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Simulation of L-Band Analog Receiver using ADS software for Ground Station Receiver Applications

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ABSTRACT: This paper presents the detailed simulation steps of L-Band receiver used for ground station receiver applications and it was designed by using Agilent Technologies Advanced Design System software. The receiver system is designed especially for reception of weak / low input signals from the ground station. This receiver system consists of low noise amplifiers, band pass filters and high gain amplifiers. The L-Band radio-frequency (RF) is translated into a standard 70MHz intermediate frequency (IF), to handle the signals in digital domain by using commercially available technologies. The receiver system capabilities are tested such as to amplify the weak input signal and to produces maximum gain by using ADS software.

Index Terms: **L-Band radio-frequency, ADS software, ground station receiver, high gain amplifier and Low Noise Amplifier.**

I. INTRODUCTION

This paper describes the two important receiver concepts: selectivity and sensitivity. These parameters are the most comprehensive figures of merit in receiver performance and are influenced by many sub-figures of merit, such as noise performance of the individual building blocks, linearity, gain distribution, and image rejection ratio.

1. Sensitivity:

Sensitivity is defined as the minimum signal level at the receiver input such that there is a sufficient signal-to-noise ratio (SNR) at the receiver output for a given application. It can be specified in units of dBm (decibels relative to one mill watt), along with reference impedance (50 Ω for most systems), and is typically measured in an interference-free environment [1].

Noise Figure:

The overall sensitivity is directly related to the noise figure of the receiver, which is impacted by noise from individual blocks in the receiver as well as the gain distribution of the receiver chain. The noise figure is defined as a ratio between the SNR at the input and the SNR at the output of the circuit:

$$F \equiv \frac{Input\ SNR}{Output\ SNR}$$

$$NF \equiv 10\log(F)\ (\mathrm{dB})$$

where F is noise factor and NF is the noise figure of the system.

2. Selectivity:

Receiver selectivity is a performance measure of the ability to separate the desired signal from these unwanted interfering signals. It usually becomes important in the near-far situation where the desired signal is weak and there is a strong adjacent band/ channel interfering signal at the receiver input [1].

3. Receiver Dynamic Range

The dynamic Range (DR) of a receiver is defined as the ratio of the maximum input level that the circuit can tolerate, to the minimum input level that is still detectable [1].

Many receivers must be capable of handling a very wide range of signal powers at the input while still producing the correct output. This must be done in the presence of noise and interference which occasionally can be much stronger than the desired signal [4]. The Advanced Design System (ADS) from Agilent Technologies provides this RF analog/digital co-simulation capability, enabling such things as time-saving trade-off studies for the performance requirements on each side of a communications system [3].

II. OVERVIEW OF L-BAND ANALOG RECEIVER

Generally the implementation of a ground station receiver system consists of different low noise amplifiers at various stages, band pass filters with different bandwidths and high gain amplifier as shown in Figure 1.

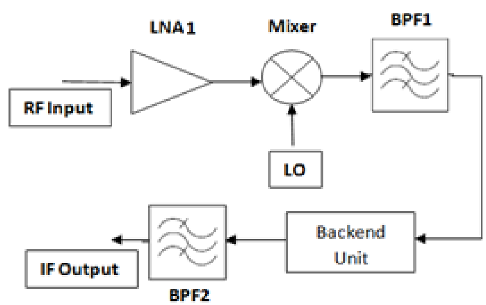

Fig 1: Architecture of L-Band ground station receiver

The ground station receiver system consists of two stages. The first stage is a frequency translation stage. It includes a Wideband low-noise amplifier (LNA), a single down-conversion mixer using a local oscillator (LO) and Band Pass filter. The second stage includes a standard 70MHz IF Backend unit with narrow band pass filters. The standard intermediate frequency stage is chosen such that it can handle the signals in digital domain by using commercially available technologies for higher data rates [2].

The first decision was to use a down conversion or up conversion receiver. Down conversion means the input signal frequency converts to an IF frequency that is lower than the input frequency. Up conversion is when the conversion to a higher IF frequency occurs. Since the input RF signal ranges from 1000MHz to 2000MHz in the L-Band range, down conversion is easier to accomplish due to availability of filters and number of conversions required [5].

The Backend unit consists of narrow band low-noise amplifier (LNA), Band Pass Filters, programmable attenuator and a cascaded two stage High Gain Amplifier (HGA) as shown in figure 2.

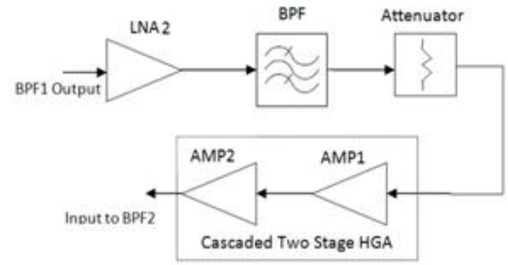

Fig 2: Architecture of the backend unit a subsystem of L-band receiver.

The channel filtering takes place at the IF frequency by a band pass filter with *fixed* center frequency at the IF. This means that the channel selection takes place at the first mixing process by selecting the local oscillator (LO) frequency, such that the RF signal is shifted down by different amounts to locate the desired channel at the fixed IF [1]. This IF receiver was selected based on the performance that was readily available coaxial designs. While the bandwidth of the IF filter is considerably wider than what would generally be used in practice, the effect that this filter has on the system performance makes an interesting point to consider through simulation [3].

III. DESIGN OF L-BAND ANALOG RECEIVER USING ADS SOFTWARE

1. Stage 1- Frequency Translation:

The L-Band receiver was implemented by using Agilent technologies Advanced Design Systems (ADS) software. The first stage of the receiver consists of an input single frequency power source (P_1Tone) delivering -100dBm of power at 1690MHz in L-Band range followed by Wideband Low noise amplifier with noise figure of 1.7dB operating at 0.01-3GHz. The LNA in first stage gives a decent gain of around 30dB with low noise figure. For any ground station receiver it is the minimum requirement at the input stage. The LNA output of a radio-frequency signal is fed to a mixer with internal

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local Oscillator having LO frequency of say 1620MHz. The desired IF is RF minus LO which gives output Intermediate Frequency of

70MHz. The resultant IF signal is passes through a Band Pass Filter of Pass bandwidth of 20MHz and the entire schematic of first stage as shown in figure 3.

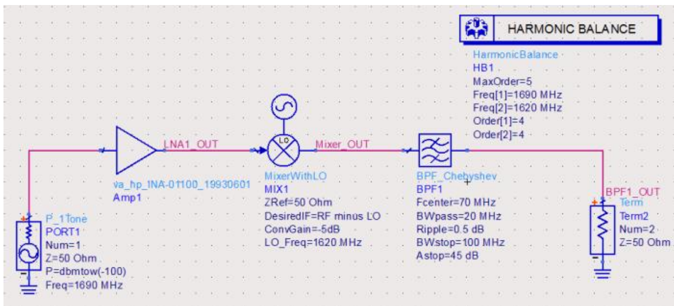

Fig 3: Schematic used for down converting input RF to IF

Simulated Results:

The first stage of the receiver was simulated with the help of Harmonic Balance (HB) simulation [6]. The input signal power is very low around -100dBm in L-band frequency range varies from 1000MHz to 2000MHz (typically at 1690MHz). The output of wideband low noise amplifier is -64dBm as shown in figure 4.

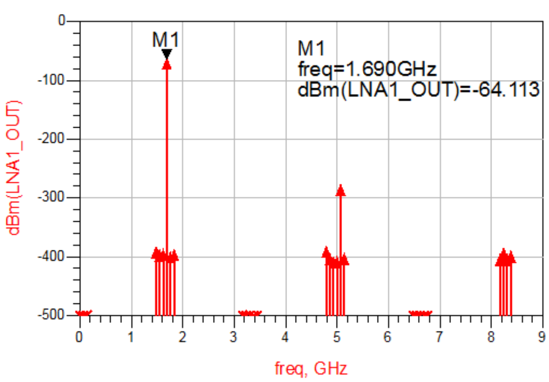

Fig4: Simulated output of HB at Low Noise amplifier (LNA1_Out)

This LNA1_Out output is fed to the mixer with LO having LO frequency of 1620MHz and the desired IF is RF minus LO. The output of mixer is having two main frequency components along with other harmonics, they are RF plus LO (3.310GHz) and RF minus LO (70MHz) as shown in figure 5. The mixer is having conversion gain of -5dB and different S11 & S22 values.

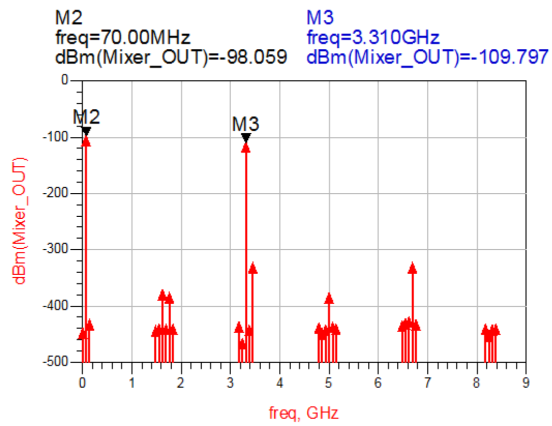

Fig 5: Simulated output of HB at mixer (Mixer_Out)

The desired IF is selected by passing the Mixer output through a Band Pass filter having fixed center frequency of 70MHz with 20MHz pass bandwidth. This band pass filter has 3dB of conversion/insertion loss [6]. The output of BPF is shown in figure 6.

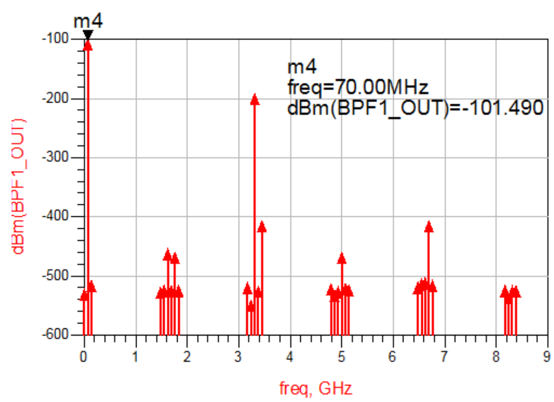

Fig 6: Simulated output of HB at Band Pass filter (BPF1_Out)

The first stage of the L-Band receiver gives an output power approximately -100dBm at 70MHz intermediate frequency. Generally ground station receivers can capable of receiving weak/low input signals at any frequency within the L-Band range and is down-converted to standard 70MHz IF frequency.

2. Stage 2- Backend unit:

The second stage of the L-Band receiver is a standard IF high gain receiver as shown in

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figure 7. The output power of first stage is fed to the input of the second stage.

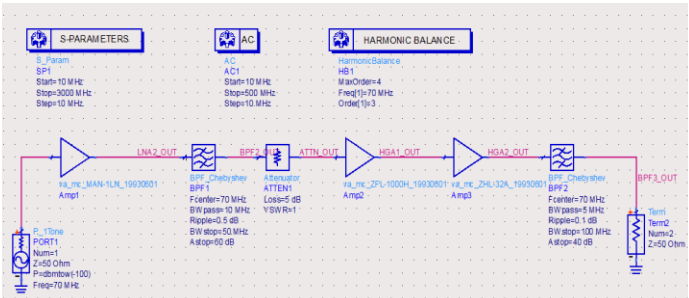

Fig 7: Schematic used for backend unit of L-Band receiver

It consists of a single frequency power source having input power of -100dBm at 70MHz intermediate frequency as shown in figure 8. The input RF power can be used either fixed of variable. The backend stage is also consists of a Low-noise amplifier with noise figure of 2.8dB with around 40dB of gain operates at 0.5-500MHz. Then BPF1 is chosen such that it narrow pass BW of 10MHz. After the band pass filter an attenuator is used with attenuation of 5dB.

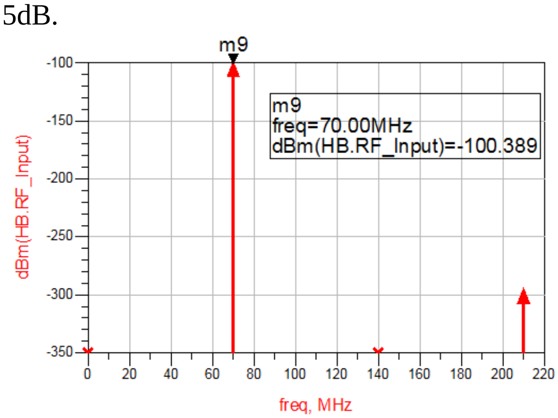

Fig 8: simulated input power at p_1 tone

The attenuator is used as programmable attenuator with 0-70 dB of attenuation in steps of 5dB. The importance of programmable attenuator is to improve the signal level or strength. If the input signal strength is weak then the attenuation is less otherwise it should be more based on the input signal strength. The output of the attenuator is given to the cascaded two stage high gain amplifier (HGA) having the gain of around 65-75dB and this output passes through another band pass filter of 5MHz narrow bandwidth.

Simulated Results:

1. AC Analysis:

The AC analysis of second stage is shown in figure 9 [6]. The output spectrum is very narrow because here chebyshev band pass filters and narrow pass bandwidths are chosen. If wide bandwidths are needed then choose the pass bandwidths appropriately.

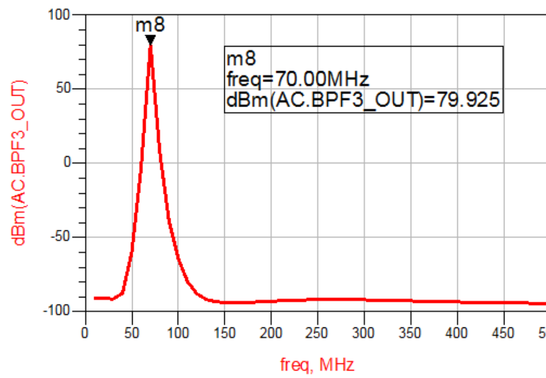

Fig 9: Simulated output of AC analysis

2. Harmonic Balance Simulation:

The Harmonic balance simulation of the second stage is given for the input power levels -100dBm and produces an output power of -20dBm with improved signal strength of 80dBm as shown in figure 10.

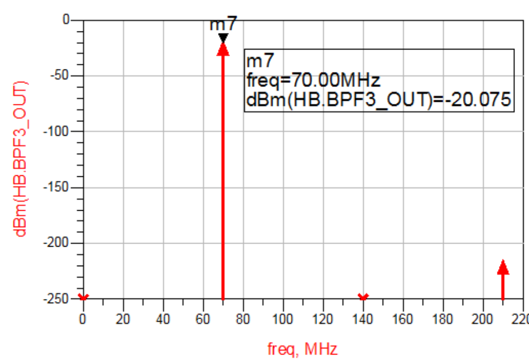

Fig10: simulated output of Harmonic Balance simulation

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3. S-parameter Analysis:

The s-parameters analysis gives the receivers overall gain (S21) at 70MHz intermediate frequency is about 80-90dB based on input signal level as shown in figure 11.

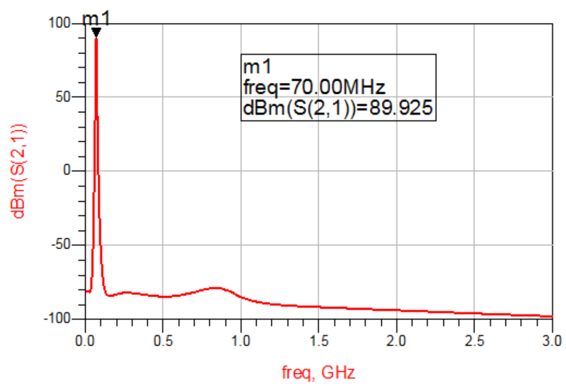

Fig 11: simulated output of total gain of the receiver system using S-parameters

4. Dynamic Range Testing:

The dynamic range of the receiver is tested for only at 5dB of attenuation with the help of harmonic balance simulation. The output of amplifiers may not reach the saturation state when less attenuation is applied. Thereafter attenuation is increased to maintain the amplifiers in active region. Here the input power is -50dBm at 70MHz intermediate frequency as shown in figure 12.

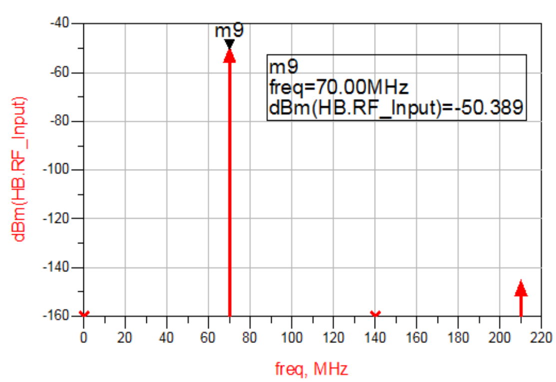

Fig 12: simulated input power of -50dBm at p_1 tone

The Harmonic Balance simulation gives 27.849dBm of output as shown in figure 13. Which indicates -55dBm to -50dBm is the dynamic range for this L-Band receiver.

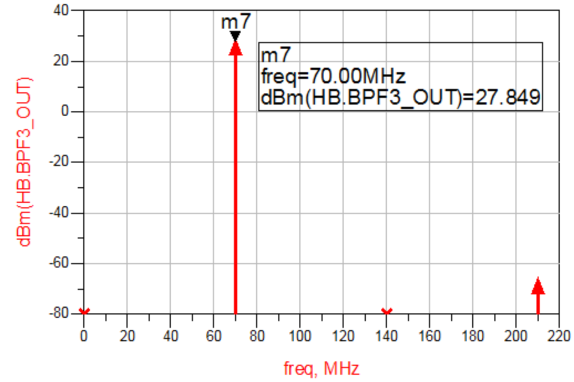

Fig13: simulated output of Harmonic Balance simulation

The output powers for variable input powers from -100dBm to -50dBm at 70MHz intermediate frequency as noted in the following table 1 through simulation using ADS software.

Input Power(dBm)	Output Power(dBm)
-100	-20.075
-90	-10.075
-80	-0.077
-70	9.906
-60	19.735
-55	24.312
-50	27.849

Table1: Output power for different input powers

IV. Conclusion

The L-Band analog ground station receiver system was simulated by using Agilent technologies Advanced Design System software. The performance of the receiver system has been considered for different input power levels using various simulation techniques. The capabilities of L-Band receiver system is also tested such as it can amplify weak/low input signals and produces maximum gain. The dynamic range of the receiver system is identified with the help of harmonic balance simulation. The simulated results with corresponding output plots are analyzed.

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BIOGRAPHIES

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