A 4.0-12.0 GHz Low Power High Gain UWB LNA Using Current Reuse Technique

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***Abstract*—** In this paper, a high, flat gain and low noise factor for a 4-12 GHz single ended ultra-wideband low noise amplifier (LNA) applications. The proposed LNA uses current reuse technique for low power consumption, high and flat gain. To achieve wideband input matching, the shunt-shunt resistive feedback and degenerative parallel LC technique are used. The output matching is achieved by using cascaded LC technique. The proposed LNA dissipates 6.35 mW under supply voltage of 1.8 V, achieves the input reflection S11 below 14.11 dB, while the output reflection S22 below 16.28 dB, the gain S21 15.44-16.76 dB, and the noise figure NF 1.30-2.58 dB. This LNA is designed and simulated by a TSMC 0.18 m process.

Keywords *- Low noise amplifier (LNA), ultra-wideband (UWB), current reuse, cascaded LC technique*.

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I. INTRODUCTION

IN 2002 the Federal Communications Commission (FCC) has approved Ultra-Wideband (UWB) technology for commercial applications with allocated band 3.1 to 10.6 GHz. The new technology (UWB) supports the applications that need high data-rate wireless communication, high security, low power consumption, and low cost capabilities. To achieve these requirements or these specifications of UWB, the first block of the receiver is the most sensitive block, a wide band low noise amplifier (LNA) that is required to amplify the very low power signal that is coming from antenna and decrease the noise as possible. The design of the UWB LNA is one of the challenges in radio frequency integrated circuit (RFIC) field, which needs to provide and improvement the high and flat gain, good input matching, good output matching, low noise factor, low power consumption, small die area, and overall specifications have high figure of merits (FOMs). In recent years, many UWB LNAs have been reported [1-6] such as current reuse technique [1-3], which achieves high and flat gain and low power consumption for wideband LNA. Dual-RLC-Branch technique [3, 6], which achieves wideband input matching and low noise figure (NF). Cascode and cascade techniques [2-3], to control wideband gain and output matching network. This paper is organized as follows. In Section II, the description of the proposed UWB LH-LNA is presented.

The simulation results and conclusions are illustrated in Section III and Section IV, respectively.

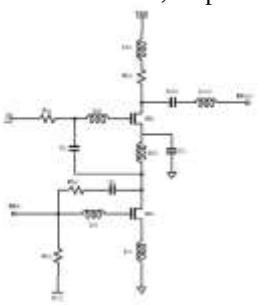
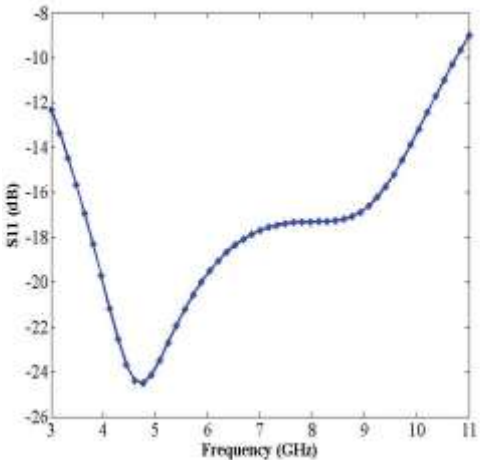
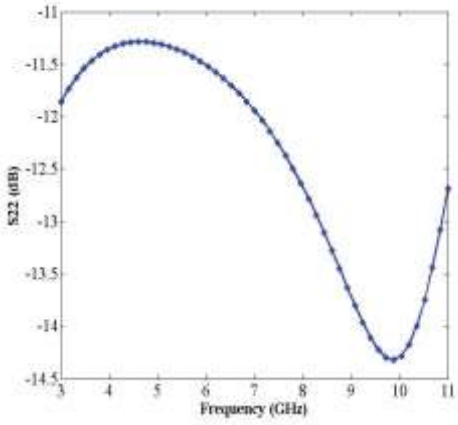


Fig.1 Proposed UWB LH-LNA

II. CIRCUIT DESIGN OF UWB LH-LNA

Fig.1 shows the proposed UWB LH-LNA. It consists of two stages form common source (CS) topology and overall design construct cascode architecture. The main advantages of cascode architecture are high and flat gain and low noise figure, but it has a big problem specifically; high power consumption, current reuse is used to solve this problem in the proposed UWB LNA.





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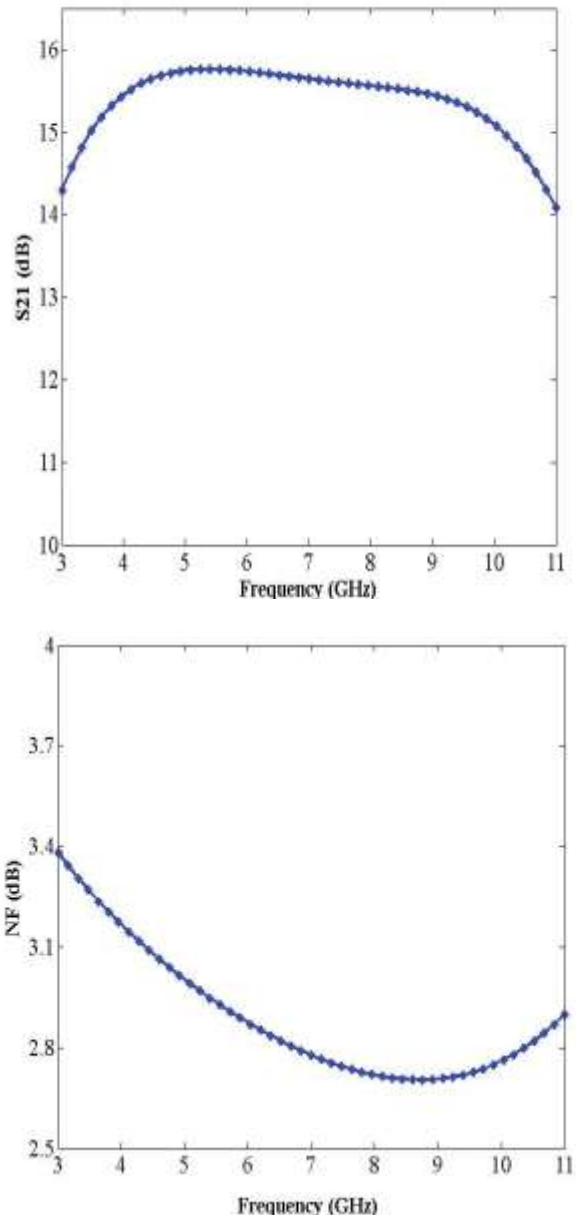

Fig. 2 The simulated (a) Input matching S11, (b) Output matching S22, (c) Gain S21, and (d) Noise NF versus frequency characteristics of the 3.1 _ 10.6 GHz CMOS UWB LH-LNA

A. Current Reuse Theory

The current reuse architecture proposed to solve some problems as reverse isolation between input and output, small gain, and large power consumption. It depends on decreasing the sources of driving current by using the dc current of the output stage in the input stage. There are different types of current reuse architecture as [1-3] the HL-LNA based on methodology in [2, 3].

B. Circuit Design

The objective of the first CS stage provides input return loss to 50 _ by adapting the RFB, the source degeneration inductive element LS1, and the channel of M1 transistor and by selecting appropriate values the input matching is will be good, the equations behave S11:

$$S_{11} = \frac{Zin - RS}{Zin + RS} \qquad (1)$$

$$Zin = \left(\left(\frac{L_{G1} + L_{S1}}{LD1gn} \frac{RFB}{n1} \right) + S \frac{(L_{G1} + L_{S1})}{gm_1} + \frac{1}{S} \frac{(L_{G1} + L_{S1})}{gm_1 LD_1 C1} + \frac{1}{gm1Cgs1} + \frac{L_{G1} R_{FB}}{C_{gs1} L_{d1}} \right) \qquad (2)$$

Then S11 given by:

$$S11 \approx \frac{S^2 + S\left(\frac{RFE}{L_{D1}} + \frac{L_{s1} g_{m1}}{C_{gs1}(LG1 + L_{S1})} - Rs \right) + \left(\frac{1}{L_{D1} C_1} + \frac{1}{C_{gs1}(L_{G1} + L_{S1})} + \frac{gm1RFBL_{s1}}{Cg_{s1}(L_{G1} + L_{S1})} \right)}{S^2 + S\left(\frac{RFE}{L_{D1}} + \frac{L_{s1} g_{m1}}{C_{gs1}(LG1 + L_{S1})} - Rs \right) + \left(\frac{1}{L_{D1} C_1} + \frac{1}{C_{gs1}(L_{G1} + L_{S1})} + \frac{gm1RFBL_{s1}}{Cg_{s1}(L_{G1} + L_{S1})} \right)} \qquad (3)$$

The second objective of the first stage provides noise figure as low as possible by choice appropriate values for M1 transistor, LS1, and LG1 as shown in equation (4).

$$F \approx 1 + \frac{R_{FB} \left(Y_{gm1+} + \frac{1}{RLD_1} + \frac{SLD_1}{R_{FB}} \right)}{SL_{D1} g^2 m1 \left(R_{FB} \right) + S^2 + L^2 D1} \frac{1}{\left(\frac{1}{Rs} + \frac{1}{RFB} + \frac{1}{RLG_1} + \frac{1}{RLS1} \right) Z_{tn}^2} \qquad (4)$$

Where the second part, CS stage M2, which improves the flatness of gain, amplify the output signal of M1, and 50 _ output matching. To achieve high and flat gain by selecting appropriate channel of M2 transistor, drain inductor LD2 and resistor RD2, and gate inductor LG2. The gain of proposed UWB LH-LNA is presented in equation (5). C1 and C2 are AC coupling paths for signals into M1 and M2, respectively. Co helps a high frequency ac current into source of M2 goes to ground and thus helps to avoid interference coupling back to M1 [3].

$$AV = gm1gm2 \frac{SL_{D1} \left(SL_{D2} + R_{D2} \right)}{S^2 C_{gs} L_{G2} + \left(\frac{C_{gs2}}{C_2} + \frac{C_{gs2}}{C_0} \right)} \qquad (5)$$

The UWB LH-LNA is designed by TSMC 0.18_μm and the component parameters of UWB LH-LNA are listed in table 1.

III. RESULTS AND DISCUSSION

The UWB LH-LNA supplied by 1.2 V and consumed 7.21 mA. Fig. 2(a) and Fig. 2(b) show the simulated S11 and S22 versus frequency characteristics of the UWB LH-LNA, respectively. S11 of -12.6 ~ -24.5 dB and -11.28 ~ 14.32 dB were achieved over the 4.0 _ 12.0 GHz band of interest. The simulation result shows, both S11 and S22 are lower than -12dB, which means that LH-LNA works in good input matching and output matching, the reason of this is due to the choice of appropriate values for the input matching network(M1, LG1,LS1, CS1, and RFB) and the output matching network (M2,

LG2,LD2, Co, COUT, and LOUT). Fig. 2(c) shows the simulated 6,_versus frequency characteristics of the UWB LH-LNA. High and flat 6,_ of 15.44 ~ 16.76 dB was achieved over the 3.1 _10.6 GHz band of interest. The flatness of S21 15.1 ± 0.65 dB due to use the current reuse technique and cascade architecture. Fig. 2(d) shows the simulated 78 versus frequency characteristics of the UWB LH-LNA. Low NF of 2.7 ~ 3.38 dB was achieved over the 4.0 _ 12.0 GHz band of interest. 78 mainly effected by first stage especiallyM1, RFB, and gate resistance. Table 2 is a summary of the CMOS UWB LH-LNA, and the recently reported state-of-the-art CMOS UWB LNAs. It can be seen, that our CMOS UWB LH-LNA exhibits good input and output matching S11, high and flat S21, low NF, and low power consumption and for fair comparison between UWB LH-LNA and different LNA topologies the figure of merits (FoMs) calculated in [5] from the following equation:

$$FoM = \frac{\text{Gain avreage X BW}\left[\text{GHz}\right]}{\text{Pac}\left[\text{mW}\right] \text{X} \left(\text{Faverage}^{-1}\right)} \quad (6)$$

Where Gain average is the average gain, BW is the desired bandwidth, Pdc is the power consumption, F average is the noise factor of LNA.

IV. CONCLUSION

The UWB LH-LNA circuit using current reuse technique has been proposed. It has designed and simulated by a TSMC 0.18 _m process for UWB impulse-radio receivers. This paper focus on low power consumption and noise figure, high and flat gain, and good input and output matching. The low power, high, and flat gain achieved by taking the advantage of current reuse technique. The low noise figure and good input matching achieved by controlling shunt-shunt feedback resistive, M1 transistor, and input LC (LG1, LS1, and Cgs1) network. Good output matching is achieved by adding cascaded LC (LOUT and COUT)

Table 1: Parameters values for proposed CMOS UWB LH-LNA

Parameters	*Value*	*Parameters*	*Value*
(W/L)M1	*160 m/0.18*	L_{D2}	*1.59nH*
(W/L)M2	*12 /0.18*	R_{D2}	*25*
L_{s1}	*12]pH*	R_{FB}	*500*
L_{G1}	*838pH*	C_1	*800fF*
R_{G1}	*2K*	C_2	*3pF*
L_{D1}	*5.277nH*	C_0	*5pF*
L_{G2}	*960.7pH*	*Cout*	*9.1pF*
R_{G2}	*3k*	*Lout*	*432.7pH*

Table 2: A Summary of the proposed CMOS UWB LH-LNA, and the recently reported CMOS UWB LNAs

	This work	*[1]*	*[2]*	*[3] (LNA-1)*	*[4] (LNA1)*	*[5] (ST CGLNA)*
year	*2012*	*2011*	*2010*	*2010*	*2010*	*2009*
Tech. CMOS	*0.18*	*0.18*	*0.18*	*0.18*	*0.18*	*0.13*
BW (GHz)	*3-11*	*3-11 3.1 - 10.6*	*3.1 - 10.6*	*2.9-7.1*	*2.8 -6.2*	*3 -11*
Vdd(V)	*1.2*	*1.5*	*1.5*	*1.8*	*0.9*	*1.3*
S11(dB)	*<- 10.61*	*<-10*	*<- 13.5*	*<- 11.8*	*<-9*	*<-7.5*
S21(dB)	*14.44-15.76*	*15.6*	*7-12*	*11.2 ±2.3*	*11.5*	*7-10*
S22(dB)	*<- 11.28*	*<- 10.5*	*<- 10.1*	*<- 12.7*	-	-
Power (mW)	*8.65*	*14.1*	*4.5*	*10.34*	*2.5*	*2.4*
NF (dB)	*2.7-3.38*	*2.8-4.7*	*5.27-7*	*3.61-4.68*	*3.8*	*2.9-3.6*
FoM I	*33.89*	*14.083*	-	-	*13.7336*	*22.3*

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