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PARAMETRIC PERFORMANCE ANALYSIS OF RF MIXER

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ABSTRACT:This paper focuses on the design of radio-frequency (RF) mixers and their performance analysis, including a broad-band down converter mixer, an up converter mixer and a down converter mixer with high linearity. The basic mixer topology used in this report was the Gilbert cell mixer, which is the most popular active mixer topology used in modern communication systems. First, a broadband down converter mixer with variable conversion gain is designed using 0.350µm CMOS technology. The mixer worked from MHz to GHz, Frequency By changing the effective transistor size of the transconductor and the load, the mixer is able to work in three different modes with different conversion gain and power consumption. Second, an up and down converter mixer with sideband selection

Keywords:ADS, Conversion Gain, Gilbert Mixer, Noise Figure.

I.INTRODUCTION

RF Mixer is a 3-port active or passive device is designed to yield, a sum and a difference of frequencies at a single output port when two distinct input frequencies are inserted into the other two ports. A common misunderstanding about mixers is that a Mixer is only a nonlinear device. Actually an RF Mixer is fundamentally a linear device, which is shifting a signal from one frequency to another, keeping (faithfully) the properties of the initial signal (phase and amplitude), and therefore doing a linear operation. From the moment that we use a nonlinear device to perform the mixing operation, Mixers have relatively high levels of intermodulation distortion, spurious responses, and other undesirable nonlinear phenomena. In contrast to frequency multipliers and dividers, which also change signal frequency, mixers theoretically preserve the amplitude and phase without affecting modulation properties of the signals at its ports.

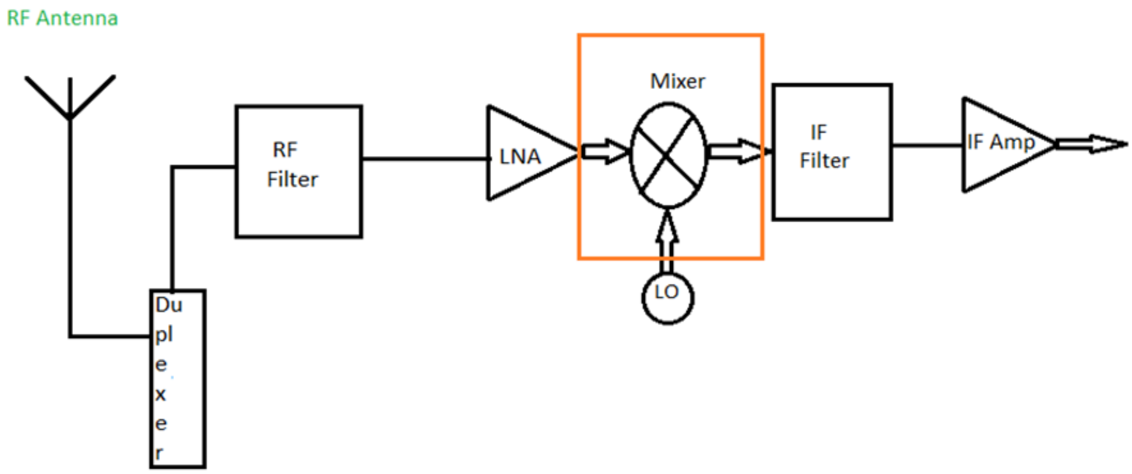

Figure 1. RF receiver building blocks

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Mixers generally have a gain stage, a switching stage, and a differential IF output such as the one shown in Figure 2. The current in the RF frequency is amplified by the gain stage at the bottom of the circuit. The current is then steered to one side of the output or the other depending on the value of the LO. The result is a mixing of the LO and RF frequencies.

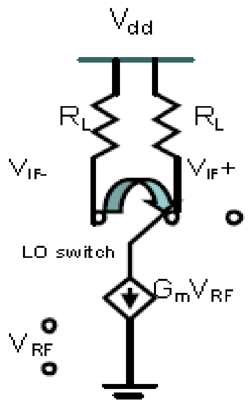

Figure 2. Simple Conceptual schematic of a mixer

It is well known that linear, time-invariant systems are not able to produce outputs with spectral components that are not present at the input. That is, in order to perform frequency translation, the circuits used as mixers must be either nonlinear or time varying. Although the techniques used to realize mixing are quite different for different mixer topologies, the essence of all mixers lies in the concept of multiplying two signals in the time domain. Suppose that the two input signals of the mixer are

$X(t) = A\cos(\omega_1 t)$ and

$Y(t)\ B\cos(\omega_2 t)$

The multiplication can be expressed as the following equation

$$A\cos\omega_1 t\cdot B\cos\omega_2 t=\frac{AB}{2}\cos(\omega_1-\omega_2)t+\frac{AB}{2}\cos(\omega_1+\omega_2)t$$

II.SYSTEM ARCHITECTURE

A System Block Diagram

The Figure 3 shows traditional Gilbert Cell mixer shows The RF signal is applied to the transistors M2 & M3 which perform a voltage to current conversion. For corrects operation these devices should not be driven into saturation and therefore, signals considerably less than the 1dB compression point should be used. Performance can be improved by adding degeneration resistors, on the source terminals of M2 & M3. MOSFET M4 to M7 form a multiplication function, multiplying the linear RF signal current from M2 and M3 with the LO signal applied across M4 to M7 which provide the switching function. M2 and M3 provide +/- RF current and M4 & M7 switch between them to provide the RF signal or the inverted RF signal to the left hand load. M5 & M7 switch between them for the right hand load.
The two load resistors form a current to voltage trans-formation giving differential output IF signals.

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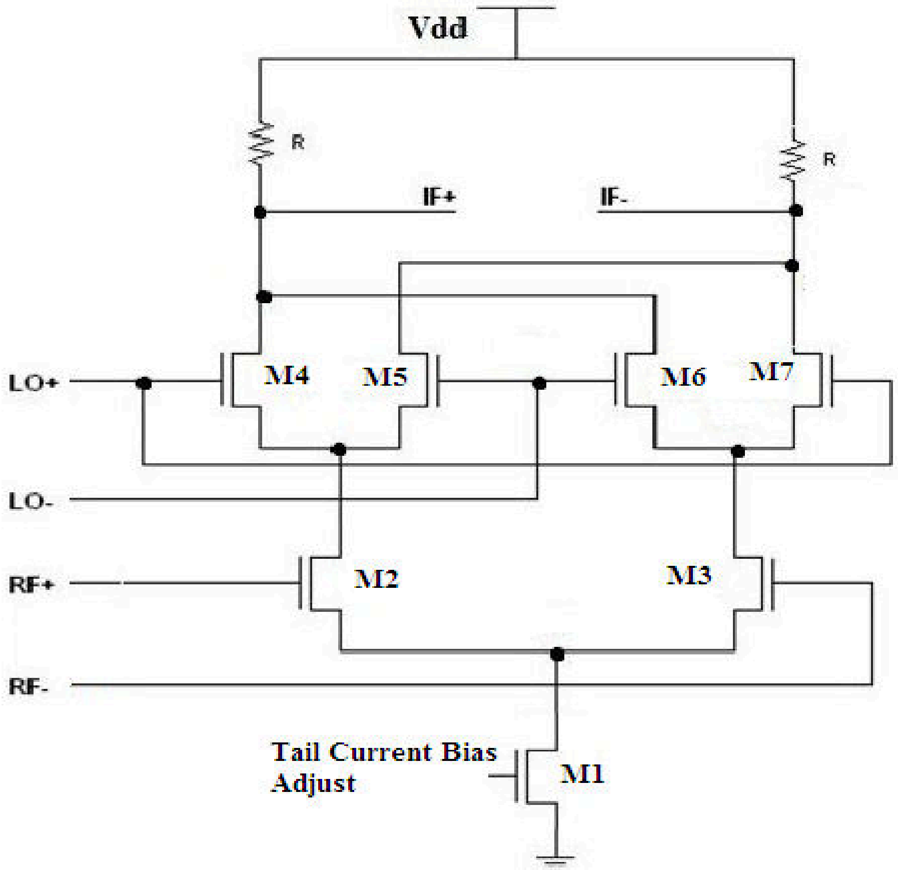

Figure 3. Gilbert cell Mixer

B Source Degeneration

An important mixer requirement is linearity. There are several ways to increase linearity such as increasing the voltage supply or increasing the current. However, the most common and effective method to improve linearity is to use some type of source degeneration. Figure 4 shows the mixer with source degeneration resistors and Figure 5 with source degeneration inductors. Resistors are used when the size of the circuit needs to be minimized. Inductor degeneration is usually preferred because it has no thermal noise to degrade the noise Figure, and it saves headroom because there is no voltage drop across it. In the design, resistor degeneration was used because the circuit must operate over a broad bandwidth. [7].

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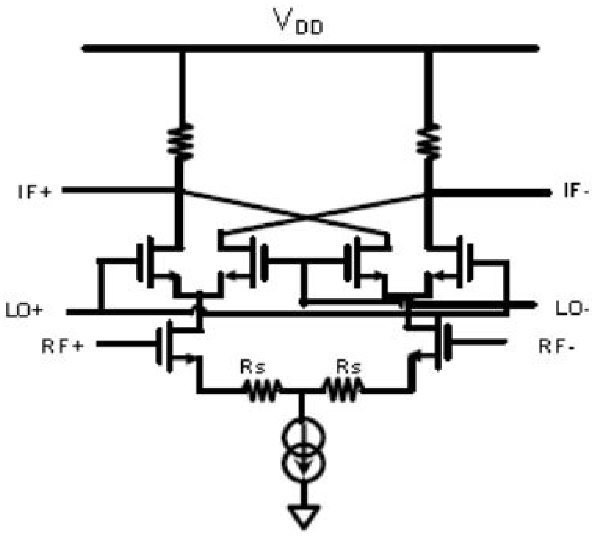

Figure 4: Source Degeneration Resistor

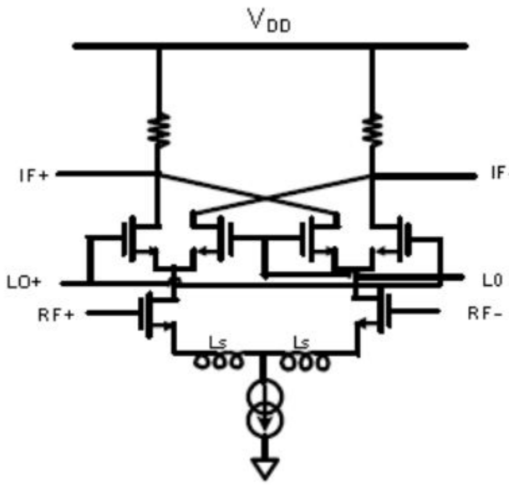

Figure 5: Source Degeneration Inductors

III.MIXER ANALYSIS

C Design Steps of Gilbert Mixer

Due to complexity of the signals in today's digital communications, proper Mixer design is crucial for solutions. Design procedure or steps are different according to designer or transceiver but commonly used steps are as follows:

- Selection of Transistor
- DC Biasing
- Gain
- Noise Figure
- Linearity

All transistors are to operate in the saturation region. For this requirement to be met, two expressions must be satisfied once these conditions have been satisfied it is possible to approximate the transistor behaviour in the saturation region through the following equation.

$VGS \geq VT$ (1)

$VDS \geq (VGS - VT)$ (2)

Conversion Gain

$gm = 2ID / (VGS - VT)$ (3)

$IIF (t) = sgn[\cos(\omega LOt)](IDC + IRF \cos\omega RF t)$

$IRF = -gmVRF$

Where gm is the transconductance of M1. The square wave can be expanded into the following series:

$sgn[\cos(\omega LOt)] =4/\pi(\cos\omega LOt) -4/3\pi[\cos(3\omega LOt)] +4/5\pi[\cos(5\omega LOt)]$

Substituting the above equation into iIF (t), the second-order intermodulation (IM2) products can be found as:

$iIF (t)IM2 = -2/\pi[gmVRF [\cos(\omega RF t -\omega LOt) + \cos(\omega RF t +\omega LOt)]$

Thus, the voltage conversion gain (CG) of the mixer is simply:

$CG =2/ \pi [gmRL]$ (4)

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IV.MIXER PERFORMANCE

D Noise Figure

Figure 6 shows Noise Figure Vs Conversion Gain Simulation simulates "All Sideband" (DSB) NF since all images are included in noise and conversion gain calculation. This is identical to the Hot-Cold measurement technique used by most noise figure measurement systems. Figure 7 shows the output of noise figure, conversion gain with Local oscillator power.

The noise figure gets worse if more harmonics of the LO source are added, or if their power levels are set higher, here in this mixer noise figure simulation LO power is set to Noise generated due to each component available in proposed Gilbert mixer is simulated and as shown in table no.07, after simulating Gilbert mixer generate total noise figure is 7.034dB at 45MHz frequency with respect to 2.826 dB Conversion gain.

$$NF\_dB=10*\log(NF\_linear) = 7.343 \text{ Db}$$

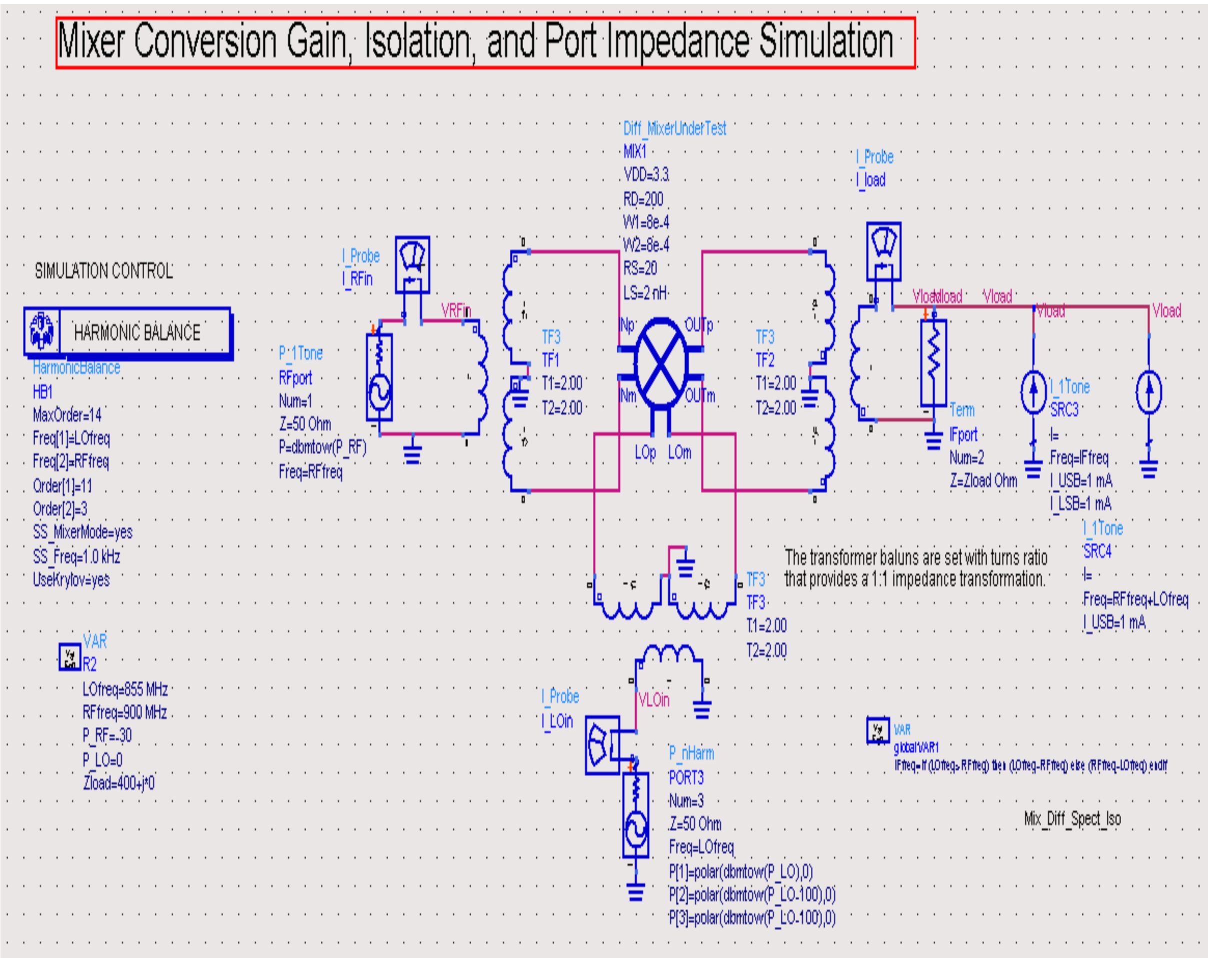

Figure 6 Mixer Conversion Gain, Isolation, and Port Impedance Simulation

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V. RESULT AND DISCUSSION

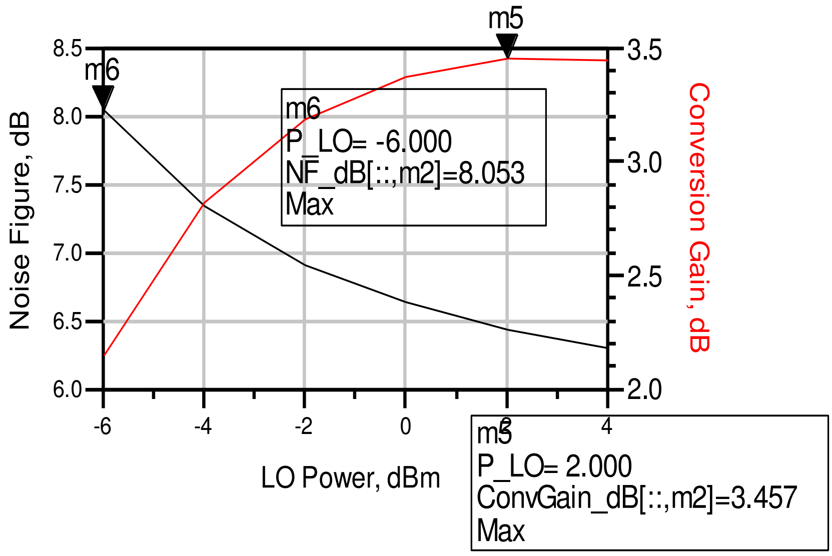

Figure7. Noise Figure Vs Conversion Gain

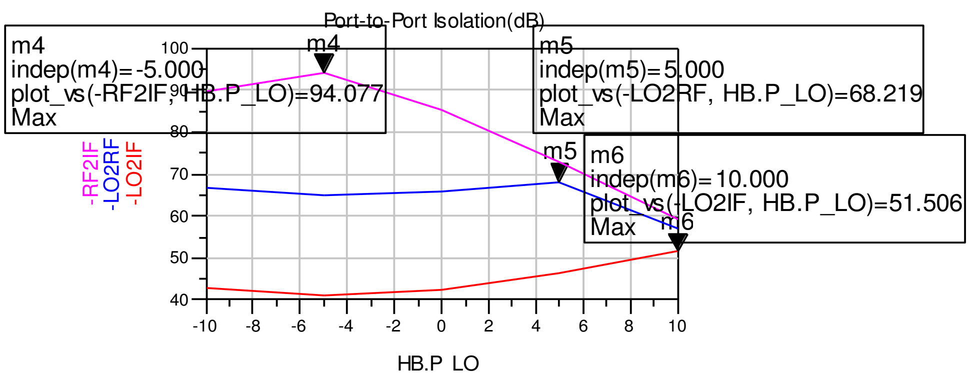

Figure 8. Port-To-Port Isolation

E Spectrum

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Figure 9 shows the input and output spectrum of proposed Gilbert mixer i.e. IntermediateFrequency Spectrum and Radio Frequency Spectrum. In the input spectrum marker m1 at the highest node of spectrum shows 45MHz output frequency which is desired output of Gilbert mixer, IF_Spectrum of -28.881 max.

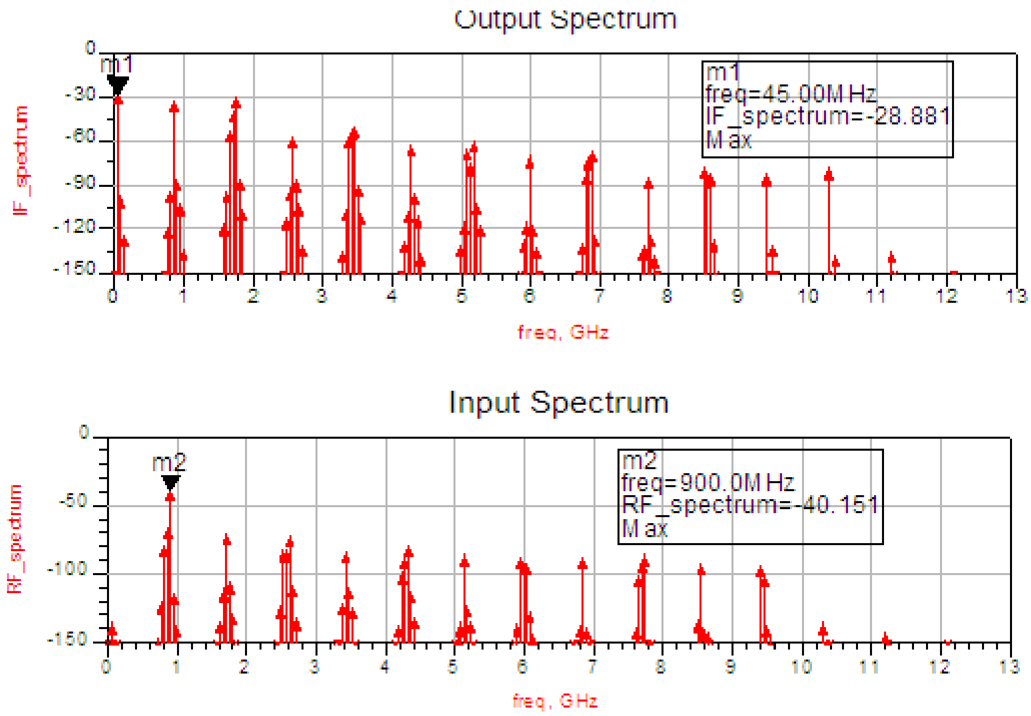

Figure 9 output and input spectrum

Table 2: Results of Mixer

Sr.No.	Parameter	TheoreticalValue	SimulatedValue	Deduction
1.	RF	900 MHz	900 MHz	Pass
2.	LO	855 MHz	855 MHz	Pass
3.	IF	45 MHz	45 MHz	Pass
4.	Conversion Gain	≥ 4 dB	3.457	Acceptebale
5.	Noise Figure	≤ 8	7.345	Pass
6.	Supply voltage	≤4 v	3.33 v	pass

VI.CONCLUSION

Theoretical value and simulated value are matched .Gain, port to port isolation and noise figure was improved due to use of Gilbert mixer with inductive source degeneration for GSM applications .Also we can obtain the different values of RF for different applications.

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