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# DEVELOPMENT OF 150.4MHz CW SOLID-STATE AMPLIFIER

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*Abstract*

A 150.4MHz to 155.4MHz, 300W continuous wave solid-state amplifier as an accelerator power source has been developed by us. In order to increase the lifetime of MOSFET and meet the requirements of every parameters, Drain voltage and quiescent current is set at a better point with a well-designed heat dissipation structure, we make the solid state amplifier stable in performance. Taking the microwave leakage into account, the chassis structure is optimized and designed, and the microwave absorption device is adopted to make the structure compact, protect other parts not affected by the microwave leakage. After the assembly is completed, the working parameters meet the design requirements very well. The MOSFET flange temperature and output parameters meet the design requirements.

## INTRODUCTION

RF power amplifier is a traditional key component in the field of microwave technology. It is an important part of the microwave system and is still in the process of continuous development. Currently solid-state amplifiers are the most active part of microwave power sources. With the development of semiconductors, the development of solid-state amplifiers has entered a new climax [1].

Many years ago, electric vacuum tubes as the microwave source in the accelerator system. They output different energies. We can see in the Table 1 [2].

Table 1: Different Power Device in Common use in Accelerator

| Device | Frequent | Mode | Power |
|---|---|---|---|
| Electric vacuum tubes | 30~300 MHz | CW and pulse | ~2.5 MW |
| IOT | 500~1500 Mhz | CW and pulse | 100 kW |
| Klystron | 300~10 GHz | CW and pulse | 2 MW |
| FET | | CW and pulse | 1250 W |

In recent years, solid-state amplifiers are used more and more in accelerator system. Some of them as exciting source to provide incentives to the klystron, some of them as RF sources to the excitation cavity.

In this paper, a high power CW solid-state amplifier is designed for superconducting cavity power source. MOSFET has many advantages such as small size, voltage control, low heat generation and so on, therefore, NXP's MOSFET - MRFE6VP61K25H is selected by us as the core to design the final amplifier module. The 10W small power amplifier module with the gain is 35 dB is used as the boosting stage, combine with the power supply system, the power monitoring system, the cooling system, and the control system, we completed the solid-state amplifier.

## CIRCUIT DESIGN

### The Overall Circuit Design

The overall principle is shown in Figure 1. The low-power RF signal enters the push-level amplifier module through the input coupler and the RF switch. The push-level module inputs the amplified RF signal to the final amplifier module, and the final output high-power signal is output through the output coupler. The coupler coupling ends are connected to the corresponding power detection module to detect input, output, and reflected power in real time. The signal of detection modules are input to the control system to protect the amplifier modules and display power on the screen. Table 2 shows insertion loss.

Table 2: Insertion Loss in the RF Circuit

| Item | Insertion Loss |
|---|---|
| The coaxial cables of input | 0.6 dB; |
| RF switch | 0.4 dB |
| The coaxial cable between pusher amplifier and final amplifier | 0.2 dB |
| The coaxial cables of output | 0.4 dB |
| Isolator of output | 0.4 dB |

Considering that the maximum input power is 0dBm, we could calculate and get:

P(the input power of pusher amplifier)≤-1 dBm;
P(the output power of pusher amplifier)≤34 dBm;
P(the input power of final amplifier)≤33.8 dBm.

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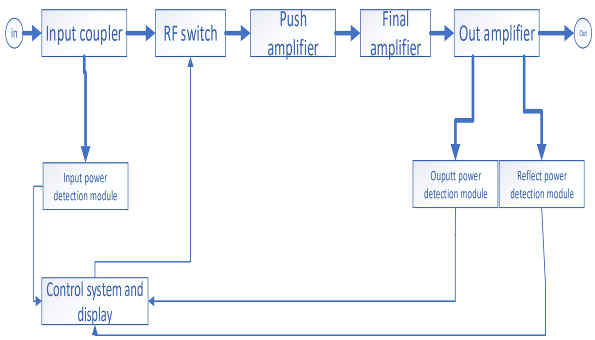

Figure 1: Basic block diagram.

### *The Final Amplifier Module*

The relationship of the drain voltage, gain and power could be obtained as are shown in Figure 2 and Figure 3. Because the gain of pusher amplifier module we design is 35dB and the final output power is 300 W(54.8 dBm) [calculate by Eq. (1)], the gain of final amplifier module should more than 21.8 dB. From Fig. 2 we could get that the efficiency decreases with increasing drain voltage. So low drain voltage is prefered. But the MOSFET may get saturation when in high power output condition. This cause us bother more heart dissipation. Therefore, comprehensive consideration, the drain voltage is set to 42 V, $I_{Dq}$ is set to 100 mA, then we get the gate voltage -2.36 V.

$$P = 10 \bullet \log_{10}\left(\frac{p}{p_0}\right) \tag{1}$$

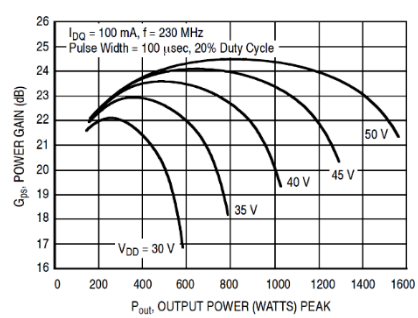

Figure 2: Power Gain versus Output Power Peak.

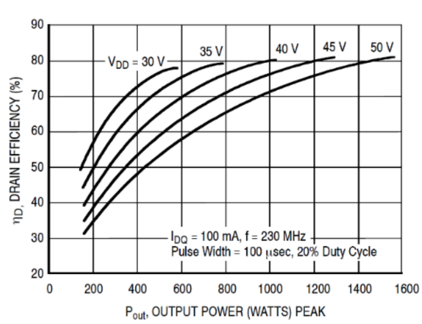

Figure 3: Drain Efficiency versus Output Power.

According to the data sheet [3], reference the Reference Circuit Schematic ( Fig. 5) and the Reference Circuit Component Layout ( Fig. 6), we make some modifications, adjustments and design matching input and output circuits and a power supply circuit, then finally get the final amplifier module circuit component layout (Fig. 7) .

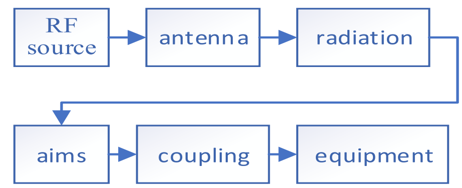

Figure 4: Microwave emission and mechanism of action.

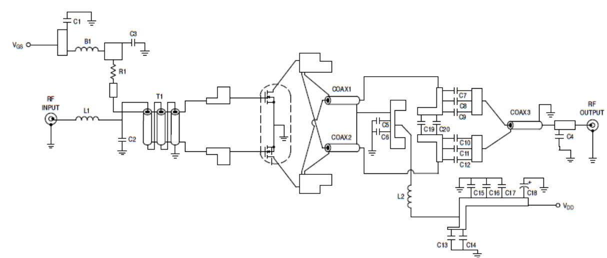
Figure 5: Reference circuit schematic.

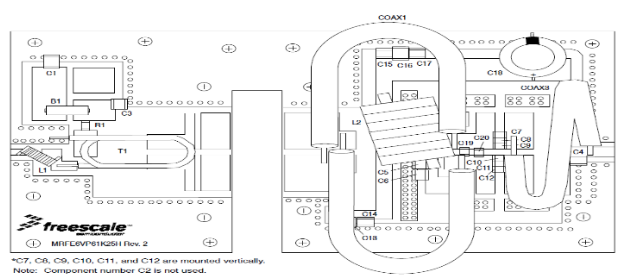

Figure 6: Reference circuit component layout.

### *The Microwave Leakage*

There are many ways to cause microwave leakage microwave radiation leakage. Such as from the RF coaxial, the circuit board, power supply line.

Microwave emission and mechanism of action are shown in Fig. 4.

Leakage through the power supply line is the most direct way. It would though the power supply line feed in the control system, monitor system.

Power line coupling is a way of microwave interface that can't be avoided. Power line coupling is similar to transmission cable coupling. The power line is often exposed to microwave field, so it is easy to introduce microwave interference [4]. According to the equation Eq. (2), a thin aluminium could shield the microwave in the space. And we use electrolytic capacitors between the end of positive electrode and ground which provide power to amplifiers. This will absorb the microwave leakage from power line.

$$A = 131.43\sqrt{f\,\mu_t \delta_t} \tag{2}$$

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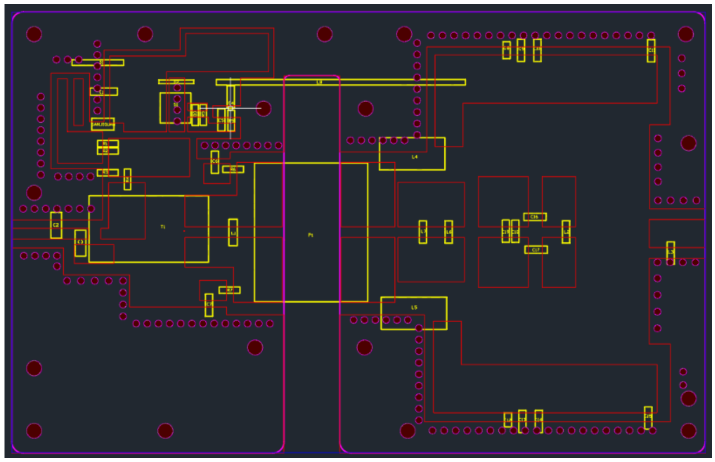

Figure 7: Amplifier module circuit component layout.

## TEST RESULT

### *Maximum Power*

The power of the signal source is set to 0 dBm, change the frequency from 150.4 MHz to 155.4 MHz by 1 MHz and measuring the power of output simultaneously, then we get the curve of frequency versus output power (Figure 8). We can see that the maximum power require has been met over the entire bandwidth and the flatness is 0.75 dB, which is better than the require (1dB).

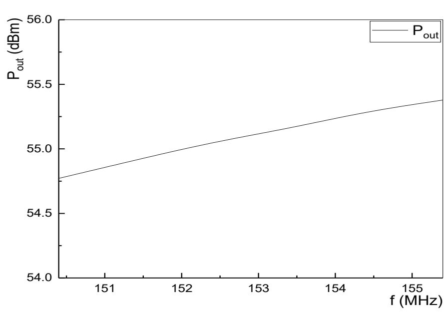


Figure 8: Frequency versus Output power.

### *Linearity*

Second the frequency is set to 153 Mhz. Then we can get the curve of the power of input versus output (Figure 9).It is show in the curve that the amplifier is working at a far position from the P1 dB compression point. This proves that the output matching circuit is well designed.

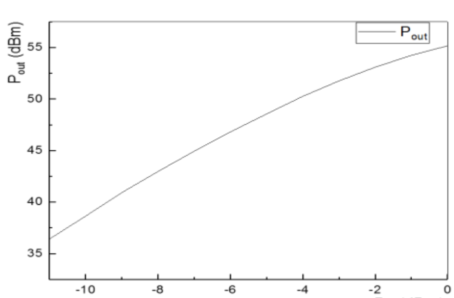


Figure 9: Power of input versus output.

## CONCLUSION

This paper presents a solid-state amplifier which is service for cyclotron system. By adjusting the MOSFET drain voltage and quiescent current of the final amplifier properly, it is set to a good operating mode. Heat dissipation, protection, microwave radiation shielding etc. are took into account, the amplifier systems are designed rationally to make the solid-state amplifier work normally. The output power in the entire band from 150.4 MHz to 155.4 MHz is more than 300 W. The flatness is better than 1dB. It could be utilized in the cyclotron system and driving the conducting cavities.

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