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BANDWIDTH ENCHANCMENT of DAVID FRACTAL ANTENNA USING DIAMOND SHAPED RESONATOR FOR PORTABLE MECHATRONIC DEVICES

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ABSTRACT:

In this paper a diamond shaped resonator is loaded on a David fractal microstrip patch antenna with defected ground structure to further enhance bandwidth across both operating band of a normal first iteration level David fractal patch antenna. The proposed antenna structure has been designed on 56x64 mm^2 ground plane.The simulation process has been done using CST Microwave Studio EM simulation tool. The proposed antenna shows dual band operation. Based on simulation results, it observed that when a diamond shaped resonator is loaded both operating bandwidth has improved. Prototype of proposed antenna was fabricated and tested. The measured results are in good agreements with the simulated ones, which demonstrate that this design provides a way to obtain enhanced bandwidth. The properties of antenna such as bandwidth, S parameter, radiation pattern and gain in both resonant frequencies has been investigated and analysed. Both operating frequencies are very well suitable for portable mechatronic devices for data acquisition and data transmission using modern wireless communication protocols like zigbee, Bluetooth etc.

Keywords: Bandwidth enchantment, David fractal, defected ground structure, proximity fed.

1. INTRODUCTION

The invention and development of the microstrip patch antenna is a milestone in wireless communication systems and due its increasing demand innovations and developments are continuously performed in microstrip antenna research. Microstrip patch antennas are widely used in wireless communication systems because they are low profile, of light weight, of low cost, of conformal design, and easy to fabricate and integrate [1]. Even though microstrip patch antenna offers number of merits its greatest disadvantage is its low bandwidth [2]. Theoretically two techniques can be applied to enhance the bandwidth of a standard simple microstrip patch antenna. The first technique is to increase the substrate or ground plane - patch separation thickness by using a thicker substrate [3] which results in serious degradations in impedance mismatch and large radiation loss [4].On the other hand, by decreasing the substrate permittivity we can achieve wider bandwidth for the antenna but reducing dielectric constant leads to more spurious radiation and higher cross-polarisation level [5]. In recent years number of research methods has been developed to enhance the bandwidth of conventional microstrip patch antennas such as using parasitic patches [6], employing electromagnetic band gap structures [7], loading chip resistor [8], by using antennas loaded with complementary metamaterial element [9], by using complementary rhombus resonator [10], by cutting slots in the radiating elements [11] etc. In this study a diamond shaped resonator is loading across the radiating element to enhance the operating bandwidth.

Microstrip patch antennas can be fed by a variety of methods. The popular methods used for exciting radiating elements are microstrip feed line [12], coaxial probe fed [13], proximity coupling method [14] and aperture coupling method [15]. In this work the proposed antenna is excited using proximity coupling technique because it offers number of merits over other methods [16]. Defected ground structure has been used in the field of microstrip antennas for enhancing the bandwidth and gain of microstrip antenna and to suppress the higher mode harmonics, mutual coupling between adjacent element, and cross-polarization for improving the radiation characteristics of the microstrip antenna [17]. In this work the propsed antenna is excited using proximity coupling method and an H shaped defect is etched in the ground plane to enhance antenna operating parameters,

In this work, proximity coupled David fractal antenna [18] with defected ground structure loaded with a diamond shaped resonator is designed and fabricated for bandwidth enhancement. The diamond shaped resonator can resonate with the electromagnetic wave and significantly improve bandwidth performance of the proposed David fractal antenna. Mechatronics [19] is an advance engineering field where mechanics, electronics, computing and control technology combine to improve performance of mechanical systems at all levels. Modern portable mechatronic devices use various types of sensors to sense various parameters and send it via Zegbee, Bluetooth or GSM/GPRS connection to the remote devices [20]. For effective communication low profile, light weight, flexible patch antennas are placed inside portable mechatronic devices. The proposed antenna with enhanced bandwidth is a suitable choice for this purpose. The article is divided into four sections: the section one is an introduction to microstrp antennas and fractal antennas; the section two is dedicated to describe the evolution stages of the proposed proximity fed microstrip patch antenna; in the third section of the paper, the main simulated and measured results are presented and discussed; and, the conclusions of this work are described in the section four.

2. ANTENNA DESIGN AND FABRICATION

2.1 Evolution Stages of the Proposed Proximity fed Array Antenna

The important parameters to be considering while designing a microstrip patch antennas are its thickness of the substrate, dielectric constant of the substrate, shape of the basic radiating element and primary resonating frequency. In the proposed antenna we are selecting commonly used FR4 substrate because it offers sufficient strength and it is cheaply available. It has a dielectric constant of 4.3 and thickness of 1.6mm. The shape of the basic radiating element is hexagonal and its primary resonant frequency is 1.8GHz. Design idea of the proposed proximity fed David fractal antenna with DGS, with enhanced bandwidth begins with a hexagon shaped patch antennas as depicted in Fig. – 1 (a). Each side of the hexagon shaped antenna has a length of 24.7 mm and this antenna is single band antenna resonating at 1.8GHz. This frequency band is astandard frequency band used in wireless communication system. The usage of multiband antennas has been increased due to multiple applications carried out in a wireless portable devices. In order to achieve dual band characteristics David fractal geometry is introduced in to the hexagon shaped patch as illustrated in Fig.-1 (b) and this fractal geometry is called first iteration level David fractal geometry, which has a reasonably good bandwidth in both operating frequencies. Fig. – 1(c) depicts structure of the proposed antenna, where a diamond shaped resonator is placed in the start shaped open space at the center. This design and simulations were carried out for a primary resonant frequency nearly equal to 1.8 GHz with FR-4 substrate. The simulation of the proposed fractal antenna with enhanced bandwidth is carried out with CST Microwave Studio, which is a specialist tool for the 3D EM simulation of high frequency components and CST works by using the FDTD technique.

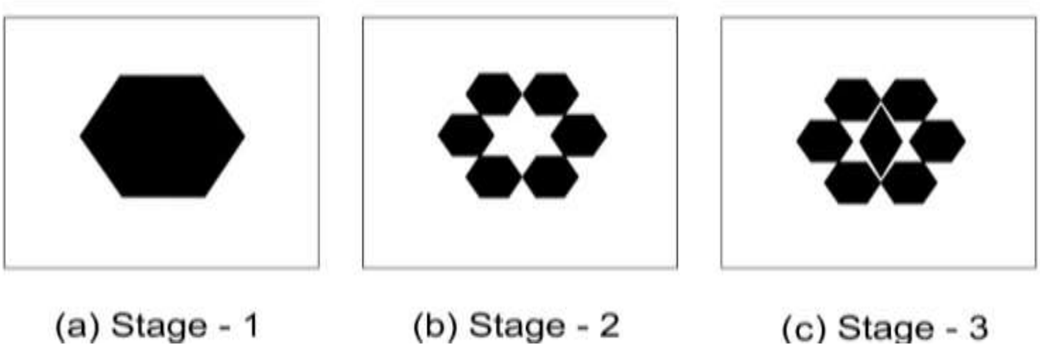
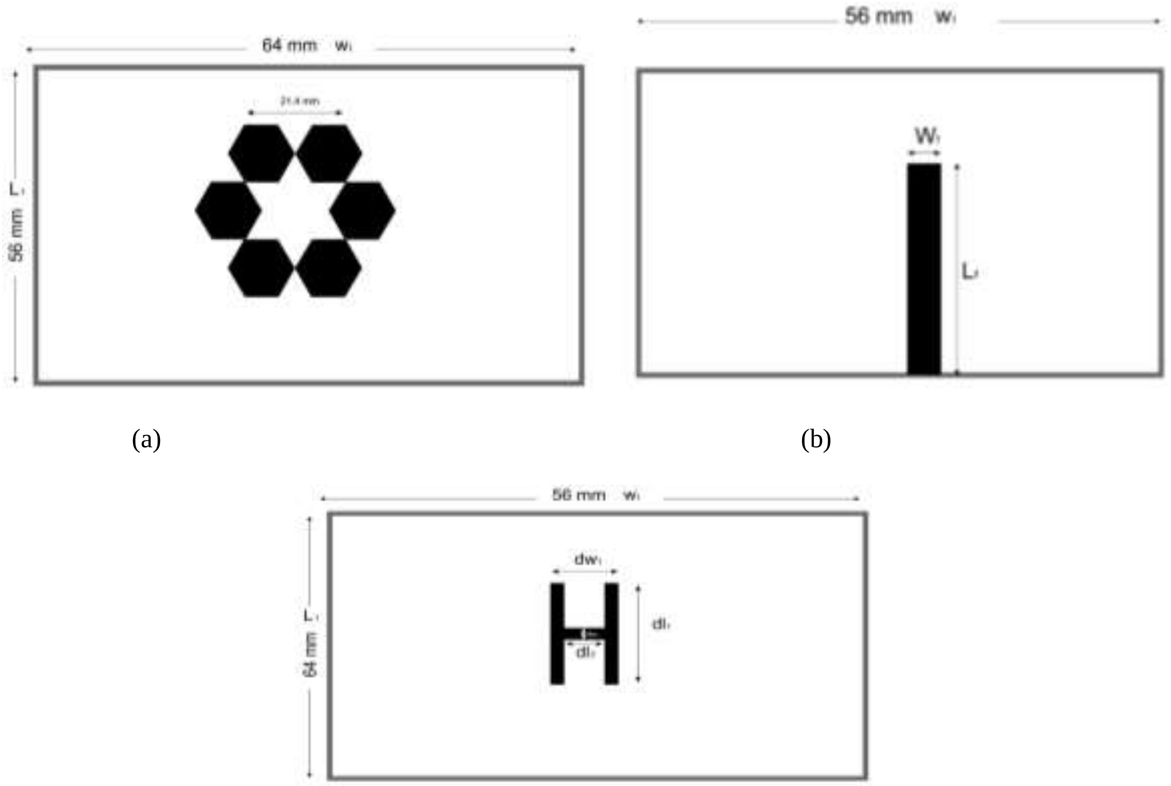


Figure -1. Evolution stages of the proposed proximity fed David fractal microstrip patch antenna with DGS with enhanced bandwidth

2.2 Antenna Configuration

The Fig. - 2, illustrates the geometry of the proposed proximity fed David fractal microstrip patch array antenna with DGS with enhanced bandwidth. The proposed antenna has been designed and fabricated on FR-4 substrate with dielectric constant of 4.3, loss tangent of 0.001 with height of 1.6mm. Fig.- 2 (a), shows the top view of the proposed proximity fed David fractal microstrip patch antenna with DGS with enhanced bandwidth. In the proposed antenna configuration two FR4 substrate layers are used, a top layer and a bottom layer. The radiating element is etched on the upper side of the top substrate layer and is as shown in Figure -2 (a). The radiating element is excited using proximity coupling method and RF feed line is printed on the upper side of the bottom substrate as illustrated in Fig. - 2(b). Fig. -2(c) depicts the bottom view of the proposed proximity fed David fractal microstrip patch antenna with DGS with enhanced bandwidth. As seen in the Fig. -2(c) an H shaped defect is etched in the ground plane in order to achieve both enhanced coupling of RF signal to radiating elements and to alter current flowing paths. The optimized dimensions of the proposed antenna are given in Table 1.



(a) (b)

(c)

Figure - 2. Geometry of the proposed proximity fed David fractal microstrip patch array antenna with DGS with enhanced bandwidth.

Table - 1. Optimized dimensions of the proposed antenna

L_1	64 mm	L_f	42.4 mm	dl_1	23.7 mm	dw_1	3.0 mm
W_1	56 mm	W_f	4.5 mm	dl_2	9.6 mm	dw	2.8 mm

Three dimensional view of the proposed proximity fed David fractal microstrip patch antenna with DGS with enhanced bandwidth is depicted in Fig. - 3. In the case of fabricated antenna there is no spacing between both FR4 layers. Fig. – 4 illustrates the side view of the proposed proximity fed David fractal microstrip patch antenna with DGS with enhanced bandwidth.

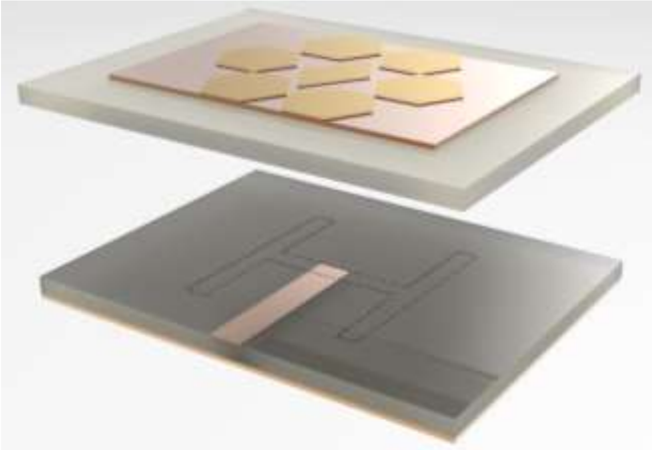
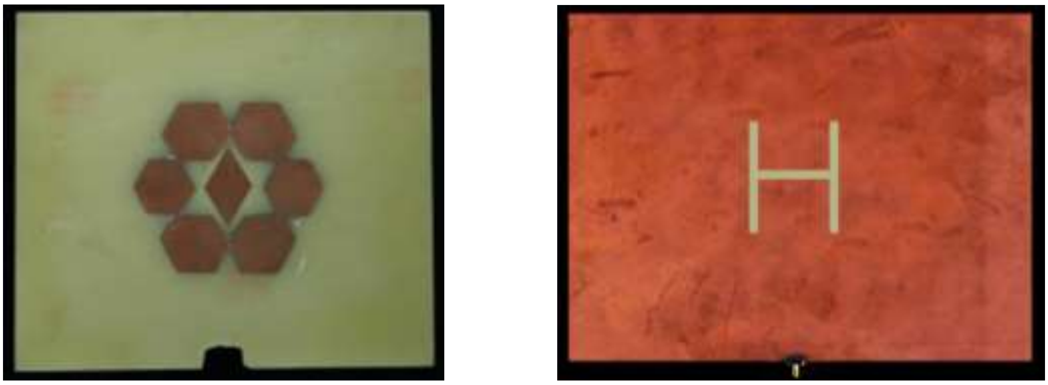


Figure -3. Three dimensional view of the proposed antenna.

Figure -4. Side view of the proposed antenna.

In order to validate the performance of the proposed proximity fed David fractal microstrip patch antenna with DGS with enhanced bandwidth prototype of the simulated antenna with optimized dimensions is fabricated. Photographs of the fabricated antenna are illustrated in Fig. -5.



(a) top view (b) bottom view

Figure -5. Photographs of the fabricated proximity fed David fractal microstrip patch antenna with DGS with enhanced bandwidth

3. RESULTSAND DISCUSSION.

The measurements are carried out using Agilent E5063A ENA series RF network analyser, which can be used for testing passive components like antennas up to 18 GHz. The calibration of the network analyser is performed using short – open – load- through technique. The test is performed within the 1.5GHz to 3GHz band. Fig. -6 depicts comparison of S_{11} plot between David fractal patch antenna with DGS, with and without resonators. From the illustration it is observed that David fractal patch antenna with DGS, without resonator resonates at 1.794GHz and 2.458GHz respectively while our proposed David fractal antenna with DGS with resonator resonates at 1.79GHz and 2.444GHz respectively. The measured bandwidth of the first iteration level proximity fed David fractal microstrip patch antenna with DGS and without resonator is 42MHz and 34MHz respectively across first and second operating band. While the measured bandwidth of the proposed antenna with resonator is 68MHz and 48MHz respectively. It is observed that bandwidth across the first band is enhanced by more than around 70% and while it is enhanced by more than around 40% across the second operating band.

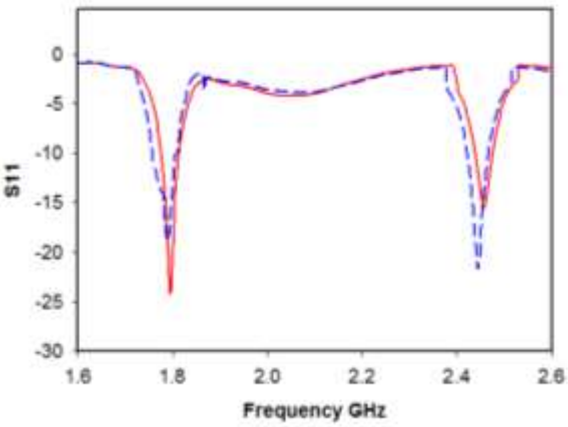
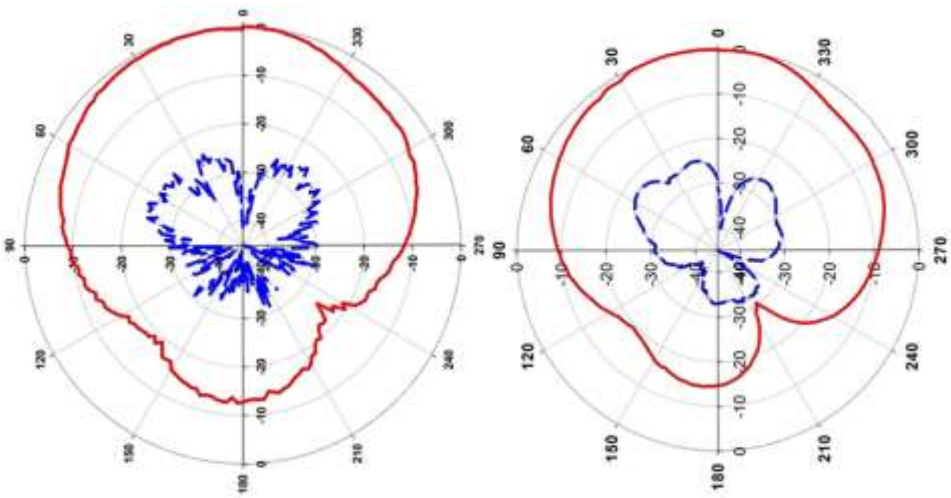
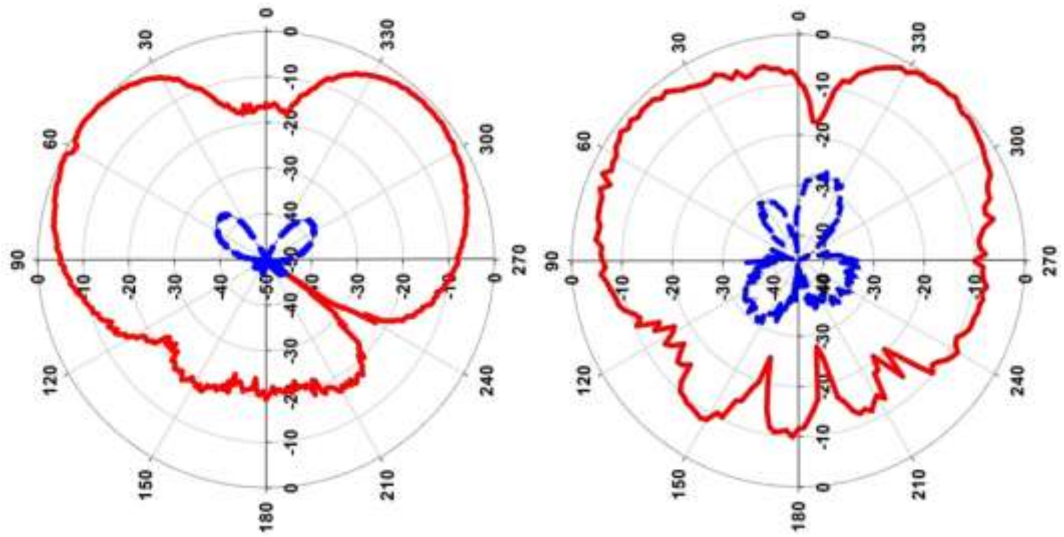


Figure – 6. Comparison of S_{11} between David fractal patch antenna with (blue dotted line) and without resonator (red bolded line)

The measured radiation patterns of the proposed proximity fed David fractal microstrip patch antenna with DGS with enhanced bandwidth in the E plane (y-z plane) and H plane (x – z plane) are plotted at the resonant frequencies of 1.79 GHz and 2.44 GHz is depicted in Fig. - 7. At the lower resonant frequency the maximum power was received at the bore sight direction. It is observed that the radiation patterns are almost directional with reasonable cross polarization in the lower band. The radiation pattern of the antenna at the second resonant frequency of 2.444GHz is shown in Fig.(c) and (d). The beam maxima of the antenna radiation pattern are few degrees away from the bore sight.



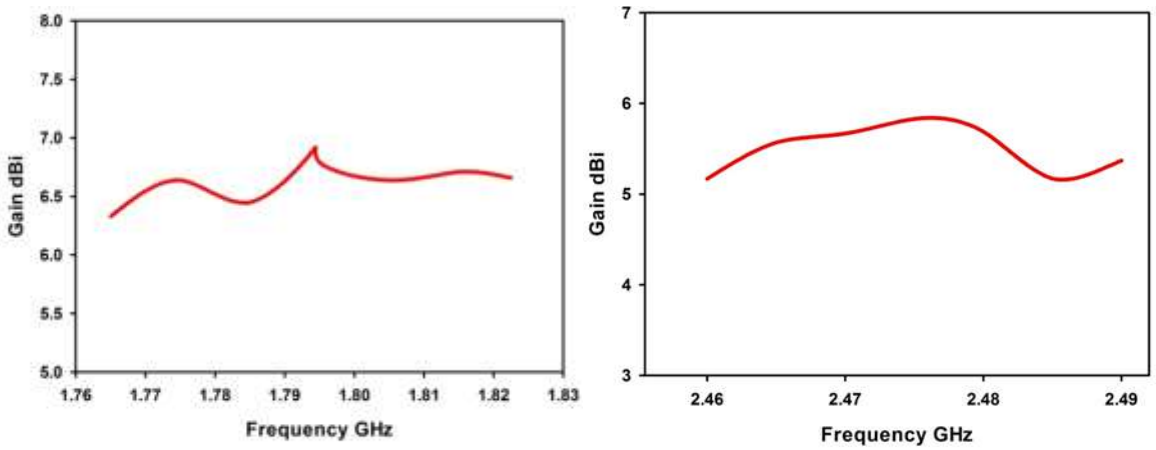
(a) (b)



(c) (d)

Figure 7. Measured and normalized radiation patterns of the proposed proximity fed David fractal microstrip patch antenna with DGS with resonator at (a & b) lower resonant frequency of 1.79 GHz, and at upper resonant frequency of 2.444 GHz.

The measured gain of the proposed proximity fed David fractal microstrip patch antenna with DGS with resonator is at 6.92dBi at lower resonant frequency and 5.89dBi respectively at second resonant frequency is illustrated in Fig. -8. The operating bands of the antenna make it suitable for cellular communication Bluetooth, Wi-Max and Wi-Fi applications



(a) (b)

Figure -8 .Measured gain with frequency of the proposed proposed proximity fed David fractal microstrip patch antenna with DGS with resonator at (a) first band and (b) second band

4. CONCLUSION

Design and characterization of a prototype of a proximity fed David fractal microstrip antenna with defected ground structure loaded with a diamond shaped resonator with dual band operation on a FR4 substrate were described. With the addition of resonator in to radiating surface, resulting in improving antenna bandwidth in both operating frequencies when compared with same antenna structure without diamond shaped resonator. The resonating frequencies of the developed proximity fed David Fractal microstrip patch antenna with DGS loaded with resonator are at 1.79GHz and 2.444GHz respectively. Both the operating frequencies find applications in portable wireless communication devices. The first band finds application in GSM mobile phone communication and the second band finds applications in either Bluetooth, Wi-Fi and WLAN. The antenna exhibited good directional radiation pattern with good gain in both operating frequencies. The bandwidth of the proposed antenna increases by 70% and 40% respectively across first and second operating bands compared with that of the antenna without the diamond shaped resonator. It can be conclude that a simple structure modification provides a way to obtain the bandwidth enhanced dual band patch antenna. The developed proximity fed microstrip antenna is suitable for portable mechatronic devices for data acquisition and data transmission purpose.

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