Dynamic Range of the 130 - 200 MHz Band GMRT Receiver

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Introduction

Giant Meterwave Radio Telescope (GMRT) receiver system has been designed to operate at frequency bands centered at 150 MHz, 235 MHz, 327 MHz, 610 MHz and L-Band covering 100 to 1450 MHz band. The L-band is split into four sub-bands centered at 1060 MHz, 1170 MHz, 1280 MHz and 1390 MHz, each with a bandwidth of 120 MHz. The 150 MHz, 235 MHz and 327 MHz bands have about 40 MHz bandwidth and the 610 MHz band has about 60 MHz bandwidth. Recently the 150 MHz front-end system has been modified with enhanced bandwidth of 70 MHz ranging from 130 to 200 MHz on an experimental basis (1). Two such front-ends have been installed in C01 and C05 antennas.

This report deals with the dynamic range issues of this modified front-end and the receiver chain upto the antenna base receiver (ABR) output. Particularly the effect of strong interference from Pune TV carriers around 175 MHz on the receiver performance has been highlighted.

150 MHz Receiver at the antenna

The receiver system at the antenna consists of the front-end located at the prime focus of the dish antenna and Antenna Base Receiver (ABR) at the antenna shell. The feed consists of a pair of dipoles placed above plane reflector for each orthogonal polarization. Dipole is folded type with one arm of the folded element being thick. The feed has a wide bandwidth from 120 MHz to 240 MHz (2).

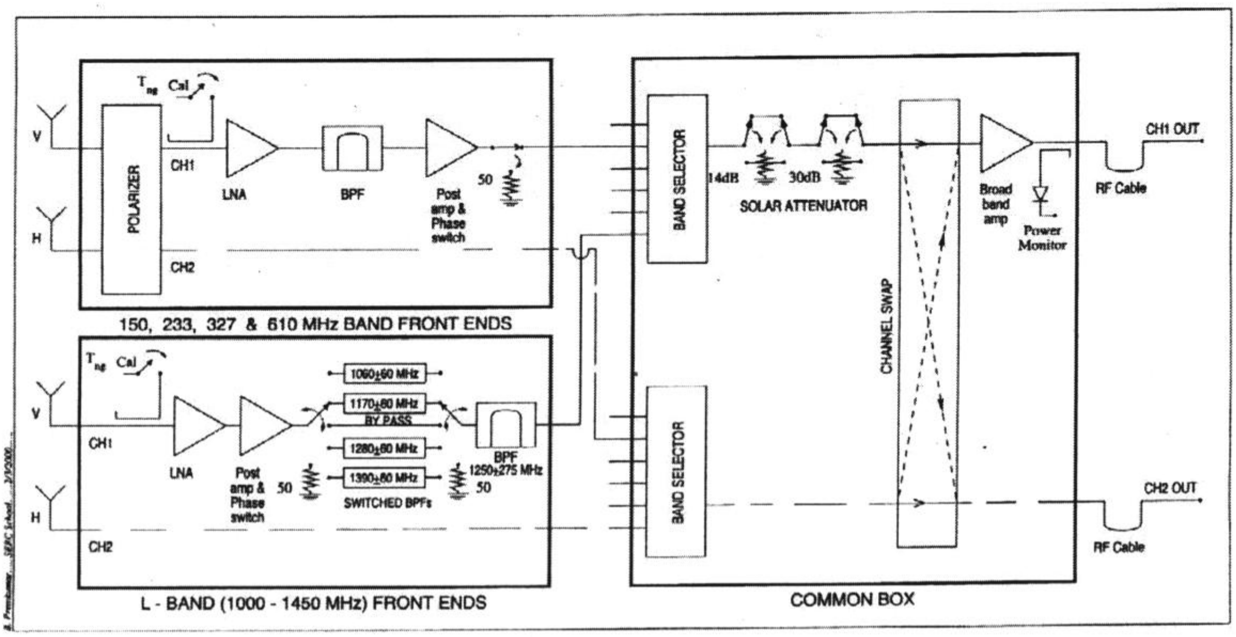

Figure - 1: Block diagram of RF Front - End

A block diagram of the GMRT RF front-end is shown in figure - 1. In the modified 150 MHz front-end the band pass filter (BPF) consists of the combination of a High pass filter with a cut off frequency of 130 MHz and a Low pass filter with a cut off frequency of 200 MHz. The combined insertion loss is about 1 dB. For normal operation with 150 MHz front-end, 14 dB solar attenuator is used. The dynamic range of this modified 150 MHz front-end is estimated using MATLAB Simulation and the results are as shown in Simulation Table - 1. The table contains information related to the components used in the front-end and performance at each stage. The RF power levels and the dynamic ranges shown in the table are estimated for 32 MHz bandwidth. It can be seen that the Compression Dynamic Range (CDR) is about 52 dB and Spurious Free Dynamic Range (SFDR) is about 43 dB at the output of the front-end. The details of the dynamic range related issues can be found in (3) and (4). From the simulation table the output noise floor is around -44 dBm and the CDR is around +52 dB for 32 MHz bandwidth. This means the 1 dB compression point (P_{1dB}) is +8 dBm. Also, the input third order intercept point (IIP_3) is -31 dBm and the total gain of the system is 52 dB. This amounts to the output third order intercept point (OIP_3) of +21 dBm.

The front-end output is connected to the Antenna Base Receiver (ABR) through a 93 meters of low loss foam cable. At 150 MHz the cable loss is 5 dB. At the ABR the RF signals are down converted to an IF of 70 MHz output. At this IF stage bandwidths of either 5.5 MHz. 16 MHz or full RF band can be selected. The IF signals at 70 MHz are then translated to a second IF of 130 MHz and 175 MHz for polarization channels 1 and 2 respectively. The maximum bandwidth available at this stage is 32 MHz for each channel. In Simulation Table - 2 the various components of the ABR are shown with the performance results at the output of each stage. The results of this table are given after integrating the front end with the ABR. It can be seen that the CDR before the ALC amplifier unit is around 47 dB for a 32 MHz bandwidth. However after the ALC amplifier unit, the CDR drops to around 28 dB. The SFDR falls from 37 dB to 27 dB after the ALC unit for 32 MHz bandwidth. It can be concluded from the table that the 1 dB compression point (P_{1dB}) is +8 dBm and the output third order intercept point (OIP_3) is +19 dBm. The overall receiver noise temperature is around 290 Deg K. The gain of the ABR alone is around 29 dB. With 14 dB solar attenuator setting, the level of the 175 MHz RFI due to Pune TV is around -16 dBm (1). If this interfering signal is allowed to go through the entire ABR chain without filtering, it will saturate the final stages of the receiver. However if this RFI is filtered out with saw filters at 70 MHz IF stage, it will not saturate the receiver.

We can see from the simulation table - 2 that at the output of the mar3B where it enters the SAW filter (saw1) the CDR is around 47 dB and the SFDR is around 39 dB. The ABR gain upto this stage, with programmable attenuator set to 16 dB, is around -1 dB. Therefore the level of 175 MHz RFI at the input of the SAW filter is -17 dBm which is 14 dB lower than the 1 dB compression point of -3 dBm at that stage. The OIP3 at this stage is around +8 dBm. From the equation below, the Third order inter-modulation products (IM_3) estimated for two carriers of -17 dBm magnitude each are - 67 dBm.

$$IM_3 = 3\,Pout - 2OIP_3 \quad (dBm)$$

These levels are 17 dB below the noise floor of -50 dBm at this stage.

Conclusion

In this report we have attempted to analyze the 150 MHz receiver upto antenna base. The interference levels and the spurious products generated within the receiver due to 175 MHz Pune TV carrier are estimated using MATLAB simulation of the receiver performance. These figures may be useful for taking the decision whether to incorporate the band reject filter to suppress the band near 175 MHz or not.

Acknowledgment

We would like to thank Dr. Anish Roshi for the useful discussions and for providing the band reject filter and low pass filter units. We thank Mr. Vilas Bhalerao for his active participation in the integration and installation of the modified front end.

References

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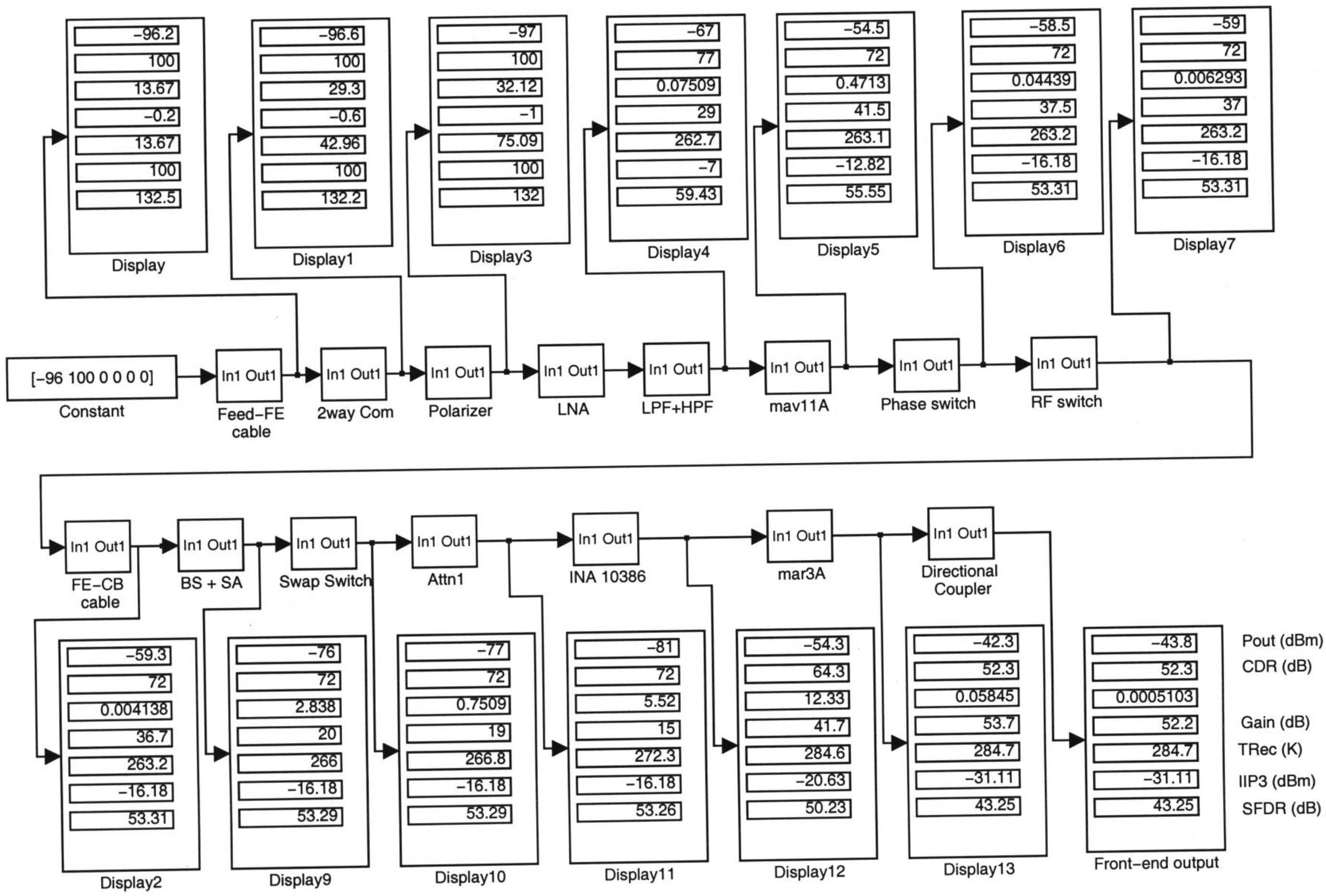
Simulation Table – 1

150 MHz Front End System with 130 – 200 MHz Frequency coverage and 14 dB solar attenuator



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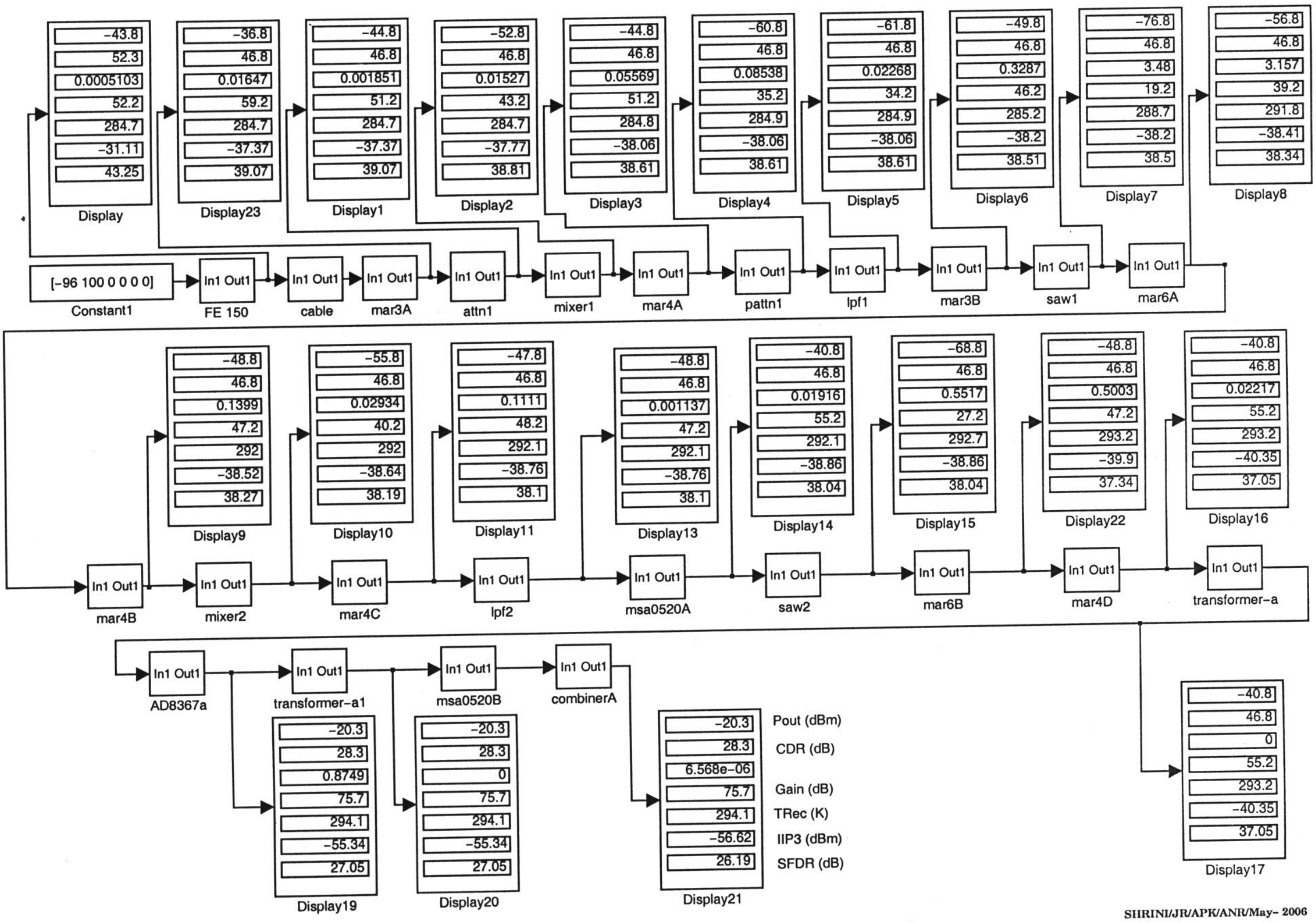
Simulation Table – 2

150 MHz Receiver at the Antenna with New ALC



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