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A Multiband Tree-shaped Microstrip Antenna for Wireless Communication

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Abstract

In the modern world, wireless communications are growing very fast and changing the world of antennas. Conventional antennas are insufficient to meet the requirements in the field of wireless communications. The continuous evolution of wireless communication systems has added cost, size, bandwidth, gain, and polarization constraints to the antennas used. In this paper, the performance of the microstrip antenna is enhanced by overlapping the patch elements. A tree-shaped micro-strip antenna is presented here, in which the tree-shaped geometry emerged from five overlapping circles on the substrate. The proposed antenna could operate in the X and Ku bands. The antenna is resonant at 9.3 GHz, 10.07 GHz, 11.76 GHz, and 13.16 GHz frequencies and has various applications such as satellite communications, radar, terrestrial broadband, space communications, and amateur radio. The built antenna has an improved radiation pattern as compared to conventional antennas.

I. INTRODUCTION

Evolution has answered many of nature's challenges, leading to long-term solutions. During the evolution, various solutions were tested, and successful solutions were further developed. Nature has always inspired human performance and provided effective structures and processes. Nature's capabilities far exceed those of humans in many areas, and copying multiple traits and idiosyncrasies can significantly enhance our technology.

In recent times, the micro-strip patch antenna is considered an important candidate in the wireless communication system, and it has been continuing to fulfil the challenging demands of the new generation antenna technology [1,4]. Numerous types of designing techniques have been reported with multiple applications in different frequency domains[5, 6]. Microstrip antennas have been widely used in modern wireless systems due to their inherent characteristics, such as being lightweight, low cost, moderate gain, and low complexity [7-14]. The antenna design is based on the major requirements of the wireless communication system. Modern communication systems require antennas with wideband and/or multi-frequency modes of operation. Several other types of licensed narrowband systems exist in this area. The literature is full of research on how to improve microstrip antenna performance. People build antennas and vary their building parameters, material properties, and simulation conditions, leading to a complex way [15-20]. For example, authors in [15] have employed a slotted radiating patch. Here an attempt has been made to enhance the antenna activity by overlapping antenna elements. Although we are not dealing with that particular problem, merely trying to usher in a new direction to control the frequencies using different proportions of the overlapping regions. It would vary depending on a certain problem but would give a handy tool to implement.

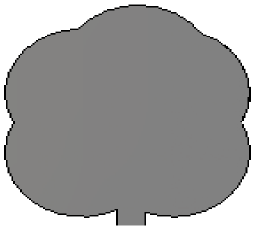
In this paper, a multiband microstrip antenna consists of five equal radius circles, partially overlapping each other. The proposed structure is stimulated by the feedline methods. The reported antenna geometry is being operated in the X and Ku bands (8-14 GHz). A suitable selection of patches and the feed line element dimensions could lead to a good radiation pattern, gain and surface current distribution. The antenna performance at different resonance frequencies has been shown here. The proposed antenna shows better performance than conventional antennas.

The paper is organized into the following sections. The introduction is mentioned in Section I. Section II presents the methodology, and section III discusses the results and discussion. The last section consists of the conclusion.

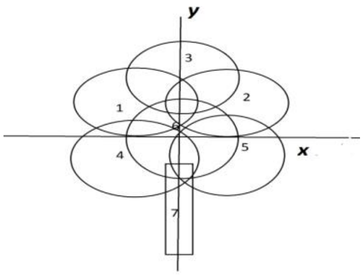
II. MATERIALS AND METHOD

Figures 1(a) and 1(b) show the antenna geometry and configuration.

The computer simulation technology software was used with a powerful CST microwave studio tool to design and simulate the antenna.



(a) Front views



(b) Internal architecture

Figure 1. Proposed antenna geometry

In the initial step, circles are oriented on the FR-4 epoxy, having the relative permittivity ε_r = 4.4, substrate thickness *h* = 1.59mm, and loss tangent tanδ = 0.025. The microstrip line feed is 2mm x 7 mm in Figure 1(b). The patch and the substrate are located on the ground plane (28mm x 24mm). Four circles of equal radius are created on the primarily built circles; the antenna geometry consists of five equal radii (5mm) circles, which are oriented differently from each other. Here, speculation has been made that the overlapping area of the circles is responsible for improving gain, return loss, and other radiation characteristics.

III. RESULTS AND DISCUSSION

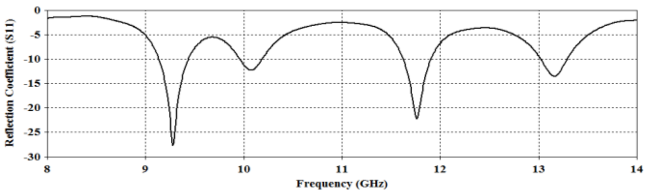


Figure 2. Variation of the return loss concerning the frequency

The return loss curve against frequency is shown in Figure 2. The antenna shows resonance at 9.3 GHz, 10.07 GHz, 11.76 GHz, and 13.16 GHz frequencies. The variation of gain to frequency is shown in Figure 3(a). The gain values are 6.91 dBi, 7.25dBi, 10.15dBi, and 8.81dB at these resonance frequencies. The 3D form of the gain is also depicted in Figure 4. The red regions show a high gain. At the 9.2GHz, the maximum gain lobes appear at the top (equal angle with the Y axis), while at the second resonance frequency, the magnitude of the gain at the top looks almost similar, but there are some red lobes at the bottom. So the antenna has a high gain, as shown in Figure 4(a). The maximum gain appears in the middle of the Y and Z axes at the third resonance frequency. At the fourth resonance frequency of 13.16 GHz, the built antenna offers a maximum gain.

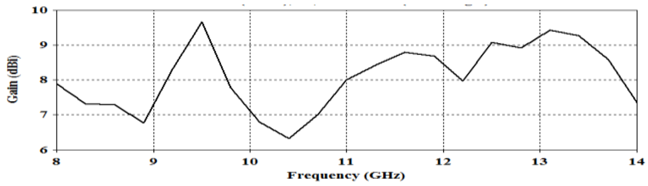
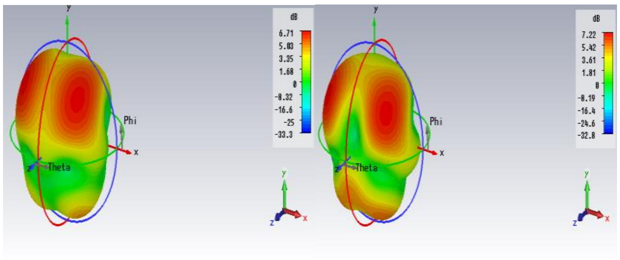
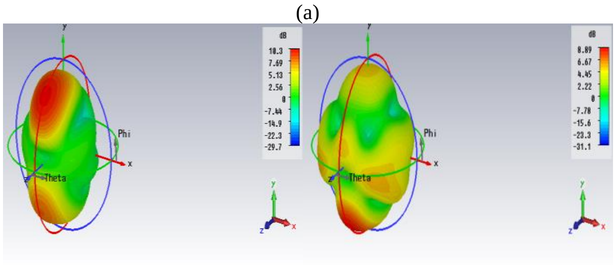


Figure 3. 2D gain configuration to the frequency (GHz)



(a)



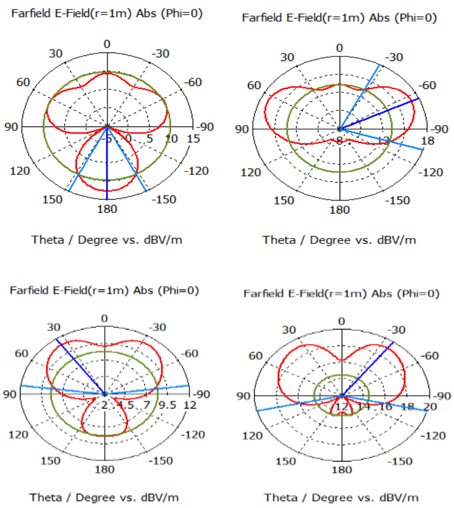
(b)

Figure 4. 3D gain configuration at resonant frequencies. (a)7.2GHz and 9.2GHz; (b)10GHz and 11.7GHz

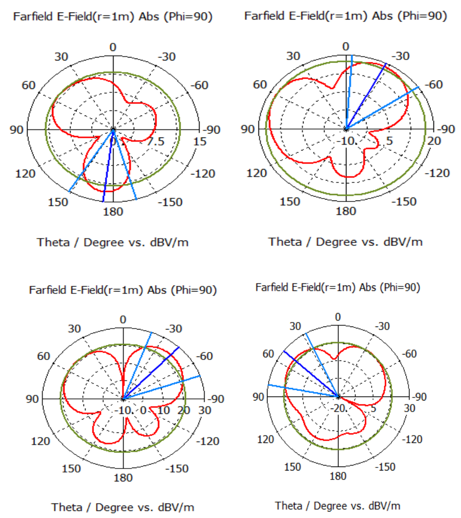
The resonant frequencies have various applications in satellite communications, radar, terrestrial broadband, space communications, and amateur radio.

The E and H radiation patterns at different resonance frequencies are shown in Figure 5. At the first resonance frequency, the major lobe is orientated at an 180^0 angle while minor lobes are oriented opposite. The E radiation pattern tilts by 60^0 angle at 10.07GHz frequency. At the third and fourth resonance frequencies, the maximum radiation pattern bends by 60^0 angle, and minor lobes arise opposite to the patch elements (Figure 5(a)). H radiation patterns are shown in Figure 5(b). The maximum radiation appears normal to patch at 9.3GHz frequency while at remaining frequencies, the H radiations lobe bends by 45^0 angle.

The surface current distribution on the patch element antenna is shown in Fig. 6. The maximum current distribution appears at the feed and patch junction. An average magnitude of the current appears at the patch boundary at the first and third resonance frequencies. At the second and fourth resonant frequencies, maximum current density appears at the circles' centre and outer boundary (yellow regions). The maximum magnitude of the current is found at the end of the feed line. There are scopes of using unique, symmetrical, fractal structures for particular applications, for improvement of the existing standard structures, or borrowing structures found in nature[21-26].



(a)



(b)

Figure 5. Elevation radiation pattern at resonance frequencies of (a) E plane and (b) H plane

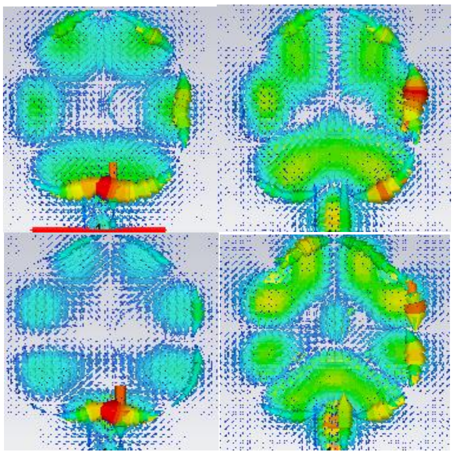


Figure 6. Surface Current distribution profile of proposed antenna at 7.2GHz, 9.2GHz, 10GHz, and 11.7GHz frequencies.

IV. CONCLUSION

A low-profile multiband antenna based on the tree shape is proposed here. The antenna simulation is carried out in a time-domain solver-CST. Simulated results show a significant performance of the created antenna. A simple geometry, high gain, and moderate radiation pattern are characteristic features of a newly designed antenna. Detailed analysis of the surface current distribution is also provided in this work. An overlapping phase of antenna elements may be the key to increasing the antenna performance. Moreover, other antenna parametric studies, such as varying the circle radius and feed element dimensions, could further extend this work.

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