National Centre for Radio Astrophysics

Internal Technical Report

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GMRT Upgrade

Signal Flow Analysis for GMRT Signal Transport System

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Ver 1.1	10 July 2014	Final Version

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We also thank **Prof. S.K. Ghosh** *Centre Director NCRA,* for giving constant support during this work.

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1.0) Introduction:

This report attempts to study the signal flow analysis of the cascaded Fibre Optic chain which covers up to 25km range over a frequency band of 50MHz to 1600MHz. This report carry forward previous report by Mr. Arun Kumar Heddallikar to one step ahead with considering all major and minor changes.

In the following report the fiber optic system analysis is done using XLS and Spectrum microwave and the simulated results are compared with practical results.

Block Diagram of GMRT Transport System:

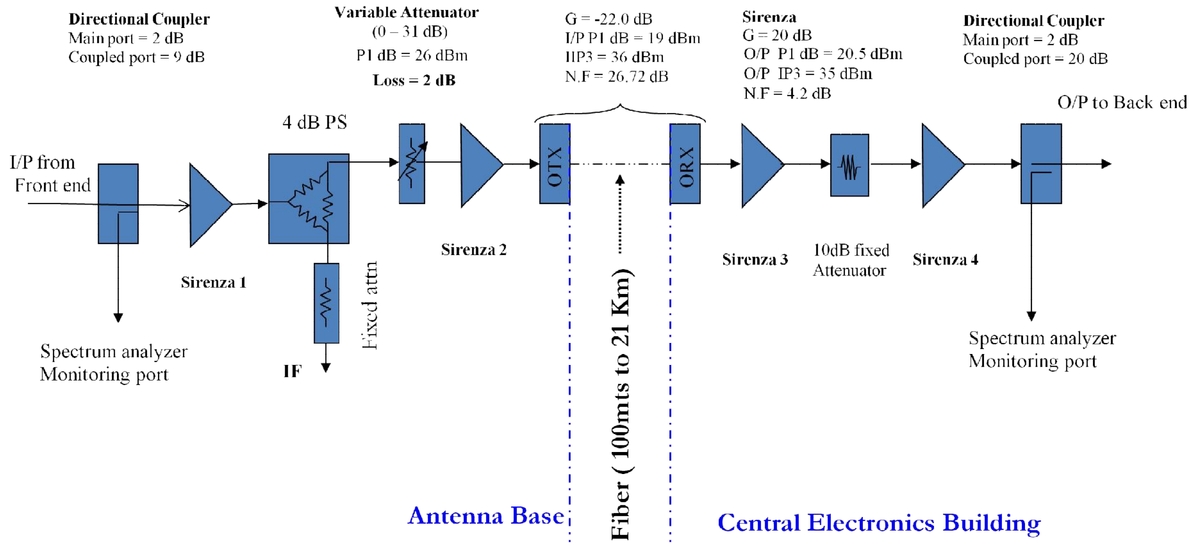


Fig.1

1.1) <u>Cascaded Performance:</u>

Cascaded performance of Fiber optic system done using XLS calculation, Spectrum Microwave Simulation 7.0 and results are compared with practical measurement and given as a summary.

1.1.1) <u>Parameters optimised for the cascaded system</u>

<u>Gain:</u> Gain is a measure of the ability of a device to increase the power or amplitude of a signal from the input to the output.

<u>Noise Figure:</u> Noise figure is the increase in noise power of a device from the input to the output. In effect, it is the amount of decrease of the signal-to-noise ratio.

<u>1 dB compression:</u> The 1-dB compression point is the measure of receiver performance that indicates the input level at which the receiver begins to deviate radically from linear amplitude response. In a linear device, for each dB of input-level increase, there is a corresponding dB increase in output level. In the case of input overload, the output does not continue to increase with each input increase, but instead, the output tends to limit. The input level at which the output deviates from linear response by 1 dB is known as the 1-dB compression point.

Intercept Point: The device is fed with two sine tones with a small frequency difference. The *n*-th order inter modulation products then appear at *n* times the frequency spacing of the input tones. The presence of 2 or more tones in a non-linear device generates inter modulation products, these products are the sum and difference of multiples of the fundamental tones i.e. if f1 and f2 are slightly spaced fundamental frequencies then third order products will be 2f2-f1 or 2f1-f2.

Signal to Noise ratio: It is defined as the ratio of signal power to the noise power.

Equivalent Input Noise: EIN is defined as the amount of RF noise at the input of a link that would be needed to produce the amount of noise observed at the output of the link if the total link itself were noiseless. Its units can be mW/Hz or dBm/Hz.

Dynamic Range:

Compression Dynamic Range: It's a receiver linear range over which it can detect minimum signal (Sensitivity) to saturation level (1 dB compression point) of an input signal in the bandwidth of concern.

Spurious Free Dynamic Range: of a system is the range between the smallest signal that can be detected in a system (i.e., a signal just above the noise level of the system), and the largest signal that can be introduced into a system without creating detectable distortions in the bandwidth of concern.

Headroom: of a receiver is defined as the range between the minimum detectable signal level at input of system to the maximum signal level it can handle in the bandwidth of concern.

XLS Spread sheet Calculation: In XLS spread sheet calculation we need to take individual block details like gain, noise figure, P1 dB and IP3. Followings are the methods/formulas used to calculate cascaded performance. The following block shows the n devices are connected and the each devices value is given. Gain 'G' in dB, Noise Figure 'N.F' in dB, Input 1 dB compression point 'IP1 dB' in dBm and input third order intercept point 'IIP3' in dBm. Where f is noise factor.

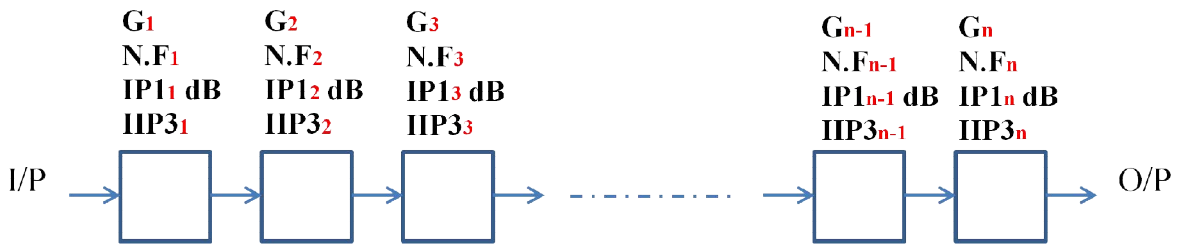


Fig.2

Fig 4

$$g = 10^{G/10} \qquad G = 10 * Log\,(g)$$

$$f = 10^{N.F/10} \qquad N.F = 10 * Log\,(f)$$

$$p1dB = 10^{P1\,dB\,/10} \qquad P1\,dB = 10 * Log\,(p1\,dB)$$

Cascaded system Calculation:

Gain:

$$g = (g1 * g2 * g3 * - - - - - - - - g\,n - 1 * g\,n)$$ Or

$$G = G1 + G2 + G3 + - - - - Gn - 1 + Gn$$ ….. (1)

Noise Figure:

Cascaded noise factor (By using Friis formula)

$$\mathrm{f} = f1 + \frac{\mathrm{f2} - 1}{g1} + \frac{\mathrm{f3} - 1}{g1 * g2} + \cdots + \frac{\mathrm{fn} - 1}{g1 * g2 * \ldots gn - 1}$$

Noise Figure $N.F = 10 * Log\,(f)$ …. (2)

Input P1 dB:

$$\frac{1}{\mathrm{ip1dB}} = \frac{1}{ip1dB1} + \frac{\mathrm{g1}}{\mathrm{ip1dB2}} + \frac{\mathrm{g1 * g2}}{ip1dB3} + \cdots + \frac{g1 * g2 * \ldots\ldots * gn - 1}{ip1dBn}$$

…. (3)

$$P1\,dB = 10 * Log\,(\,1/ip1dB)$$

Input IP3:

$$\frac{1}{\mathrm{iip3}} = \frac{1}{iip31} + \frac{\mathrm{g1}}{\mathrm{iip32}} + \frac{\mathrm{g1 * g2}}{iip33} + \cdots + \frac{g1 * g2 * \ldots\ldots * gn - 1}{iip3n}$$

…. (4)

$$IIP3 = 10 * Log\,(\,1/iip3)$$

System Thermal Noise

Noise power is based on the thermal noise power at the input of the system, along with system gain and noise figure:

Thermal noise $P = k * T * B$ [Watts],

where, k = Boltzmann constant = 1.3807 * 10^{-23}

T = Ambient temperature {^{o}K}

B = Bandwidth {Hz}

$$P\ [dBm] = 10 * \log_{10}(1000 * k * T * B) \quad \text{.... (4)}$$

For T = 290 K

P [dBm] = - 173.975 dBm / Hz

We have the thermal noise at the input, add the system gain and the additional noise added by the system (the NF) to get the noise power at the output:

$P_{Noise@Output}$ [dBm] = $P_{Noise@Input}$ + $Gain_{System}$ + NF_{System}

= -173.97 + 38 + 6.84

= -129.13 dBm / Hz

= -129.13 + 10 * Log (300 x 10^3)

$$\boldsymbol{PNoise@Output\ [dBm] = -74.35\ dBm\ /\ 300\ KHz}$$

The above result shows the minimum expected noise floor of the output of fiber optic system for a given resolution bandwidth in spectrum analyzer.

Dynamic Range

Compression Dynamic Range:

$$C.D.R = IP1\ dB - N.F - 10 * Log(k * T * B) \quad \text{..... (5)}$$

C.D.R = –20.25 – 6.84 – (–173.9)

C.D.R = 146.89 dB / Hz

C.D.R = 60.86 dB / 400 MHz

Spurious Free Dynamic Range:

$$S.F.D.R = \frac{2}{3}[IIP3 - N.F - 10 * Log\,(k * T * B)] \qquad \text{...... (6)}$$

S.F.D.R = 2/3 (– 6.48 – 6.84 – (–173.9))

S.F.D.R = **107.10** dB / $Hz^{2/3}$

S.F.D.R = **49.76** dB / 400 $MHz^{2/3}$

Head room Calculation:

Minimum input signal level that can be detected by system for 400MHz bandwidth is -81dBm and the maximum input signal level without saturating system is -21dBm.

So Head Room is 60 dB/ 400MHz

For 20 dB SNR at input, the minimum signal level is -61dBm and

For 20 dB SNR Head Room is 40dB / 400MHz

Cascaded Block Diagram of Receiver Chain

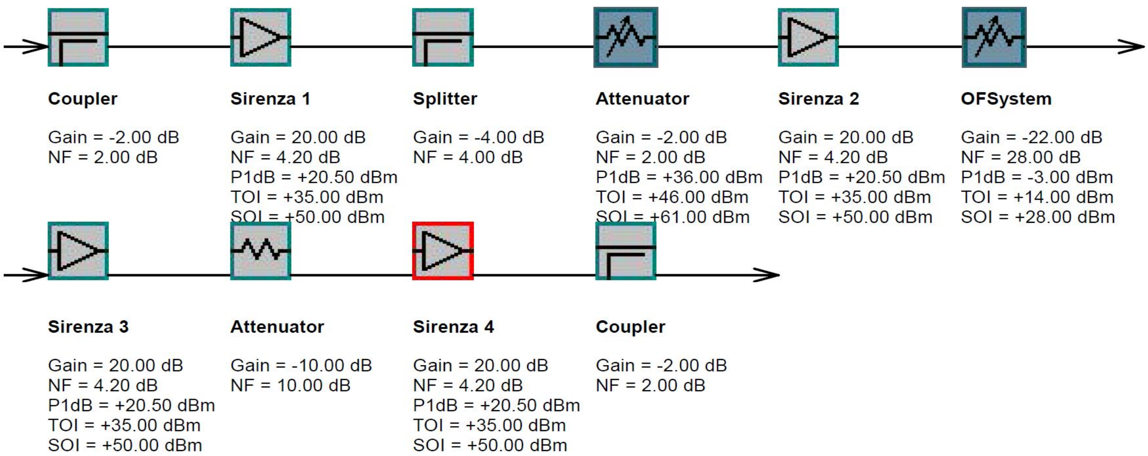


Fig.3

1.2) Summary:

With 1 dB Attenuation for 400MHz Bandwidth

Parameters	Spectrum Microwave Simulation	XLS Calculation	Practical Measured values†
Gain (in dB)	**38**	**38**	**38**
Noise Figure (in dB)	**6.86**	**6.84**	**-**
Input 1 dB compression point (in dBm)	**-20.24**	**-20.24**	**-21**
Input third order intercept point (in dBm)	**-6.46**	**-6.48**	**-6**
Compression Dynamic Range (dB/Hz)	**144**	**146.8**	**144**
Compression Dynamic Range (dB/ 400 MHz)	**59.45**	**60.85**	**58**
Spurious Free Dynamic Range (dB/Hz 2/3)	**105**	**107.10**	**105**
Spurious Free Dynamic Range (dB/400MHz 2/3)	**49.1**	**50.7**	**48**

† values from Ref 7

1.3) Effect of varying Attenuation on GMRT Transport System

Attenuation	NF	IP1 dB	IP3 dB
2	6.84	-20.24	**-6.46**
5	7.41	-17.26	**-3.48**
9	8.79	-13.36	**0.46**
17	14.11	-5.77	**7.98**
25	21.48	0.11	**13.76**
31	27.38	2.37	**15.93**

1.4) Plots between variable attenuation and NF, IP1dB and IP3dB:

Noise figure Vs. Variable Attenuation

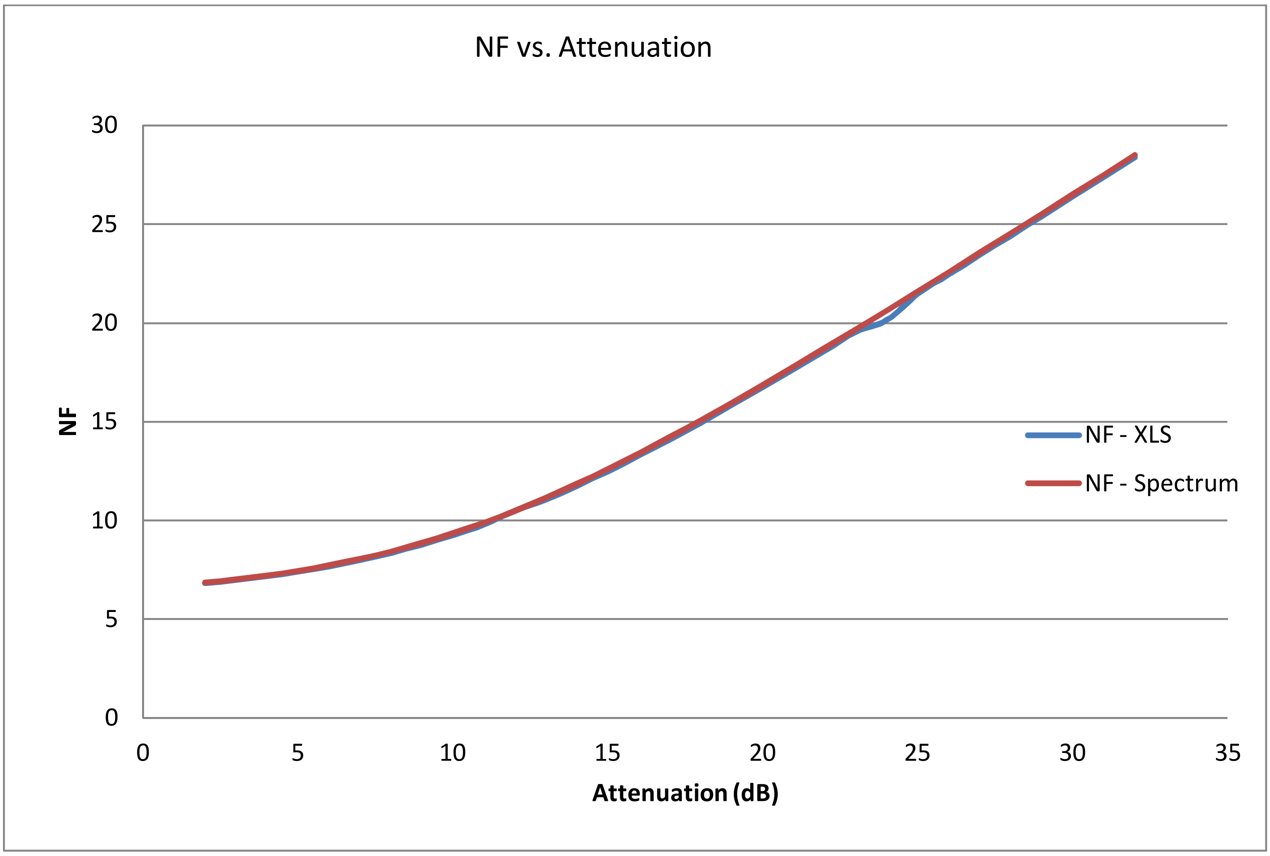


Fig. 4

IP1dB Versus Var. Attenuation :

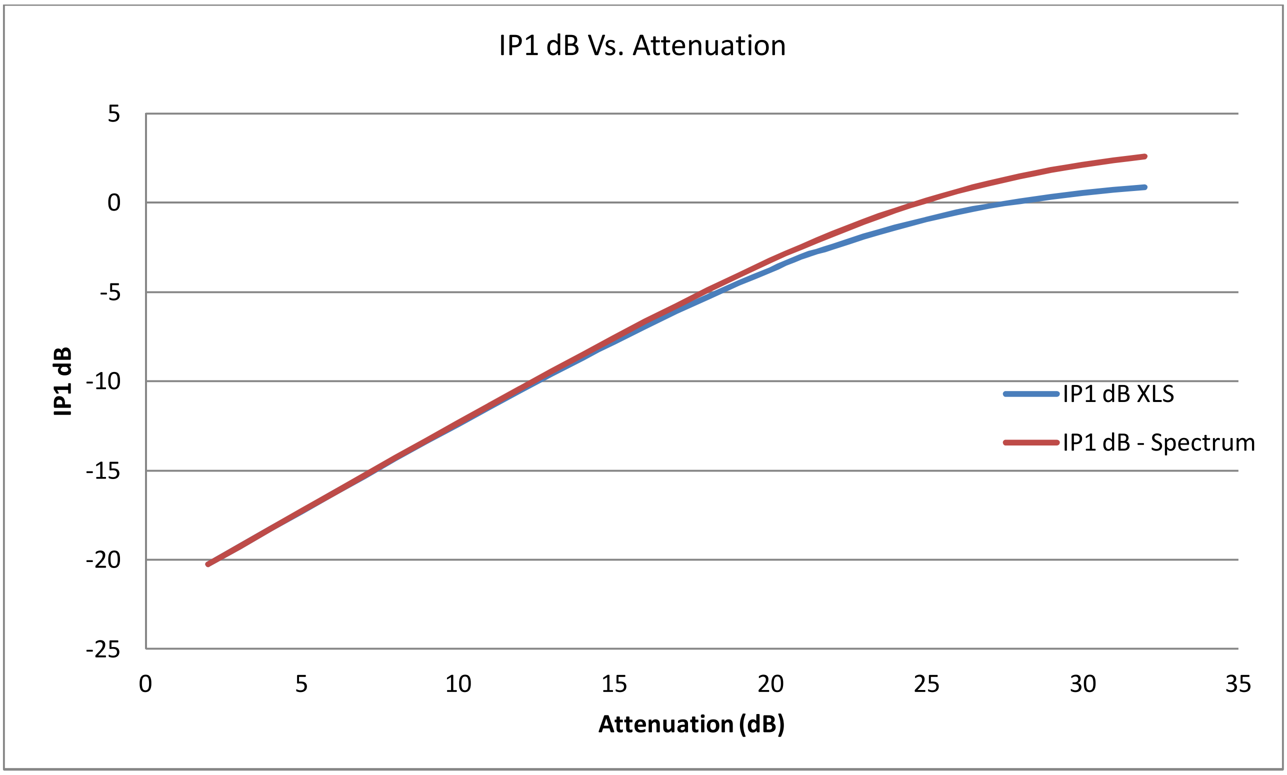


Fig. 5

IP3 dB Vs. Var. Attenuation :

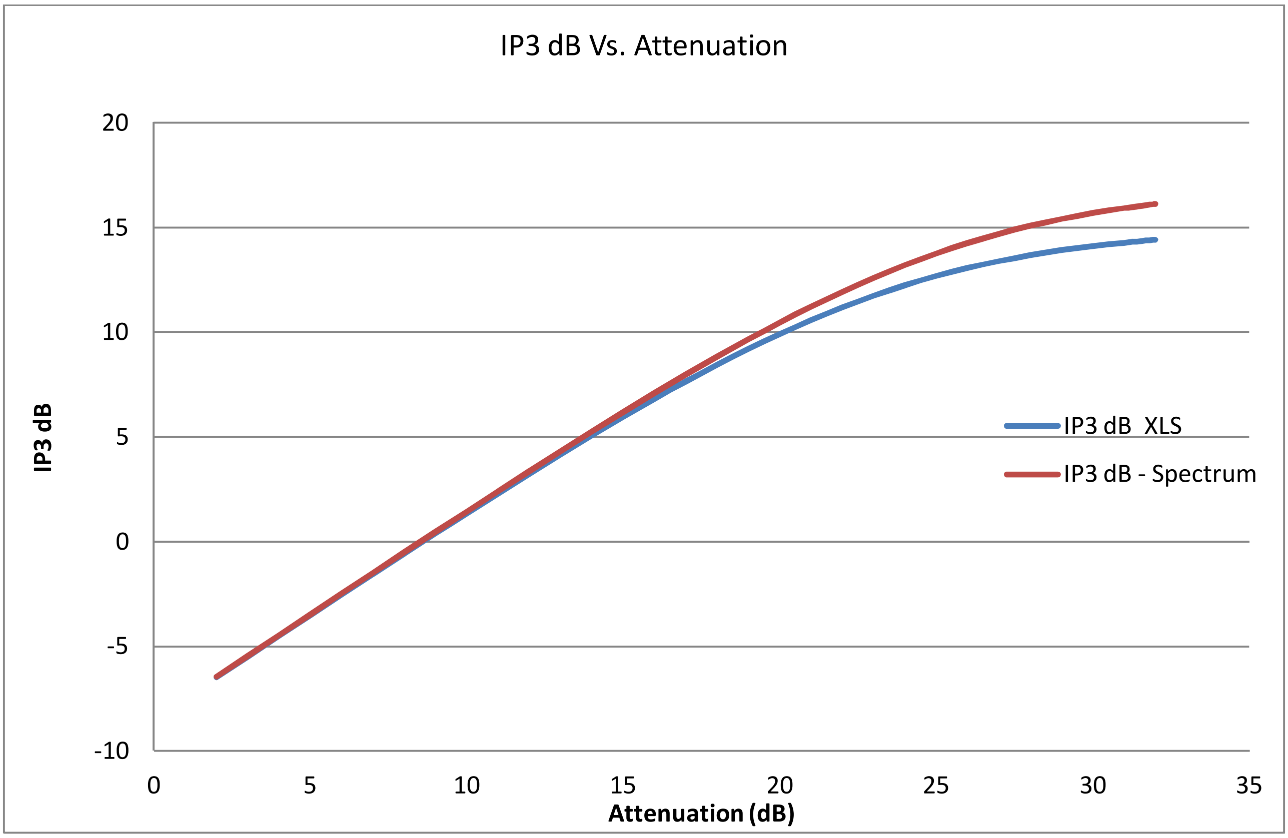


Fig.6

CDR Vs. Var. Attenuation (for 400 MHz Bandwidth) :

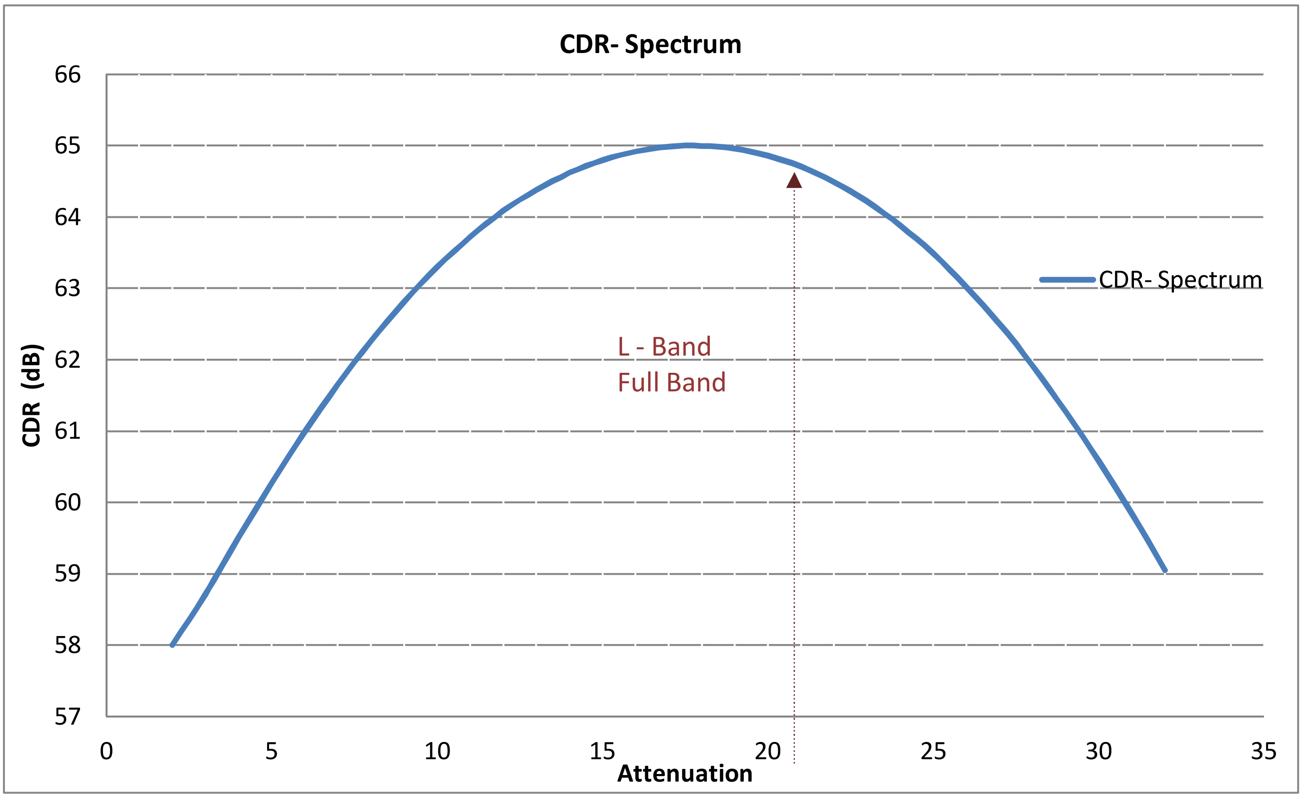


Fig. 7

SFDR Vs. Var. Attenuation (for 400 MHz Bandwidth):

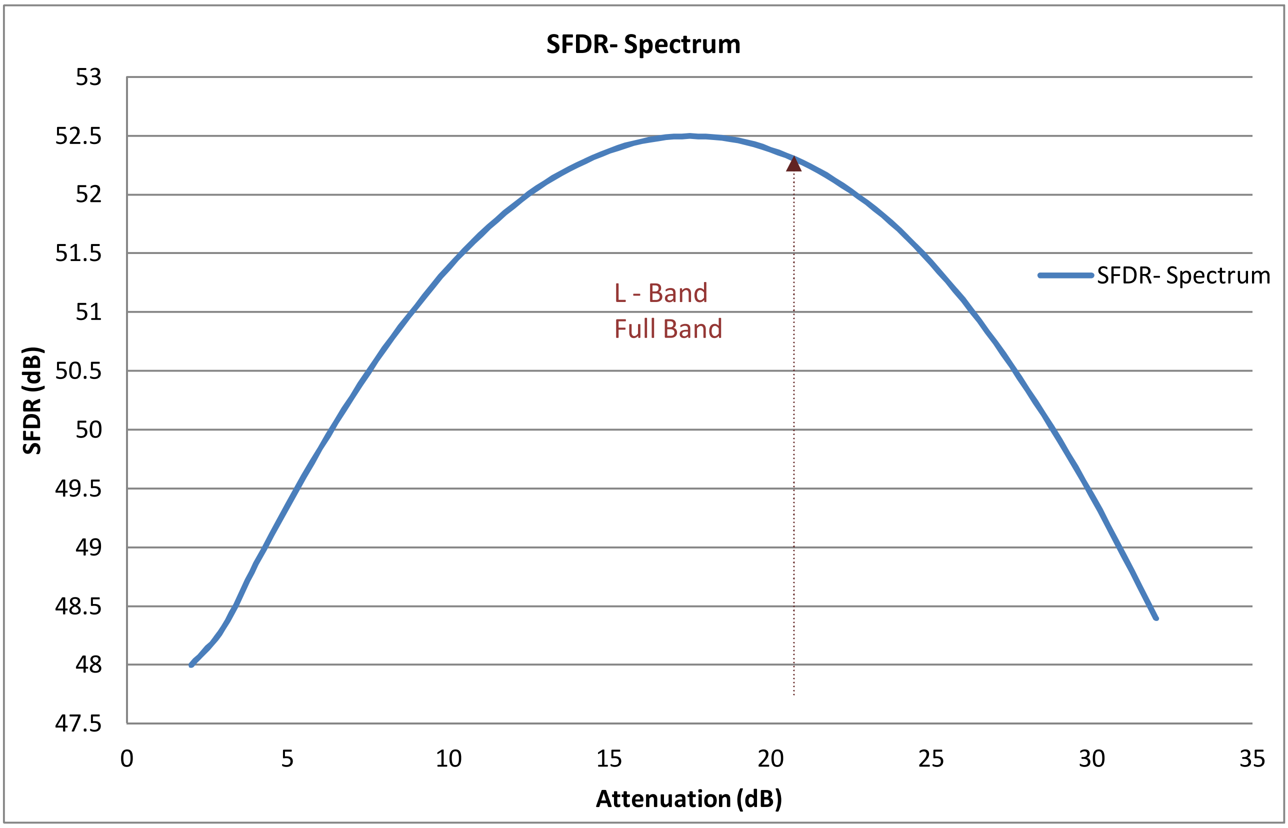


Fig. 8

CDR Vs. Var. Attenuation (for 250 MHz Bandwidth) :

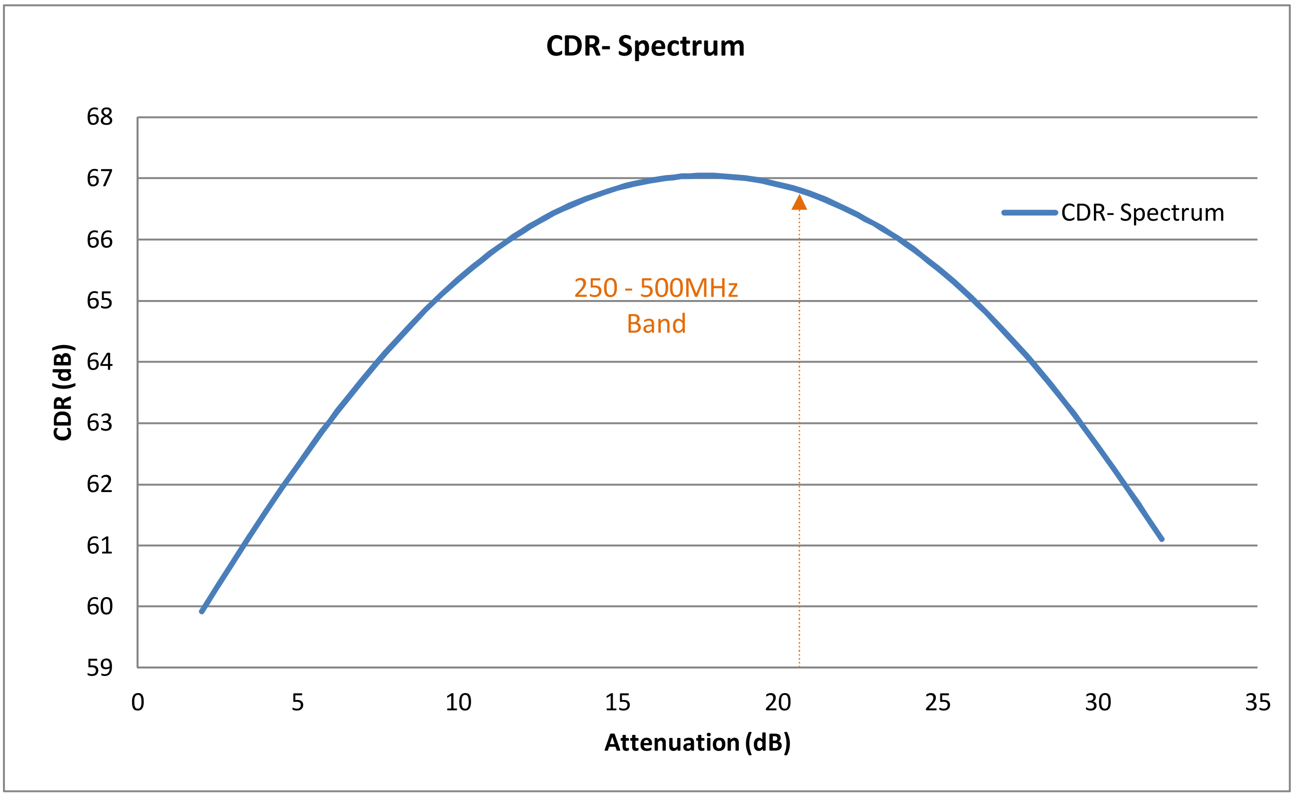


Fig. 9

SFDR Vs. Var. Attenuation (for 250 MHz Bandwidth) :

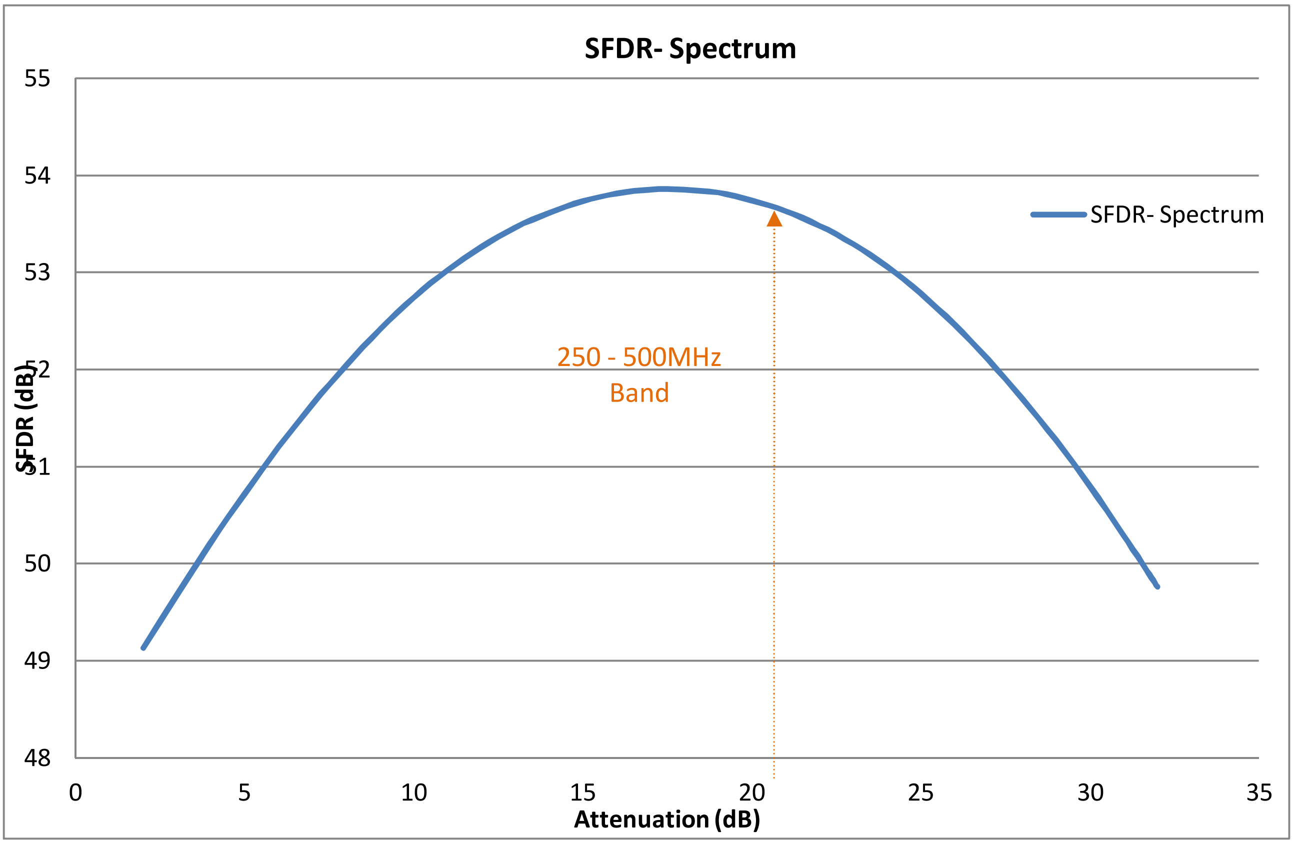


Fig. 10

CDR Vs. Var. Attenuation (for 350 MHz Bandwidth) :

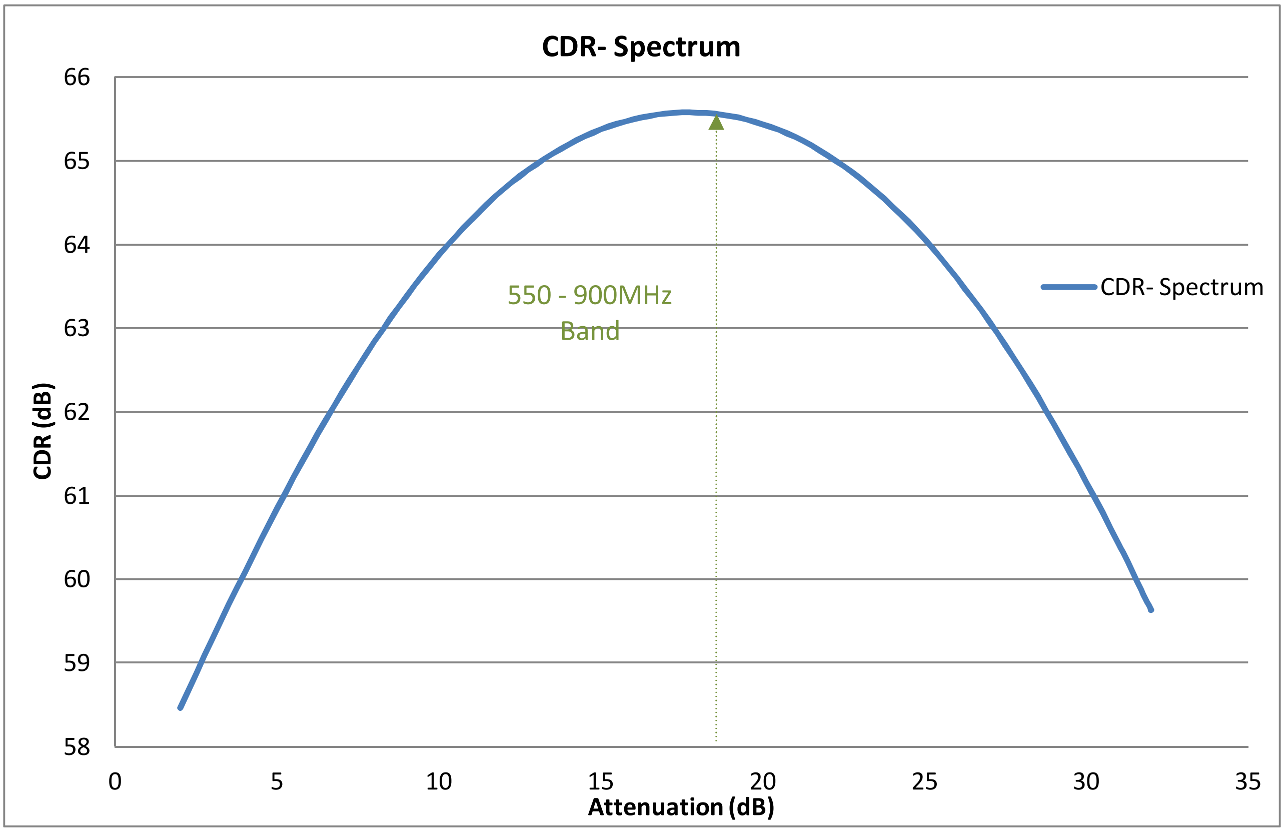


Fig. 11

CDR Vs. Var. Attenuation (for 350 MHz Bandwidth) :

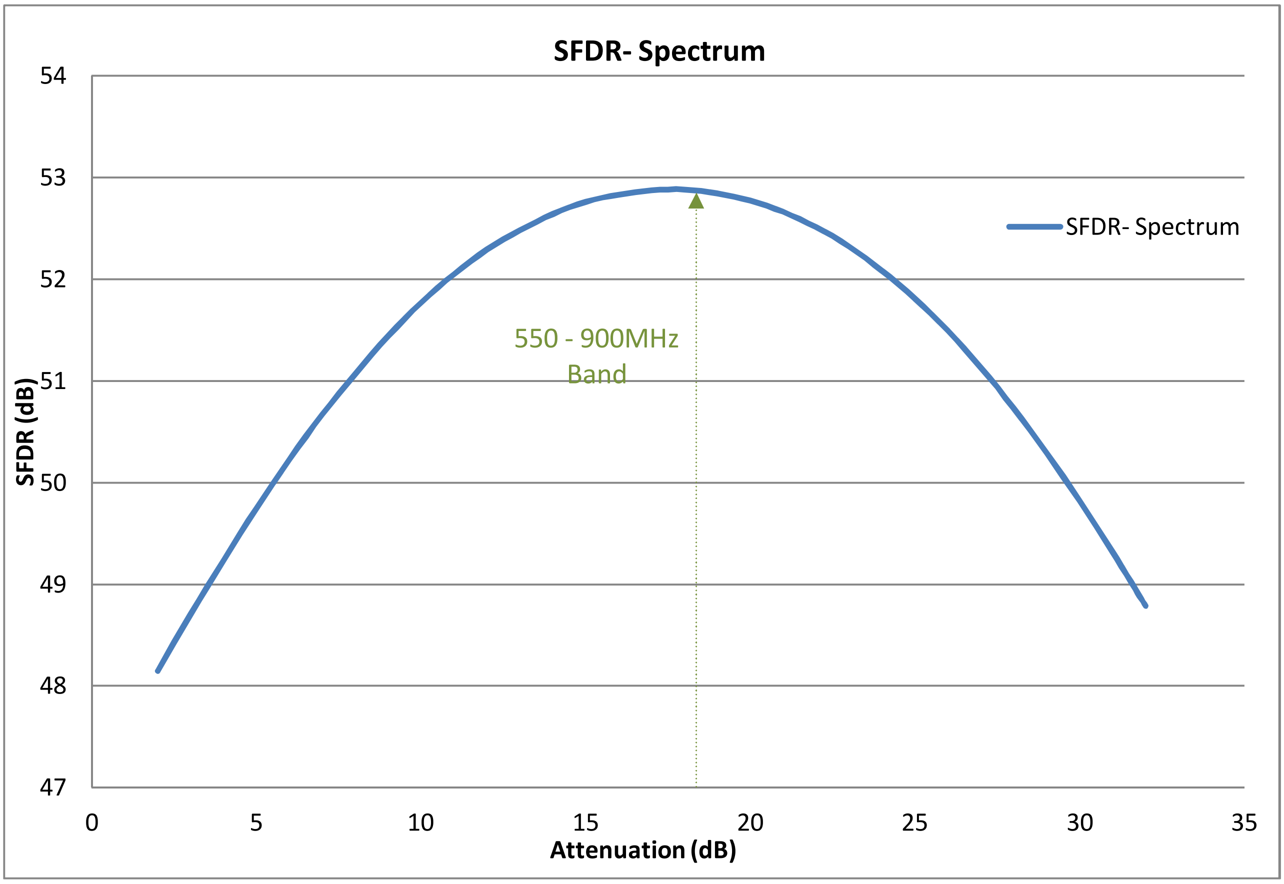


Fig. 12

2.0) <u>For 250 – 500 MHz Band:</u>

The input RF operating point of the analog fiber optic link is -45 dBm for 400 MHz bandwidth and this the expected RF power from frontend system at antenna base. The 250-500 MHz band has only 250 MHz bandwidth and the RF attenuator at the antenna base is adjusted to a value of 21 dB (Suggested Value) to meet -53 dBm / RBW 300 kHz requirement of backend system at receiver room. The frontend power is much higher at lower band and the received frontend power is adjusted with the RF attenuator at the fiber optics input to ensure fixed operating point for all RF bands. This also takes care of varying bandwidth of the frontend system. The plot below shows the band and the RF power level at fiber optics receiver in the receiver room. The marker power at 327 MHz / RBW 300 kHz is around -50 dBm and this agrees with the design specification.

Off source power level of four Antennas measured at Receiver room :

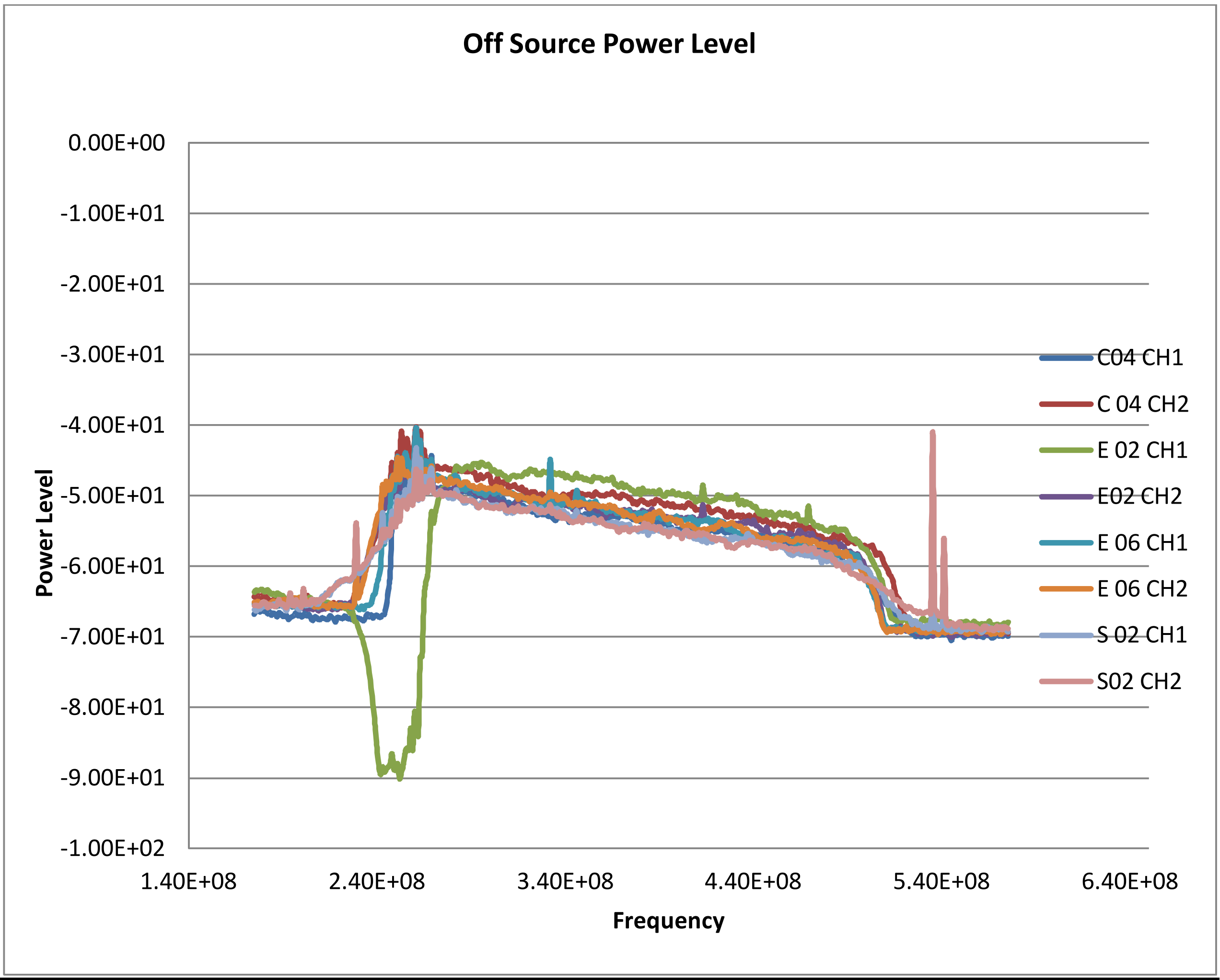


Fig. 13

2.1) Cascaded Front End and OFS Performance (For 250-500 MHz Band) for 21dB of Attenuation at RFPIU :

Summary:

With 21 dB Attenuation for 250MHz Bandwidth

Parameters	Spectrum Microwave Simulation
Gain (in dB)	**74.5**
Noise Figure (in dB)	**0.74**
Input 1 dB compression point (in dBm)	**-59.14**
Input third order intercept point (in dBm)	**-45.31**

Compression Dynamic Range (dB/Hz)	**111.08**
Compression Dynamic Range (dB/ 250 MHz)	**27.10**
Spurious Free Dynamic Range (dB/Hz 2/3)	**83.27**
Spurious Free Dynamic Range (dB/400MHz 2/3)	**27.29**

3.0 For L – Band (Full Band):

Expected power level at OF output is -55 dBm for 300 KHz RBW to maintain -24 dBm power for Back End System and we are achieving this by setting attenuation of 21 dB (OF Attenuation @ RF PIU for both Channel), so effective gain of the system from FE output to OF output with such attenuation is 17 dB.

Off source power level of four Antennas measured at Receiver room :

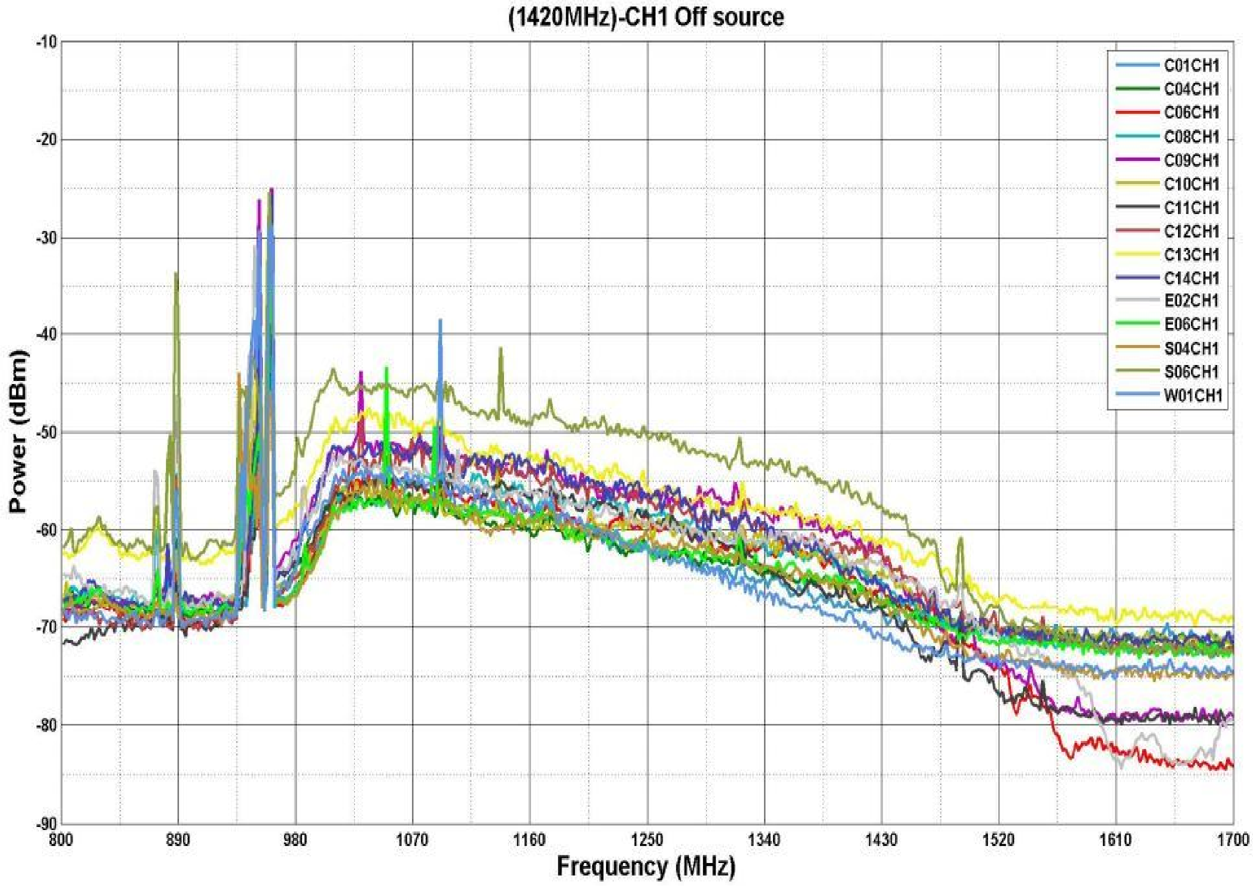


Fig.14

3.1) Cascaded Front End and OFS Performance (For L- Band Sub Band) for 9dB OF Attenuation:

For 120 MHz Bandwidth (For L- Band Sub Band)

3.1.1) 1060 MHz Sub Band :

As per data given by Gaurav Parikh the minimum detectable signal is -91.39dBm(for 120 MHz) and gain is 54.65 dB. So overall gain of the system is 83.65(Considering OF Attenuation of 9 dB means 4, 4) and expected signal at the output of OFC is -35dBm but we are getting approx -44 dBm.

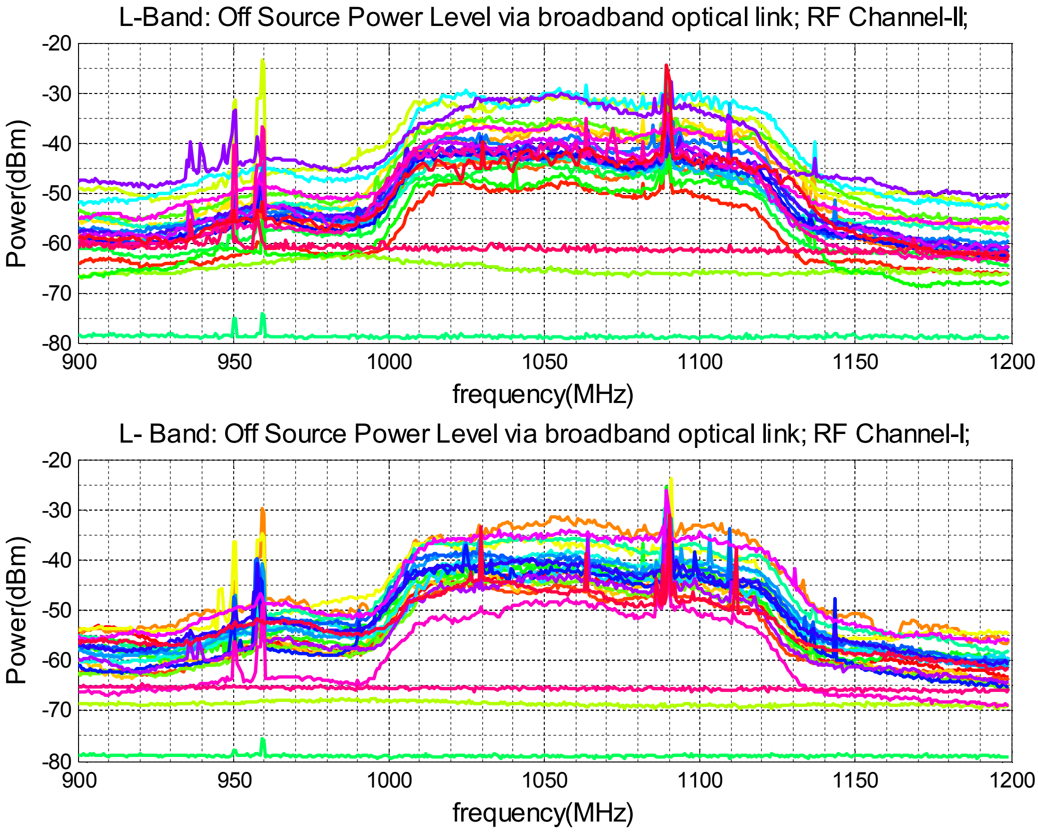


Fig. 15

(i) Summary:

With 9 dB Attenuation for 120 MHz Bandwidth

Parameters	Spectrum Microwave Simulation
Gain (in dB)	**84.65**
Noise Figure (in dB)	**0.74**
Input 1 dB compression point (in dBm)	**16.43**
Input third order intercept point (in dBm)	**30.77**
Compression Dynamic Range (dB/Hz)	**103.09**
Compression Dynamic Range (dB/ 120 MHz)	**22.25**
Spurious Free Dynamic Range (dB/Hz 2/3)	**77.58**
Spurious Free Dynamic Range (dB/120MHz 2/3)	**23.75**

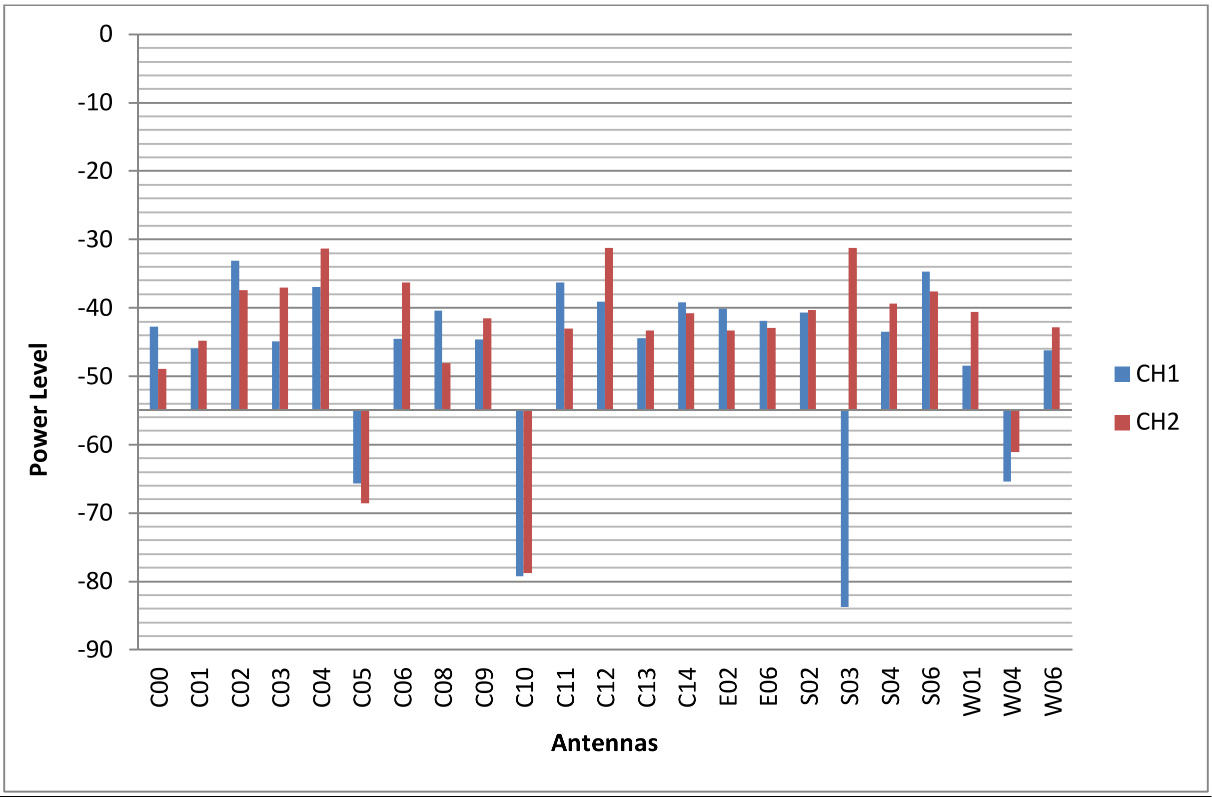


Fig. 16

This graph shows variation of Offset power level to achieve -24dBm for Back end system. This shows how much attenuation is needed to achieve -24 dBm power for backend system. Earlier we have suggested L-band sub band attenuation of 7,7 but later it is changed to 4,4. As from this graph it is clear that still we need extra 7 dB of attenuation to achieve -24 dBm for maximum antennas.

3.1.2) __1170 MHz Sub Band :__

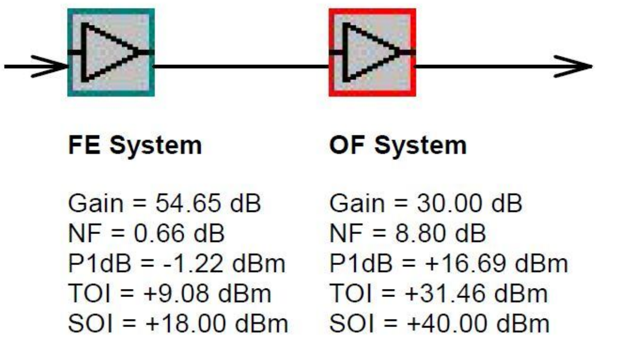
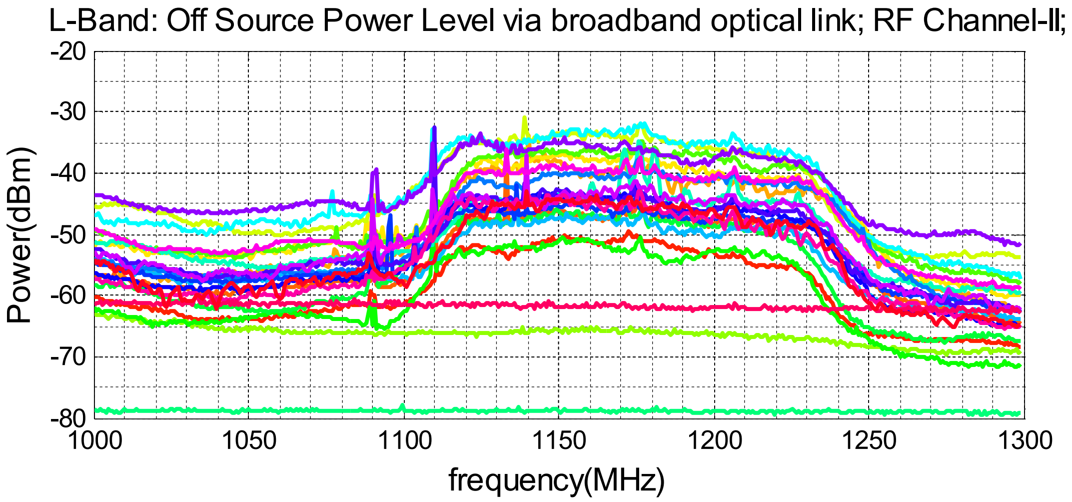


Fig.17

As per data given in signal flow analysis for L-Band by Gaurav Parikh's report the minimum detectable signal is -91.39dBm(for 120 MHz) and gain is 54.65

dB. So overall gain of the system is 83.65(Considering OF Attenuation of 9 dB means 4, 4) and expected signal at the output of OFC is -33dBm but we are getting approx -45 dBm.



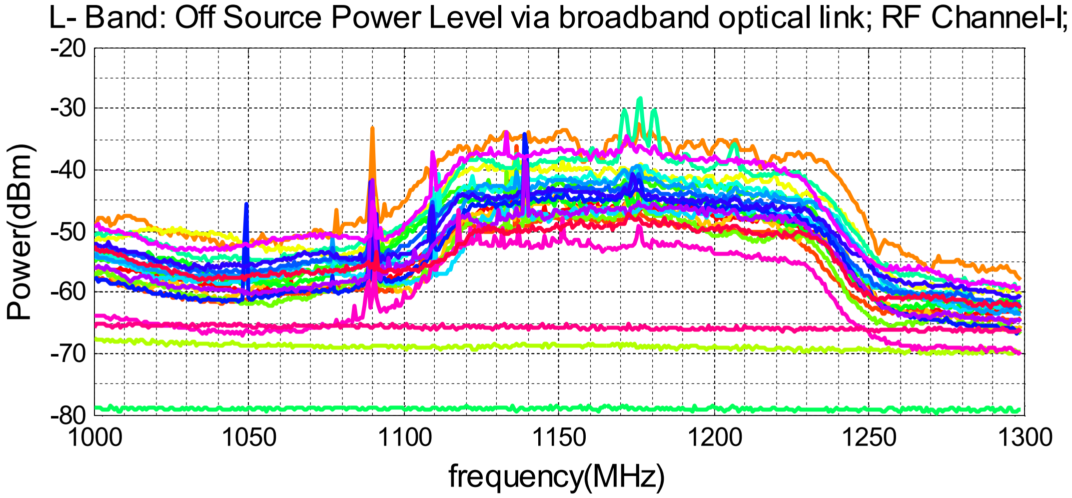


Fig. 18

(i) Summary:

With 9 dB Attenuation for 120 MHz Bandwidth

Parameters	Spectrum Microwave Simulation
Gain (in dB)	**84.65**
Noise Figure (in dB)	**0.66**
Input 1 dB compression point (in dBm)	**16.43**
Input third order intercept point (in dBm)	**30.77**
Compression Dynamic Range (dB/Hz)	**103.12**

Compression Dynamic Range (dB/ 120 MHz)	**22.33**
Spurious Free Dynamic Range (dB/Hz 2/3)	**77.64**
Spurious Free Dynamic Range (dB/120MHz 2/3)	**23.78**

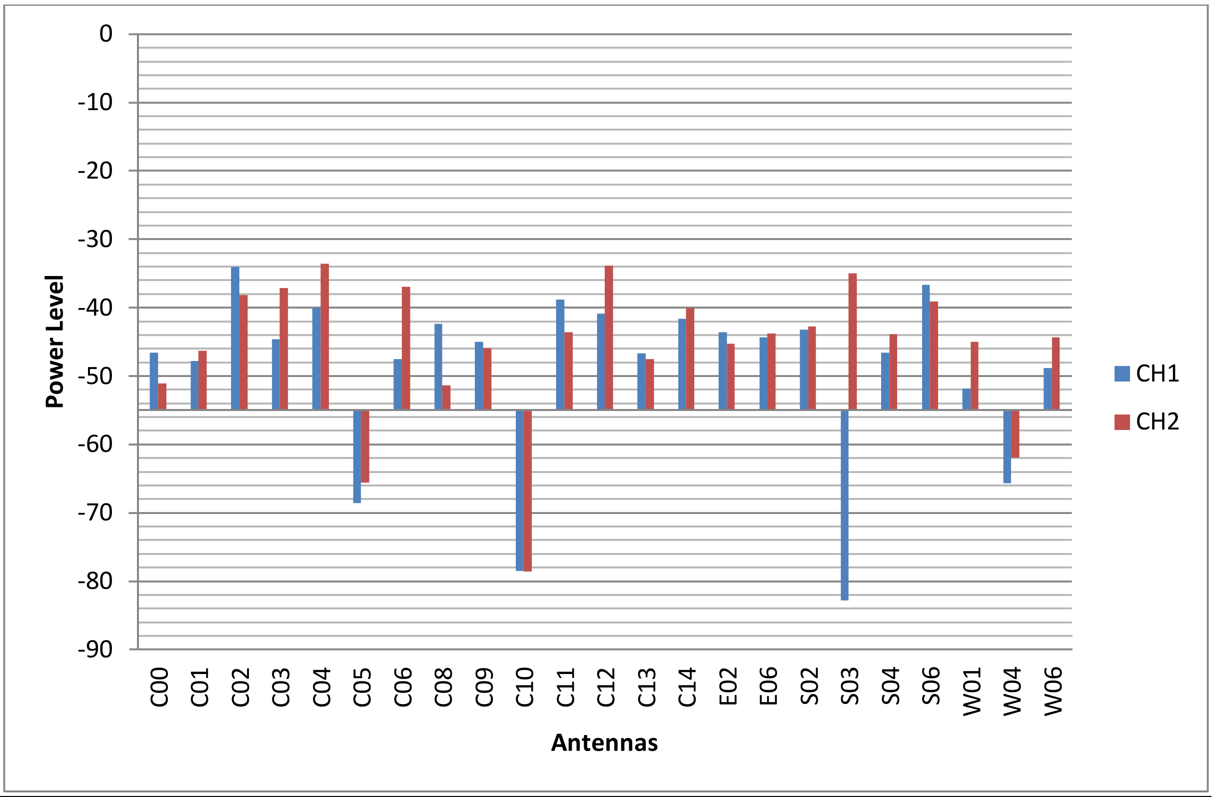


Fig. 19

This graph shows variation of Offset power level to achieve -24dBm for Back end system. This shows how much attenuation is needed to achieve -24 dBm power for backend system. Earlier we have suggested L-band sub band attenuation of 7,7 but later it is changed to 4,4. As from this graph it is clear that still we need extra 7 dB of attenuation to achieve -24 dBm for maximum antennas.

3.1.3) <u>1280 MHz Sub Band :</u>

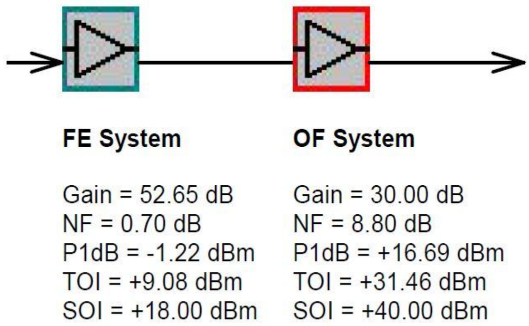


Fig. 20

As per data given in signal flow analysis for L-Band report the minimum detectable signal is -93.3dBm(for 120 MHz) and gain is 52.73 dB. So overall gain of the system is 82.65(Considering OF Attenuation of 9 dB means 4, 4) and expected signal at the output of OFC is -37dBm but we are getting approx -45 dBm.

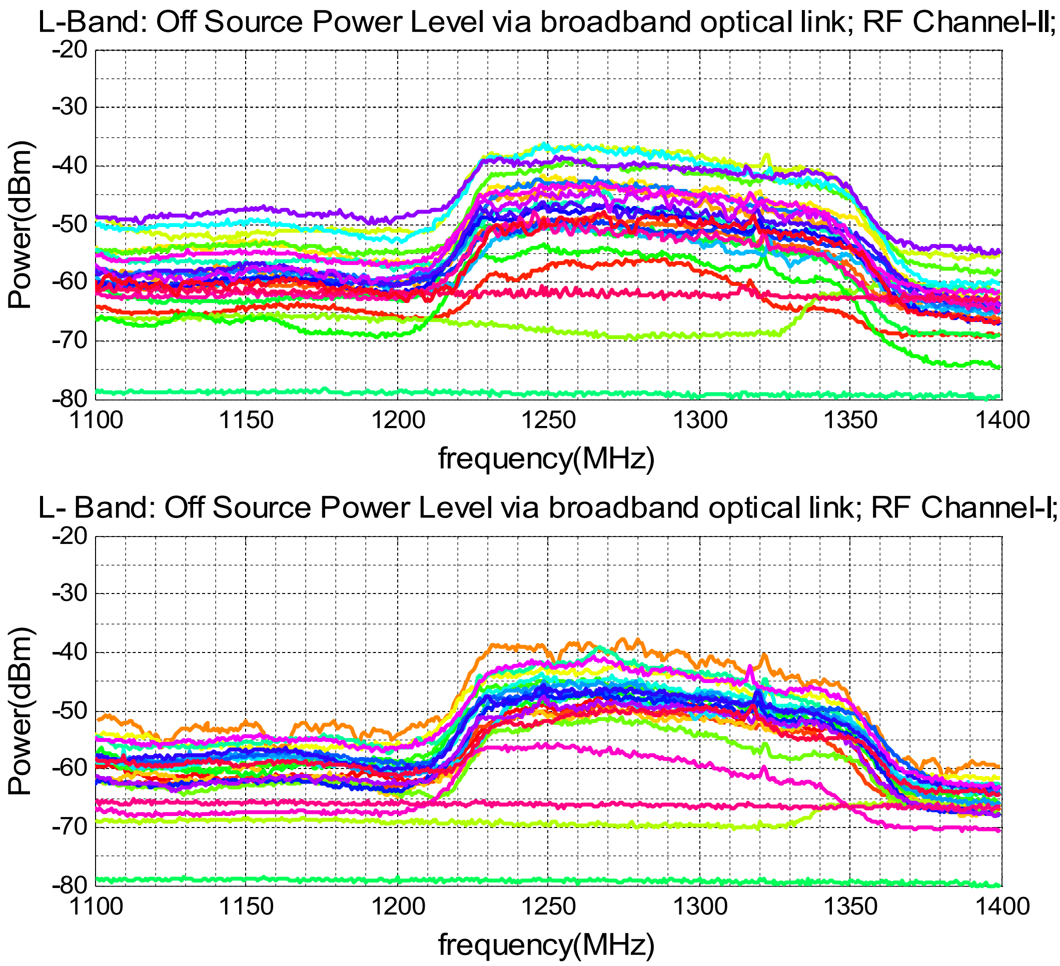


Fig. 21

(i) Summary:

With 9 dB Attenuation for 120 MHz Bandwidth

Parameters	Spectrum Microwave Simulation
Gain (in dB)	**82.65**
Noise Figure (in dB)	**0.70**
Input 1 dB compression point (in dBm)	**16.43**
Input third order intercept point (in dBm)	**30.77**
Compression Dynamic Range (dB/Hz)	**105.08**
Compression Dynamic Range (dB/ 120 MHz)	**24.29**
Spurious Free Dynamic Range (dB/Hz 2/3)	**78.95**
Spurious Free Dynamic Range (dB/120MHz 2/3)	**25.09**

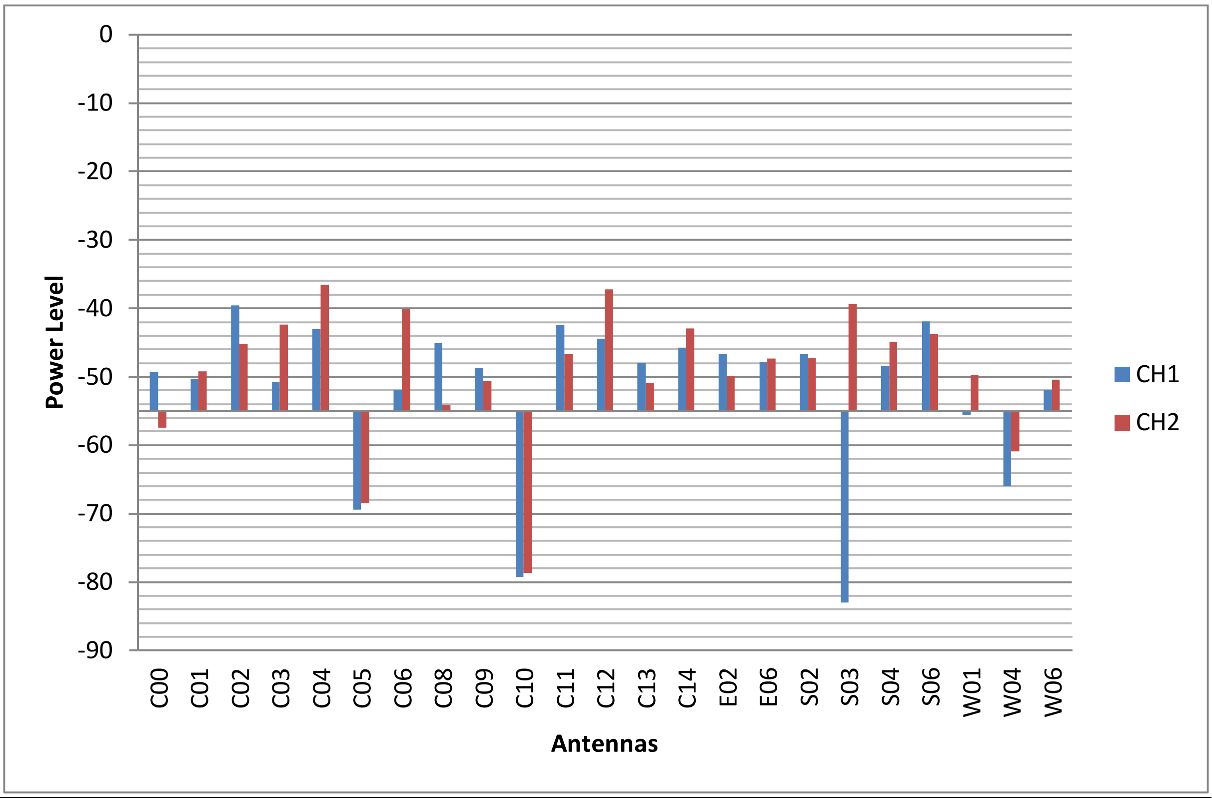


Fig. 22

This graph shows variation of Offset power level to achieve -24dBm for Back end system. This shows how much attenuation is needed to achieve -24 dBm power for backend system. Earlier we have suggested L-band sub band attenuation of 7,7 but later it is changed to 4,4. As from this graph it is clear that still we need extra 7 dB of attenuation to achieve -24 dBm for maximum antennas.

3.1.4) <u>1390 MHz Sub Band :</u>

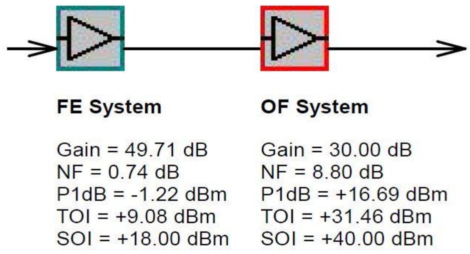


Fig. 23

As per data given in signal flow analysis for L-Band minimum detectable signal is -91.24dBm(for 120 MHz) and gain is 49.71 dB. So overall gain of the system is 79.71(Considering OF Attenuation of 9 dB means 4, 4) and expected signal at the output of OFC is -38dBm but we are getting approx -45 dBm in channel 2.

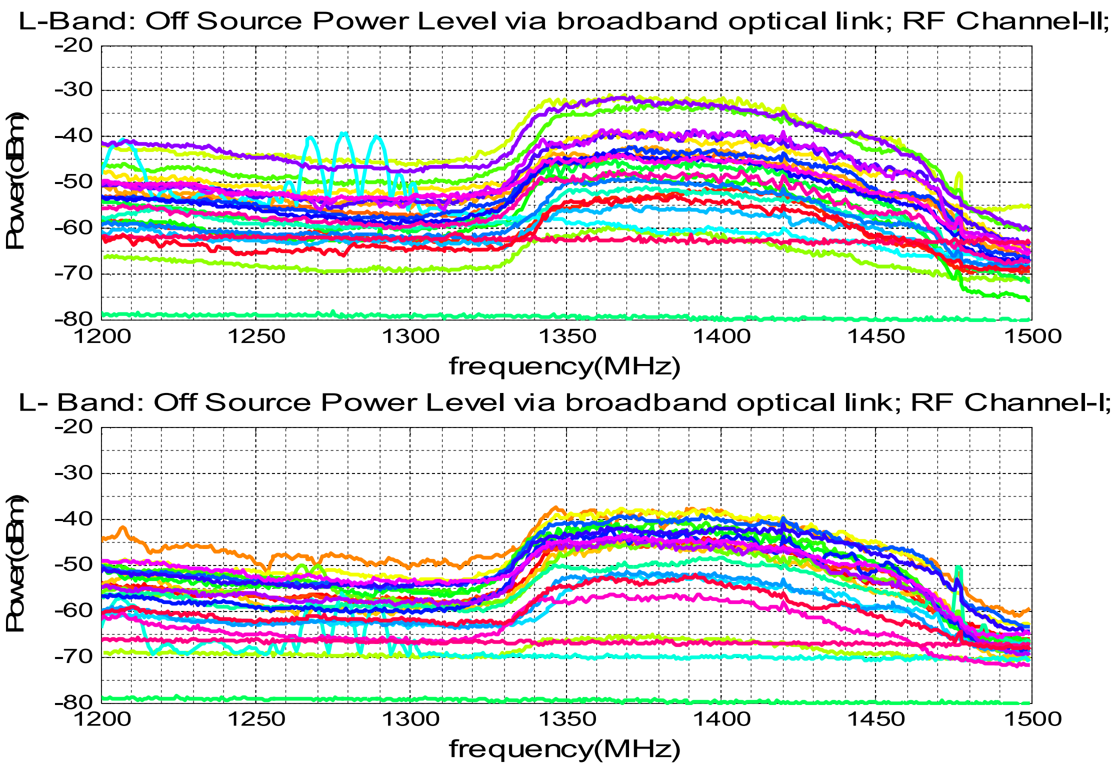


Fig. 24

(i) Summary:

With 9 dB Attenuation for 120 MHz Bandwidth

Parameters	Spectrum Microwave Simulation
Gain (in dB)	**79.71**
Noise Figure (in dB)	**0.74**
Input 1 dB compression point (in dBm)	**-62.28**
Input third order intercept point (in dBm)	**-49.7**
Compression Dynamic Range (dB/Hz)	**107.98**
Compression Dynamic Range (dB/ 400 MHz)	**27.19**
Spurious Free Dynamic Range (dB/Hz 2/3)	**80.88**
Spurious Free Dynamic Range (dB/400MHz 2/3)	**27.02**

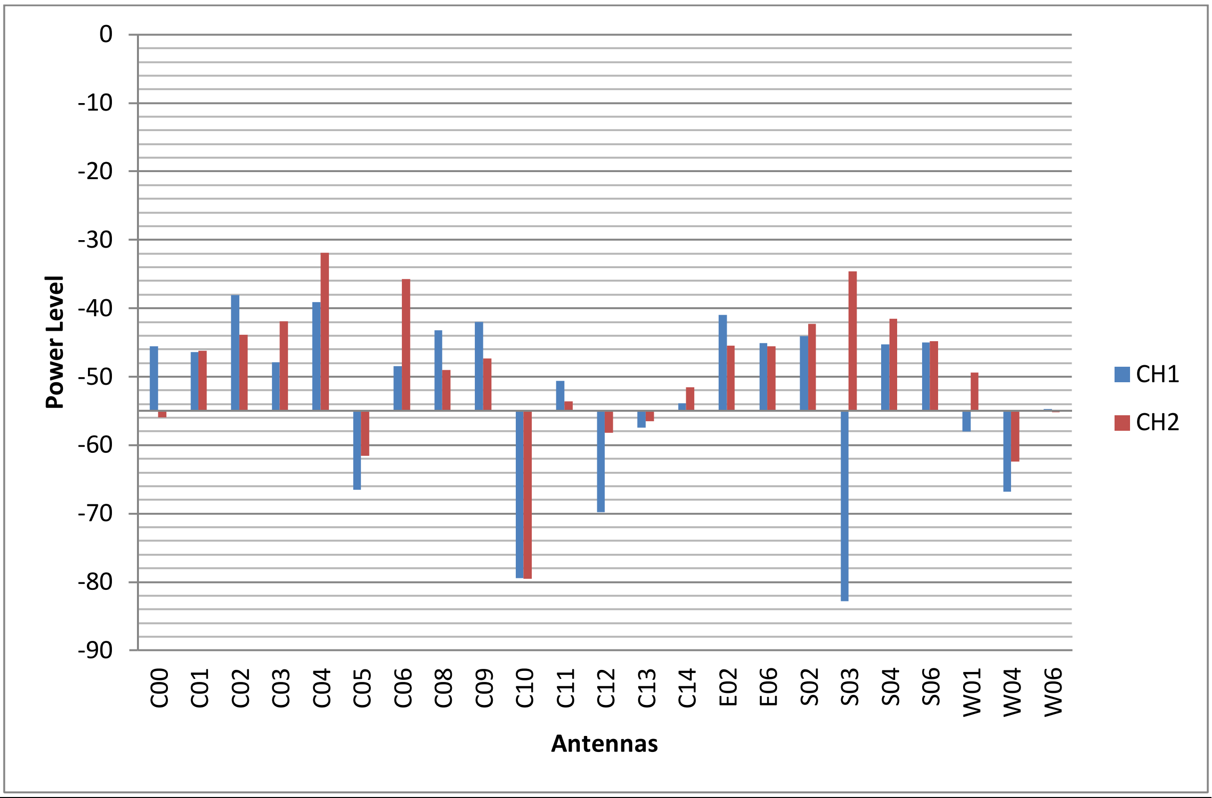


Fig. 25

This graph shows variation of Offset power level to achieve -24dBm for Back end system. This shows how much attenuation is needed to achieve -24 dBm power for backend system. Earlier we have suggested L-band sub band attenuation of 7,7 but later it is changed to 4,4. As from this graph it is clear that still we need extra 7 dB of attenuation to achieve -24 dBm for maximum antennas. So we recommend 7,7 OF attenuation to achieve -24dBm for back end .

4.0) <u>130 260 MHz Band :</u>

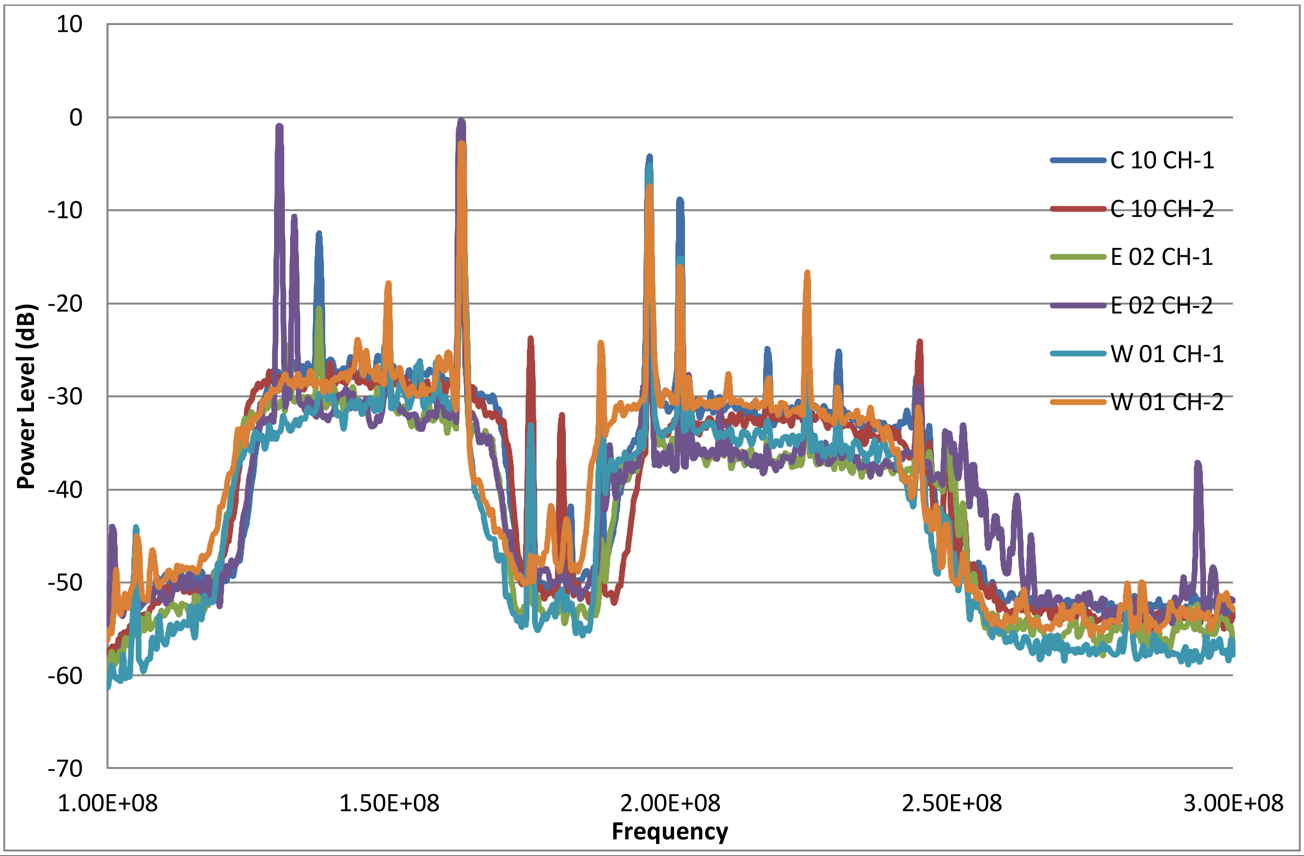


Fig. 26

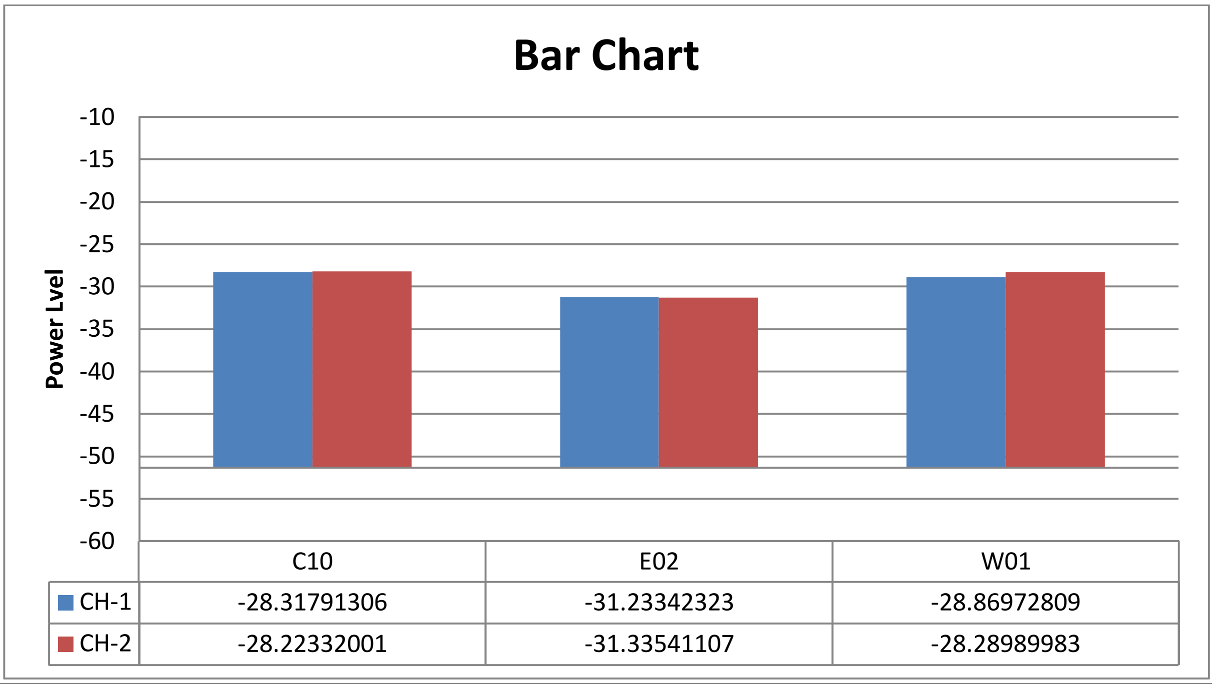


Fig. 27

From graph power optical fiber output is -30 dBm (approx) for both antennas, and desired power level is -51.3 to meet this power we have to adjust OF attenuation to 20 dB (i.e. 10 10)

5.0) Reference :

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