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Design a U-sloted Microstrip Antenna for Indoor and Outdoor Wireless LAN

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ABSTRACT

The main objective of this paper is to design and optimize the probe fed Microstrip patch antenna and to improve the parameters such as VSWR bandwidth. In this paper, the wideband characteristics for patch antenna are achieved by using substrate thickness variation techniques. The patch antenna using probe feeding method is designed for three substrate thickness values such as 3.2 mm, 1.6 mm and 0.8 mm. Parameters such as VSWR bandwidth is compared for all the antennas. The Patch antenna with probe feed is simulated using IE3D simulator for 900 MHz resonant frequency with acceptable VSWR value of 2 and linear polarization is achieved. The simulation of antenna is done using dielectric material FR4 with dielectric constant of 4.4. The U-Slot embedded on a patch antenna of substrate thickness 1.6 mm also achieves the required bandwidth. The designed antenna can be used for indoor and outdoor wireless LAN.

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INTRODUCTION

In the past few years, the concept of creating microwave antennas using microstrip has gain much attention and possible practical designs are now emerging. Microstrip patch antennas have gained popularity in today's world of wireless technology due to its many advantages such as low-profile, low cost, ease of integration with other components, mechanically robust and simple to fabricate. However the main drawback with microstrip antennas lies in its narrow bandwidth. Microstrip patch antenna is a type of open wave guiding structure, which consists of a radiating patch on one side of a dielectric substrate and a ground plane on other side (Rashid A. Saed and Sabira Khatun, 2005; Bahl, P. Bhartia, 1980; Kin-Lu Wong, 2002). A patch antenna is a narrowband antenna fabricated by etching the antenna element pattern in metal trace bonded to an insulating dielectric substrate with a continuous metal layer bonded to the opposite side of the substrate which forms a ground plane. Recently many methods and vary shapes are suggested to designing a microstrip antenna are given in (Mak, C.L., K.M. Luk, 2000; Shan-Cheng Pan, Kin-Lu Wong, 1997; Roy, J.S., 2007 Jolani, F., A.M. Dadgapur, 2008; Tlili Boutheina, 2009). Design of Coaxial fed microstrip antenna for LEO satellites are discussed in (Nazifa Mariam, 2008). Effects Of Ground Plane Size On a Square microstrip patch antenna designed on a low- permittivity substrate with an air gap is discussed in (Minh Tuan Nguyen, 2010).

2. Design of Proposed U-Slot Patch Antenna:

The procedure for designing the microstrip patch antenna has been discussed below. The transmission-line model is employed to design the required microstrip patch antenna.

2.1. Design Specification:

The three essential parameters for the design of a rectangular microstrip patch antenna are, Frequency of operation (f_r), Dielectric constant of the substrate (ϵ_r) and Height of the substrate (h).

2.2 Design Equations:

The following Table 1 shows the design equations for proposed U-Slot microstrip patch antenna.

2.3 Bandwidth Enhancing Techniques:

The patch antenna is one of the main components for portable wireless devices because of its low profile, light weight and low cost. However, the requirement of frequency bandwidth is becoming greater in present wireless communication systems. This contradicts the inherent narrow impedance

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bandwidth (BW) of patch antennas. Hence many researchers are focusing on the development of impedance bandwidth enhancement techniques for patch antennas. These techniques include the employment of thickness of substrate, selection of suitable patch shape, using parasitic elements, stacked elements, impedance matching and U-shape slot patch. In this paper we used U-Slot patch for enhancing bandwidth**.**

Table 1: Design Equation s for Proposed U-Slot Antenna.

Parameters	Equations	Design Parameters		
		Substrate Heights (mm)		
		0.8	1.6	3.2 m
Width of the Patch	$W = \frac{C}{2f_r}\sqrt{\frac{2}{\epsilon_r + 1}}$	101.4	101.4	101.4
Effective dielectric constant	$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2}$	4.324	4.26	4.16
Length of the Patch	$L = \frac{C}{2f_r\sqrt{\epsilon_{eff}}} - 2\Delta_L$	79.4	79.2	78.93
Length Extension of Patch	$\Delta L = 0.412h\frac{(\epsilon_{eff} + 0.3)(W/h + 0.264)}{(\epsilon_{eff} - 0.258)(W/h + 0.8)}$	0.37	0.698	1.391
Length of the Ground Substrate	$L_g = L + 6h$	84.20	88.2	96.93
Width of the Ground Substrate	$W_g = W + 6h$	106.2	110.	119.4

Where C = 3x 10^8 m/s (free space velocity)

f_r = resonant frequency (900MHz)

ϵ_r = Dielectric constant of the substrate

A wideband patch antenna is designed by cutting U-slots on the patch. It is firmly established that U-slot patch antenna can provide impedance bandwidth in excess of 30% for air substrate thickness in excess of 20% for microwave substrates of similar thickness. U-slot was also applied on planar ultra wideband antennas to introduce band notch for minimizing interference. However in microstrip patch antennas, U-slot was mainly proposed for bandwidth enhancement rather than introducing band notch.

U-slot technique can also be used to design patch antennas with dual and multi-band patch antenna using the L-probe feeding technique. By cutting U-slots in the patch, notches are introduced within the matching band, resulting in multi-band operation. Slot loaded technique is proposed in this paper for broadband antenna design. Slot plays an important role to control the wideband behaviour of the antennas. There are three parameters to characterize the slots, namely slot length, slot position and slot width. When the slot is small, the antenna has one resonant frequency, when the slot length increases another higher resonant frequency appears.

To counteract the inductance introduced when using a thick substrate, capacitance can be introduced by adding a concentric annular gap around the probe feed resulting in 16% bandwidth. The U-slot patch antenna consists of probe fed rectangular patch with U-shaped slot. The U-slot introduces a capacitance allowing the use of thick substrate and induces second resonance near the main resonance of the patch. The rectangular U-slot patch antenna has an average gain of 7 dBi and good pattern characteristics.

2.3.1Proposed U-Slot:

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Table 2: Proposed U-Slot Antenna Dimension.

Parameters	Dimensions
Length of the Patch	120mm
Width of the Patch	147mm
Thickness of Patch	1.6mm
Length of U-slot	73.5mm
Width of U-slot	60mm
Length of ground substrate	129.6mm
Width of ground substrate	156.6mm

3. Simulation of Proposed Microstrip Patch Antenna:

The derived equations, developed by observing the RF current paths on a patch antenna, were used as starting points for the U-shaped patch antenna design. Numerous rounds of simulations were performed for optimizing the design , the IE3D three-dimensional (3D) electromagnetic (EM) simulation software from zeland software was used in modeling the patch antenna, each simulation run required about 30 minutes with good accuracy on a standard personal computer (PC). The U-shaped patch antenna's radiation pattern with the directional pattern typical of patch designs is generated. Simulated maximum antenna gain is close to 20 dBi. Because of its compact size, generous bandwidth and high gain, the U-shaped patch antenna is well suited for point-to-point applications in WLAN systems.

3.1 Design of U- Slot Microstrip Patch Antenna:

The antenna structure in Fig 1 consists of a rectangular patch dimension W × L. This proposed patch antenna is designed using probe feeding method also designed for three substrate thickness values such as 3.2 mm, 1.6 mm and 0.8 mm. In first step single patch rectangular microstrip antenna is design without cutting any slots.

The following procedure describes the steps to construct the geometry of the rectangular microstrip antenna and to obtain the result using the simulation software IE3D. By knowing the Length (L), Width (W) and feed point (X^0, Y^0) of the rectangular microstrip antenna for the specified frequency and substrate material, the geometry of the antenna is constructed in the simulation software IE3D and the simulated results are obtained. On the IE3D, a structure is described as asset of polygons, and a polygon is described as a set of vertices.

RESULTS AND DISCUSSION

The results and discussion are divided into two parts which consist of parametric study, and experimental results and discussion. In Section 3.1, parametric study including the simulated results of return loss, radiation patterns and efficiency of the proposed antenna will be discussed. On the other hand, Experimental results are presented in Section 3.2 where the measured results of the fabrication antenna and the simulated results are compared and discussed.

4.1Parametric Study:

Using the Zeland's IE3D software, the antennas were designed and the parameters like Radiation Pattern, Return Loss, and VSWR are studied. An antenna radiation pattern is a 3D plot of its radiation far from the source. It usually takes two forms, the elevation pattern and the azimuth pattern. The elevation pattern is a graph of the energy radiated from the antenna looking at it from the side. The azimuth pattern is a graph of the energy radiated from the antenna looking at it from directly above the antenna.

Return Loss is the ratio, at the junction of a transmission line and terminating impedance or other discontinuity, of the amplitude of the reflected wave to the amplitude of the incident wave. It describes the reduction in the amplitude of the reflected energy, as compared to the forward energy. Standing Wave Ratio (SWR) is the ratio of the amplitude of a partial standing wave at an antinode (maximum) to the amplitude at an adjacent node (minimum), in an electrical transmission line. The SWR is usually defined as a voltage ratio called the VSWR, for Voltage Standing Wave Ratio.

From the investigated design parameters, two of them have a very obvious effect in determining the performance of the antenna. The parameters that show the most effect on H. In order to check the changes of the frequencies shift or bandwidth changes, parametric studies for each parameter have been optimized and obtained from the simulation of different height substrate as shown in Fig 2.3 and 2.4. These figures show the difference in the return losses according to substrate height changes. These effects will be explained and summarized in this section. In figure 4, it shows the return loss based on variation in the substrate height of the U-slot (h) from 0.8 mm to 3.2 mm.

However, there is a noticeable change on the bandwidth is given in Table 3. From the simulation results the return losses varies from -22 dB to -22.9dB according to substrate height changes from 0.8 mm to 3.2mm dB. Not only that, but also the resonant frequency moves to the lower band due to the increase in the substrate height. The good characteristic of the return loss and the bandwidth is obtained when (H) is 3.2 mm. As a result, the antenna can be easily constructed on any other band by choosing the appropriate width and height for U-slots. The radiation patterns at 900MHz frequency of indoor and outdoor applications are plotted as 2(d), 3(d) and 4(d). From the radiation patterns it can be observed that there is a stable response throughout the WLAN bands with -22dB, -15dB and -14 dB for various thicknesses respectively.

4.1.1Patch Antenna with Substrate Thickness of 0.8 mm:

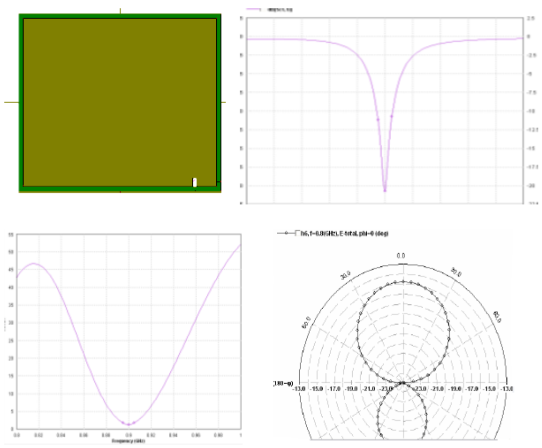

Fig. 2: (a) Simulated MGRID Geometry of Patch Antenna (b) Simulated return loss characteristics of the proposed antenna with change in frequency (c) Simulated VSWR characteristics of the proposed antenna with change in frequency (d) Simulated radiation pattern.

4.1.2 Patch Antenna with Substrate Thickness of 1.6 mm:

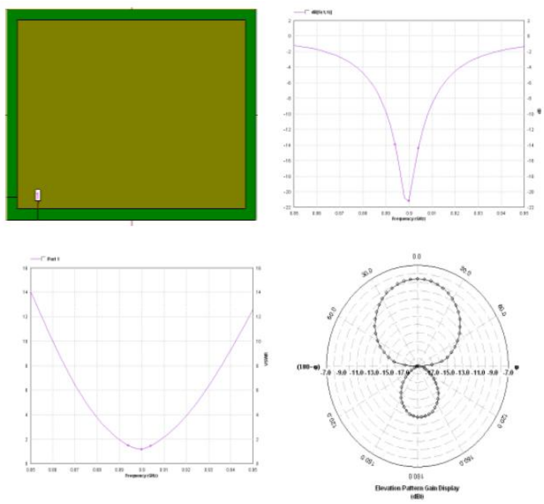

Fig. 3: (a) Simulated MGRID Geometry of Patch Antenna (b) Simulated returns loss characteristics of the proposed antenna with change in frequency (c) Simulated VSWR characteristics of the proposed antenna with change in frequency (d) Simulated radiation pattern.

4.1.3 Patch Antenna with Substrate Thickness of 3.2 mm:

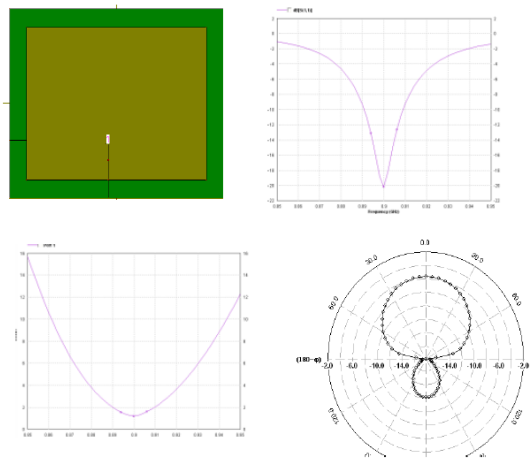

Fig. 4: (a) Simulated MGRID Geometry of Patch Antenna (b) Simulated returns loss characteristics of the proposed antenna with change in frequency (c) Simulated VSWR characteristics of the proposed antenna with change in frequency (d) Simulated radiation pattern

4.1.4 Simulated Result for U-Slotted Antenna:

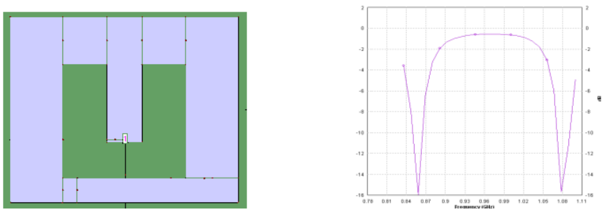

Fig. 5: (a) MGRID Geometry of U-Slotted Patch Antenna (b) Return Loss Vs Frequency.

Table 3: Output Parameters of IE3D Simulation for U-slotted Antenna.

Thickness in mm	3.2	1.6	0.8
Bandwidth in MHZ	21	17	13
Frequency in GHZ	900	900	900
Probe Feed Point	(39,-39)	(-42,-34)	(-5,-18.6)

The following Table 3 shows the Output Parameters of IE3D Simulation for U-slotted Antenna.

4.2 Experimental Results and Discussion:

In order to validate the simulation results from IE3D software, the proposed antenna has been fabricated according to the specifications given in the previous section. Figure 7 (a) 8(a) and 9(a) shows the prototype of the antenna with various thicknesses. The proposed antenna was fabricated, tested, and compared with simulated results. The return loss was measured using Agilent N5230A vector network analyzer. In figure 7 (b), 8(b) and 9(b) shows the measured values of the S11 in the final design are compared with the simulated data. Fig 10(a) and 10(b) shows the fabricated U-slot antenna and return loss. It was found that the simulated and measured results were in good, confirming that the simulated results were obtained with reasonable accuracy. The difference between the simulated and measured results might be attributed to the fabrication process.

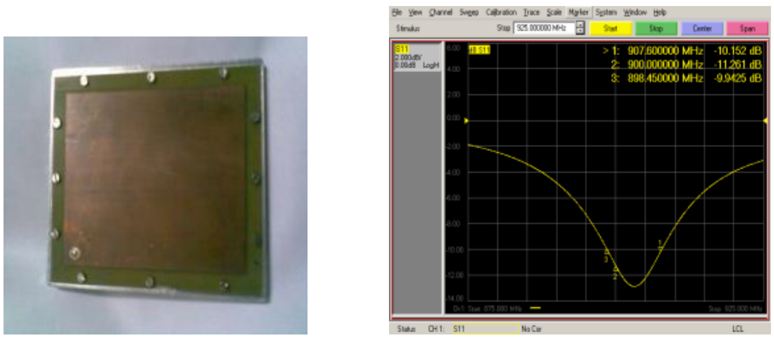

Fig. 7: (a) Fabricated Patch Antenna for Substrate Thickness H =0.8 Mm and 7(b) Return loss Vs Frequency.

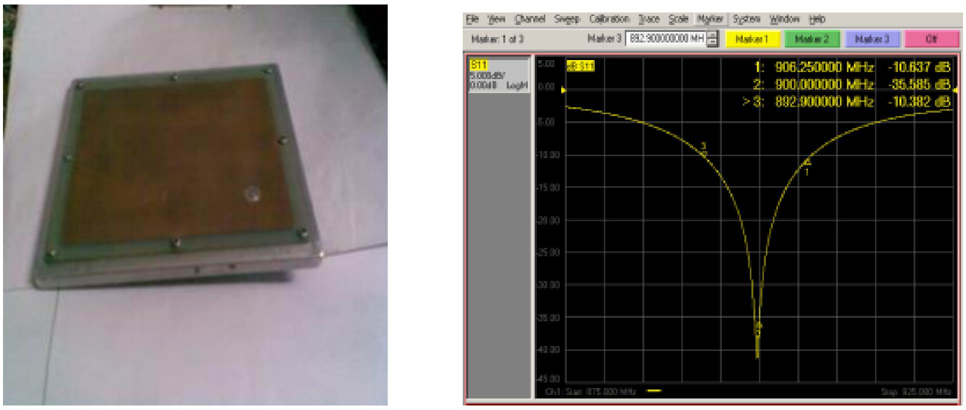

Fig. 8: (a) Fabricated Patch Antenna for Substrate Thickness H = 1.6mm and 8(b) Return Loss Vs Frequency.

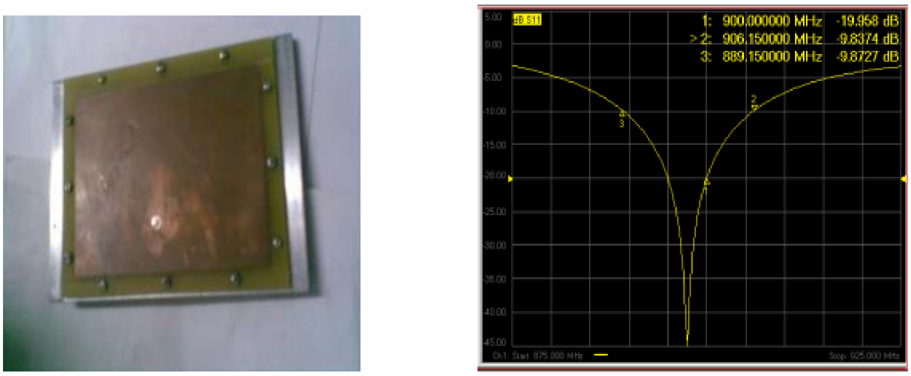

Fig. 9: (a) Fabricated Patch Antenna for Substrate Thickness H = 3.2mm and 9(b) Return Loss Vs Frequency.

4.2.1 Measured Result for U-Slotted Antenna:

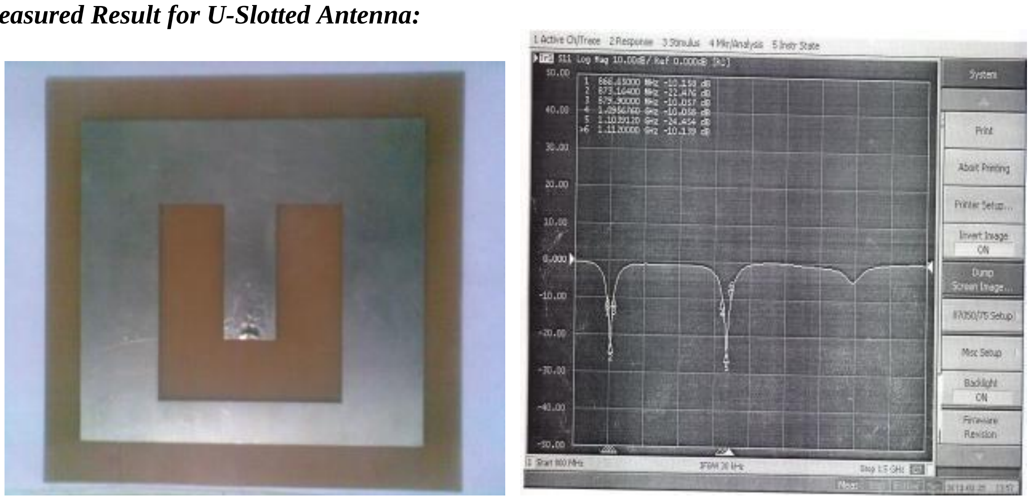

Fig. 10: (a) Fabricated U-Slot Antenna and 10(b) Return Loss Vs Frequency.

The following Table 5 shows the comparison of measured and simulated operating frequencies with their bandwidths U slotted antenna.

5. Conclusion:

The various aspects associated with the design of a rectangular coaxial fed patch antenna with IE3D simulation procedures are explained .With the help of simulation and measured results; it is proved that the bandwidth increases as the substrate thickness of patch antenna increases. The U-slots are incorporated on a patch antenna to achieve a required bandwidth. The U-slotted patch is a popular design where the resonant slot is bent to U-shape and placed on the patch thereby obtaining a wideband operation with single-layer substrate.

Table 5: The measured and simulated operating frequencies with their bandwidths.

Parameters	Simulated Result			Measure Value		
	Thickness (mm)			Thickness(mm)		
	0.8	1.6	3.2	0.8	1.6	3.2
Bandwidth in MHz	13	17	21	9	13	17
Return Loss in dB	-22	-22.3	-22.9	-22	-40	-45
Frequency MHz	900	900	900	895	898	898

In this paper, patch antenna for three substrate thickness and U-slot incorporated on a rectangular patch is designed and fabricated. The impedance bandwidth of this antenna can be improved by selecting the proper dimensions of the rectangular slot and choosing the optimal values. An impedance bandwidth of 17 MHZ is achieved for the design of Microstrip Patch Antenna having 3.2 mm thickness. The measured results are in good agreement with simulated results. In future U-slot embedded on a Microstrip Patch Antenna of substrate thickness 3.2 mm with shorting pin or shorting wall achieves higher bandwidth with reduced size of Patch Antenna.

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