DUAL-POLARIZED ANTENNA BASED ON MEMS TECHNOLOGY FOR TERAHERTZ POLARIMETRIC RADAR

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Abstract

Planar integrated antenna has special advantages in Terahertz application, but with disadvantage of low gain. In this paper, a novel Terahertz integrated dual-polarized horn antenna at 900 GHz is proposed which can be used in a Terahertz polarimetric radar system. The processing of this type horn antenna combine two kind MEMS techniques, DRIE etch and wet etch. The structure of the horn include two parts, pyramid horn back cavity and octagonal horn front cavity. There are many tunable parameters of the horn. FEM method is used to analyze it, this new type integrated horn antenna can improve the radiate performance of planar integrated dual-polarized antenna elements.

1 Introduction

Terahertz wave has higher frequency and shorter wavelength at band compared with microwave and millimeter wave, so smaller device is needed. Antenna is this kind device whose size is close related to wavelength.

MEMS (Micro-electromechanical Systems) technology is a cross-science, which studies the coupling relationship of characteristic parameters from different branches of science. These relationships can be used to analyze and solve the problems in MEMS design and manufacture. MEMS manufacture process will not change the geometric parameters of structure, but will affect the properties of materials, and this will affect the electronical and mechanical features of structure.

Polarimetric radar is capable of measuring polarization-dependent attributes of a target, and is an increasing important tool in MMW and also THz remote sensing. It needs to transmitting horizontally and vertically polarized waves.

In 1990, G. M. Rebeiz and his members designed integrated horn antenna, they integrated planar antenna on μm thick thin-film substrate, and the thin-film is put in a silicon pyramid cavity by using MEMS wet etching technique. This method is a very good solution to the problem of supporting the thin-film and enhance the antenna radiation, but because of restrictions on the thickness of silicon wafers (usually no more than 800μm), the aperture of integrated horn are severely restricted. In order to enhance the radiation, they integrated a machining horn and MEMS horn together to form a "quasi-integrated" horn antenna. Quasi-integrated method is feasible in the lower frequency of sub-millimeter wave band, to about 900GHz, machining will create great difficulties [2]-[5].

In this paper, a kind of new type dual polarized antenna structure based on MEMS technology is proposed, which is suitable for high frequency sub-MMW band polarimetric radar.

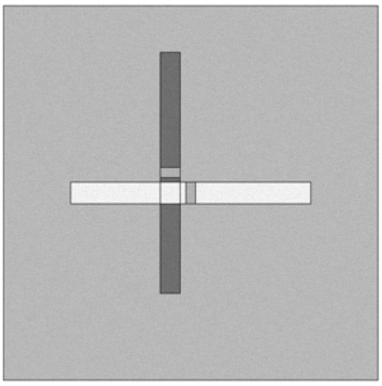
2 Fabrication Techniques

DRIE (deep reactive ion etching) and KOH wet etching are two types of MEMS processing technology. SCS (Single crystalline silicon) is the main material in both MEMS technology, which has many good features. Its properties can be changed observably by adulterating a little adulterant. The surface roughness can reach nm level by chemical polishing. It has good elasticity and rigidity, and also good properties on anisotropic etching and cleavage. In the method of anisotropic wet etching, the V shape groove can be realized on (100) wafer, on which the inclination of (100) plane and (111) plane is 54.7°, while the vertical side groove can be realized on (110) wafer, the dimensional tolerance of which can reach 1.0 μm. (see Fig. 1) Many kinds of bonding technologies can be adopted in MEMS packaging. SFB (Silicon fusion bonding) is one of them, which is a simple and cheap technology for Si wafer. Si-Si bonding, one kind of SFB, is adopted in this paper. There are many methods of making metallic thin films: electroplating, sputtering and EB (Electron beam). The sputtering method can make gold films at the 10nm level.

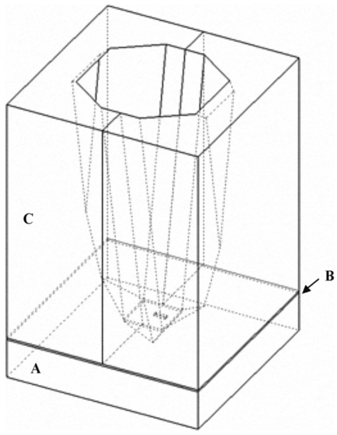
3 Antenna structure

In G. M. Rebeiz's designs, only wet etching technology was utilized. The vertex angle of pyramid back and front cavity is limited to 70.6° because of the silicon crystal characteristic[2]. Front cavity part is also restricted in the silicon wafer's thickness highly, although may stack multi-layers wafers to increase horn's length. Therefore antenna's radiation performance is quite fixed, particularly radiation pattern shape of antenna. Although the "quasi-integrated" method can improve radiation gain by choosing different flare angle of machining horn, but in the 900GHz frequency band, the wave length only about 300 μm, machining horn is very difficult to obtain the guarantee.

Therefore this paper proposed one kind integrated horn antenna structure (see Fig.1), which is manufactured by using MEMS processing completely.



(a)



(b)

Fig. 1 (a) Structure of dual-polarized dipole antenna
(b) Structure of octagonal integrated horn antenna

Structure of dual-polarized dipole antenna is shown in Fig. 1 (a), it is a simple dual-polarized structure but very effective in THz band. It is about 1μm thick silver or gold formed on Silicon or GaAs membrane. At the apex of dipole antenna, Schottky diode or SIS detectors can be integrated. Schottky diode detector works at room temperature, while SIS detector must work at super conductor temperature. Both detectors are inherent, so couple between two detectors on same membrane doesn't need consideration.

In Fig. 1 (b), total structure of integrated horn antenna is given. Part A is pyramid horn back cavity manufactured by using KOH wet etching technology on silicon wafer, whose angle is 70.6 °, and is sputtered with gold layer internal. Part B is planar dual –polarized dipole antenna on thin-film substrate shown in Fig. 1(a). Part C is octagonal horn cavity structure combine both dry etching and wet etching processing technology. The manufacture steps of part C are shown below.

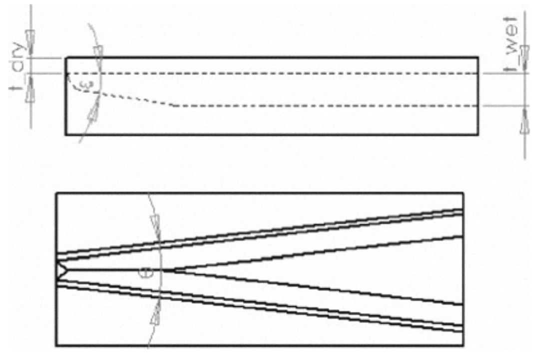


Fig. 2 side view and vertical view of octagonal horn cavity Structure

Step 1: Dry etching, etching depth is t_dry, horn angle is θ. In order to integrate together with back cavity structure, t_dry equals half of width of the cavity opening a.

Step 2: KOH wet etching, etching depth is t_wet, form vertical angle ε. Half of octagonal shape horn formed after this step.

Step 3: Sputter gold layer inside the horn. Then the same two halves bonded together, and the extra part is cut by dicing techniques.

At last, integrate A, B and C together, it is the final integrated horn antenna structure. A trench can be etched on part A, which is left for integrated circuit and transmission line to use.

This structure can greatly satisfy the demand for precision. Tunable parameters of this structure include flare angle of front cavity θ, the depth of wet etching t_wet, length of front cavity l and height of back cavity h_a

4 Modeling and Simulation

The length of the dipole is 0.4λ at 900GHz. Radiation pattern and VSWR of it show in fig.3. The radiation patterns and VSWR parameters of Antenna 1 and antenna 2 are almost same. The isolation between the orthogonal antennas is below -22dB in 850-950 GHz range.

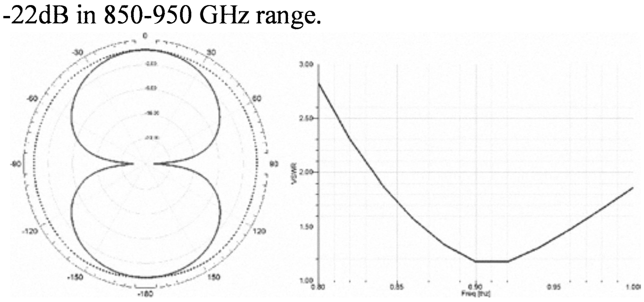


Fig. 3 Radiation pattern and VSWR of 900GHz dipole antenna

Height of back cavity A *h_a* has great influence on the performance of total integrated horn antenna. Choose *h_a* as 0.38λ、0.7λ and 0.9λ, while *θ* and *t_wet* are fixed

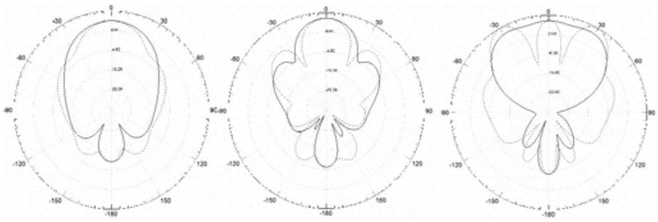


Fig. 1 Radiation patterns at different h_a (0.38λ, 0.7λ and 0.9λ)

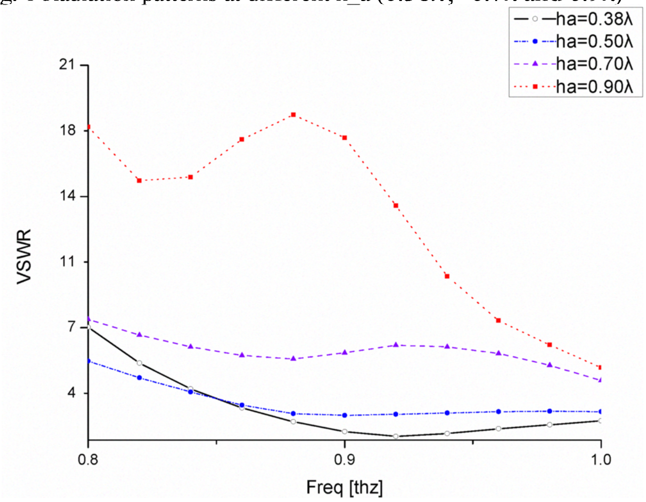


Fig. 2 VSWR at different h_a

When *h_a* increases, the width of the antenna main lobe increased. But after 0.8λ, main lobe spited. From the VSWR result, we can see that the standing wave worsened with the increase of *h_a*. Considered the radiation and VSWR results, *h_a*=0.38λ is a good choice.

Select *h_a*=0.38λ, *l*=1.4mm, change the value of *θ* and choose right *t_wet*, makes the shape of front cavity rotation symmetry. When the value of *θ* select 20°, 30° and 40°, radiation pattern of 30° and detail results are shown as follows.

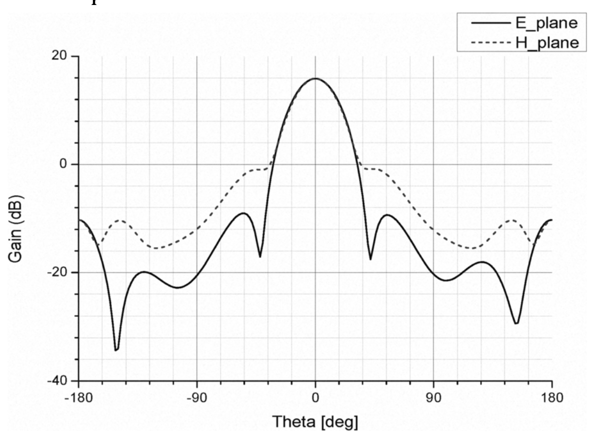


Fig. 3 Radiation pattern when θ=30°

TABLE 1

Results of different values of *θ*

θ (deg)	Gain (dB)	HPBW(E plane)	HPBW(H plane)
20°	14.1	40°	34°
30°	15.9	28°	28°
40°	17.2	24°	26°

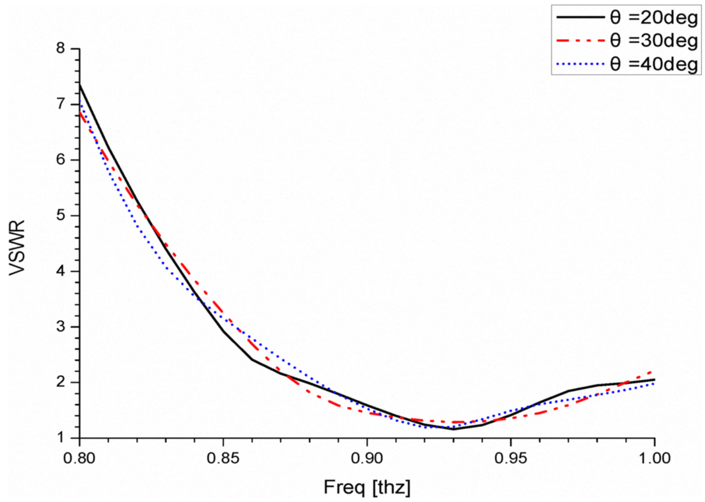


Fig. 4 VSWR results of different θ

From the above results, we can see that the dry etching angle of front cavity is influence on radiation performance. When the angle *θ* increases, width of main lobe of the antenna becomes narrower while gain increased as a result of a fixed length of the front cavity, the greater the angle *θ*, the greater the aperture. This is consistent with traditional horn antenna theory. VSWR results do not change much with the angle. In practice, we can design integrated horn antenna meets the needs of the application by controlling the angle *θ*.

In the simulation, depth of wet etching *t_wet* is chosen to make the height and width of horn are approximately the same. But in practice, *t_wet* should be chosen to satisfy the demands of E-plane pattern. The depth of wet etching is limited by the thickness of silicon wafer.

If the length of front cavity *l* is increased, higher gain will get. Select *θ*=30° , at this condition, the patterns of E-plane ane H-Plane are almost symmetry within ±30° , which will satisfy the quai-optical system if used. Set different values of *l*.

TABLE 2

Results of different values of *l*

l (mm)	Gain (dB)	HPBW(E plane)	HPBW(H plane)
1.4	15.9	28°	28°
2°	18.6	22°	22°
2.5°	20	18°	18°

5 Conclusion

Through the FEM analysis of dual-polarized integrated horn antenna at 900GHz band, we can see that this novel MEMS-based antenna can be a very good way to improve radiation performance of planar integrated antenna. Tunable parameters of this horn structure include flare angle of front cavity *θ*, the depth of wet etching *t_wet*, the depth of DRIE etching *t_dry*, length of front cavity *l* and height of back cavity *h_a*. The antenna has polarization isolation about 22dB, and symmetry radiation pattern in main lobe range. In future, we will integrate SIS detectors and fabricate the whole integrated antenna system.

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