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An Octagonal Ring Slot Patch Antenna for Various wireless Services

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Abstract*: Keeping under consideration demand of multiband performance, a miniaturized octagonal slot rectangular patch antenna is proposed exploiting defected ground structure. Fabricated on FR4 ($\mathcal{E}_r$=4.4), the size of proposed design is 30×35×1.6 mm^3. The radiator is fed by a 50Ω microstrip feed line. The antenna exercises its power in three frequency bands IEEE 802.11b/Bluetooth; HiperLAN2 and IEEE802.11a/WiMAX. Various antenna characteristics such as return loss, gain, radiation pattern and VSWR are also examined and presented.*

Keywords*: octagonal slot; microstrip patch; multiband; wireless applications; FR4*

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I. Introduction

The radio communication today focuses much on broadband and multiband nature. Makers are hence forced to make designs that meet the multiband requirements. Size is also a matter of interest as being small sized is an important aspect of optimization in this field. Due to their many promising characteristics, the microstrip patch antenna has received the consideration of researchers over the past work. From 1970's till now, patch antenna laid their uses in a never ending series of applications varying from wireless communication to biomedical diagnosis [1].

II. Background

Though earlier work noted by Deschamps goes back to 1953, Bob Munson actually invented patch antenna in 1972 and started becoming popular since then [2-4]. Back in their earlier days patch were not much liked because they had low power and efficiency, high Q, very poor bandwidth (<5%) and poor polarization purity. The reason of their ever growing popularity now is their increased bandwidth (>30%), efficiency and versatility in terms of pattern, resonant frequency, impedance matching and polarization. Their specialty lies in size constrained and high performance applications. 21st century research on microstrip patch antenna aims to multiple functionality, improved gain, wide bandwidth, size reduction and impedance matching. Numerous methods have been dictated for achieving wide bandwidth [5-6] and to increase gain [7-8]. Many conventional practices such as employing varactor diodes, switches and PIN diodes are used for obtaining multiband operation [9-11]. But, these designs present reconfigurable frequency operations with bi-state ON/OFF control. Making use of active components also increases design complexity and it also needs extra biasing network. The designing of Photonic Band-Gap (PBG) structure on ground plane [12] also helps in receiving multiband characteristics but it degrades the antenna efficiency. Multiple patches with a slot-coupled procedure were also used to acquire multiband results [13].One more technique to find the multiband feature is to use Meander lines in the radiator. Meandering is obtained by introducing many narrow slits at the patch's non radiating edges. The stimulated patch's surface currents are meandered, resulting into much lengthened current path for a fixed linear patch dimension [14]. This behavior has a tendency to lower the fundamental resonant frequency; therefore it should be used for lower frequency works. Coplanar waveguide can also be used with patch but due to the absences of ground plane radiations are increased [15]. In [16], a multiband response was achieved by employing a modified ground plane. This technique not only enhances the bandwidth and gain of an antenna but is also very easy to implement and fabricate.

III. Antenna Design

The proposed antenna designed is simulated using CST Microwave studio, 2011. The radiator is a rectangular patch having an octagonal ring slot in it and the rectangular patch being fed by 50Ω microstrip feed line. The antenna dimension is 35 mm x 30 mm with thickness of 1mm. A larger dielectric constant implies smaller patch size resulting in lower bandwidth and such small antenna is difficult to fabricate. By etching a defected ground plane and rectangular patch as the radiator the reflection loss is obtained less than -10 dB. A center- fed patch optimizes the input impedance. Lower the values of permittivity (Ɛr), better are the results but much smaller permittivity value increases fringing effect. High thickness endows with wider bandwidth and low thickness endows with narrow bandwidth. But if the thickness is enlarged beyond a certain limit then more radiation occurs. An increase in the width of the feed line leads the antenna not to operate in the requisite band. Figure 1 shows the patch and ground of the proposed geometrical design of the multiband antenna. Table 1 shows the various parameters of the design. All the parameters are in millimeters (mm).

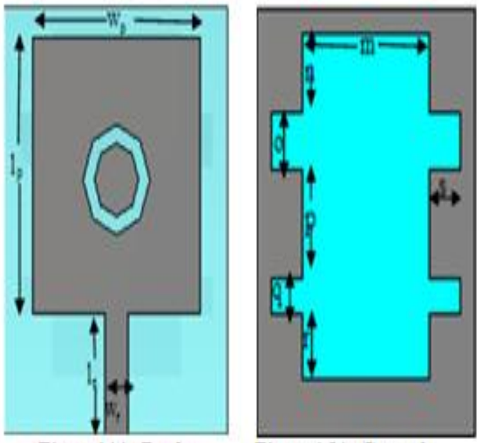


Figure 1(a): Patch Figure 1(b): Ground

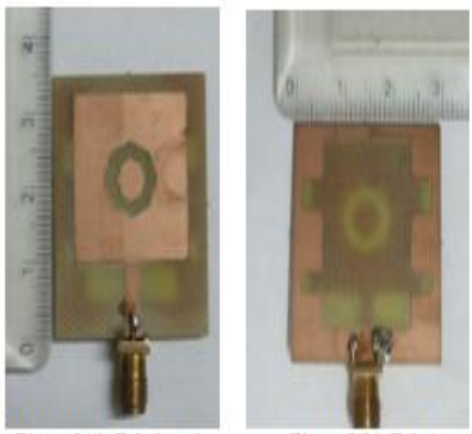


Figure 2(a): Fabricated Patch Figure 2(b): Fabricated ground

The prototype is fabricated using standard photolithography process. The process of photolithography engrosses UV light exposure through a mask to project the illustration of a design onto the substrate. Rest of the material is then removed using a suitable solvent. The fabricated prototype, both patch view and modified ground, is shown in Figure 2.

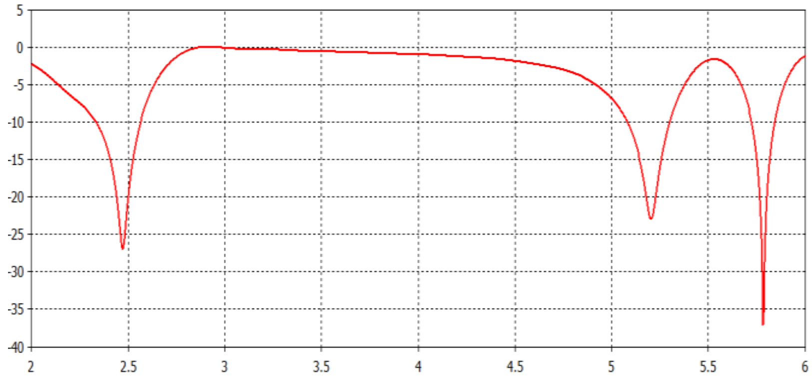
Table I: List of Parameters

Parameter	**Dimension**
Length of patch, l_p	22.4
Width of patch, w_p	23.7
Length of feed, l_f	10
Width of feed, w_f	3
Outer radius of octagonal slot	4. 5
Inner radius of octagonal slot	3
M	1
N	6.
O	4.
P	9
Q	3
R	5.
S	4.

IV. Simulation Results

This slotted tri-band patch antenna is design using Computer Simulation Technology (CST) Microwave Studio, 2011. Antenna parameters like VSWR, Return loss, Gain, surface current distribution, electric and magnetic field, Smith chart, Radiation pattern etc can also be examined with the help of CST. These antenna parameters are studied to measure the performance of the proposed antenna. It works efficiently on three different frequency bands. The characteristic impedance of an antenna should be 50Ω for perfect impedance matching. Reflections are produced in case of impedance mismatch and it is measured in terms of return loss. Return loss should be less than -10dB ideally but taking into account the actual work environment condition it is taken less than -20dB. Figure 3 show that the antenna operates at resonant frequencies 2.49GHz having a return loss of -26.93dB; 5.2GHz having return loss of -22.99dB and 5.8GHz having a return loss of -37.04dB.

Figure 3: Return Loss



One of the most important graphical tools for high frequency application is Smith Chart. From a straightforward mathematical view, a smith chart is representation of all possible complex impedances with respect to coordinates defined by reflection coefficients. The tool facilitates to quickly calculate many parameters, such as reflection coefficient, admittance, return loss, VSWR, insertion loss and transmission coefficient from the complex impedance.

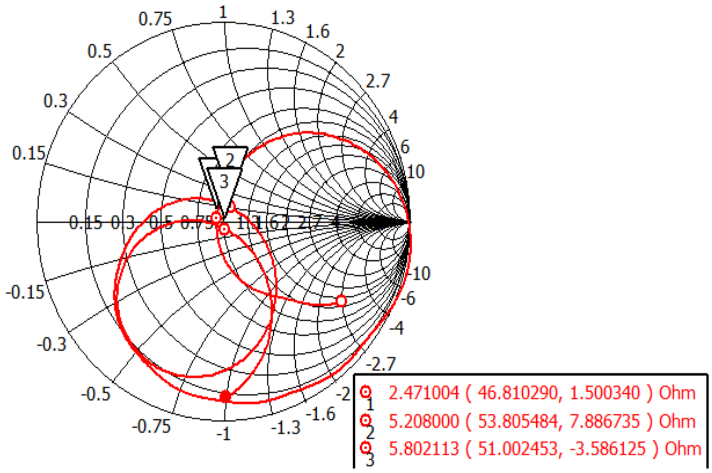


Figure 4: Smith Chart

As shown in Figure 4, the impedance at the three resonating frequencies is approximately equal to the industry standard of 50 Ω, which shows a good impedance matching of the antenna and thus a lesser return loss as required Graphical demonstration of the radiation characteristics of an antenna is its Radiation Pattern. It is the combination of E-plane and H-plane pattern. Figure 5, Figure 6 and Figure 7 shows the radiation pattern (E and H plane) at 2.49GHz, 5.2GHz and 5.8GHz respectively.

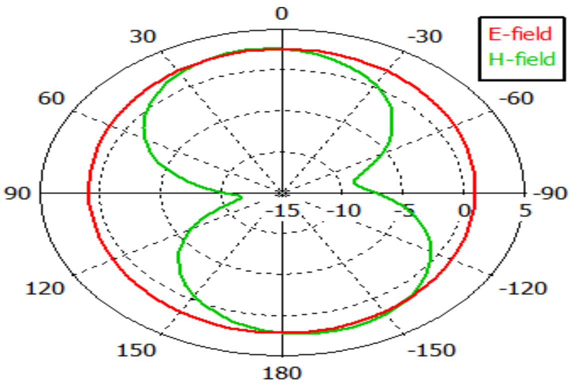


Figure 5: E-plane and H-plane pattern at 2.49GHz

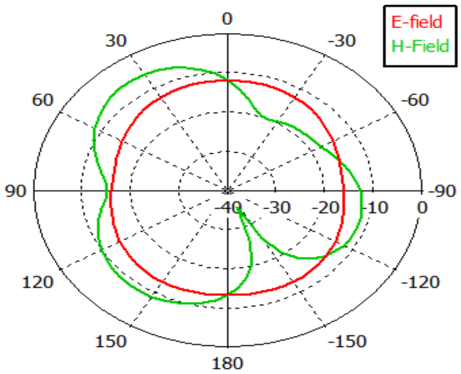


Figure 6: E-plane and H-plane pattern at 5.2GHz

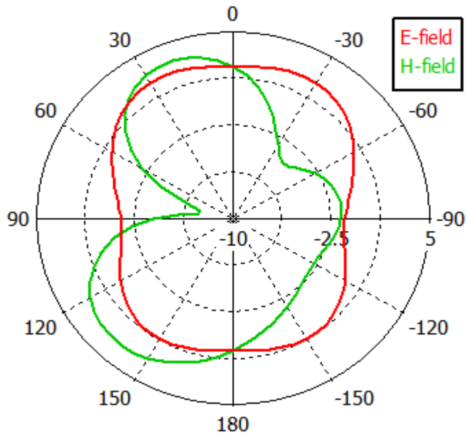


Figure 7(a): E-plane and H-plane pattern at 5.8GHz

To get more insight about the proposed design, surface current circulation simulated results are presented in Figure 8 for the three resonating frequencies.

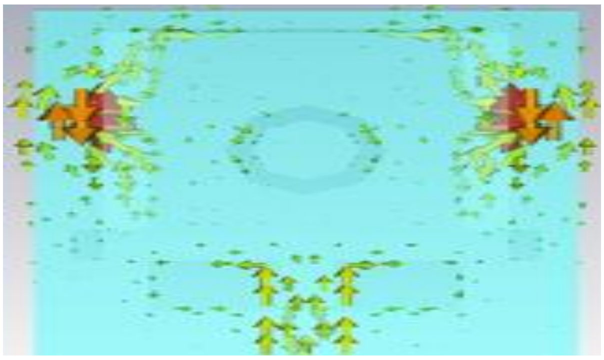


Figure 8(a): Surface Current for 2.49GHz

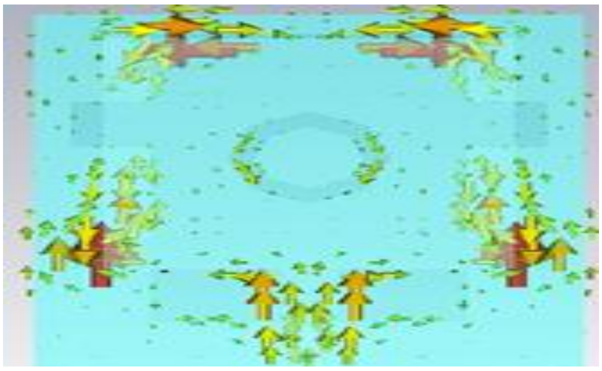


Figure 8(b): Surface Current for 5.2GHz

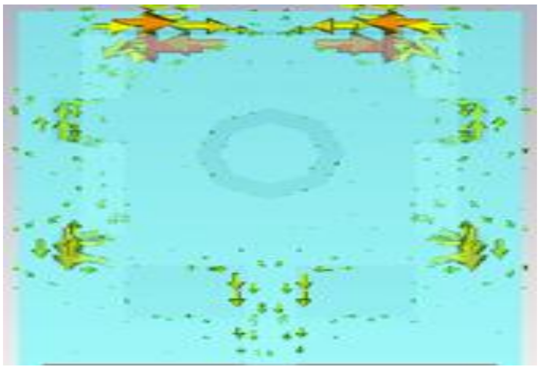


Figure 8(c): Surface Current for 5.78GHz

IEEE Gain at 2.49GHz is 2.054dB, at 5.2GHz is 5.17dB and at 5.78 GHz is 2.06dB. As already discussed this reduced gain and non- Omni directional radiation pattern is a consequence of implementing defected ground structure.

V. Experimental Results

The experimental result verification of the fabricated prototype was performed using Vector Network Analyzer (VNA); ROHDE & SCHWARZ ZVA 40. The Vector Network Analyzer is a sophisticated tool proficient of making speedy and precise measurements in frequency and time domain within a frequency range of 10MHz to 40GHz [15] and here has measured the magnitude and phase of the S-parameters, VSWR and Smith Chart. The built in signal processor scrutinize the transmitted and received data and displays the results in many plot formats. Figure 9 shows the measured return loss of octagonal ring slot patch antenna.

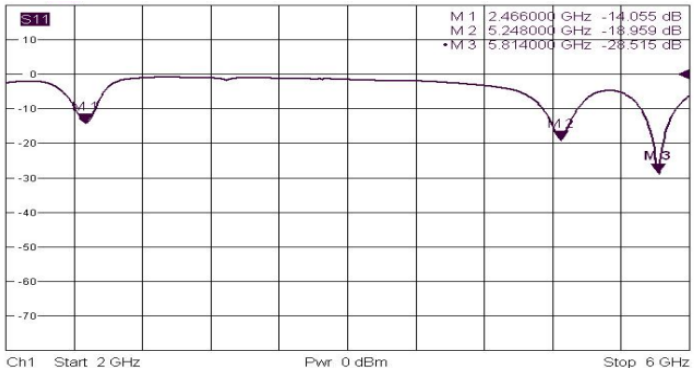


Figure 9: Measured Return Loss

It is clearly shown that the three resonant frequencies are approximately same as the simulated results and can be considered to be in good match with the simulated results. However, this variation in the experimental results is due to the fact that practically FR4 substrate is very lossy to use above 4GHz as well as realistic environment is also very different from the one considered for simulated results. Moreover, soldering of SMA connector also induces some losses and frequency shift. So, extra care is needed to solder the connector to microstrip feed. Figure 10 and Figure 11 illustrate the experimented VSWR and smith chart.

Figure 10: Measured VSWR

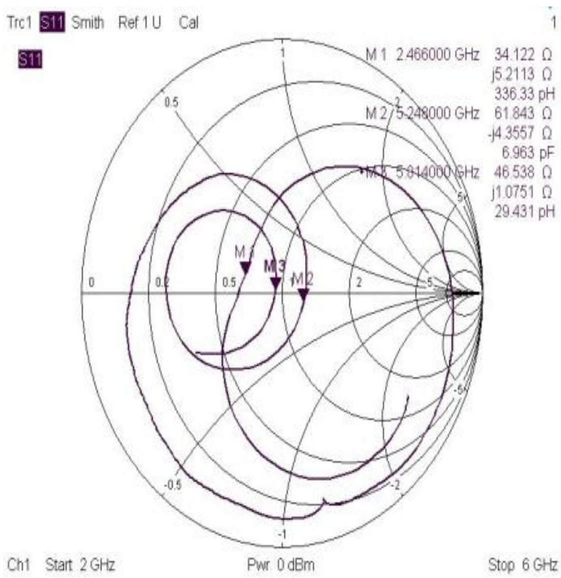


Figure 11: Measured Smith Chart

It can be observed that both the measured results are in a good agreement with the simulated results.

VI. Future Research Directions

Every design always has a scale of enhancement on which others might work on. Some of those points in this proposal might be reduction of the band ranging from 2.33-2.53GHz which is having the problem of interference. One of the main criteria of optimization is size of antenna. More work can be done on size reduction of the proposed design. Further exploration can be done on how the gain can be improved. The same design can be implemented with a different feeding technique and the effects can be observed.

VII. Conclusion

A miniaturized octagonal slot antenna is proposed and its various parameters are presented and discussed. The proposed antenna works on three frequency bands with bandwidth 2.37-2.53GHz, 5.09-5.3GHz and 5.72-5.85GHz with their resonant frequency as 2.49GHz, 5.2GHz and 5.8GHz respectively. These three bands lay their uses for Bluetooth/IEEE 102.11b, HiperLAN/2 and WiMAX/ IEEE 802.11a. The return loss is much below -20dB which justifies the efficient working of the antenna. However, the first frequency band of 2.37-2.53GHz is much broader than that required of the application and hence will lead to interference. VSWR, Radiation pattern, gain and directivity of the proposed antenna are also presented.

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