The Application of PBG Configuration in Planar Spiral Antenna

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Abstract: For the requirement of 3G mobile terminal at present, we have designed a new kind of WCDMA mobile terminal spiral antenna with PBG structure, which is capable of working in 1920~2170 MHz frequency broad band. Applying PBG configuration in planar spiral antenna, the characteristics is improved significantly and the size is also reduced. It makes the band width reach 250 MHz, which covers the whole emitting and receiving frequency band of WCDMA system. This antenna has been simulated and designed by using simulation design software, and the experiment results are agree well with the simulation results, which show that the varied period configuration of PBG is more benefit to improve antenna performance.

Key words: 3G, planar spiral antenna, PBG, WCDMA system

1. INTRODUCTION

As the development of wireless communication systems and the increase of consumers, much higher requirement is needed for the capability of system communication. Thus, the third generation of mobile communication system has been put forward, in which WCDMA (Wideband Code Division Multiple Access) system using direct direct-sequence spread-spectrum technology provides wideband multimedia services including images and data etc., except for conventional voice service. The RF working frequency range of this system is 1920~2170 MHz, with 250 MHz frequency bandwidth and 13% relative bandwidth. So for the antenna design of WCDMA mobile terminals, we require large bandwidth, small in size, above 0 dB gain and uniform covering provided on the entire orientation plane. [1]

For the terminal antennae of current commercial mobile-phones, whip antenna is utilized mainly. But there are some shortcomings, such as uneasy miniaturization and existed biological proximity effects to cause nonuniform covering of radiation directions. Planar spiral antenna, with many particular advantages, such as wide frequency bandwidth, light in weight, low section, capability of co-shaping, low cost and high radiation efficiency etc., has been studied widely and developed quickly. [2]

The configuration of so-called PBG (Photonic Band-Gap) is just a kind of periodic structure, by which PBG characteristics can be realized. Making use of its band-stop characteristics, we can implement filtering in wide band, increase the efficiency of amplifiers and improve the orientation fields of antennae. [3] For achieving PBG configuration in microstrip antenna, we make etching along the microstrip line direction on ground plane to form pinholes in periodic arrangement, meantime maintaining medium substrate unchanging. By the application of PBG configuration to planar spiral antenna, the efficiency of antenna will be elevated with improved performance and decreased size.

As the foundation of antenna development, we design a new kind of planar spiral antenna, in which PBG configuration is applied to improve the performance. With Microwave Office (MWO) professional design software, the antenna has been simulated roundly, and the influence of band-gap periodic variation in PBG configuration been also analyzed in detail. Finally through experiment analysis, the result shows that period-variety structure of PBG is more benefit for improving antenna's performance.

1-4244-1035-5/07/$25.00 .2007 IEEE.

2. DESIGN OF PLANAR SPIRAL ANTENNA

Considering a planar spiral antenna, every arm is constituted by two helical curves with equal angle and δ as origin angle difference. Four edges of two arms are four helical curves with equal angle, as shown in Fig.1. The equations of helical curves are

$$r_1 = r_0 e^{a\phi}, \qquad r_1' = r_0 e^{a(\phi-\delta)}, \qquad r_2 = r_0 e^{a(\phi-\pi)}, \qquad r_2' = r_0 e^{a(\phi-\delta-\pi)} \qquad (1)$$

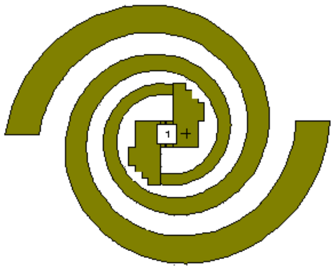

Fig. 1 Layout of planar spiral antenna

where r_1 and r'_1 are respectively the internal and external edges of one arm, and r_2 and r'_2 are respectively the internal and external edges of another arm. r_0 is the distance from the initial point to the origin point, and a is the angle between the tangent of helical curve and vector radius r. Here, we take $r_0 = 0.3$ cm, $a = 0.221$, $\delta = \pi/2$, and the maximum outer radius $R = 1.3$ cm.

2.1 Principle analysis of planar antenna

Planar spiral antenna, ascribed to frequency independent antenna series, is a kind of more universal ultra-wide band antenna with good impedance, orientation field and circular polarization characteristics in very wide frequency band. Its structure is determined completely by the angle and according to the similarity principle, but its orientation and impedance characteristics are all independent with frequency, that is, reaching wide frequency band effect. [4] The radial length of helical curve r is about 1/4 of the wavelength corresponding to lower frequency limit, and the upper frequency is limited by the inner radius r_0 of helical curve. Most radiation is from the circumference of the antenna structure, a region of about one wavelength, so it will be better when the total length of single antenna arm is equal to or bigger than one wavelength. Here, the coaxial line feeding mode is utilized for antenna feed.

2.2 Application of PBG configuration

PBG configuration is a kind of artificial periodic structure, realized mainly by adding another kind of medium periodically in one kind of medium. It can restrain electro-magnetic waves at a certain range of frequency to propagate in the medium. By using PBG configuration, we can suppress surface wave and increase the antenna gain by utilizing high impedance surface characteristic. With the forward radiation being enhanced and the back & side lobes restricted, unidirectional radiation is achieved. [5]

Here, FR-4 is selected as the material for the antenna medium substrate, whose permittivity is 4.4 and thickness is 0.08 cm, and MWO of AWR company is used for the design of spiral antenna. At first, the medium layer and metal layer are set up. Setting the thickness of metal layer $T = 0.020$ mm and in term of those parameters listed above, a planar spiral antenna is drawn in EM with coaxial feed set at the antenna center.

Fig.2 shows the return loss S_{11} of planar spiral antenna without PBG configuration, from which it can be seen that there is the maximum return loss -3.9 dB in the working frequency band between 1.8~3.3 GHz and the minimum return loss -9.3 dB at 2.8 GHz. Though the results are due to wide frequency band, there is still a certain distance from the required target. Now a PBG configuration is added by etching six same rectangle apertures at the antenna back, as shown in Fig.3, which is able to be compared to the required wavelength in orders of magnitude. The substrate is in square shape with 5 cm length and in the figure L = 1.9 cm, W = 1.3 cm, h_0 = 0.2 cm, h_1 = 0.4 cm, h_2 = 0.3 cm. The return loss of antenna with this PBG configuration is given in Fig.4, with the working frequency band moving down to 1.2~2.8 GHz. Most return losses have fallen below -5 dB, except for the middle part without reaching the requirement.

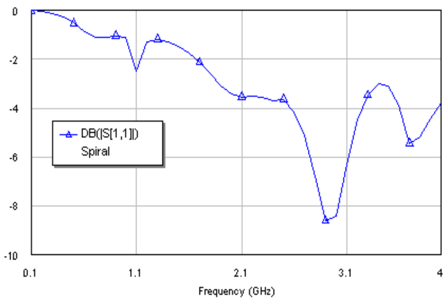

Fig.2 Return loss S_{11} of antenna without PBG

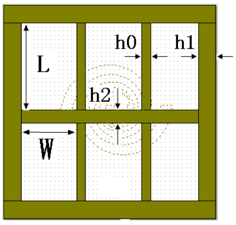

Fig.3 PBG structure

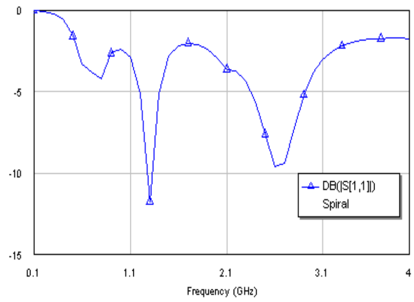

Fig.4 Return loss S_{11} of antenna with PBG

If the aperture sizes are same in PBG configuration, i.e. with the same period, it will affect some frequency of antenna. Through experiments and analysis of simulated data and figures, the results show that several frequencies will be influenced if the aperture sizes are different, i.e. with different periods. So as shown in Fig.5, the length L_1 of aperture at the first row is changed as 2.2 cm and the length $L2$ at the second row as 1.6 cm, meanwhile the substrate size is maintained unchanging. Also, the widths $W1$, $W2$ and $W3$ of apertures at the first, second and third columns are changed as 0.9 cm, 1.4 cm and 1.5 cm respectively. The return loss S_{11} of antenna with PBG configuration shown in Fig.5 is presented in Fig.6, from which it is obvious that the working frequency band is already at 1.4~2.4 GHz and all return losses in band are below -10 dB with the minimum -21 dB. That is, the S11 performance of antenna in the whole pass-frequency-band meets the requirement, with the bandwidth up to 1 GHz.

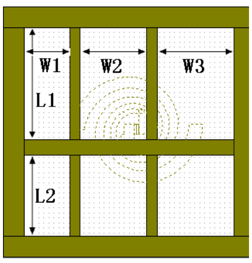

Fig.5 PBG structure with different periods

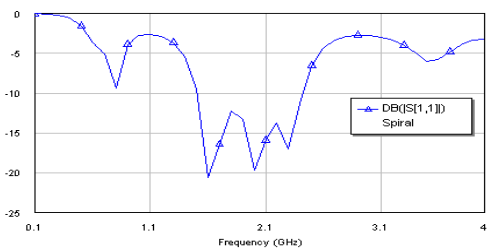

Fig.6 Return loss S_{11} of antenna with PBG with different periods

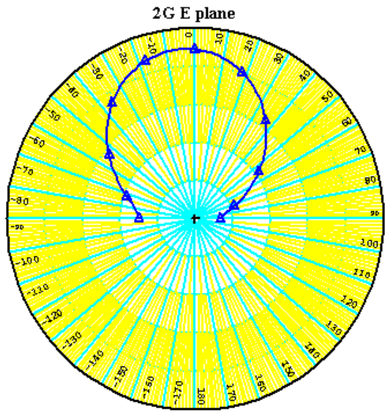

Fig.7 E-plane radiation patterns of antenna at *f* =2 GHz

Fig.7 gives the simulated E-plane radiation patterns of planar spiral antenna at f = 2 GHz. From the figure, it can be seen that there is almost full direction on half plane with the maximum gain in 0° direction and the minimum gains in 90°

and -90° directions.

3. CONCLUSION

A new kind of antenna used for 3G mobile terminal communication has been designed based on the fundamental of planar spiral antenna, in which the addition of PBG configuration is put forward at the first time. Using different periods in PBG configuration, the performance of antenna is improved with elevated efficiency to accord with the requirement of WCDMA mobile terminal antenna as one of 3G standard. By a mass of simulation experiments and detailed analysis, some results are given as follows:

a) With the advantage of wide frequency band, the planar spiral antenna accord with the requirement of WCDMA mobile terminal antenna in 3GPP protocol. This antenna can replace conventional whip sleeve antenna to become a kind of novel internal antenna. In practical realization, it can be co-shaped with the body of mobile phone and the feeding network can be made together with the antenna structure, which is suitable for volume-produce by using lithography.
b) The size of this planar spiral antenna is smaller than general rectangle microstrip antenna, and its bandwidth is bigger than that of the latter.
c) With PBG configuration added, the size of this planar spiral antenna is decreased and the bandwidth is improved further.
d) PBG configuration with different periods can improve the performance of antenna all the more by compared to that with fixed period, for example, the return loss will fall down greatly and the bandwidth also increase.

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**** This Project is supported by Fujian Province National Scientific Foundation: A0510001**

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