Design and performance improvement of a low noise amplifier with different matching techniques and stability network

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Abstract— *This paper proposes the design of a Low noise amplifier (LNA) for 5 to 6GHz range of frequency. The design of LNA plays an important role in the communication receiver as it has to amplify the received signal without adding much noise. The performance of the L NA is analyzed for different matching network for input return loss, output return loss, reverse gain and forward gain. The stability of the LNA has been increased by introducing stability network. The proposed LNA with L-L matching and with stability outperforms the other design. The design is performed using Advanced Design System tool. The proposed LNA achieves better performance compared to the existing design.*

Keywords— *Component, formatting, style, styling, insert.*

I.   INTRODUCTION

Demand of wireless communication systems with robust transmitting and receiving performance is growing tremendously due to the modern technology intense society. In wireless communication, receivers need to detect and amplify the incoming low power signals without adding much noise. A low noise amplifier (LNA) often used as the first stage of this receivers. So the design of amplifiers is the simple matter of setting the optimum condition for particular transistor. The performance of the LNA is analyzed based on noise figure, high gain and stability factor. The performance of the LNA is affected based on the matching and stability network. Hence, this paper proposes the design of LNA with different types of matching and stability based network. The proposed LNA have been designed and simulated by using Advanced design System (ADS).
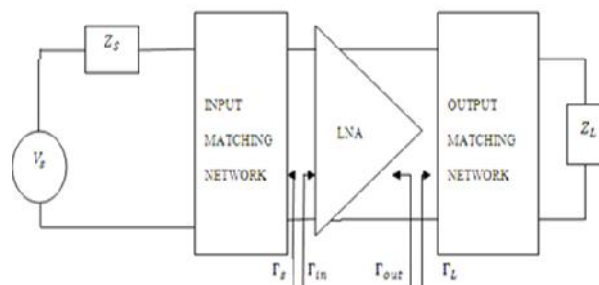

FIG.1 COMPLETE STRUCTURE OF LOW NOISE AMPLIFIER

II.   RELATED WORK

In paper [1] CMOS 0.35μm technology has been used for the design of LNA and uses single ended configuration design. The LNA has been designed for low frequency of 1800MHz. For this low frequency the noise figure achieved is high. In [2] wide band LNA has been designed using HEMT transistor and coupler for low frequency bend only. As the coupler is used to achieve high gain, it is not cost efficient and complexity in the design also increases. In [5], the author designed LNA using MESFET transistor for 5 to 6 GHz frequency range. For matching network LC combination has been used. The Gain achieved is 15.83db. The author achieved the poor stability in the design and noise figure increases as the frequency is increased.

CMOS 0.18μm technology has been used to design LNA for cognitive radio frequency in [6]. Two stages have been used for the design and the noise figure achieved is very high. In [7], different combination of matching networks has been used for the design of LNA. The gain achieved is minimum and noise figure is high at 6 GHz frequency. L-L Duality matching network has been used for input and output matching [8]. The stability achieved is minimum and gain also minimum at 6 GHz frequency. The LNA proposed in [9] does not work in low frequency and consumes high power. The author in [10]

used common gate and cascade amplifier for good matching and high gain. The gain achieved is comparatively low at 8.72 GHz. Since the author used two topologies the complexity also increases.

In paper [11] describes the novel method which is used to isolate the DC circuits from the AC signals. Generally stubs are used for impedance matching for that radial stubs are used in the designed LNA circuit. it will gives as low impedance at low frequency. Similarly if it is high frequency means produces the high impedances. In paper [12] describes the analysis and design of Low noise amplifier (LNA) based on cascade circuit with resistive feedback. The LNA circuit has -matching network with resistive shunt feedback for wideband input matching. Design a low noise amplifier for ultra wideband receiver is discussed in paper [13]. The design of LNA is based upon differential architecture with enables the balun transformer. This design may produce the improved noise figure at very low frequency. In paper [14] exhibits the combined architecture of Low noise amplifier. This means microstrip antenna integrated with low noise amplifier. This design improves the complexity due to integrated architecture. A novel method of designing wideband low noise amplifier using a sub threshold technique is discussed in paper [15]. The design of LNA comprises common gate and common source stage. The power reduction is achieved by driving the front end common gate transistor in sub-threshold region. If the designed circuit operates beyond the threshold region means it will degrades the performance of an LNA.

III.   PROPOSED DESIGN

The communication receiver should detect and amplify the weak signals without adding much noise. In any communication receiver Low Noise Amplifier (LNA) is the most important key component and is placed as the first block in a communication receiver. In the design of LNA choosing a transistor for an RF amplifier is very complicated. Each transistor has a unique current rating and operating voltage and also specifies the breakdown voltages which will not be exceeded by the applied dc voltage.

In the proposed design of LNA BJT_MODEL NPN transistor has been used. The transistor module is analyzed in the name of BFP 640 SOT 343 from the ADS library. This transistor can be operated over the range of 5-6 GHz frequency range. This range of frequency can be used in wireless application. The design of LNA consists of three modules.

- DC biasing network design

- Matching network design

- Stability network design

3.1 DC biasing network design

The design of low noise amplifier is mainly based upon biasing network design. The purpose of the bias network is to set the operating point of the transistor. According to the transistor characteristics low noise amplifier will be maintained in stable region. The proposed LNA uses BJT in current controlling switches. The operating point value are chosen as V_{ce} =3v (common emitter voltage), V_{be}=0.7v (base emitter voltage),Ic=10mA(collector current),Vto=1.3v(threshold voltage) [5],[7]. The DC biasing network in the proposed LNA shown in fig.2
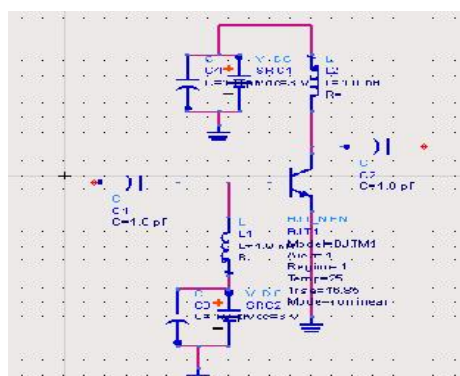

FIG.2 DC BIASING NETWORK OF THE PROPOSED LNA

3.2 Matching network design

The purpose of using matching network in LNA which makes the input and output impedance transform to 50ohm impedance. Impedance matching will provides the maximum power transfer between source and load terminal. If impedance mismatch will be occurs between source and load terminal mean standing waves exhibits on the transmission line [5],[7],[8]

According to the design specifications, source and load terminal impedance can be spitted into two types

* Input matching network

* Output matching network

There are different types of matching network available in LNA design. Some will discussed in below section. The proposed LNA design uses the L-type and -type matching. The following figure shows the different types of matching network.
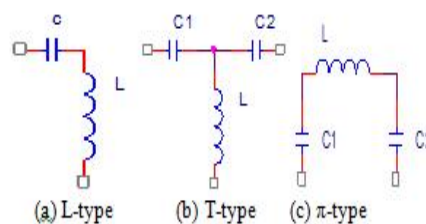
FIG .3 DIFFERENT TYPES OF MATCHING NETWORK

3.3 Stability design

The stability of an amplifier is one of the important considerations in LNA design as the transistor may fail to work due to oscillation present in the circuit. Hence to increase the stability of LNA circuit RLC feedback is established from base terminal to ground terminal. This RLC feedback is established at both input and output matching network. This can be analyzed from the S-parameter, matching network and termination [5], [7], [8]. The stability can be calculated in terms of two conditions: (i) Conditional stability (ii) Unconditional stability. For conditional stability, the stability factor k<1. This depends on source and load termination. Hence the transistor will be stable for certain range of source and load impedances. For unconditional stability, the stability factor k>=1. This also depends on source and load termination. Hence the transistor will be stable for certain range of source and load impedances [5], [7], [8].

The stability factor (k) is calculated by using scattering parameters. Due to oscillation, LNA is may fail to work in stable condition because of the unstability of the transistor. To maintain the transistor as stable it requires the unconditional stability [7] which given by (1) and (2)

$$k = \frac{1 - |S_{11}|^2 - |S_{22}|^2 + |\Delta^2|}{2|S_{12}S_{21}|} > 1$$

(1)

$$\Delta = |S_{11}||S_{22}| - |S_{12}||S_{21}| < 1$$

(2)

The proposed LNA design has analyzed with two kind of stability network. Which means stability based network (WSC) and without stability (WOSC) based network. In following figure shows the RLC feedback circuit to improve the stability of the network.
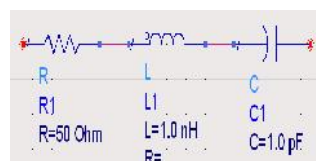

FIG. 4 RLC FEEDBACK CIRCUIT

IV.   RESULTS AND DISCUSSION

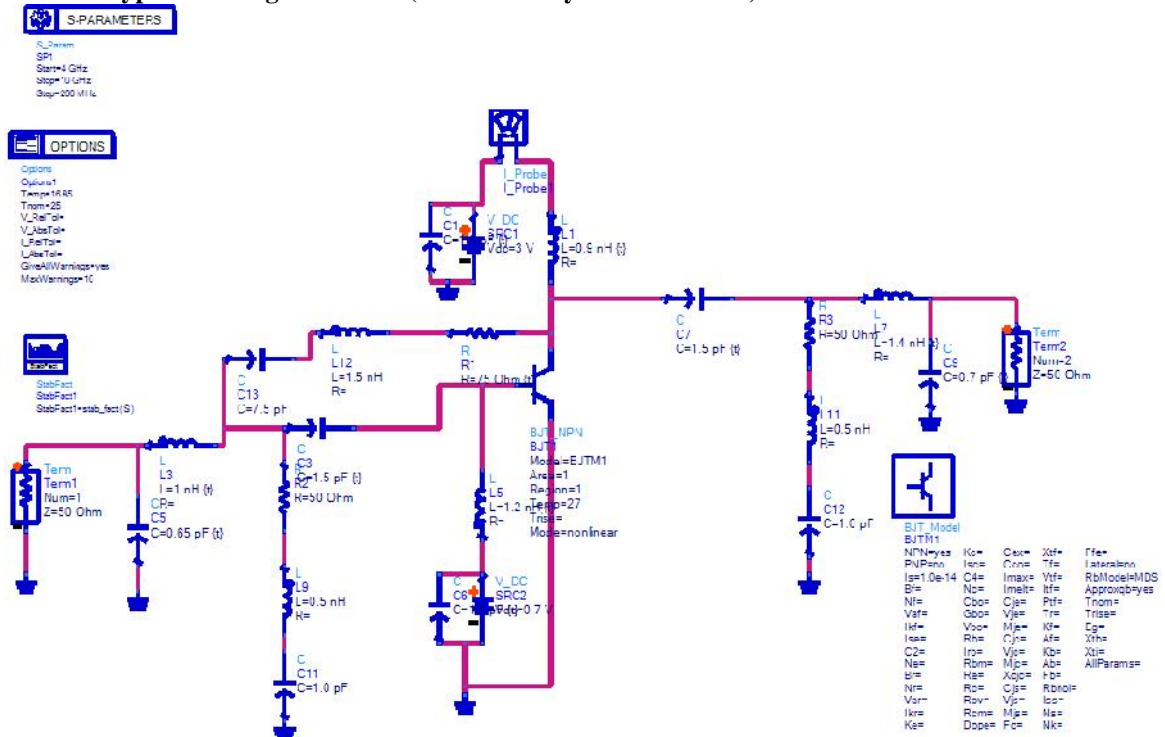### 4.1 Type: 1 L-L Type Matching at 5.8 Ghz (With Stability And Feedback)
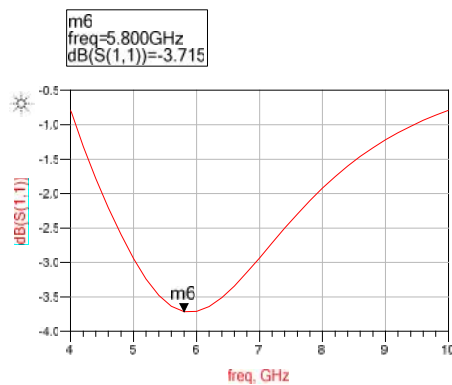

FIG. 5 L-L TYPE MATCHING WITH STABILITY LNA CIRCUIT
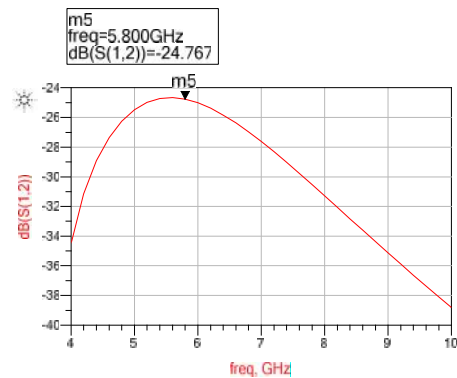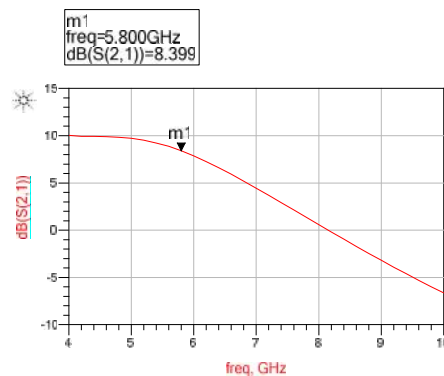

FIG 6(A)

FIG 6(B)
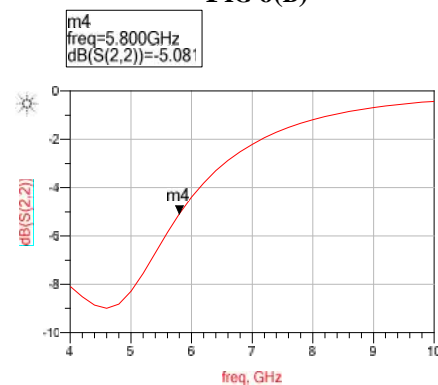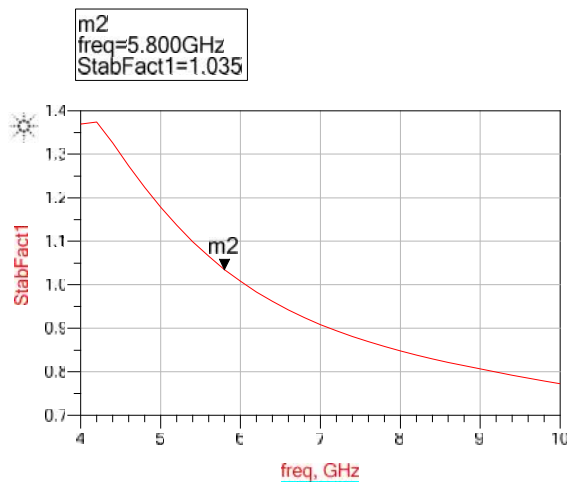

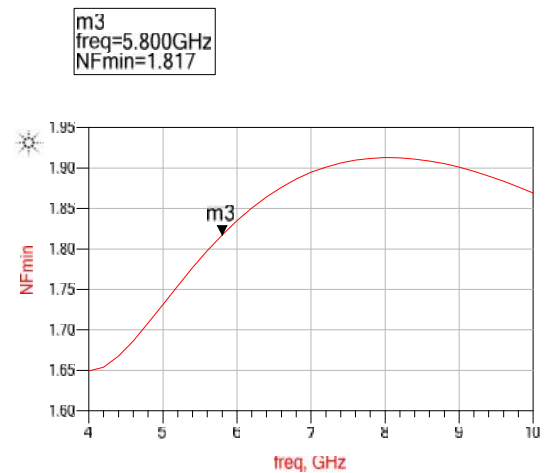**FIG 6(C)**

FIG 6(D)

FIG 6(E)

FIG 6(F)

FIG. 6 (A) INPUT RETURN LOSS (S$_{11}$), (B) REVERSE GAIN (S$_{12s}$), (C) FORWARD GAIN (S$_{21}$), (D) OUTPUT RETURN LOSS (S$_{22}$), (E) STABILITY FACTOR, (F) NOISE FIGURE V$_s$ FREQUENCY FOR L-L MATCHING

The results for L-L matching network with stability and feedback are shown in fig .6.

4.2 Type: 2 L-L Type Matching At 5.8 Ghz(Without Stability And Feedback)
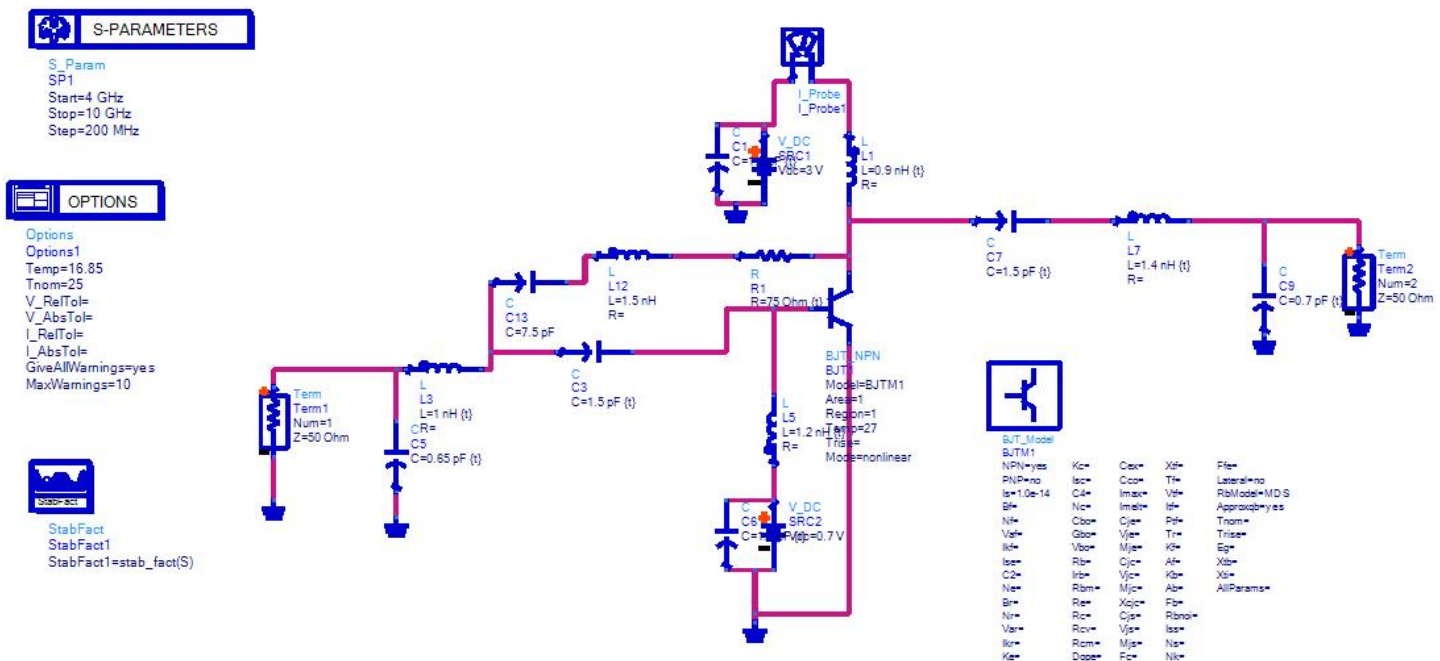

FIG .7 L-L TYPE MATCHING WITHOUT STABILITY LNA CIRCUIT

The input reflection coefficient is -3.715dB, reverse transmission coefficient is-24.767dB, forward transmission coefficient is 8.399dB, output reflection coefficient is -5.081dBs, stability factor is 1.035dB and noise figure is 1.817dB.So the stability factor is greater than one it will shows the unconditional stability.
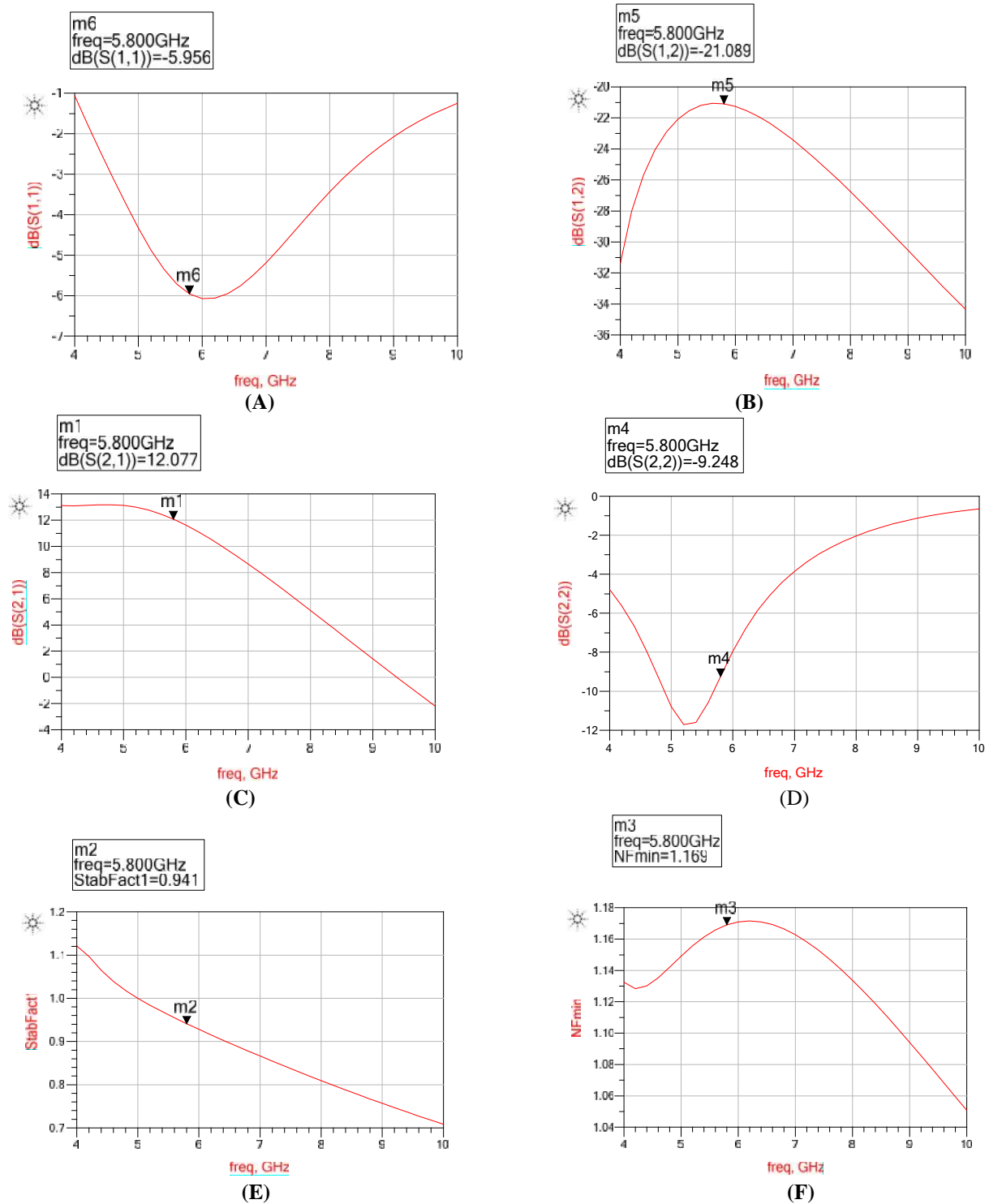
(A)

(B)

(C)

(D)

(E)

(F)

FIG. 8 (A) INPUT RETURN LOSS (S$_{11}$), (B) REVERSE GAIN (S$_{12s}$), (C) FORWARD GAIN (S$_{21}$), (D) OUTPUT RETURN LOSS (S$_{22}$), (E) STABILITY FACTOR, (F) NOISE FIGURE

V$_s$ frequency for L-L matching

Fig. 8 shows the results for L-L matching without stability and feedback. The input reflection coefficient is -5.956dB, reverse transmission coefficient is-21.089dB, forward transmission coefficient is 12.077dB, output reflection coefficient is -9.248dB,

stability factor is 0.941dB and noise figure is 1.169dB.So the stability factor is less than one it will shows the conditional stability.

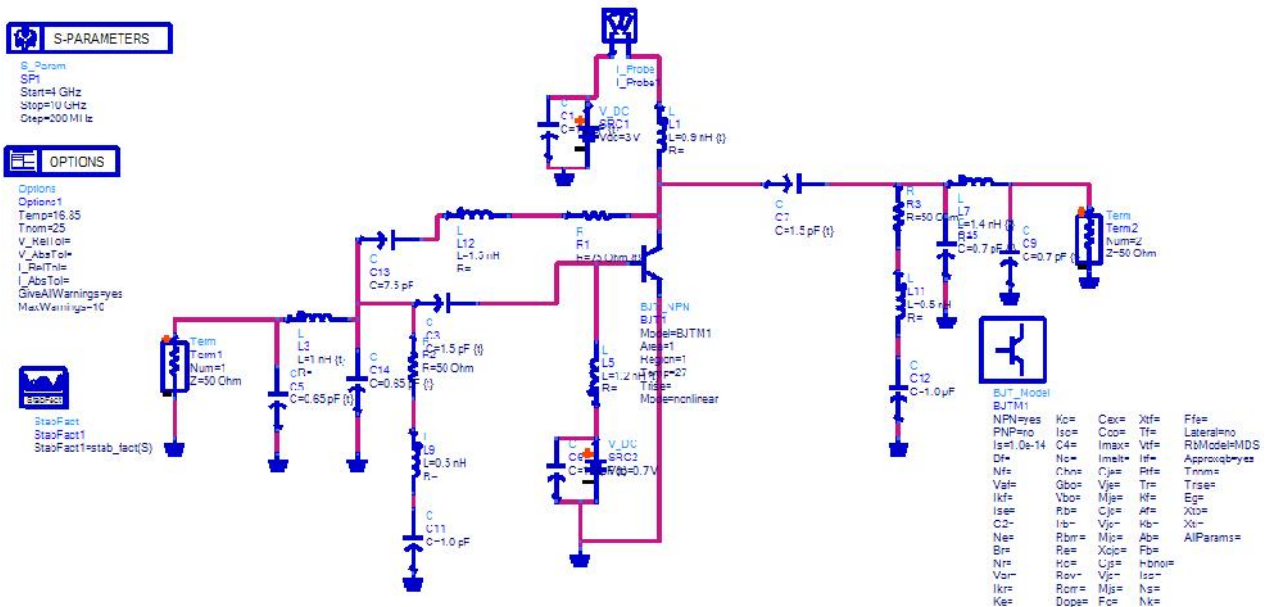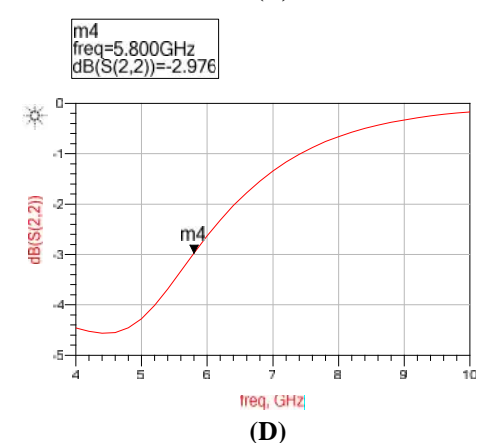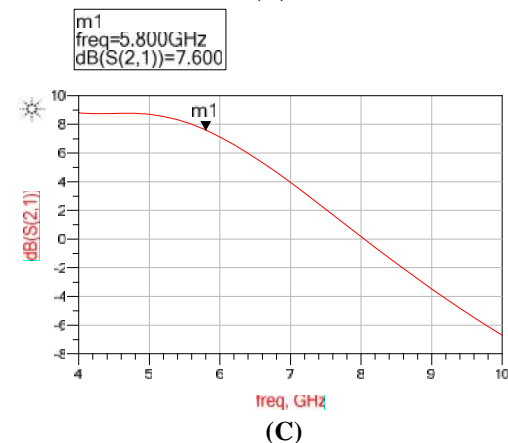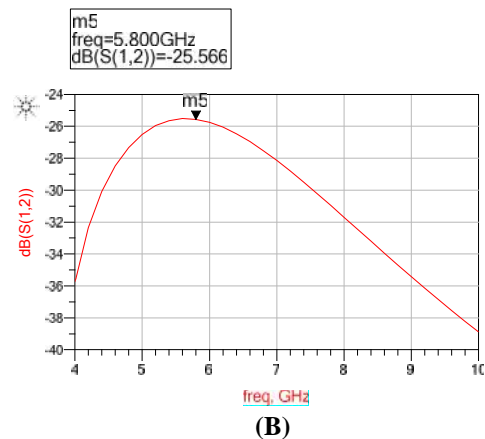## 4.3 TYPE: 3 - Type Matching At 5.8ghz (With Stability And Feedback)

FIG .9 - TYPE MATCHING WITH STABILITY LNA CIRCUIT

(A)

(B)

(C)

(D)

(E)   **(F)**
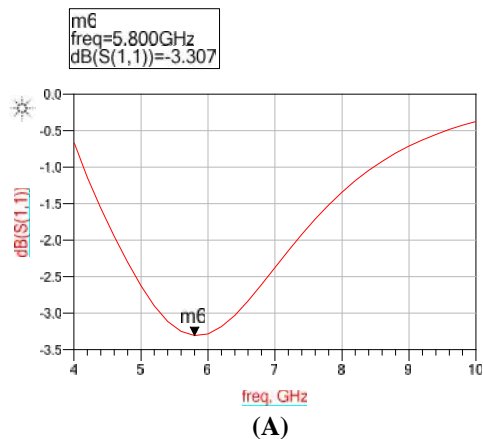
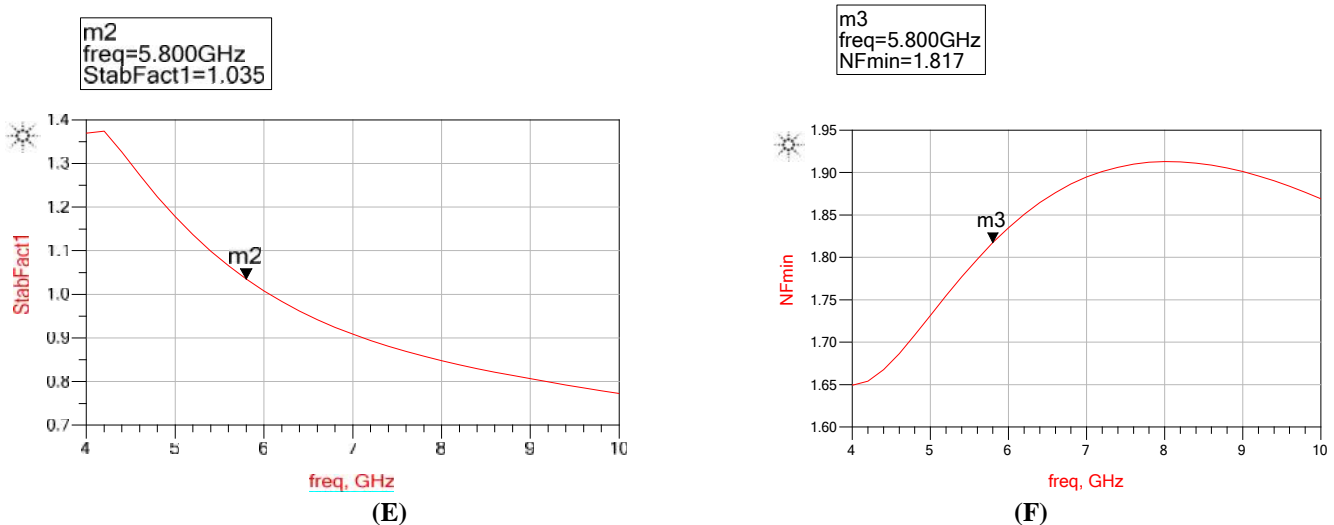**FIG. 10** (A) INPUT RETURN LOSS (S_{11}), (B) REVERSE GAIN (S_{12}), (C) FORWARD GAIN (S_{21}), (D) OUTPUT RETURN LOSS (S_{22}), (E) STABILITY FACTOR, (F) NOISE FIGURE V_s FREQUENCY FOR   -   MATCHING

Fig.10 shows the results for   -   matching with stability and feedback. The input reflection coefficient is -3.307dB, reverse transmission coefficient is-25.566dB, forward transmission coefficient is 7.600dB, output reflection coefficient is -2.976dB, stability factor is 1.035dB and noise figure is 1.817dB.So the stability factor is less than one it will shows the unconditional stability.

4.4 TYPE: 4   -   Type Matching At 5.8 ghz (Without Stability And Feedback)
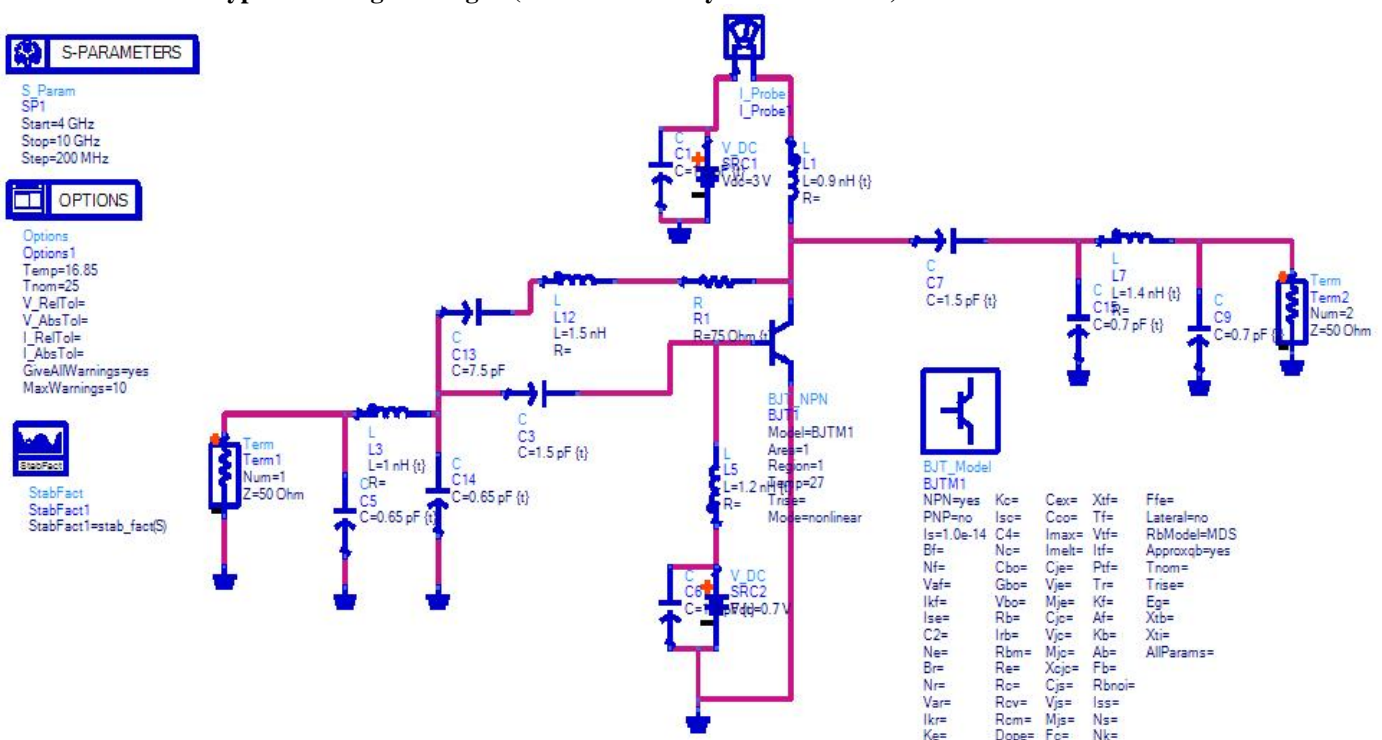
FIG .11 -   TYPE MATCHING WITHOUT STABILITY LNA CIRCUIT

(C)

(D)

(C)

(D)

(E)

(F)
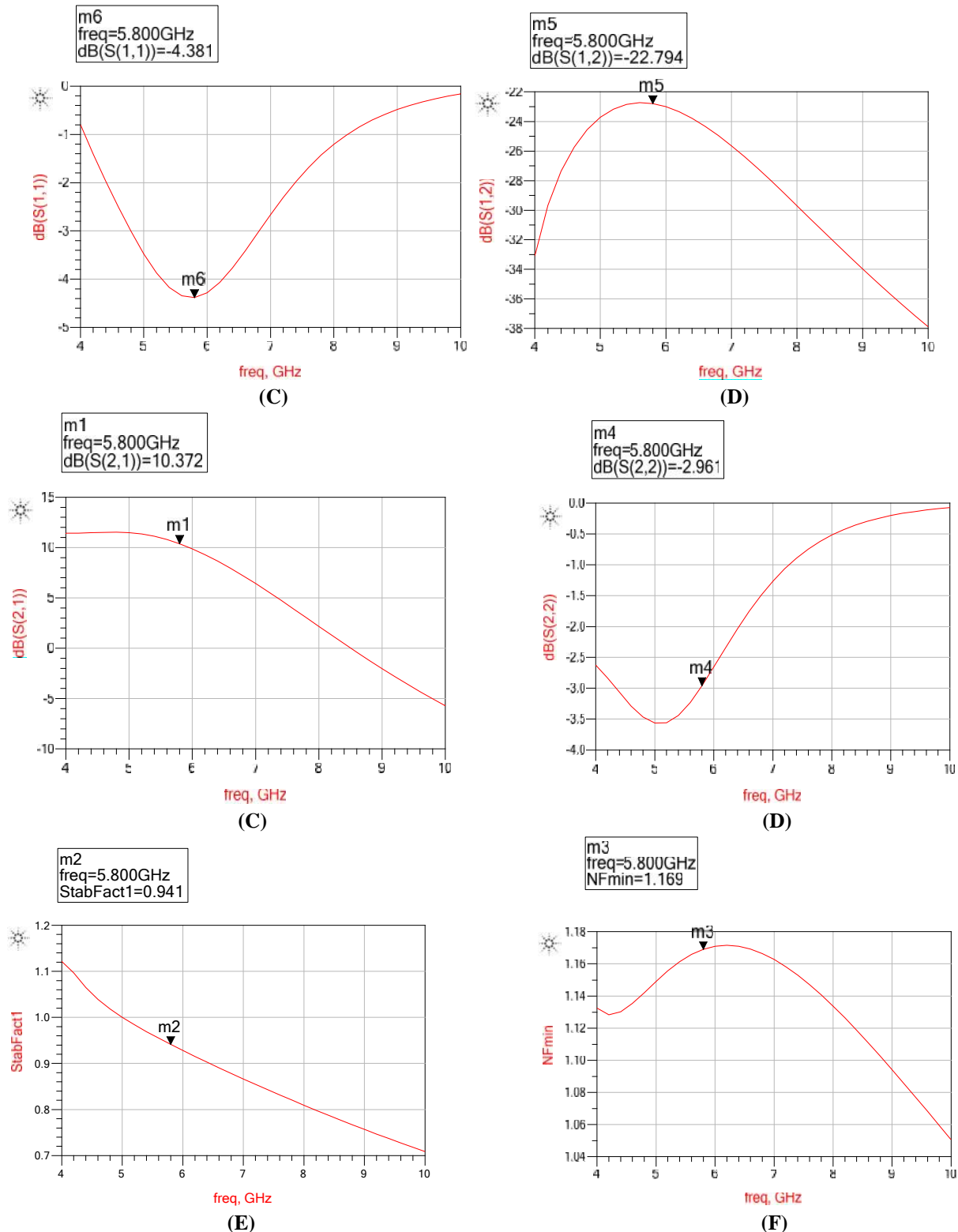
FIG. 12 GIVE THIS AS (A) INPUT RETURN LOSS (S₁₁), (B) REVERSE GAIN (S₁₂), (C) FORWARD GAIN (S₂₁), (D) OUTPUT RETURN LOSS (S₂₂), (E) STABILITY FACTOR, (F) NOISE FIGURE Vₛ FREQUENCY FOR - MATCHING

The results for - matching without stability and feedback are shown in fig 12. The input reflection coefficient is -4.381dB, reverse transmission coefficient is-22.794dB, forward transmission coefficient is 10.372dB, output reflection coefficient is -

2.961dB, stability factor is 0.941dB and noise figure is 1.169dB.So the stability factor is less than one it will shows the conditional stability.

TABLE 1
COMPARISON TABLE FOR DIFFERENT MATCHING TECHNIQUES

TYPE	L-L MATCHING		- MATCHING	
PARAMETERS	*WOSC*	*WSC*	*WOSC*	*WSC*
S_{11}	-5.956	**-3.715**	-4.381	-3.307
S_{12}	-21.089	**-24.767**	-22.794	-25.566
S_{21}	12.077	**8.399**	10.372	7.600
S_{22}	-9.248	**-5.081**	-2.961	-2.976
STABILITY FACTOR	0.941	**1.035**	0.941	1.035
NOISE FIGURE	1.169	**1.817**	1.169	1.817

V. CONCLUSION

This paper proposes the design of LNA and its performance improvement using L-L matching and - matching network. The stability of the LNA has been improved by incorporating stability network in the design. Among all the design, L-L matching with stability outperforms.

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