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A Design of Compact Dual-Band Magnetoelectric Dipole Antenna

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ABSTRACT

A compact dual-band magnetoelectric (ME) dipole antenna is proposed in this article. The antenna consists of two rectangular patches, two copper columns, and two substrates. The feeding is achieved through a bottom microstrip and rectangular slots, with the two symmetrical rectangular patches serving as electric dipoles and the two copper columns acting as magnetic dipoles. Electromagnetic simulations were conducted using Ansys HFSS, and the results indicate that the antenna achieves a return loss of less than -10 dB in the frequency ranges of 18.6-22.2 GHz and 27.7-32.1 GHz. The impedance bandwidths for the two bands are 17.8% and 14.8%, respectively. Two resonant points are observed at 19.1 GHz and 20.3 GHz in the low band, and at 28.8 GHz and 31.3 GHz in the high band. The realized gains are 4.3-5.2 dBi and 8.2-8.8 dBi respectively.

KEYWORDS

Dual Frequency; Magneto Electric Dipole; Antenna; Millimeter Wave.

1. INTRODUCTION

With the rapid development of modern wireless communication technology, the shortage of spectrum resources and the increasing demand for high data rate. Dual band antenna can support signal transmission of multiple frequency bands at the same time, effectively improve communication efficiency and make full use of limited spectrum resources, especially in high-density urban areas. Millimeter wave band has attracted much attention due to its large channel capacity, wide bandwidth, high transmission quality and small size of components. Millimeter wave band has become one of the key technologies of future wireless communication systems due to its rich spectrum resources, high channel capacity and low transmission loss[1, 2]. However, the use of millimeter wave band also faces many challenges, including large attenuation of signal in the atmosphere, short propagation distance and large antenna size [3]. In order to solve these problems, the design and application of dual band antenna has become a research hotspot.

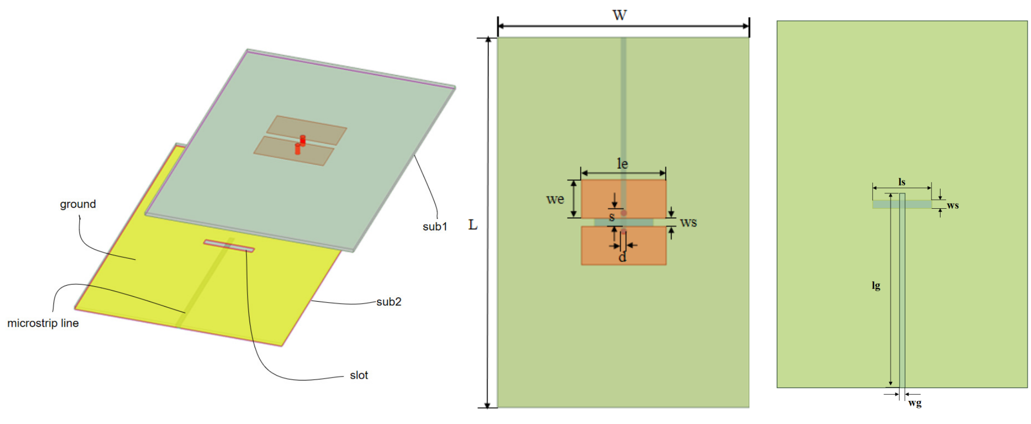
The k/ka band has a wide range of applications, including personal communication networks, broadband access, Satellite Internet, military communications, etc. [4, 5, 6]. These applications put forward high requirements for antenna design, including high gain, low sidelobe, wide coverage and high c/i [7]. To meet these requirements, researchers have developed various types of k/ka band antennas, such as shared aperture antenna [8], broadband communication satellite multi beam antenna and high-precision TT&C antenna.

There are two main types of dual frequency antenna, dual-mode dual frequency antenna [9][10] and hybrid dual frequency antenna [11, 12]. In order to meet the growing demand for mobile data, millimeter wave dual band antenna has become a key research direction, resulting in many different research results. A compact dual wideband millimeter wave magnetoelectric dipole antenna is proposed in [13]. The antenna consists of a short-circuit patch and a planar dipole, and is fed by a quadrangular probe. The prototype antenna is only 24 mm high at 1.9 GHz, achieving a wide impedance bandwidth of 24.9%, an average gain of about 8.2 DBI, and the isolation between the two ports is more than 29 dB. In [14] proposed a compact dual broadband millimeter wave magnetoelectric dipole antenna. The antenna is composed of two layers of dielectric. A pair of mirror U-shaped patches are designed on the upper dielectric plate, and SIW cavity is designed on the lower dielectric plate. A pair of metallized vias connect the U-shaped patch with the slot. The U-shaped patch can work as an electric dipole in 0.5 λ and 1 λ modes. The slot and two metallized vias can be equivalent to a folded slot as a magnetic dipole, and can also work in 0.5 λ mode and 1 λ mode. When the 0.5 λ mode of e dipole and M dipole are at the same or close frequency, the 0.5 λ mode of magnetoelectric dipole is excited.

The 1λ mode of an electromagnetic dipole can also be excited in the same way. Therefore, a dual-mode magneto electric dipole is formed. A cavity fed dual-mode magneto electric dipole with characteristic frequencies of 25 GHz and 40 GHz was designed to achieve broadband antenna matching performance. Through dual-mode operation, the dual frequency me dipole avoids additional radiation structures operating in additional frequency bands, achieving a compact structure in the millimeter wave frequency band.

2. ANTENNA ANALYSIS AND DESIGN

The designed dual frequency magneto electric dipole antenna structure is shown in Figure 1. The antenna consists of two layers of Rogers 5880 substrates, with a lower substrate thickness T1 of 0.254mm and an upper substrate thickness T2 of 0.787mm. The middle of the two layers is a metal layer with a rectangular groove. The top layer of the substrate consists of two symmetrical rectangular metal patches as the electric dipoles of the antenna. Two metal pillars are embedded on the top substrate to connect the middle floor and the top rectangular patch as magnetic dipoles.



(a) (b) (c)

Figure 1. Antenna Structure(a)Configuration of the proposed ME antenna.(b)Top view of ME antenna. (c)Microstrip feed structure.

Two symmetrical electric dipole metal patches have two modes: half wavelength and full wavelength (0.5 λ and 1 λ), and the same two metal pillars as magnetic dipoles also have two modes: half wavelength and full wavelength (0.5 λ and 1 λ). In order to match two modes at the same impedance port

$$Z = \frac{Z_1 Z_2}{Z_1 + Z_2} . \quad (1)$$

According to formula (1), in order to make $Z_{0.5}=Z_1$, you need $Z_{0.5e}=Z_{1m}$ and $Z_{0.5m}=Z_{1e}$, where Z_{1e} and Z_{1m} represent the impedance of electric dipoles and magnetic dipoles at half wavelength, and similarly, and represent the impedance of electric dipoles and magnetic dipoles at all wavelengths. In an ideal scenario, the input impedance of a half wavelength electric dipole is approximately 73 Ω at its radiation axis (the center of the antenna). This value is based on the radiation characteristics and impedance matching of the antenna. According to the theory of impedance matching

$$Z_1 \cdot Z_2 = \frac{\eta^2}{4} . \tag{2}$$

$$\eta = \frac{\mu}{\varepsilon} . \tag{3}$$

If formula (2) is satisfied, then these two antennas are theoretically matched with each other, which means they can effectively radiate energy. From formula (3), α=377 Ω can be obtained, and from (1) and (2), $Z_{0.5}=Z_1$=64Ω can be obtained.

Table 1. Designed antenna parameters(UNIT: MILLIMETER)

PRM.	VALUE	PRM.	VALUE
W	17	L	25
we	2.6	le	5.7
s	0.95	d	0.4
ws	0.55	ls	4
wg	0.4	lg	14.04

3. SIMULATION RESULTS AND ANALYSIS

The electromagnetic simulation software Ansys HFSS was used to simulate the antenna, and the simulation results showed that the return loss of the antenna was less than -10dB in the frequency bands of 18.6-22.2GHz and 27.7-32.1GHz is shown in Figure 2. The corresponding impedance bandwidths of the two frequency bands were 17.8% and 14.8%, respectively, and there were two resonance points in the low frequency band of 19.1GHz and 20.3GHz, and in the high frequency band of 28.8GHz and 31.3GHz. As shown in Figure 3, the realized gain is 4.3-5.2dbi and 8.2-8.8dbi respectively.

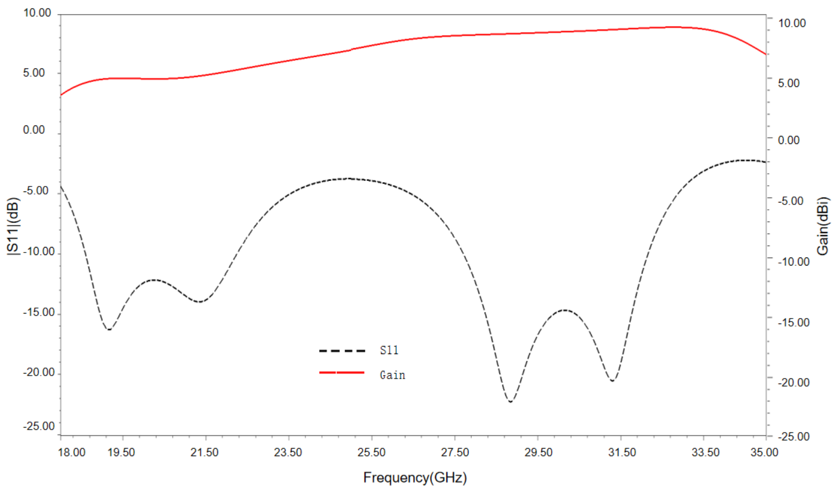


Figure 2. Simulated |S11| and gain of the proposed ME antenna.

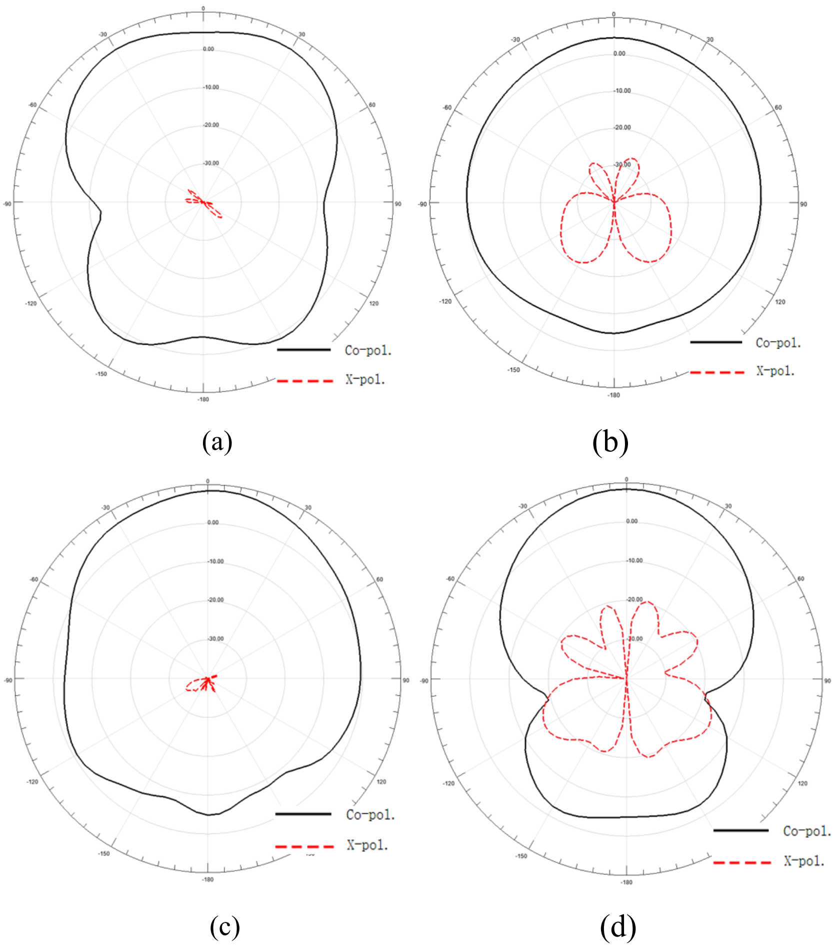


Figure 3. Radiation patterns of the proposed antenna. (a)E-plane and (b) H-plane at 19.15GHz (c)E-plane and (d) H-plane at 28.85GHz.

4. CONCLUSION

A small magneto electric dipole antenna operating in the K and Ka bands was analyzed and designed, and its feasibility was verified and analyzed through electromagnetic simulation software Ansys HFSS. The simulation results show that the antenna has a return loss of less than -10dB in the frequency bands of 18.6-22.2GHz and 27.7-32.1GHz, corresponding to impedance bandwidths of 17.8% and 14.8%, respectively. There are two resonance points in the low-frequency band at 19.1GHz and 20.3GHz, and in the high-frequency band at 28.8GHz and 31.3GHz, respectively. The achieved gains are 4.3-5.2 dBi and 8.2-8.8 dBi, respectively.

CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest.

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