Tech.Report

SSK/ 01-08-2003
Author: S.Sureshkumar

GMRT's 150 MHz Receiver – Performance limitations & Solutions for Improvement

Experimental setup & measurements: S.Sureshkumar/M.Gopinathan/Kalpesh Chillal

Summary

1. Problems in using 150 MHz:

a. Strong RFI in-band and out-off band.

b. Poor Filter rejection at front-end.

c. MAR 3 (Post amplifier) saturates front-end box.

d. Common-box saturates early due to MAR 3 post amplifier.

e. High front-end gain saturating down the receiver chain.

f. IF (70 MHz) stage saturates early.

g. The combined P1dB with F.E+C.Box+ IF(70 MHz) is too low.and **the max. RF input that can be given to Front-end system is only – 75 dBm.**

2. Experimental Results:

S.no.	Sub-system	Input 1 dB compression point
1.	Front-end box	-27 dBm
2.	Common box (Solar Attn. = 0 dB)	-20 dBm
3.	IF System (70 MHz)	-25 dBm
4.	F-end + C.Box + IF (70 MHz) (With Solar Attn. = 0 dB)	-75 dBm

3. Blocking performance of the 150 Receiver system - TV signal.

a. A TV signal of –26 dBm to Front–end input saturation of the usable passband signal in front–end.

b. A TV signal of –30 dBm to the input of IF (70 MHz) saturates the IF signal.

4. Solutions

a. Remove MAR 3 amplifier in front–end box.

b. Improve 150 BPF at Front–end.

c. Replace MAR 3 amplifier with high dynamic range amplifier.

d. Always use Solar attenuator at 150 MHz.

e. Fiber optic system have higher saturation level.

f. Proper selection of IF attenuators provide better dynamic range.

Introduction: The global spectral feature from the reionization epoch which may be present over the whole sky has put tremendous pressure on the 150 MHz band at GMRT. The strong RFI at this band limits the usage of this band. The report list out the crucial pit–falls of various sub–systems performance (**based on recent measurements at Lab and antenna site**) and suggest a feasible solution (improved components and effective techniques).

Problems with 150 MHz band: Strong and numerous RFI lines at this band prevents the use of the present design at 150 MHz band. The existing 32 MHz bandpass filter at the front–end system have poor rejection at outside band. A TV signal at 175 MHz have only 5 dB rejection when compared to 150 MHz passband. **New filters to limit the strong RFI lines have not helped much due to the overall system dynamic range from front–end to down the chain is not sufficient for using this band.** Figure 1.1 to 1.3 show the listed RFI and its level at the front–end output [1].

150 MHz feed: The 150 MHz thick dipole feed is very very broad having 120 MHz bandwidth. This wide bandwidth brings in lot of RFI to the front–end system and overloads the system. A narrow band dipole [2] will help in reducing the stress on the receiver system.

Front-endsub-systen: The front-endsystem has a high gain 150 MHz LNA followed by a MAR 3 post amplifier. The MAR 3 saturates at -2 dBm input level leading to the early saturation of the front-end box at -27.5 dBm. Figure 2.1 and 4.1 shows the 1 dBm compression point measurement results.

150 MHz bandpass filter: The 150 MHz bandpass filter have poor rejection above 166 MHz. This brings in strong RFI lines like television transmission signals 175 MHz and 181 MHz. Similarly the lower cut-offof the filter is about 134 MHz but a strong RFI line at 133 MHz gets only 2 dB rejection.

Common-box sub-systen: The common-box also has a MAR 3 amplifier following the broadband amplifier. The MAR 3 gets saturated with an input power of -2 dBm and this limits the 1 dB compression level of the common-box to -25 dBm (when 0 dB solar attenuator is selected). This may be just sufficient for the other bands demanding high gain but for the 150 MHz the system reaches saturation at an early stage. Figure 2.2 shows the 1 dBm compression measurement results.

IF 70 MHz sub-systen: The first downconversion is the second most important to the front-end system. Based on recent measurements done at C02 antenna, it is seen that the IF sub-system get saturated at - 25 dBm. Figure 2.3 shows the 1 dB compression point measurement results.

Combined performance: The combined performance of the three sub-system with a solar attenuator of zero dB shows that ***IF system reaches early saturation for a front-end input level of about -75 dBm. This is an alarming situation with the presence of strong RFI.*** Figure 3.1 shows the comparison of the three system. With a 14 dB solar attenuator the IF system recovers and gives 14 dB more dynamic range. With the 14 dB solar attenuator the maximum front-end input can be -69 dBm for a linear performance. *Figure 3.2 explains the advantage of using solar attenuator.*

But this is not sufficient since the RFI lines are much more stronger than this level and the system remains saturated ever. *Hence filters to curtail the strong RFI has not provided satisfactory results with the present 150 MHz receiver of GMRT.*

Blocking performance: Literature [3] illustrates a novel technique to measure the blocking performance, which quantifies the receiver degradation effect due to the presence of a single, dominant, out-of-bancinterference. Measuring the 1-dBcompression point due to the blocking can be done by combining a small, desired sinusoid signal with a large, undesired sinusoid signal, and applying them to the receiver input. The desired sinusoid is at the receiver's tuned frequency and is adjusted for a 10-dB signal-to-noise ratio (SNR) in thpassband. The amplitude of the undesired, out-of-bandis then increased in steps until passband signal gets reduced by 1 dB at the output.

The above experiment was done with the front-endsystem and the IF system using 150 MHz as the desired signal and 175 MHz as the out-of-bandsignal. Figure 1.3 gives the experimental results. The results show a power level of -26 dBm TV (175 MHz) signal can reduce the passband signal (150 MHz) by 1-dB. Similarly if the RF input to the (70 MHz) IF sub-system contain a level of -30 dBm at 175 MHz, the IF signal reduces by 1-dB. This emphasises the importance of rejecting the television transmission and other strong RFI signals out of and. Also this clearly shows the need for narrow-bandfeed so that we don't bring in much of RFI into the system and degrade the pass-bandperformance.

Modifications to 150 MHz band: The above experimental results and its analysis clearly show that modifications has to be done at every stage of the system to make the 150 MHz band usable at GMRT.

Feed: A narrow band 150 MHz feed will really help in reducing strong RFI lines at this band. But we need to decide how narrow the feed to be and ensure we don't lose time in replacing the feed at GMRT.

Front-end sub-system: The front-end sub-system eventhough does not saturate early when compared to common-box or IF system but could be generating IMD products in the presence of strong RFI lines. The solution could be one of the following three solutions.

Solution 1 :The MAR 3 post amplifier limits the 1-dB compression level of front-end box to -27 dBm , replacing it with MSA 0520 will improve 1-dB compression level to - 14 dBm. The MSA 0520 is having output 1-dB compression level of + 23 dBm while MAR 3's corresponding figure is + 10 dBm. The gain of MSA 0520 is only 8 dB (Gain of MAR 3 is 13 dB) but is adequate of for the 150 MHz band. Figure 4.2 shows the analysis of this scheme.

Solution 2: A suitable attenuator can be inserted in between the LNA and the post amplifier (MAR 3) to avoid saturation of post amplifier. An attenuator of 14 dB prevents saturation of MAR 3 and improves the 1 dB compression level of front-end box to -14dBm similar to earlier solution 1. Figure 4.3 shows the analysis of solution 2.

Solution 3: The MAR 3 post-amplifier have only 13 dB and adding a pad for 14 dB implies that the amplifier itself can be removed and the 1-dB compression point of the front-end box improves to -14 dBm from the present -27.5 dBm.

Since the IF has a lower saturation level, the high gain at the front-end is of little use and one can do away with the post amplifier. Figure 4.4 shows the analysis of solution 3.

150 MHz bandpass filter: The bandpass filter at the front-end have poor cut-off at the strong RFI lines outside the 32 MHz band as shown in figure 1. 3. The roll-off at higher cut-off is poor and a sharp cut-off filter will help in rejecting the strong signals like TV. Similarly the lower side has a RFI at 133 MHz and rejecting is a must since it have only 2 dB rejection. A notch filter or off-tuned filter can help in rejecting this RFI. Improvement in filter will help in getting better blocking performance at 150 MHz.

Common-box: From figure 2.2 it is clear that the common-box gets saturated early compared to any other system at -20 dBm. This performance will affect all bands of GMRT. The poor performance of the common-box is due to the MAR 3 amplifier used in common box similar to the 150 MHz front-end box This can be improved by the following two ways:

1. Use of solar attenuator at the input of the common-box. Figure 3.2 clearly show the difference in linearity performance with 0 dB solar attenuator and 14 dB solar attenuator.

2. Replace the existing MAR 3 post amplifier with MSA 0520 having +23 dBm output compression level and gain of 8 dB improve the 1 dB compression point. A dual stage can

provide an equivalent gain to MAR 3 without reaching early saturation. A better device also could be a viable solution.

IF System: Measurements with 70 MHz IF stage show that the amplifier at the input of the system has low compression point. Replacing with a better input amplifier will be of help to all bands with the high gain front-end system.

Any later saturation can be tackled with IF pre- and post-attenuators of the IF system. The Fiber optic system's 1 dB compression is far-behind these values and the system will be linear with the above modification. The usage of solar attenuator will help a lot when limited with dynamic range of the receiver system. It will be better to rename the solar attenuator as front-end attenuator so that the facility is usedalways.

Conclusion: The early saturation of front-end and common-box due to MAR 3 post amplifier need to be tackled with one of the above listed modifications. The usage of solar attenuator will be of more help in bringing the system in linearity. Better filter at 150 MHz is required to improve the over-all blocking performance of the system at this band. Similar experiments need to be done for every sub-system of the receiver chain to search for any other performance limiting factors.

Reference:

1. "A study on 150 MHz band RFI & detect usable band", S.Sureshkumar, B.Ajit Kumar Preliminary tech-report, GMRT, dated – 20-9-20(.2

2. " A narrow band dipole for 150 MHz " Student project Ajay, kumal, guided by S.Sureshkumar, G.Shankar, dated – July 2003.

3. " Receiver Dynamic Range " , Robert E. Watson, WJ communication, inc.

Acknowledgement: I Thanks Shri. G.Shankar for his encouragement and guidlines all through the report and for reviewing the results obtained. I thank Mr. Ajit Kumar for kind enough to review the experimental results which gave confidence in presenting them here. I thank Mr. S.Ramesh and Mrs. Manisha Parathe for helping me during system measurements.

Figure 1.0 Blocking performance at 150 MHz band

Usable frequency band in 150 MHz at GMRT		
Lower cut-off in MHz	Higher cut-off in MHz	Bandwidth MHz
134	146	12
148	157	9
169	173	4
182	—	> 14

Figure 1.1 ~~Suable~~ USABLE bandwidth

Strong RFI in 150 MHz passband of GMRT	
Frequency in MHz	Power in dBm at C-box output
150.2	−65.2
159.2	−45.7
163.1	−59.2
165.2	−60.5
166.7	−52.8

Figure 1.2 RFI in passband

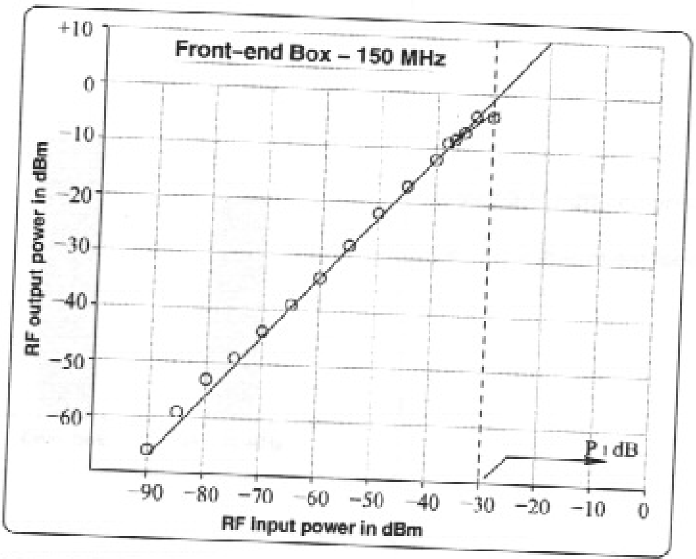
Strong RFI outside 150 MHz passband of GMRT		
Frequency in MHz	Power in dBm at C-box output	Filter Rejection
133.1	−33.2	2 dB
175.0	−35.3	5 dB
181.0	−45.0	7 dB

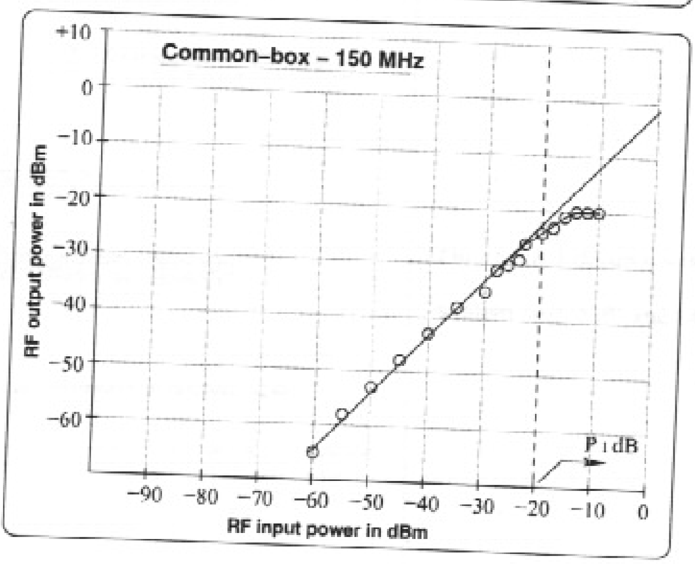
Figure 1.3 RFI out-off band

Blocking Performance at 150 MHz for TV signal	
Sub-System	Power level of 175 MHz TV signal in dBm reducing passband signal by 1 dB
Front-End Box	−26 dBm
IF 70 MHz	−30 dBm

Figure 1.4 Blocking performance of 150 Receiver for TV signal.

Linearity performance – 150 MHz band – GMRT





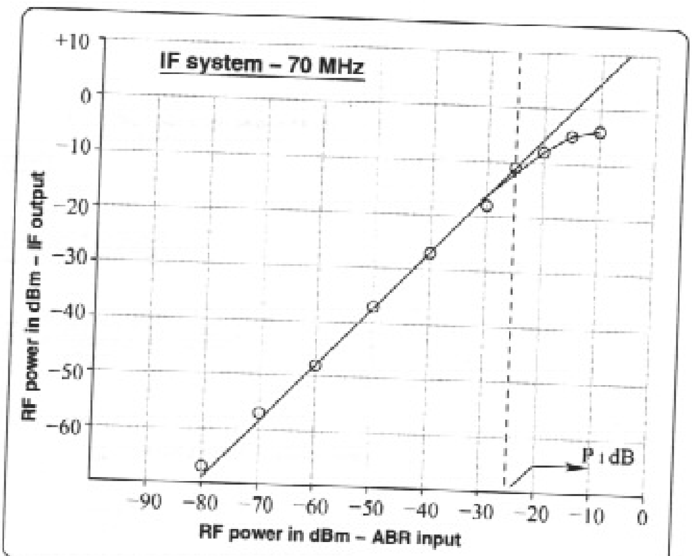
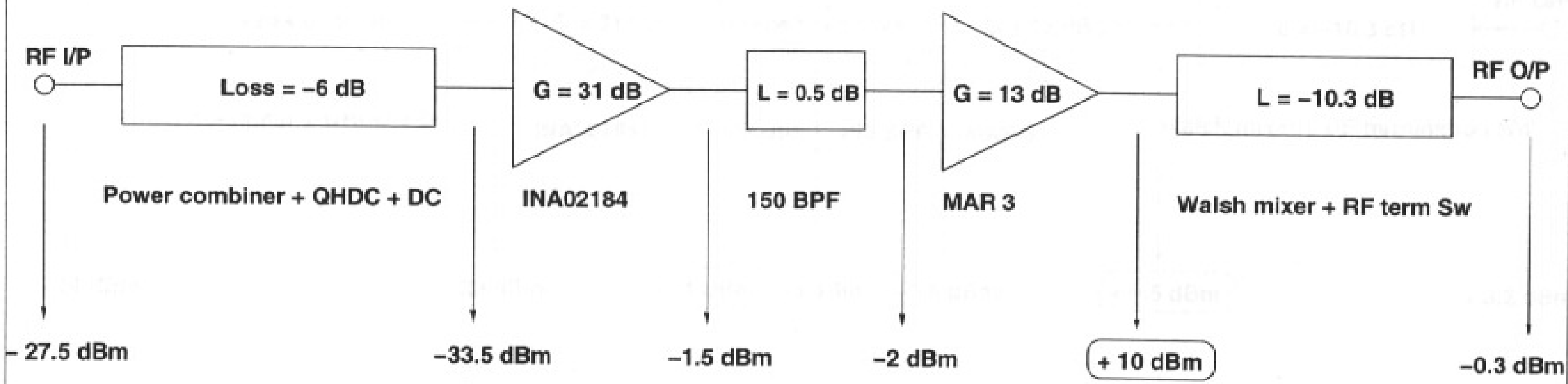


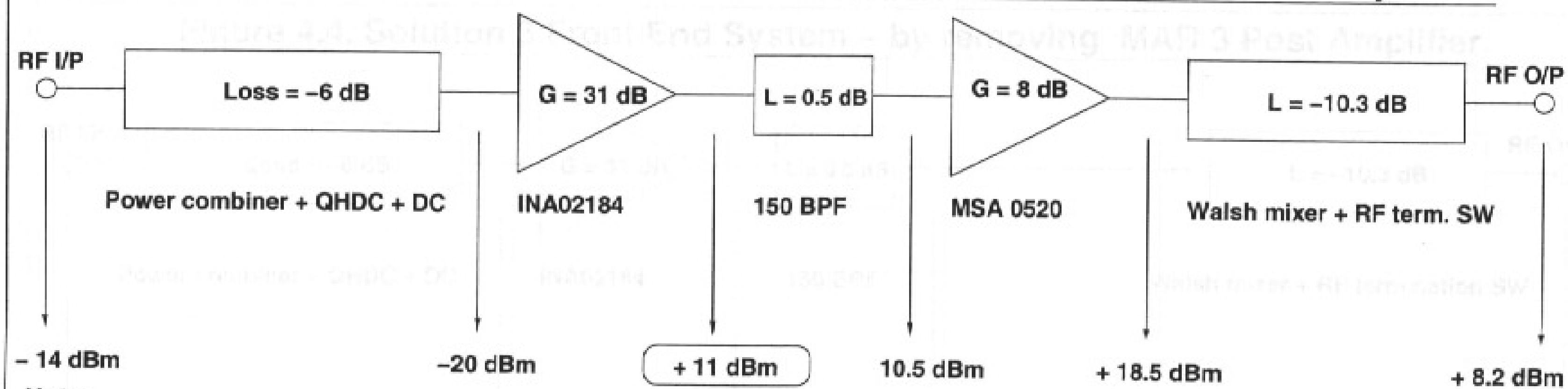
Figure 4.1 Present Front–End System for 150 MHz band at GMRT



NOTE:

_ 27.5 dBm is the 1 dB compression point for Front–end box due to the saturation of MAR 3 amplifier.

Figure 4.2 Solution 1: Front–End System – MSA 0520 replaces MAR 3 amplifier.



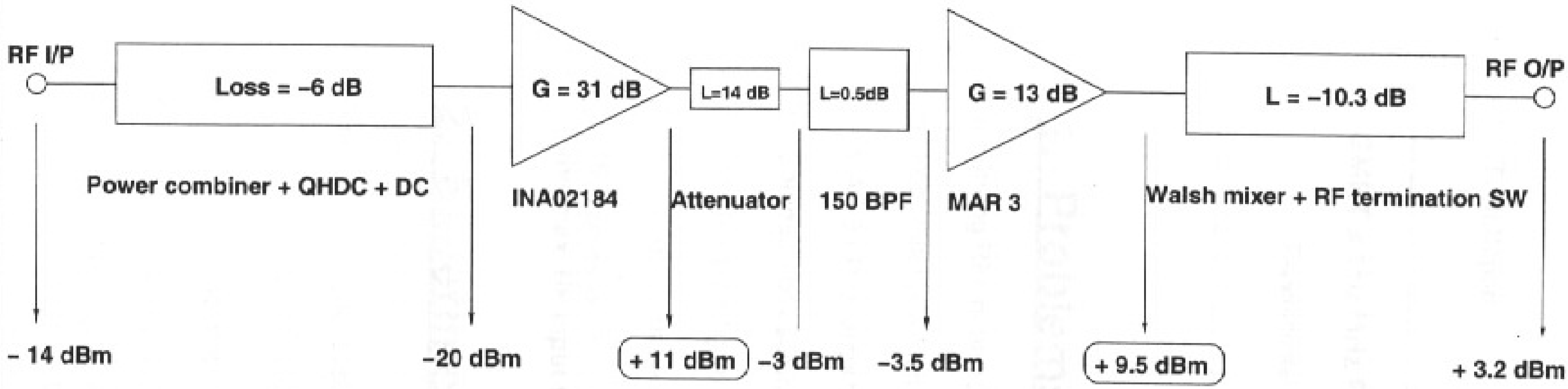
Note:

MSA 0520 – 1 dB compression point at output is + 23 dBm

INA 02184 – Reaches 1 dB compression point at + 11 dBm output power.

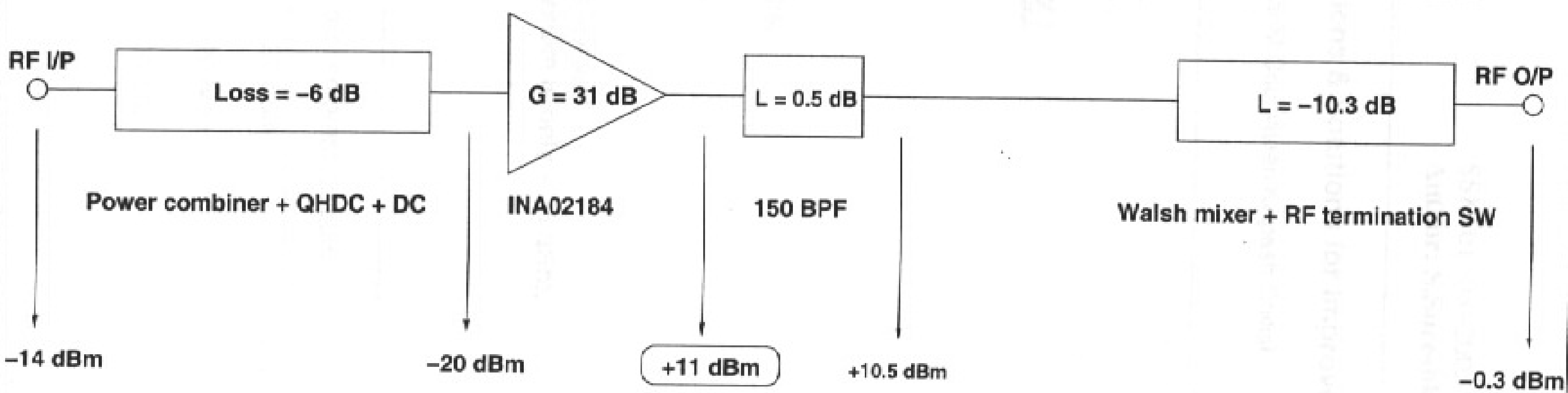
The Front–end box I dB compression point has been increased from –27.5 dBm to – 14 dBm i.e. increaed by 13.5 dB

Figure 4.3. Solution 2: Front-End System – by inserting attenuator after LNA.



INA 02184 and MAR 3 – Reaches 1 dB compression point and – 14 dBm is the maximum power input to the 150 MHz front-end box.

Figure 4.4. Solution 3 Front End System – by removing MAR 3 Post Amplifier.



MAR 3 amplifier is totally removed. Hence – 14 dBm is the maximum power input to the 150 MHz front-end box.