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DESIGN OF RF FRONT-END MIXER WITH A GAIN OF 15 dB OVER THE BAND OF 3.1-10.2 GHz FOR AN ULTRA WIDE BAND RECEIVER

Pankaj Jha, Satyendra Sharma
Electronics & Communication Department, IIMT, Greater Noida, India, 201308
Pankaj.maahi@gmail.com

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ABSTRACT

A CMOS Mixer for Ultra Wide Band (UWB) Receiver is proposed. The Mixer maintains a gain of 15 dB over the band of 3.1-10.2GHz. The Mixer achieved a noise figure ranging from 9 - 9.5 dB over the same band of operation. The active mixer topology is adopted here for the direct conversion receiver because of its superior gain and noise figure compared to the passive mixer. This paper also demonstrates that a low-power, high performance UWB down-conversion mixer can be realized using 0.13-µm CMOS technology.

Keywords: UWB, Noise Figure, Gain, Conductance.

I. INTRODUCTION:

Super heterodyne receiver has been the most dominant radio receiver architecture for the last 70 years. Main advantage this architecture offers is that signal at high frequency is down-converted to lower frequency [1]. In most of the applications, the LNA is followed by a mixer in the receiver. The main function of the mixer is to translate the modulated radio-frequency signal into a low frequency signal for further processing. If input frequency is ω_1 and local oscillator (LO) frequency is ω_2 then, a mixer will generate difference and sum component of the input frequencies at $\omega_1+\omega_2$ and $|\omega_1-\omega_2|$. The function of such frequency translation can be realized by either linear multiplication or non-linear operation [2]. To achieve better efficiency for frequency conversion, the non-linear operation is adopted in most of the RF designs. During the process of frequency translation, besides the wanted signal, many undesired signals are also generated due to the nonlinearity of the circuit. These unwanted frequency components may interfere with the circuit operations and degrade the receiver performance considerably if they are not sufficiently rejected. It is also essential to realize the mixer with reasonable linearity, so that the impact of mixing with the external interferers can be minimized. For the mixer circuit, IIP3, IIP2 are the important design parameters to measure the linearity besides the conversion gain and noise figure [3]. Down conversion mixer is an important RF component in wireless transceivers. Down conversion mixers are responsible of translating signal from RF to IF or analog baseband directly [4]. If parasitic effects of internal nodes are ignored, mixers can be considered as broadband systems. Here, by broadband, it is meant that if LO frequency is varied over the whole band of interest, the resulting frequency characteristic of IF signal should be same throughout the band. In reality, there are parasitic capacitances associated with internal nodes, which at high frequencies become a dominant factor the frequency response of conversion gain depends on two things. One is the loss of high frequency RF signal before switching due to internal parasitic capacitances. Other is the loss at the output of the mixer due to parasitic capacitance at that node [5]. While designing a broadband mixer, the main objective is to minimize the conversion gain variation in each IF band due to both factors. Overall maximum variation in conversion gain in all IF bands combined should be less than 1dB [6]. In general, there are two categories of mixer circuits based on the ability of signal amplification, namely an active mixer and a passive mixer. Moderate signal gain is readily achievable in active mixer design but the linearity is limited because of voltage headroom issue between the supply rail and the circuit ground. In contrast, a passive mixer can offer superior linearity performance because they are lossy and always perform as a non-linear switch during the down-conversion of the RF signal to baseband frequencies. The implementation of the active mixer is more advantageous than the passive counterpart in the direct conversion receiver [7]. To improve the overall DCR performance, the combined front-end gain of Low Noise Amplifier and mixer needs to be sufficiently high (> 20 dB) to improve the SNR of the receiver signal [8]. Because of the conversion loss, the use of a passive mixer in a DCR will degrade the noise figure of the receiver chain. Furthermore, higher gain is required for the LNA to compensate the signal loss from the passive mixer. When the gain of the amplifier is too high (> 30 dB), the stability of the system becomes the critical issue and oscillation will happen if the isolation from the output of the Low Noise Amplifier to the input is not enough [9].

II. MIXER FUNDAMENTALS

Since linear and time invariant circuits cannot produce outputs with spectral components different from what are present in the input, mixers must be either nonlinear or time variant. The mixer operation is a multiplication in time domain [1]. To illustrate this point consider mixer model of Fig. 1.

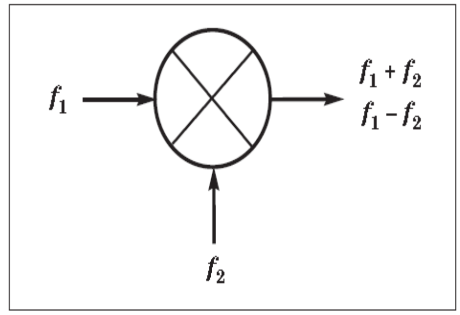

Fig. 1 Fundamental of Mixer circuit

where f_1 is the Reference frequency, and f_2 is the Local Oscillator frequency.

Output frequencies of the mixer circuit are known as intermediate frequencies.

III. PORT TO PORT ISOLATION

Port-to-port isolation is a metric for leakage of signal from one port of the mixer to another. It is defined as the ratio of the signal power available into one port of the mixer to the measured power level of that signal at the one of the other mixer ports assuming 50Ω impedance of each port. The criticality of leakage is different from one port to another [2]. One of the important leakage is the LO to RF leakage which is shown in Fig. 2. Since, LO signal is usually much higher in amplitude, it can easily leak to the RF port through substrate and parasitic capacitances of either mixer or the LNA. LO can also leak back to the antenna after leaking from LNA and get transmitted. Another effect of this LO leakage is that it can mix with LO signal inside the mixer and get down converted to DC resulting in a DC offset [3].

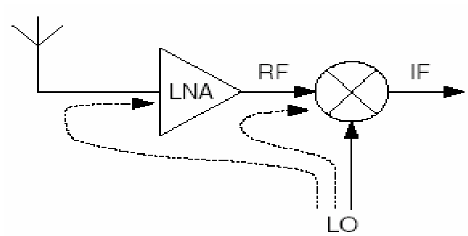

Fig.2 LO to RF leakage

This dc offset can saturate the baseband especially the $V_{GA.}$ The worse case can be when this DC offset is time varying. Another important port leakage is from LO to IF. As said before, LO power is much greater than the IF and RF power levels. If LO - IF isolation is poor, high amplitude LO signal can easily saturate the baseband. RF to LO leakage will allow the interferers and spurs present in the RF signal to interact with the LO, which can cause problems in direct conversion architecture due to the low-frequency even-order intermediation product [4].

IV. PROPOSED UWB MIXER

The active mixer topology is adopted here for the direct conversion receiver because of its superior gain and noise figure compared to the passive mixer. Among the active mixer circuits, the double-balanced Gilbert cell mixer is commonly used in RF applications [5]. It can provide a moderate conversion gain and low noise figure, it also offers good isolation between the RF, LO and IF-ports. The schematics are shown in Fig. 3. The NMOS differential pair, M1 and M2, forms the input trans conductance stage (g_m-stage). The PMOS LO switches, M3 through M6, are folded with respect to the g_m-stage. PMOS devices with moderate W/L are sufficiently fast to completely steer the current from the g_m-stage to the LO switches with reasonable LO amplitudes. The folded topology offers a key advantage over the standard stacked topology for allowing independent settings of the bias currents through the g_m-stage and LO switches [6]. The bias current for the gm-stage should be high enough to achieve the desired CG, NF, and IIP3. However, the bias current through the LO switches should be minimized to suppress DC offset, thermal and 1/f noise. The Vgs of the LO switches is set near V_t to achieve a low bias current and at the same time ensure that the required LO amplitude remains at a reasonable level (350 mV pp) for complete current commutation.

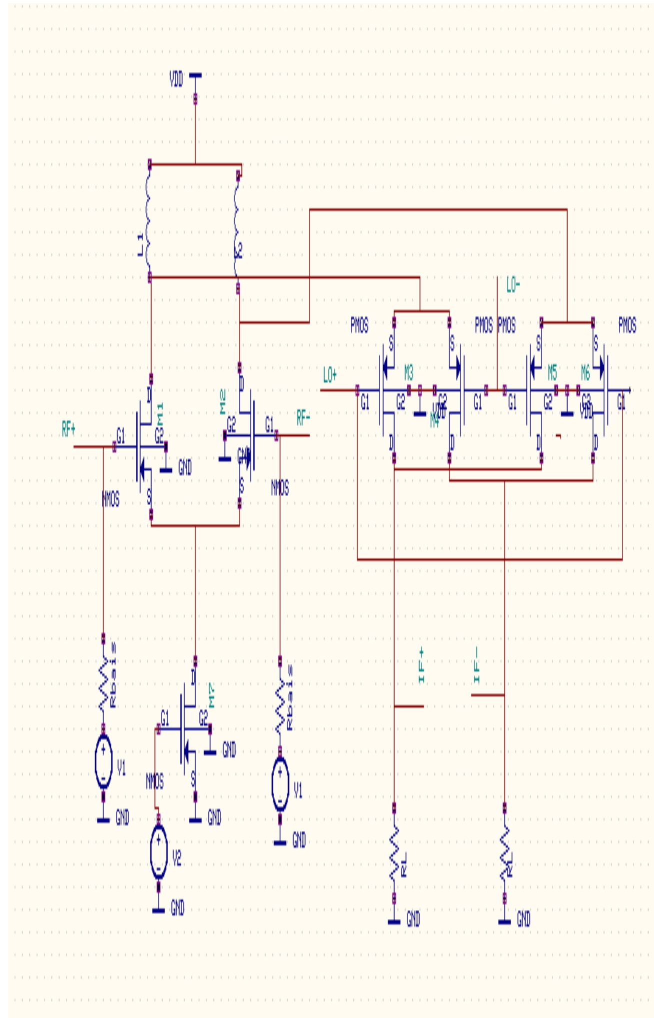

Fig. 3 Proposed UWB Mixer

V. PERFORMANCE OF MIXER: CONVERSION GAIN

A mixer's frequency converting action is characterized by conversion gain (active mixer) or loss (passive mixer). The voltage conversion gain is the ratio of the RMS voltages of the IF and RF signals. The power conversion gain is the ratio of the power delivered to the load and the available RF input power [7]. When the mixer's input impedance and load impedance are both equal to the source impedance, the power and voltage conversion gains, in decibels, are the same. Result is shown in Fig. 4.

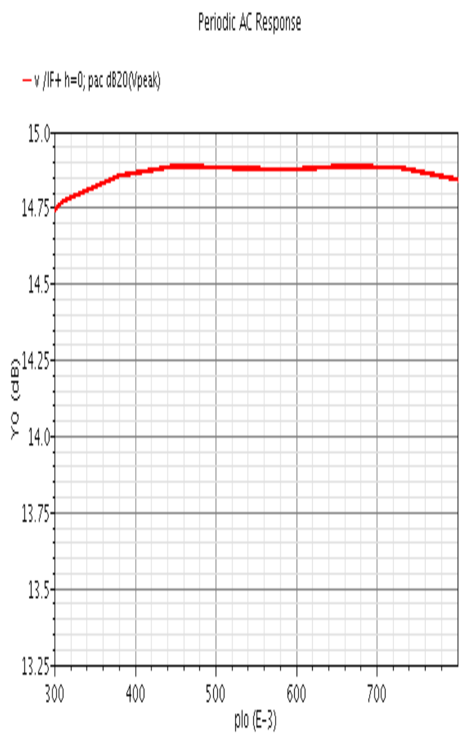

Fig. 4 Conversion gain

The gain is achieved up to 18dB which is Given in fig. 5.

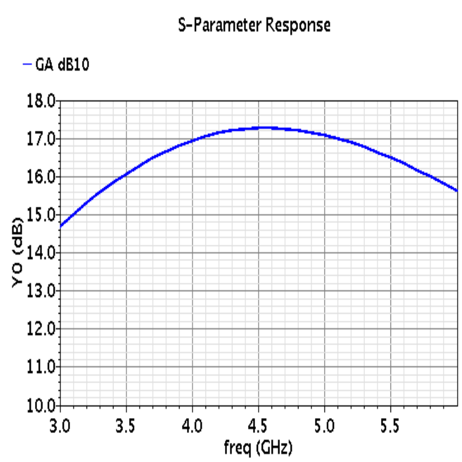

Fig. 5 Gain of Mixer

The noise figure analysis is given in fig. 6

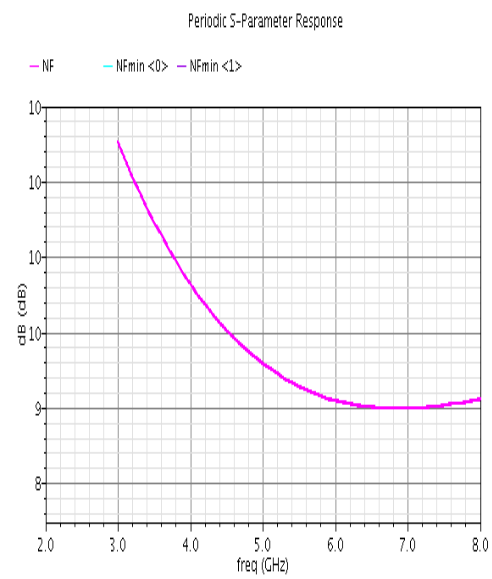

Fig.6 Noise figure of mixer

In small signal conditions the output power increases linearly with increase in the input signal power, when circuits shift toward large signal operation this relation is no longer linear. The 1dB compression point is a measure of this nonlinearity. This is power where the output of the fundamental crosses the line that represents the output power extrapolated from small signal conditions minus 1dB [9]. The recommended approach to calculate the 1dB CP and IIP3 is to apply large LO and one medium RF tone and perform the QPSS analysis then the second tone as a small tone close to the RF signal frequency and perform the QPAC Low power.

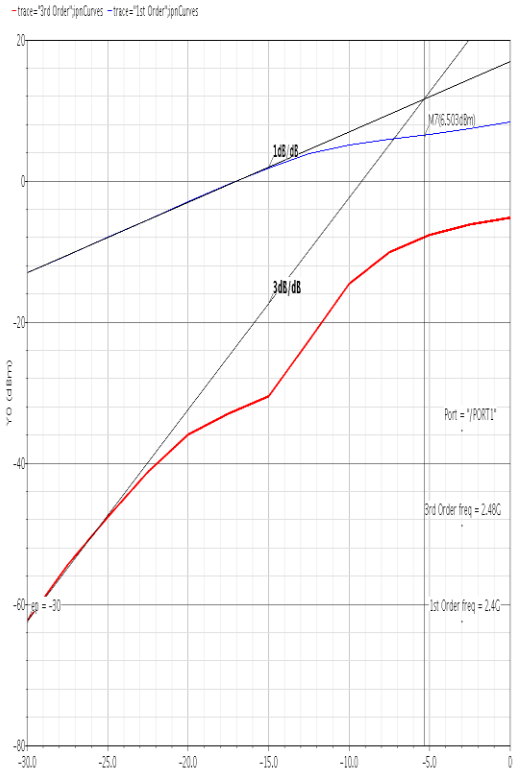

Fig. 7 IIP3 using QPSS and QPAC

Table 1: component value of Mixer:

M_1(W) = 16µ	M_5(W)= 48 µ	L_1= 18.4nH	R_L= 2k
M_2(W) = 16 µ	M_6(W)= 48 µ	L_2= 18.4nH	R_{bais}= 50
M_3(W) = 320 µ	M_7(W)= 48 µ	V_1= 235m	VDD=!.2V

VI. CONCLUSION:

A UWB Mixer is designed and simulated. Tradition Gilbert cell mixer is not provide good isolation between LO and RF port. But in this design mixer provides good isolation because of two separates blocks of RF and LO i.e. g_m stage and switch stage. It maintained the gain of 18 dB, and show better performance in terms of Noise Figure and IIP 3.

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