Compact Multiband Microstrip Patch Antenna For Wireless Applications

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***Abstract*—A Microstrip patch antenna that can be used for Wi-Fi, Bluetooth and WIMAX frequencies, has been proposed in this work. The objective of the work is to design an antenna with multiple resonances at 2.45 GHz, 3.6 GHz and 5.3 GHz and miniaturization of the patch using high dielectric constant. Microwave substrate of size 30mm x 30mm havinga dielectric constant of 10.2 and a loss tangent of 0.002 is used to fabricate the antenna.The desired frequencies are obtained by cutting slots in the patch and impedance matching is done by providing defective ground. The miniaturized antenna is fabricated through photo etching process, tested and the results are validatedwith simulation result.**

Keywords—multiband, slots, Wi-Fi, WIMAX, Bluetooth, defective ground.

I. INTRODUCTION

The Microstrip patch antennas are obvious choice for handheld and compact wireless devices due to their advantages like small size and weight. The size of wireless devices is reducing exponentially which demands more compact and high performance antenna devices. In addition, multiband operation is inevitable nowadays, and most of the modern handheld wireless devices are operating in the multiple bands of frequency. Many research works have been reported based on miniaturization of the antenna without affecting antenna performance. Most of them are based on altering the patch shapes such as introducing slots, defective ground structures, etc[1-4]. In the case of patch antenna, the resonant length is depend on the dielectric constant (ε_r) of the material and hence one of the methods of antenna miniaturization isto use microwave substrates with high dielectric constant [5], [6]. An increase in dielectric constant provides a size reduction factor on the order of ε for the leaky dielectric and cavity resonator type antennas like Microstrip patch antenna. This method of miniaturization is beneficial when the electrical length of the substrate is small compared to wavelength, even though this method of is susceptible to surface wave excitation and difficult to match with 50Ω impedance line [1]. Another important approach for antenna miniaturization is to modify the antenna geometry. There are many patch shape alterations such as E-shaped patch [2], S-shaped patch [3], spiral ground slots [4] etc. for improved performance. The technique of ground cut is applied in the design of Microstrip antenna, which reduces the resonance frequency and size of the antenna [7].

In the present work, a miniaturized antenna is proposed using high dielectric constant material with multiple resonance obtained by cutting slots. defective ground structuresare used forimpedance matching because high dielectric substrate used for miniaturization leads to difficulty in matching. The defective ground can increase the total effective length of the antenna, thereby reducesthe physical resonance length [7]. The proposed antenna in the present work is designed for Wi-Fi, WiMAX and Bluetooth frequencies, which are 5.3 GHz, 3.6 GHz and 2.4 GHz respectively. Slots have been cut based on parametric studies in the patch in order to generate multiple resonance bands.

II. ANTENNA DESIGN

The antenna design and simulations are done in Ansys HFSS 14. The main objective of the present work, antenna miniaturization, is achieved by using high dielectric microwave substrate (C-MET LD10.2 material) material with dielectric constant of 10.2, which is almost double compared to conventional FR4 epoxy substrate. The overall size of the substrate used is 30 mm (L) x30 mm (W) x 1.27mm (H).

A. Slots for multiple resonance

A microstrip transmission line is used to feed the antenna.The choice of the microstrip feed, as opposed to a coaxial line is based on the ease of fabrication and stability. The microstrip feed provides an additional parameter to design the antenna. The required frequencies are Wi-Fi, WiMAX, and Bluetooth. Cutting slots in the patch will increase the effective length and disturb electric field. Two slots have been cut in the patch in order to generate two additional frequencies other than the natural resonance of the patch which is 5.3GHz.

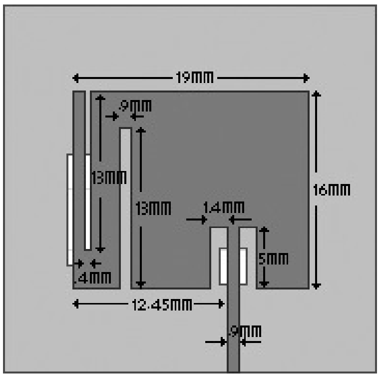

Fig.1.The proposed antenna structure

The dimensions of the slots are selected as λ/4 and optimized using parametric studies. Therequired frequency bands are Bluetooth and WiMAX band, which are 2.4 GHz and 3.6 GHz respectively are obtained by two slots as shown in Fig. 1. These slots increase the effective length of the patch without increasing the physical length. The slot loading is expected to contribute some inductance and capacitance to the antenna impedance.

B. Slots for impedance matching

The impedance is matched by inset feed as shown in Fig. 1 and defective ground structure is shown in Fig. 2.The defective ground plane makes the antenna bidirectional in nature. The inset length is optimized after cutting the slots in order to match perfectly with the 50 ohm line. Two slots have been cut in ground as shown in Fig. 2. The smaller slot on the left is provided exactly under the micro strip feed line. This slot is used to reduce the reflections of the 3.6 GHz. The bigger slot in the ground used to match 2.4 GHz and it placed under smaller slot in the patch as shown in Fig. 2. The effect of the feed linewidth on coupling is studied and fine-tuned further using HFSS and found the optimum feed linewidth.

III. Simulation and Tuning

The design is optimized using HFSS software. As discussed earlier, slotted antenna with highdielectric material is difficult to match with the 50 ohm line, and hence standard inset length is optimized after cutting the slot. At 2.4 GHz, the electric field is much concentrated on the smaller slot in the patch as shown in Fig. 3. The electric field distribution for the 3.6 GHz is shown in Fig. 4. The electric field at 5.3 GHz is much more uniform than the other two frequencies as shown in Fig. 5. If the axial ratio from which polarization can be determined isgreater than 5 dB, then polarization considered as linear. The proposed antenna has linear polarization. The efficiency obtained from simulation studies is 80%, 60% and 41% for 5.3 GHz, 3.6GHz and 2.4 GHz respectively.

IV. Results and Discussion

The proposed antenna is fabricated and tested in order to validate the simulation results. The fabricated antenna is shown in Fig. 6. Acomparison of the simulated and measured S11 results are shown in Fig. 7.

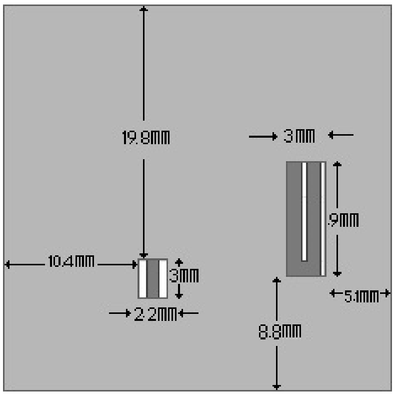

Fig. 2. The defective ground plane

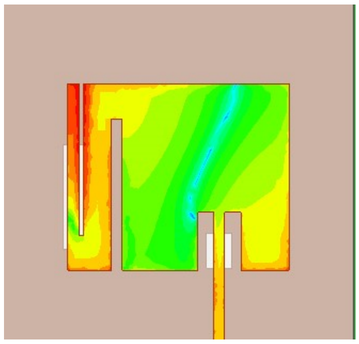

Fig. 3. E- Field at 2.4 GHz

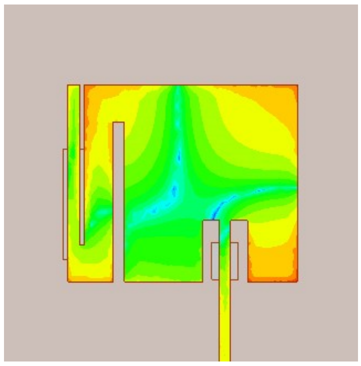

Fig. 4. E- Field at 3.6 GHz

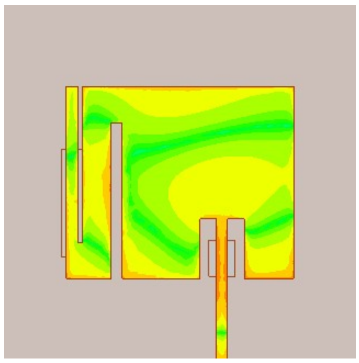

Fig. 5. E- Field at 5.3 GHz

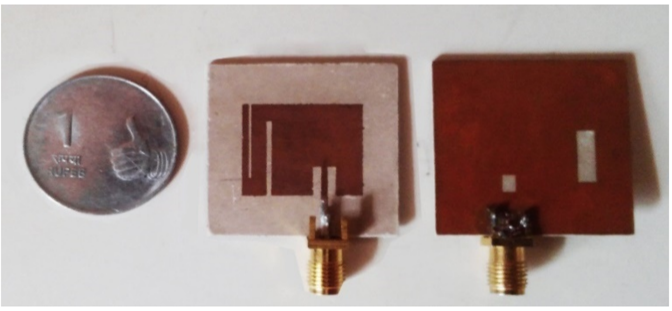

Fig. 6. Fabricated antenna

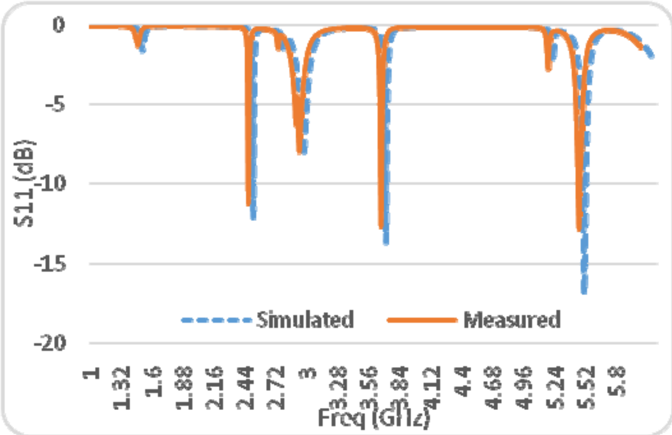

Fig. 7. Measured vs simulated return loss

It is clear from Fig. 7 that there are slight differences in the measured S_{11} resultscompared to the simulated ones, which may bedue to the fabrication error. There are some nulls in the measuredradiation pattern unlike simulation results. This nullsin the E plane is the result of the cancellation of E-fields in the far field, whichare radiated by the two opposing magnetic currents due to the slots. The equivalentmagnetic currents, flowing in the upper and lower side ofthe ground plane, are in opposite directions and consequently their radiation in the point of symmetry at the E plane canceleach other[1].

The parallel slots in the patch can reduce the potential bandwidth of microstrip antennas. The advantages of creating parallel slots outweighs this problem [8]. The electric field around the edges increases as the ground plane size decreases which increases the Ohmic loss in the ground plane. As the ground plane size decreases, the directivity of the slot antenna is reduced. The miniaturization is achieved by high dielectric substrates, which can cause surface waves and there by affect gain. The gain obtained is 3.36 dB, 2.18 dB and 1 dB for 5.3 GHz, 3.6 GHz and 2.4 GHz respectively. The radiation from the edges causes surface wave diffraction, which in turn reduce the directivity of the slot antenna with a finite ground plane. The slotted antenna compared to basic patch without slot, surface current path of the resonant patch can be lengthened, resulting in the decrease of corresponding resonant frequencies [1]. The return loss, 10 dB bandwidth and antenna gain variation with the slot lengths are gradually decreasing. As a consequence of slot cutting, the radiating patch area becomes lower, which reduces the antenna gain, bandwidth and return loss. This is one of the main reason for low gain. The radiation patterns for each resonating frequency are shown in Fig. 8. , Fig. 9 and Fig. 10 respectively.

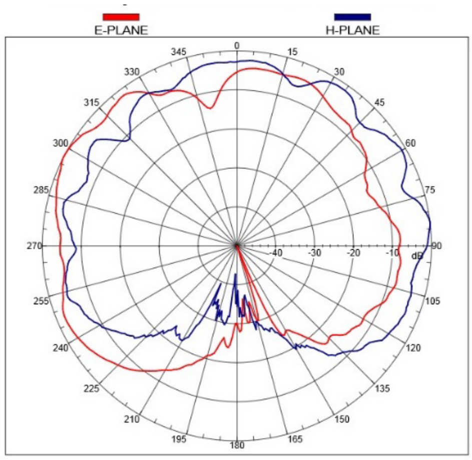

Fig. 8. Measured radiation pattern for 2.4GHz

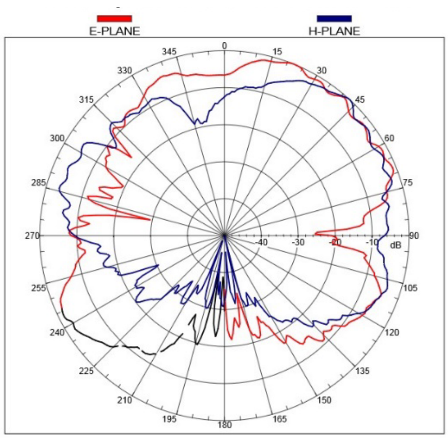

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Fig. 9. Measured radiation pattern for 3.6GHz

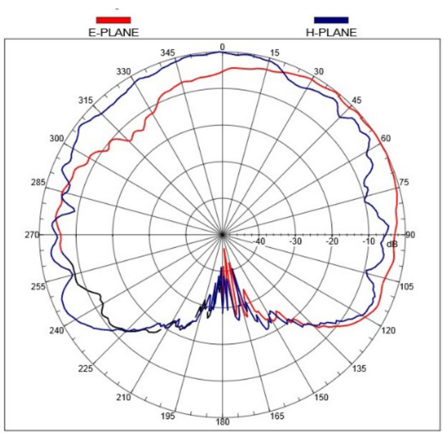

Fig. 10. Measured radiation pattern for 5.3GHz

V. Conclusion

A miniaturized antenna that can be used for wireless standards such as WI-FI, WiMAX and Bluetooth has been presented. Ansys HFSS 14 is used to simulate and optimize the antenna dimensions. Two slots have been cut in the patch in order to generate lower frequencies such as Bluetooth and WiMAX bands. Antenna miniaturization has been obtained by using military standard high dielectric constant substrate material having dielectric constant of 10.2 and loss tangent of 0.002 and 41% of size reduction is achieved in the case of 2.4 GHz. The proposed antenna is fabricated and tested in order to validate the simulation results. Defective ground structure has been used to reduce the reflections and inset feed is used to match the impedance. The defective ground structure consists of two rectangular slots. The dimensions of the slot have been obtained by parametric studies. The proposed antenna works on three wireless frequencies, which are 2.4GHz, 3.6 GHz and 5.3GHz. The antenna designed in the present work has acceptable radiation pattern and gain of 3.6 dB, 2.1 dB and 1dB for 5.3GHz, 3.6 GHz, and 2.4GHz respectively.

Acknoledgment

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