ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 9, September 2015

DESIGN OF VLSI BASED 3.0-10.6-GHZ CMOS ULTRA-WIDEBAND LOW NOISE AMPLIFIER USING SHUNT FEEDBACK TECHNIQUE

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ABSTRACT: This paper introduces an Ultra-wideband Low Noise Amplifier (UWB LNA) with high gain and low noise figure for wireless communication system receivers in 3.0-10.6 GHz range of Ultra-wideband frequency. For the designedUltra-wideband Low Noise Amplifier following parameters are calculated, the input return loss (S_{11}) less than -6.5dB,reverse isolation(S_{12}) of UWB LNA is 47$\pm$30 dB, the maximum gain (S_{21}) greater than 12dB, the output return loss (S_{22}) less than -8.5dB and Noise Figure (NF) of designedUWB LNA is 2.275dB. The schematic ofUWB LNAis designed using United Microelectronics Corporation (UMC)0.18µm CMOS technology file. All the simulation results are carried out on Cadence SPECTRE tool.

KEYWORDS*:* Low Power, Linearity, CMOS, Ultra-wideband (UWB), LowNoise Amplifier (LNA) and Analog electronics.

I. INTRODUCTION

Ultra–Wideband (UWB) systems are a new technology capable of transmitting data over a wide range of frequency band with very low consumption of power and high rates of data processing [6]. Ultra-Wideband systems are widely used in imaging systems, vehicular and ground-penetrating radars, and Communication systems. This technology replaces almost every cable at office and home withWirelessconnections that features hundreds of megabits of data per second. Although the Ultra-Wideband standard [4] has not completely defined, the most proposed applications are allowed to transmit a signal in a band range between 3.0-10.6GHz. Two possible approaches have emerged to exploit the allocated spectrum. First is “multiband” approach, with fourteen 500-MHz sub bands, OFDM modulation and possibly a frequency-hopping scheme.[7] And other one is called “impulse radio”, based on the transmission of very short range of pulses, with pulse position or polarity modulation[3].
Recently, RF-CMOS processes have become more and more popular for RFICs design because it is cost-effective and compatible with the silicon-based system on chip (SOC) technology. In Ultra-Wideband receiver front end design, Ultra-wideband Low Noise Amplifier is a critical block that receives small signal from the whole UWB Band (3.0-10.6GHz) and amplifies it with a good signal-to-noise ratio. A Low Noise Amplifier should accommodate large signals without distortion, and frequently must also present specific impedance, such as 50Ω, to the input source. In additional, high and flat power gain, input and output impedance matching and good noise figure performances across the whole UWB band are required. Recently, several CMOS UWB LNAs have been reported[9]. Low and flat Noise Figure (NF) performances across the whole UWB band are required. For an UWB LNA designed in OFDM systems, power linearity is a tight requirement for

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suppressing adjacent channel interferences, while it is relaxed in the UWB pulse-radio system. Many wideband input-matching networks for UWB LNAs have been proposed lately. For instance, a wideband input matching with small power dissipation and die size can be realized by the common-gate input topology.

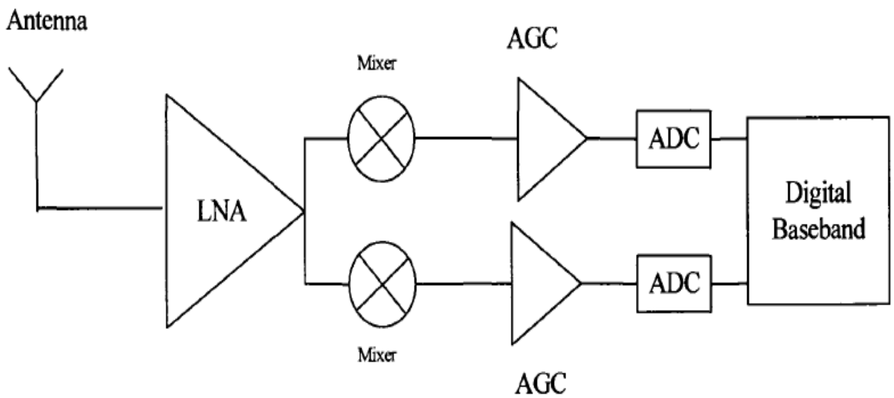

Figure 1: Basic block diagram of UWB Receiver

Nevertheless, it was found that single-stage common-gate amplifier cannot provide sufficient power gain, and extra stages are required to boost the gain, resulting in ripples in the pass-band due to the non-broadband inter-stage matching [5].

II. PROPOSED DESIGN AND CIRCUIT DESCRIPTION

The designed circuit of Ultra-wideband Low Noise Amplifier shown below in fig.2

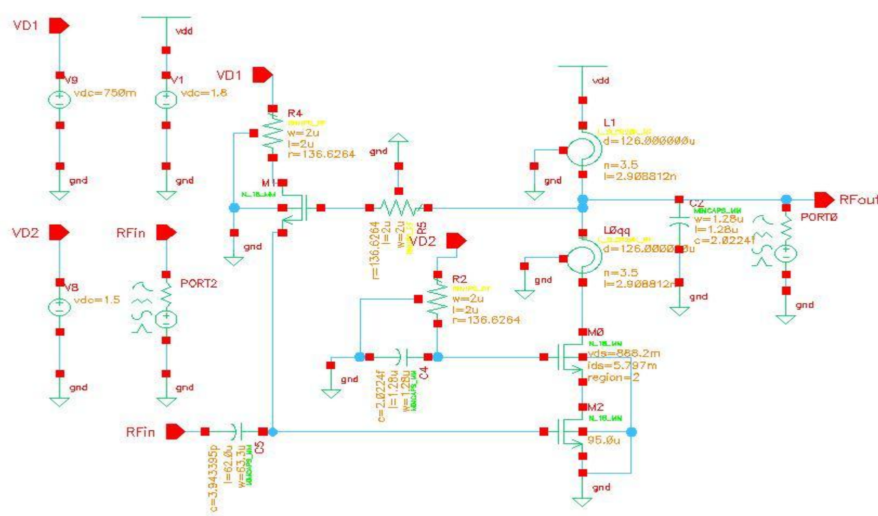

Figure 2: Schematic of UWB LNA

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Vol. 4, Issue 9, September 2015

An UWB LNA using feedback amplifier with wideband, flat gain and small size is design. The feedback capacitor supersedes by a transistor in this active shunt feedback technique. The active shunt feedback technique for wideband matching not only tends to flat gain but also increase the isolation from input to output. The feedback resistance ($R_{feedback}$) is determined by feedback amplifier to get a 50Ω matching and decrease the Noise Figure(NF) by using few number of matching device. The proposed UWB LNA is suitable for both the UWB pulse radio and OFDM system applications. The proposed UWB LNA consists of cascade amplifier (M_1& M_2) with a feedback amplifier M_3[1]. Two inductors determine the output response at the output of the system. Capacitor C_1 is the bypass capacitor. M_2 behaves as a common gate circuit. The feedback transistor M_3 is used to improve isolation between input and output.
The cascode amplifier and common drain feedback amplifier form a negative feedback network to increase stability of the circuit. The resistance $R_{feedback}$represent the miller equivalent theory input resistance of the feedback network.

A. Design issue

The input impedance of the proposed UWB LNA is

$$Z_{in} = R_{feedback} \parallel Z_{cascode} \quad \text{......................... (1)}$$

Where,$R_{feedback}$represent impedance of the feedback network and $Z_{cascode}$ correspond to cascade amplifier since in parallel combination low value will dominate. The input impedance of proposed UWB LNA Z_{in} is dominated by low impedance of the feedback network [2]. The $R_{feedback}$ is determined by gm_3 and size of transistor M_3 by selecting proper value of gm3 and adjusting the size of M_1. Input matching network of impedance 50ohm can be achieved.
For wideband input matching it requires the quality factor for the input matching network should be low to increase the bandwidth response. The Q factor of the resistive shunt feedback LNA can be expressed as

$$Q \approx \frac{1}{R_s + \left(\frac{1-A_v}{R_{feedback}}\right).\omega_0.C_{gs1}} \approx \frac{R_{feedback}}{1-A_v} \quad \text{............ (2)}$$

Where $R_{feedback}$ is feedback resistance and A_v is the open loop gain.

According to eq. (2) low feedback resistance that is low $R_{feedback}$and high A_v can be reduced the input network Q factor to increase the bandwidth. By proper selecting size and biasing of transistor M_3 the proposed UWB LNA has wideband input matching. The active feedback network reduce Q factor for wideband output matching network for bandwidth extension.

For shunt feedback LNA, the Noise Figure can be calculated as [3]

$$NF \approx 1 + \frac{\Upsilon_{gm}}{R_s .g_m} + \frac{1}{R_s .\ R_L .\ g_m^2} + \frac{4\ .R_s}{R_{feedback}}\left(\frac{-1}{1+\frac{R_{feedback}\ +R_s}{(1+g_m\ .R_s)R_L}}\right)^2 \quad \text{............... (3)}$$

Where γ_{gm} = Noise excess parameter of M1

R_L = Impedance of load network

$R_{feedback}$ = Feedback resistance of the network

According to eq.(3) high $R_{feedback}$ yield a low Noise Figure. However high $R_{feedback}$ reduces bandwidth and therefor there exist a trade-off between NF and bandwidth. By selecting proper value of gm_3 and R_2, the proposed LNA can achieve wideband matching; the proposed LNA can achieve wideband matching applicable noise figure and flat gain. Two voltage

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biasing $bias_1(V_{b1})$ and $bias_2(V_{b2})$ are need for proposed UWB LNA design. Voltage $bias_1(V_{b1})$ used to operate common drain transistor M_3. Proper biasing of M_3 help to achieve wideband input matching. Second voltage $bias_2(V_{b2})$ operate common gate transistor M_2 arranged with M_1 as cascade configuration. The NF of LNA is increase if the noise from biasing source is not filtered out. This can be done by using appropriate filtering capacitor. Also an external bias from external power supply can increase the IIP3 of LNA compared to LNA with on chip bias.

B. Circuit optimization

The element sizes and dimensions directly influence the performance of the system. Since Trans- conductance and drain current value depending on the size of the transistor and mode of operation. Also slightly change in value of passive element make great change [7]. Consider the drain current value for any transistor it is given by increasing the gain but it will also increase the noise figure value because it will increase the drain current noise. Noise figure increase with the frequency of operation hence it should be adjusted to limit maximum Noise Figure.Resistance(R_4)provide additional feedback resistance together with transistor M_3. Value of $R_{feedback}$ set trade-off between bandwidth and noise figure. Feedback transistor M_3 set trade-off between gain (S_{21}) and input isolation (S_{11}), increase in transistor size result increase in gain but it will also increase input isolation (S_{11}) coefficient. Size of transistor M_2 mainly influences the bandwidth. Two inductor L_1 and L_2set to resonate at particular value. Out of two, inductor L_1 used to resonate so that give narrow band response whiles inductor L_2 resonate to give wideband response. The combine response is to determine the gain and bandwidth of the LNA two inductor partially cancel the parasitic capacitance at the input of the LNA, which would otherwise affect the impedance matching at the high frequency. Since inductor used to occupying large die area therefor it is necessary that inductor size should be as small as possible without affecting least design parameter requirement. Dimension value of the transistor is summarized below with length fixed to 0.18µm.

III. SIMULATION RESULTS

For the proposed UWB LNA, following parameters are estimated S-Parameter i.e. S_{11} =Input isolation, S_{12} = reverse isolation, S_{21} = Max. Gain, S_{22} = output return loss and Noise Figure (NF). All the simulated results are obtained using Cadence Spectre Simulator.

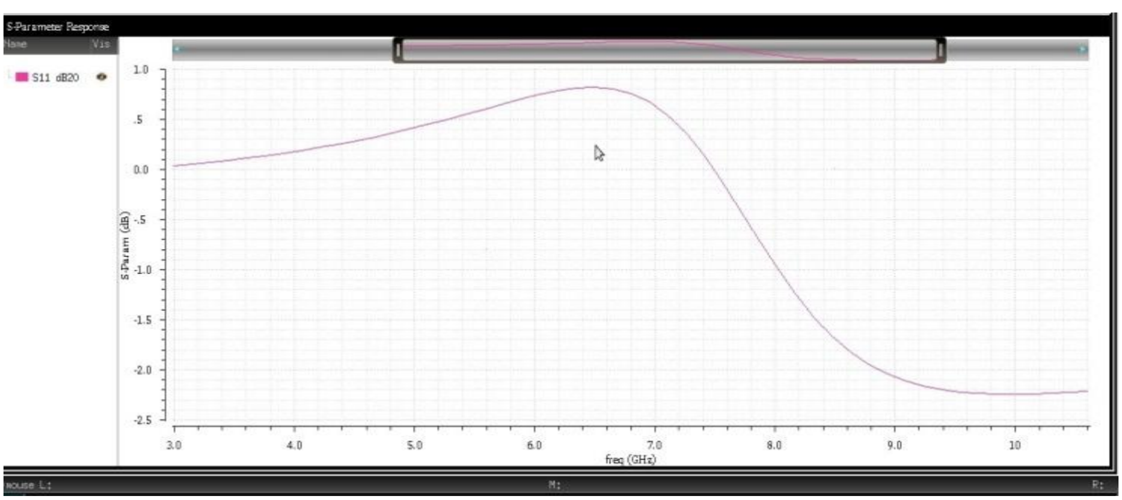

Figure3: S_{11} (input isolation) versus Frequency Curve

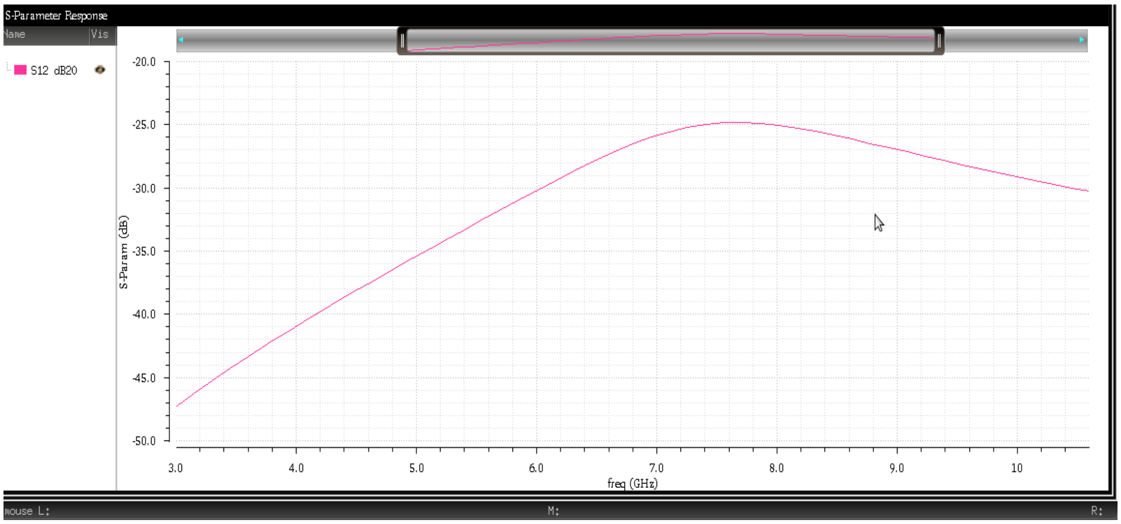

Figure4: S_{12} (reverse isolation) versus Frequency

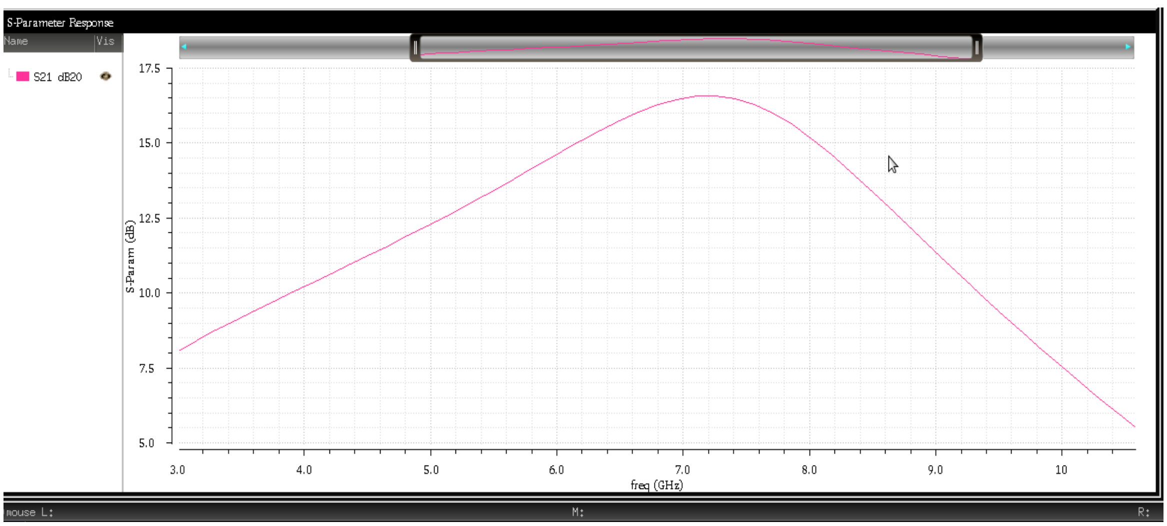

Figure5 : S_{21} (gain) versus Frequency

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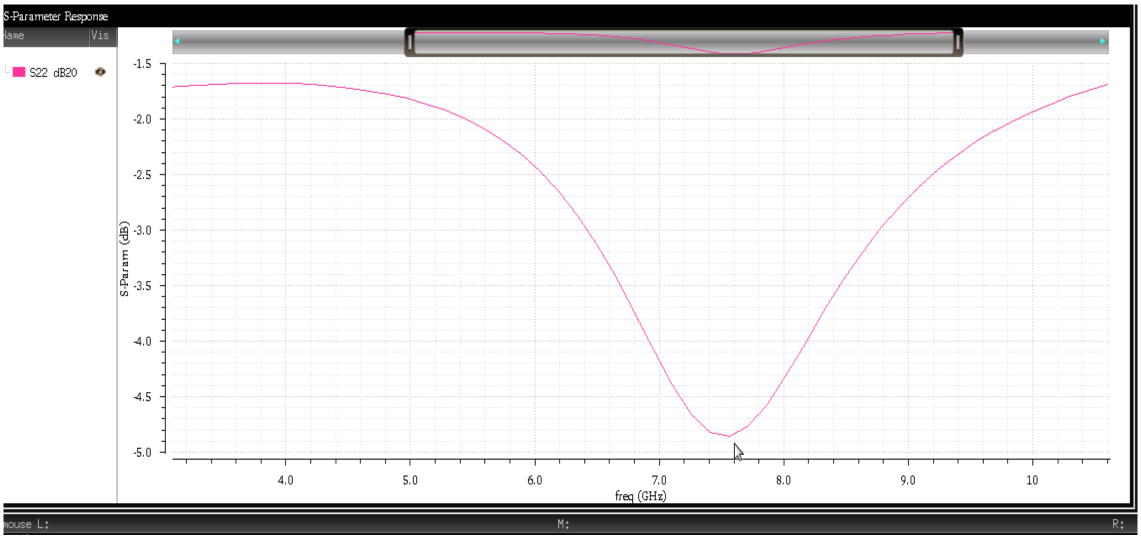

Figure 6: S_{22} (output return loss) versus Frequency

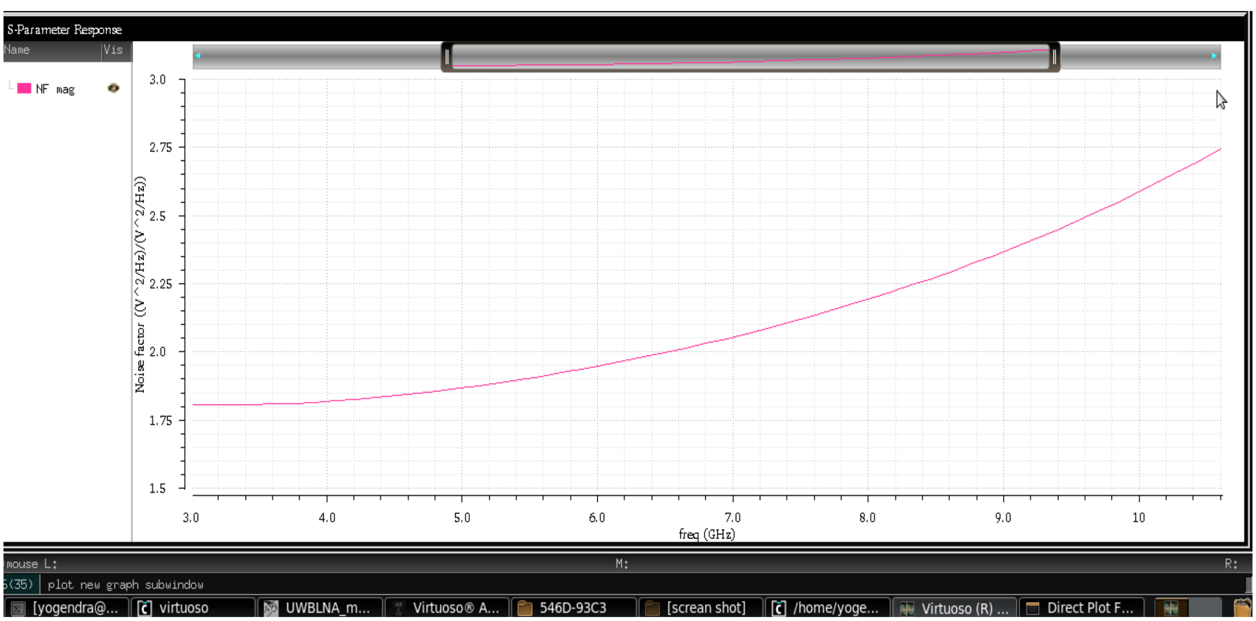

Figure7: Noise Figure (NF) Of LNA

Layout of designed Ultra-wideband LowNoise Amplifier as shown in figure 8.Layout design process done for the post simulation of the designed circuit using layout editor tool in cadence.

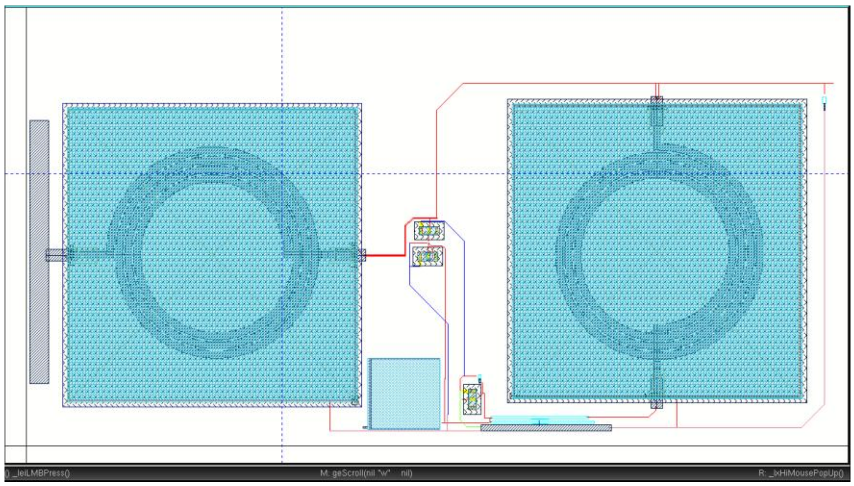

Figure8: Layout of designed UWB LNA

IV. CONCLUSION

Through this research, the compact low cost low power UWB CMOS low noise amplifier based on Active shunt feedback technology were developed, with the tuneable operating frequency band. The designed UWB circuit have the potential applications in short range communication.

Reference	[5]	[2]	[1]	[3]	This Work
Technology (µm)	0.18 CMOS	0.18 CMOS	0.18 CMOS	0.18 CMOS	0.18 CMOS
Frequency (GHz)	2-9	0.5-11	3.0-10.6	3.0-10.6	3.0-10.6
S11 dB	<-10	<-9	<-12	<-8.6	<-2.3
S12 dB	NA	NA	NA	<-26	<-38.1
S21(Max. Gain) dB	10.2	10.2	13	12.89	16.7
S22 dB	<-8	NA	<-14	<-10	<-4.8
NF_{min}	3	3.9	4	3.74	2.275
Area (mm^2)	211.45	NA	202.575	NA	208.105
Power Dissipation(mW)	22	14.4	4.6	10.34	12.25

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