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DESIGN OF RF FRONT END MIXER CIRCUIT FOR AN ULTRA WIDE BAND RECEIVER

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ABSTRACT: *Ultra-Wideband (UWB) technologies are widely accepted as the center piece of ubiquitous wireless interconnects for next generation Wireless Personal Area Networks (WPAN). It finds potential exciting applications in high-connectivity and high interoperability multimedia consumer products within personal operating space, such as wireless home video distributions systems, and high-speed, high-mobility cable replacement solutions, such as Wireless Universal Serial Bus (W-USB) and wireless IEEE-1394 Fire wire. Many active academic and industrial works have been dedicated to the implementation of UWB transceivers, however, a monolithic UWB radio expanding across full 3.1–10.6 GHz UWB spectrum is yet to be accomplished. Targeting Multi-Band Orthogonal Frequency Division Multiplexing (MB-OFDM) UWB, one of the two major competing industrial UWB standards, this paper focuses on system and circuit co-design of a fully integrated CMOS direct-conversion Mixer with emphasis on architectural issue, and circuit topologies of its RF front-end. In this paper, a CMOS Ultra-wideband mixer was designed and simulated. Specific architecture has been selected Mixer implementation of an Ultra-wideband communication system. The basic architecture of the Mixer maintains a gain of 15dB over the band of 3.1-10.2GHz. The Mixer achieved a Noise figure ranging from 9-9.5dB over the same band of operation.*

KEYWORDS*: UWB, CMOS, MIXER, GAIN*

1. 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. 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 $\omega_2$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. 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, IIP2are the important design parameters to measure the linearity besides the conversion gain and noise figure 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. Therefore, it is not surprising that many different frequency mixers have been used in state-of-the-art literatures. These mixers can be categorized as active/passive, current commutating/ potentiometric, single-balanced/ double-balanced and etc.

MIXER FUNDAMENTAL

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. As discussed before mixer operation is a multiplication in time domain. To illustrate this point consider mixer model of Fig.1

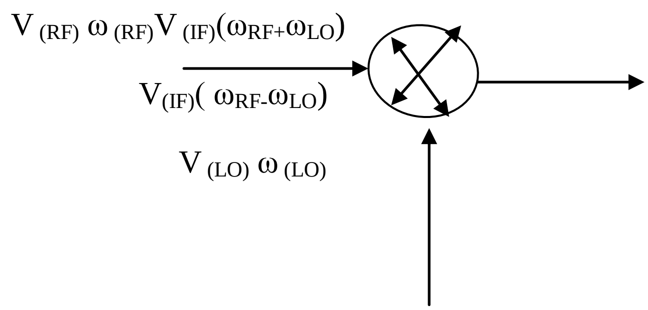

Fig1 Mixer model

The Output of the Mixer Is Given By

$V_{IF}(t) = A_{RF} Cos(\omega_{RF})t*A_{LO} Cos(\omega_{LO})t$

$A_{RF}A_{LO}/2\{Cos (\omega_{RF+}\omega_{LO})t +Cos (\omega_{RF} - \omega_{LO})t\}$

For down-conversion mixers Cos $(\omega_{RF+}\omega_{LO})$ t term is filtered out

Mixer Parameters

Conversion Gain

Conversion gain is defined as the ratio of the desired IF output to the RF input. This gain can be expressed either in terms of power or voltage such as

Voltage Conversion Gain =
Power Conversion Gain=
IF power delivered to the load
Power available from the RF source

For on-chip implementations usually voltage gain is specified. Active mixers are capable of providing both power and voltage gain, whereas passive mixers (except parametric converter) can only provide voltage gain.

NOISE FIGURE ANALYSIS

Noise of a mixer can be expressed in terms of input or output referred noise voltage or power spectral density. Another method is to use a noise metric which is relative to the noise contribution of the source impedance RS. One such metric is noise figure, which for a mixer is defined as a ratio of signal to noise ratio at the RF port to the signal to noise ratio at the IF port of the mixer. There are two ways to calculate the signal to noise ratio at the output of the mixer based on the type of frequency translation.

1. Double Side Band (DSB) Noise Figure
2. Single Side Band (SSB) Noise Figure

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. 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. This dc offset can saturate the baseband especially the VGA. The worst case can be when this DC offset is time varying.

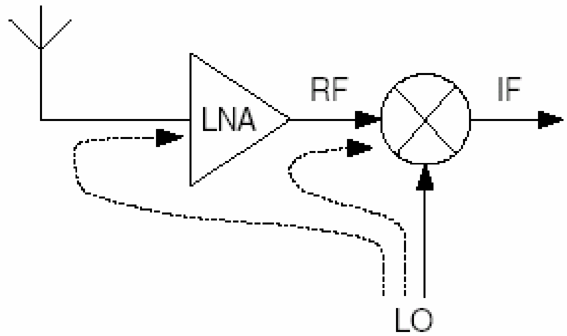

Fig 2 LO to RF leakage

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.

4.2.4 *Linearity*

It is interesting to note that mixer is essentially a non-linear device and still its linearity is important. In a real mixer, in addition to the mixing of the RF and the LO tones, their respective harmonics mix with each other producing the additional tones at the output. These additional tones can fall in the IF band and can degrade the signal. This is especially important in wide IF band mixers.

Similar to linearity metrics in RF amplifiers, linearity of the mixer is measured in terms of 1-dB compression point (P1dB), second and third order intercepts points (IP2 and IP3), spurious free dynamic range (SFDR) and compression free dynamic range(CFDR).The second-order linearity of mixer is more interesting to study. One significant mechanism comes from the self-mixing, which is resulted from capacitive coupling (finite isolation) between RF and LO ports. Besides self-mixing, both RF trans conductor and switching pairs introduce even order nonlinearity.

ULTRA WIDEBAND MIXER

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. 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.

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. To improve the overall DCR performance, the combined front-end gain of LNA and mixer needs to be sufficiently high (> 20 dB) to improve the SNR of the receiver signal. 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 LNA to the input is not enough.

4.4 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. Not only it can provide a moderate conversion gain and low noise figure, it also offers good isolation between the RF, LO and IF-ports. The port-to-port isolations are very important to the performance of direct conversion receiver. Tradition Gilbert cell mixer is not provide good isolation between LO and RF port .But in my design i.e. modified of Gilbert cell mixer provides good isolation because of two separates blocks of RF and LO i.e. Trascoductance stage and switch stage.

The schematics are shown below as fig 3. The NMOS differential pair, M1 and M2, forms the input Trascoductance stage (g_m-stage). The PMOS LO switches, M3 through M6, are folded with respect to the gm-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. 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/fnoise. 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 mVpp) for complete current commutation. The small bias current in the LO switches also allows the usage of large load resistances to increase the CG without consuming large IR drop from the limited voltage headroom. This work demonstrates that a low-power, high performance UWB down-conversion mixer can be realized using 0.13-µm CMOS technology. The folded topology utilizing PMOS devices in the switching stage and broadband RF chokes for biasing is shown to be an effective technique for both low-voltage and wideband operation. The proposed mixer topology can also suppress the impact of device mismatch on DC offset. The key sources to the mixer DC offset are measured systematically using a multi-step procedure under different excitations.

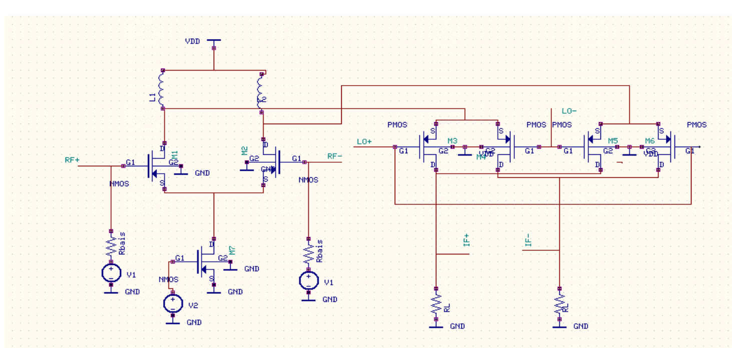

Fig.3 Proposed UWB Mixer

SIMULATIONS AND PERFORMANCE OF MIXER

This work demonstrates that a low-power, high performance UWB down-conversion mixer can be realized using 0.13-μm CMOS technology. The folded topology utilizing PMOS devices in the switching stage and broadband RF chokes for biasing is shown to be an effective technique for both low-voltage and wideband operation. The proposed mixer topology can also suppress the impact of device mismatch on DC offset. The key sources to the mixer DC offset are measured systematically using a multi-step procedure under different excitations. Mixer circuits are designed and simulated in this project. In MIXER, the two-stage cascode topology is selected, so that the mixing can be done in two steps. . The NMOS differential pair, M1 and M2, forms the input Trascoductance stage (gm-stage). The PMOS LO switches, M3 through M6, are folded with respect to the gm-stage. PMOS devices with moderate W/L are sufficiently fast to completely steer the current from the gm-stage to the LO switches with reasonable LO amplitudes. The simulated results of Mixer are presented in Figure4 to Figure.7.The voltage conversion gain, noise figure, and IIP3 are 8.2 dB, 9.0 dB and -6.5dBm respectively. All the data is based on an LO input of300 mVpp.

4.5.1 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**.** When the mixer's input impedance and load impedances both equal to the source impedance, the power and voltage conversion gains, in decibels, are the same. Note that when you load a mixer with a high impedance filter, this condition is not satisfied. You can calculate the voltage conversion gain in two-way: Using a small signal analysis, like PSS with PAC or PXF. The PSS with PAC or PXF analyses supply the small-signal gain information. A second method is to use a two tone large-signal QPSS analysis which is more time-consuming.

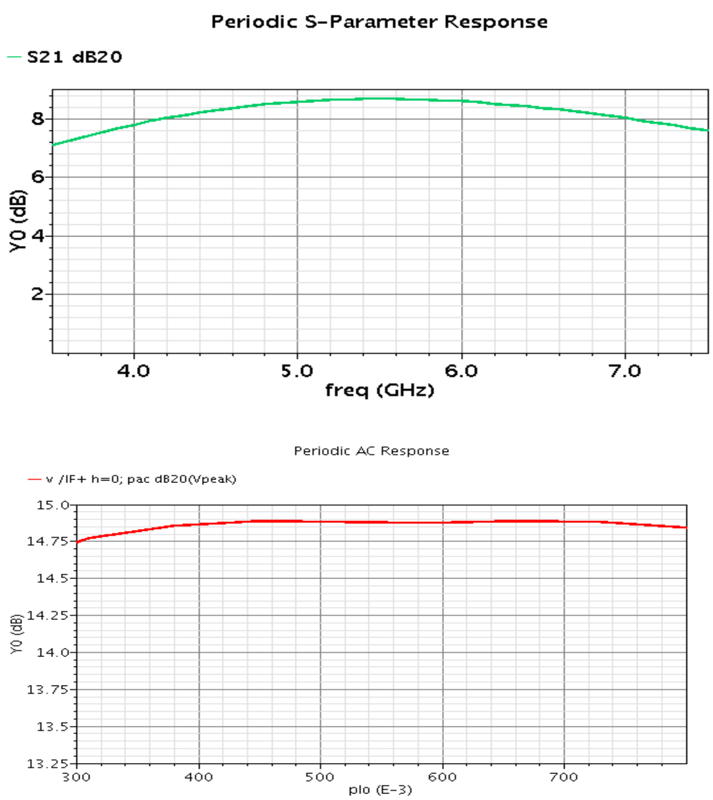

Fig.4 Conversion gain with respect to LO power

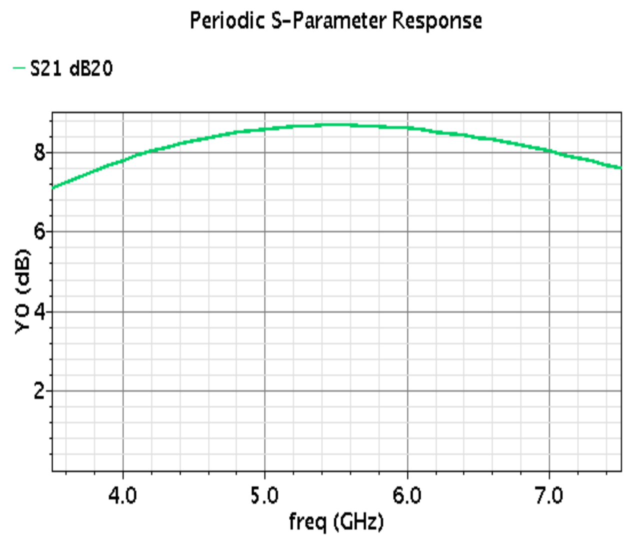

Fig.5Gain over frequency range 3.5G to 7.5G

However, in some applications (direct conversion receivers) the signal present at the image frequency contains useful information, and hence the NFDSB is measured and calculated.

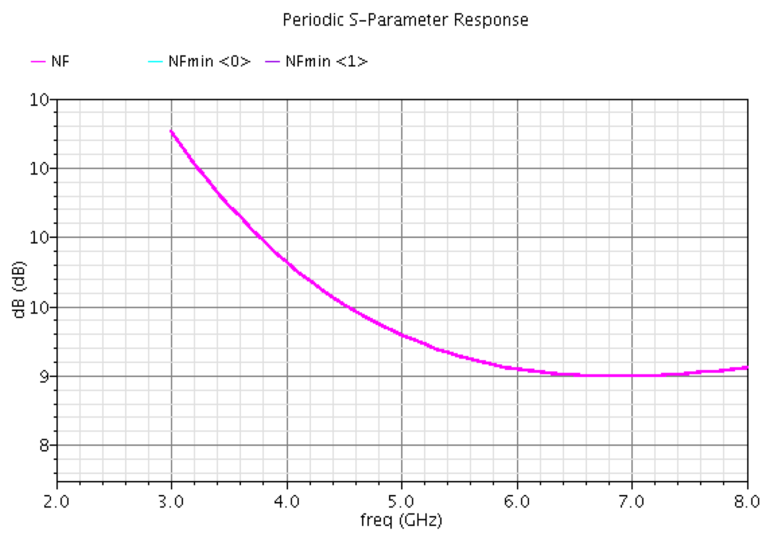

Fig 6 Noise Figure of Mixer

IIP3

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.

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 you apply the second tone as a small tone close to the RF signal frequency and perform the QPAC.

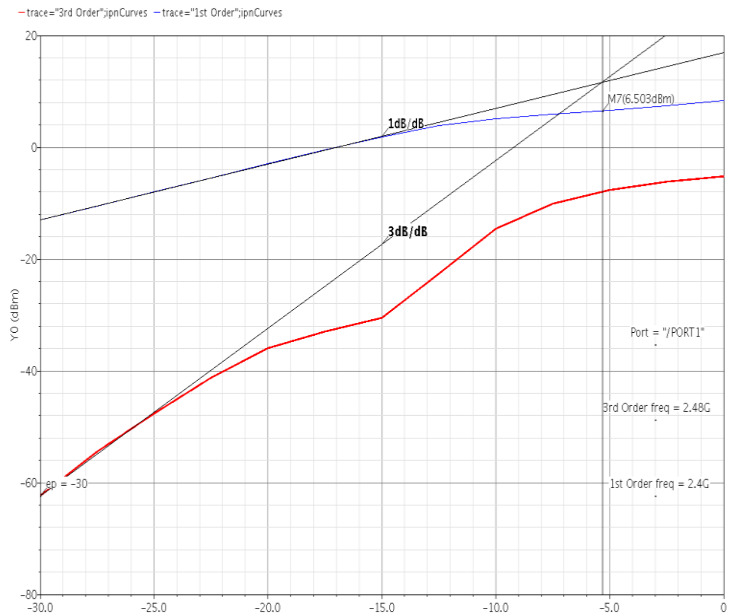

Fig 7 IIP3 using QPSS and QPAC

CONCLUSION

Tradition Gilbert cell mixer is not provide good isolation between LO and RF port .But in my paper i.e. modified of Gilbert cell mixer provides good isolation because of two separates blocks of RF and LO i.e. Trascoductance stage and switch stage. The NMOS differential pair, M1 and M2, forms the input Tran's conductance stage (gm-stage). The PMOS LO switches, M3 through M6, are folded with respect to the gm-stage. PMOS devices with moderate W/L are sufficiently fast to completely steer the current from the gm-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 gm-stage and LO switches. All simulation results are shown in figure.

COMPONENT VALUE OF MIXER

M_1(W)= 16u	M_5(W)= 48u	L_1= 18.4nH	R_L= 2k
M_2(W)= 16u	M_6(W)= 48u	L_2= 18.4nH	R_{bais}= 50
M_3(W)= 320u	M_7(W)= 48u	V_1= 235m	VDD=1. 2V
M_4(W)= 48u		V_2= 980m	

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