

The Design and Simulation of A Low-mid Frequency RF Low Noise Amplifier Based on ADS

^{1,2,3}Feng He, ^{1,2,3}Zhihui Huang, ^{1,2,3}Pengfei Wu

^{1,2,3}College of Optoelectronic Engineering, Chongqing University of Posts and Telecommunications, Chongqing, China

¹College of Communication and Information Engineering, Chongqing University of Posts and Telecommunications, Chongqing, China

Abstract

Aiming at the problem of the microstrip is too long to realize layout which using ADS to design a low-mid frequency RF low noise amplifier. A 87 MHz to 108 MHz RF low noise amplifier which has 20 dB gain and less than 2 dB noise factor was designed. It could be gotten from the result of its EM-Circuit co-simulation that ADS is a useful tool to achieve the design of high frequency RF amplifier, as well as the design of low-mid frequency RF power amplifier which couldn't use the microstrip line to substitute the passive components.

Keywords

ADS, Low-mid Frequency, RF, Low Noise Amplifier, EM-Circuit Co-simulation

I. Introduction

The design and simulation of high frequency RF amplifier based on ADS software has been relatively mature. By the literatures [1-2] it can be seen that the design and simulation based on ADS for amplifier can help us to reduce the number of layout, and achieve the purpose of to save the cost and cycle of designs. However, in nowadays, when wireless communication in the era of information is highly developed, the applications of low-mid frequency wireless communication technology, such as campus radio, digital radio and others, is widespread. In order to improve the design efficiency of the RF amplifier, it is necessary to study the design and simulation of low-mid frequency RF amplifier based on ADS software. In the ADS, the equivalent length of the microstrip line can be calculated by a given inductance value, as shown in the formula (1):

$$l = \frac{11.81L}{Z_0 \sqrt{\epsilon_r}} \quad (1)$$

l is the length of the microstrip line, the unit is in; L is the inductance value, the unit is nH; Z_0 is the characteristic of microstrip line on PCB impedance; By the formula (1), the length of the microstrip line which is calculated in the low-mid frequency is too long, and it not only increases the geometry size and cost of the whole module, but also brings the difficulties to implementation layout. Then, if microstrip line can not be instead of a passive component, whether it is able to use the ADS software to design and simulate a low-mid frequency RF amplifier well?

Next, we will illustrate the above problem by designing and simulation a low-mid frequency RF low noise amplifier based on the ADS software.

II. The theoretical analysis of low noise amplifier

A. The Analysis of Noise Factor

Noise factor is the primary parameter of low noise amplifier to analysis. its physical meaning is that: when a signal pass a amplifier, the noise generated by the amplifier can make the ratio

of signal to noise becomes worse, and the down multiple of the ratio of signal to noise is noise factor [3]. For class m amplifiers, the total noise coefficient is mainly decided by single circuit noise factor NF and gain the A_v [4], namely

$$NF_{tot(m)} = 1 + (NF_1 - 1) \frac{(NF_2 - 1)}{A_{v1}} + \dots + \frac{(NF_m - 1)}{A_{v1}A_{v2}\dots A_{v(m-1)}} \quad (2)$$

Due to the gain of single-stage amplifier is generally far greater than 1, we can see the total noise coefficient of multistage amplifier is mainly decided by the first stage amplifier through the formula (2), and the noise coefficient of the first stage amplifier circuit become the main factor that affects the whole circuit. Therefore, the input matching network of a low noise amplifier circuit, which is the first stage in the whole module of amplifier, is designed mainly by the optimal noise coefficient.

B. The Analysis of Stability

Stability factor is a factor which must be considered for any amplifying circuit design. It refers to the ability that the amplifying circuits curb the change of environmental factors and maintain the normal amplification of amplifier circuit. Define the expression of the S parameter of active devices [5] as follows:

$$\Delta = S_{11}S_{22} - S_{12}S_{21} \quad (3)$$

$$K = \frac{1 - |S_{11}|^2 - |S_{22}|^2 + |\Delta|^2}{2|S_{12}S_{21}|} \quad (4)$$

If the LNA meet requirements:

$$K > 1, |\Delta| < 1 \quad (5)$$

The amplifier is unconditionally stable.

C. The Analysis of Gain

According to the matching conditions of linear network input and output impedance, there are three kinds of power gain: the definition of a working power gain, converter power gain and power gain [6]. For the low noise amplifier in reality, power gain generally refers to the measured gain in a standard cases that the impedance of source and load are 50 ohm. In order to ensure the best noise factor, the input matching requirements of low noise amplifier must accord to the best match of the noise to design. The best match point of noise generally is not the biggest gain points, and in this case the matching gain is called related gain. Thus gain G is general smaller than the biggest gain by 2-4 dB [6].

D. Return Loss

Return Loss(RL)also be called reflection loss, and it is the reflection due to the mismatch of impedance. It is the reciprocal of reflection coefficient. Input reflection coefficient is said with the S parameter:

$$S_{11} = 20\lg(\Gamma) \tag{6}$$

Γ is the reflection coefficient. If using the S parameter to represent the input return loss, then the formula is:

$$RL = -S_{11} \tag{7}$$

So when a matching circuit is being designed, input and output impedance matching performance of amplifier generally is represented by the S parameter S11, S22.

Because the low noise amplifier not only has the parameters which have to be consulted in the design of back-end amplifier, but also has its unique sensitive parameters-the noise factor. So this article chooses the design and schematic diagram-landscape joint simulation of a low noise amplifier to illustrate the question whether ADS can also be used to design and simulate a low-mid frequency amplifier well.

III. The Design of The Low Noise Amplifier

A. The Indicators of The Design :

- Working frequency band:87-108MHz;
- Noise factor:<2.0dB;
- Gain G>20dB;
- The return loss of input and output > 10 dB;

B. Selecting the Component

According to the indicators of the design, we selected 2SC3356 power tube to carry on the design. Because it has characteristics of low noise, high power gains as well as ideal large dynamic range current.

C. Dc Simulation

Through a DC simulation in ADS software, we got the simulation results of DC analysis shown in Fig.1.

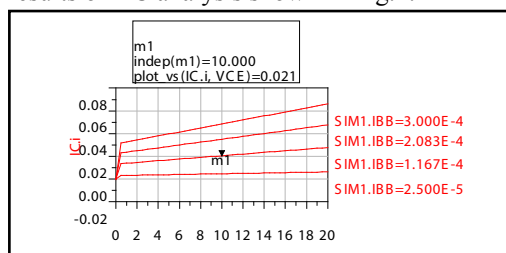


Fig.1: The DC feature figure of 2SC3356

Combination of the 2sc3356 data book, we took the static working point of the triode for VCE = 10V, IC = 20 mA.

D. The Design of Bias Circuit and The Analysis of Stability

According to the previous analysis, in this design, we set the VCC = 12.5V, VCE = 10V, IC = 20 mA. Combined with these parameters, we designed the bias circuit with ADS. Joining DC and RF choke devices and relevant simulation control in the schematic diagram, and then we simulated and optimized its stability. Through the simulation result shown in Fig.2, we can see that in the design frequency the stability coefficient meet the design requirements, but the biggest gain which can be improved through the match in the late is only 18.147dB.

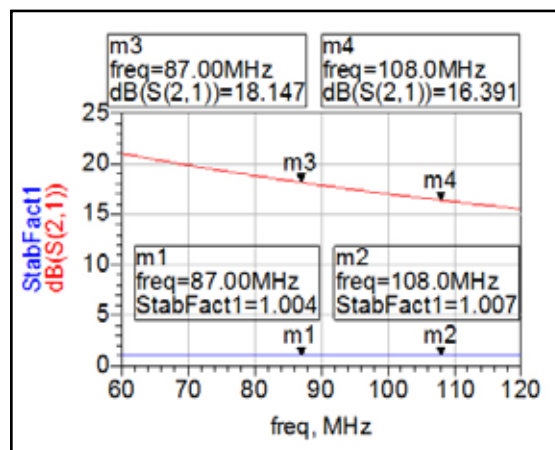


Fig. 2: The curve of maximum gain and stability after optimization

E. The Input Matching

We simulated schematic diagram for the noise coefficient, and shown the round of noise and power in the data display window. For the low noise amplifier, first consideration is the minimum noise, so we choose the minimum noise points matched to 50 ohm impedance. And the simulation diagram of the noise coefficient after matching as shown in Fig.3.

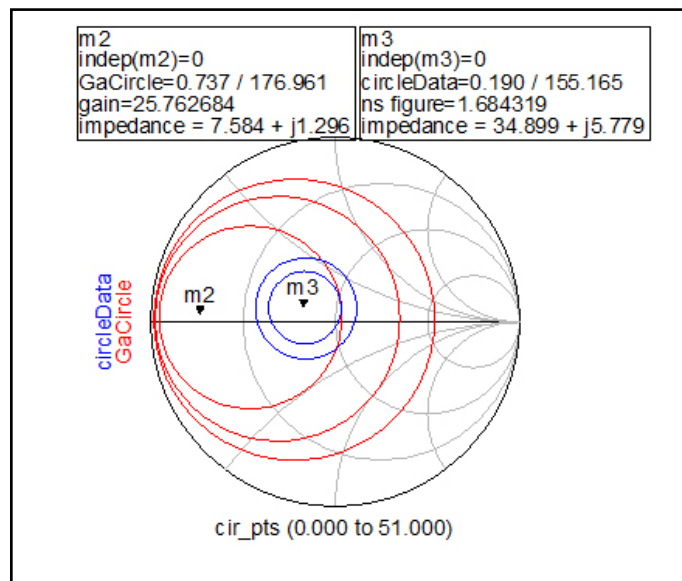
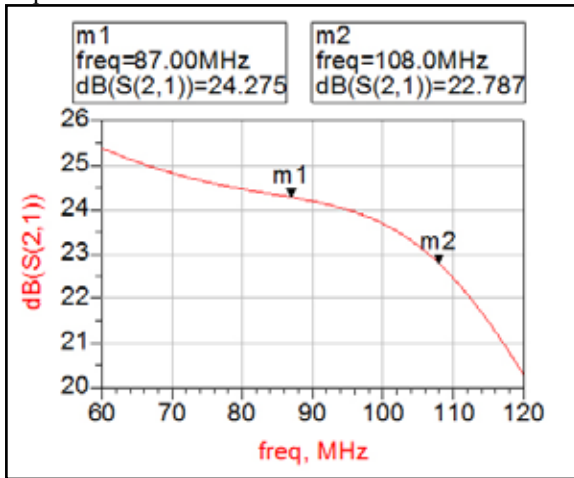


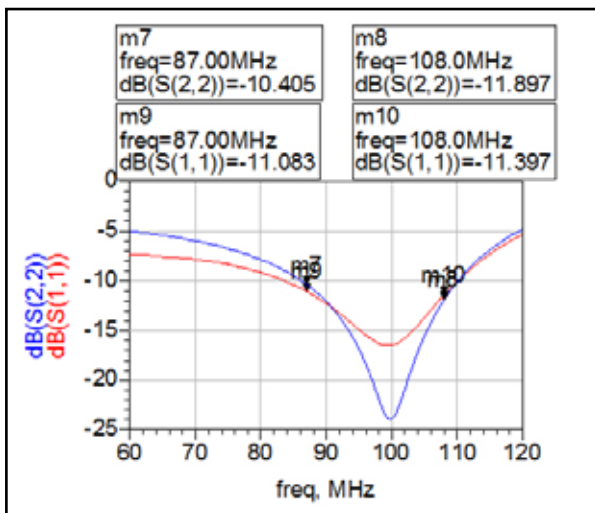
Fig.3: The Smith chart of circleData and GaCircle after the match

F. The Output Match of The Maximum Gain

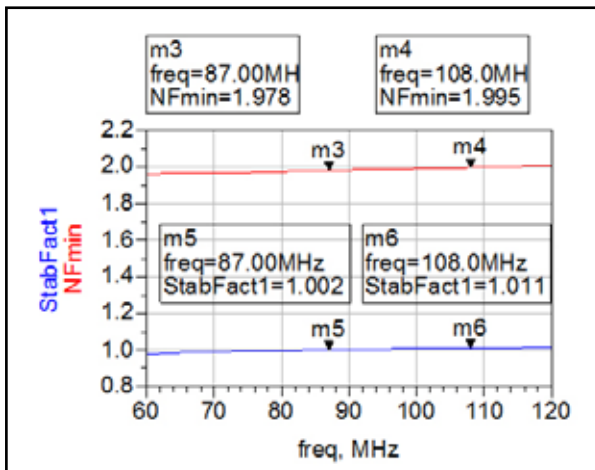
In order to achieve maximum gain, we need match the output impedance to 50 ohm in the output matching networks. Then we simulated and optimized the principle diagram with the output matching network, and the simulation diagram is shown in Fig.4, which we can find that the indicators meet the design requirements.



(A)The simulation result of Gain



(B)The simulation result of return loss



(C)The simulation result of noise and stability

Fig. 4: The simulation results of the final circuit after optimization

Consider the design frequency, we can not choose microstrip to replace the separation of passive components. So the final circuit principle diagram of the amplifier is shown in Fig.5.

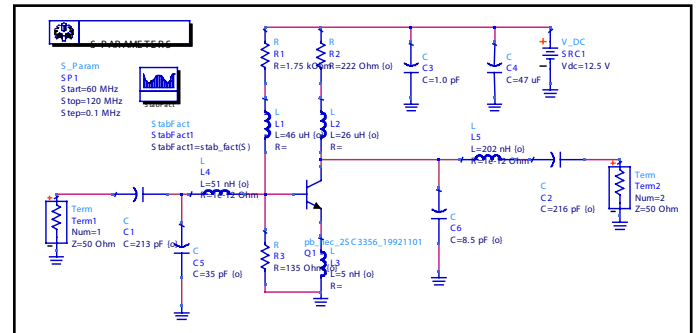


Fig. 5: The final circuit principle diagram of the amplifier

G. The Production of Layout and Electromagnetic Simulation of Based on The ADS Software

Because the microstrip line cannot instead of a discrete in the design spectrum, we must first finish the packaging drawings of each discrete device respectively. Then we added the packaging to the corresponding discrete in the schematic diagram. After finishing the number setting for each port in the schematic diagram, we generated a layout in the layout window. Through the steps of the landscape layout, wiring, hole arrangement, we can get the schematic diagram for electromagnetic simulation finally as shown in Fig.6.

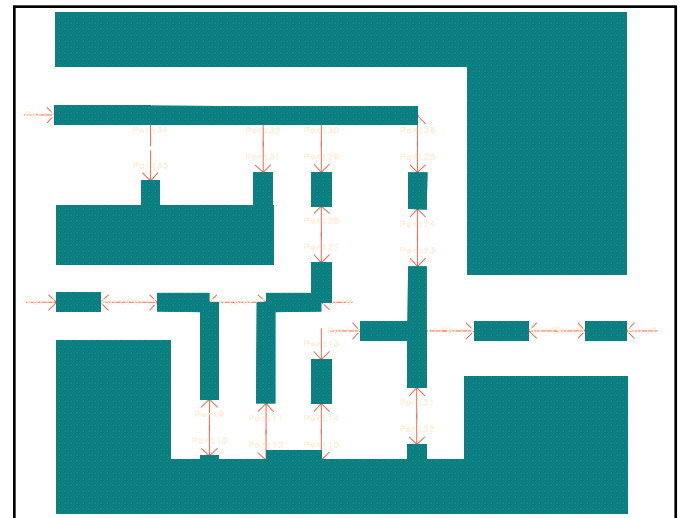


Fig. 6: The layout of Electromagnetic simulation

Then we set the parameter of the dielectric-slab, and add the schematic diagram to library file. And it is the resulting schematic diagram which can be used in the co-simulation.

IV. The implementation of EM-Circuit co-simulation

We create the components in the library file which just created and add it to a new schematic diagram window. Then adding all the discrete devices, input/output port, power supply, and the simulation required controls to the schematic diagram, and connection them, as shown in Fig.7.

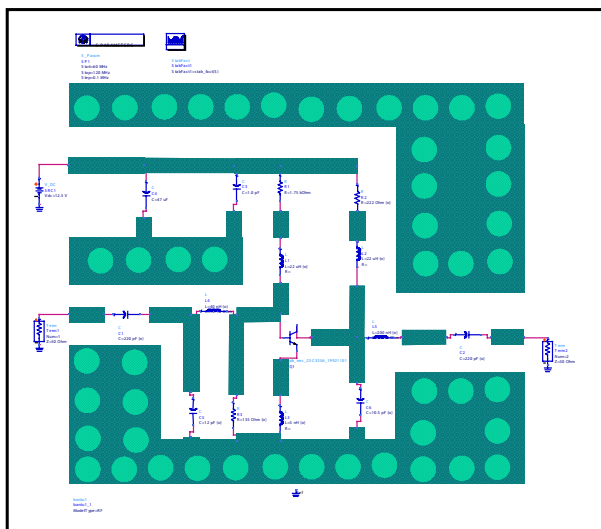
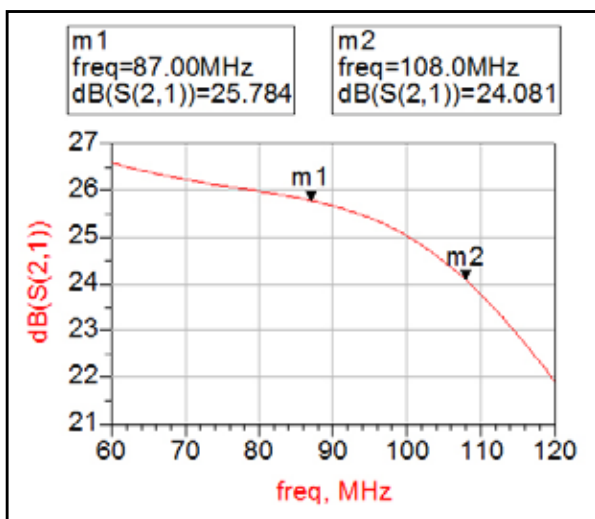
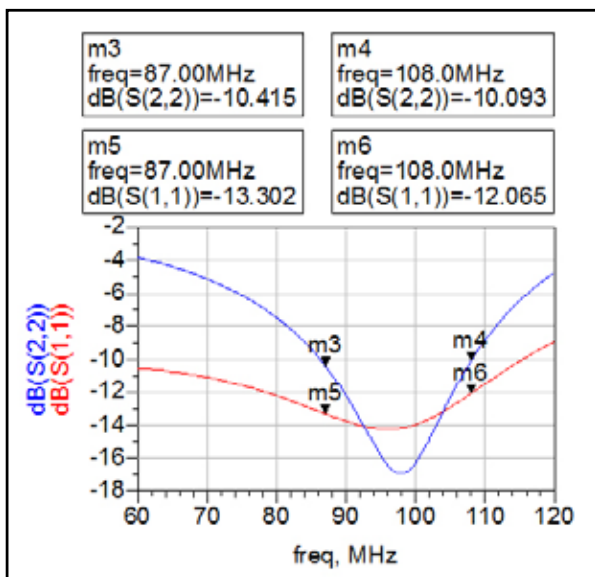


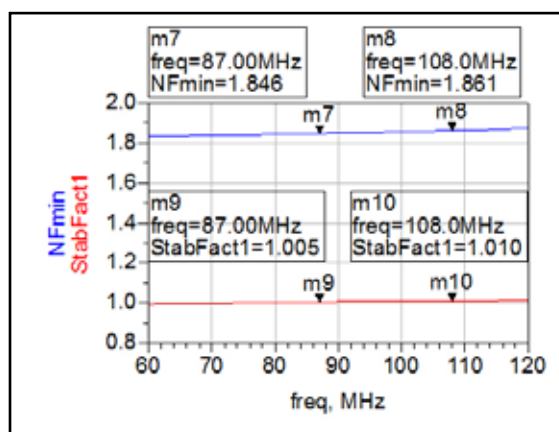
Fig. 7: The schematic diagram for EM-Circuit co-simulation Run the simulation. And the finally result is shown in Fig.8.



(A) The simulation result of Gain



(B)The simulation result of return loss



(C)The simulation result of noise and stability

Fig.8: The result of EM-Circuit co-simulation

From the result of EM-Circuit co-simulation, it can be seen that in the design spectrum $S(1, 1)$, $S(2, 2)$ are less than 10 dB, $S(2, 1)$ which is minimum of 24.081dB at 108MHz is bigger than 20dB, the minimum factor of stability is bigger than 1 at 87 MHz, and the maximum of the minimum noise coefficient which is 1.861dB at 108 MHz which is less than 2dB. Therefore, the results of the EM-Circuit co-simulation are relatively close to the simulation results of the final circuit, and meet the design requirements. It shows that the result of the design is ideal.

V. Conclusion

We systematically introduced the process of the design and EM-Circuit co-simulation about a low noise amplifier at 87 MHz to 108 MHz which is a low-mid frequency based on ADS software. It illustrates that the ADS not only can finish the design of high frequency RF amplifier, but also have good performance at the designing of RF amplifier which cannot use the microstrip to replace the passive discrete device in low-mid frequency.

References

- [1] Wang Y. A class-S RF amplifier architecture with envelope delta-sigma modulation[C]//Radio and Wireless Conference, 2002. RAWCON 2002. IEEE. IEEE, 2002: 177-179.
- [2] Ravelo B. Baseband NGD circuit with RF amplifier[J]. Electronics letters, 2011, 47(13): 752-754.
- [3] CONG Mi-fang, NAN Jing-chang, LI Jiu-chao. Design and Simulation of RFID Low Noise Amplifier Based on ADS[J]. Computer Simulation, 2011, 28(4): 393-396.
- [4] Cline D W, Gray P R. A power optimized 13-b 5 Msamples/s pipelined analog-to-digital converter in 1.2 μ m CMOS[J]. Solid-State Circuits, IEEE Journal of, 1996, 31(3): 294-303.
- [5] Liu Chang-jun, Huang Ka-ma, Yan Li-ping. Design of Rf communication circuit [M]. Science Press, 2005.
- [6] WU Xian-zhi, SUN Ling, BAO Zhi-hua. The Design of Low-Noise Amplifier for UHF RFID Reader[J]. Journal of Nantong University(Natural Science Edition), 2009, 8(2): 8-10.