A Printed Helix-type Antenna Array for Wireless Communications at High Frequencies

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1. Introduction

Helix antenna [1] has distinguished characteristics of radiation. Depending on its designed structure, a variety of operations may be created including linear or circular polarizations, and omni- or directional patterns. The cost and complexity will increase significantly if it is employed in the applications of antenna arrays in the manufacture and RF circuit design. This paper proposes an alternative method to realize the antenna structures based on printed circuit technologies [2]. This method is particularly useful in the applications of array antennas at high frequencies since the wavelength is relatively small and makes the printed circuit technology suitable. The advantages are that the manufacture of the antenna subsystem may be performed at a very low cost and in an effective way. Numerical studies on the antenna characteristics are presented in this paper.

2. Design Concepts and Antenna Configuration

The design concepts are illustrated in Figure 1, where a multi-layer substrate with finite size is shown. The thickness of each layer as well as its dielectric constant may different in general, and is assumed to be same for simplity. A 60 x 60 x 3.2 mm3 FR4 substrate is selected to demonstrate the concept, where 8 layers are assumed. Thus the thickness of each layer is 0.4mm. This assumption is based on the current industrial capability to mass manufacture. The realization of the helix wire is based on a discretization of the loops into several arc segments that can be printed on the interfaces between layers. The connections between arc segments are performed by imposing a vertical via perpendicular to arc segments. In the current example, two loops of helix wires are considered. Thus each layer prints a quarter of the loop by strip lines, where 0.4mm width strip line is used and the diameter of the via is 0.25mm. These values of the parameters may be realized by industries. Note that since the helix wires are printed within the dielectric substrates, the radius of the loops differs from that in a free space. The equivalent dielectric constant should be taken into account. In this example, the radius of the loop is 1.9mm. Those designs allow the operational frequencies located at a range of 9~19GHz as to be shown later.

As for array studies, 9 elements with an equal spacing are considered in this example, which is sufficient to examine the impact on the antenna performance due to mutual coupling effects between elements.

3. Characteristic Studies

(1) Characteristics of a single element

The return loss of the proposed antenna element is shown on Figure 2. The -10dB bandwidth is about 9.5 GHz, which is very broad covering the frequency range of 9.05-18.6 GHz. Also the axial ratios as well as the phase difference between the two principal components are shown on Figure 3(a) and (b), respectively. It is observed that the smallest axial ratio occurs at $\theta = 0$, which is approximate 2.46dB, and increases at wider angles. The phase difference is approximate 91 degrees. Thus the radiation exhibits elliptical polarization. The gain in this case is approximate 5.2dBi.

(2) Characteristics of an array

In this study, the array with a variety of element spacing is analyzed. One first considers the return loss with respect to various spacing. In particular, a corner and central elements are considered with results shown in Figure 4(a) and (b), respectively. In this case, a shorter distance implies a stronger mutual coupling between elements, and will result in larger return losses over a large portion of the frequency band. However, the current study shows no significant impact on the return losses as observed in Figure 4 (a) and (b), where almost all return losses with respect to various spacing distances retain below -10 dB. The performance of the axial ratio is next examined, where 12.4GHz is assumed for the applications of satellite communications. It is observed from Figure 5 that the strong mutual coupling may distort the axial ratio significantly, as the spacing distance decreases to 4.5mm, the axial ratio may reach 11.79dB. However, as the spacing distance is close to 12 mm (half wavelength in a free space) the axial may be significantly improved. Note that the axial ratio for a single element is approximately 2.46dB.

The characteristics of the radiation pattern are shown on Figure 6 and 7. It is observed that the gain of the antenna array increases as the spacing distance increases and the 3dB beam width deceases. In another words, the radiation pattern becomes more directive. In comparison with the axial ratio, it is observed that the best spacing distance is approximately a half wavelength of the free space. Also shown on Figure 6 are the sidelobe levels below the peak of the patterns.

4. Conclusion

This paper presents an alternative approach to realize the helix antenna based on printed circuit technologies, which is particularly low cost in the manufacture. Characteristic studies based on numerical simulation exhibits that the proposed structure retains distinguished performances as originally provided by helix antennas in a free space. In particular, when used in the array arrangement, the gain and CP characteristics may be significantly improved. The proposed structure will have a broad application in the high frequency wireless communications.

Reference

[1] J. M. Tranquilla and S. R. Best, "A study of the quadrifilar helix antenna for Global Positioning System applications," *IEEE Trans. Antennas Propagate.*, vol. 38, pp. 1545-1550, Oct. 1990.

[2] Uei-Ming Jow; Ying-Jiunn Lai; Ching-Liang Weng; Chang-Sheng Chen; Chin-Sun Shyu; "Functional embedded RF circuits on multi-layer printed wiring board (PWB) process" *Electronic Components and Technology Conference,* 2005. Proceedings. 55th Vol. 2 pp. 1634-1641, 31 May-3 June 2005.

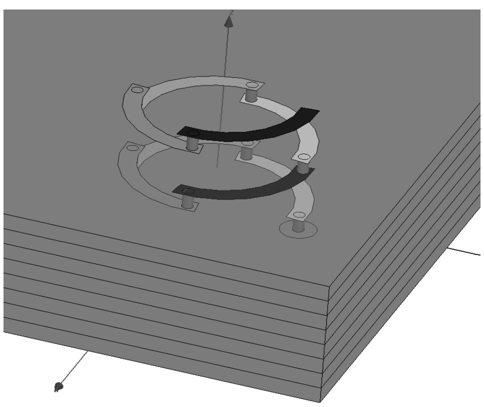
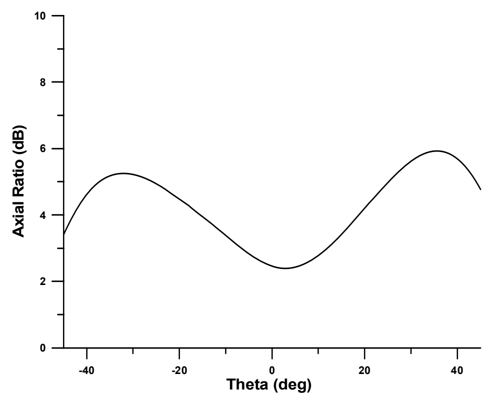


Figure 1: Printed helix-type antenna structure



(a) Axial Ratio

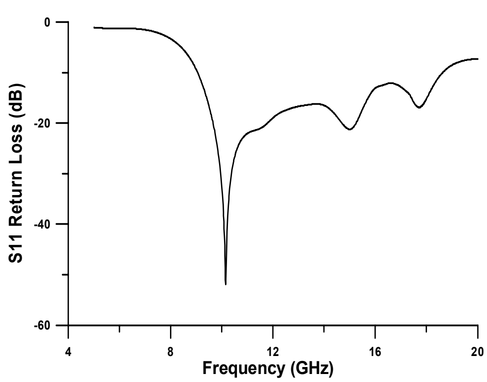
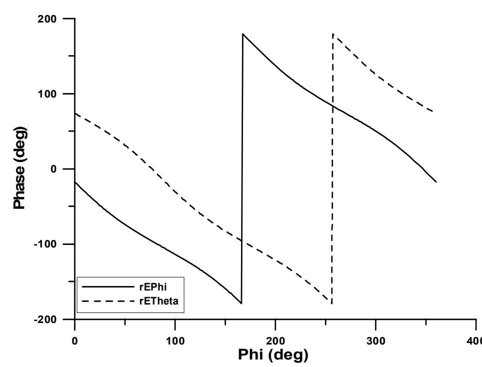
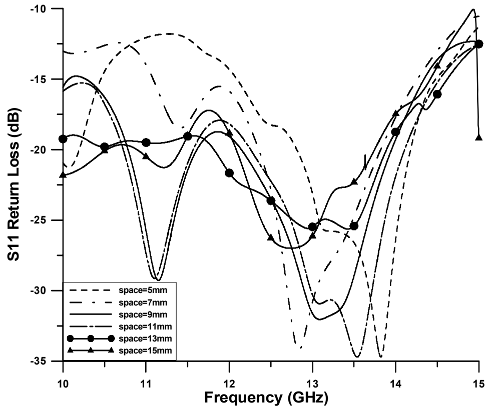


Figure 2: The return loss of t he antenna element.

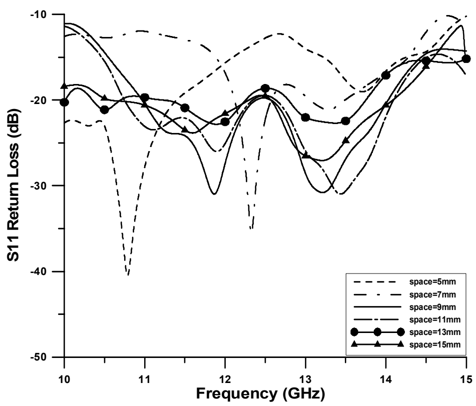


(b) Phase difference

Figure 3: The axial ratio and pattern's phase difference of the antenna element.



(a) Corner element



(b) Central element

Figure 4: The impact of return loss with respect to various spacing values.

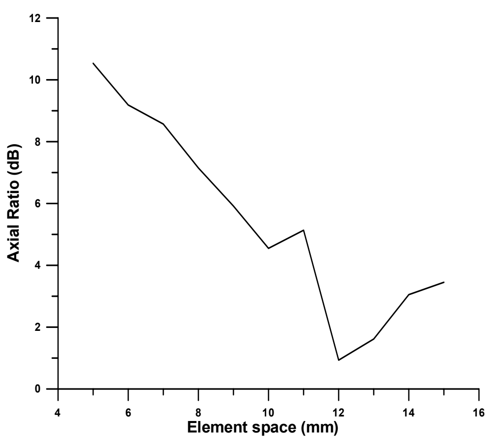


Figure 5: Axial ratio of the array's pattern with respect to elements' spacing

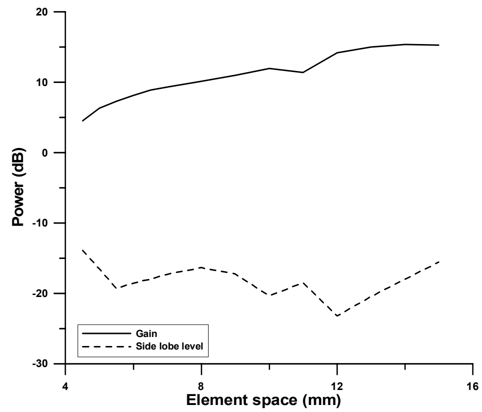


Figure 6: Gain and sidelobe level of the array's pattern

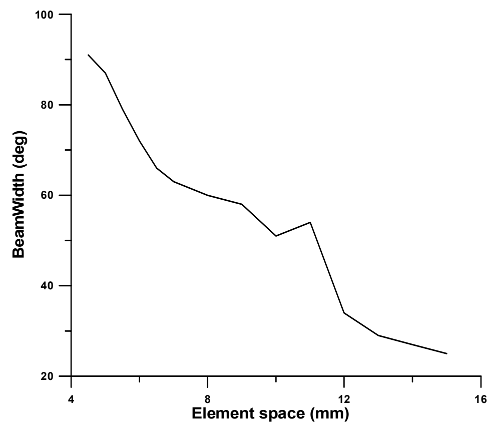


Figure 7: 3 dB beamwidth of the array's pattern