Analysis and design of a quasi-optical monopulse antenna at sub-millimeter wavelengths

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Abstract: A quasi-optical (QO) monopulse antenna operating at sub-millimeter wavelengths is described in this paper. The Finite Difference Time Domain (FDTD) method is adopted for investigating the radiation performance of sum-difference patterns. For suppressing the sidelobe levels of sum radiation patterns, a hyperbolic-plano dielectric lens with cutting segments is introduced. The simulated results show good monopulse performance with the sidelobe levels below -10.0 *dB*, the maximum null-depth approximately -30.0 *dB*, and the amplitude unbalance below 1.25 *dB*.

Keywords: Quasi-optical (QO), Monopulse antenna, Sub-millimetre wavelengths.

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1. Introduction

Monopulse antennas, which have the good performance in tracking speed, tracking precision and anti-jamming ability, have received more considerable attention in inter-satellite communication systems [1]. Various forms of monopulse antennas or sum-difference comparator, which are made of the conventional transmission lines such as waveguide, microstrip lines, substrate integrated waveguide, etc., have been thoroughly investigated at microwave and millimetre wavelengths. However, as the operating frequency increasing, especially over 300 *GHz*, the waveguide, microstrip lines, and substrate integrated waveguide components unavoidably have the drawbacks of higher ohmic-power losses, being difficult to manufacture, and being sensitive to the structure parameters. Consequently, quasi-optical [2, 3] technology will become increasingly effective at sub-millimetre wavelengths. In 1996, a novel low-loss and polarization-independent quasi-optical monopulse comparator operating at 140 *GHz* was developed [4]. In 2005, An Gang analysed the properties of quasi-optical monopulse antenna feed structure based on this comparator combined with spherical lens at W band [5]. In this paper we demonstrate a new monopulse antenna based on quasi-optical sum-difference comparator at sub-millimetre wavelengths. And then a hyperbolic-plano lens with cutting segments is introduced to suppress the sidelobe levels.

2. The quasi-optical monopulse antenna

The quasi-optical monopulse antenna is composed of the following sub-components: the feed horn such as diagonal horn or corrugated horn, a spherical thin lens, and a quasi-optical sum-difference comparator. Fig. 1 shows the configuration of the monopulse antenna marked with the relevant parameters. Gaussian beam is radiated from the feed horn with the predefined beam waist w_0.

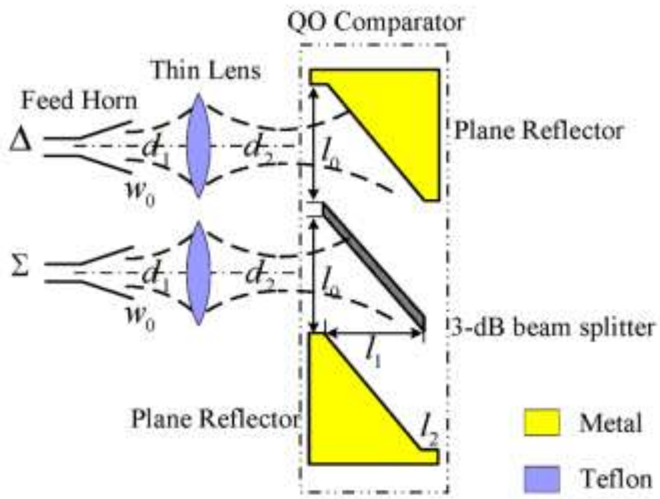

Fig. 1 Configuration of the monopulse antenna.

A spherical thin lens of focal length f is a focusing element, which couples the Gaussian beam into the quasi-optical comparator. For the thin spherical lens, the incident and output distance of Gaussian beam is d_1 and d_2, respectively. The quasi-optical comparator is composed of two parallel plane reflectors and a low-loss quasi-optical 3-*dB* substrate beam splitter symmetrically positioned between them. The 3-*dB* substrate beam splitter and the two parallel plane reflectors have equal surface dimensions and are arranged parallel to each other and at a 45 °angle to the input plane. The relevant parameters of the quasi-optical monopulse antenna are listed in Table. 1.

Tab. 1 The relevant parameters (Units: *mm*)

w_0	d_1	d_2	f	l_0	l_1	l_2
1.50	8.36	8.36	8.36	4.62	4.62	0.80

The FDTD method is adopted for calculating the radiation performance of the monopulse antenna. Fig. 2a and Fig.2b present the sum and difference radiation patterns, respectively.

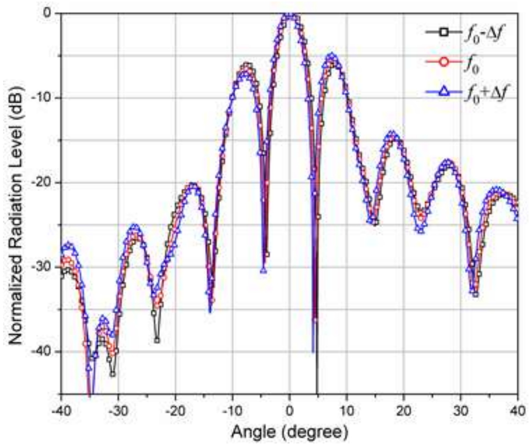

Fig. 2a Normalized radiation sum patterns

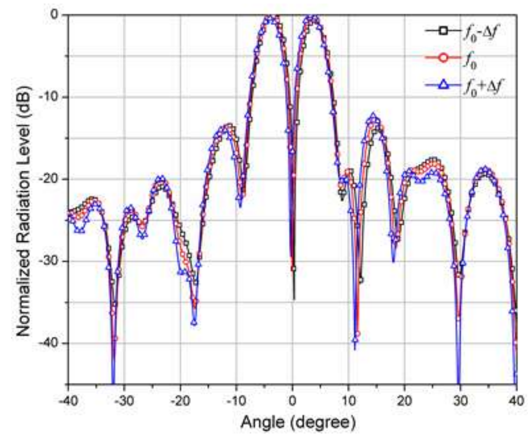

Fig. 2b Normalized radiation difference patterns

The results from the Fig. 2a and Fig. 2b show that the maximum null-depth and amplitude unbalance in difference patterns are approximately below -30.0 *dB* and 0.65 *dB* at the centre frequency 375 *GHz*, respectively. Nevertheless, the sidelobe levels in sum patterns are only below -5.0 *dB*. Therefore, in the following section a hyperbolic-plano dielectric lens with cutting segments is illustrated for suppressing the sidelobe levels in sum patterns.

3. The monopulse dielectric lens antenna

The dielectric lens is a hyperbolic-plano lens, which is cut a part in the centre. The cutting segments can compensate the phase difference of output aperture fields when sum port feeding. Fig. 3 presents the configuration of a monopulse dielectric lens antenna and the related parameters are: d = 14.94 *mm*, R_1 = 3.38 *mm*, a_1 = 2.48 *mm*, R_2 = 5.70 *mm*, a_2 = 3.65 *mm*, R_3 = 8.96 *mm*, a_3 = 4.54 *mm*, a_0 = 12.60 *mm*. Moreover, the *f*-number of original hyperbolic-plano lens is 0.95.

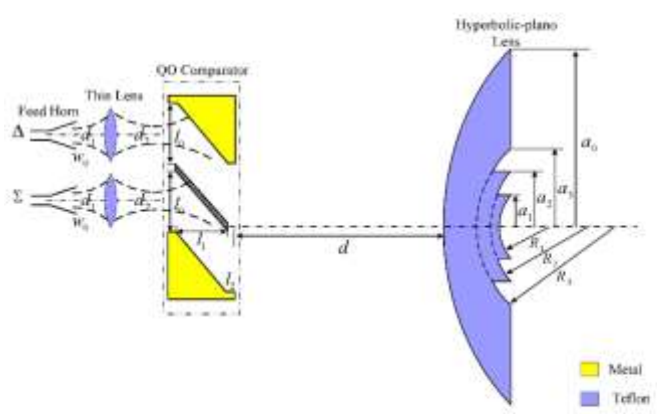

Fig. 3 Configuration of the monopulse dielectric lens antenna

Excited at the sum and difference port respectively, we can achieve the sum and difference radiation patterns. Fig. 4a and Fig. 4b demonstrate the corresponding radiation patterns. The results in Fig. 4a and Fig. 4b demonstrate that this type of monopulse dielectric lens antenna has good sum-difference radiation performance, where the sidelobe levels is increased from below -5.0 *dB* to below -10.0 *dB*, the maximum null-depth is approximately -30.0 *dB*, and the amplitude unbalance is below 1.25 *dB*.

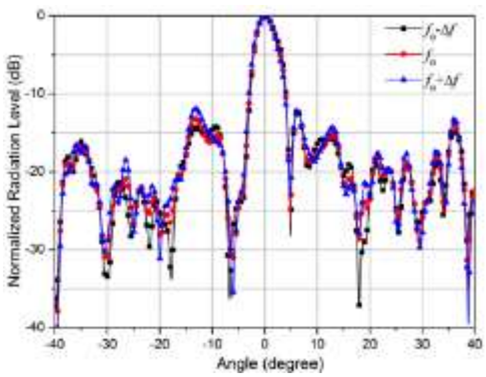

Fig. 4a Normalized radiation sum patterns

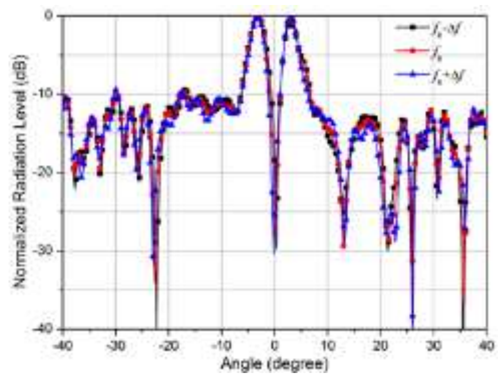

Fig. 4b Normalized radiation difference patterns

4. Conclusion

A quasi-optical monopulse antenna operating at sub-millimetre wavelengths is demonstrated by rigorous numerical computation. For improving the radiation performance, a hyperbolic-plano dielectric lens with cutting segments is introduced to design a monopulse dielectric lens antenna, which shows good sum-difference radiation performance.

Acknowledgements

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References

[1] G. J. Hawkins, D. J. Edwards, and J. P. McGeehan. “Tracking system for satellite communication”. *IEEE Proc.*, 135, 5, 393-407 (1988).

[2] P. F. Goldsmith. “Quasioptical Systems: Gaussian Beam Quasioptical Propagation and Applications”. *IEEE Press*, (1998).

[3] Dou. Wenbin. “Millimeter Wave Quasi-optical Theory and Techniques (in Chinese)”. Higher Education Publishing Company, (2006).

[4] J. Rolf. “A novel quasi-optical monopulse-tracking system for millimeter-wave application”. *IEEE Trans. Antennas Propag*., 44, 4, 466-477 (1996).

[5] G. An and W. B. Dou. “Analysis of a sphere lens quasi-optical monopulse antenna/feed structure”. *J. of Electromagn. Waves and Appl*., 19, 1, 83-93 (2005).