

## DESIGN, SIMULATION AND ANALYSIS OF A SUPERHETRODYNE RECEIVER USING EDA

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### Abstract

A single stage down conversion super-heterodyne receiver has been designed, simulated and analyzed using Electronic Design Automation (EDA) software. Depending on the dynamic range requirements and noise figure requirements, the gains of the LNA is adjusted so as to enable the receiver to have maximum dynamic range and minimum noise figure. The receiver was been modelled on the Electronic Design Automation simulator, using the in-built components available. All the parameters were set as per the requirements and then the model is simulated. The data obtained from the simulation is analyzed by using the data display screen where any kind of plot (rectangular, polar, smith chart or tabular list etc) can be plotted for the data available.

**Keywords** - EDA, LNA, Superheterodyne, Receiver, BPF, Amplifier, Noise Figure, Dynamic Range

### I. INTRODUCTION

A receiver is a circuit used in a communication/radar system to receive the information or data signal that has been transmitted by a transmitter. Transmitting a signal of some frequency is easier compared to receiving a desired signal out of a many noise signals and undesired (spurious) signals. The performance of any communication/Radar system is dependant largely on the efficiency of the receiver used in it. This is the reason why receiver design became a very important and complex stage in the communications system designing. The main intention behind using a communication system is to communicate or transfer information from one point in space to another point. In such a system if the receiver is not efficient and doesn't pick up the desired signals efficiently then, the entire purpose of using a communication system is lost. Day by day numerous techniques are being invented for efficient transmission of data and accordingly the receiver configurations are also changing. The basic principle behind the receiver remain unchanged but when more and more specifications are to be met, the constraints on the design of the receiver become more and more. In order to be able to design a receiver with any level of complexity we must be very strong with the basic principles behind the receiver working and its design. We must also identify the potential areas where we generally face difficulties in the design process.

### Applications

- Communication Systems:
- Direction finding:
- Radio Ranging
- Telemetry and Control system:
- Electronic Counter Measure (ECM) system:

### Super-Heterodyne Receiver and Its Advantages

From the day the receiver designing was started, many configurations have been design and developed. Some of the configurations that were used previously are:

- Tuned Radio Frequency (TRF) Receiver
- Super-regenerative Receiver
- Crystal Video Receiver

Although these receivers have been employed in Communication as well as Radar systems, the Super heterodyne has been used mostly because of its

- Good sensitivity
- High gain
- Selectivity
- Reliability

The Super heterodyne receiver has exceptional capability of separating the wanted signals from the

unwanted and hence has good sensitivity also. Because of this high sensitivity and selectivity it can detect weak signals even in the presence of noise and interference. In microwave communications domain the noise picked up by the receiver antenna is comparably less. The main source of noise in these microwave communication receivers is the internal noise that is generated within the receiver because of the presence

**Noise figure:**

The total noise figure at the output of a receiver may be considered to be equal to the thermal noise power obtained from an ideal receiver multiplied by a factor called the “Noise Figure”.

$$F_n = (S_i/N_i) (S_o/N_o)$$

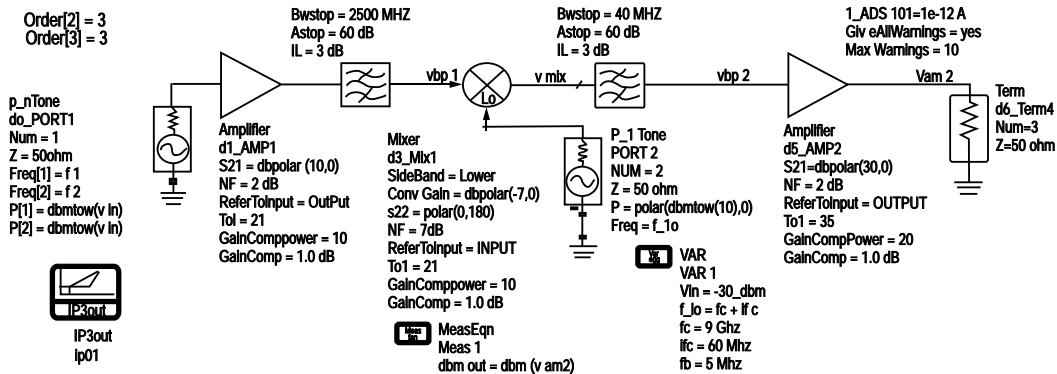


Fig. 1. A Superhetrodyne Receiver with Two Signals at the Input

of nonlinear devices such as amplifiers and mixers. But, the Superhetrodyne receiver has ways to minimize this noise and separate the required signal from this noise provided it is properly designed as shown in Fig.1. Because of these qualities, the Superhetrodyne receiver is widely used in the Communication and Radar domain. Almost all the communication applications employ the Superhetrodyne receiver. Even though lots of advanced techniques like DSP are being incorporated into the receiver configurations, the basic configuration of the receiver i.e. the Superhetrodyne configuration is not being changed.

Keeping in view the wide range of this receiver, this paper discusses how to model, design and simulate the Superhetrodyne receiver. For simplicity of analysis, we have chosen a single-stage down-converter configuration for the simulation and analysis.

**Parameters which has to be Analysed**

**Dynamic Range:**

The Dynamic range is defined as “The range between the 1-dB compression point and the minimum detectable signal (MDS)”.

$$DR = Pin,1dB - MDS$$

$$MDS = 10\log KTB + 3 \text{ dB} + NF$$

$$\text{Eqn } TO1output = 1.5 * m5 - 5 * m6$$

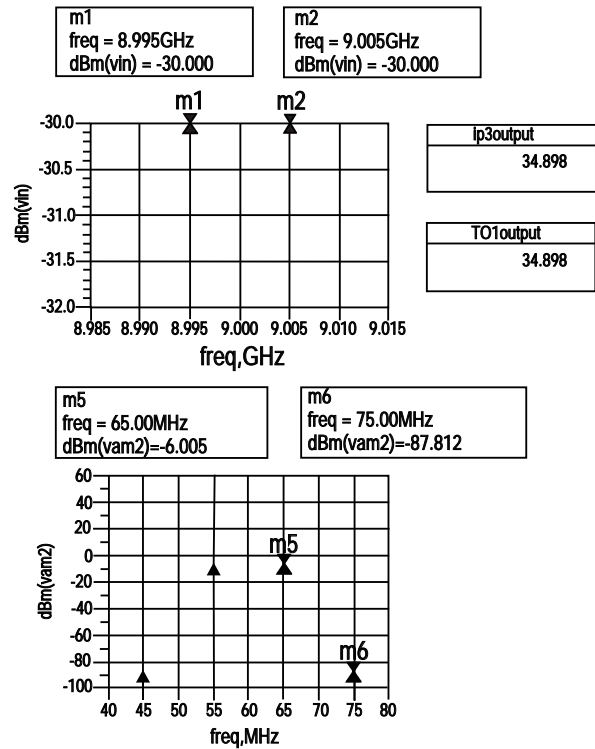


Fig. 2. Simulation of TOI Using 2 Signals

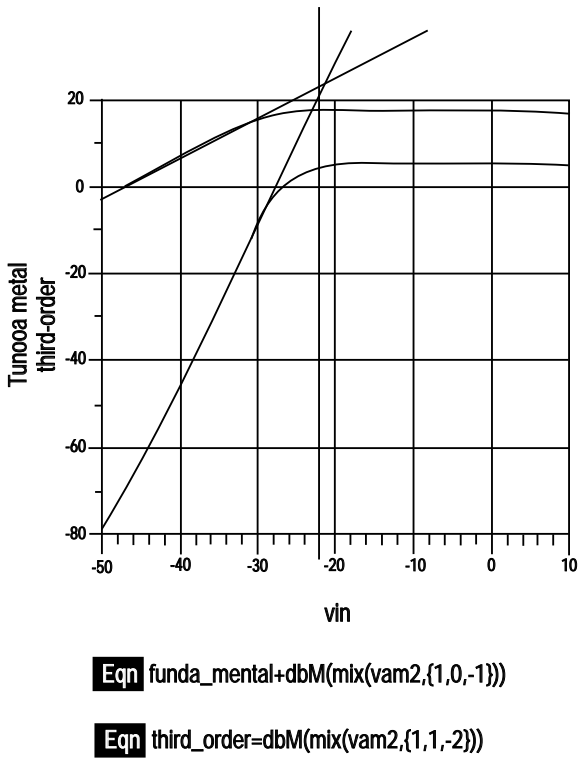


Fig. 3. Simulation of TOI Using Power Sweep

“The Noise Figure may be interpreted, therefore as a measure of the degradation of signal-to-noise ratio as the signal passes through the receiver”.

Noise Figure of networks in cascade:

$$F_0 = F_1 + (F_2 - 1)/G_1 + (F_3 - 1)/G_1 G_2 + \dots + (F_N - 1)/G_1 G_2 \dots G_N \quad \dots (1)$$

Considering only two networks in cascade,

$$F_0 = F_1 + (F_2 - 1)/G_1 \quad \dots (2)$$

**II. COMPARISON**

Now we shall compare the three configurations of the receiver in all aspects. For this purpose, the various characteristics of the three receivers wre tabulated below. By looking at them we can know which one is the optimum configuration for us.

First let us have a look at the values of the overall input 1-dB compression point and the overall

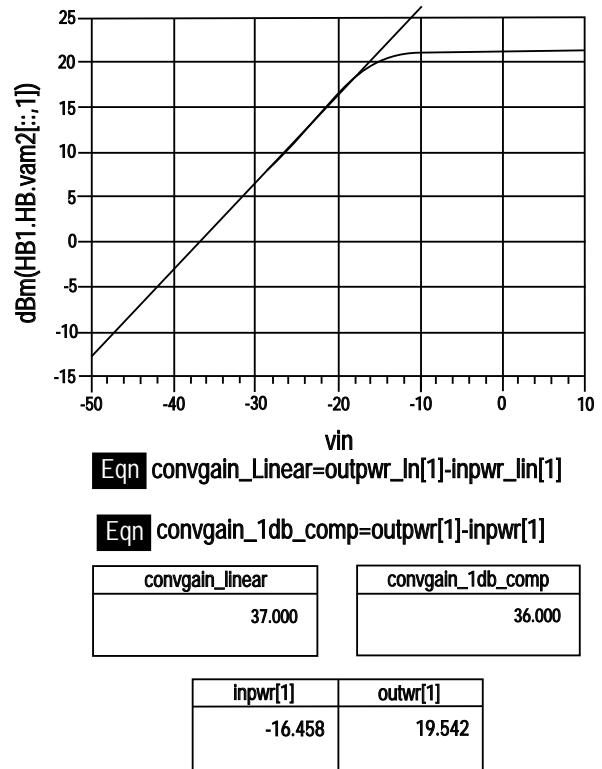


Fig. 4. Simulation of RF-IF Gain compression

input Third Order Intercept point that were obtained theoretically for each of the configuration as shown in Table 1.

**Table 1. Overall input 1dB point and 701**

LNA Gain (dB)	IF Amplifier Gain (dB)	Overall Input 1-dB point (dBm)	Overall Input TOI (dBm)
10	30	- 6.49	4.5
20	30	- 16.45	- 5.5
30	30	- 26.45	- 22.42

The Table 2 shows the Noise Figure, Minimum Detectable Signal, Dynamic Range and Spurious Free Dynamic Range calculated theoretically for each of the compression configuration

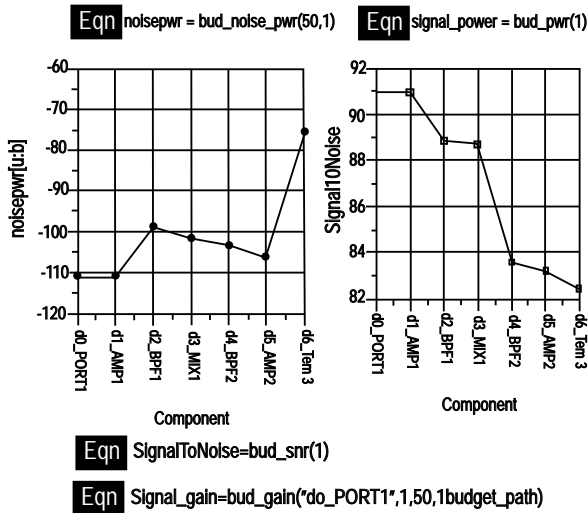


Fig. 5. Simulation of Budget Analysis

Table 2 Theoretical Analysis

LNA Gain (dB)	IF Amplifier (dB)	Noise Figure (dB)	MDS (dBm)	Dynamic Range (dB)	Spurious Free Dynamic Range (dBm)
10	30	6.67	- 94.32	87.82	58.54
20	30	2.75	- 98.24	81.79	54.52
30	30	2,08	- 98.92	72.47	48.31

III. OBSERVATIONS

1. For the **LNA Gain= 10 dB** configuration, the 1-dB point, TOI, Dynamic Range and SFDR are exceptionally good as shown in fig 2.. Even the interference in power level between the desired IF signal and the inter-modulation products is very high so that the inter-modulation products is very high so that the inter-modulation products have no effect on the reception of the desired signal. But, the Noise figure is very high (around 6.67 dB) which is not desirable in most of the applications

2. For the **LNA Gain = 20 dB** configuration, the Noise Figure is moderate (not very bad) and also the 1-dB compression point, TOI, Dynamic Range and SFDR all are moderate.
3. For the **LNA Gain = 30 dB** configuration, the Noise Figure is very low, which is a very good advantage for communication receivers and other receivers where sensitivity is very important. But, the 1-dB compression point, TOI, Dynamic Range and SFDR are very less. This is not desirable in any receiver because Dynamic Range is the most important characteristic for any receiver. Another disadvantage of the high gain configuration is that the level of the inter-modulation products is very high and this is the reason for the low TOI and Dynamic Range.

IV. CONCLUSION

So, the conclusion is that, "if the receiver is required to have a high dynamic range and high Third-Order Intercept Point then, the LNA gain has to be low. The cost that we pay for reducing the LNA gain is an increase in the noise figure. Reducing the LNA gain by a large amount will result in a very high Noise Figure which is not desirable for efficient reception. So, the conclusion is that the LNA gain must not be too high or too low, it must be just sufficient to have a respectable Noise Figure and a good Dynamic Range

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