Design and Simulation of Duplexer Based on Terahertz Technology

Xinxin Fang* and Ke Pang
Beijing Institute of Technology, School of Information and Electronics, Beijing, China

*Corresponding author e-mail: fang18235140593@163.com

Abstract. In this paper, a broadband polarization isolation device suitable for the terahertz band is designed by combining optics and electromagnetics. The 3D simulation software Ansoft HFSS is used to simulate the parameters of the polarization isolators and polarization converters in the module, and the final result graph is given. Finally, the polarized isolators and polarization converters were processed by the soft material processing technology and terahertz absorbing materials at home and abroad, and the assembly test was carried out. The test results prove that the transceiver isolation combined device has the advantages of high isolation and small transmission loss in the 450 ± 15GHz frequency band, which meets the technical specifications and has broad application prospects.

1. Introduction
The transceiver isolator is located between the transmitter, the receiver and the antenna in the communication system. Its main function is to ensure that the output signal generated by the transmitter is transmitted to the antenna in one direction and not to the receiver when the transmitter is in normal operation; Secondly, when the receiver is in normal operation, the input signal converted from the electromagnetic wave received by the antenna is guaranteed to be transmitted to the receiver in one direction and not to the transmitter. The terahertz band is close to the infrared band, and it has many kinds of light-like characteristics, so the isolation technology in the terahertz band is more considered to be designed by optical or optical and electromagnetic combination. The isolators in the 675GHz scanning imaging radar developed by the US Jet Propulsion Laboratory use high-resistance silicon materials. Due to the width of the beam itself and the thickness accuracy of the beam splitter, the actual measured loss is greater than the actual engineering requirements. The 680GHz radar system in [2] uses waveguide-type orthogonal mode converters to achieve high isolation, but due to processing limitations and precision limitations, there is much room for improvement in terms of performance. In 2009, Beijing Institute of Technology's Target Characteristics Laboratory designed a 220GHz reflective transceiver isolation network, which consists of two key components: polarization converter and polarization isolators. These transceiver isolation devices can provide more than 60dB isolation. Its transmission loss is less than 1dB and its performance is excellent. Polarization converter is an important part of the power divider, the main function is to achieve polarization conversion. In recent years, due to the use of metamaterials, the polarization converter has entered the sub-wavelength conversion stage. The Cui Tiejun team of Southeast University proposed a “work” type cell structure to implement orthogonal transformation on the surface of the metamaterial, but not for the terahertz band;
Iranian scientists applied double-layered cross-shaped artificial materials to traditional circularly polarized antennas to improve the purity of circular polarization of antennas. However, due to limitations in processing accuracy, it is difficult to apply to engineering practice. This paper design a reflective transceiver isolation network the isolation network uses metamaterial as the dielectric substrate, which is easy to process, provides isolation greater than 40dB, and transmission loss less than 3dB, which is easy to popularize in practical engineering.

2. Design and simulation

Figure 1 is a structural diagram and schematic diagram of a polarized isolator. Observing the structure diagram of the polarized isolator, it is composed of a layer of non-metallic material of a certain thickness and a parallel metal grid. The isolator needs to be combined with the combined device. The signal transmission path is placed at a 45 degree angle. When the transmitting antenna is in operation, a transmitting signal \( E_T \) is incident at a 45 degree angle with the polarizing isolator. It is assumed to be a horizontally polarized wave. At this time, the polarization direction and the polarization isolators are at 45 degrees, the signal can be decomposed into a component \( E_{TS} \) whose polarization direction is perpendicular to the polarization barrier metal grid and a component \( E_{TR} \) whose polarization direction is parallel to the metal grid. The component \( E_{TS} \) passes directly through the polarization isolator, and the component \( E_{TR} \) is reflected by it. When the polarization isolator receives the echo signal \( E_R \), the polarization direction is polarized with the polarization isolator, and the metal grating is parallel to the line polarization electromagnetic wave \( E_{TS} \), and the signal is directly reflected by the polarization isolator to be received by the receiving antenna end.

The polarization converter is a two-layer structure. As shown in Fig. 2, the spacing between the two layers is \( \frac{n \lambda}{4} \), such that each layer is composed of a metal pattern and a dielectric substrate, and the metal pattern is a periodically arranged metal grid and Square metal blocks are arranged one after another. When incident wave incidence, the structure produces different equivalent inductance values in the orthogonal direction, these equivalent inductances cause the quadrature component to be different from the phase delay when projected onto the metal layer of the polarization converter. The method causes a phase difference between the two orthogonal components.

In this paper, the HFSS simulation software is used to simulate the model of the polarized isolator, and the influence of the dielectric base imine of different thickness on the performance of the isolator is analyzed. The non-metallic material of the metal grating supported by the base material of the polarized isolator is polyacyl. An film that reduces the insertion loss of the device.

![Figure 1.](image)

Figure 1. (a) and (b) are structural and schematic diagrams of a polarized isolator.
The change in insertion loss of the polarized isolator after changing the thickness of the dielectric substrate is as shown in Fig. 3 and Fig. 4. When the thickness of the dielectric substrate is increased, the dielectric loss of the polarized isolator is increased, and when the thickness of the dielectric substrate is fixed, along with the frequency the insertion loss of the polarized isolator increases linearly. When the thickness of the dielectric substrate fluctuates between 8μm and 12μm, the insertion loss of the polarized isolator fluctuates from 0.118 to 0.168dB, which is about 0.05dB can be ignored. Analyze the relationship between the performance of the model and the electromagnetic properties of the material. Select the polyimide film as the dielectric substrate and the thickness is 10μm.

For the polarization converter, the main function is to realize the conversion between linear polarization and circular polarization. The performance mainly needs to investigate the amplitude difference, phase difference and insertion loss of the two orthogonal polarization components. The spacing between the two layers is given the problem of fixed spacing, if the spacing is too small, the fixing is difficult, so the spacing is set to three-quarters of the wavelength, which is 500μm. Fig. 5 and 6 show the amplitude difference and phase difference between two orthogonal electric field components. In the frequency range of 430-470GHz, as the frequency increases, the amplitude difference of the two components passing through the transmissive polarization converter generally shows an increasing trend, almost linear growth; the phase difference of the two orthogonal polarization components shows a downward trend as a whole. It is also almost linearly reduced; the combined insertion loss of two orthogonal polarization components is the smallest at 435GHz, which is about -0.724dB, and the synthetic insertion loss on both sides of the frequency appears monotonously increasing. The combined insertion loss of the two components fluctuates within -0.725 to -1.104dB, and the less than 2dB, the polarization converter works well in the 450 ± 15GHz band, which can well achieve various requirements.
Figure 4. The result of the isolation results in different thickness.

Figure 5. (a) and (b) are the amplitude and phase difference results of the polarization converter.
3. Testing results

Through simulation design, the device is processed, and the polarization isolators and polarization converters are assembled and finally tested. The design index of this paper is center frequency is 450GHz, transmission loss is less than 3dB, and isolation is greater than 40dB. Due to center frequency and bandwidth it can be determined according to the frequency distribution characteristics of transmission loss and isolation, so the main test indicators are transmission loss and isolation. The transmission loss test results of the signal transmitted through the transceiver isolation device in the 0 degree and 90 degree directions are shown in Fig. 7. As shown in Fig. 7, the transmission loss of the system is less than 3dB in the 450 15GHz frequency band, which satisfies the index.

![Figure 6. Polarization converter synthetic insertion loss result.](image1)

![Figure 7. The test results of insertion loss.](image2)

![Figure 8. The test results of Isolation.](image3)
As shown in Fig. 8, in the 450±15GHz band, the isolation of the transceiver isolation device is between 53.919dB and 59.641dB, both greater than 40dB, the insertion loss is small, the bandwidth is wide, and the simulation results are basically consistent with the test results. The duplexer meets the design requirements.

References

[1] K.B. Cooper and R.J. Dengler, “THz Imaging Radar for Standoff Personnel Screening”, in IEEE Transactions on Terahertz Science & Technology, 2011, pp: 169-182.

[2] D.A.Robertson and P N. Marsh, “340 GHz 3D radar imaging test bed with 10 Hz frame rate”, in Proceedings of SPIE - The International Society for Optical Engineering, 2012, pp: 8362:8365.

[3] C.A.Leal-Sevillano, and K.B.Cooper, “Compact Duplexing for a 680-GHz Radar Using a Waveguide Orthomode Transducer”, in IEEE Transactions on Microwave Theory & Techniques, 2014, pp: 2833-2842.

[4] J.H.Lu and K. L.Wong. “Single-feed circularly polarized equilateral-triangular microstrip antenna with a tuning stub”. in IEEE Transactions on Antennas & Propagation, 2000, pp: 1869-1872.

[5] H.F.Ma and G.Z. Wang.“Broadband circular and linear polarization conversions realized by thin birefringent reflective metasurfaces”, in Optical Materials Express, 2014, pp:1717-1724.