ISSN: 2278 – 1323
International Journal of Advanced Research in Computer Engineering & Technology (IJARCET)
Volume 5, Issue 5, May 2016

Design and Analysis of Multiband Slotted Microstrip Antenna for Wireless Applications WLAN/WiMAX

Dinesh Pratap Singh, Virendra Singh

Abstract— **In this paper, a multi-band rectangular microstrip antenna (RMSA) is designed and simulated by two different single-slotted, which symmetrical Z shaped compact multiband microstrip antennas with slot structure in ground plane as Defect Ground Structure. Each open-ended slot in the single-slotted antenna is responsible to generate a wide impedance band result in shifting to lower frequencies by the effect of the ground slot. The position of each open-ended slot is varied to work the antenna in a suitable resonant band (3.75–4.15 and 5–5.5 GHz). The proposed antenna meets the required impedance bandwidth, essential for multi-band IEEE 802.11ac WLAN/WiMAX applications. The dimension of the antenna (50 X 50 X 1.575 mm) on FR4 substrate.**

Index Terms— **DGS, multi-band, WLAN /WiMAX, open-ended slot, rectangular ground slot, Z shaped etc.**

I. Introduction

High mobility requirements and multiple frequencies necessary for wireless communication devices increase the interest for compact, low-profile and multiple band antennas in recent years. The frequency ranges of 1-5.5 GHz are used for wireless local area network (WLAN), Wi-Fi , WiMax etc. that offers data rate up to 54 Mb/s. Different techniques for design of multi-band WLAN antenna have been used in [1]–[4]. However, the design compactness was reduced with the dimension of the antenna (38x34x1.575 mm) and ground size (50x50x1.572 mm). Different techniques for WiMax/WLAN muli-band designs are reported in [2]–[6]. However, these microstrip antennas are not specifically designed for WLAN 802.11ac multi band in which four operating band centers are separated by 0.5-1 GHz. Therefore, one of the design considerations is to suit the required impedance bandwidth necessary for the WIMAX/WLAN multi-band application along by maintaining the proper separation frequency gap between them.

The Impedance bandwidths of an S-shaped multiband microstrip antenna [8] and an E-shaped single-band microstrip antenna [9] are enhanced about >4 % and 24%, respectively, by using open-ended rectangular slots. Compact and broadband design methods of low-profile microstrip antennas have been discussed in [10]. In this paper, the design of a dual-band microstrip antenna for WLAN IEEE 802.11y band application is realized by aggregating two simply designed single-slotted compact microstrip antennas with rectangular ground slot. The ground slot of each single-slotted antenna creates a effect of slow wave and shifted down the 10-dB impedance band to lower frequencies [11]. Parametric study of length and position of each open ended slot on each -10dB impedance band is shown. The proposed configuration was designed and simulated HFSS software.

Manuscript received May, 2016.

Dinesh Pratap Singh, *M Tech Scholar, Department of Electronics and Communication.,*

Virendra Singh, *Asst. Professor, Department of Electronics and Communication Engineering, SIRT, Bhopal*

II. Antenna Design

After the selection of three parameters based on application, i.e. frequency of operation, height of substrate and permittivity of dielectric material, next step is to calculate width and length of the patch.

Step 1: Calculation of Width (W)

$$W = \frac{1}{2f_r\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad 1$$

where, μ_0 is the free permeability, ε_0 is the free space permittivity and ε_r is relative permittivity.

Step 2: Calculation of Effective Dielectric Coefficient (ε_{reff}) the effective dielectric constant is

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}[1+12\frac{h}{W}]^{1/2} \qquad 2$$

Step 3: Calculation of Effective Length (L_{eff})

The effective length is

$$L_{eff} = \frac{C}{2f_0\sqrt{\varepsilon_{reff}}} \qquad 3$$

Step 4: Calculation of Length Extension (ΔL)

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{rff}-0.258)(\frac{W}{h}+0.8)} \qquad 4$$

Step 5: Calculation of Length of Patch (L)

The actual length of radiating patch is obtained by

$$L = L_{eff} - 2\Delta L \qquad 5$$

Step 6: Calculation of Ground Dimensions (Lg, Wg)

$$L_g = 6h + L \ , \ W_g = 6h + W \qquad 6$$

The geometry of each double slotted antenna is formed by stages of modifications. In the first stage, a rectangular microstrip antenna (L_p= 34 mm, W_p=38 mm) is designed to work as reference antenna (Antenna 1) as shown in Fig. 1. The dimension of the substrate is 50x 50 x1.5875 mm, and it is an FR4 epoxy with relative permittivity ε_r=4.4

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and tangent loss = 0.02. Excitation is made through a coaxial core of an SMA connector (inner diameter=1.5 mm and outer diameter=2.5 mm) at 2.45 mm away from the center of the RMSA as shown in Fig. 2. In the later stage, two rectangular open-ended slots L_1 and L_2 of nearly quarter-wave in length at patch resonance are inserted separately inside the RMSA (Antenna 2 and Antenna 3, respectively) as shown in Fig. 3 and 4. It results in enhancement of the multiband of single-slotted RMSAs (Antennas 2 and 3) with respect to Antenna 1.

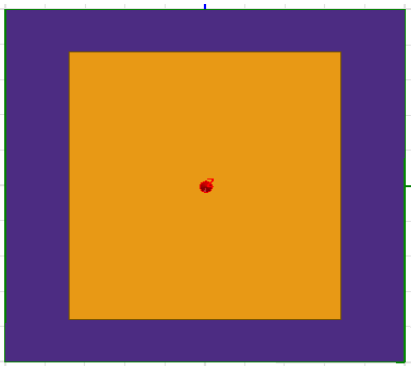

Fig 1(a). Patch Geometry 34 x 38 mm

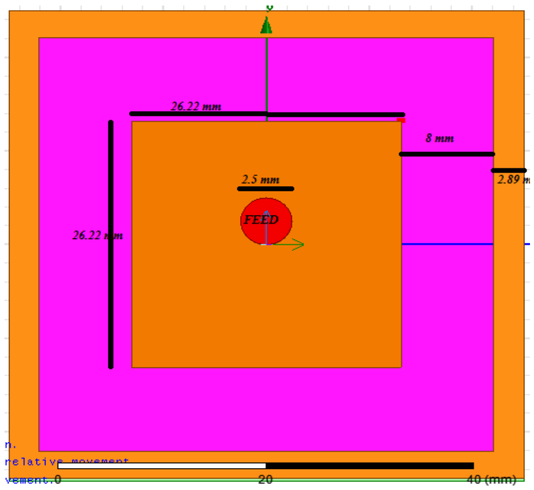

Fig 2. Proposed design for DGS

Center Ground: 26.11 x 26.22 mm

Outer Ring: 2.89 in width at 8 mm from center ground

The ground plane acts as signal return path, and the ground slot creates a discontinuity in the structure as the signal return path and produces a slow wave effect that is responsible to shift down the frequency to lower values. The ground-plane area size is added with DGS with 26.22 x 26.22 mm with Outer Ring 2.89 mm in width at 8 mm from center ground.

Defected ground structure increases the performance of the system by modifying the ground plane metal of microstrip (coplanar or stripline waveguide) circuit intentionally. DGS is formed by etching off a simple shape on the ground plane that is called as "defect". The different dimensions and shapes of the defect customized the shielded current distribution in ground plane that result in the propagation of the electromagnetic waves and controlled excitation through the substrate layer. This modification will also change the other characteristics of a transmission line such as inductance and line capacitance.

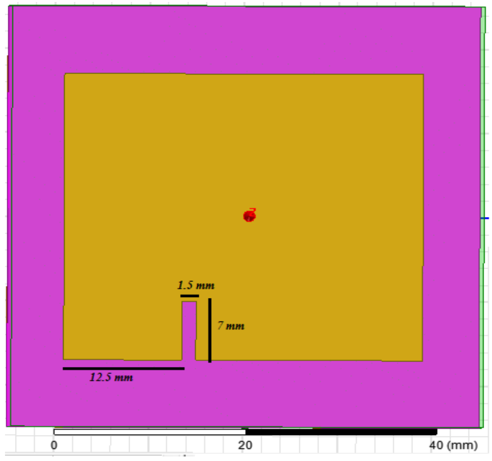

Fig 3 DGS with Slot 1 Antenna 2

Slot 1 dimensions 1.5 X 7 mm from12.5 mm from edge.

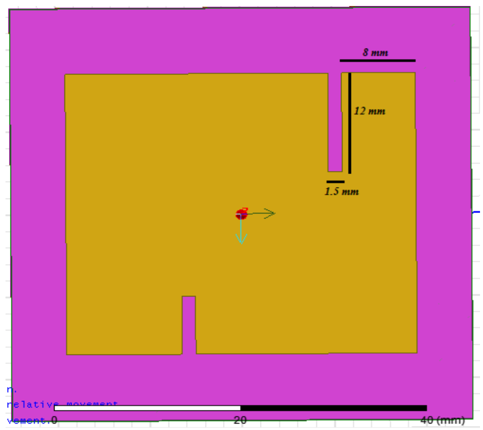

Fig 4 DGS with Slot 2 Antenna 3

Slot 2 Dimensions: 1.5X12 mm, 8 mm from second edge.

In short we find that any defect etched in the ground plane of microstrip can increases the effective inductance and capacitance. The shape of the defect may be varies from the simple shape to the complex shape for the enhanced performance depending on the shape and configuration of DGS. In order to increase bandwidth DGS has been used. DGS is realized by cutting shape from ground plane. Shape can be simple or complex. When DGS has been applied to antenna corresponding inductive part increases and this results in high effective dielectric constant hence bandwidth reduced. It is noted that within particular area of ground different DGS produces different resonant frequencies and bandwidth as well

III. SIMULATION AND RESULTS

The simulated results are shown in Fig 5 for proposed design, i.e., where 4 resonant frequencies 3.75 GHz, 4.06 GHz, 5 GHz and 5.5 GHz can be clearly distinguished. The selection of the dielectric material (here the Dielectric FR_4 Epoxy ε_r=4.4, substrate of thickness 1.575 mm, is used which is common and easily available) is important for the performance characteristics of the patch antenna. Each dielectric material has a specific dielectric constant which affects the output characteristics and desired parameters of the microstrip antenna.

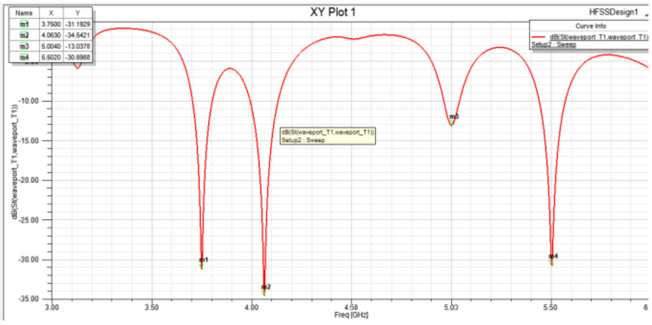

Fig. 5 Return loss vs. frequency for proposed design for Antenna 3.

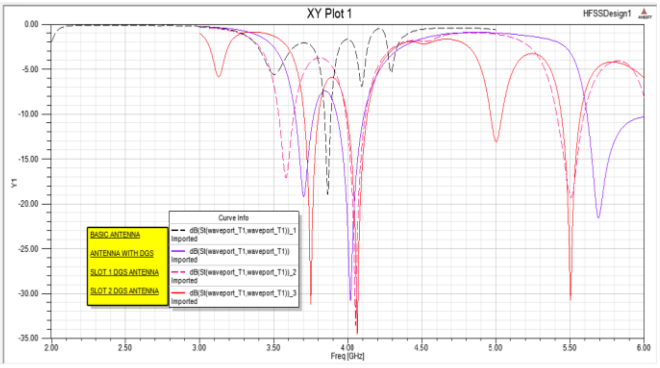

Fig. 6 Combined return loss vs frequency for all the designs.

The antenna simulation software HFSS, simulated all designs of S_{11} are shown in Figure 6, where four operating frequency bands are obtained for the proposed designed antenna. The antenna exhibits the characteristics of the multiband operation, i.e., a measured -23.75 dB S_{11} for 3.6 GHz, -34.54 dB S_{11} at 4.06 GHz, -13.03 dB S_{11} at 5 GHz and -30.69 dB S_{11} at 5.5 GHz, covering the WLAN/WiMax applications. The results of return loss , VSWR, impedance, directivity and bandwidth are given in Table. I

Geometry	Resonant Frequency	Return Loss S_{11} dB	VSWR	Impedance (ohms)	Band width (MHz)
Antenna Basic	3.85 GHz	-18.6	1.35	71.5	50
Antenna DGS	3.69 GHz 4.05 GHz 5.68 GHz	-18.7 -32.82 -20.33	1.2 1.3 1.18	53 51 44	130 190 380
Antenna 2 Single Slot with DGS	3.58 GHz 4.05 GHz 5.5 GHz	-17.01 -32.59 -19.01	1.3 1.04 1.24	33 33 34	110 140 200
Antenna 3 2 Slots with DGS	3.75 GHz 4.06 GHz 5.0 GHz 5.5 GHz	-23.75 -34.54 -13.03 -30.69	1.09 1.04 1.57 1.06	48 49 50 51	100 140 90 130

Table. I Combined results for all design

IV. CONCLUSION

We have designed and simulated multiband microstrip antenna with defect ground structure which has a resonating frequency of 3.75 GHz, 4.06 GHz, 5.0 GHz and 5.5 GHz with return loss of -23.75 dB, -34.54 dB, -13.03 dB and -30.69 dB. This proposed multiband antenna has wide application in WLAN/WiMAX of wireless communication. Further optimizations can be possible to achieve required operating frequencies. This paper presents a geometric configuration for the Microstrip Patch Antenna with defect ground structure for WLAN/WiMAX wireless applications, which provides a mean, to get higher bandwidth and gain without using particular techniques [11].

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