Design and Simulation of an Improved Multiband Microstrip Slot Patch Antenna Used in Wireless Applications

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ABSTRACT

Antennas play very important role in the performance and consistency of any wireless communication system. In this work we have design, investigate, and optimize the various parameters as well as the bandwidth of a multi-band microstrip antenna using different positions of slot patch and defected ground plane structures (DGS) techniques. A Roger RT/ duroid 5880 substrate with dielectric constant 2.2, and ground plane with an area of 80mm×90mm have been chosen for operation at three different frequency bands centered at (2.30-2.7) GHz, (4.0-4.7) GHz and (5.2-5.8) GHz. The operation scope of the proposed structures is intended to work for WLAN, IMT (International mobile telecommunications) and WiMAX applications. Ansoft-High Frequency Structured Simulation package (Ansoft-HFSS) has been used as realization software of the proposed antennas.

1. INTRODUCTION

The microstrip patch antenna is the key building element in wireless communication and Global Positioning system nowadays since it was first demonstrated in 1886 by Heinrich Hertz and its practical application by Guglielmo Marconi in 1901. The most of the recent trend in communication industry is towards compact devices [1]. Wireless communication technology has changed and expanded at an incredible rate particularly within the latest ten years. Moreover, the demand for wireless communication services has increased due to the fast growth of wireless technology and new revolutionary applications. Since antenna is the milestone of most wireless communication without which the term could have not reached this age of technology, Patch antennas play a very significant role in this kind of applications due its simplicity, compatibility, and easiness of fabrication. It can take any shape and be fed through different schemes.

Multi-band wireless communications present a fundamentally different approach to wireless communications compared to conventional narrowband systems. Global interest in the technology is huge. The need for multi-band operation techniques has piqued a surge of interest in antenna design by providing new challenges and while maintaining high gain, high radiation efficiency and good axial ratio over a desired frequency range. In a multipath rich wireless channel, deploying multiple antennas at both the transmitter and receiver achieves high data rate without increasing the total transmission power [3]. The IEEE 802.11 standard was proposed in 1997 for WLANs application. After few years new standard was proposed, operating on the 2.4 GHz ISM band (2.4 - 2.484 GHz), is called 802.11b or 802.11 HR (High Rate), which provides a data rate up to 11 Mbps. The IEEE 802.11y standard was approved in 2008, operating on the 3.6 GHz frequency. The change of band shows that 802.11a and 802.11b products are not compatible. Therefore, the IEEE proposed 802.11g standard which is compatible with both 802.11b and 802.11a technology. The 802.11g standard was accepted in 2003, so a dual and Tri-band antenna is a requirement for WLAN applications [4]. For obtaining multiband and wideband characteristics different techniques have been used like cutting a slot in the patch, fractal geometry and DGS (Defected Ground Structure). DGS can be realized by cutting a shape from the ground plane. The shape can be simple or complex. When DGS has been applied to antenna equivalent inductive part get increased and this cause high effective dielectric constant hence bandwidth reduced [7].

2. ANTENNA STRUCTURE

This design includes two techniques, where the microstrip patch antenna consists of a U- slot in the patch element and defected ground structure techniques, the capacity of generating three separate bands with good impedance matching conditions. This work is divided into three parts; where the first part consists of convention rectangular microstrip antenna with operation frequency at 2.4GHz, then in the second part a

U-slot is added in patch antenna to get multiband frequency. The third includes a (DGS) technique into the 'U' shaped microstrip antenna.

2.1. Conventional Microstrip Antenna Design

The microstrip patch antenna design use rectangular patch shape with use Rogers RT/duroid 5880(mt) substrate having dielectric constant of $\varepsilon_r = 2.2$ feeding by microstrip method with input impedance of 50Ω. The other parameters as shown in table [1].

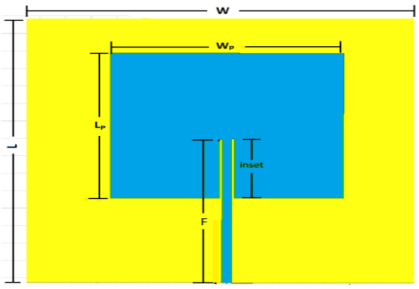

Fig.1: The structure of a normal conventional patch antenna

TABLE 1: Parameter of the proposed MSA

Parameter	Value
Frequency	2.4GHZ
Substrate material	Rogers RT/ duroid 5880(mt)
Height of the substrate	1.9
Material of the patch	Copper
Width of substrate (w)	80
Length of substrate (L)	90
Patch width (Wp)	45
Patch length (Lp)	41.5
Thickness of the ground	0.2

Figure 2 Shows results of return loss at 2.4 resonant frequency for a conventional microstrip patch antenna.

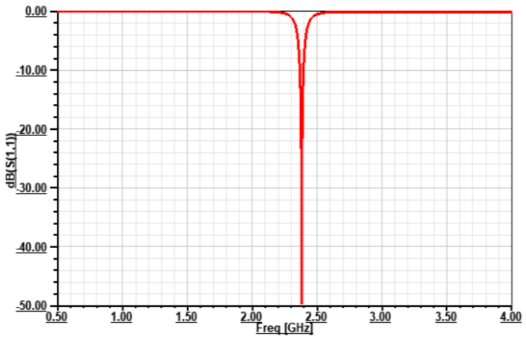

Fig.2: Return loss (S_{11}) of conventional microstrip patch antenna at 2.4 GHz.

Figure 3 depicts a total gain of the conventional microstrip patch antenna.

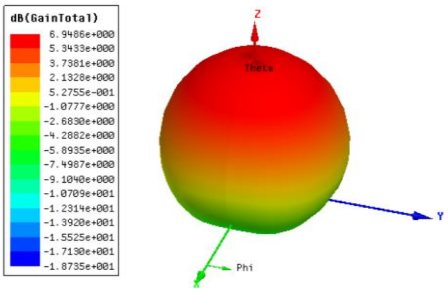

Fig.3: 3D Radiation pattern of designed normal conventional patch antenna at 2.4 GHz

2.2. Proposed Design Structures

2.2.1. U-Slot Shape Structure with DGS

This section describes the microstrip patch antenna with U-slot technique on the main patch with one cut on the ground plane. This divides the latter into parts which help the whole proposed antenna structure to work for triple band mode; in the range of operating frequencies and band limits between 2.4GHz till 5.8GHz.
The proposed antenna, shown in fig.4 has the same configuration of the achieved design in the first part with the addition of U-slot on the rectangular patch and cut on the surface of the ground plan (DGS)on the antenna.

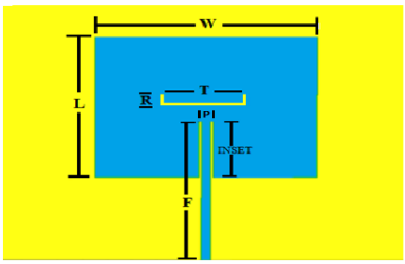

Fig.4: The geometry of the top view of U-slot microstrip antenna

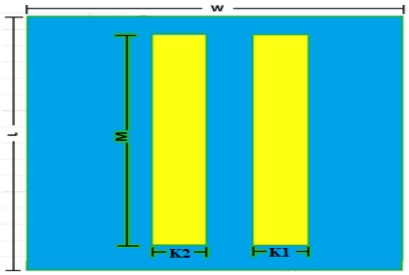

Figure 5: The structure and dimensions of back view with DGS

The configuration of proposed triple-band microstrip patch antenna with DGS are summarized in the table (2) below.

TABLE 2: Dimensions of the proposed U-slot with (DGS) microstrip antenna

Parameter	Value (mm)	Parameter	Value (mm)
F	16.78	V	5
Inset	1.9	R	1.5
A	24.25	T	20
K1	9	M	78
K2	9		

2.2.1.1. Simulation and Results

Figure 6 and table 3 below shows given results stages of improvements in the antenna performance. By explaining the effect of DGS by each cut on the surface of the ground plan uses HFSS.13 software to calculate values of bandwidth and return loss at each stage. The location of the cuts has been optimized using the optimization feature in the simulation program to get the best result.

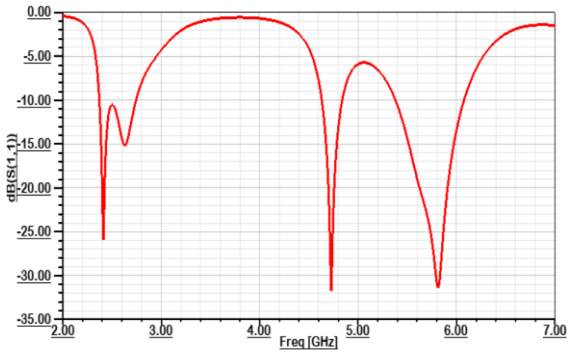

Fig.6: Simulated return loss of proposed U-slot and DGS microstrip antenna With Tri-resonant frequency

TABLE 3- Parameters values of triple-band antenna with U-Slot and DGS

f (GHz)	BW (MHz)	RL (-dB)	Gain (dB)	Efficiency (%)
2.4	377	25.91	5.35	98.04
4.7	211	31.6	5.35	
5.8	703	31.32	5.35	

2.2.2. E-Slot Shape Structure with DGS

This part of design is based on adding slot E-shape in center of rectangular micro-strip patch antenna and add (DGS) technique by cutting three pieces of ground plane. In the model that was designed in the previous part, the slot that using working on to change of the disruption of current in the patch to achieve triple-band operation at 2.4GH,4.7GH and 5.8G.

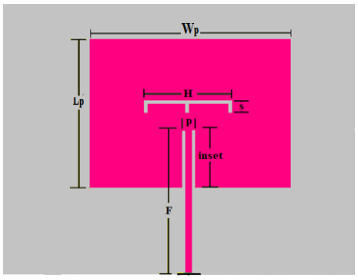

Fig.7: The geometry of the top view E-slot microstrip antenna

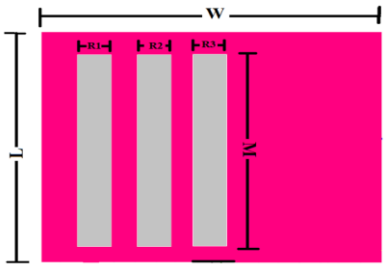

Fig.8: The structure and dimensions of back view with DGS cuts

TABLE 4: Dimensions of the proposed E-slot with (DGS) microstrip antenna

Parameter	Value(mm)	Parameter	Value(mm)
F	16.78	V	5
Inset	24.25	N	0.3
A	1.9	T	0.2
R1	9	M	78
R2	9		
R3	9		

2.2.2.1- Simulation and Results:

Fig.9 shows results and achieved improved antenna by using DGS. Each cut on the surface of the ground plan was arranged by HFSS13 package by calculating values of bandwidth and return loss for each stage. The location of the cuts has been optimized using the same package to get acceptable results.

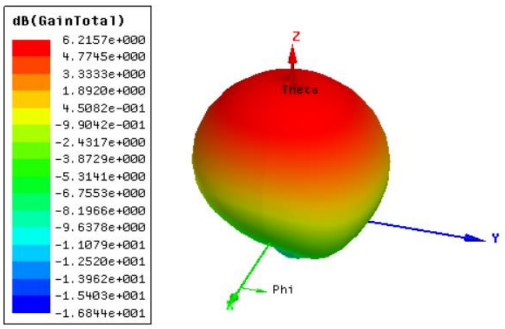

Figure 9: Simulated Return-Loss of the proposed antenna with E-Slot and DGS

TABLE 5: Parameters values of triple-band antenna with E-Slot and DGS

f (GHz)	BW (MHz)	RL (-dB)	Gain (dB)	Efficiency (%)
2.4	61	22	6.215	97.55
4.7	175	33	6.215	
5.8	688	50	6.215	

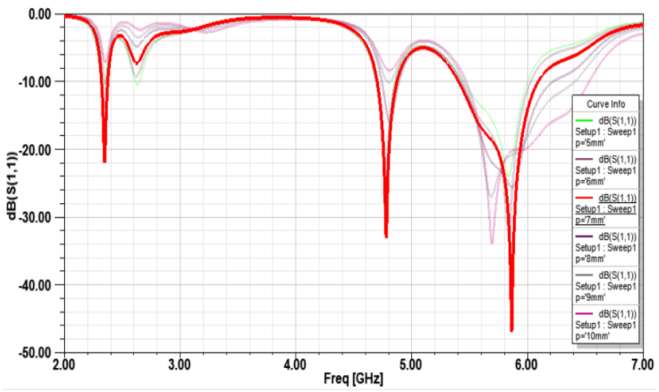

Fig.9: 3D Radiation Pattern Gain of Microstrip antenna with E-slot &DGS.

2.2.3. H-Slot Shape Structure with DGS

This design focus on adding slot H-shape in center of rectangular micro-strip patch antenna in the model that was designed in the first part. The slot used to change the disruption of current in the patch antenna with added Defected Ground Structure (DGS).

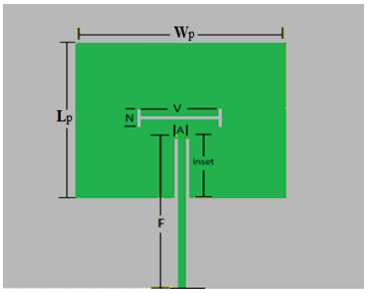

Fig.10: The geometry of the top view H-slot microstrip antenna

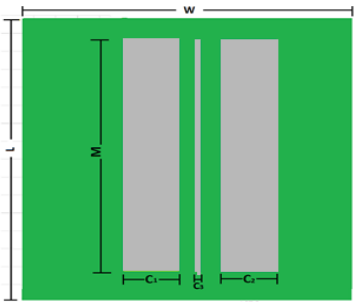

Fig.11: The structure and diminution of back view with DGS

TABLE 6: Dimensions of the proposed H-slot with (DGS) microstrip antenna

Parameter	Value(mm)	Parameter	Value(mm)
F	16.78	V	5
Inset	24.25	N	1
A	1.9	T	0.2
C1	9	M	78
C2	9		
C3	1		

2.2.3.1- Simulation and Results:

Fig.9 and table 5 shows results and achieved improved antenna by using DGS. Each cut on the surface of the ground plan was arranged HFSS13 package by calculating values of bandwidth and return loss for each stage. The location of the cuts has been optimized using the same package to get acceptable results.

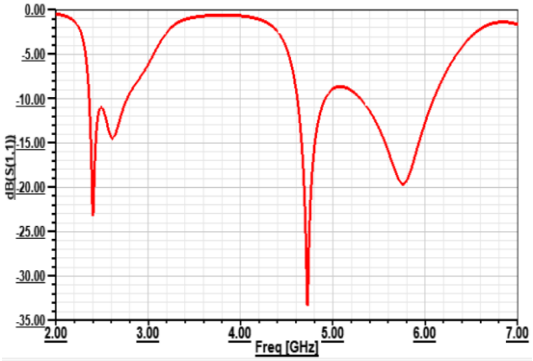

Figure12. Simulated Return-Loss of Microstrip antenna with H-slot &DGS

TABLE 7: Parameters values of triple-band antenna with H-Slot and DGS

f (GHz)	BW (MHz)	RL (-dB)	Gain (dB)	Efficiency (%)
2.4	400	23.2	5.35	98.11
4.7	303	33.2	5.35	
5.8	783	19.5	5.35	

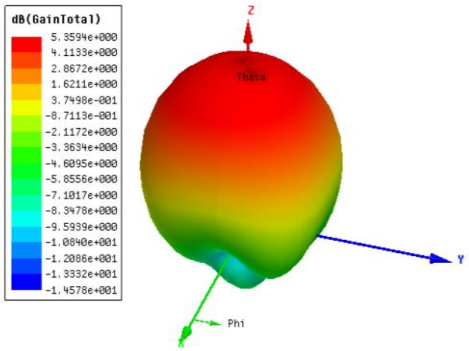

Figure13. 3D Radiation Pattern Gain of the proposed microstrip antenna with H-slot &DGS

3. CONCLUSION

A conventional structure of a microstrip antenna has been designed and tested to perform different techniques toward improving RL and BW.
U, E, and H cuts on the patch have been tested and results are very encouraging for better bandwidth with acceptable return loss.
The obtained design with it varieties gives valuable chance to be applied in wireless applications

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