

Terahertz Dual Polarizations Offset Reflector Antenna Using Sic And CFRP Material

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Abstract - The high gain offset reflector antennas for dual polarizations terahertz application are proposed. The two reflector antennas are made of silicon carbide material and thermally stable carbon fiber-reinforced plastic respectively. The electroforming technology is used to make the high precision corrugated horn. Several mechanical and electrical tests procedures were done to verify the antenna specifications. Special efforts was made to find a reasonable and quick method to measure the large antenna patterns based on exact optical test, the results using this method are comparable to that of the near field test. The side lobe level of the silicon single polarization reflector is about -32dB, while the dual polarizations patterns of carbon fiber-reinforced plastic reflector antenna have side lobes level of -24dB and -26dB.

Index Terms —Terahertz High Gain Antenna, silicon carbide, electroforming, three coordinates test

1. Introduction

Metal reflector antenna have been used for many decades, however, with the antenna frequency increasing to terahertz (THz), much more rigorous demand accuracy of antenna surface is needed. It is very difficult to reach up to 1 micro mm RMS surface accuracy using relatively “soft metal” (such as alumina). The Planck space telescope and Herschel payloads [1] used the reflectors by stable carbon fiber-reinforced plastic (CFRP) and silicon carbide (Sic) material. Reflectors manufactured from thermally stable CFRP sandwich structures and Sic can have the RMS surface accuracy much higher than that of metal, but their making process are more complex. Comparing with the traditional ortho-mode transducer (OMT), the polar grids is more suitable for the THz use due to its low loss parameter. On the other hand, large dimension high gain antenna patterns test using near field method is a very boring and monotonous task, in addition, when the antenna is in cryo-temperatures conditions, no feasible test method can be found to measure the antenna patterns. In this paper the large aperture high gain antenna patterns by physics optics software based on the optical test data is analyzed, this method can also be spread to the antenna patterns analysis under cryo-temperatures condition.

2. Quasi-optics design of the THz antenna

Millimeter wave quasi-optical technique is the high frequency electromagnetic paraxial approximation [2]. The Gaussian beam optics is used to simulate the propagation, coupling and transformation of electromagnetic waves in space. The quasi-optical system uses free space electromagnetic waves as the transmission medium.

The quasi-optical system configuration refers to the ordering and arrangement of the individual components such as the offset angles, grids, the mirror position to couple the together the beams specified for the required components (fig.1). Of course the f/D ratio should be taken into account firstly to meet the antenna system.

The corrugated horn usually work in balance mixed-mode [3], Hermite mode can be used to expand aperture field. Taking into account the asymmetry of the offset parabolic antennas, it would be more convenient using Cartesian coordinates.

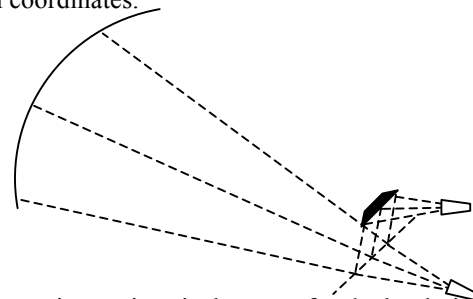


Fig.1 Schematic quasi-optical system for dual polarizations antenna.

3. Antenna Mechanical Tests

(1) Sic Reflector roughness (RMS) measurement

The three-coordinates measuring machine of Zeiss was used to test the surface of Sic reflector, and the results is shown in Fig.2 and Fig.3a. It can be seen that the root-mean-square error (RMSE) of antenna surface is $0.6\mu\text{m}$. Considering the wavelength is around 0.8mm , the RMSE of antenna surface is 0.07% of the wavelength, which is enough to meet the requirements of antenna surface.



Fig.2 Sic reflector antenna under surface roughness test using three-coordinates measuring machine

(2) CFRP Reflector Surface Roughness (RMS) Measurement and Grid tests

We use two electronic theodolites to measure the CFRP reflector surface roughness (RMS), the mean square root of

the reflector surface is 0.0136mm. Special effort was made to ensure the grid and plate were parallel to each other.

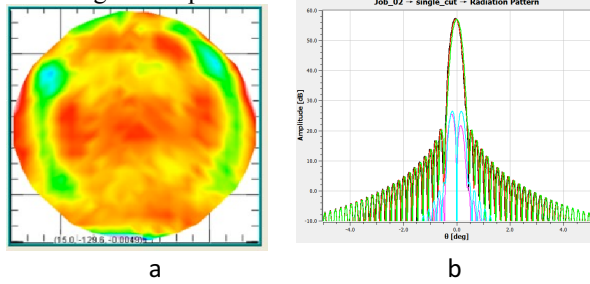


Fig.3 SiC antenna patterns using physics optics
a. Surface roughness distribution b. antenna pattern by the PO and surface data

4. Antenna Patterns Test

(1) Antenna patterns estimation using physics optics(PO)

The actual pattern of antenna can be obtained by putting the measured three-dimensional coordinate of sample point into physical optics method. This kind of analysis method has high universality, and provide a equivalent test method with effectiveness and accuracy for electrically large antenna, Extremely High Frequency(EHF) antenna(more than 600 GHz), antenna in the testing conditions(vacuum tank can be used for shielding electromagnetic wave).

(2) Antenna(SiC) patterns Using near field system

The radiation pattern of the THz SiC reflector is shown in Fig.4. It can be concluded that the side lobes of the THz SiC reflector antenna are below -32 dB and -33dB with regard to the peak level of the two principal plane. The evenly distributed phase of caliber field indicate that the antenna has high surface accuracy. The main-beam efficiency is around 93%, which meet the requirements of THz/millimeter wave detection. The THz reflector antenna radiation pattern based on measured coordinate is shown in Fig. 3b. It can be seen that the side lobes are below -32dB, which is in good agreement with the measured result. Thus the physical optics analysis based on surface test can be used for replacing the conventional antenna measurement.

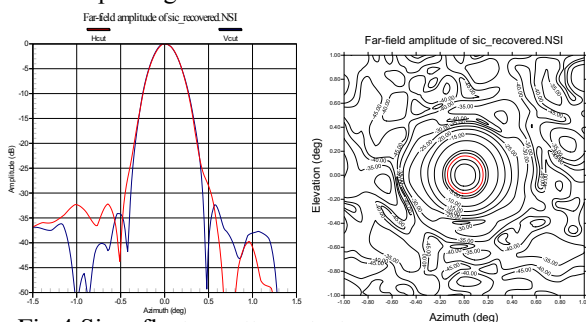


Fig.4 SiC reflector patterns test

(3) Antenna(CFRP) patterns Using near field system

The patterns of the CFRP reflector antenna were also measured by the near field system(Fig.5). The main channel patterns are depicted in Fig.6a and 6b, and the side channel patterns(reflected by grid and plate) are shown in

fig.7b. It can be seen that the side lobes in main channel are less than -24dB, and the side lobes in the side channel is less than -26dB.

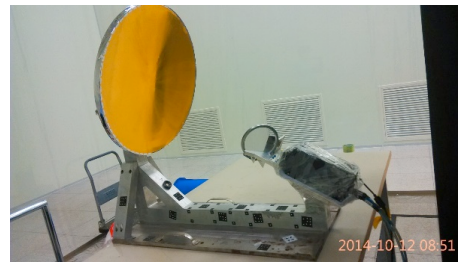


Fig.5 CFRP dual polarizations antenna under near field test

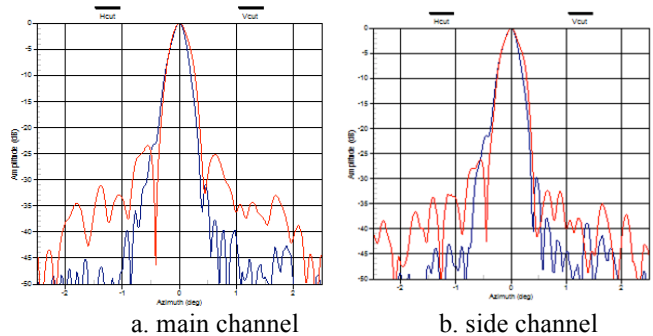


Fig.6 CFRP dual polarizations antenna patterns by near field test

5. Conclusion

The very short wavelength of THz waves brings forward high request on fabrication of antenna. The electroforming was used to fabricate high accuracy corrugated horn with complicated inner structures. SiC together with CFRP material with high specific stiffness and low thermal expansion coefficient were used to processing THz reflector antenna, the surface metallization ensures the THz signal reflection. The surface accuracy of SiC reflector is 0.6μm, while the CFRP surface accuracy is 13μm. The physical optics analysis with three-dimensional coordinates of measured surface are used to obtain the pattern. This kind of analysis method provide a alternative test method for electrically large antenna, EHF antenna, antenna in the testing conditions or other unsuitable direct testing conditions. The results of planar near field measurement show that the side lobes of the SiC reflector antenna are below -32dB, while the side lobes level of CFRP antenna are -24dB and -26dB, which meet the requirements of THz submillimeter wave remote sensing demand for antenna.

References

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