Diamond Shaped Microstrip Fractal Antennafor Biomedical Applications

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ABSTRACT:

In this paper, a diamond-shaped micro-strip patch antenna is created using fractal patterns. Industries include factories, the study of conductors, and the realm of medicine, where antenna were frequently utilised for imaging purposes. Different feeding techniques, including micro-strip feeding, inset feeding, and coaxial feeding, are used to simulate and compare the proposed antennas. Comparing these three feeding methods, the inset feeding antennafeeds better than other feeding methods. The created antenna is small in size of 20L*1.6W* 20H with FR4substrate. A variety of factors, such safeguarding patients, miniaturisation, biological compatibility, minimal power and energy consumption, limited frequencies in functioning, as performance must all be taken into attention to allow the implants antenna to function more reliably and constantly. The glass- reinforced epoxy laminate material FR-4 with a dielectric constant of 4.4 has been selected as the dielectric material for this method. In the design of implantable sensors, choosing the antenna is a difficult problem because it affects how well the entire implant performs. For implantable medical applications, we can choose Rogers5880 substrate. For the entire operational frequency range, the DS- MPA has a Voltage Standing Wave Ratio (VSWR) of 1.64 and a Return Loss (RL) of -23.01dB. HFSS is used to design and model the antenna and achieves good output response. It resonates at frequency ranges of 3.8, 5.6 and 8.2 GHz.

Keywords: Industrial, Scientific, and Medical (ISM), Biomedical applications, FR-4, VSWR, Return Loss,5G applications.

1. INTRODUCTION:

Today, different types and shapes of antenna are being developed using different substrate materials. An antenna is an electric device which converts electric energy into radio waves and vice versa. It is being used for radiating and receiving the radio waves. Micro-strip antenna plays a vital role in Wireless communication. MSA is a radio antenna which is small, less weight, and easy for manufacturing. Many industries needed a compact, miniaturized and affordable wireless devices. Micros trip antennas are developed using different substrate materials and different geometries based on the operating frequency.[10]There are various frequency bands for biomedical applications, including ISM (Industrial, Scientific, and Medical), which has a 2.4 GHz frequency band, MICS (Medical Implantable Communication Service), and Med Rad (Medical Device Radio band), whose frequency range is 401- 457 MHz. Popular in biomedicine is the implanted antenna, which can pick up bio-signals and send them to an outside device. It is used in medicine, healthcare, and the treatment of cancer. Both the doctor and the patient can benefit from the ability to self-monitor. The human body contains implantable antennas that are used to monitor things like temperature, blood pressure, and sugar levels. Fractal designs are used to create a diamond-shaped micro- strip patch antenna. For more effective analysis, fractal structure was used.[14]The term "fractal" describes a wide range of extremely asymmetrical curves or patterns that are reproducible at all scales. The functionality of the traditional antennas is improved by the employment of fractal structures. The fractal structures are derived using a variety of shapes, including square, rectangle, triangle, trapezoid, circle and oval. The proposed micros trip antenna is made by cutting a rhombus with a side length of 4 mm to get the diamond-shaped micros trip antenna. Tuning stubs are also employed in conjunction with the structures to enable broadband operation. The antenna's performance is influenced by the substrate's thickness, permittivity, and material.[2]

2. LITERATURE REVIEW:

In order to minimize the size of the radiation structure, a triangular MPA is created for automotive applications. In vehicular communications, it can be used to identify blind spot detection. With a 79% compactness, the proposed structure operates at a frequency of 5.88 GHz. The authors of this research have designed a rectangular MPA for use with Wi- Fi.[5]To make the physical structure smaller, self symmetry fractal patterns are used. The Sierpinski carpet fractal shapes are added to the ground portion of the MPA to create the DGS. It causes the antenna to operate in the 2.4 GHz frequency band and results in a size reduction of up to 32.9%.

The modified Koch-fractal structures in the ground portion of the MPA are used by the authors of this technique to achieve the desired miniaturization. The suggested design results in an improved BW and a practical reduction in physicalsize of up to 20.35%.[1]

The authors propose a compact fractal MPA for Long Term Evolution (LTE) application. The coplanar waveguide feed is included to minimize thedesign's physical dimensions and enhance BW.[4] The fractal patch's dimensions were changed to provide an RL of -23.45 dB, a VSWR of 1.14, and a BW of 375 MHz .

The authors of this strategy suggested an MPA design for communications with multiple functions. The ground is divided into H, L, and U-shaped slotsin the miniature design. The proposed structure is considerably smaller than the usual one as a result of the use of fractal structure. [8]The response range of the suggested antenna is from 1 GHz to 8 GHz. The structure's gain ranges from 2.1 to 3.87 dB, and its directivity is between 4.3 and 5.3dB.

The authors proposed a coaxially fed, circular MPA. This antenna is made to emit at a frequency of

5.12 GHz. This antenna's design and verification were done in the HFSS simulator. The working frequency of the proposed structure, which ranges from 5.17 to 5.32 GHz, is guaranteed to resonate at

5.248 GHz. RT/duroid with a constant of 2 was used as the substrate material for this antenna. An antenna's key performance indicators are evaluated and confirmed. [11]

The fractal structure on a 5.2 GHz rectangular MPA patch section was proposed by the creators of this suggested antenna. The antenna works in several frequency bands as a result of the fractal construction. The best RL, gain, and VSWR are achieved in the corresponding frequency bands. The HFSS simulator is utilized to design and verify the proposed antenna, and FR-4 has been selected as its dielectric medium.[12]

$\lambda/4$ impedance converter has been added to the design for the best impedance matching. The performance of the suggested structure has undergone several iterations, from which the secondone is constructed and evaluated. The addition of fractal design results in a size decrease of 43.7% when compared to the traditional one. The antenna's operating frequency is 2.14 GHz, and the RL at that frequency has been measured to be -24dB.[13]

3.FRACTAL GEOMETRY ANTENNA:

Fractals were first defined by Benoit Mandelbrot in 1975 as a means of classifying structures of non-integer size. Fractal geometry is a very good solution to reduce the size of the antenna. Fractal antennas have interesting features due to their geometry.[3]Antennas with intriguing features like multi-band operation and miniaturization can be realized because of the special traits of fractals including self-similarity and space-filling properties.

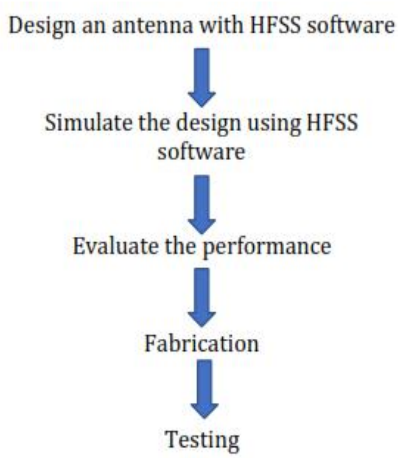
4. DESIGN OF DIAMOND SHAPED MICRO STRIP FRACTAL ANTENNA:

The suggested antenna was created and tested using the High Frequency Structure Simulator(HFSS). The dielectric material FR-4 with a width of 1.6 mm was chosen for the proposed DS-MPA design. The proposed DS-MPA's fundamental design is a 20 mm long, ground-mounted patch. 20 Because of the unique characteristics of fractals, including as self-similarity and space-filling qualities, it is possible to create antennas with exciting features like multi-band operation and miniaturization. It uses the transmission feeding technique. Every iteration uses the same 10 mm feed length and placement. The suggested antenna uses iterative approaches that were calculated through a computer or mathematicalprocedure.[15]The DS-MPA design is created by cutting a rhombus with a side length of 4 mm in order to achieve the proposed antenna miniaturization in this case.

PARAMETERS	VALUES
Substrate material	FR 4
Substrate height	20mm
Substrate length	20mm
Substrate width	1.6mm
Dielectric constant(FR4)	4.4
VSWR	1.6
Feeding method	Inset feeding
Gain	3.5dB
Max Power	50W
Connector	SMA
Loss tangent	0.001
Impedence	50 ohms

The square geometry can be stretched to create a fractal structure in the middle square fractalslot, which reduces the size of the structure. Use an iterative process with a 10 mm feed length and the same feed position for all iterations. Iteration uses frequencies between 2GHz and 8GHz. This paper's main contribution is the design of a diamond fractal antenna for improved performance in terms of size reduction and return loss measurements.[6]Thesecond way results in the antenna structure's compactness, which is a crucial quality for the biological application. These fractal grooves measure 4 mm, 2 mm, and 1 mm on either side. The geometry of the fourth iteration, which has square fractals with lengths of 1 mm, is a rhombus with sidesof 4 mm each. The proposed antenna uses 45% less space than the current design while maintaining the same resonant frequency. Therefore, it is claimed that at 5.9 GHz, the size of the proposed antenna design has effectively been reduced to 45%. Low dielectric constant and an increase in the fringing field at the patch periphery are caused by a thick substrate, which also increases the radiatedpower.[16]

5. DESIGN FLOW:



6. ITERATION PROCESS:

The iteration method calls for repeatedly performinga step a predetermined number of times. The square-cutting process is repeated to produce the suggested antenna design.Four iterations were carried out for this project in order to boost the antenna parameters.

1. **First iteration**: Cutting square geometry with4 mm-long sides in the center of the square patch, asshown in fig. 1, yields a diamond-shaped fractalantenna. VSWR of 1.067 and return loss of -33.97 dB.

2. **Second iteration:** The outcomes of the second iteration of the suggested fractal antenna are shown in Figure 2. One square fractal slot with square geometry, each with a side length of 4 mm, is taken in the center, and four additional slots, each with a side length of 2 mm, are taken on each of the four corners of the central slot. At the resonant frequency, a VSWR of 1.04 and a return loss of -34.01 are available.

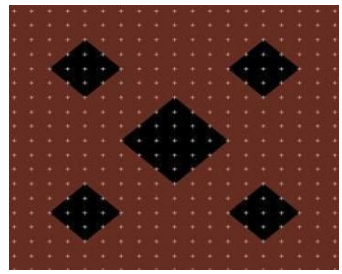


Fig 1.1:Iteration 1

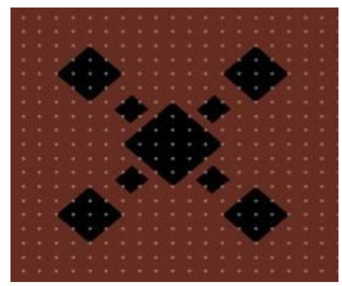


Fig 1.2: Iteration 2

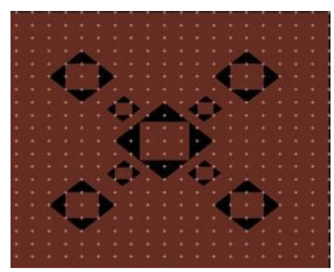


Fig 1.3: Iteration 3

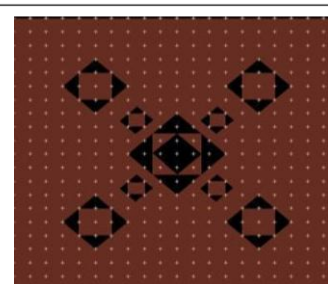


Fig 1.4: Iteration 4

3. **Third iteration:** In this single center square fractal slot, square geometry is deployed, and smaller versions of the same structured fractal are taken on each of the four corners of the central slot. These fractal slots, which are depicted in figure 3, have dimensions of L1=4mm, L2=2mm, and L3=1mm oneach side.

4. **Fourth iteration:** In the fourth iteration, a diamond-shaped fractal with equal sides and a 1 mm dimension is used in a rhombus geometry with 4 mm-long sides on each side. There are four identical slots with a 2 mm length in each corner away from the center. For the specified resonant frequency, a VSWR of 1.64 and a reflection attenuation of -23.01 are achieved in this instance. The square geometry can be stretched to obtain a fractal structure in the center square fractal slot, which results in a smaller structure.[9]These fractal grooves are 4mm, 2mm, and 1mm wide on both sides.

Hence, it is stated that the size of the proposed antenna design has been effectively reduced to 45% at 5.9 GHz.When compared to the existing design, the proposed antenna consumes 45% less area with the same resonant frequency. The frequency range used for iteration is 2GHz to 8GHz.The return loss is increased from -20.89 dB to 29.79 dB, radiation efficiency is improved from 97.66% to 100%, and compactness of 9.83% is gained over the conventional antenna by inserting a diamond-shaped slot with ideal geometries at a suitable place. As a result, it is claimed that the DS- MPA design's size has been efficiently decreased to 45% at 5.9 GHz.[7]

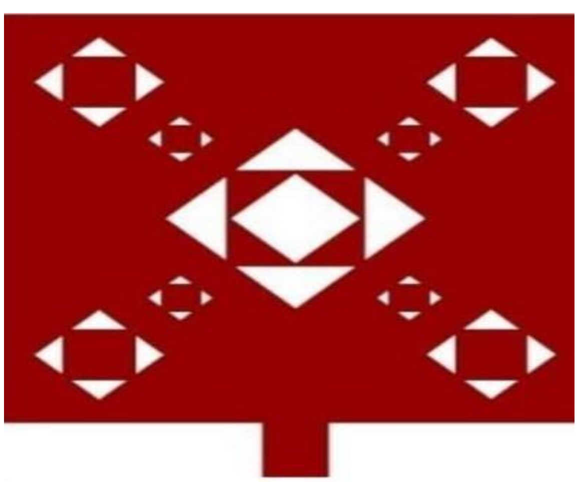


Fig 2.1: SUBSTRATE

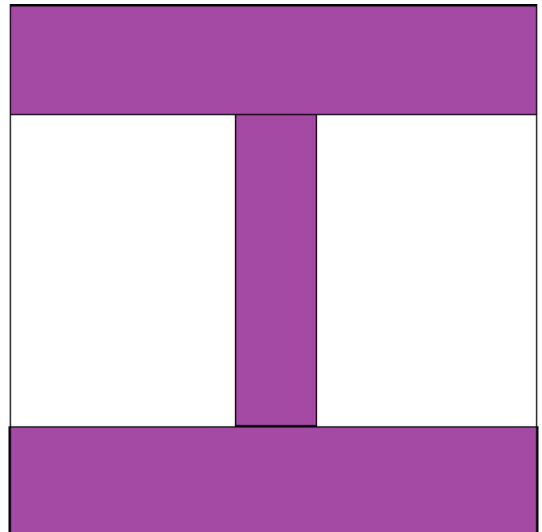


Fig 2.2: GROUND

7. RESULTS OF DIAMOND SHAPED MICRO STRIP FRACTAL ANTENNA:

The developed biomedical implantable patch antenna is tested in space and constructed on a Roger RT5880 substrate with a 0.254mm thickness. The implanted antenna's S11 is measured using a vector network analyzer (VNA).In the case of the simulated results, the planned antenna covers the bandwidths from 800 MHz to 1000 MHz (200 MHz) at 915 MHz, however in the case of the measurements, the antenna covers the bandwidths from 795 MHz to 998 MHz (203 MHz) at 915 MHz.

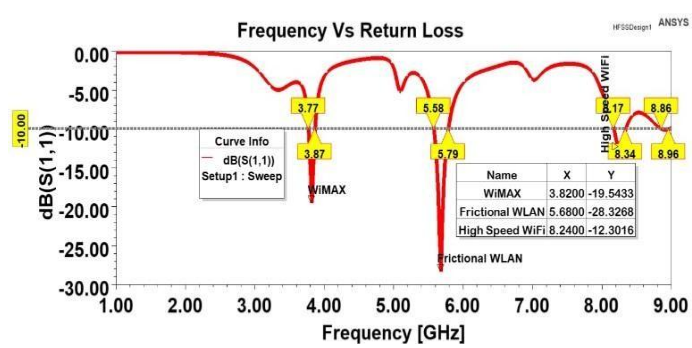


Fig 3: Front -to- Back ratio of DS- MPA

The suggested DS-MPA's performance results have been evaluated using factors like VSWR, Gain, reflection attenuation, and operating frequency. This suggested antenna was constructed, tested, and figures a and b serve as proof of the gain and 3D gain plot of the DS-MPA design for values ranging from 0° to 180° and -200° to 200°, respectively.

The Gain is increased to 5dB in this instance, demonstrating that the DS-MPA provides the best Gain. The measured Gain of 4.3 dB is shown in Figure a.

The gain in a particular direction is described in terms of dB, and this front-to-back ratio is used to compare such gains. The front-to-back ratio of the proposed structure's mode 1 DS-MPA is plotted in

3.50 dB at a frequency of 3.82 GHz. At 3.28 GHz, the ratio in mode 2 is depicted at 5.68 dB of ideal gain.

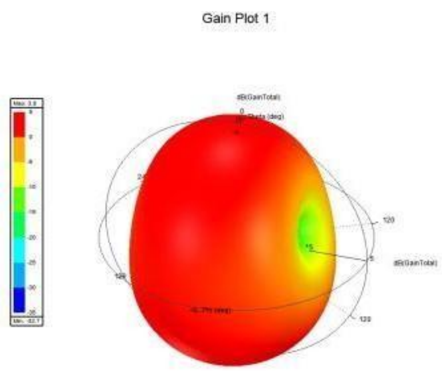


Fig 4: The gain of DS- MPA antenna

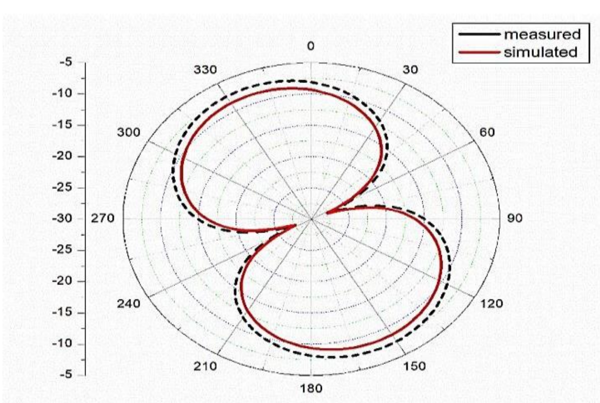


Fig 5: 3D gain plot of DS-MPUantenna

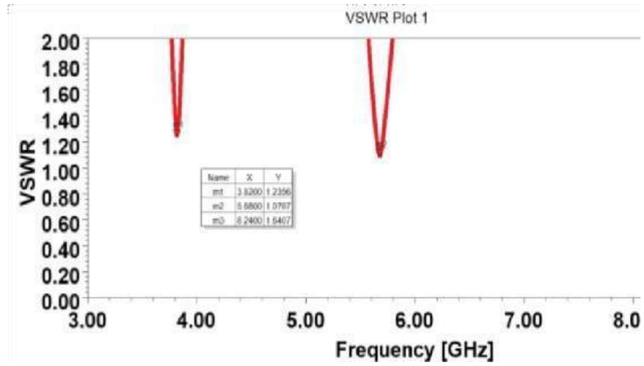


Fig 6: VSWR of the DS-MPU

Gain of 4.3 dB is displayed in Figure a. The VSWR of the DSMPU antenna is shown in Figure C. Each band has a permissible VSWR value, which ranges from 1.23 for 3.82 GHz to 1.07 for

5.68 GHz to 1.64 for 8.24 GHz. The DS-MPU's output has a value close to 1, which verifies that the whole input signal is intended to be radiated with very little reflection.

8. CONCLUSION:

The fractal structure can minimize the patch size without impacting the antenna performance, such as reflection attenuation, radiation pattern, or VSWR, according to the results of the suggested DS-MPA. The SAR values are found to be 8.1W/kg inside the skin. The VSWR, RL, and Gain values forthe DS-MPA are 1.65, -23.01, 3.51, and 3.87, 5.2,

5.8, and 6.9 GHz, respectively. The antenna performance was investigated with body and without body: the results show negligible deterioration. The various design stages demonstrate the increases in bandwidth and reflection coefficient. The iterations I, II, III, and IV unmistakably demonstrate how the self likeness and symmetry modify the reflection attenuation. This antenna is miniaturized and an idealapplicant for in-body biomedical application.

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