Design of millimeter wave radar amplification module

Cao Wang*, Chuan Chen* and Yong Fang

College of Information Science and Technology, Chengdu University of Technology, Chengdu, Sichuan, China
*a-e-mail: 841069891@qq.com
* Chuan Chen’s e-mail: xfyhyz@cdut.edu.cn

Abstract. In this paper, the millimeter wave radar amplification device is designed using the MWG303 power amplifier chip of Milliway Electronic Technology Co., Ltd. The whole device comprises an input waveguide microstrip transition structure based on Rogers 5880 and an output waveguide microstrip transition structure based on quartz. And waveguide structures such as waveguide turn and waveguide lift, in this design, the waveguide microstrip transition circuit is designed and simulated in the 3D electromagnetic field simulation software HFSS of Ansoft Company, and then the parts are combined, and the micro-assembly test is carried out after CAD processing. The results show that the gain can reaches more than 10dB. The design has the advantages of high gain, good flatness, practical structure and so on.

1. Introduction

Millimeter wave refers to the wavelength of the electromagnetic spectrum between 1 mm to 10 mm, the corresponding frequency range is 30GHz~300GHz. millimeter wave communication research began in the 1950s. In the late 1980s, millimeter wave has mature devices such as active and passive devices, and the emergence of high electron mobility transistor series (HEMT, PHEMT) has created good conditions for the development of various millimeter wave systems. With the development of society, millimeter wave has been increasingly paid attention to in broadband communication, wireless access and other fields [1]. Compared with microwave system, millimeter wave system has short working wavelength, small volume, high flexibility, light weight, large capacity, and wide frequency band. It can achieve image, digital and analog compatibility. Compared with infrared light, millimeter wave system has strong penetration ability and can operate under harsh environment [2]. In the working process of millimeter wave, the power level amplification is an important process, which is realized through the power amplifier. Under the condition of sufficient output power, the signal can be transmitted far enough, and the stability of the system and the quality of information can be greatly improved.

In the actual product design process, due to design or processing problems, the power amplifier designed in the original system can not meet the requirements of product output power amplifier, it is necessary to add a separate power amplifier peripheral to its external, to achieve the design power of the entire system. In this paper, the power amplifier peripheral of a millimeter-wave radar system is designed. Compared with the design of Ka-band high-power amplifier [3], its cavity structure is in the same position and different plane, which can effectively amplify the system power without changing the position of its output waveguide. The main improvements are: 1. Higher working frequency band
compared with Ka band; 2, input and output in the same position in different planes; 3. Rogers 5880 soft substrate is used for input waveguide microstrip transition, and quartz substrate is used for output waveguide microstrip transition, which has the characteristics of small transmission loss and low dispersion in high frequency band.

2. Solutions
In this paper, the power amplifier devices of 71GHz~80GHz are designed, and the power amplifier chip is designed by the MWG303 GaAs PHEMT process of Milliway Microelectronics Company. The working band can cover 71GHz~80GHz, the power supply is supplied by +4V voltage VDD, and the normal working current is 180 mA. The WR10 (1.27 mm * 2.54 mm) standard waveguide transmission TE10 mode, the input waveguide microstrip transition structure with thickness of 0.127 mm Rogers 5880 soft substrate, output waveguide microstrip transition using quartz substrate thickness of 0.127 mm, its dielectric constant is 3.7, the input waveguide joint original coplanar waveguide, designs the coplanar waveguide cavity waveguide transition structure.

3. Materials and Methods

3.1 Coplanar waveguide conversion
This amplifier module is vertically placed on the original PCB circuit board, and the microstrip on the circuit board is in the form of coplanar waveguide. Since the input is a standard waveguide cavity, it needs to be converted from coplanar waveguide to waveguide cavity. At the position of the waveguide cavity in contact with the coplanar waveguide, the size of the waveguide is larger than that of the standard WR10 waveguide. This design can maximize the conversion of the electromagnetic wave transmitted by the coplanar waveguide into the TE10 mode that can propagate in the waveguide cavity, greatly reducing the power loss. The model and simulation results are shown in Figure 1 below.

![Figure 1.Coplanar waveguide model and simulation results](image)

The simulation results show that in the frequency band 71GHz~85GHz, the return loss S11 is less than -20dB, and the loss at the center frequency point is -31dB, indicating that the signal in the coplanar waveguide can be effectively transferred into the waveguide cavity.

3.2 Input waveguide and waveguide microstrip transition structure
Input waveguide microstrip transition structure using Rogers 5880 soft substrate design, its thickness is 0.127 mm, the characteristic impedance of 50 Ω microstrip line of metal belt line width is 0.36 mm, thickness is 0.02 mm, we using Ansoft company 3D electromagnetic field simulation software HFSS simulation of waveguide microstrip transition circuit design. In the waveguide microstrip transition structure, the part extending into the waveguide can be regarded as the transmitting antenna extending into the rectangular waveguide. In order to make the energy of the waveguide receive by the microstrip
to the maximum extent, the microstrip probe designed should be placed in the place where the electric field is strongest in the waveguide. Generally there is a set of probe width and short road distance data, makes a probe impedance under frequency variation is minimal, in keeping with the width of 0.36 mm of 50 Ω microstrip line matching, the transition between the probe and microstrip line part should be inserted into a 1/4 wavelength change of impedance section, realize the impedance matching.

In the transmission structure of waveguide, the propagation direction of electromagnetic wave needs to be changed. When the reflection coefficient is not too high, waveguide lifting and waveguide corner are often used to achieve this in order to facilitate mechanical processing. Waveguide lifting is composed of two waveguides, and the waveguide corner is realized in a single corner way. Meanwhile, the edges are optimized to be round edges to reduce the reflection and improve the matching effect [4]. Its simulation model and results are shown in Figure 2.

![Figure 2. Input waveguide model and simulation results](image)

As can be seen from the figure, in the 67GHz~82GHz frequency band, the return loss S11 is less than -20dB, the insertion loss is less than -0.3dB, and the center frequency point is -25dB, which has a wide range of working frequency band and fully meets the design requirements.

### 3.3 Output waveguide and waveguide microstrip transition structure

Compared with RT5880, around 100 GHZ its transmission loss increase rapidly, process accuracy is bad, in order to minimize the transmission loss, combined with the actual situation, the quartz substrate waveguide microstrip transition structure is adopted at the output end, and the metal microstrip in the probe is chamfered to better improve the bandwidth range. Two waveguide cavities are used in the waveguide transmission structure. The simulation model and results are as follows:

![Figure 3. Output waveguide and simulation results](image)

According to the simulation results, in the frequency range of 70GHz~83GHz, the output return loss is less than -20dB, the central frequency point is -24dB, and the insertion loss S12 is less than -0.06dB, which fully meets the design requirements.
3.4 Overall structure
The input and output structures are combined together, and the chip is connected by gold wire bonding in the middle, and the chip is directly welded to the cavity to improve its heat dissipation performance. The simulation model and CAD processing diagram are as follows:

![Figure 4. Overall model and CAD assembly drawing](image)

3.5 Gain and return loss test results
After the design is completed, the model is exported to CAD and processed. After micro-loading and electro-loading, the final gain performance is tested, and the following test results are obtained.

![Figure 5. Gain test results](image)

The results show that the gain is greater than 10dB in the range of 76~80GHz, which meets the design requirements of power amplifier.

4. Conclusion
This design uses the power amplifier products manufactured by the GaAs PHEMT process produced by Milliway Microelectronics Company to realize the power amplification function of millimeter-wave radar with 10dB at 76GHz~80GHz. Two waveguide microstrip transition structures are used to ensure the best performance under the lowest economic conditions. The waveguide input and output structures are in the same position and in different planes, the output position of the original product is unchanged, only the amplification power does not change the structure, the gain of the simulation results is up to the standard, the flatness is good, and the bandwidth meets the design requirements.
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