Front. Electr. Electron. Eng. 2012, 7(4): 381–385
DOI 10.1007/s11460-012-0218-7

RESEARCH ARTICLE

B. K. MISHRA, Vinitkumar Jayaprakash DONGRE, Megha GUPTA

A broadband helical loaded square cavity back antenna array

Abstract In this paper, a fundamental advancement of the basic helix design which expands to array having good bandwidth is proposed. The helix is inserted in a cavity. The result is a new antenna design that offers the performance characteristics and advantages of the conventional helix but in a much more compact physical size envelope. A 4-element rectangular helical array has been designed. For miniaturization and impedance matching, the helical wire is replaced by a rectangular cross sectioned strip. It has been observed that when the helix is inserted in a cavity, it behaves differently from a normal helical antenna. The effects of the cavity on the number of turns, the impedance of total antenna, and the reflection coefficient have been analyzed. The array is designed for 2.4 GHz. The return loss obtained is less than −10 dB and the bandwidth is more than 1.3 GHz for the array.

Keywords antenna array, broadband helical antenna, helix impedance matching, strip helix, square cavity back

1 Introduction

In satellite communication systems, propagation of radio waves [1] through the ionosphere suffers Faraday rotation at some frequencies; thus, circularly polarized waves would be desirable in order to maintain reliable data and information signal transmission. The wide bandwidth of helical antennas lies in the fact that they are of the traveling-wave type [2], while their circular polarization property may be attributed to their effective loop-dipole geometry. The helical antennas can be used as a single element, as a feed element, or in arrays as well.

Initial research work was done on helical antenna and its properties [2], furthermore, the gain enhancement of helical array had been introduced. The rectangular radial line helical array antenna used short helical antenna as its radiation element, each helix was excited by the energy coupled by a probe from a radial line waveguide; then, assembled a number of subarrays to a high gain array antenna [3]. The sequential rotation technique was introduced in array for axial ratio improvement [4]. The reduction in size of antenna is achieved by helical loaded cavity back antenna [5], but there is a further scope for the bandwidth enhancement. For enhancing the bandwidth of the antenna, array is formed with the helical loaded cavity back antenna.

The broad bandwidth antennas are required for communication purposes; and the multiple antennas that are required for any communication system can be reduced by the use of single broadband antenna. This paper is focused on the enhancement of bandwidth with the reduction in size of an antenna. The antenna designed here is helical loaded square cavity back for the propose of size reduction; and then, a 4-element array has been formed.

Received September 28, 2012; accepted October 22, 2012

B. K. MISHRA, Vinitkumar Jayaprakash DONGRE (✉), Megha GUPTA
Thakur College of Engineering and Technology, Mumbai 400101, India
E-mail: dongrevinit@gmail.com

2 Helical antenna cavity design

2.1 Cavity design

The essential parameters for the design of a helical antenna [6] are the frequency of operation, the height of the helix, the diameter of the helix, the dimensions of the square cavity, and the number of turns of the helix. From the relation of frequency and wavelength, we get to know about the dimensions of the antenna. The frequency of the operation is 2.4 GHz. The axial length of the helix is approximately equivalent to a quarter wavelength. Because of the fringing effect and the self-capacitance of the helix, the electrical length of the helix is approximately 6% less than a quarter wavelength [6]. To get a proper compatibility between the height and the diameter of the helix, the ratio between these two parameters is $1.0 < b/d < 4.0$, where b is the height of the helix and d is the diameter of the helix, as shown in Fig. 1.

From this ratio, various values of the diameter of the helix are possible. Three diameter values, i.e., 14.69 mm,

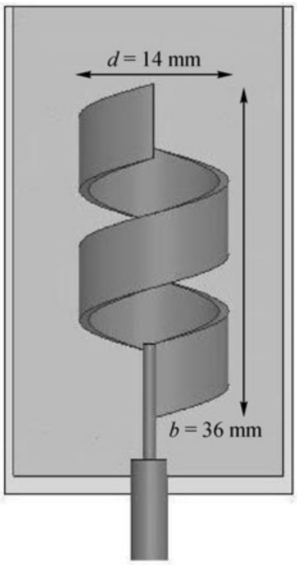

Fig. 1 Helix loaded in square cavity with size of 29 mm × 29 mm and height of 60 mm

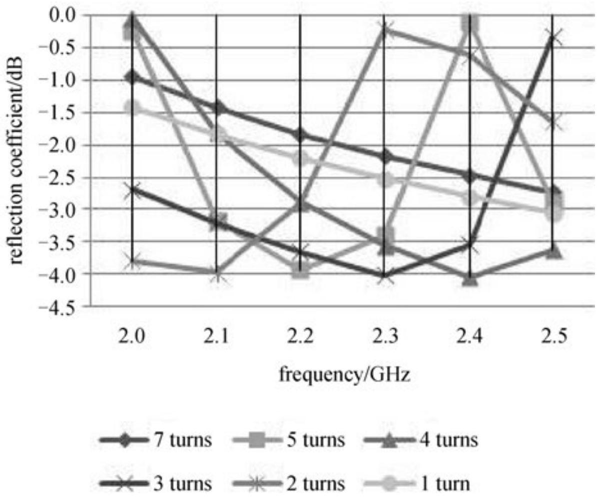

Fig. 3 Reflection coefficient for helix diameter of 16.32 mm in square cavity

16.32 mm, and 18.36 mm, are considered for the design. The numbers of turns are 7, 5, 4, 3, 2, and 1. Eighteen combinations are made with these parameters. The cavity inner side is selected as 29 mm × 29 mm and the height is selected as 60 mm for all the possible combinations. The reflection coefficients for all the three helix diameters are shown in Figs. 2, 3, and 4.

The highest reflection coefficient is −4.2 dB for 14.69 mm diameter and two turns design; it is almost constant when the frequency ranges from 2.1 GHz to 2.4 GHz. This was the design for a single helix. Thus, the design of the helix with the diameter of 14.69 mm is selected, and based on this design, various other combinations for the array are made. It is hard to implement any impedance matching technique in a cavity; therefore, the wire helix is replaced by a rectangular strip helix.

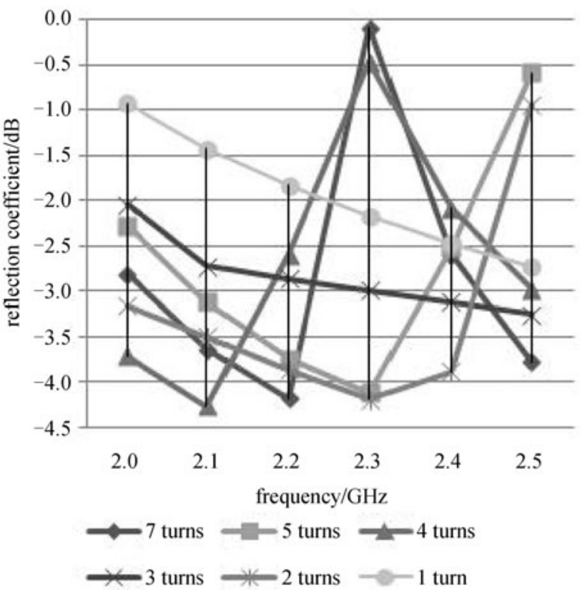

Fig. 2 Reflection coefficient for helix diameter of 14.69 mm in square cavity

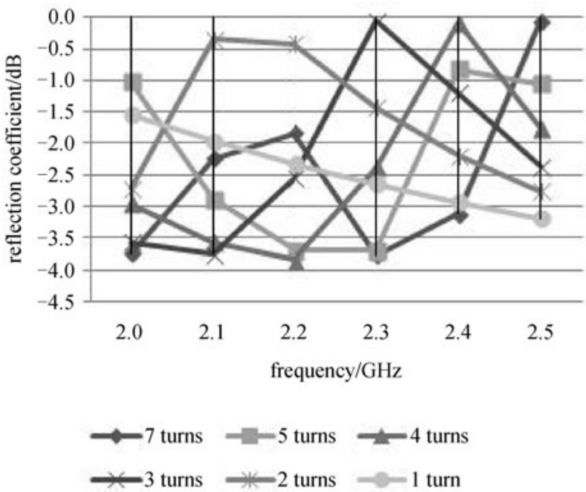

Fig. 4 Reflection coefficient for helix diameter of 18.36 mm in square cavity

2.2 Array design

The array proposed here is center fed as shown in Fig. 5. Each element is at a distance of a quarter wavelength from the center.

The feed is a 50 Ω coaxial cable SMA connector. A helical array can be formed by positioning the helices such that the fields from the elements add in some directions and

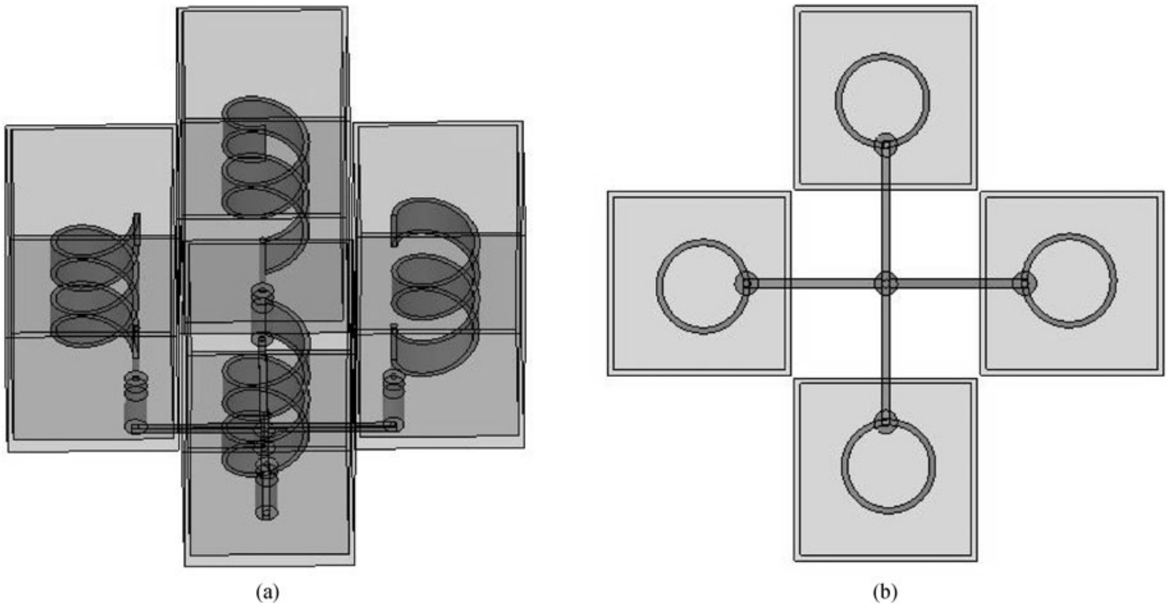

Fig. 5 Helical loaded square cavity back antenna in 4-element array. (a) Side view; (b) top view

cancel in others [2]. In the design proposed for placement of helices, sequential rotation technique [4] is used to improve the circular polarization performance of the antenna. In this technique, 90° rotation is given to each element of the array.

The design which finally gave the desired result had two turns, with the square cavity of 29 mm × 29 mm and the strip height of 8 mm. The reflection coefficient for the antenna array is shown in Fig. 6. This result shows that the bandwidth of the array is increased significantly to 1.31 GHz, within the frequency range of 2.19 GHz to 3.5 GHz. Figure 7 shows the radiation pattern for the designed array antenna, which is a doughnut shape.

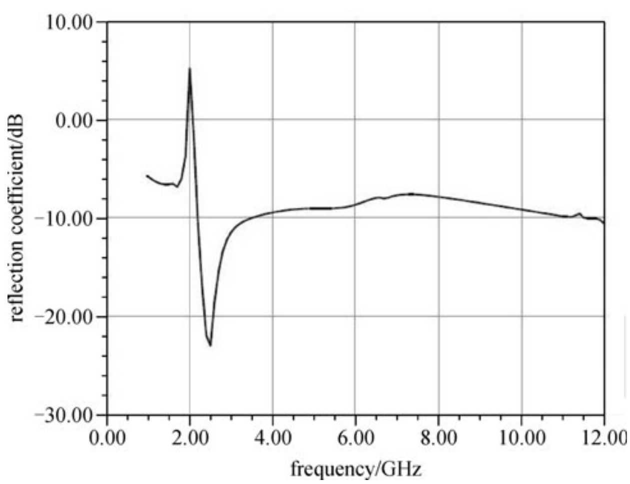

Fig. 6 Reflection coefficient of 4-element array design

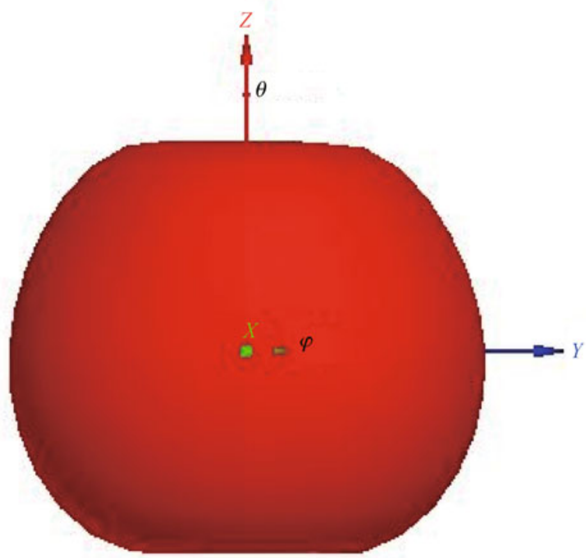

Fig. 7 Radiation pattern for antenna array

3 Result and discussion

While working on this antenna, many technicalities regarding minute design specifications were also observed. Factors like the length of the side of the square cavity (*S*), the height of the helix above the cavity, the strip height, the diameter of the helix, and the number of turns of the helix are very important in the design. Change of a few millimeters in the dimensions may cause a huge difference in the output.

During the complete design, many observations were made. It was observed that the most important parameter for a helical antenna to operate successfully is its impedance. Antenna impedance should be matched with that of the feed. The wire helix conductor was replaced by a strip. Variations in the dimensions of the strip affected the impedance of the antenna, as shown in Fig. 8. It can be seen from Fig. 8 that when the strip width is 6 mm, the impedance is 120 Ω; but when the strip width is increased to 8 mm, the impedance is closer to 50 Ω, at the frequency of 2.4 GHz.

Changes in the length of the side of the square cavity (*S*) can also change the parameters of the array. As it can be seen from Fig. 9, when *S* is 20 mm, the reflection coefficient is approximately −8.2 dB; but when *S* is increased to 29 mm, the reflection coefficient reaches to about −22 dB, at the frequency of 2.4 GHz.

Variations in the dimensions of the strip also affect the reflection coefficient of the antenna. Figure 10 shows that when the height of the strip is 6 mm, the reflection coefficient is mostly in the range of −5 dB to −10 dB; and the bandwidth is also very less as 0.6 GHz. However, when the strip height is 10 mm, the bandwidth is 2.07 GHz. Furthermore, in this design, a strong back lobe is observed.

Figure 11 shows the variation of the reflection coefficient with changes in the height of the helix above the cavity. When the height of the helix above the cavity is 11 mm, the resonant frequency obtained is 2 GHz; and when the height of the helix above the cavity is 10 mm, the resonant frequency is 2.4 GHz.

4 Conclusion

Although the length of the helix is the deciding parameter for the center frequency, the strip height, the length of the

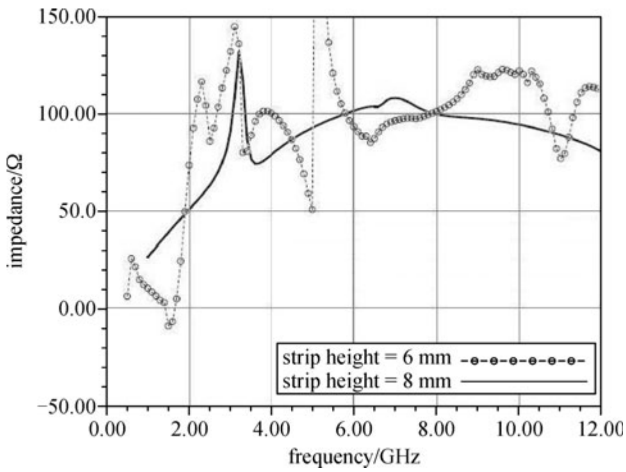

Fig. 8 Impedance variation for the proposed antenna array with various strip heights

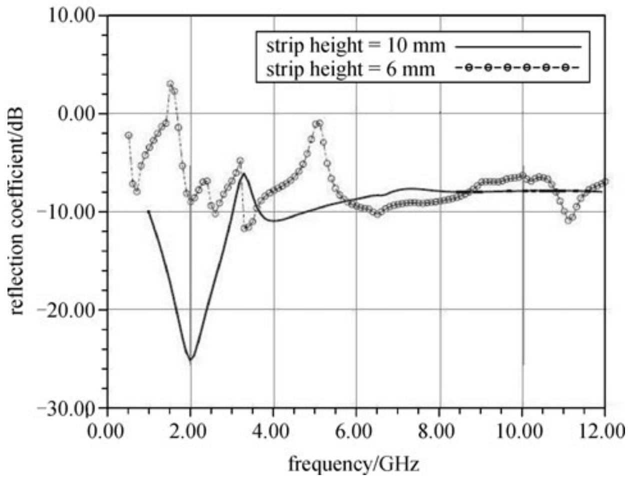

Fig. 10 Variation in reflection coefficient with changes in strip height

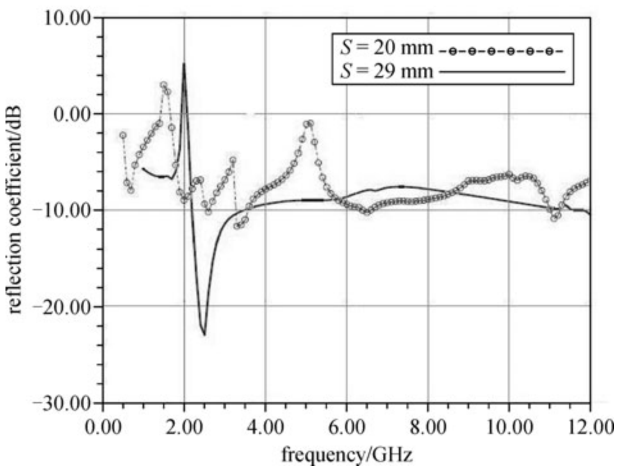

Fig. 9 Variation in reflection coefficient with changes in length of side of square cavity

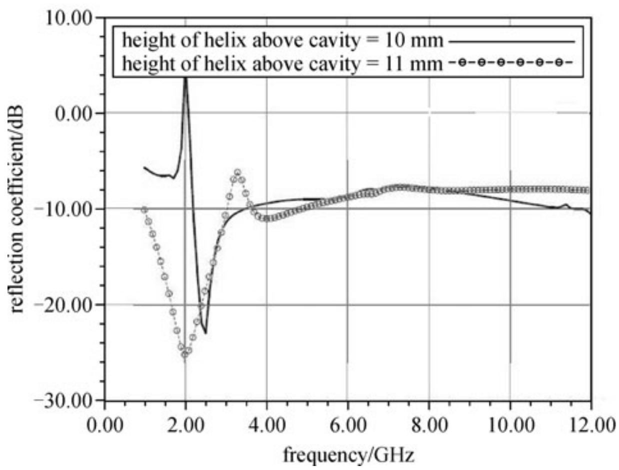

Fig. 11 Variation in reflection coefficient with changes in height of helix above cavity

side of the square cavity, and the height of the helix from the cavity also affect the frequency. With increase in the strip height, better reflection coefficient is achieved. The height of the helix above the cavity base affects the resonant frequency. Increase in the length of the side of the square cavity improves the bandwidth of the array. The helix which is working at 2.4 GHz gives a good reflection coefficient of about −22 dB. The bandwidth obtained is about 1.31 GHz.

This type of antennas can be used for broadcasting in communication. It can also be used for aircrafts as the size of antenna is compact.

References

1. Li X Q, Liu Q X, Wu X J, Zhao L, Zhang J Q, Zhang Z Q. A GW level high-power radial line helical array antenna. IEEE Transactions on Antennas and Propagation, 2008, 56(9): 2943–2948
2. Kraus J D. Antennas. 2nd ed. New York: McGraw Hill, 2001
3. Zhang J Q, Liu Q X, Li X Q, Zhao L. Design of the 4-element rectangle radial line helical array antenna. In: Proceedings of IEEE International Conference on Microwave and Millimeter Wave Technology. 2010, 1: 690–692
4. Li X Q, Liu Q X, Zhang J Q, Zhao L. 16-element single layer rectangular radial line helical array antenna for high power applications. IEEE Antennas and Wireless Propagation Letters, 2010, 9: 708–711
5. Dongre V J, Mishra B K. Compact size helical loaded cavity backed antenna by helical resonator filter. Communications in Computer and Information Science, 2011, 145: 278–282
6. Zverev A I, Blinchikoff H J. Realization of a filter with helical components. IRE Transactions on Component Parts, 1961, 8(3): 99–110