Hexagonal Microstrip Patch Antenna with Defective Ground Structure for Wideband Applications

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Abstract: The complexity and variety of modern wireless communication devices have resulted in an increase in the need for high-performance and wideband antennas. This research proposes an innovative approach for enhancing the bandwidth of hexagonal patch antennas using a microstrip line feed and the Defected Ground Structure (DGS) technology. The area of the hexagonal patch with defective ground structure wideband antenna is 32×24 mm^2. The wideband ability and compact dimensions of the hexagonal patch antenna make it attractive. The DGS approach is used to change the resonant behavior of the antenna, resulting in a significant bandwidth enhancement. The simulation results demonstrate that combining DGS with the microstrip feed leads to significant enhancements in gain, radiation characteristics, and impedance bandwidth. The approach has potential for a range of wireless communication applications that demand wide performance in a compact antenna design.
Keywords: DGS, Gain, Impedance Bandwidth, Resonator, Wideband.

1. Introduction:

A literature research on wideband hexagonal patch antennas reveals a rising demand for the development of miniature, effective wideband antennas for uses in a number of wireless communication applications. The radiating patch was used when combined with Defected Ground Structure, Microstrip Line Feed Techniques, Metamaterial, and Fractal Approaches to enhance bandwidth. The hexagonal patch's particular shape, according to researchers, may enable wider impedance bandwidths than regular shapes.DGS technologies like as slots and meander lines have been utilized to change the antenna's resonance frequency, resulting in significant bandwidth improvements.Feedline design advances such as tapered and stepped feeds have been investigated to increase bandwidth performance. To efficiently cover a wide range of frequency bands, dual-band and tri-band hexagonal patch antennas have been developed. The Koch snowflake and other fractal designs have been utilized to increase the bandwidth of hexagonal patch antennas.

An equilateral triangular patch receives a monopolar patch antenna with the addition of a V-shaped slot. The symmetrical triangular radiating patch antenna resonated in three separate modes when short pins were employed. From 4.82 GHz to 6.67 GHz, the monopole antenna has an impedance bandwidth of 1.85 GHz. The resonating frequency of the monopolar patch antenna has a gain of 5dBi and suited for indoor WLAN [1] base station antennas.

The resonators were used to increase the impedance bandwidth of the optically transparent meshed patch antenna, and it is solar cell compatible. And the optically transparent meshed patch antenna [2] worked within an operating frequency bandwidth from 2.413 GHz to 2.478 GHz, with stable radiation characteristics.

The wideband patch antenna array was created in order to reduce mutual coupling with parasitic patch elements [3]. The antenna's impedance bandwidth ranged from 3.35GHz to 3.95GHz and was 0.65GHz. The antenna's cross polarization was less than -38dB in the broadside direction. In the operational frequency band, the antenna's measured gain varies as of 12.6 dBi to 13.6 dBi. With the use of two coupling networks, the antenna was able to reach an impedance bandwidth without requiring any changes to its shape. Dielectric resonator antenna fed by E-shaped metal strip circularly polarized antenna [4] was used for the impedance bandwidth enhancement. An impedance bandwidth covering 0.81 GHz, from 3.59 GHz to 4.4 GHz, was successfully accomplished by the antenna. the circularly polarized antenna simulated results agree with the measurement results. And it was used for WiMAX applications.

The improved impedance bandwidth can be achieved by using a tri-modal broadside patch antenna [5]. The antenna was capable of operating in the 3 GHz band and is appropriate for 5G communications. Over the operational frequency band, the broadside tri modal patch antenna radiation characteristics remained stable.With the use of a dielectric slab superstrate [6], the gain of the dual polarized patch array antenna was improved. The measured gains for the two polarizations were 18.3 and 18.4 dBi. With 116% and 113% respectively for aperture efficiency.

Multiple input and output antenna with meta-surface had been developed [7]. The antenna size was compact, and the decoupling structure, which comprises of strips and slots on the ground plane and meta-surface, offers good isolation. The antenna demonstrated exceptional diversity performance, strong isolation of more than 32 dB, a low envelope correlation coefficient, and a 9.99 diversity gain.

In this paper, the hexagonal defective ground constructed antenna improves the antenna's impedance bandwidth while retaining the antenna's gain. To improve an impedance bandwidth hexagonal patch with defective ground structure and microstrip line feed line is implemented. The size of the antenna is 32mm × 24mm and the FR4 substrate height 1.6 mm. The initially developed hexagonal patch antenna is working at 5.5 GHz frequency and gain of 6 dBi with the bandwidth of 0.5 GHz. The hexagonal patch antenna's impedance bandwidth has been increased to 5.5 GHz by using the Defective Ground Structure approach, allowing it to work well over the frequency range of 3 GHz to 8.5 GHz. The entire operating frequency of the proposed compact hexagonal wideband antenna radiation characteristics is stable and also it less effect on the antenna gain.

2. The construction of the Wideband Hexagonal Patch Antenna:

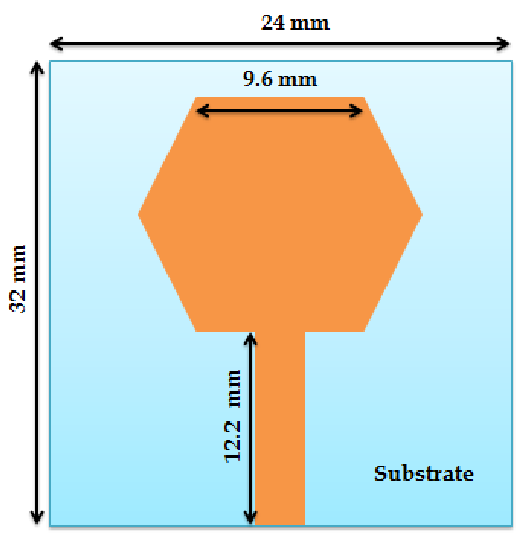

Fig 1 (a): The Front View of the initial Hexagonal Patch Antenna

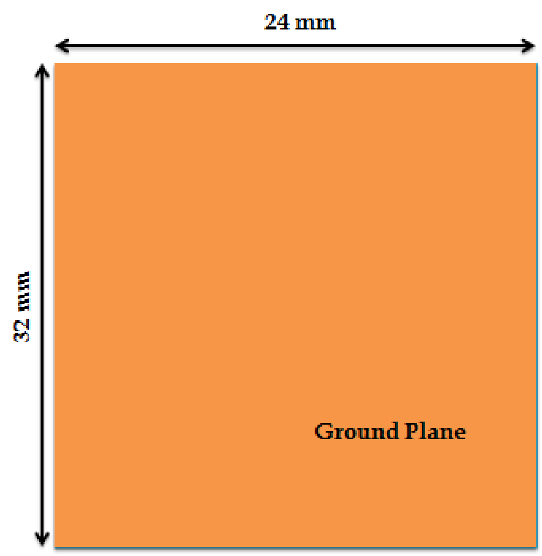

Fig 1(b): The Back View of an initial Hexagonal Patch Antenna

The proposed initial Hexagonal patch antenna is designed to operate at 5.5 GHz frequency. The Figure 1. (a) and (b) depicts the front and back views of the proposed antenna with perfect matching between the radiating element with the microstrip line and ground Plane. In this initial design the size of the proposed antenna ground plane is 32mm × 24mm. The side length of the Hexagonal is “a”=9.6mm. Perimeter, Apothem and Area of the hexagonal patch antenna are 57.6 mm, 8.314 mm and 126.72 mm^2 correspondingly. The initial proposed antenna is exhibits the linear polarization.

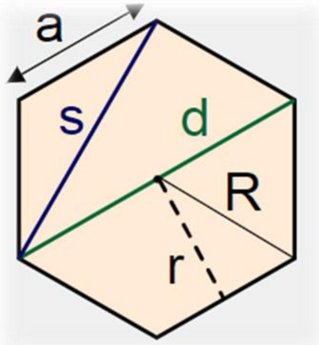

Fig 1(c): The Structure of the Hexagonal

The figure 1. (c) depicts the structure of the proposed patch antenna. From the figure 1. (c) "a" is the length of the hexagonal patch. The parameters "s" and "d" shows short and long diagonals of the patch antenna. The "r" and "R" are the Apothem and Circumcircle Radius of the Hexagonal.
The resonating frequency of an initial Hexagonal Patch antenna is 5.5 GHz. The formula for to calculate the Resonating frequency is shown in equation (1)

$$f_r = \frac{c}{2a\sqrt{3}} \frac{1}{\sqrt{\varepsilon_{eff}}} \quad ....(1)$$

Where

a= length of the Hexagonal Patch side
c= Speed of Light

$\varepsilon_{eff} = Effective\ Dielectric\ Constant$

3. Results and Discussion:

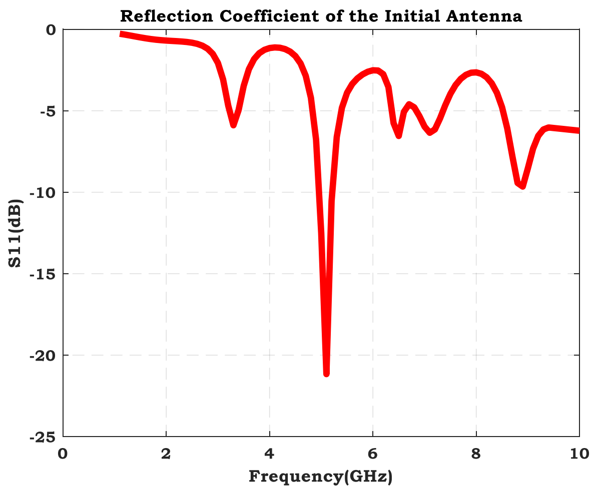

Fig 2: The Reflection Coefficient of an initial Hexagonal Patch Antenna

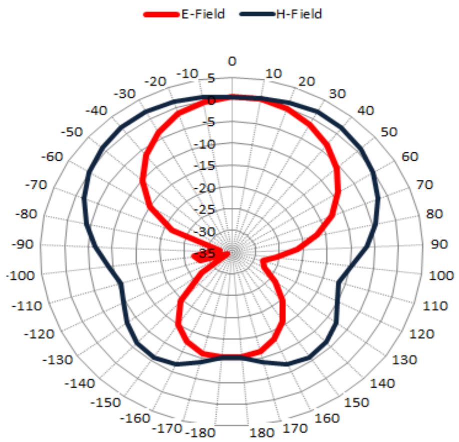

Fig 3: Radiation Pattern of an initial Hexagonal Patch Antenna

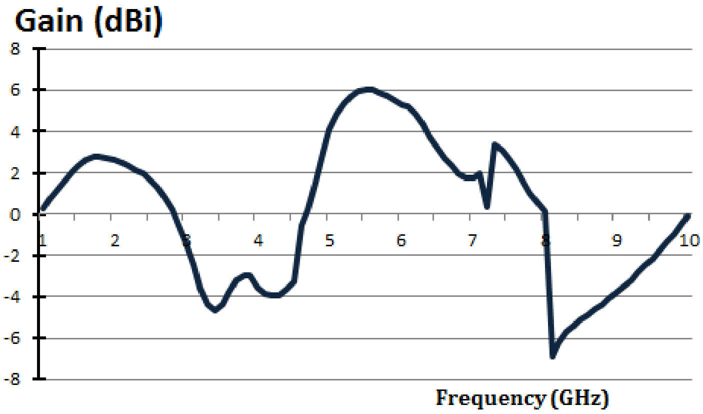

Fig 4: The Gain (dBi) of the initial an Hexagonal Patch Antenna

The proposed antenna reflection coefficient is presented in figure 2. The impedance bandwidth of an initial proposed antenna is 0.5GHz operating frequency from 5.1 GHz to 5.6 GHz. For the entire frequency of operation the VSWR of an antenna is less than 2. An impedance matching between the Hexagonal patch antenna and microstrip line, the presence of standing waves is very less in the transmission line. The principal plane of the hexagonal patch antenna has stable radiation patterns over the frequencies from 5.1 GHz to 5.6 GHz. The Figure 3 depicts the Electric-plane and H-Plane radiation characteristics of an antenna.

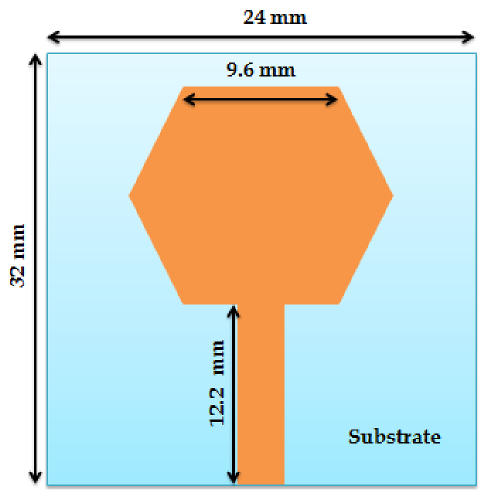

Fig 5(a): The Front View of the Proposed Wideband Antenna

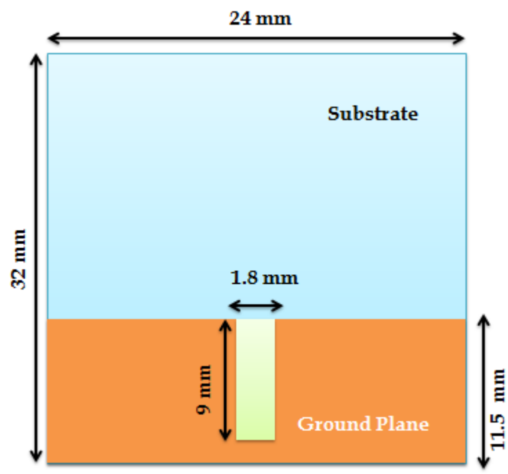

Fig. 5(b): The Back View of the Proposed Wideband Antenna

The figure 4 shows the gain characteristics of an initial Hexagonal patch antenna. The maximum gain of the antenna is 6 dBi achieved at 5.5 GHz frequency.

The proposed wideband Hexagonal patch antenna is used to operate in wide band applications. The Figure 5 (a) and 5 (b) shows the front and back views of the proposed antenna with perfect matching among the radiating patch with the microstrip line.

DGS allows gaps, patches, and other discontinuities in the ground plane. These substances generate parasitic structures that interact with electromagnetic waves. By carefully arranging the shape and dimensions of these defects, certain resonances may be suppressed. DGS can drastically change the effective dielectric constant of the substrate within an antenna element. The dielectric constant influences the phase velocity of electromagnetic waves. By modifying the dielectric properties, DGS modifies the phase velocity of waves traveling through the substrate. This contributes to the decrease of impedance mismatches and an increase of bandwidth. The DGS works primarily as a distributed capacitive or inductive loading, altering the electrical length of the antenna. Surface wave losses can lower the bandwidth of an antenna. DGS structures can help to mitigate these losses.

This antenna design employs DGS techniques such as impedance matching networks and careful antenna geometry design to decrease reflection coefficient and control the phase of the reflection coefficient within the desired frequency range, resulting in wideband operation with strong impedance matching.

This guarantees that the antenna is effective over the designated frequency range and well-matched. In order to reduce reflections and retain high performance throughout a large frequency range, rigorous design and impedance matching techniques are often required to achieve a low VSWR for a wideband antenna.

A wideband antenna's radiation pattern describes the many directions in three-dimensional space where the antenna transmits electromagnetic energy. It offers important details regarding the gain and directivity of the antenna throughout a variety of frequencies within its bandwidth, as well as other directional properties.

It means that they radiate energy equally in all horizontal directions, perpendicular to the antenna's axis. These antennas are widely used in applications that demand coverage in all directions.

When compared to an isotropic radiator, which is a hypothetical point source radiating equally in all directions; the gain of the antenna measures how well the antenna concentrates its energy in a specific direction. as wideband antennas, gain is frequently stated as dBi (decibels relative to isotropic) and may change with frequency.

A wideband hexagonal patch antenna's simulation and measurement results must be compared with DGS as a crucial stage in the validation process to make sure the antenna will function as intended in practical applications. To improve the design and performance of the antenna, any inconsistencies should be thoroughly investigated and modified.

It can be difficult to balance bandwidth improvement and gain in a wideband antenna design since there is frequently a trade-off between these two factors. Wideband antennas are made to work with a variety of frequencies. However it can be challenging to simultaneously achieve both a wide bandwidth and a high gain.

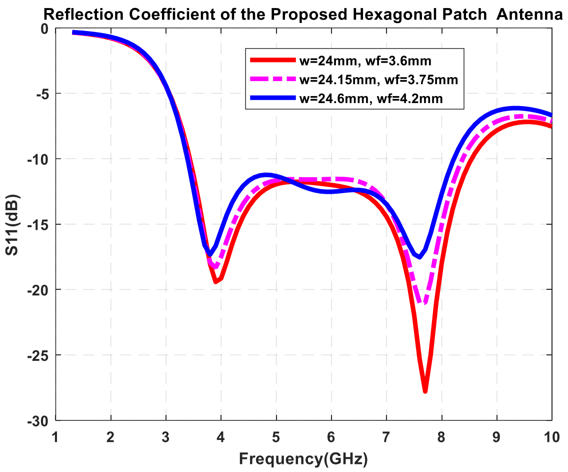

Fig.6(a): The Reflection Coefficient of the Proposed Wideband Antenna

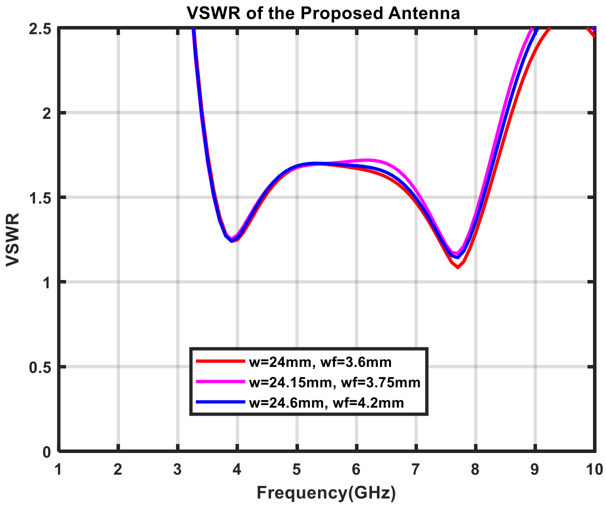

Fig.6(b): The VSWR of the proposed Wideband Antenna

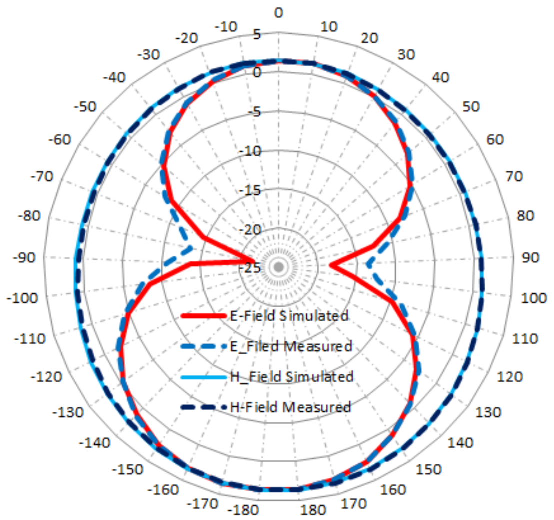

Fig.7: The Radiation Pattern of the Proposed Wideband Antenna

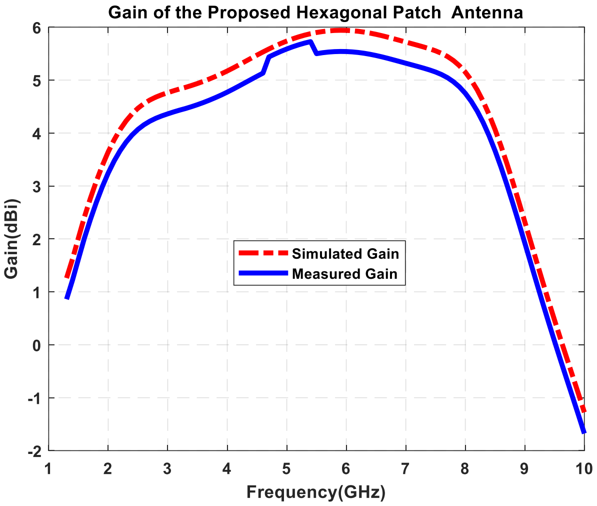

Fig.8: The Measured and Simulated Gain of the Proposed Wideband Antenna

Table1: Comparison between Existing antennas with Proposed Antenna.

S.No	Reference	Size (mm3)	Technique	Bandwidth (GHz)	Maximum Gain (dBi)
1	[1]	21.5×32×3	Monopolar with V-shaped slot	1.85	6.5
2	[2]	30×30×1	Three Meshed patches with Proximity Coupling	0.065	7.2
3	[3]	14.2×14.2×0.4	Multiple patches	0.60	13.6
4	[5]	48×48×1.1	Circular Ground plane	0.69	7.5
5	Proposed Antenna	24×32×1.6	DGS with Slot	5.5	6

Table 1 depicts the contrast between existing antennas with the hexagonal patch antenna. In this Defective Ground Structure technique is implemented along with the slot in the ground plane. The proposed antenna achieved an impedance bandwidth of 5.5 GHz with a maximum gain of 6 dBi. The operating frequency of an antenna is 5.5 GHz. The impedance bandwidth of the proposed hexagonal patch antenna reflection coefficient and vswr are shown in figure figure 6. (a) and 6.(b).

Fig.9(a): The Front View of the fabricated Proposed Wideband Antenna

Fig 9(b): The Back View of the fabricated Proposed Wideband Antenna

Proposed antenna measured and simulated radiation characteristics and gain are shown in figures 7 and 8. The fabricated proposed antenna with defective ground structure front and back views is shown in figure 9.

4. Conclusion

The integration of Defective Ground Structure into the hexagonal patch antenna has shown to be an effective technique to accomplish wideband performance. This study not only enhanced our comprehension of antenna design, but it also has great potential for a variety of practical applications in current communication systems. The antenna effectively covers the 5.5 GHz bandwidth with a gain of 6 dBi which remained consistent throughout the operational frequency. The proposed Wideband hexagonal patch antennas with DGS can be used in mobile phones, tablets, laptops, and other portable communication devices. Whereas wideband hexagonal patch antennas with DGS have several benefits such as wide bandwidth and compact size. The impedance matching and resonance properties of the antenna can be changed by the presence of that surround metallic objects, conductive structures, or even the user's hand. The operating frequency of the antenna may change as a result, or its effectiveness could decrease. Wideband hexagonal patch antennas with DGS capabilities are created and optimized for specific operating circumstances. When utilized in actual environments, these antennas could interact with nearby objects or materials and lose some of their efficiency.

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