ISSN: 1813-4890

Dual-band Fabry-Perot resonant cavity antenna

Hao Zhang

School of Electronic Engineering, Tianjin University of Technology and Education, Tianjin 300000, China

18822105703@163.com

Abstract

This paper presents a dual frequency Fabry Perot resonator (FPR) antenna fed by an F-shaped probe. The antenna is connected by four parallel metal plates perpendicular to the ground plane. Its resonant frequency can be controlled by changing the distance between the parallel plates. The two impedance bandwidths of the proposed antenna simulation are 4.4% (20.72-21.65ghz) and 5.5% (24.4-25.67ghz), respectively, which have dual frequency characteristics in the millimeter wave band. At the same time, the maximum gain in the two frequency bands is 9.1dbi and 5.9dbi, respectively.

Keywords

Dual-band antennas, Fabry-Perot resonators, Millimeter wave.

1. Introduction

With the rapid development of wireless communication, the demand for bandwidth in modern systems is higher than ever before to adapt to more communication channels [1]. Therefore, the carrier frequency of modern wireless systems gradually rises to K-band and higher frequency band. For this reason, a variety of antennas have been reported, including microstrip antenna [2], microstrip reflective array antenna [3], lens antenna [4] and dielectric resonator antenna (DRA) [5]. When the frequency increases, the efficiency of microstrip antenna and microstrip reflective array antenna may be significantly reduced due to metal and surface wave losses. Although the efficiency problem can be alleviated by using lens antenna and DRA, their manufacture is relatively inconvenient.

Due to the advantages of high directivity, high efficiency, low profile and easy fabrication, the Fabry Perot resonator (FPR) antenna has attracted extensive attention in the past decade [6]. The traditional fpr antenna is composed of a metal ground plate, a parallel partial reflector and a primary radiation source, and its resonant frequency depends on the spacing between the parallel plates [7]. In order to improve the performance of FPR antenna, some design techniques have been applied to the ground plate and partial reflector. For example, artificial magnetic conductors or high impedance surfaces have been used to replace metal grounding plates to reduce antenna height [8]. In order to broaden the bandwidth, some reflective surfaces can adopt non-uniform figure [9], multi-layer structure [10], or even non-planar shape [11]. Generally, the partial reflection surface of FPR antenna has very high reflectivity (close to 1 but less than 1), resulting in a high directional radiation pattern with a narrow beam . However, in mobile communication, the wide beam [12] or sector beam [13] antenna has a larger coverage than the narrow beam [14] antenna, so it is more attractive.

It has been found that the Fabry Perot resonator (FPR) [15] with high Q value can be used as an antenna in the millimeter wave and sub millimeter wave bands. FPR was originally used in optical research , and its principle is based on multiple reflections between two closely spaced reflective plates. The distance between the two reflective plates is a multiple of half wavelength, which determines the resonant frequency of the resonator. The preliminary study found that

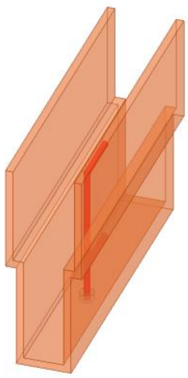
ISSN: 1813-4890

the cross polarization field of the E-plane radiation pattern was significant. In order to reduce cross polarization, [17] introduced two grooves in the parallel plate for the first time, and studied the influence of these grooves on the antenna performance in this paper. The proposed antenna places an L-shaped probe between two solid reflection parallel plates [18]. The L-shaped probe protrudes from the ground plane, excites the FPR mode, and generates a probe mode, which can be combined with the FPR mode to expand the bandwidth. Reference [19] proposed an improved differential fpr antenna with a pair of ridge structures at each side opening of the parallel plate. The improved antenna can reduce the sidelobe level by about 22dB.

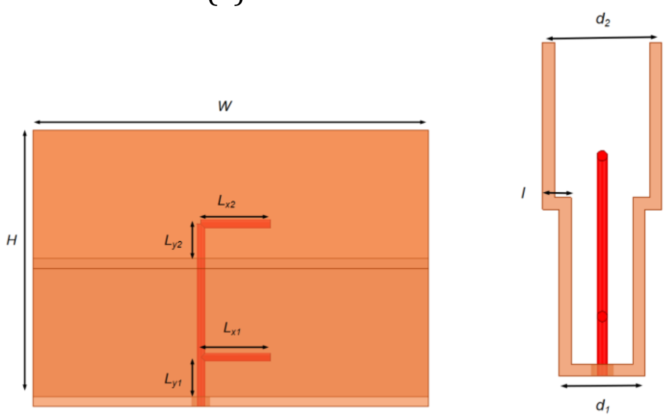
This paper presents a dual frequency Fabry Perot resonator (FPR) antenna fed by an F-shaped probe. The antenna is connected by four parallel metal plates perpendicular to the ground plane. The two impedance bandwidths of the proposed antenna simulation are 4.4% (20.72-21.65ghz) and 5.5% (24.4-25.67ghz), respectively. It has dual frequency characteristics in the millimeter wave band, and the maximum gain in the two frequency bands is 9.1dbi and 5.9dbi, respectively.

2. Antenna structure

Fig.1 shows the structure of an F-probe-fed FPR antenna made of a single piece of copper. The main body of the antenna consists of four parallel conductive plates perpendicular to the ground. The upper conductive plate is connected to the lower layer by two conductive plates parallel to the ground. The lower layer of vertical parallel conductive plates is connected by a horizontal ground plane with a thickness of Hg. The length of each plate is W, the height is H/2, and the thickness is T. The distances between the upper and lower conductive plates are d1 and d2 respectively. The F probe is located at the center of the ground plane with a radius of R. The lengths of its vertical and horizontal arms are Ly1, Ly2 and Lx1, Lx2 respectively.



(a)Antenna 3D View



(b)Antenna structure side view (c)Antenna structure front view

Fig 1. The proposed antenna structure.

Table 1 Detailed dimensions of the antenna (unit: mm)

parameter	W	H	l	d_1	d_2	R
size	40	27	2.4	7.2	10	0.435
	L_{x1}	L_{x2}	L_{y1}	L_{y2}	T	H_g
	2	2	6	3	1	1

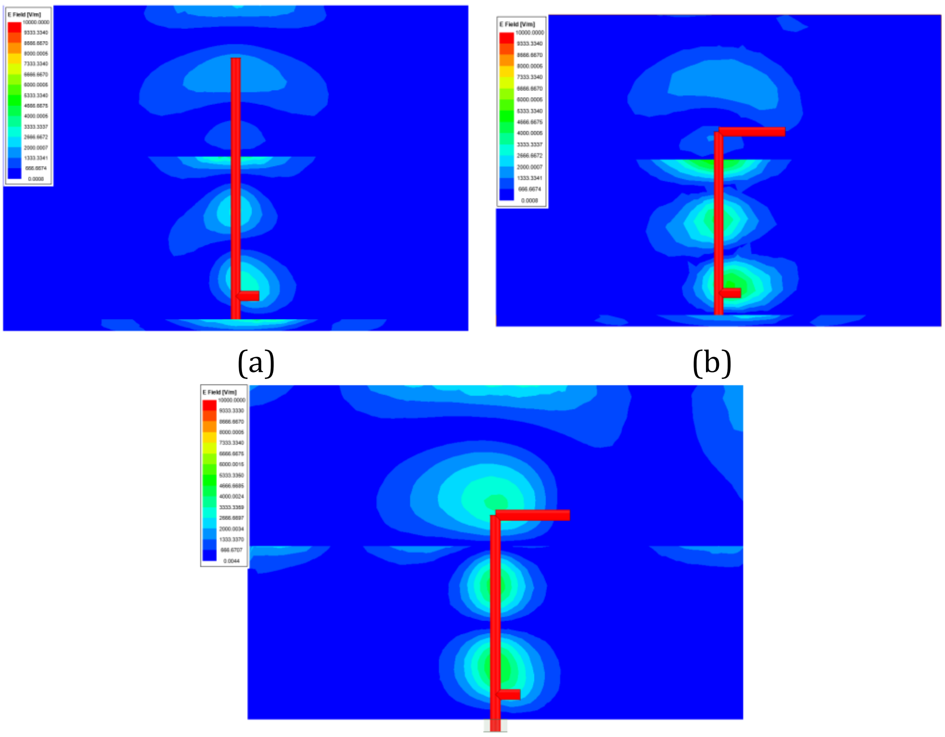
3. Antenna principle analysis

For an ideal air-filled FPR, where the infinite conducting plates are separated by a distance d, the resonant frequency is [24]

$$f_0 = \frac{nc}{2d} \tag{1}$$

Where n is the mode number of the FPR and c is the speed of light in a vacuum. In this design, n = 1 is selected and the distance between the plates is about half a wavelength. However, in practical applications, the size of the FPR plate is limited, so the actual resonant frequency will deviate from the theoretical value.

From formula (1), it can be seen that the operating frequency of the FPR antenna is related to the distance d between the two conductive plates. Therefore, this chapter designs the antenna shown in Fig.2. The two FPR antennas with a distance of d1 and d2 between the plates are fed simultaneously by an F-shaped probe, so that the antenna works in two different frequency bands, thus having dual-frequency characteristics.



(a) (b)

(c)

Fig.2 Simulation field of FPR antenna at 21 GHz (a) Electric field radiation pattern of linear probe without conductive plate (b) Electric field radiation pattern of F probe without conductive plate (c) Electric field radiation pattern of designed FPR antenna

ISSN: 1813-4890

4. Antenna parameter analysis

In order to explore the influence of various parameters in the FPR antenna on the antenna performance, Ansoft HFSS was used to perform a detailed parameter scan on the proposed antenna.

From the curve in the Fig.3, it can be seen that the change of LX2 has a greater impact on the low-frequency part. When LX2 is 5mm, the impedance bandwidth is the largest. After comprehensive comparison, it is finally found that when LX2=6mm, the antenna obtains the most ideal performance.

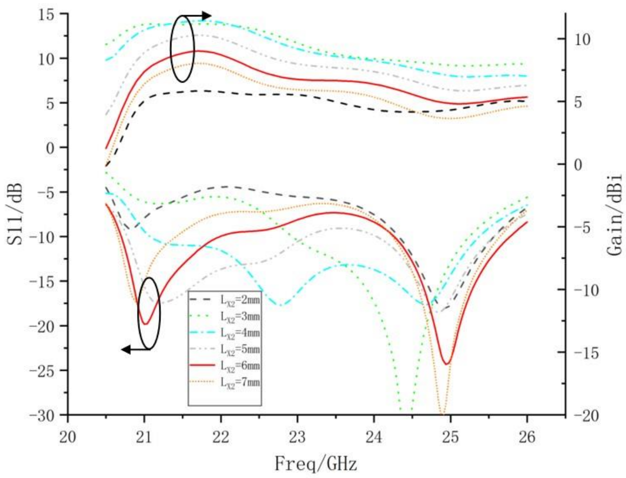


Fig.3 The influence of Lx2 on antenna performance

Ly2 represents the length of the upper part of the F probe in the FPR antenna in the Z direction. As can be seen from Fig.4, in the low frequency band, the reflection coefficient curve of the antenna gradually moves up with the increase of Ly2, and the impedance bandwidth gradually decreases; in the high frequency band, the reflection coefficient of the antenna gradually moves toward the low frequency direction with the increase of Ly2. After comprehensive comparison, it is finally found that when Ly2=3mm, the antenna obtains the most ideal performance.

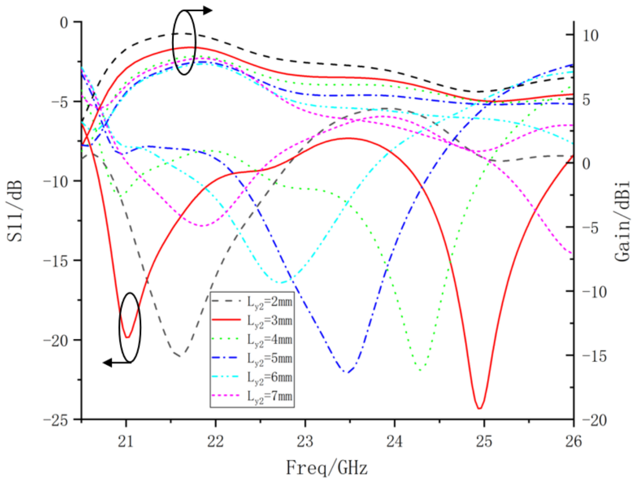


Fig.4 Effect of Ly2 on antenna performance

5. Results Analysis

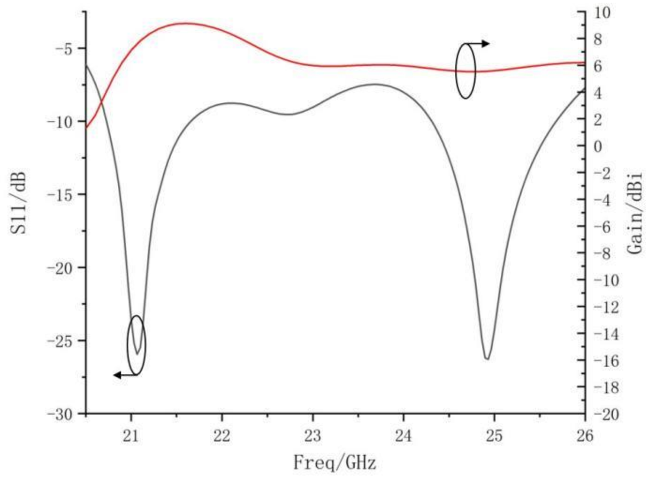
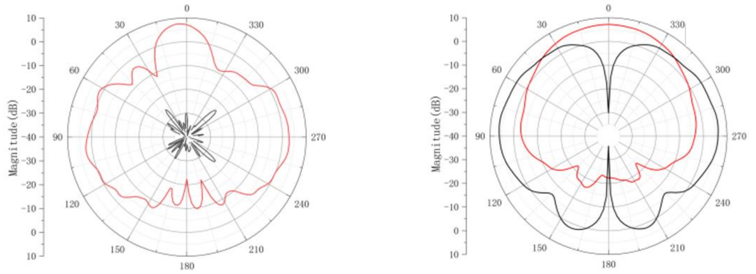
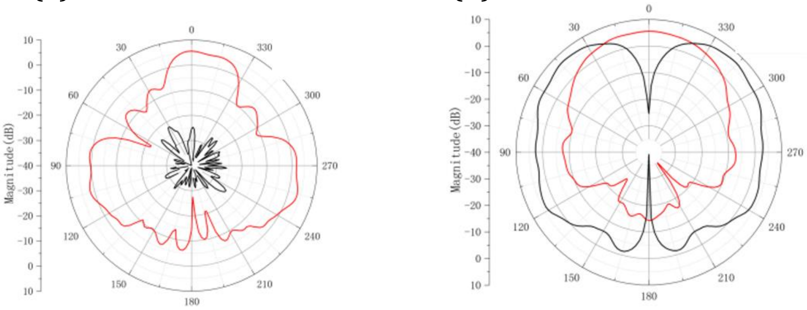


Fig. 4 Simulated gain and impedance bandwidth of the proposed antenna

Fig. 5 shows the simulation results of the reflection coefficient and antenna gain of the designed FPR antenna. It can be seen from the figure that the two impedance bandwidths of the proposed antenna simulation are 4.4% (20.72 - 21.65GHz) and 5.5% (24.4-25.67GHz), respectively, and it is a dual-band characteristic in the millimeter wave band. At the same time, Fig. 6 shows the simulated gain of the proposed antenna, and the maximum gain in the two frequency bands is 9.1dBi and 5.9dBi respectively.



(a)E-Plane at 21.0 GHz (b)H-Plane at 21.0 GHz



(b)E-Plane at 25.0 GHz (d)H-Plane at 25.0 GHz

Fig.5 Antenna simulation radiation pattern at 21.0 GHz and 25.0 GHz

6. Conclusion

This paper studies a novel F-probe fed FPR antenna. By using an F-shaped feeding probe, the FPR mode is excited between four parallel plates. At the same time, the F probe excites the probe mode, which can be used to broaden the overall impedance bandwidth of the antenna. Since the proposed antenna is usually larger than other resonator-type antennas, it is less sensitive to manufacturing tolerances. This is especially important at millimeter-wave frequencies with smaller wavelengths. The ideal size was obtained through simulation, and the simulation results were finally obtained. The two impedance bandwidths are 4.4% (20.72 - 21.65GHz) and 5.5% (24.4-25.67GHz), and the maximum gains in the two bands are 9.1dBi and 5.9dBi, respectively.

References

[1] IEEE Criteria for Broadband Wireless Metropolitan Area Networks,IEEE 802.16, 2009.

[2] D. M. Pozar, "Consideration for millimeter wave printed antennas,"IEEE Trans. Antennas Propag., vol. 31, no. 5, pp. 740–747, Sep. 1983.

[3] D. M. Pozar, S. D. Targonski, and H. D. Syrigos, "Design of millimeter wave microstrip reflectarrays," IEEE Trans. Antennas Propag., vol. 45,no. 2, pp. 287–296, Feb. 1997.

[4] X. Wu, G. V. Eleftheriades, and E. van Deventer, "Design and characterization of single- and multiple-beam MM-wave circularly polarized substrate lens antennas for wireless communications," IEEE Trans. Antennas Propag., vol. 49, no. 3, pp. 431–441, Mar. 2001.

[5] Dielectric Resonator Antennas, K. M. Luk and K. W. Leung, Eds.Baldock, U.K.: Research Studies Press, 2003.

[6] T. Matsui and K. Araki, "Gaussian-beam open resonator with highly re-flective circular coupling regions," IEEE Trans. Microw. Theory Tech.,

[7] Dielectric Resonator Antennas, K. M. Luk and K. W. Leung, Eds.Baldock, U.K.: Research Studies Press, 2003.

[8] A. Petosa, Dielectric Resonator Antenna Handbook. Norwood, MA:Artech House, 2007.

[9] R. Sauleau, P. Coquet, and T. Matsui, "Low-profile directive quasiplanar antennas based on millimetre wave Fabry-Perot cavities," IEE Proc.-Microw. Antennas Propag., vol. 150, no. 4, pp. 274–278, Aug.2003.

[10] Z. C. Ge, W. X. Zhang, Z. G. Liu, and Y. Y. Gu, "Broadband and highgain printed antennas constructed from Fabry-Perot resonator structureusing EBG or FSS cover," Microwave Opt. Tech. Lett., vol. 48, no. 7,pp. 1272–1274, Jul. 2006.

[11] J. R. Kelly and A. P. Feresidis, "Array antenna with increased elementseparation based on a Fabry-Perot resonant cavity with AMC walls," IEEE Trans. Antennas Propag., vol. 57, no. 3, pp. 682–687, Mar. 2009.

[12] Z. G. Liu, W. X. Zhang, D. L. Fu, Y. Y. Gu, and Z. C. Ge, "Broadband Fabry-Perot resonator printed antennas using FSS superstrate with dissimilar size," Microwave Opt. Tech. Lett., vol. 50, no. 6, pp.1623–1627, Jun. 2008.

[13] T. Akalin, J. Danglot, O. Vanbesien, and D. Lippens, "A highly directive dipole antenna embedded in a Fabry-Perot type cavity," IEEE Microw. Wireless Compon. Lett., vol. 12, no. 2, pp. 48–50, Feb. 2002.

[14] H. Boutaye, K. Mahdjoubi, A. C. Tarot, and T. A. Denidni, "Directivity of an antenna embedded inside a Fabry-Perot cavity: Analysis and design,"Microwave Opt. Tech. Lett., vol. 48, no. 1, pp. 12–17, Jan. 2006

[15] Y. Ding and K. W. Leung, "L-shape probe-fed Fabry-Perot resonatorantenna for millimeter-wave applications," in Proc. IEEE Antennas Propag. Symp., Jun. 2009, pp. 1–4.

[16] H. Nakano et al., "C-figured loop antennas," Electron. Lett., vol. 31,no. 9, pp. 693–694, Apr. 1995.

[17] K. M. Luk, C. L. Mak, Y. L. Chow, and K. F. Lee, "Broadband microstrip patch antenna," Electron. Lett., vol. 34, no. 15, pp. 1442–1443,Jul. 1998.

[18] K. Lu, Y. Ding and K. W. Leung, "A New Fabry-Perot Resonator Antenna Fed by an L-Probe," in IEEE Transactions on Antennas and Propagation, vol. 60,no. 3, pp. 1237-1244, March 2012

[19] K. Lu and K. W. Leung, "Differential Fabry–Perot Resonator Antennas," in IEEE Transactions on Antennas and Propagation, vol. 61, no. 9, pp. 4438-4446,Sept. 2013,