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RECONFIGURABLE OCTAGON SPLIT RING RESONATOR MICROSTRIP PATCH ANTENNA

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Abstract
This paper presents the design and analysis of a reconfigurable octagon split ring resonator microstrip patch antenna. The objective of this work is to fulfill the demand for multiband applications in modern wireless communication systems. The antenna structure consists of an octagon-shaped split ring resonator integrated as a microstrip patch, with a patch dimension of 11.6×11.6 mm². By strategically tuning the geometric and feed location, the antenna is capable of operating at two distinct frequency bands within the range of 2.4 GHz and 5.2 GHz, facilitating frequencies reconfiguration within a single antenna unit. Design parameters such as Voltage Standing Wave Ratio (VSWR), return loss (S11), bandwidth, and gain are investigated using High Frequency Structure Simulator (HFSS). The proposed antenna offers considerable gain and bandwidth suitable for multiband wireless applications.
Keywords — Reconfigurable antenna, HFSS, Return loss, VSWR, Radiation Pattern

I. INTRODUCTION

The antenna is a metallic structure that receives or transmits radio electromagnetic waves. Antennas come in all shapes and sizes from the smaller ones that can be found on a roof to watch TV and can be as big as those that receive or transmit signals from satellites that are miles away through space. Reconfigurable antennas, like the octagon split ring resonator (SRR) microstrip patch antenna, are prized for their adaptability to changing communication needs, a key requirement in modern wireless systems. The octagon shape of SRRs offers advantages such as improved bandwidth and reduced size. These antennas, featuring a microstrip patch with embedded octagon-shaped SRRs, allow for tuning the operating frequency and allows polarization diversity. Reconfigurability is typically achieved using varactor diodes or other tuning mechanisms integrated into the SRRs, enabling dynamic adjustments in frequency, polarization, and radiation characteristics. This versatility makes reconfigurable octagon SRR microstrip patch antennas ideal for applications requiring adaptability and high performance, such as cognitive radio, satellite communication, and wireless sensor networks. The reconfiguration of an antenna is achieved by altering the radiated fields of the antenna’s effective aperture. It is based on a purposeful rearrangement of the antenna currents or a reconfiguration of the antenna’s radiating edges. This redistribution of properties results in a change in the antenna’s functionalities. Such change of functions allows users to propose reconfigurable antennas for various wireless communication platforms. The resonant frequency of an octagonal patch antenna depends on its width dimensions and the dielectric constant of the substrate.

The Microstrip patch antennas are widely used in Radar applications, Biosensors and in general Communication like WLAN, MIMO, WI-FI, Bluetooth etc. This paper proposes a reconfigurable octagon split ring resonator microstrip patch antenna, designed to operate at 2.4 GHz and 5.2 GHz frequencies to make it suitable for ISM band of operation. The section-2 describes the design equations that are used for the calculations. And section 3 describes the 3D modeling of the antenna design using HFSS software. The section 4 presents the discussion on the comparison of the results for the simulated and fabricated model.

II. LITERATURE SURVEY

In the 1950s, there was consideration of using microstrip structures to transmit electromagnetic waves. Deschamps was the one who created the first antenna [1]. Munson followed up with a formal introduction of it as planar antennas on missiles. When scientists discovered that over half of the power in a microstrip radiator escapes as radiation in the early 1970s. Consequently, microstrip antennas were characterized as a microstrip emitting patch with a significant radiation loss. Subsequent research demonstrated that the discontinuities at either end of the microstrip transmission line were the source of this radiation process. Microstrip antennas had a number of drawbacks when they were first developed, including low power, low efficiency, high Q, poor polarization purity, limited bandwidth, and poor scan capacity in spite majority research works do accept their simplicity in design, flexibility and adaptive features while designing fractal structures and low profile making it suitable to be a suitable candidate for developing onboard antennas for airborne systems too.

Reconfigurable octagon split ring resonator (SRR) microstrip patch antennas reveals a growing interest in their application in modern wireless communication systems. The reconfigurability of these antennas, which allows for adjustments in frequency, polarization, and radiation patterns, is particularly advantageous for meeting the diverse requirements of different communication standards and environments. The use of SRRs enhances the performance of microstrip patch antennas by enabling tuning of the operating frequency and achieving polarization diversity. The octagon geometry of the SRRs offers benefits such as improved bandwidth and reduced size compared to traditional circular or square shapes. Various reconfigurability techniques, including varactor diodes, MEMS switches, liquid crystals, and RF/microwave switches, have been explored to achieve the desired antenna characteristics. Recent research has focused on novel designs, fabrication techniques, and performance improvements of these antennas. Simulation and measurement results demonstrate the effectiveness of reconfigurable octagon SRR microstrip patch antennas in terms of frequency tuning, polarization diversity, and radiation efficiency. Challenges remain in terms of complexity, power consumption, and integration, suggesting the need for further research to address these issues and explore new opportunities for advancement in the field.As per [7] The substrate material plays critical job deciding the size and transfer speed of a receiving wire. Expanding the dielectric consistent diminishes the size yet brings down the data transfer capacity and effectiveness of the receiving wire while diminishing the dielectric consistent expands the data transfer capacity however with an expansion in size

III. Design Equations & Considerations

This paper proposes the design of the antenna model with the following design specifications as substrate is FR4 epoxy with a dielectric constant of 4.4. The length of radiating patch is 28.30 mm and width is 38.04mm. The Length (L) and width (W) values are obtained using the following standard design equations (1, 4)

A. *Operating frequency (f_0)*

The operating frequency of the antenna is very important factor. The ISM frequency band is 2400MHz to 2483.5MHz, which is used for Bluetooth, WLAN and other applications. Hence, the resonant frequency selected for design is 2.4 GHz.

B. *Dielectric constant of a substrate (ε_r / ε_{reff})*

The dielectric material chosen for configuration is FR4 epoxy having dielectric constant of 4.4. A substrate having high dielectric constant ought to be chosen on The grounds that higher the dielectric constant and more modest the elements of the receiving wire. Because of Lower value of dielectric constant and less loss tangent offer wider bandwidth and directivity.

Table -1 Various Materials and dielectric constant

S. No	Substrate	ε_r value
1	PTFE	2.1
2	Quartz glass	3.7
3	Fr4_epoxy	4.4

C. *Equations*

By using below equations, parameters of the patch are calculated:

Patch Width:

$$W = \frac{C}{2f_0\sqrt{\frac{\varepsilon_r+1}{2}}} \quad (1)$$

Where, C is the Velocity of light $(3\times 10^8\, m/sec)$. f_o is resonant frequency in GHz. ε_r is dielectric constant for the substrate Fr4.

By substituting f_0, ε_r,C values in above equation, width of the patch is 38.03mm.

Effective dielectric constant:

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{\frac{-1}{2}} \quad (2)$$

Where, h is height or thickness of the substrate given as 1.6 mm. Substituting ε_r=4.4, W=38.03mm, h=1.6mm obtained ε_{reff}=4.3996mm.

Extended length of patch due to fringing field:

$$\Delta L = 0.412\times h\times \frac{(\varepsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)} \quad (3)$$

By substituting ε_{reff}=4.3996mm, W=38.03mm, h=1.6mm the value of ΔL=0.748mm.

Length of the patch:

$$L = \frac{C}{2f_0\sqrt{\varepsilon_{reff}}} - 2\Delta L \quad (4)$$

By substitutingΔL=0.748mm, f_0 =2.4 GHz, ε_{reff} =4.3966mm, the length of the patch L=28.30mm.

Effective length of the patch:

$$L_{eff} = L + 2\Delta L \quad (5)$$

By substituting L=28.30mm, ΔL=0.748mm, value of L_{eff} =29.796mm

Length of the substrate:

$$L_s = L + 6h \quad (6)$$

By substituting L=28.30mm, h=1.6mm the value of L_s=37.9mm

Width of the substrate:

$$W_s = W_p + 6h$$

Octagon Side Length (S): The side length of the octagon can be calculated based on the area of the patch using the formula for the area of an octagon:

$$S=\frac{Ap}{2(1+\sqrt{2})}$$

Width of the Microstrip Feed Line (Wf)**:** The width of the microstrip feed line can be calculated using the standard formulas for microstrip lines, considering the characteristic impedance required for your design.

Octagon Circumscribed Circle Radius (r): The radius of the circumscribed circle around the octagon can be calculated as:

$$r=R\times \sqrt{2+\sqrt{2}}$$

By using above equations, the following antenna model is Designed

Figure1 shows the designed Antenna model

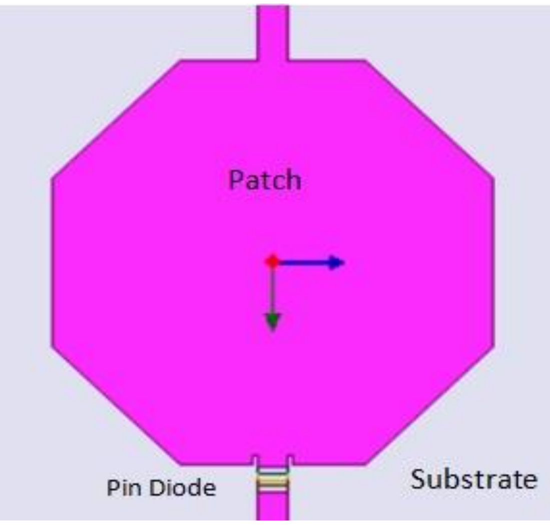

Figure-1

IV. RESULTS AND DISCUSSION

Considering the design parameters of above Table and resonating frequency as 2.4 GHz and 5 GHz the simulation results are obtained from HFSS software.

A. *Return Loss*

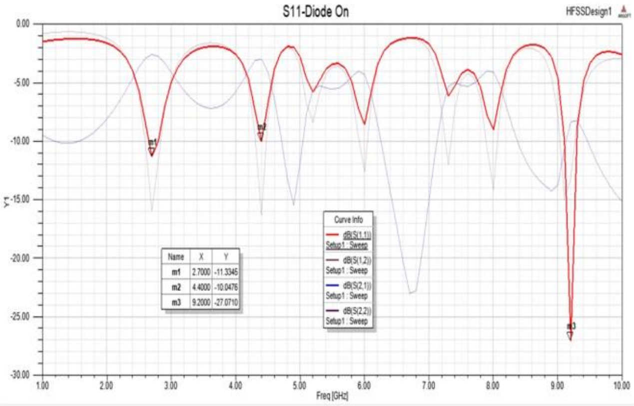

Figure 2 Return Loss when Diode is ON

Figure 2 shows the reflection coefficient in dB refrains recurrence of octagonal microstrip patch antenna at 2.7 GHz and 4.4 GHz recurrence reproduced Microstrip Fix Radio wire alone displays reflection coefficient of -11.3345 dB and -10.0476 dB Model is designed. The return loss may change, depending on the new frequency configuration. The antenna should be designed to maintain a low return loss across its reconfigured frequency bands.

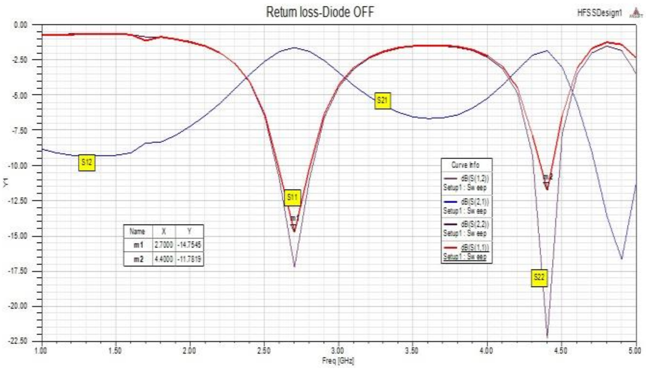

Figure 3 Return Loss when Diode is OFF

Figure 3 shows the reflection coefficient in dB refrains recurrence of octagonal microstrip patch antenna at 2.7 GHz and 4.4 GHz recurrence reproduced Microstrip Fix Radio wire alone displays reflection coefficient of -14.7545 and -11.7819dB Model is designed by using HFSS. The return loss will be optimized for the default frequency configuration, ensuring good impedance matching and minimal power reflection.

By using the HFSS software results are more sophisticated. May be the mesh structure and computational parameters varied. This gives the clear understanding about using the HFSS software. The return loss indicates how much power is reflected back to the source. A lower return loss value is desired, indicating better matching between the antenna and the transmission line.

B. *VSWR*

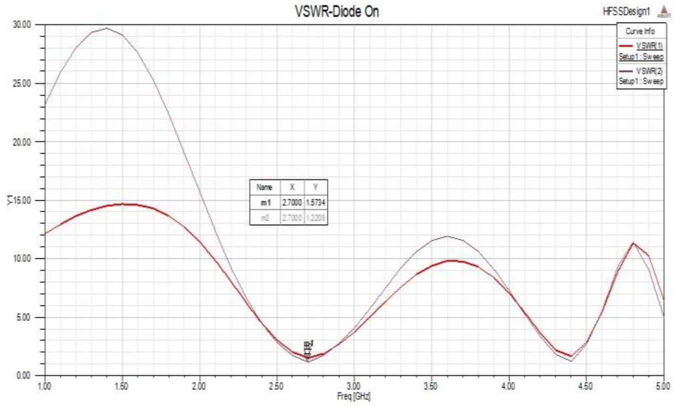

Figure 4: VSWR when Diode is ON

Recreation consequences of VSWR are acquired by utilizing HFSS. Figure 4 shows chart of VSWR stanzas recurrence of octagonal microstrip patch antenna. At 2.7 GHz and recurrence mimicked octagonal microstrip patch antenna alone shows the VSWR of 1.5734. The VSWR may change with the new frequency configuration but should remain within acceptable limits for efficient power transfer.

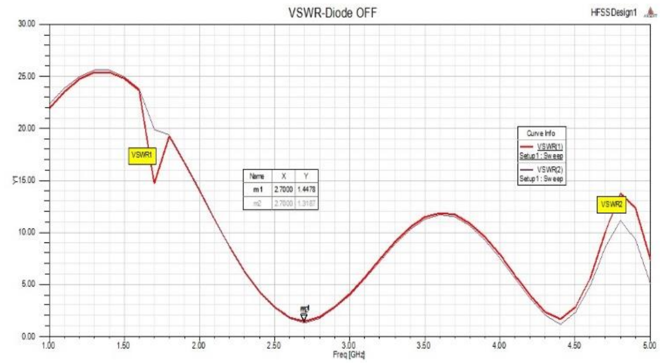

Figure 5: VSWR when Diode is OFF

Figure 5 shows chart of VSWR stanzas recurrence of octagonal microstrip patch antenna. At 2.7 GHz recurrence mimicked octagonal microstrip patch antenna alone shows the VSWR of 1.4478. The VSWR will be low, indicating efficient power transfer and minimal reflections.

VSWR is another measure of how well the antenna is matched to the transmission line. It is the ratio of the maximum voltage to the minimum voltage along the transmission line. A VSWR close to 1 indicates a good match, while higher values indicate poor matching. For most applications, a VSWR of less than 2 is acceptable.

c. Radiation pattern

Figure 6 represents When the diode is turned on, the octagonal patch antenna simulated at 2.4 GHz with HFSS achieved a 2D gain of 2.303dB.

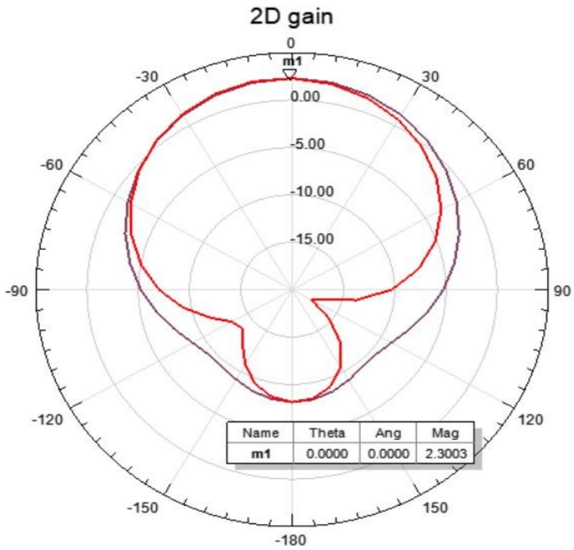

Figure 6 Gain when the Diode is ON
(∅=0 to 360 and θ=0 to 360)

Figure7 shows When octagonal patch antenna is simulated at 2.4 GHZ using HFSS, the obtained radiation efficiency of designed model is 11.9142dB when diode is in ON condition.

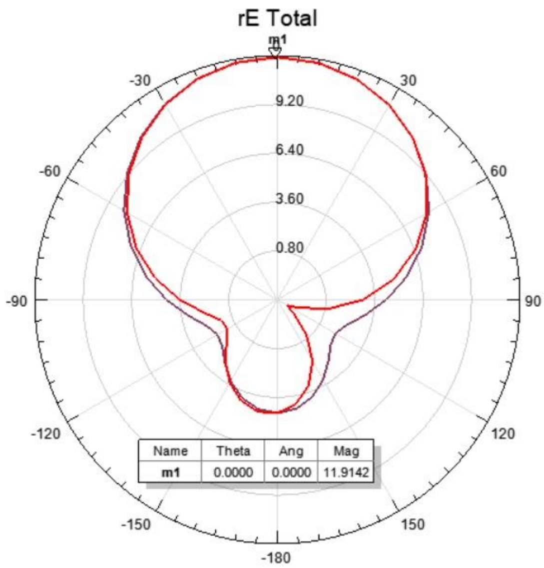

Figure 7: Radiation efficiency when Diode is ON
(∅=0 to 360 and θ=0 to 360)

Figure 8 represents the octagonal patch antenna simulated at 2.4 GHz using HFSS, realized 3D gain is 1.0926 dB when diode is in ON condition.

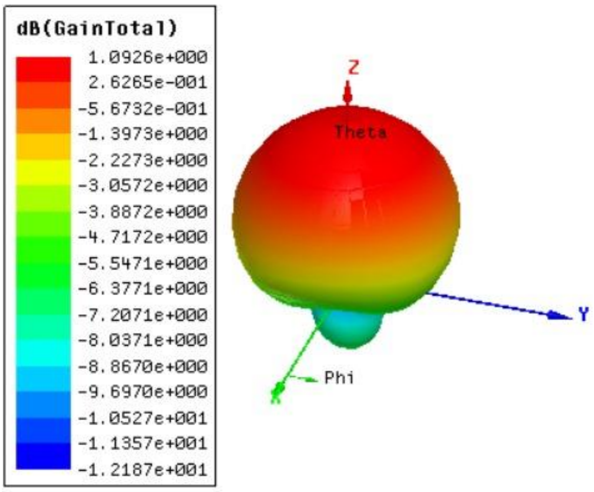

Figure 8: 3D Gain when Diode is ON
(∅=0 to 360 and θ=0 to 360)

Figure 8 represents the Maximum 3D gain of the designed model. The radiation pattern may change slightly with the new frequency configuration but should still provide directional radiation suitable for wireless communication.

In a reconfigurable antenna like the octagon split ring resonator (SRR) microstrip patch antenna, the radiation pattern can change when the antenna is reconfigured to operate at different frequencies. The radiation pattern describes how the antenna radiates electromagnetic waves in space. When the antenna is reconfigured to operate at a different frequency, the radiation pattern may shift or change shape slightly. This change can affect the antenna's coverage area, directionality, and polarization characteristics.

Figure 9 shows When the diode is turned off, octagonal patch antenna simulated at 2.4 GHz with HFSS yields a 2D gain of 2.8964 dB

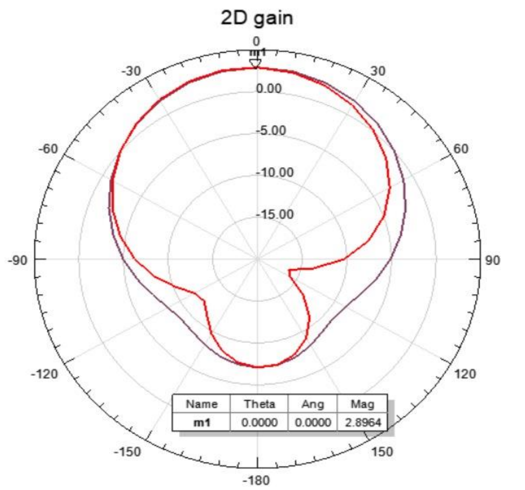

Figure 9: Gain when the Diode is OFF
(∅=0 to 360 and θ=0 to 360)

Figure 10 shows When octagonal patch antenna is simulated at 2.7 GHZ using HFSS, the obtained radiation efficiency of designed model is 12.0435 dB when diode is in OFF condition.

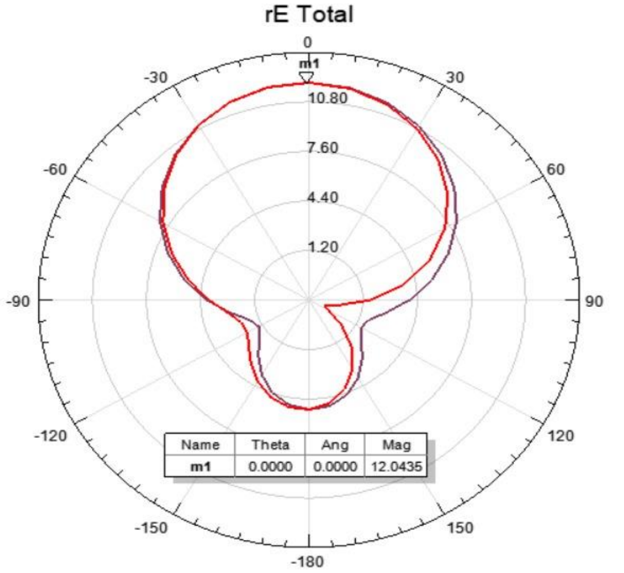

Figure 10: Radiation efficiency when Diode is OFF ($\emptyset$=0 to 360 and θ=0 to 360)

Figure 11 represents the The octagonal patch antenna simulated at 2.4 GHz using HFSS, realized 3D gain is 1.905dB when diode is in OFF condition

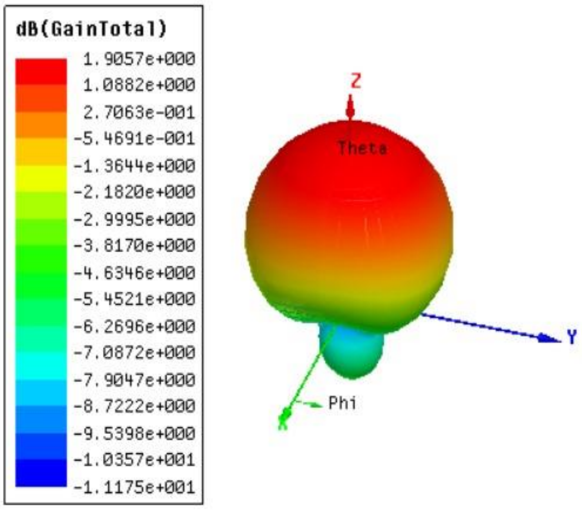

Figure 11: 3D Gain when Diode is OFF ($\emptyset$=0 to 360 and θ=0 to 360)

The radiation pattern will be optimized for the default frequency bands, providing directional radiation suitable for wireless communication. The ability to switch the varactor diodes on and off allows for dynamic adjustments in the antenna's operating frequency bands, providing flexibility and adaptability to changing communication needs.

S. No	Parameter	When Diode is ON	When Diode is OFF
1	Return loss	-11.33 dB -10.04 dB	-14.754 dB -11.7dB
2	VSWR	1.5734	1.4478
3	3D Gain	1.09 dB	1.90 dB

Table 2 Comparison of parameters when diode is ON and OFF

Table 2 shows the results of a designed antenna model, when the diode is in ON and OFF conditions.

V. CONCLUSION

In this paper a summary of the techniques and methodologies used to design, optimize and apply reconfigurable antennas is presented. Several techniques are proposed to achieve the reconfiguration mechanism of antennas. This paper presents the design of an antenna that reconfigures at two operating frequencies of the ISM band in ON state and in OFF state.

The S11 parameter and gain have been evaluated for two frequencies. In ON state S11 value obtained at -11.33 dB at 2.7 GHz and -14.754 dB in off state. A gain of 1.09 dB in ON state and gain of 1.90 dB in OFF state is achieved. The demand for antennas that can rearrange themselves in response to the present and future requirements of wireless communication systems will persist due to the requirement for a single antenna to perform several roles. The operation of reconfigurable antennas can be automated, controlled and optimized using many techniques, such as graph models etc.

Essentially, the antenna design's ground plane functions as an impedance matching circuit, adjusting the input impedance and thus altering the operational bandwidth in response to variations in the antenna feed size. Across the whole bandwidth, octagonal microstrip antennas offer virtually omnidirectional radiation patterns.

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