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Research and Design of Broadband Power Amplifier with Feedback Structure Based on ADS

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Abstract: The power amplifier based on the CGH40010 power tube design often needs to improve the circuit structure to ensure the stability due to its poor stability. However, this method often causes problems such as reduced amplifier gain and reduced efficiency. After the design of the input matching circuit and the output matching circuit, it still cannot be effectively improved. This paper proposes a power amplifier design scheme with a feedback structure, which improves the gain and efficiency, and the available bandwidth is effectively broadened.

1. Introduction

With the rapid development of wireless communication, people have higher requirements for the distance of wireless communication, which makes the research of power amplifier as an important part of the wireless communication link more attention by many scholars. At present, the main application frequency centers of wireless communication are concentrated in the two frequency points of 2.4GHz and 3.5GHz. The research on 2.4GHz and its surrounding frequency bands has matured, and many researchers have set their sights on the new communication frequency band centered on 3.5GHz. At the same time, as wireless communication links require wider communication frequency bands, the research of broadband power amplifiers has gradually attracted attention. The performance of the RF power amplifier determines the overall performance of the communication link, so designing a broadband power amplifier with excellent performance has become the goal of scholars' research. RF engineers often use design software for simulation testing when designing. Scholars generally use ADS software for the design of power amplifiers, so that when designing the amplifier circuit, they can accurately understand the circuit performance and optimize the circuit parameters in real time.

At present, the international research on CGH40010 power amplifier is basically focused on the 2.4GHz frequency band. According to the parameters given in the Datasheet, the small signal gain is about 16dB at 2.0GHz, and the small signal gain is about 14dB at 4.0GHz. It can be seen that the gain of the power amplifier in the 3.5GHz frequency band should be between 14-16dB. But in fact, because the stability of the CGH40010 power tube is less than 1 when the amplifier circuit is designed, it cannot be used as a qualified amplifier without adding an auxiliary circuit. Therefore, after adding auxiliary circuits to increase stability, the gain and efficiency of the power amplifier will be adversely affected. The actual gain is only between 12-13dB.

This text mainly carries on the structural innovation and improvement to the power amplifier designed by the CGH40010 power tube. Through the optimization of the feedback structure, a higher gain is achieved at 3.5 GHz, the available bandwidth is expanded, and the efficiency of the power amplifier is optimized.

2.   Theoretical analysis of broadband power amplifier with feedback structure

The design of a power amplifier generally includes processes such as DC analysis, stability analysis, Load-Pull, output circuit matching, Source-Pull, input circuit matching, and microstrip conversion. The performance of the power amplifier depends on the gain and efficiency. For broadband power amplifiers, the width of the available bandwidth also needs to be considered.

For the amplifier circuit, the circuit structure containing the feedback network can effectively change the performance of the amplifier. After the feedback circuit and the amplifier circuit of the power amplifier form a closed loop, the output signal is transmitted to the input terminal again to achieve the purpose of forward feedback, thereby improving the gain and efficiency of the amplifier.
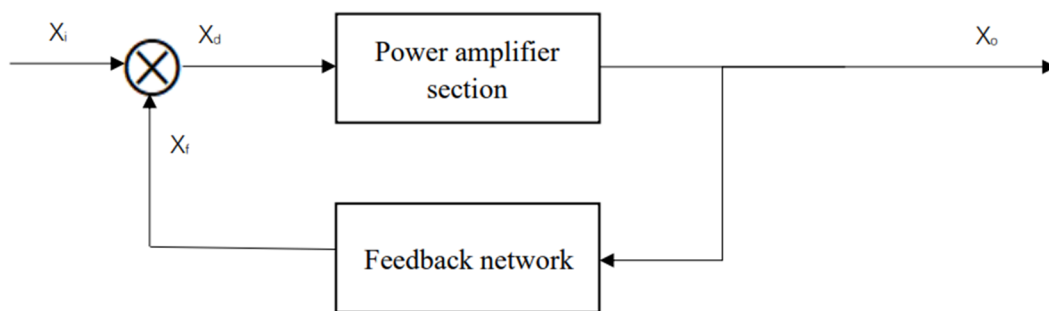

Fig 1. Structure diagram of feedback structure power amplifier

Collector Efficiency:

$$\eta_c = \frac{P_{\text{out}}}{P_c} = \frac{P_{\text{out}}}{U_{DC} \times I_{DC}} \tag{1}$$

Power added efficiency:

$$\eta_{PAE} = \frac{P_{\text{out}} - P_{\text{in}}}{P_{DC}} \tag{2}$$

Power amplifier total efficiency:

$$\eta_T = \frac{P_{\text{out}}}{P_{DC} + P_{\text{in}}} \tag{3}$$

This research hopes to adopt a feedback structure, so that the signal at the output end is returned to the input end through a feedback circuit connected with a large resistance. Through the parameter adjustment and optimization of the power amplifier circuit, the stability and gain can reach the usable value at the same time. Gain, efficiency and available bandwidth have all been improved.

3. Design of CGH40010 feedback broadband power amplifier

3.1. General broadband power amplifier design

For the design of CGH40010 broadband power amplifier, we can follow the general power amplifier design rules: DC analysis, stability analysis, bias circuit design, input matching circuit and output matching circuit design, microstrip line conversion, and finally simulation experiments. Due to the stability defect of the CGH40010 power tube itself, the general method is to connect a small resistor

and a capacitor in parallel and connect them to the input terminal to increase the circuit stability.
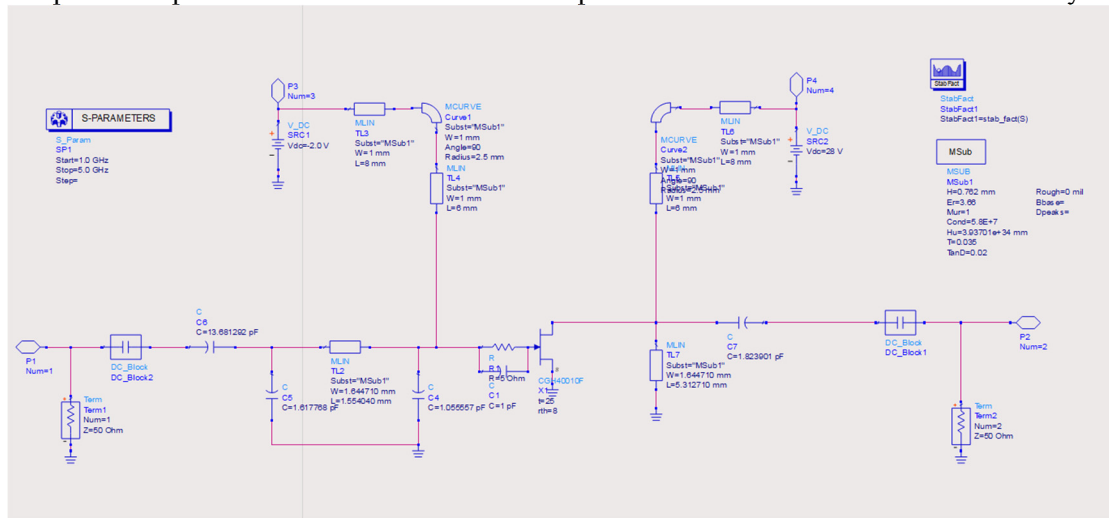

Fig 2. CGH40010 power amplifier design circuit structure

Due to the poor stability of the CGH40010 power tube itself, stability measures were added to the circuit, which changed the input impedance and output impedance values under 3.5GHz given in the Datasheet. At this time, it is generally necessary to use Load-pull and Source-pull to obtain the actual impedance. In this process, the gain of CGH40010 given by the Datasheet is about 16dB, and the output power given by the datasheet is 13w, so the input power is 25dBm. Load-pull and Source-pull can be used after determining the input power.

Conversion of output power value corresponding to P_{1dB}:

$$10 \lg P_{out}(mW) = (dBm) \tag{4}$$

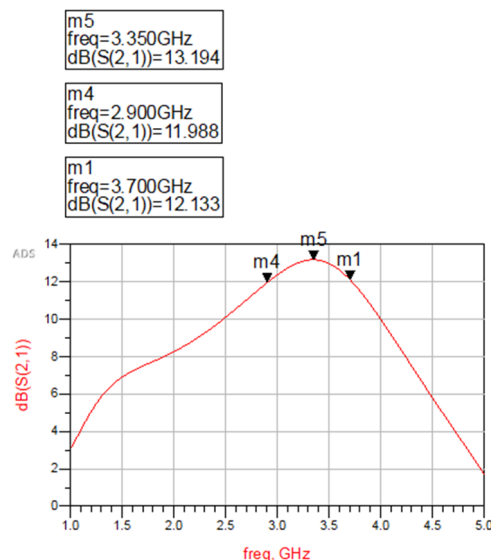The experimental results obtained by simulation are shown below.

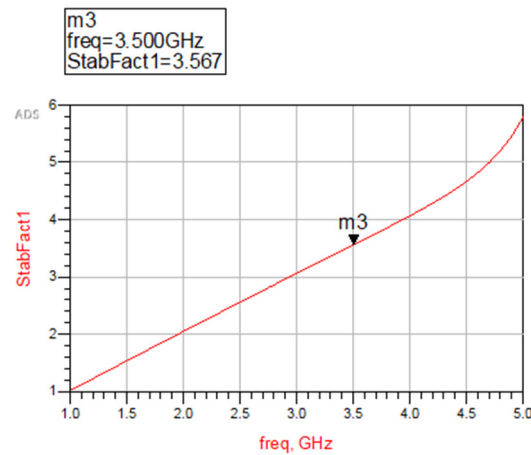Fig 3. Gain curve of power amplifier at different frequencies

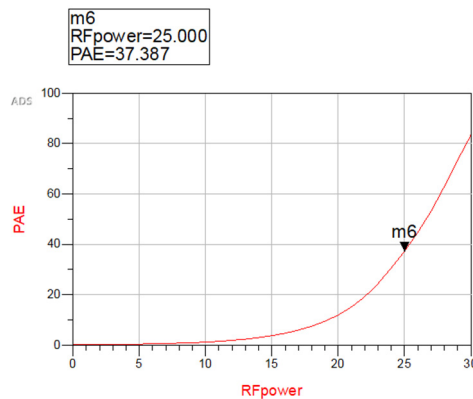Fig 4. The stability change of power amplifier at different frequencies

Fig 5. The efficiency of the power amplifier when the transmit power is 25dBm

If the value of the available gain is specified as 12dB or more, the available bandwidth is 800MHz. And the highest point gain is about 13.194dB, which is the normal gain achieved by the generally designed CGH40010 power amplifier in the 3.5GHz frequency band. According to the filter tuning optimization, the final gain fluctuates no more than 0.2dB. Because the input terminal has improved the circuit structure in order to increase the stability, the actual gain is difficult to reach the 14-16dB given by the Datasheet. This amplifier is a class AB power amplifier, and has added a stabilizing circuit, so the efficiency is only 37.387%.

3.2. Feedback structure broadband power amplifier
This research not only carried out the actual design and research on the previous CGH40010 power amplifier, but more importantly, proposed a feedback circuit structure, which feeds the amplified signal from the output end to the input end via the feedback circuit, so as to realize the gain improvement and bandwidth of the overall amplifier circuit. A large load is added to the feedback circuit to ensure stability, and inductance and capacitance elements are added to other parts of the circuit to optimize gain and bandwidth.
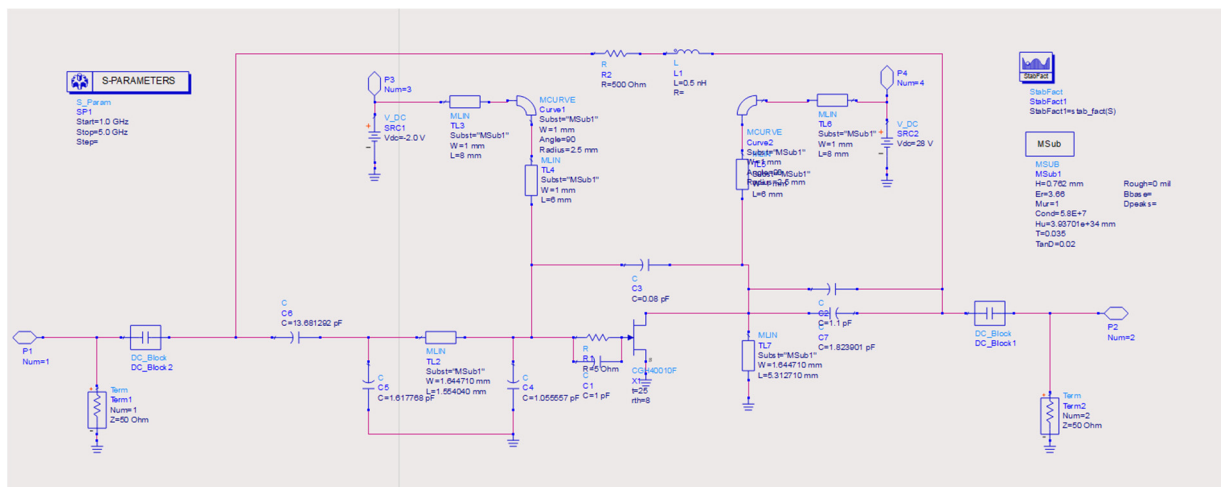
Fig 6. Improved feedback structure CGH40010 power amplifier design circuit structure

In order to make the CGH40010 power amplifier closer to the actual design, the ideal microstrip line in the circuit is replaced with the actual microstrip line. The material used is Rogers R04350 plate, the dielectric constant is 3.66, the dielectric thickness is 0.762mm, and the tangent loss angle is 0.02.

Choose a microstrip line with a width of 1mm in the selection of the bias circuit, which can effectively prevent current breakdown. In order to save PCB space during production, a 90° corner with a radius of 2.5mm can be used.

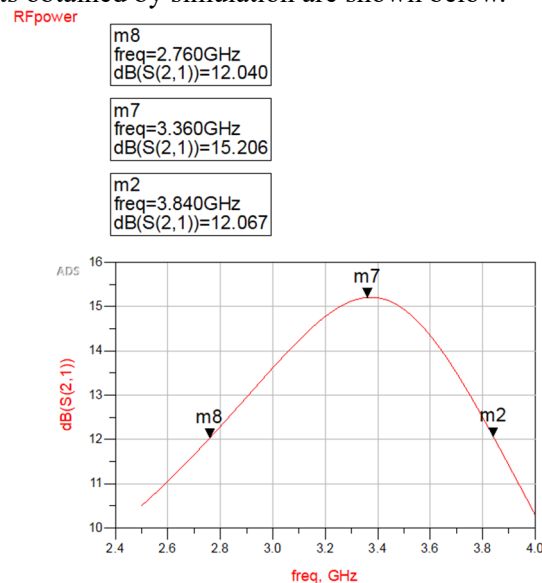The experimental results obtained by simulation are shown below.

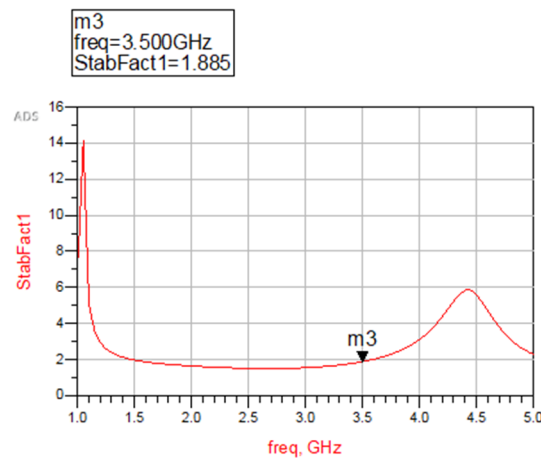Fig 7. Gain curve of power amplifier at different frequencies

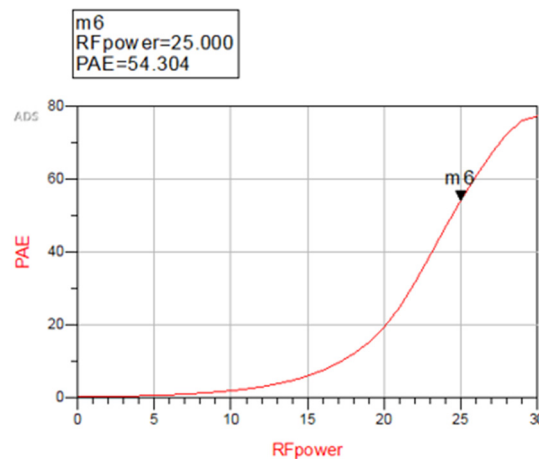Fig 8. The stability change of power amplifier at different frequencies

Fig 9. The efficiency of the power amplifier when the transmit power is 25dBm

If the value of the available gain is specified as 12dB or more, the available bandwidth is 1.08GHz, and the bandwidth is increased by 280MHz. And the highest point gain has reached 15.206dB, which is 2.012dB higher than the previous power amplifier gain. This is the gain achieved by the CGH40010 power amplifier in the 3.5GHz band after the feedback structure is improved. According to the filter tuning optimization, the final gain fluctuates no more than 0.2 dB. And the stability has reached more than 1, which can be used as a usable device. The efficiency of the power amplifier reached 54.304%.

4.Conclusions

This design uses a feedback structure to improve the circuit structure of the power amplifier, so that the highest point gain is increased by about 2dB, the available bandwidth is expanded by nearly 300MHz, and the efficiency is increased by nearly 20%, successfully achieving the goal of improvement. And the stability also meets the requirements of general power amplifiers, and the microstrip line is also designed with actual materials, which meets the design requirements of actual power amplifiers.

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