Design and Analysis of Single Layer Proximity Fed Sierpinski Fractal 2x1 Array Antenna Embedded on Hexagon Shaped Patch with Defected Ground Structure

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Abstract—A novel innovative technique for producing a single layer proximity fed triple band antenna based on second iteration level Sierpinski fractal geometry implanted on a hexagonal shaped array antenna is being presented for next-generation cellular networks. The steps of fractal array antenna growth are examined. The array antenna is supplied using a single layer proximity fed method. The suggested single layer proximity fed hexagonal shaped array antenna with defective ground structure is developed and simulated using CST Microwave Studio, and characteristics such as bandwidth, return loss, directivity, and radiation pattern are investigated. The second iteration level single layer proximity fed array antenna's simulated -10 dB impedance bandwidth for the lower band is 237 MHz (1.6480 – 1.8850 GHz) with peak resonance at 1.8010 GHz, the middle band bandwidth is 66 MHz (2.4280 – 2.4940 GHz) with peak resonance at 2.4640 GHz, and the upper band bandwidth is 69 MHz (2.9080 – 2.9778 GHz) with peak resonance at 2.9 GHz. This antenna may be used for a wide range of wireless communication applications.

Index Terms—Single layer proximity fed, sierpinski fractal 2x1 Array Antenna, hexagon shaped patch, defected ground structure

I. INTRODUCTION

Communication systems may be wired or wireless, and the medium utilised for communication can be directed or unguided. In wired communication, the medium is a physical conduit that guides the signal from one location to another, such as coaxial cables, twisted pair cables, and optical fiberlinks. This kind of medium is referred to as a “directed medium.” Wireless communication, on the other hand, does not need a physical link and instead transmits information via space. Because space is utilised for signal transmission without any direction, the medium employed in wireless communication is known as an unguided medium. Even though there are no cables involved in wireless communication, antennas are used to send and receive messages. The antenna system is one of the most crucial yet least understood parts of any radio communication platform. The antenna system connects the radio system with the rest of the world. Antennas are electrical devices that transform electrical impulses into radio signals, which are transmitted as electromagnetic (EM) waves, and vice versa. Electromagnetic waves move across space and are electromagnetic waves. In a wireless communication system, an antenna may be used to transmit and receive signals. Research has lately focused on developing a wireless communication system employing a multiband antenna due to its compact size, high data transfer rate, and low cost. Multiband and shrinking capabilities in a single antenna design are essential for running many wireless applications. Microstrip antennas have long been a popular choice for use in a variety of wireless communication applications due to their low cost, simplicity of design and production, light weight, and small size [1]-[4].

Microstrip antennas are a novel kind of antenna. It was designed to facilitate the simple integration of an antenna and associated communication system driving circuitry on a single printed-circuit board or semiconductor chip, enabling tiny antennas to be easily integrated into portable wireless communication devices [5]. Microstrip antennas are used in satellites, missiles, aeroplanes, spacecraft, mobile phones, wireless communication systems, radars, and remote sensing. Microstrip antennas are the most extensively used in wireless devices due to their simplicity of integration and small size. Microstrip antennas are low-profile and feature a two-dimensional flat structure. They have low-radiation antenna characteristics [6]. A half-wavelength metal patch serves as the basis for a microstrip antenna. The length of the antenna is maintained constant so that it may operate as a resonator. Between the metal patch and the ground plane, a dielectric material is placed. Because it has a conducting patch, a microstrip antenna is also known as a microstrip patch antenna. Copper is a common material for the patch. When a thin microstrip antenna is triggered from a feeding network, waves are produced and reflected in the dielectric material. When the waves hit the metal patch's corners or edges, some of the incident energy is radiated outwards. Conducting patches may be rectangular, circular, triangular, elliptical, hexagonal, rhombic, pentagonal, and other shapes. Rectangular or
circular metal patches are the most prevalent in microstrip antennas. A hexagonal patch antenna is excellent for array antenna construction since it uses less surface area than a rectangular patch antenna. Regardless of patch shape, the radiation characteristics of circular, hexagonal, and rectangular patch antennas are identical [7]. A dielectric substance is used between the metal patch and the ground plane. The dielectric constant is critical for antenna performance. For optimal antenna performance in microstrip patch antennas, use a thick dielectric material with a low dielectric constant. A dielectric substrate with a thickness of d, complete metalization on one of its surfaces, and a metal patch on the other comprise the geometry of a microstrip antenna. The substrate is often quite thin (d) [8].

A microstrip antenna, also known as a printed antenna or patch antenna, is a photolithographically made antenna that is placed on a Printed Circuit Board (PCB). A microstrip antenna consists of a patch of metal foil in various shapes on the surface of a printed circuit board, as well as a metal foil ground plane on the other side. The vast majority of microstrip antennas are built up of a two-dimensional array comprising many patches. The antenna is connected to the transmitter or receiver by foil microstrip transmission wires. A radio frequency current is used to connect the antenna and the ground plane. When a thin microstrip antenna is triggered from a feeding network, waves are produced and reflected in the dielectric material. When waves hit the metal patch’s corners or edges, a portion of the incident energy is radiated outwards. Four of the most frequent feeding methods [7] include microstripfeed-line, coaxial probe, aperture coupling, double substrate layer proximity coupling, and single substrate layer proximity coupling. Microstripfeed-line [9] is the easiest to construct since it just involves the connection of a conducting strip to the patch and can therefore be regarded a patch extension. Controlling the inset placement makes modelling and matching simpler. The drawback with this strategy is that when the substrate thickness increases, the quantity of surface wave and spurious feed radiation increases as well, limiting the bandwidth [9]. With input impedances of 50 or 75 ohms, which may be achieved by modifying the inset position, modelling and matching is simple. The downside of this strategy is that as the substrate thickness grows, spurious radiation increases as well, limiting the bandwidth (typically 2-3%) [10]. Controlling the patch’s length and width enables for precise matching. Inset feeding is discussed and analysed [11], a form of this feeding method that is becoming increasingly popular these days.

The second kind of contact feeding mechanism is coaxial feed. The cable used here is known as coaxial cable because of its structure. It is made up of a signal-carrying physical channel and a concentric physical channel that run parallel to each other and is separated by a dielectric insulating material [12]. The outer channel provides the ground. The inner conductor of the coaxial is connected to the antenna’s radiating patch, while the outside conductor is connected to the ground plane. The main advantage of this feeding method is that the feed may be placed anywhere within the patch for impedance matching. This feed system is easy to construct and emits little spurious radiation [13]. Its primary disadvantage is that it has a restricted bandwidth and is difficult to replicate due to the need to drill a hole into the substrate. Furthermore, the greater probe length leads the input impedance to become more inductive for thicker substrates, producing matching concerns [14]. To enhance bandwidth, a thick dielectric substrate is used, however this has a number of disadvantages, including spurious feed radiation and matching difficulties. The bandwidth, on the other hand, may be raised using the strategies outlined above. For diverse applications, several microstrip patch antennas with coaxial feed have recently been shown [15].

In aperture coupling, a ground plane separates two unique substrates. In this technique, the feed circuitry (transmission line) is shielded from the antenna by a conducting plate with a hole (aperture) for energy transfer. A slit in the ground plane between the two substrates links energy to the patch through a microstrip feed line on the bottom side of the lower substrate [16]. This design allows for separate optimization of the feed mechanism and the radiating element. The top substrate is normally thick and has a low dielectric constant, whereas the bottom substrate has a high dielectric constant. For pattern formation and polarisation purity, the middle ground plane isolates the feed from the radiation element and eliminates spurious radiation interference [17], [18]. The fundamental benefit of this feeding method is that it allows for self-optimization of feed mechanism elements. It’s especially useful in situations when we don’t want to link layers using wires. The disadvantage of this feed is that it requires multilayer construction.

The proximity coupling technique is the next non-contacting feeding method, and proximity coupled microstrip patch antennas are the result [19]. This kind of feed technology is often referred to as electromagnetic coupling method. The radiating patch is etched on the top side of the upper substrates, while the feed line is etched on the top side of the lower substrates. The main advantage of this feed strategy is that it eliminates spurious feed radiation and provides extremely high bandwidth due to the overall increase in the thickness of the micro strip patch antenna. In order to maximise individual performance, this technique allows for the employment of two different dielectric medium, one for the patch and the other for the feed line. The primary benefit of this feeding strategy is that it eliminates spurious feed radiation while maintaining very high bandwidth [20]. This method also permits the use of two different dielectric mediums, one for the patch and the other for the feed line. The main drawback of this feeding approach is that it is difficult to construct since both
dielectric layers must be properly aligned [21], and the overall thickness of the antenna configuration is bulky and difficult to handle. While the typical proximity coupled feeding strategy has many benefits, it also has two major disadvantages: it is difficult to construct owing to the two dielectric layers that must be precisely oriented, and it increases the antenna's overall thickness. Another fed method is proposed [22], in which the radiating patches and feed line are in the same plane, reducing the complexity of antenna designs while maximising the advantages of proximity feeding approaches while minimising the challenges. Gap linked patches are theoretically described and their advantages are given in a variety of research papers [23]-[25]. Using the recommended feeding technique, where the microstrip patch is not supplied directly, a single layer proximity coupling approach was employed to produce multiband [26] and patch array antennas [27]. In this design, the feed line excites a pair of quarter-wavelength patches that are electromagnetically coupled to the microstrip feed-line. This novel single layer proximity feeding method is used in all of the antenna topologies presented in this chapter. Microstrip patch antennas are narrow-band antennas at their most basic level. These devices have a one-to-two-percentage-point impedance bandwidth. There are two natural techniques of increasing the bandwidth of a single layer direct fed microstrip patch antenna. By introducing horizontally coupled parasitic patches to the driven patch [28], using fractal geometry in developing radiating patch shape [29], stacking techniques [30], adding additional strips [31], using DGS [32], using a meta-surface ground plane [33], and so on, we can make a single band antenna resonate as a multiband antenna.

The evolution of modern wireless communication networks has been remarkable. The need for small, lightweight antennas with multiband capability to enable global communication standards and services for personal wireless communications systems has grown significantly. A typical microstrip patch antenna only resonates at one frequency, however multiband antennas are becoming increasingly prevalent. Multiband patch antennas are being investigated because they cover a variety of wireless communication services such as GSM, Bluetooth, Wi-Fi, Wi-Max, DCS, CDMA, and PCS, as well as ISM band applications for residential devices, scientific, and industrial systems. Many antenna applications cover numerous frequency bands, necessitating the creation of an antenna that can work efficiently across many bands without needing modifications to the antenna's shape or construction [34]. Researchers have proposed a variety of methods for making multiband microstrip patch antennas. PIN diodes [35], switches [36], and varactor diodes [37] are some of the conventional methods used for multiband operation. However, since they need an extra biasing network, these designs increase the system's complexity and make it harder to use. There are other methods for creating dual, triple, quad, or even higher resonances, but the antenna's compactness is also crucial. Some well-known techniques include ground planes with two rectangular strip slots [38], exciting radiating patches with dual fed [39], using coupled resonators network [40], using closed C shape conductive strips around the patch [41], using conducting strips along with radiating patches [42], using fractal structures [43], using the concept of stacking [44], using defected ground structure [45], and so on.

In biology, geography, and engineering, fractal geometry may be used in a variety of ways. Antenna designs, biological signal processing, picture processing, and frequency selective surface designs have all used fractal geometries in the engineering field. It is a relatively new research area in antenna design. Fractal antennas and the associated superset fractal electrodynamics, on the other hand, are a hot topic of research right now [46] due to a number of enticing properties. Fractal geometries are complex geometric formations with self-similarity, self-scaling, and space-filling characteristics. They're a suitable match for smaller antenna designs because of these features. Electrically enormous features are formed due to the space-filling property. The self-similar property makes it possible to use an iteration function system with similar forms. Self-scaling iteration function systems may use forms from a variety of scales. Because of these qualities, they may be compactly packed and hence easily represented in small places. Using the self-scaling, space filling, and self-similarity properties of fractals, the antenna shrinking process may be completed, resulting in electrically incredibly long curves with a little organised physical space [47]. Because of its self-similarity, self-scaling, and space-filling properties, Fractal geometries are often used in Fractal antenna designs. When fractal antennas are compared to standard antennas, it is found that fractal antennas have a much larger bandwidth while having a significantly lower antenna size. Fractal antennas that are multiband but not harmonics in nature may be used to produce multiple resonant frequencies [48]. As a consequence, antenna designs based on fractal geometries are suitable for a broad variety of wireless applications. Microstrip antennas with better bandwidth and multiband operating features have recently been successfully produced using various fractal topologies. Some of the commonly used fractal geometries to construct microstrip antennas include the Sierpinski gasket [49], multiple circular loop [50], stacked plus shape [51], Pythagorean Tree [52], Minkowski Fractal [53], Durer pentagon [54], Koch Island [55], Hilbert curve [56], David fractal [57], and others.

A DGS, or Defected Ground Structure, is a flaw on the ground plane of a purposefully created printed microstrip board. The present flow route is forcefully altered or adjusted, and the path length may sometimes increase [58], [59]. It is often constructed in the form of an etched-out pattern on the ground plane. Deflected ground structures have been used in microstrip antennas to
enhance bandwidth, gain, suppress higher mode harmonics, mutual coupling between neighbouring elements, and cross-polarization in order to improve the microstrip antenna's radiation characteristics. The inclusion of DGS to the antenna ground plane affects key antenna performance parameters including input impedance and current flow. The DGS idea has been effectively used to increase bandwidth [60], multiband characteristics [61], radiating patch size reduction [62], cross polarisation reduction [63], mutual coupling reduction [64], and the design of wide band antennas, among other things. The performance of patch antennas with faulty ground structures is determined by the shape, size, and positioning of faults at certain positions on the ground plane. Microwave devices often use DGS for compactness and efficacy, as well as to reduce return loss. It’s also used to improve radiation efficiency [65]. To create a faulty ground structure, the ground plane is carved with diverse shapes and patterns. Some of the more well-known and researched forms are summarised in [66]-[70].

The single layer proximity feeding method is used to activate two of the three unique 2x1 array antennas described in this chapter. A single layer proximity fed 2x1 hexagon shaped microstrip patch array antenna with a faulty ground construction is the first issue discussed. This is a dual band antenna with a microstrip feed line in the centre of the top layer of the substrate and hexagon-shaped radiating patches on each side of the feedline separated by a small gap. First iteration level Sierpinski fractal geometry is put in hexagon shaped radiating components on both sides of the feed line to construct the second 2x1 array antenna. This array is a dual band setup with a lot of bandwidth. The third array structure is created by weaving the basic array configuration with the second iteration level Sierpinski fractal geometry. A triple-band antenna with greater bandwidth makes up the third antenna array. To boost RF power electromagnetic coupling with the radiating components, the ground plane is carved with an H-shaped defect. All three array antennas were simulated using CST microwave studio, and the simulated antennas were constructed using optimum dimensions. The CST Studio Package is a high-performance 3D electromagnetic (EM) analysis software suite that may be used to design, evaluate, and optimise EM components and systems. CST MWS delivers rapid insight into your high-frequency designs’ EM behaviour, as well as extra solver modules for specialised applications. The simulated and measured results are quite close to each other. The three working bands of the recommended 2x1 array antenna are beneficial for a wide range of wireless communication technologies.

II. EVOLUTION STAGES OF THE PROPOSED MICROSTRIP PATCH ARRAY

Fig. 1 depicts the development of the proposed 2x1 fractal array antenna. This hypothesised antenna development step is broken down into three phases, with further examination in the sections below.

Fig. 1. Evolution stages of the proposed fractal 2x1 array antenna

A. Antenna Design Procedure

By equating the corresponding areas as illustrated in Fig. 2, the equations for the hexagonal microstrip patch antenna may be derived from the resonant frequency equations of the circular microstrip patch antenna given in [56]. A circular patch antenna’s basic resonance frequency is determined by

\[ f_r = \frac{X_{\text{res}} C}{2\pi\varepsilon_r a_e} \sqrt{\frac{\varepsilon_r}{\varepsilon_t}} \]

where

- \( f_r \) = resonant frequency of the patch
- \( X_{\text{res}} = 1.8411 \) for the dominant mode TM
- \( C = \) velocity of the light in free space
- \( \varepsilon_r = \) relative permittivity of the substrate
- \( \varepsilon_t = \) effective radius of the circular patch and given by
  \[ a_e = a\left(\frac{1}{2}\right)^{1/5} + 1.7726 \]

The actual radius of the circular patch antenna is ‘a,’ and the height of the substrate is h in the preceding equation. By connecting the areas of the circular and hexagonal patches as stated in the equation below, the
aforementioned equations may be used to create a hexagonal microstrip patch antenna.

$$\Pi a_e^2 = \frac{3\sqrt{3}}{2} \frac{s^2}{2}$$

Where 's' is the side length of the hexagonal patch.

Fig. 2. Formation of a hexagonal shape from a circle.

**B. Basic Single Layer Proximity Fed Patch Antenna**

The steps of antenna design evolution that led to the invention of a single layer proximity fed microstrip patch antenna are discussed in this section. As shown in Fig. 3, the procedure starts with the antenna shape. A hexagon-shaped radiating patch plus a microstrip feed line make up the microstrip patch antenna. Both the hexagonal patch and the feed line are printed on the substrate's top surface. An H-shaped defect is etched off the opposite side of the substrate to create a defective ground plane. The microstrip line is near to the hexagonal patch, which has a gap G. From the feedline to the radiating patch, RF power is electromagnetically linked. The antenna is intended to resonate at 1.8GHz, with the dimensions optimized using CST Microwave Studio, a power EM modelling programme, and validated using antenna design formulae found in textbooks. The antenna is made of FR-4 and has a height of h and a permittivity of $\varepsilon_r$.

![First stage of proximity feed antenna](image)

(a) top view (b) bottom view

Fig. 3. First stage of proximity feed antenna (a) top view and (b) bottom view

**C. Basic 2x1 Single Layer Proximity Fed Array Antenna**

The main problem with the aforementioned antenna arrangement is that it has a single resonance, and the radiation pattern's beam maxima are slightly slanted at 270 degrees away from the bore sight direction. In order to address these issues, another hexagon-shaped patch with the same dimensions is put on the opposite side of the microstrip feed line in the next development step, as shown in Fig. 4. The basic single layer proximity fed 2 x 1 microstrip patch array antenna with defective ground structure is formed using this setup. The multiband features of this array antenna arrangement are shown, and the patch dimensions have been optimised to guarantee that both operating frequencies are adequate for wireless communication applications. As indicated in Fig. 4, the radiating patches on both sides are set at a distance of 3.3 mm from the feed line's margins. The spacing between the patches' closest edges is retained at 1/12, while the spacing between the patches' mid-points is 3/8. The microstrip line that extends beyond the centre of the pair of patches serves as a tuning stub and enhances the array antenna's impedance matching. A metallic ground plane with a H slot is located on the rear side of the substrate. The patches are electromagnetically linked from the feed line, and a groove carved in the ground plane improves the coupling to the radiating patches at the same time. The newly designed antenna is 56mm x 90mm x 1.6mm and is built on a FR4 substrate with a dielectric constant of 4.4, providing excellent radiation and return loss in the appropriate bands. This array antenna has a dual band structure, and fractal geometry is inserted in both hexagon shaped patches to improve the antenna's operating characteristics. In order to optimise the operational characteristics of antennas, initially, a Sierpinsky fractal geometry is incorporated in the hexagonal array antenna at the first iteration level, then afterwards, to improve the antenna's operational parameters. The basic 2x1 hexagonal shaped array antenna incorporates Sierpinski fractal geometry at the second iteration level. The dual band first iteration level Sierpinsky fractal geometry embedded antenna is modified to a triple band antenna with increased impedance bandwidth using second iteration level Sierpinsky carpet fractal geometry. The next section discusses fractal embedded array antennas.

![Geometry of the proposed proximity fed 2x1 microstrip patch array antenna with DGS](image)

(a) top view (b) bottom view

Fig. 4. Geometry of the proposed proximity fed 2x1 microstrip patch array antenna with DGS.
Fig. 5 displays the proposed array antenna configuration's simulated and observed return loss characteristics, as seen in Fig. 4. The measured -10dB impedance bandwidth of the single layer proximity fed 2x1 array antenna for the lower band is 61.87MHz or 3.41 percent, (1.7744 - 1.8363 GHz) with resonance at 1.81 GHz, and for the upper band is 48.04 MHz or 1.72 percent, (2.7612 - 2.8093 GHz) with resonance at 2.79 GHz, whereas the simulated bandwidth is 43.7 MHz or 2.44 percent, (1.776 - 1.8197 GHz).

D. Sierpinski Embedded Hexagonal Geometry Design

The Sierpinski triangle, named after the Polish mathematician Waclaw Sierpinski, is one of the most often used fractal geometry. The Sierpinski triangle is a fractal that is self-similar. It's made out of an equilateral triangle with smaller equilateral triangles recursively subtracted from the rest of the surface. This fractal geometry may be created by continually cutting smaller triangles out of the middle of a huge equilateral triangle. This fractal geometry is also known as the Sierpinski sieve or Sierpinski gasket in literature. The Sierpinski triangle may be made from an equilateral triangle by removing triangular subsets repeatedly; the iteration phases are seen in Fig. 6. Iteration is a common method used by academics to generate innovative fractal geometry. This entails applying a step to an existing figure, seeing the effect, and then repeating the process. We may repeat this procedure infinitely many times using fractals, making it a continuous and presumably never-ending process.

As seen in Fig. 6, the iteration process uses an equilateral triangle (a). As shown in Figure 6(b), dots are drawn at the midpoints of each of the equilateral triangle's sides, the dots are linked to create another equilateral triangle, and the newly formed equilateral triangle is cut away, resulting in three new equilateral triangles (c). To create the second iteration level Sierpinski triangle, continue this technique on each of the three remaining solid equilateral triangles (see Fig. 6). (d). There will be nine equilateral triangles of equal dimension after this repetition level. The technique is repeated to create Sierpinski triangle fractal geometry's third, fourth, and higher order iteration phases. Fig. 6 illustrates the various phases of the iteration process. Fig. 7 depicts the first three iteration steps of the Sierpinski triangle geometry contained hexagon geometry. Table I summarises the number of equilateral triangles created after each iteration step.

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E. Sierpinski Fractal Geometry Embedded 2x1 Single Layer Proximity Fed Array Antenna

Fig. 8 shows the geometry of the Sierpinski fractal geometry incorporated single layer proximity fed 2x1 hexagon array antenna with defective ground structure at the second iteration level. On FR-4 substrate with dielectric constant of 4.4, loss tangent of 0.001, and height of 1.6mm, the second iteration level Sierpinski fractal geometry integrated single layer proximity fed 2x1 hexagon array antenna with defective ground structure was created. Fig. 8 (a) depicts the planned second iteration level from above. Two comparable
fractal geometry, including radiating components are printed on each side of the microstrip feed line in the Sierpinski fractal embedded 2x1 hexagon shaped array antenna. Gap G of 3.9 mm separates the feed line from the radiating element's closest edge. Fig. 8 shows a metallic ground plane with an H-shaped slit on the rear side of the substrate (b). CST Microwave Studio, a strong EM simulation programme, was used to improve the antenna's size.

Fig. 8. Geometry of the proposed single layer proximity fed second iteration level Sierpinski fractal geometry embedded hexagon shaped array patch antenna with defected ground structure. (a) top view of radiating elements along with feed line and (b) bottom view with defected ground structure.

Fig. 9. Simulated and measured return loss characteristics of the proposed single layer proximity fed second iteration level Sierpinski fractal geometry embedded hexagon shaped array patch antenna with defected ground structure.

Fig. 9 illustrates the calculated and observed return loss characteristics of a single layer proximity fed second iteration level Sierpinski fractal geometry embedded hexagon shaped array patch antenna with a defective ground structure. The antenna seems to have triple band characteristics because it operates at three resonant frequencies. The single layer proximity fed second iteration level Sierpinski fractal geometry integrated hexagon shaped array patch antenna with defective ground structure has a simulated -10 dB impedance bandwidth. The bandwidth for the lower band is 246MHz (1.6420–1.8880GHz) with a peak resonance of 1.8010GHz, the intermediate band is 69MHz (2.4280–2.4970GHz) with a peak resonance of 2.4610GHz, and the upper band is 66MHz (2.9080–2.9740GHz) with a peak resonance of 2.9410GHz. The measured impedance bandwidth of the single layer proximity fed second iteration level Sierpinski fractal geometry embedded hexagon shaped microstrip patch 2x1array antenna with defected ground structure for the lower band is 258MHz (1.6840–1.9420GHz) with peak resonance at 1.8610GHz, and for the second band is 66MHz (2.4460–2.5120GHz) with peak resonance at 2.4760GHz, and for the upper band is 63MHz (2.9680–3.0310GHz). The bandwidth and number of resonance bands are both increased as a result of the second iteration. The new antenna has triple band features, and the bandwidth in the first resonant frequency band has increased dramatically. Fig. 10 shows the three-dimensional radiation patterns of a single layer proximity fed second iteration level Sierpinski fractal geometry embedded hexagon shaped array patch antenna with defective ground structure at three resonant frequencies. The radiation patterns have a high degree of directed behaviour, as seen in the images.

Fig. 10. Simulated 3D radiation patterns of the proposed single layer proximity fed second iteration level Sierpinski fractal geometry embedded hexagon shaped array patch antenna with defected ground structure at (a) lower resonant frequency of 1.801GHz, (b) at second resonant frequency of 2.461GHz and (c) at upper resonant frequency of 2.941GHz.

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Fig. 11 shows the measured radiation patterns of the proposed single layer proximity fed second iteration level Sierpinski fractal geometry embedded hexagon shaped 2x1 patch array antenna with defected ground structure in the E plane (y-z plane) and H plane (x-z plane) at resonant frequencies of 1.861GHz, 2.476GHz, and 2.995GHz. Maximum power was received in the bore sight direction when the resonance frequency was lower. The radiation patterns in the lower band are nearly directed, with good cross polarisation. Fig. 11(c) and Fig. 11(d) depict the antenna's radiation pattern at its second resonance frequency of 2.476GHz (d). The antenna radiation pattern's beam maxima are a few degrees distant from the bore sight. In the initial resonance frequency, the antenna's half-power beam width is on the order of 1020 in the E plane and 1050 in the H plane. Fig. 11(e) and Fig. 11(f) illustrate the antenna's radiation pattern at the top resonance frequency of 2.995GHz (f). On both sides, the antenna radiation pattern's beam maxima are a few degrees distant from the bore sight direction. At the second resonance frequency, the antenna's half-power beam width is on the order of 980 in the E plane and 860 in the H plane. The pattern suggests that operating frequencies are appropriate for building antennas for use in wireless portable devices. At three distinct resonance frequencies, Table II illustrates the retrieved characteristics of the proposed triple band antenna. At the third resonance frequency, the antenna's half-power beam width is on the order of 880 in the E plane and 740 in the H plane.

At the first, second, and third resonant frequencies, the suggested single layer proximity fed Sierpinski fractal geometry embedded hexagon shaped array patch antenna with defected ground structure has measured gains of 7.21dBi, 6.74dBi, and 6.11dBi, respectively. The observed gain fluctuations throughout the operational frequency ranges are shown in Fig. 12. The antenna's working bands make it ideal for Bluetooth, Wi-Max, and Wi-Fi applications. At three distinct resonance frequencies, Table II illustrates the retrieved characteristics of the proposed triple band antenna.
The antennas presented have multiband, broadband, and close proximity between frequencies. The omnidirectional antenna, with peak resonance at 1.861GHz, 2.476GHz, and 2.995GHz, respectively. The omnidirectional antenna’s design evolution phases are described to offer information for designing, optimising, and understanding the underlying radiation process. The Sierpinski fractal antenna's design features can be seen in the radiation patterns. The suggested Sierpinski-based hexagon shaped 2x1 array antennas with DGS show good performance, and the proposed novel microstrip patch array antenna may be employed in a variety of wireless communication applications.

CONFLICT OF INTEREST

The authors declare no conflict of interest

AUTHORS CONTRIBUTIONS

Jacob Abraham studied the existing literature and designed the antenna structure and contributed to the writing of the manuscript, drawn all of the figures. S. Kannadhasan compared the advantages of the proposed system the antenna performance, and contributed to the writing of the manuscript, drawn all of the figures. All authors had approved the final version

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