Low Noise Amplifier Design for Navigation Signal Receiver

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***Abstract* - This paper presents the design and simulation of a 1.1 GHz and 2.5 GHz front end low noise amplifier for navigation signal receiving .This low noise amplifier (LNA) is design for application of receiving a signal of Indian regional navigation satellite system (IRNSS). This amplifier uses NXP's BFU730LX which is a low noise and high dynamic range bipolar junction transistor(BJT).The key points are analysis device's stability with Stability factor and the input and output impedance matching with Smith Chart and Tuning. Finally, the performance parameters of LNA were obtained with the simulation of S parameters. The simulation has been performed using Advanced Design System (ADS) 2011.10 simulation software.**

***Keywords* - low noise amplifier (LNA); ADS software; noise figure; optimization design**

I. INTRODUCTION

The Indian Regional Navigational Satellite System (IRNSS) is an autonomous regional satellite navigation system being developed by Indian Space Research Organization (ISRO) which would be under the total control of Indian government .This Navigation Satellite System Is Different from Other Satellite System Because IRNSS operates on both L band (1176 MHz) and S band (2492.08 MHz).In Navigation System First time S band are use. Design of LNA is really a critical issue is to design and develop the LNA, working on both L band and S band. Low-Noise Amplifiers are key components in the receiving end of nearly every communications system. The wanted input signal of these systems is usually very weak and the primary purpose of the LNA is consequently to amplify the signal while at the same time adding as little additional noise as possible. Its performance is measured with parameter such as noise figures, gain, return loss and stability for getting the optimum performance.

II. PARAMETER OF LOW NOISE AMPLIFIER(LNA)

Bandwidth: Bandwidth is defining the difference between the higher frequency and lower frequencies.

$$BW = f_H - f_L$$

Transducer Power Gain: It is the ratio of output signal to the input signal and also signals amplification capability of LNA. The LNA drives the transducer power gain whose power delivered to the load divided by power available from source:

$$G_t = \frac{1-|\Gamma_s|^2}{|1-s_{11}\Gamma|^2}|s_{21}|^2 * \frac{1-|\Gamma_L|^2}{|1-s_{22}\Gamma|^2}$$

Noise-Figure: It is the ratio of output SNR to the input SNR in dB:

$$NF(dB) = 10\ Log\ \frac{SNR_I}{SNR_0}$$

In the cascaded form the noise-factor (F) is given as

$$F_{total} = F_{LNA} + \frac{F_{after.LNA} - 1}{G_{LNA}}$$

1 dB compression point: The linearity is expressed by the 1 dB compression point.When the input signal is increased, a point is reached where the power of the signal is not amplified by the same amount as the smaller signal at the output.At this point where the input signal is amplified by an amount 1 dB less than the small signal gain, this point is called 1 dB compression point.

IIP3: IIP3 (input inter-modulation product) is proportional to the ratio of the first and third derivatives of the transfer characteristic. IIP3 is expressed as:

$$IIP_3 = \frac{\sqrt{4|g_{m1}|}}{\sqrt{3|g_{m3}|}}$$

III. LNA DESIGN STEPS

1. Selection of transistor

Table 1 selection of transister

BFU730LX	
GAIN	24.5 dB
NF	1.1 dB
IP3	25.5 dBm
1dB Compression point	11.7 dBm
S_{21}	23.3 dB
V_{CE}	3V
I_C	25A

2. Stability analysis

Amplifier is not reliable when it is instable condition. The stability of a circuit is characterized by stern stability factor. The circuit is stable only when K>1 and Δ<1. When the input and output reflection coefficients are less than one then we determined the absolute stability factor:

When K<1, then Smith chart is stable but when the K<0, then the Smith chart is unstable.

$$K = \frac{1 + \Delta^2 - S_{11}^2 - S_{22}^2}{2S_{11}S_{22}}$$

$$\Delta = S_{11}S_{22} - S_{12}S_{21}$$

Table 2 values of s

S_{22}	0.4056∠-30.88
S_{11}	0.1637∠-103.57
S_{21}	9.5744∠90.36
S_{12}	0.060∠72.95

After calculation find $\Delta = -0.5081$ and k=0.928.

So, transistor is unstable. For a stabilize the transistor use the smith chart matching circuit. For this matching plot a load and source circle in smith chart. Radius and center of circle is find by equations,

For load,

$$r_L = \frac{|S_{12}S_{21}|}{|S_{22}|^2 - |\Delta|^2}$$

$$C_L = \frac{(S_{22} - \Delta S_{11^*})^*}{|S_{22}|^2 - |\Delta|^2}$$

For source,

$$r_S = \frac{|S_{12}S_{21}|}{|S_{11}|^2 - |\Delta|^2}$$

$$C_S = \frac{(S_{11} - \Delta S_{22^*})^*}{|S_{11}|^2 - |\Delta|^2}$$

Transistor is unconditionally stable when this circle is completely outside the smith chart.

3. Input and output matching

The input matching network is used to make the input return loss (S11) minimized without introducing additional noise. The input matching circuit that terminates the transistor to gamma optimum (Γout) which represents the input impedance of the transistor for the best noise matches. Attenuation is lowest at 77 Ω and power handling capability is highest at 30 Ω. So, the compromise between these two parameters gives the 50 Ω resistive input impedance to design LNA. The next step in LNA design involves output matching. The input and output impedance matching is required to maximize the power transfer and minimize the reflections. Smith chart is used for impedance matching. According to maximum power transfer theorem, maximum power delivered to the load when the impedance of load is equal to the complex conjugate of the impedance of source (ZS = ZL*).

4. Simulation Circuit & Results

By using advance design system (ADS) software design a low noise amplifier circuit. The Semitic diagram is show in figure. Simulation results of LNA are shown in Figure. The designed low noise amplifier offers forward gain (S21) = 24.27 dB at 1.1 GHz and (S21) = 18.06 dB. Input return loss (S11) =- 13 dB at 1.1 GHz and (S11) =- 20 dB at 2.5 GHz. Output return loss

(S22) = -33.22 dB at 1.1 GHz and loss (S22) = -15.4 dB at 2.5 GHz. for the frequency range of 1.1 GHz to 2.5 GHz which are shown in Fig. The Stability Factor K is greater than 1 for 1.1 GHz to 2.5 GHz which indicates that LNA is unconditionally stable in this frequency range.

Table 3

Parameter	**1.1GHz**	**2.5GHz**
$\mathbf{S_{21}}$	25.7 dB	18 dB
$\mathbf{S_{11}}$	-13 dB	-20 dB
$\mathbf{S_{22}}$	-33 dB	-15 dB
Stability factor	1.11	1.39

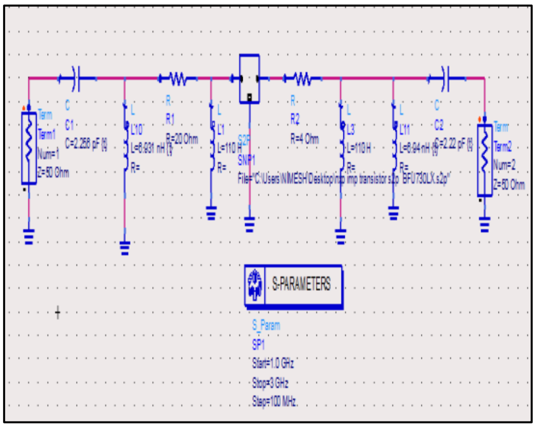

Figure 1 LNA Circuit

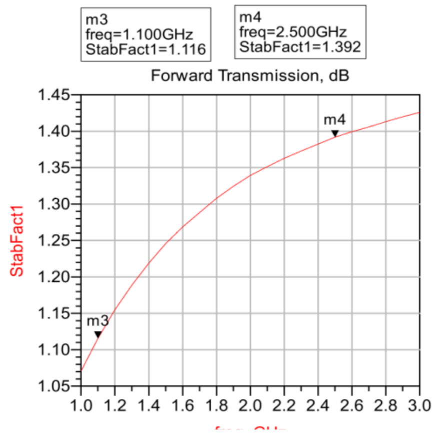

Figure 4

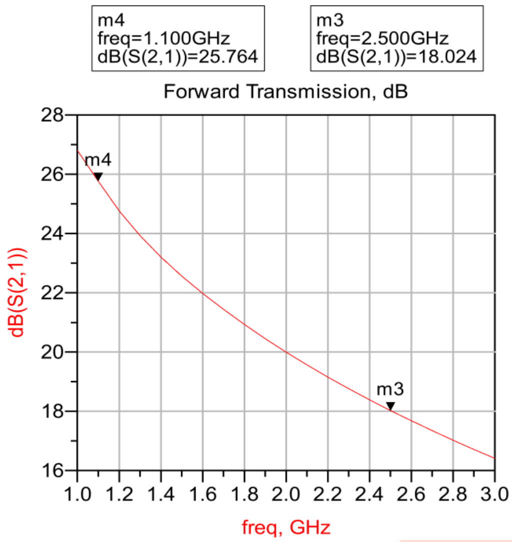

Figure 2

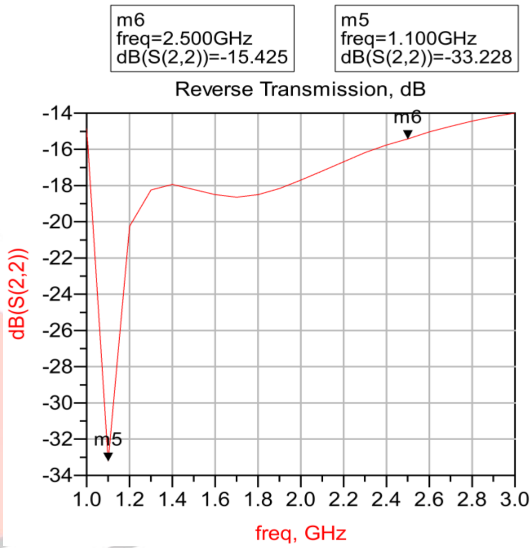

Figure 5

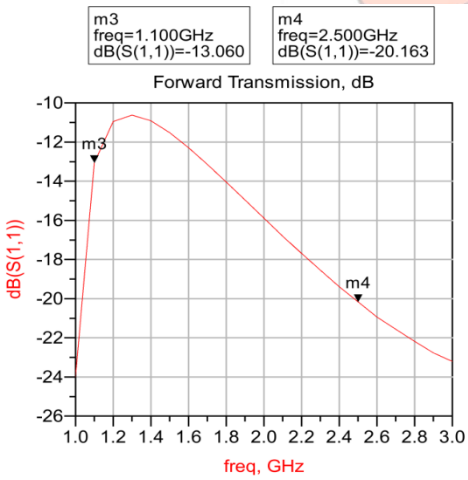

Figure 3

Forward Transmission, dB

freq	StabFact1
1.000 GHz	1.071
1.100 GHz	1.116
1.200 GHz	1.155
1.300 GHz	1.189
1.400 GHz	1.219
1.500 GHz	1.246
1.600 GHz	1.269
1.700 GHz	1.288
1.800 GHz	1.308
1.900 GHz	1.324
2.000 GHz	1.339
2.100 GHz	1.351
2.200 GHz	1.363
2.300 GHz	1.373
2.400 GHz	1.382
2.500 GHz	1.392
2.600 GHz	1.399
2.700 GHz	1.406
2.800 GHz	1.413
2.900 GHz	1.420
3.000 GHz	1.426

Table: 03

Table 5

Forward Transmission, dB

freq	VSWR1	VSWR2
1.000 GHz	1.442	1.134
1.100 GHz	1.045	1.572
1.200 GHz	1.215	1.791
1.300 GHz	1.279	1.834
1.400 GHz	1.290	1.796
1.500 GHz	1.280	1.723
1.600 GHz	1.270	1.642
1.700 GHz	1.265	1.565
1.800 GHz	1.270	1.495
1.900 GHz	1.282	1.435
2.000 GHz	1.300	1.383
2.100 GHz	1.320	1.337
2.200 GHz	1.343	1.300
2.300 GHz	1.368	1.268
2.400 GHz	1.389	1.240
2.500 GHz	1.408	1.218
2.600 GHz	1.430	1.197
2.700 GHz	1.449	1.182
2.800 GHz	1.468	1.169
2.900 GHz	1.485	1.157
3.000 GHz	1.498	1.149

IV. CONCLUSION

In this paper a front end low noise amplifier circuit has been designed and simulated for 1.1 GHz and 2.5 GHz. simulations has been performed using Advanced Design system (ADS) Software. All the parameter like forward gain (S21), return loss, stability factor has been optimized.

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