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Design and Comparison of Wide Band and Narrow Band Low Noise Amplifier for Wireless Communication Systems

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Abstract:
The receiver of wireless communication system has a key component called LOW NOISE AMPLIFIER. For wireless communication the signal at receiver point is comparatively week, so good gain and noise performance are necessary at the receiving end. In general signal from antenna goes to BAND PASS FILTER followed by LOW NOISE AMPLIFIER in wireless communication system. The desired signal at the receiver antenna is in the range of microvolts and should be amplified. This amplification should be completed with minimum additional noise using LOW NOISE AMPLIFIER. In this paper we have designed Wide band and Narrow band LNA and brief comparison is also discussed. We have simulated both Wideband and Narrow band LNA for wireless application. We conclude that Narrow band LNA has less noise and power dissipation compared to Wide band amplifier.

1. Introduction

The receiver of Wireless communication system has amplification, filtering, mixing and demodulation. In figure 1 it is shown clearly Low Noise Amplifier
Is between Band Pass Filter 1 and 2. BPF 1 is used primarily to select the band of interest of the received signal and is referred to as the band selection filter which provides enough suppression for unwanted signals. Since the signal is small in the range of microvolts and amplification is needed. This amplification should be completed with minimum additional noise injected by amplifier itself using Low Noise Amplifier. Amplification followed by BPF 2 and Mixer. Mixer with local frequency oscillator is adopted for one single frequency translation and hence is implemented using variable local oscillator frequency and fixed IF. So desired channel can be selected using proper Local Oscillator frequency. BPF 3 is used for channel filtering followed by IF amplifier to improve SNR performance and finally given to Demodulator.

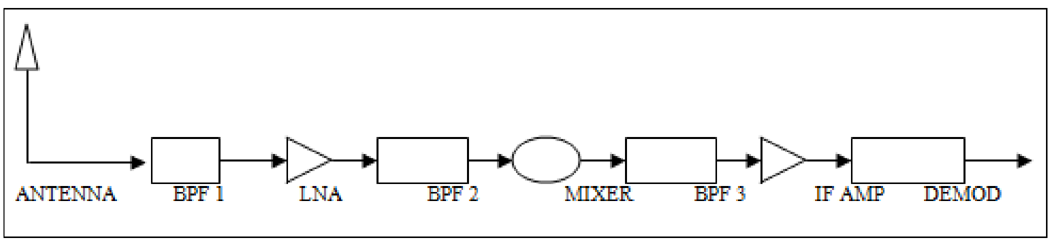

Figure 1: RF receiver for heterodyne architecture for wireless Communication [1]

2. Wideband Amplifier

The general topology of any LNA is divided into three stages: input matching network, Amplifier and output matching network. The LNA and matching network is characterized by lumped and S parameters. Wideband amplifier is implemented using active elements in feedback to achieve controlled impedance and wideband matching networks. This matching network should compensate for the frequency response of the amplifier so that we can get a flat frequency response at the output. Here we have designed Wideband amplifier using CMOS. In this design we focused mainly design of matching network and amplifier. Figure 2 shows Wideband LNA.

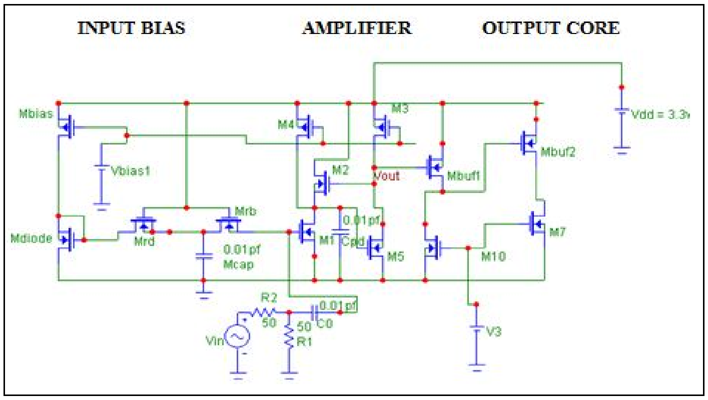

Figure 2: Wideband LNA amplifier [2]

We have implemented a matching network that will achieve a goal of achieving goal of optimum power delivery. At input matching is completed with straightforward 50 ohms R1 in the figure 2. The output matching using a pair of source followers. The core amplifier has two stages. The first stage common source transconductance structure M1 in figure 2. M1 is directly coupled with transresistance amplifier with feedback path. The feedback is introduced to modify the second stage input and output impedance. This helps to broadband the core amplifier by reducing miller capacitance of M1. The W/L ratio of transistor designed as 2.4 µm / 5 µm and D.C. bias is 3.3v.

3. Design of Wideband Lna

Let Vin as input voltage and Vout as output voltage as in figure2. gm1 and gm2 be the transconductance of M1 and M2 transistors. We derived equation for Gain, Noise figure, Current at drain end are given below.

1. Av = gm1 / gm2.
2. gm1 = $\sqrt{2 \, Id1 \, k' \, (W/L)1}$ Id1 – drain current
3. Given Av gm2 can be found. Assume Av as 10
4. Id1 < Ptotal / 4 Vdd Ptotal = total power (assumed)
5. Cut off frequency at 3db f-3db = (gm2 gm3 Rs) / (2π Cpd)
6. Noise figure NF = 1 + (2 / 3 gm1 Rs) = 2 Rs – source resistance.

Figure 3: shows Simulated Frequency response of Wideband amplifier and table 1 compares the theoretical and simulated values of wideband LNA

PARAMETERS	THEROTICAL VALUES	SIMULATED VALUES
TRANSCONDUCTANCE (gm1)	0.013 OHM^{-1}	0.015 OHM^{-1}
TRANSCONDUCTANCE (gm2)	0.0013 OHM^{-1}	0.0019 OHM^{-1}
TRANSCONDUCTANCE (gm3)	1/4.3KOHM	1/1.4KOHM
ID1 – DRAIN CURRENT	0.12MA	1.7MA
TOTALPOWER –	40 MW	22 MW
3 DB FREQUENCY	1.9 GHZ	2.6 GHZ
F1 – F2 = DEL F	100 GHZ	10 E 24 HZ.

Table 1: Design values of Wideband LNA

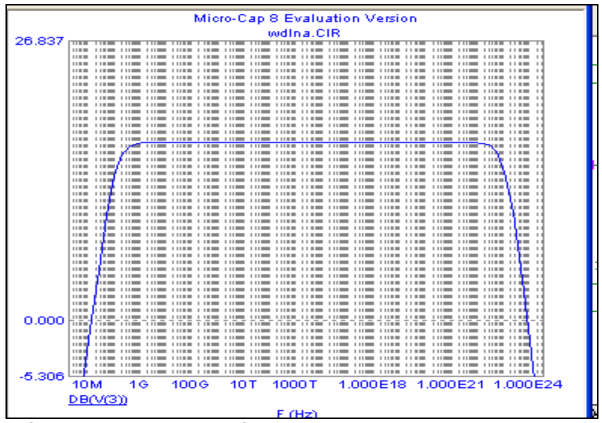

Figure 3: shows frequency response of wideband LNA Simulated using Micro capversion

To conclude Low noise factor and wide frequency response for Wideband LNA.

4. Narrow Band Low Noise Amplifier

Narrow band low noise amplifier has narrow bandwidth for its signal. So it requires impedance matching and amplification in narrow bandwidth. This can be done by principle of resonance. Hence the reactive part of the impedance is controlled to be nulled out at the resonance frequency, leaving only the resistive part to be matched with the source resistance. Here we have designed using LC tank circuit. Here the parasitic capacitance gets nulled out as inductance coupled with capacitance and tuned to resonant frequency. Therefore we have zero or infinite impedance at resonance. Figure 4 shows the Narrow band LNA circuit. Here we used Cascode configuration that give high frequency response at RF applications (Wireless applications).

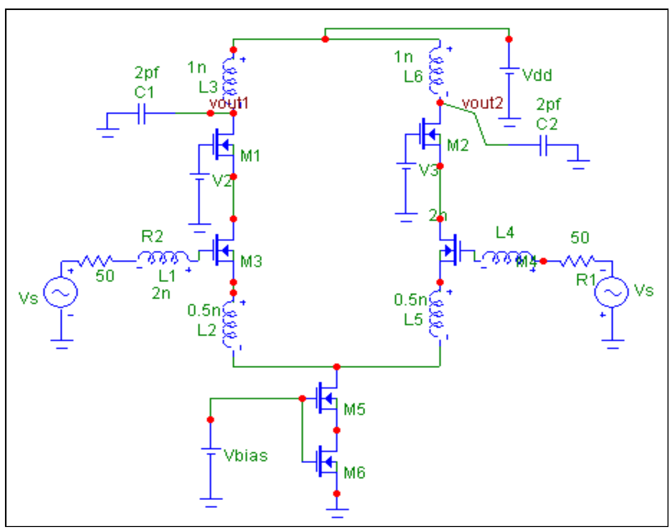

Figure 4: NARROW BAND LOW NOISE AMPLIFIER [3]

In figure 4 we used differential cascode pair and LC tuned circuit and thus we can improve circuit performance by noise figure and gain.

5. Design Of Narrow Band Low Noise Amplifier

Here we have given equation for Nioise figure, Gain, Cut-off frequency

1. NOISE FIGURE = $1 + 2 / (3\ gm\ Q^2\ Rs)$
2. $Q = 1/R\ \text{sqrt}((L1 + L2) / C)$
3. Cut-off frequency $Fc = 1 / \text{sqrt}((L1 + L2) C)$
4. Given C = 2pf and Ft = 4 Ghz we can find L1 and L2

The values for L1 and L2 are 0.5nh and 2 nh.

5. Total power = 4 Vdd Id1.
6. Gain $Av = L3/L2\ (1 / 1 - wc^2 L3\ C)$

The table 2 shows therotical values and simulated values for Narrow band amplifier.

PARAMETERS	THEROTICAL VALUES	PRACTICAL VALUES
FREQUENCY	120 GHZ	305 GHZ
NOISE FIGURE	1.5 db	1.53 db
Q	0.5	0.5
Gain	12	12
TOTAL POWER	28mw	32mw

Table 2: Design values of Narrow band LNA

Figure 5 shows Simulated Frequency response of Narrow band LNA

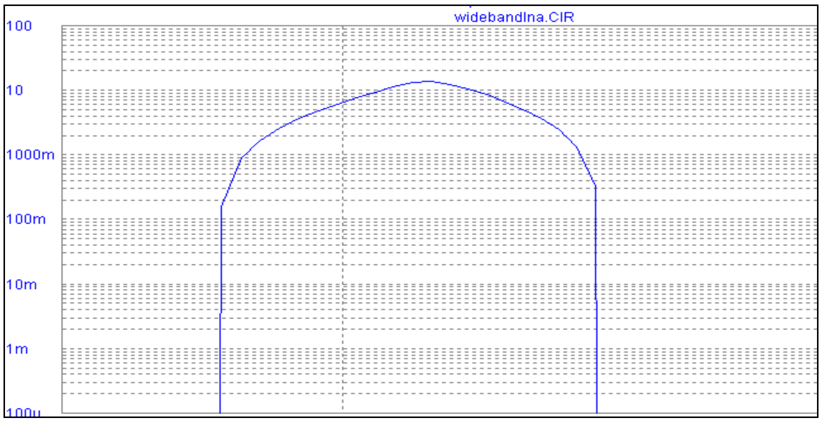

Figure 5: shows Frequency response of Narrow band LNA

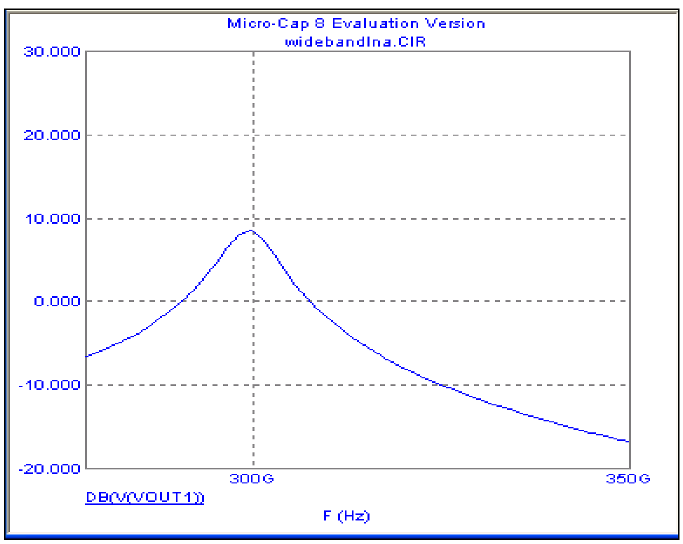

Figure 6: shows Frequency response of Narrow width

The theoretical value of FC calculated from the given formula is 120 Ghz.
From the figure 6 it is shown simulated value of Fc is 300Ghz.

6. Comparison of Wideband and Narrow Band LNA

- Narrow band LNA need Narrow band matching network which we used LC tank circuit, Narrower frequency response
- Wide band LNA uses Wideband matching network, wider frequency response
- Noise performance is poor in Wide band comparing to Narrow band
- Low noise optimization at the input and output for Narrow band LNA.
- Accurate center frequency for narrowband.
- NF and Gain for Narrow band is better than wideband

7. Conclusion

PARAMETER	WIDEBAND	NARROWBAND
VOLTAGE NOISEPOWER	1 / gm	gm
POWER	gm	gm

Table 3: gives comparison of Wide and Narrow LNA in terms of Noise power and power

Hence Table 3 clearly shows Narrow band LNA has less noise power, power dissipation and better gain than wideband LNA. Therefore Narrow band LNA used in RF applications and Wireless communication systems.

8. References

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