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Performance Analysis of Multiband Microstrip Slotted Antenna with Defected Ground

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ABSTRACT

A multiband slotted and defected ground microstrip patch antenna which operates at more than one frequency has been designed. It effectively tunes at 3GHz, 5.5GHz and 7.8GHz with satisfactory return loss obtained at these resonant frequencies, which is -10.72dB, -13.38dB and -14.55dB respectively. Size of the antenna is going to be compact. The substrate FR4 epoxy (relative permittivity: 4.4) is used in the design of the antenna. Antenna design is proposed in different type of slots such as T-shaped and rectangular-shaped etc. slots in patch. This design can be used for wide range of Wireless applications. For the simulation HFSS is used.

I. Introduction

An antenna is the most vital element of any wireless communication device. Compact antennas with improved performance are required for the Communication devices. This requires the evolution of low profile, lightweight and single feed antennas. The rapid progress in wireless communications requires the antennas that are operating at multiple frequency bands. The possible solution for the above situation is “microstrip patch antennas” as they involved in size reduction of the communication systems. It is easy to integrate the microstrip patch antenna with several RF modules for the different frequencies into one piece of device. Hence, multiband antennas that can be used simultaneously in different applications have been centre of attention of today’s many modern research projects. GSM, UMTS, WIMAX and WLAN etc. are some of the most common wireless applications used by wireless communication devices.

One of the methods to create a multiband antenna is making of slot cuts in the patch surface and ground surface. Multiple frequency bands can be achieved by different shaped slot cuts in the patch. The T, U, E and H shaped slots are commonly used shapes [2]-[3]. Different slot shape has different advantages and uses, some of slots are used to get the multi-band operation and others are used to increase the bandwidth. When we compare non slotted microstrip patch antenna with slotted antenna, the slotted antenna shows the better results such as return loss, bandwidth, gain, directivity etc.

In this paper, performance of the simple rectangular patch antenna with microstrip line feed is analyzed. The slots are made in the patch to obtain multi-band resonance frequencies simultaneously.

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II. Related work

In the past few years many new techniques have been introduced to designing microwave circuits. One of techniques is the Defected Ground Structure (DGS). There are several papers that explain the impact of different slot shapes on the resonance and radiation characteristics of a microstrip patch antenna. A paper [4] published by Gh. Z. Rafi and L. Shafai explain the effect of stacked U-shaped slot patch on the radiation parameters of rectangular U-slot microstrip antenna. These u-shaped slots effectively improve the impedance bandwidth performance of patch antennas. Another paper [11] published by Xiaosheng Guo, Weiwei Liao, Qingfeng Zhang, and Yifan Chen explain the effect of T-shaped slot on the size of the microstrip patch antenna. T-shaped slots are used to decrease the size of the antenna. In this way compactness in design is achieved.

Table1. Dimensions of Rectangular Slots

Structure	X Dimension x Y Dimension		
Slot – 1	1	X	0.3
Slot – 2	0.3	X	5
Slot – 3	0.3	X	7
Slot – 4	0.325	X	6
Slot – 5	0.5	X	10
Slot – 6	0.5	X	5.33
Slot – 7	0.5	X	5.33
Slot – 8	0.75	X	9
Slot – 9	1	x	14

Different dimensions of rectangular slots are made in the patch. On the boundary of the patch, a T-shaped slot has been introduced. The ground has been modified by making a U-shaped slot and two square shaped patches of equal dimensions. In this way a defected ground structure has been placed. The antenna effectively radiates at three frequency bands 3 GHz, 5.5 GHz and 7.8 GHz. Radiation at 5.5 GHz frequency band is due to the defected ground structure. Here the proposed antenna designed using an inset feed. The reason for the inset feed is that it decreases the input impedance. The defected ground structure is effectively involved in enhancing the bandwidth of the antenna which is explained in papers [6]-[9].

III. Antenna Design

The substrate, FR4 epoxy with a dielectric constant of 4.4 used in the designing of antenna and this antenna is designed in the simulation software High Frequency Structure Simulator (HFSS). The substrate height is taken as 1.58 mm. Figure. 1 shows the layout of the patch which consists of 9 different rectangular slots.

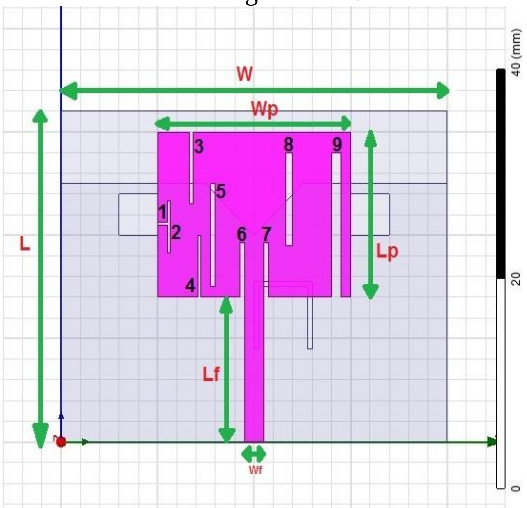

Figure 1. Design of Patch in HFSS

To get the multiple bands the rectangular slots and T-shaped slot are etched in the patch. In this design inset feed is used, shown in Figure 1. Here inset feed is used for proper matching. The Dimensions of feed rectangular patch and the substrate are given in Table II.

Table 2. Dimensions of Antenna.

Structure	Length (mm) x Width (mm)
Feed	L_f x W_f = 14 x 02
Patch	L_p x W_p = 16 x 20
Substrate	L x W = 32 x 40

The rectangular slots are unequal in length. The dimensions of these slots along the x and y axis as labeled in Figure 1, are listed in Table I.

Defected ground structure used in the design of the antenna. This defected ground has a U-shaped slot and two square shaped slots. 2D design of the defected ground structure is shown in Figure 2.

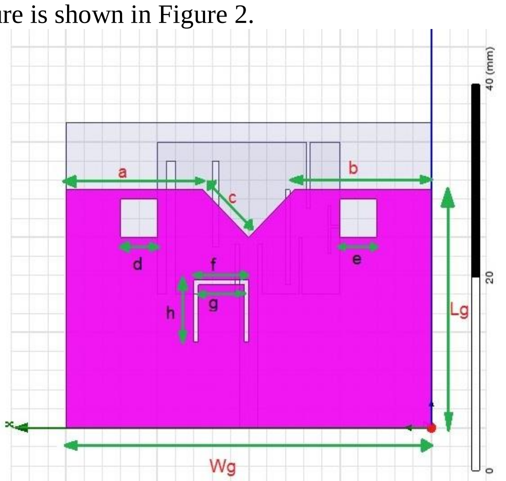

Figure 2. Design of Defected Ground in HFSS

Table III gives the dimensions of the ground plane and its slots.

Table 3. Dimensions of Defected Ground Structure

Label and Value(mm)	Label and Value(mm)
L_g = 25	d = 4
W_g = 40	e = 4
a = 15	f = 6
b = 15	g = 5
c = 5	h = 6.5

IV. Results and Discussion

Figure 3 shows simulated return loss (S11)

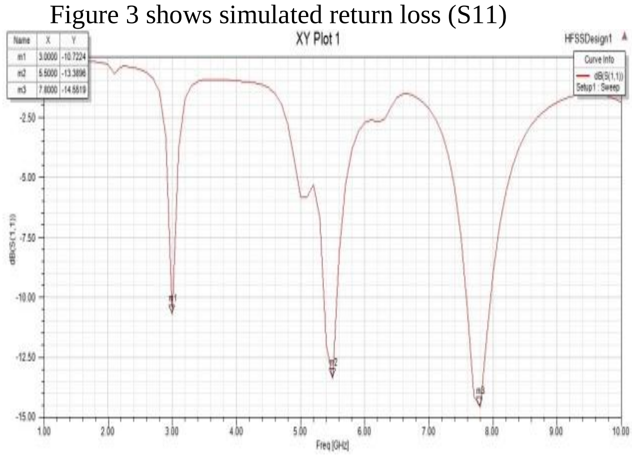

Figure 3. Simulated and Measured S11 (dB) Results versus Frequency (Hz)

The simulated results in the figure show that the return loss at 3 GHz, 5.5 GHz and 7.8 GHz -10.72dB, -13.38dB and -14.55dB, respectively. The return loss is below -10 dB for the three desired frequencies. The return loss for the corresponding frequencies is given in table IV. This shows that the antenna is radiating working efficiently.

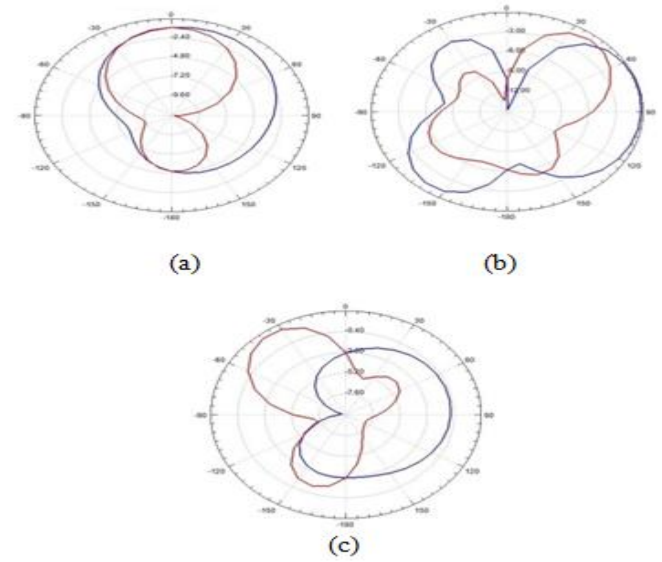

Figure 4. Antenna Gain Plots at (a) 3GHz (b) 5.5GHz and (c) 7.8GHz (The red represents phi=0deg and the purple line represents phi=90deg

The radiation patterns at 3 GHz, 5.5 GHz and 7.8 GHz are shown in Figure 4. The antenna is much restricted to a one direction at 3 GHz. If we observe the radiation Patterns at 5.5GHz and 7.8 GHz, a deviation from the directional pattern of 3 GHz is observed. At 5.5 GHz and 7.8 GHz a multi-directional pattern is observed. The slot etching in the patch is responsible for this multi-directional pattern. The slots in patch change the current path on the patch, as a result of this the antenna gives different radiation pattern. Figure 5 shows the surface current distribution at the resonant frequencies. It shows the surface current density plotted on ground and the patch surfaces for all desired frequencies. A rainbow based scheme is used to depict the structural areas responsible for the generation of three different bands. In Figure 5, orange or red color represents the strong radiating areas whereas the least radiating structural indicated in blue color

Table 4. Return Loss (S11) Results.

Resonant Frequency	Return Loss
3 GHz	-10.7224 dB
5.5 GHz	-13.3896 dB
7.8 GHz	-14.5519 dB

The current density patterns at frequency 3 GHz are given in Figure 5 (a). It is observed that the maximum current is concentrated on the edges of the rectangular slots because these edges are marked red. The resonance and radiation at 3GHz is based on the dimensions of these slots, whereas the defected ground structure has triangular groove which plays important role at the 3 GHz frequency.

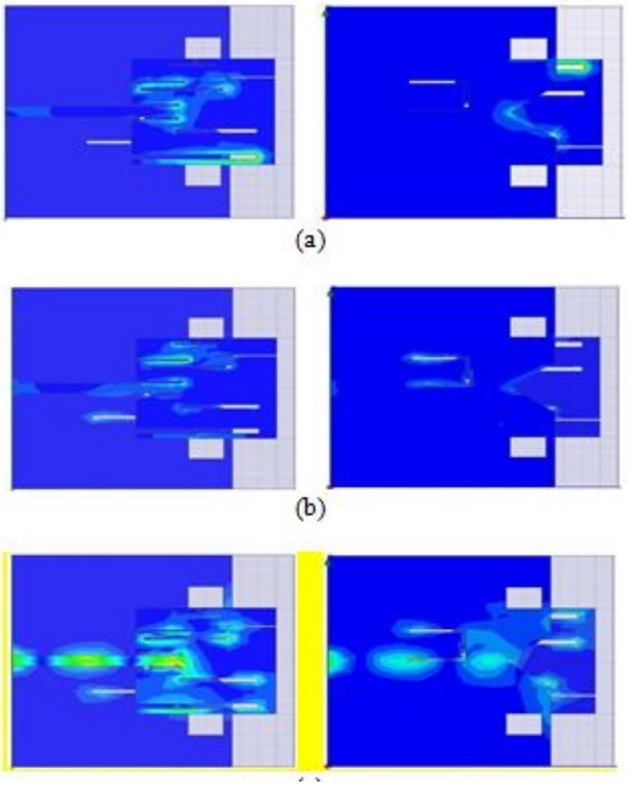

Figure 5. Surface Current Density J (A/m) of Patch and Ground at (a) 3GHz (b) 5.5GHz and (c) 7.8GHz.

The current density patterns at 5.5 GHz given in Figure 5 (b). Here the T-shaped slot in the patch help in the resonance and radiation of 5.5 GHz frequency band. The defected ground structure which has U-shaped slot is mainly responsible for resonance and radiation of 5.5 GHz frequency band.

The current density patterns at 7.8 GHz given in Figure 5(c). Here the patch which has different rectangular slots along with the defected ground structure which has U-shaped slot is responsible for the resonance and radiation of 7.8 GHz frequency band. In this way the structural areas generating the different frequency bands of the designed antenna have been analyzed.

V. Conclusion

Analysis of a slot antenna for multiband operation is presented. Rectangular and T-shaped slots are introduced on the patch and Square and U-shaped slots on ground are used for designing the proposed antenna. The defected ground structure is effectively involved in the multiband operation of the antenna. The presented antenna effectively tunes at three different frequencies such as 3GHz, 5.5GHz and 7.8 GHz. The presented antenna can be used in many applications such as WLAN and WiMAX and also can be used in devices that support more than one frequency band operation.

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