device Operating Current (mA):	75
S11 and S22 (dB)	<10 (typ.)

Measured result of SBB5089Z

Frequency In MHz	Insertion Gain in dB	Input Return Loss (dB)	Output Return Loss (dB)
50	15.82	-8	-9
100	19.85	-12	-11
500	20.84	-27	-25
1000	20.63	-16	-18
1500	20.30	-12	-13
2000	19.91	-12	-12

Gain performance over the frequency band (50 MHz – 3 GHz)



Mass produced Sirenza RF amplifer used as gain block in broadband Fiber optic System

2.3 RF power splitter

The incoming RF signal from frontend system is split into two outputs using a two way e dB power splitter. Mini-circuits device RPS-2-30+ is 50 ohms matched with 0 degree phase shift and works from 10 MHz to 3 GHz. Out of two ports one port is connected to the broadband signal path to feed the broadband analog fiber optic transmitter and the other output is connect to antenna base receiver i.e IF system with 10 dB attenuator to reduce the excess gain from the previous stage. The TNC bulk head connector on the rear panel of the PIU gets connected to the IF system to support the existing GMRT receiver chain.

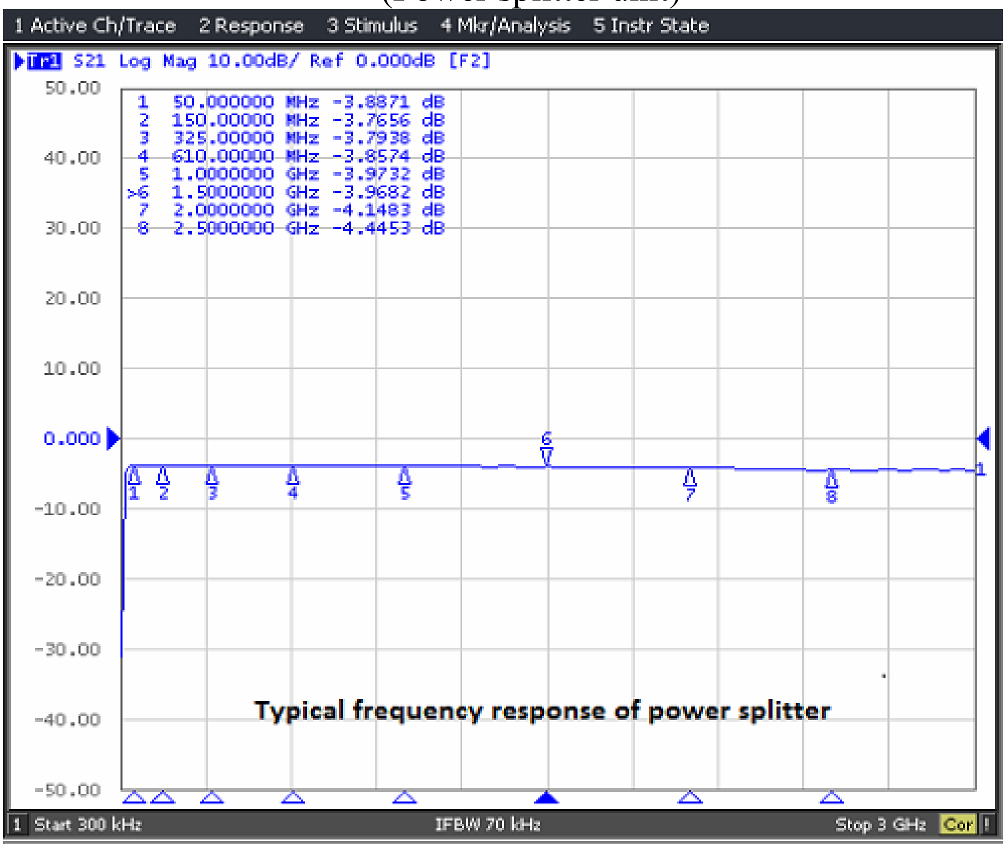
(View of RF power spitter RPS-2-3-30+)

SUM PORT	6
PORT-1	4
PORT-2	3
GROUND	1,2&5

<u>Measured Results – RF power splitter</u>

Frequency in MHz	S21 port 1 (dB)	S21 port 2 (dB)	Input Ret. Loss (dB)	O/P Ret. Loss(dB)
50	3.88	13.68	-8	-10
100	3.76	13.56	-10	-12
500	3.79	13.59	-12	-13
1000	3.95	13.79	-11	-16
1500	3.97	13.77	-13	-19
2000	4.10	13.99	-16	-17

(Power splitter unit)

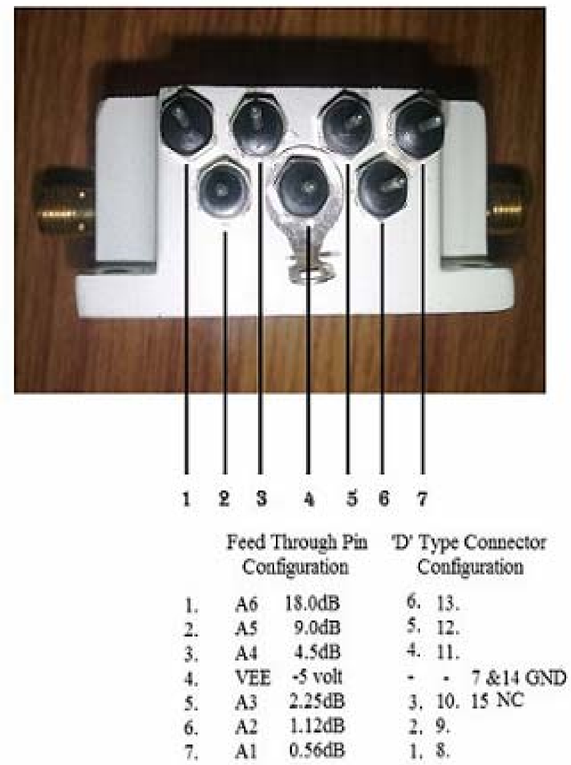


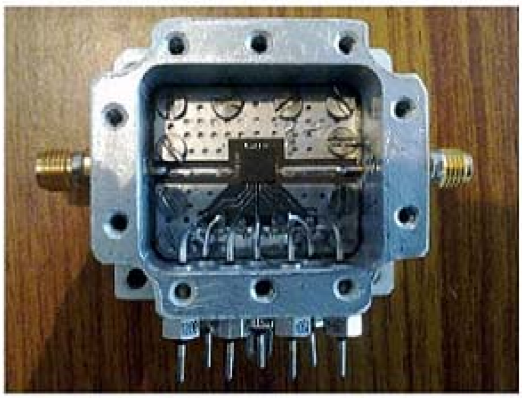
2.4 Variable RF attenuator

The 6 bit variable RF attenuator provides maximum attenuation of 35 dB in steps of 0.56 dB. The control inputs are TTL and the RF ports are matched to 50 ohms. The PQFN packaged device MAAYGM0001 is of Macom make

Pin Configuration and Truth Table of MAAT-GM0001

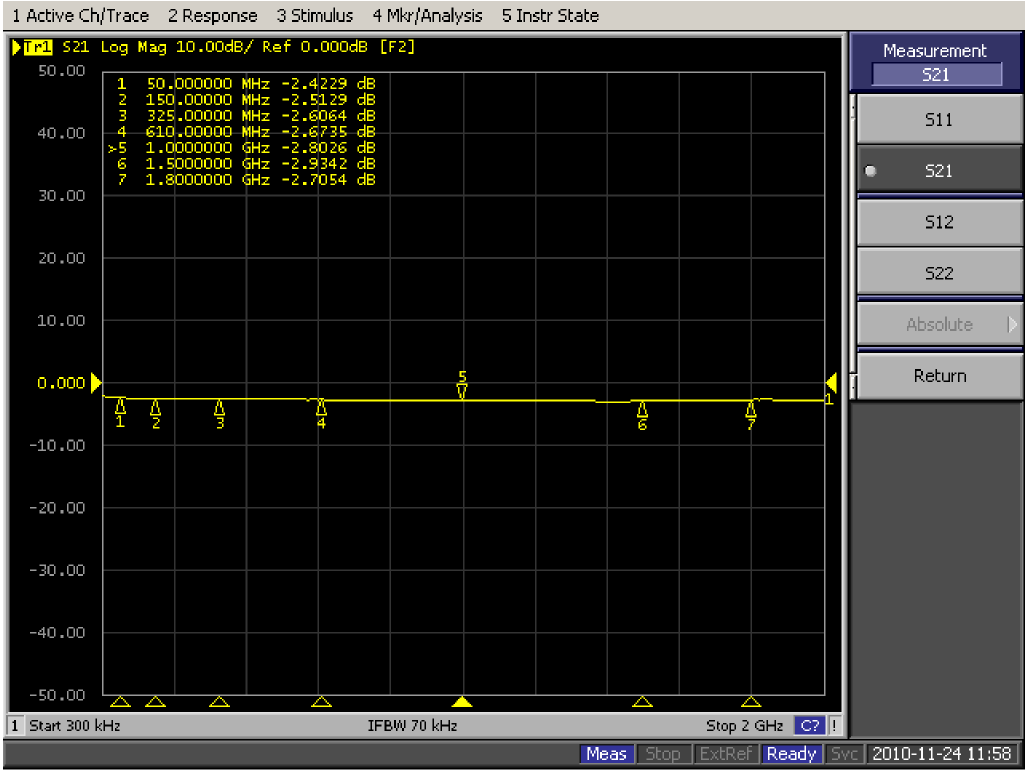
IC Pin	Designation	Description	Level	State
22	A6	18.0 dB Attenuation Bit	High	18.0 dB Atten.
23	A5	9.0 dB Attenuation Bit	High	9.0 dB Atten.
24	A4	4.5 dB Attenuation Bit	High	4.5 dB Atten.
25	VEE	DC Supply Voltage	-5V	
26	A3	2.25 dB Attenuation Bit	High	2.25 dB Atten.
27	A2	1.12 dB Attenuation Bit	High	1.12 dB Atten.
28	A1	0.56 dB Attenuation Bit	High	0.56 dB Atten.
2	RF input			
20	RF output			
		Pin Nos. 1&21, 3.19 - NC	GND connected to body	



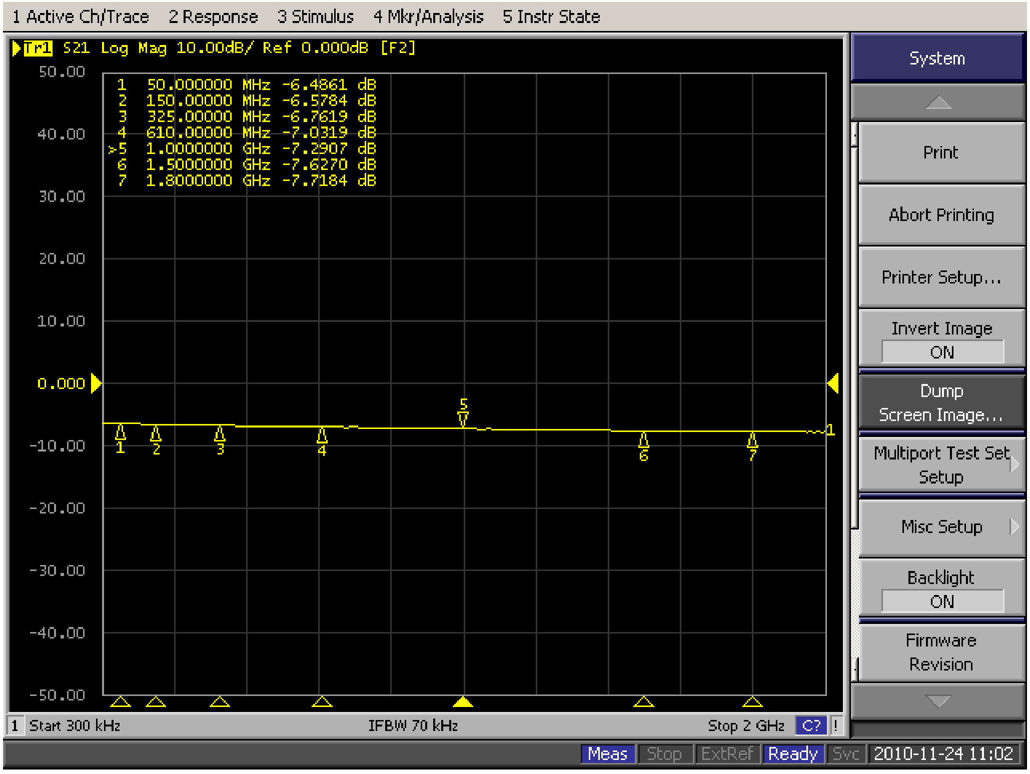


View of variable RF Attenuator Unit

Variable Attenuator 0 dB setting



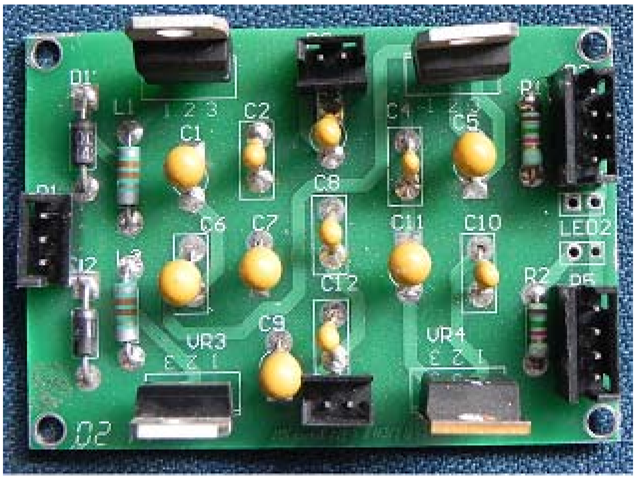
Variable Attenuator 4.5 dB setting



2.5 DC Power Supply Card.

This PIU requires +/- 5 volt DC supply for biasing the amplifier and attenuator units. The DC Regulated Power Supply, which is designed for feeding the entire FO broadband system has fixed output of DC +/- 15 volt with 3A current rating. A DC Power Supply card is made for down converting the 15 volt to 12 and 5 volts. The +/- 15 volts from the FO-DC power supply will connect to the input of the voltage regulators 7812/7912 respectively and +/- 12 volts again down converted into +/-5 volts using voltage regulators 7805 and 7905.

This is a universal card, which is designed such way that it can be used as any general purpose applications too.



New DC Power Supply Card used in PIU

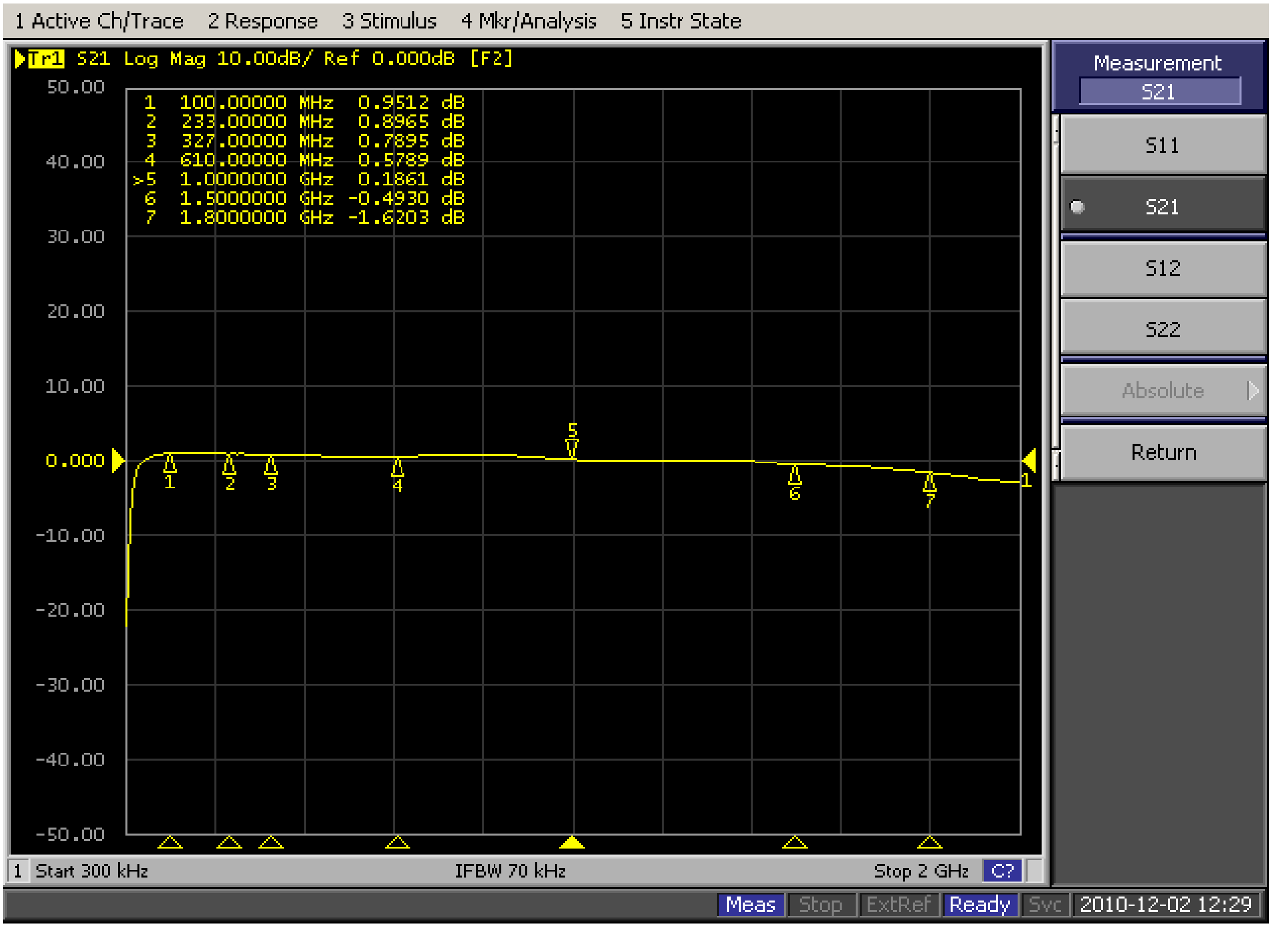
Front view of FO-DC Regulated Power Supply unit

This power supply units are designed and fabricated in FOC Lab for catering entire application of CWDM/DWDM system, and working in C06, C09, C11, S02, W04 and E06 antennae.

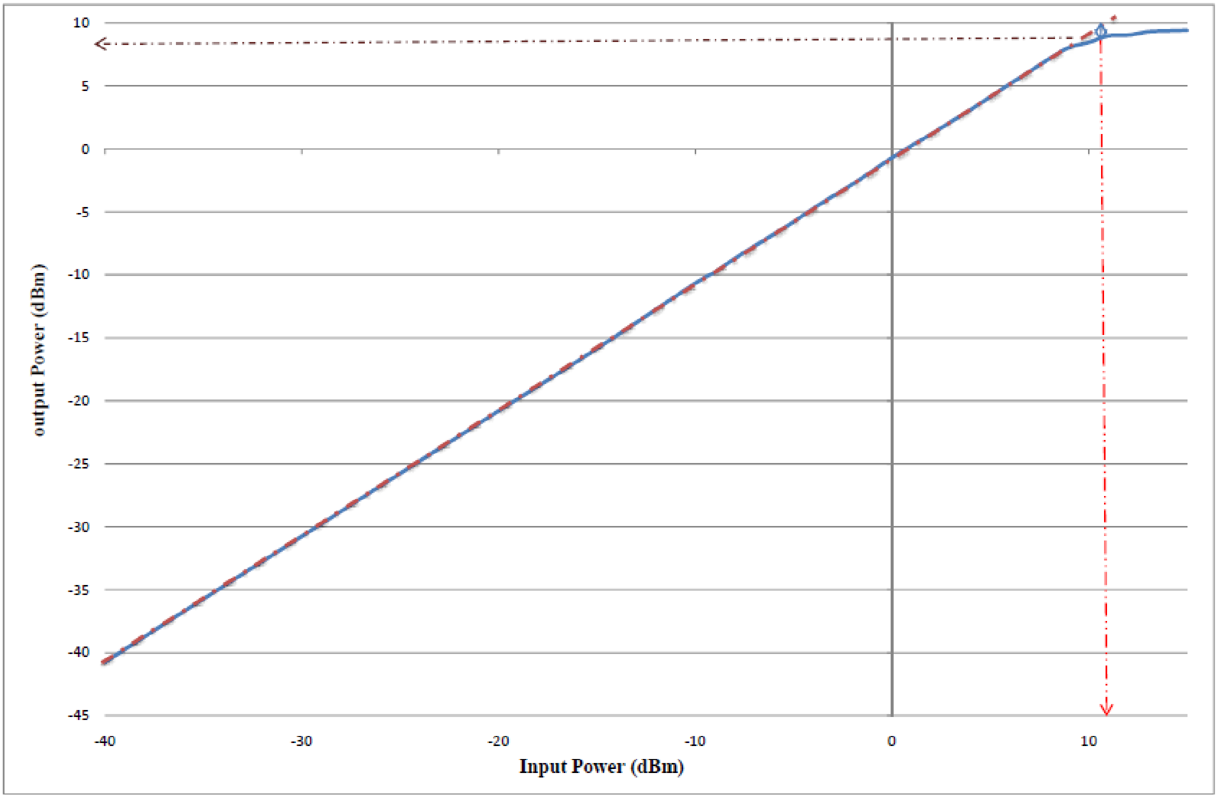
Typical Response of Integrated RF PIU (Input Power -60dBm)

FREQUENCY IN MHZ	IF Channel-1 power in dBm	IF Channel-2 power in dBm	OFTx-Ch.1 power in dBm	OFTx-Ch.2 power in dBm
100	-60.67	-60.95	-51.85	-51.96
150	-59.61	-59.50	-51.96	-51.46
233	-59.73	-59.99	-51.35	-51.24
327	-60.32	-60.10	-51.88	-51.69
610	-60.98	-61.00	-52.27	-51.95
1000	-62.14	-61.44	-54.08	-53.79
1400	-62.84	-62.88	-54.37	-54.23

Final output to GMRT- IF from RF amplifier (BBRF) PIU



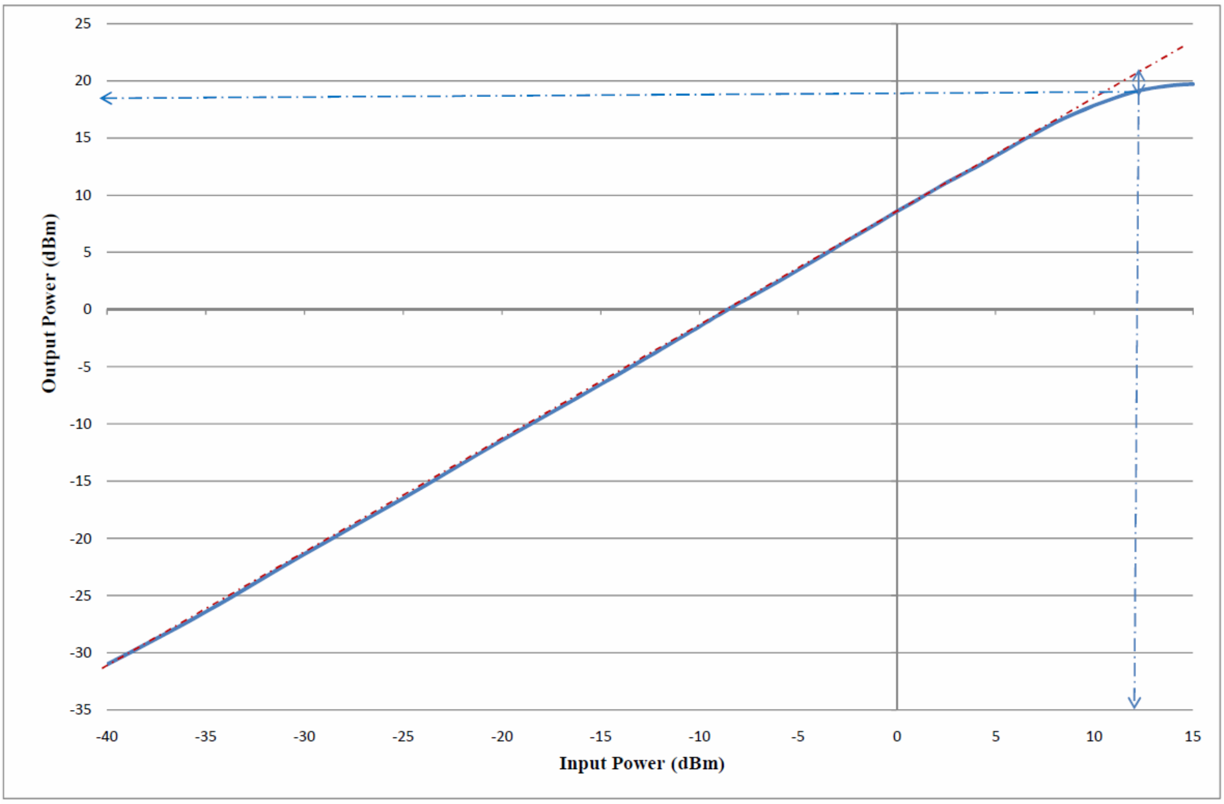
(Front End power levels to the IF input is maintained under +/- 1dB)



Linearity performance of the integrated system with respect to IF Port.
(frequency 1400 MHz)

I/P POWER	O/P POWER	I/P POWER	O/P POWER	I/P POWER	O/P POWER	I/P POWER	O/P POWER
-40	-40.75	-8	-8.7	0	-0.68	8	7.18
-35	-35.73	-7	-7.72	1	0.28	9	8.06
-30	-30.77	-6	-6.75	2	1.19	10	8.47
-25	-25.76	-5	-5.78	3	2.17	11	8.99
-20	-20.81	-4	-4.72	4	3.13	12	9.04
-15	-15.85	-3	-3.74	5	4.15	13	9.31
-10	-10.66	-2	-2.79	6	5.18	14	9.38
-9	-9.77	-1	-1.74	7	6.16	15	9.42

(All power levels are in dBm)



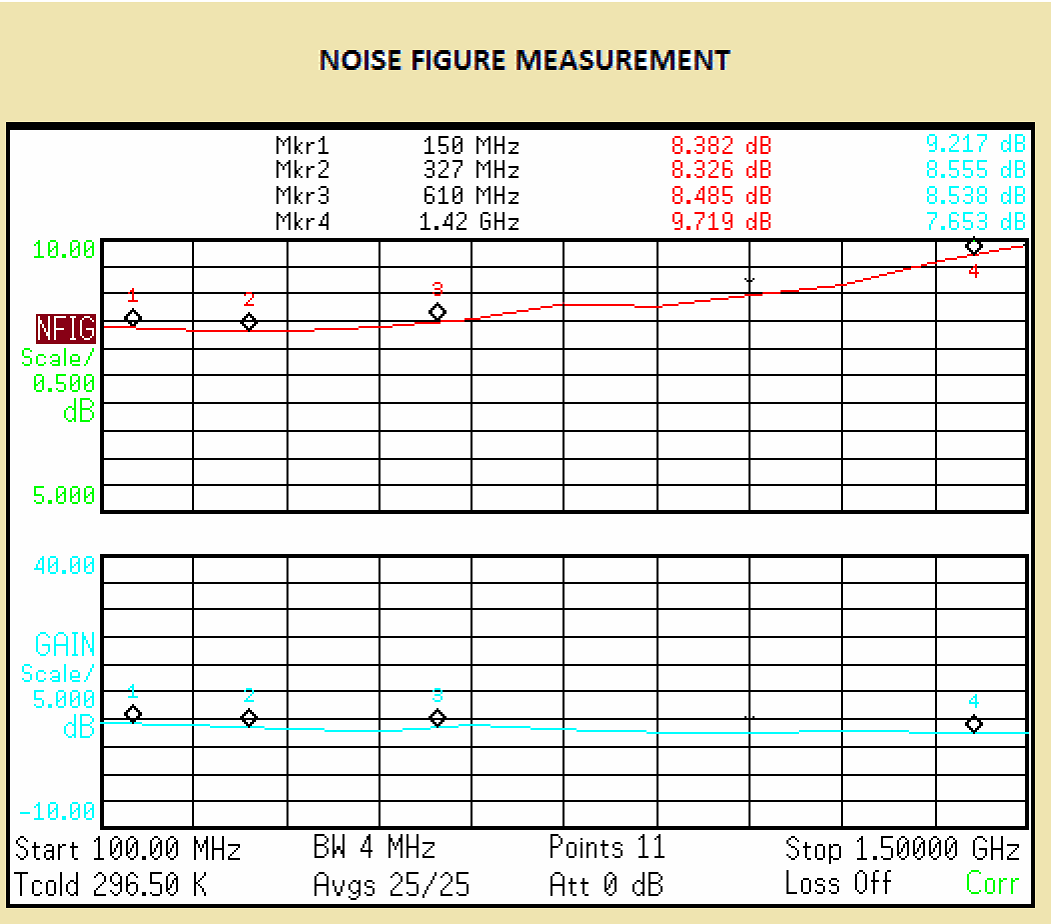
Linearity performance of the integrated system with respect to OFTx Port.
(frequency 1400 MHz)

I/P POWER	O/P POWER	I/P POWER	O/P POWER	I/P POWER	O/P POWER	I/P POWER	O/P POWER
-40	-31.05	-8	0.55	0	8.57	8	16.32
-35	-26.43	-7	1.49	1	9.56	9	17.13
-30	-21.37	-6	2.47	2	10.58	10	17.85
-25	-16.51	-5	3.46	3	11.55	11	18.49
-20	-11.44	-4	4.47	4	12.45	12	19.04
-15	-6.55	-3	5.52	5	13.43	13	19.39
-10	-1.49	-2	6.53	6	14.44	14	19.62
-9	-0.44	-1	7.55	7	15.4	15	19.72

All power levels are in dBm

Noise Figure performance

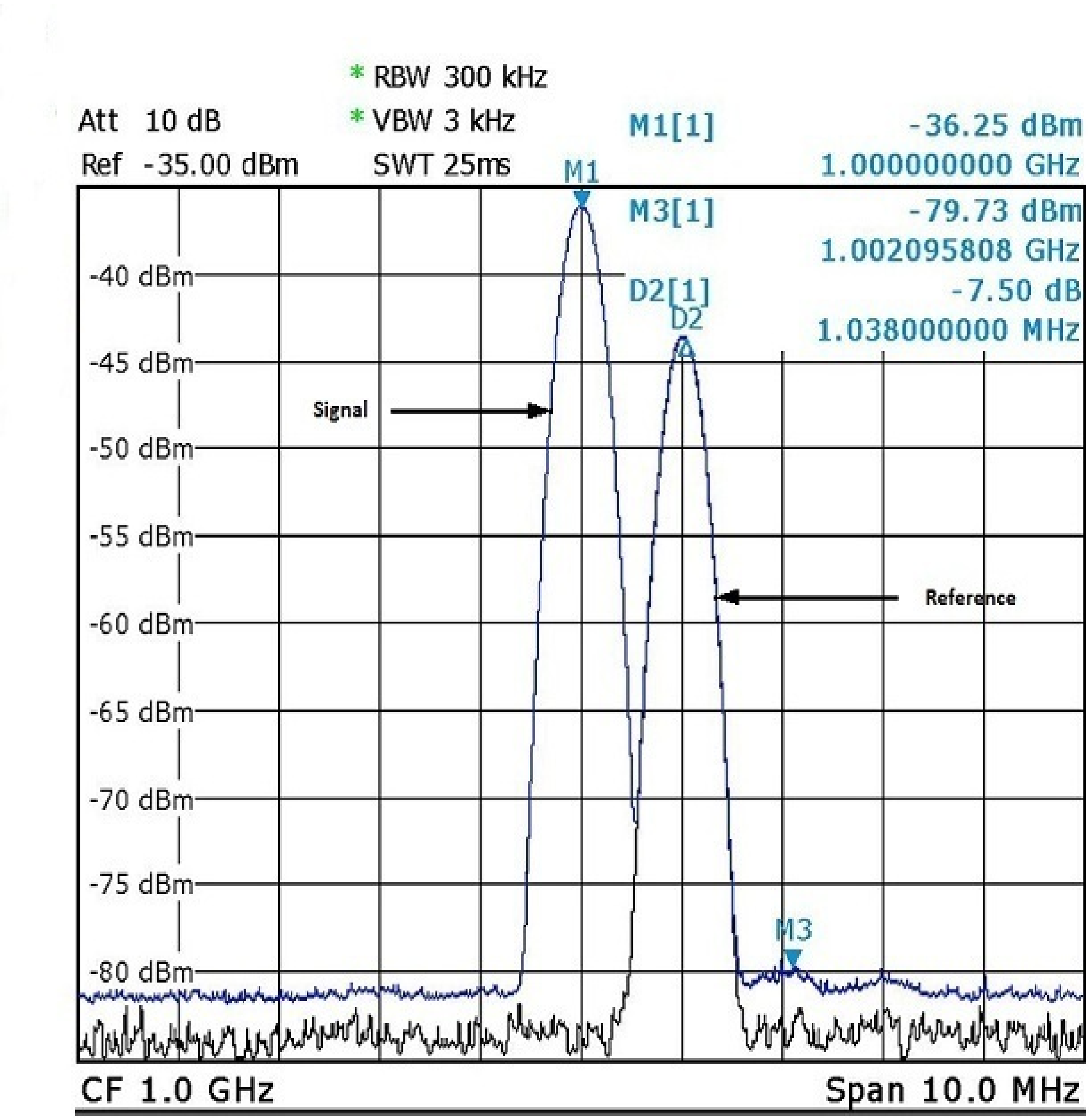
Noise figure is typical 8dB to 10dB over the full bandwidth (100MHz-1.5GHz), which is about 4 dB higher due to 4 dB attenuator placed in directional coupler before the amplifier input for better impedance matching. Below the noise figure measurement is taken using Agilent N8973A Noise figure meter.



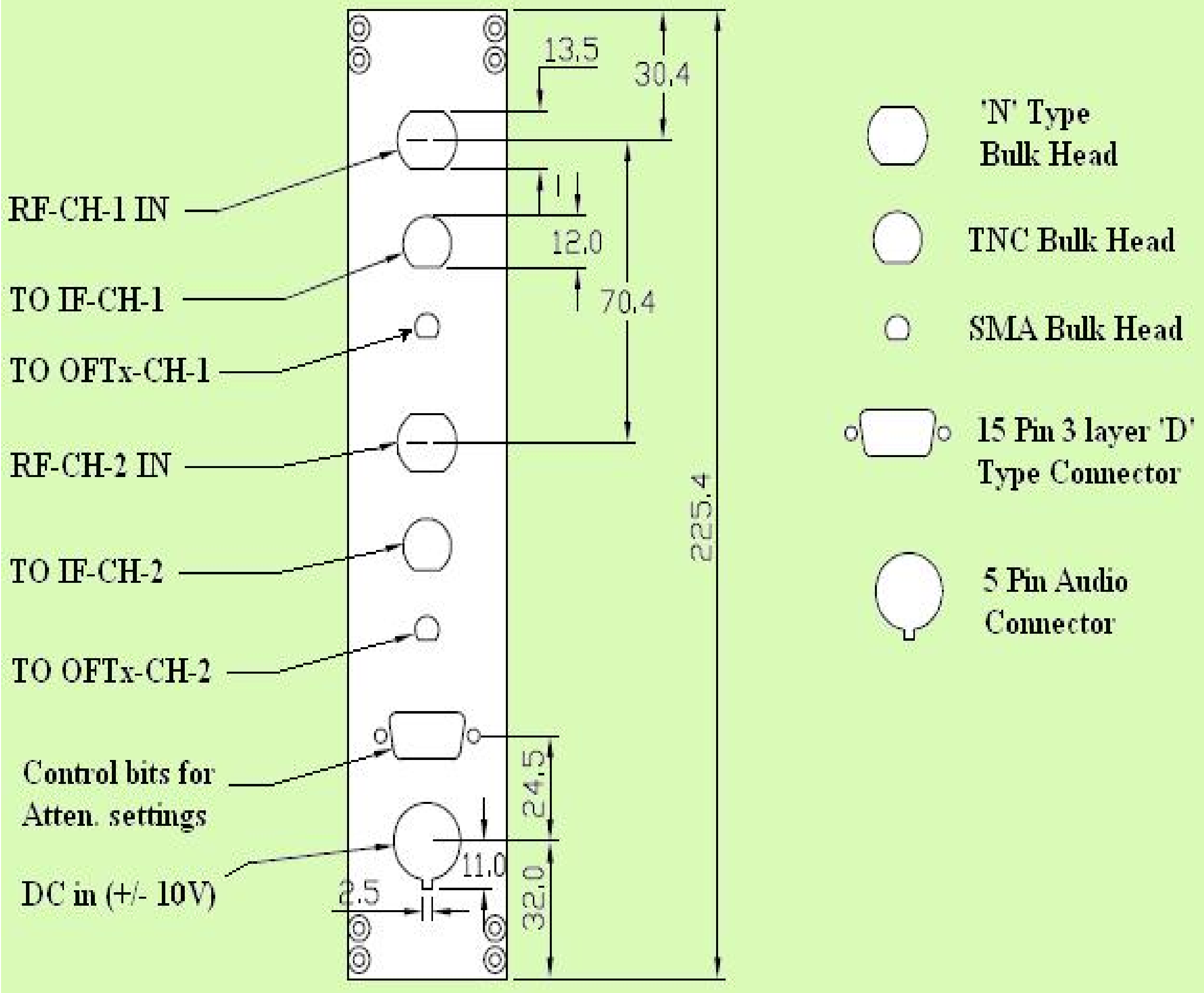
Noise Figure measurement with respect to OFTx port.

Signal to Noise (SNR) measurement

In the below plot, the marker D2 is the ‘reference’ which is signal generator directly connected to spectrum analyzer. The other marker M1 is the signal level after connecting the PIU at OFTx port and marker M3 is the noise floor level. The marker D2(1) reads the gain of the PIU. The SNR is better than 50 dB over 300KHz RBW.



SNR measurement with respect to OFTx port at 1Ghz.



REAR VIEW OF RF AMPLIFIER PIU

SUMMARY OF SYSTEM PERFORMANCE

Gain @ OFTx port	Typical 8.5 dB (+/- 1 dB)
Gain/Loss @ IF port	Typical 0 dB (+/- 1 dB)
Input Return Loss	> 10 dB
Output Return Loss @OFTX port	> 20 dB
Output Return Loss @IF port	> 25 dB

RF level @monitoring point	09 dB lower than the input power

Input Linearity range with respect to OFTx port	-40 dBm to +10 dBm
Input Linearity range with respect to IF port	-40 dBm to +08 dBm
Input 1dB compression point	+10dBm

SNR (300KHz RBW)	> 50 dB
SNR (400MHz)	>20 dB

Noise Figure (100MHz to 1500MHz)	08 – 10 dB

Thank You

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