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Design of Multiband Microstrip Antenna Using Two Parasitic Ring Resonators for WLAN/WiMAX and C/X/Ku-Band Applications

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***Abstract*—In this paper, a new planar monopole antenna for multiband applications is proposed. The antenna structure operates at five operating frequencies at 2.88 GHz, 7.58 GHz, 9.88 GHz, 11.59 GHz and 13.78 GHz which covers different communication frequency ranges. The proposed antenna consists of a quasi-modified rectangular radiating patch with a partial ground plane and two parasitic elements (open-loop-ring resonators) to serve as coupling-bridges. A stepped cut at lower corners of the radiating patch and the partial ground plane are used, to achieve the multiband features. The proposed antenna is manufactured on the Rogers RO 3010 substrate and is simulated and optimized using High Frequency Simulation System (HFSS). The antenna topology possesses an area of 41.04 x 29.98 x 1.6 mm^3. The measured results demonstrate that, the candidate antenna has impedance bandwidths for -10 dB return loss and operates from 2.68 – 3.03 GHz, 7.33 – 7.84 GHz, from 9.66 – 10.03 GHz, from 11.46 – 11.78 GHz and from 13.69 – 13.88 which meet the requirements of the wireless local area network (WLAN), worldwide interoperability for microwave access (WiMAX), C- (Uplink), X- (Uplink) band and Ku- (Uplink) band applications. Acceptable agreement is obtained between measurement and simulation results. Experimental results show that the antenna is successfully simulated and measured, and the tri-band antenna can be achieved by adjusting the lengths of the three elements and gives good gains across all the operation bands.**

Keywords— Planar Monopole Antenna; HFSS; WLAN; WiMAX; C; X & Ku.

I. INTRODUCTION

With rapid development of wireless communication systems, one of the key issues is the design of compact multi-band antenna while providing wideband characteristic over the whole operating band, especially for wireless local area network (WLAN: 2.4-2.48, 5.15- 5.35, 5.725-5.85GHz) and worldwide interoperability for microwave access (WiMAX: 2.5-2.69, 3.4-3.69 GHz), where it plays a major importance. Consequently, a number of planar antennas using several topologies have been experimentally characterized. In addition, other methods to progress the impedance bandwidth which do not include adjustment of the geometry of the planar antenna have been examined [1-4]. It is a well- known fact; Commercial UWB systems demand compact and low-cost antennas with omnidirectional radiation patterns and large bandwidth [1].

Microstrip monopole antennas illustrate truly appealing physical characteristics features, such as uncomplicated structure, compactness and low-cost of fabrication process, low profile of antenna, light in weight, ease of installation process and integration with numerous feed types. Because of all these important features, planar monopole antennas are highly attractive to be employed in advanced UWB technologies, and recent research activity is being focused on them. Measure decreasing of the planar patch antenna has been carried out utilizing a few strategies such as the utilize of high dielectric constant substrates, adjustment of the conventional patch shapes, use of short circuits, shorting-pins technique [7]-[8]. Employing high dielectric constant substrates is a simple solution, but it shows narrow bandwidth, high loss and poor ability due to surface wave excitation [9]. In order to generate the single and multiple band-notched functions, respectively, single and multiple half- wavelength ring resonators [6] are incorporate in the radiation patch topology. In [7], band- notch function is reached by using a T-shaped coupled-parasitic element in the ground plane. Also, different planar inverted-F antennas (PIFA) designs have been proposed for several bands in newest researchers. Minimize dual band (PIFA) have been reported in [10, 11], and are reached using etched slotted radiated element. In [12-17], triple band small size composite-resonator monopole antenna designs for wireless communications were presented. Theses antennas are consisting of three resonant topologies. Two types of compact short-circuited resonators were used; stepped impedance and quarter-wave resonators. The narrowband services such WLAN, Wi-MAX and ITU may generate undesired interference with the UWB band. In order to avoid this problem, it is preferable to used antenna-topologies with noch-band features. However, there are some other existing narrowband services that may cause interference with the UWB band, such as WLAN, Wi-MAX and ITU. To solve this problem, it is desirable to design antennas with band-notched characteristic to reduce potential interference [2], [3]. To

avoid these interferences, there is Several researchers, who proposed multiple antenna design methods to produce the band-notched characteristic in the UWB band, such as photonic band-gap (PBG) structure, defected ground structure (DGS), defected microstrip structure (DMS) and using slotted the patch or ground through different slots [5].
In this work, a simple method for designing a quad-band small size monopole microstrip antenna with width band features has been presented. The proposed topology is simulated and optimized and manufactured on the 41.04 x 29.98 x 1.6 mm^3 Rogers duroid 6010 substrate of, permittivity 10.2. The simulation investigations are carried out using the Ansoft HFSS commercial software [12]. Details of the antenna design are described, and fabricated and simulated return loss, radiation pattern and antenna gain results are represented and discussed in the following section. The acceptable agreement between the experimental and the simulation results is observed. The Slight deviation between the simulated and fabricated results is due to the mismatching losses and the inexactitude of the manufacturing process. The parametric investigation is accomplished to understand the characteristics of the proposed antenna.

II. ANTENNA DESIGN

The topology of the proposed monopole microstrip multiband antenna, fed by 50 Ω microstrip feed line, is shown in Fig. 1. The design consists of modified structure of a conventional rectangular patch antenna and two loaded parasitic ring resonators around of the 50 Ω feed line. The radiating patch has a length L and a width W. The W and L are the width and length of the feed line, which connect the patch with SMA connector. On the other side of the substrate, a conducting partial ground plane is placed. The dimensions of the partial ground plane are width W_{gnd} and length L_{gnd} (see Fig. 1). The width of the microstrip feed line is fixed at 2 mm. The antenna is printed on a 41.04 x 29.98 x 1.6 mm^3 or about 0.924 λ_g x 0.910 λ_g x 0.048 λ_g with λ_g = 33 mm at 2.88 GHz (the first resonance frequency) and a Rogers duroid 3010 substrate of thickness 1.27 mm, permittivity 10.2, and loss tangent tanδ = 0.003. The design processes to reach the proposed antenna are depicted in Fig. 4. The investigated antenna is connected to a 50 Ω-SMA connector for signal transmission. The parameter values of the proposed design are illustrated in Fig. 1.

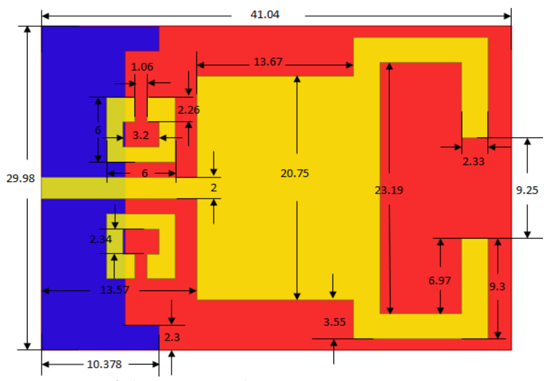


Fig. 1. Geometry of the proposed antenna structure.

III. RESULTS AND DISCUSSIONS

The investigate microstrip monopole DGS antenna with different design parameters, which can influence the bandwidth, were constructed, and the scattering results of the input impedance and radiation characteristics are demonstrated and discussed.
From Fig. 2 it is clear that, the proposed DGS antenna structure with partial ground has been achieved multiband operational frequencies. Fig. 4 illustrates the reflection coefficient characteristics of the proposed tri-band antenna. It can be seen that, in the proposed antenna, the three resonant modes are excited around the 2.88, 7.58 GHz, 9.88 GHz, 11.59 GHz and 13.78 GHz for WLAN/WiMAX and C/X/Ku-Band Applications for a $S_{11} \leq -10$dB.
In order to carry out different behaviors of this structure, several parameters of this antenna candidate are studied by varying one parameter, while others keep constant. Fig. 3 shows the steps process of the monopole antenna, the conventional square antenna (Fig. 3(a)), geometry without two ring resonators, (Fig. 3(b)), antenna with two ring resonators located along of the microstrip feed line.

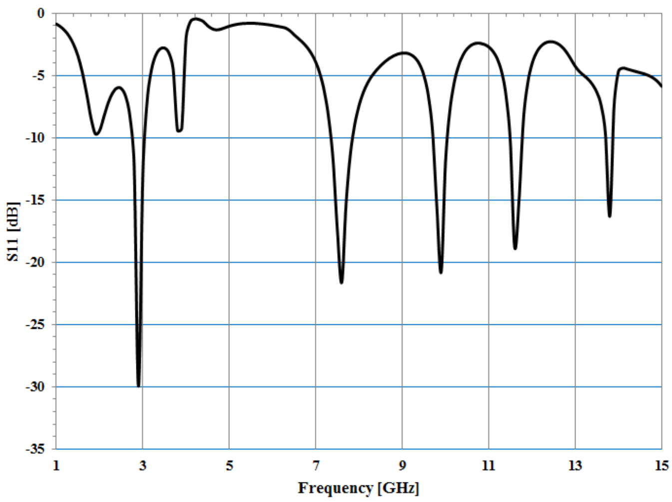
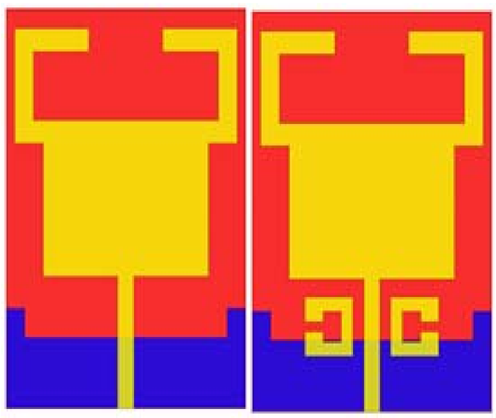


Fig. 2. The simulated S_{11} [dB] of the proposed DGS antenna.



(a) (b)

Fig. 3. Design evolution of the proposed antenna; (a) antenna I, (b) antenna II.

The achieved simulation results are computed using the high-frequency structure simulator (HFSS). Fig. 4 depicted the optimized multiband antenna.

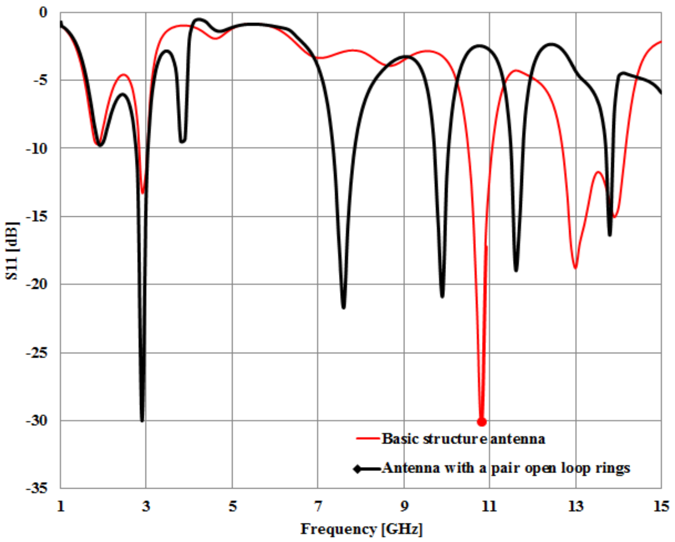
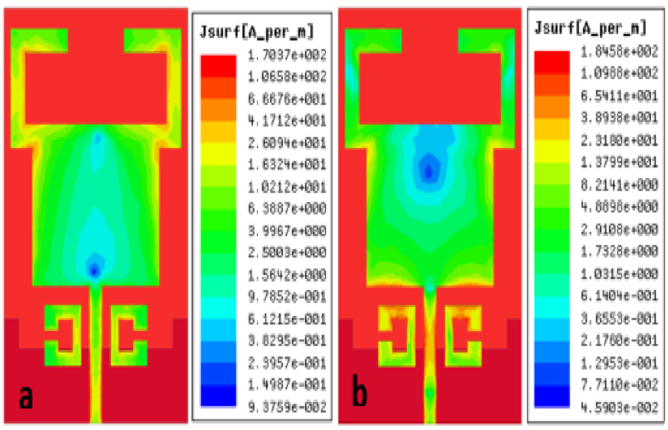


Fig. 4. Simulated reflection coefficient of various antenna designs.

As shown in Fig. 4, for the proposed antenna configuration, the conventional quasi square monopole can provide the fundamental and the next higher resonant radiation bands at 7.58 GHz, 9.88 GHz, 11.59 GHz and 13.78 GHz, respectively. As illustrated in Fig. 3, the ring resonators leads to an improvement in the broadband features and play a role in determining the sensitivity of impedance matching of such antenna. This is because it can influence the effects of electromagnetic coupling between the patch and the ground plane, hence the improvement its impedance bandwidth without any cost of size or expense. Depending on the above regenerated high frequencies at 7.58 GHz, 9.88 GHz, 11.59 GHz and 13.78 GHz can be observed.



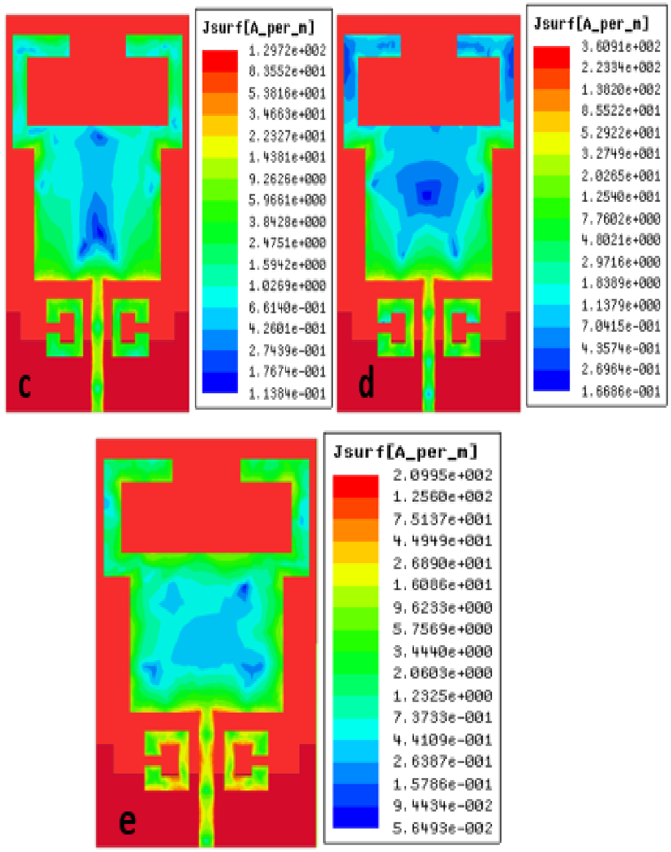
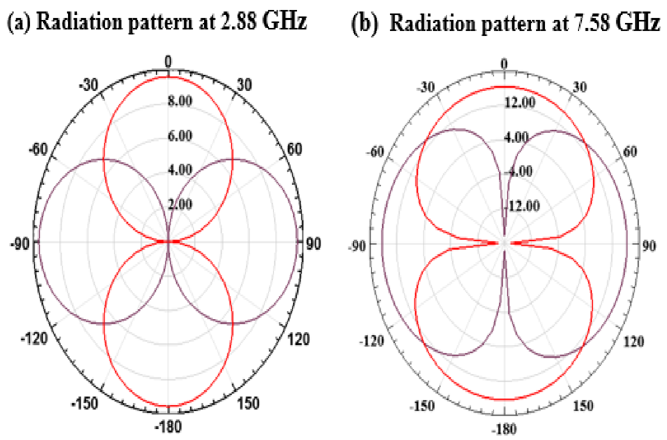


Fig. 5. Simulated surface current distribution of the proposed antenna at (a) 2.88GHz, (b) 7.58GHz, (c) 9.88GHz, (d) 11.59GHz and (e) 13.78GHz.

As shown in Fig.5, the current distributions of the proposed antenna structure at 2.88 GHz, 7.58 GHz, 9.88 GHz, 11.59 GHz and 13.78 GHz are presented respectively.

The simulated radiation patterns of the proposed microstrip antenna are presented in Fig. 6.



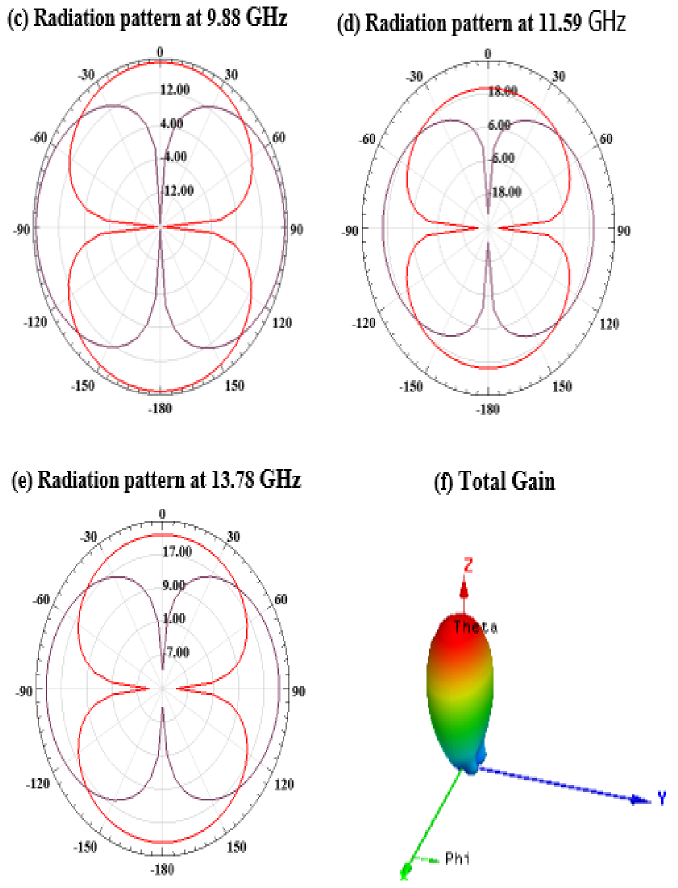


Fig.6. Simulated 2D radiation patterns of proposed antenna at respectively (a) 2.88 GHz, (b) 7.58 GHz, (c) 9.88 GHz, (d) 11.59 GHz, (e) 13.78 GHz and (f) 3D radiation pattern.

IV. THE INVESTIGATION AND EXPERIMENTAL MEASUREMENTS

After the optimizing of the proposed triple-band antenna parameters, an experimental prototype of the final design was fabricated using printed circuit technology and tested. A photograph of the fabricated antenna is shown in Fig. 7. The measurements on the fabricated antenna were carried out using a vector network analyzer (VNA), over a relatively wide frequency range from 1- 15 GHz (Fig. 8).

Figure 9 illustrates the comparison between the simulated and measured reflection coefficient S11 of the proposed antenna. The measured results clearly indicate that the proposed antenna provides at least three resonance bands. From this figure, it is clear that the simulated and measured results show a reasonable agreement. The small discrepancy is due to the fabrication tolerance which cannot be totally avoided. Concurrently, with these performances, the proposed antenna satisfies the requirements of WLAN/ WiMAX and C/X/Ku-Band applications.

Fig. 7. Fabricated prototype of the proposed antenna.

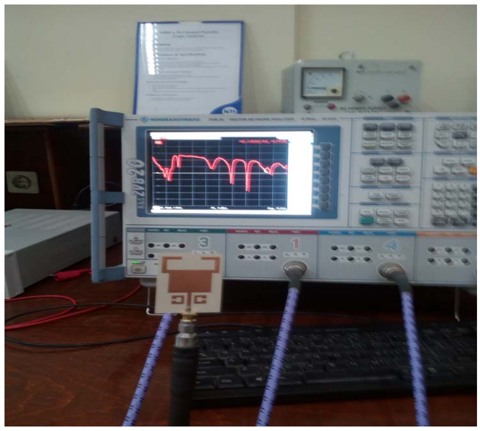


Fig. 8. Return loss of the proposed antenna using VNA.

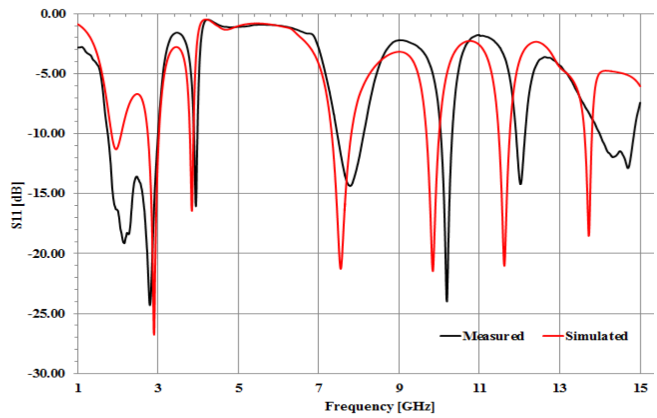


Fig. 9. Simulated and measured reflection coefficient of proposed tri-band antenna.

V. CONCLUSION

A new compact monopole antenna with multi band features for wideband applications is presented in this work. The investigated topology operates at three different frequencies at at 7.58 GHz, 9.88 GHz, 11.59 GHz and 13.78 GHz. In order to improve the impedance bandwidth and radiation characteristics and to minimize the size of conventional rectangular antenna, stepped cuts at lower corners are added to the radiating patch and a partial ground plane has been etched on the metallic ground plane. The proposed antenna is simulated and manufactured on the FR4 substrate with an area of 41.04 x 29.98 x 1.6 mm^3. The measured results show that the proposed topology operates at WLAN, WiMAX, C- (Uplink) X- (Uplink) and Ku- (Uplink) band applications. Simulation and measurement results show that the compact antenna due to its good characteristics can be a good candidate to be used in personal and mobile UWB applications. The appeared deviation between the simulation and measurement is assumed to be related to the mismatching at the SMA port and to the inaccurate of the fabrication. Taking into account the topic, comparisons between other similar antennas in aspects of size and design complexity have been made.

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