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Comparative Analysis of Single Slot and U Slot Antennas for Satellite Applications

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ABSTRACT: In this paper, two different slot antennas have been simulated using HFSS software. A basic slot antenna is compared with a U slot antenna. This is done by increasing the number of slots in basic slot antenna. Both the antennas hold their applications in satellite communication. Rogers RT/duriod 5880 substrate is used as dielectric material for the simulation setup. In this research work, we have comparatively evaluated various parameters like return loss, radiation pattern, gain, voltage standing wave ratio (VSWR) and directivity for slot and U-slot antenna.

KEYWORDS: slot antenna, U slot, Multiband, satellite application.

I.INTRODUCTION

In recent years, micro strip patch antenna have been one of the most explorable and groundbreaking idea in antenna theory. The thought of micro strip patch antennas dates back about 56 years in the U.S.A by Deschamps and in France by Gutton and Baissinot [1]. And in today's scenario, need for micro strip antennas gaining much attention in wide range of multifunctional wireless communication systems such as satellite, radar, wireless local area network (WLAN) and biomedical telemetry systems [2-4]. The micro strip antennas radiating patch can be of circular, triangular, square, and rectangular shape. And out of these shapes the rectangular patch is by far used to the highest degree. Although it is easy to examine by transmission line model. Therefore the Single band patch antenna can be recast into a dual band, triple band or multiband antenna by introducing slots in the patch at appropriate position. The shape and position of the slots plays a crucial role in determining the resonance frequency. When the slot is cut either at a suitable position inside the patch, it stimulate the another mode near the fundamental mode of the patch and that gives us dual or multi frequency response [5]. Antenna is the most essential component of the integrated low-profile wireless communication systems; therefore, miniaturizing antenna is necessary to achieve the optimal design in order to have optimum radiation pattern, high gain and better efficiency. Some wireless applications of antennas crave for operating concurrently for Wireless LAN, Worldwide Inter-operability for Microwave Access (WiMAX) and some next generation wireless technologies [6-8]. The adaptability of these applications have become possible due to their several interesting features including compact size, low profile, light in weight, planar configuration, ease in fabrication and integration with their microwave components. However there are two major drawback in their applications which are narrower bandwidth and low gain in collation to that of variant Microwave Antennas so by loading U slot in rectangular radiating patch is simple and efficient technique for procuring the desired compactness, multiband and broadband properties since these shapes radiates electromagnetic energy efficiently [9-10].

The basic geometry and configuration of the U-slot antenna was introduced in 1995 by Huynh and Lee as a single-layer, single-patch wideband linearly polarized micro strip patch antenna. Multiband antennas (Lee, Luk, Mak, & Yang, 2011) can submerge numerous wireless technologies; however, in micro strip patch antennas, the U-slot was mainly used for increasing bandwidth rather than introducing a band notch and it has been demonstrated that by introducing U-slot in a micro strip patch antenna dual band and triple-band characteristics can be designed. Therefore it had been manifested in various studies that the U-slot patch antenna can be modeled not only for wideband applications, but also for dual-band and multiple-band applications, as well as for circular polarization operation [11].

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K.F Lee et al [12] presented a method of using U-slots to design dual-band and triple-band patch antennas. So they start with a broadband patch antenna, which can consist of more than one patch. When a U-slot is loaded in one of the patches, a notch is introduced into the matching band, and the antenna behaves as a dual-band antenna. If another U-slot is loaded in the same patch or in another patch, then it results in triple-band antenna. This method is applicable for the L-probe-fed patch, the M-probe fed patch, and also for the coaxially fed and aperture-coupled stacked patches. It is noted that the gain and pattern of the dual band and triple-band antennas are very much similar to those of the original broadband antenna. Amit. A. Deshmukh and K.P Ray [13]. Analyzed that U-slot and its variation, and concluded that a half U-slot, have been used to increase the bandwidth (BW). An extensive study for the broadband behavior for, half U-slot, U-slot and double U-slot cut rectangular MSAs (RMSAs) is demonstrated. Therefore it has been observed that U-slot and half U-slot cut patches, does not introduce any additional mode, but it alter the fundamental and higher order mode resonance frequencies of the patch to yield broadband response.

N.P Yadav and J.A Ansari [14] investigated that antennas dual nature is realized by deploying shortening pin with U-slot loaded patch. Lower and upper frequency band are achieved as 443 and 287MHz and also noted that antenna shows frequency ratio of 1.4. Chai Wenwen and Zhang Xiaojuan [15]. Had studied U-slot patch antennas with ∏-shaped feed slot and concluded that the U-slot patch antenna can be designed to achieve 50% impedance bandwidth as well as 30–40% gain bandwidth. By changing the sizes of U-slot and feed slot, the wideband characteristic can be altered into a dual-frequency characteristic. Sukhbir Kumar and Hitendar Gupta [16] concluded that micro strip patch antenna with U-slot is used to achieve wideband application with less return loss. In this paper they constructed and fabricated micro strip antennas suitable for Wi-Max application that is centered at frequency 5.25GHz. So, now we will compare and carefully examine the slot patch and U-slot patch antenna loaded on rectangular micro strip patch antenna U-slot in this paper.

In this paper, it proposes efficient communication between CR nodes and spectrum utilization. Secondly the security concerns of spectrum sensing to ensure trustworthiness. It uses two selection schemes called node selection scheme (NSS) and channel selection scheme (CSS). The aim of NSS is to allow each node to check its gain in copying a message to a relay while examining its transmission effort. Using NSS, each node decides which paths should be used in order to provide minimum energy consumption without sacrificing end-to-end delay performance. Based on CSS, each node decides and switches to a licensed channel to maximize spectrum utilization while keeping the interference in a minimum level. This eventually enables CR-Networks nodes to determine optimum path nodes and channels for an efficient communication in CR-Networks. The CR technology allows Secondary Users (SUs) to seek and utilize “spectrum holes” in a time and location-varying radio environment without causing harmful interference to Primary Users (PUs). This opportunistic use of the spectrum leads to new challenges to the varying available spectrum. Using a Trust-Worthy algorithm, it improves the trustworthiness of the Spectrum sensing in CR-Networks.

II.MATHEMETICAL CALCULATION

Rectangular patch antenna Impedance can be written as [17-21].

$$Z_p = \frac{1}{(1/R_p)+(1/j\omega L_p)+j\omega C_t} \tag{1}$$

Therefore U-slot input impedance can be derived as,

$$Z_{us} = \frac{Z_{vs}Z_{hs}}{Z_{vs}+2Z_{hs}} \tag{2}$$

Where Z_{vs} = vertical slot impedance and Z_{hs}= horizontal slot impedance.

Therefore, the proposed antenna impedance can be calculated as,

$$Z_{in} = \frac{Z_pZ_{us}}{Z_p+Z_{us}} \tag{3}$$

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Antennas reflection coefficient (Γ) is given as,

$$[\Gamma] = \frac{Z_{in} - Z_0}{Z_{in} + Z_0} \quad (4)$$

Where Z_0 is the input impedance of the coaxial feed (50 ohm).
Therefore, voltage standing wave ratio (VSWR) and the return loss (RL) of the U-slot loaded on rectangular patch antenna can be calculated as,

$$VSWR = \frac{1 + [\Gamma]}{1 - [\Gamma]} \quad (5)$$

$$RL = 20 log[\Gamma] \quad (6)$$

Therefore the antennas radiation pattern can be calculated as,

$$E(\theta) = -\frac{JK_0 WV exp^{-jKor}}{\pi r} \cos(Kh \cos\theta) \frac{\sin((K_0 W/2)\sin\theta \sin\emptyset}{(K_0 W/2)\sin\theta \sin\emptyset}$$

$$\cos\big((K_0 l/2)\sin\theta \sin\varphi\big)\cos\emptyset \qquad (0 \le \theta \le \pi/2) \quad (7)$$

$$E(\emptyset) = -\frac{JK_O W exp^{-jKor}}{\pi_r} \cos(Kh \cos\theta) \frac{\sin\big((K_O W/2)\sin\theta \sin\emptyset\big)}{(K_O W/2)\sin\theta \sin\emptyset}$$

$$\cos((K_O l/2)\sin\theta \sin\emptyset)\ \cos\emptyset \sin\emptyset \qquad (0 \le \theta \le \pi/2) \quad (8)$$

Where, r is the distance of an arbitrary point, V is the radiating edge voltage, $K = Ko\sqrt{\varepsilon_r}$ and $Ko = 2\pi/\boldsymbol{\lambda}$
Gain and efficiency of the both slot patch and U-slot rectangular patch antenna structures are calculated as,

$$G = \eta . D \quad (9)$$

Where D is antennas directivity and is defined as,

$$D = \frac{4W^2\pi^2}{I_1 \lambda_0^2} \quad (10)$$

And

$$I_1 = \int_0^{\pi} sin^2\left(\frac{K_O W \cos\theta}{2}\right) tan^2\theta \sin\theta \, d\theta \quad (11)$$

$\boldsymbol{\eta}$ is the antennas efficiency, defined as the ratio of the radiated power to the input power may be expressed as,

$$\eta = \frac{R_r}{R_t} \quad (12)$$

Where

$$R_r = \frac{1}{2W_p C_p} \quad (13)$$

$$R_t = \frac{1}{W_p C_p} \quad (14)$$

III. ANTENNA DESIGN

The model is designed using FEM supported high frequency structure simulator (HFSS) software. 3D modelling is done on the Roger's RT/duroid 5880 (tm) substrate. Figure 1 depicts the schematic layout of the designed slot based microstrip patch antenna. The substrate and a patch are separated with each other by a dielectric material (air).

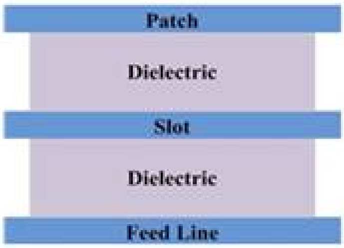


Figure 1: Layout of simulated slot patch antenna.

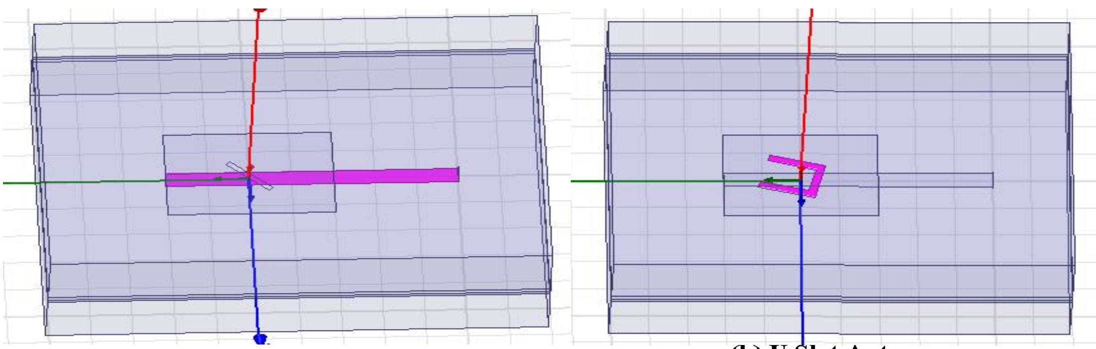
The geometry and the type of material used for designing the proposed micro-antenna are shown in Table 1. The antenna is enclosed in the rectangular (45 mm x 45 mm) shaped domain with thickness 0.75 mm. The domain contains air or vacuum within it. The basis to confine the micro-antenna in domain surrounded by a perfectly matched layer (PML) is to absorb the radiation from the antenna with least reflection so that it contains minimum return loss.

Table 1: Materials and dimensions

Name	Height	Length	Width	Material
Substrate	2.5 mm	45 mm	45 mm	Rogers RT/duriod 5880 (tm)
Ground	-10.0 mm	45 mm	45 mm	Perfect electric conductor
Patch	0.75 mm	15 mm	10 mm	Perfect electric conductor
Feed Line	0.1 mm	25 mm	4 mm	Perfect electric conductor

IV.RESULTS AND DISCUSSION

The proposed slot patch and U-slot loaded over rectangular patch antenna is fabricated and measured to verify the antenna characteristics for broadband operation. The obtained results confirm the variation in frequency bands and bandwidth with respect to increase in number of slots. To design the slot and U slot patch antenna the processing speed of the computational machine is 2.8 GHz with 2 GB RAM.



(a) Slot Antenna **(b) U Slot Antenna**

Figure 2: Schematic of Slot antenna design.

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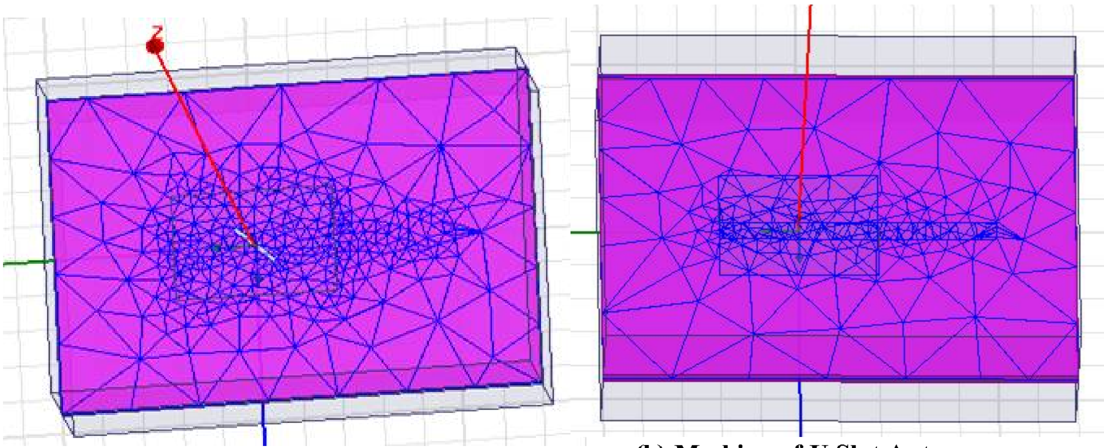
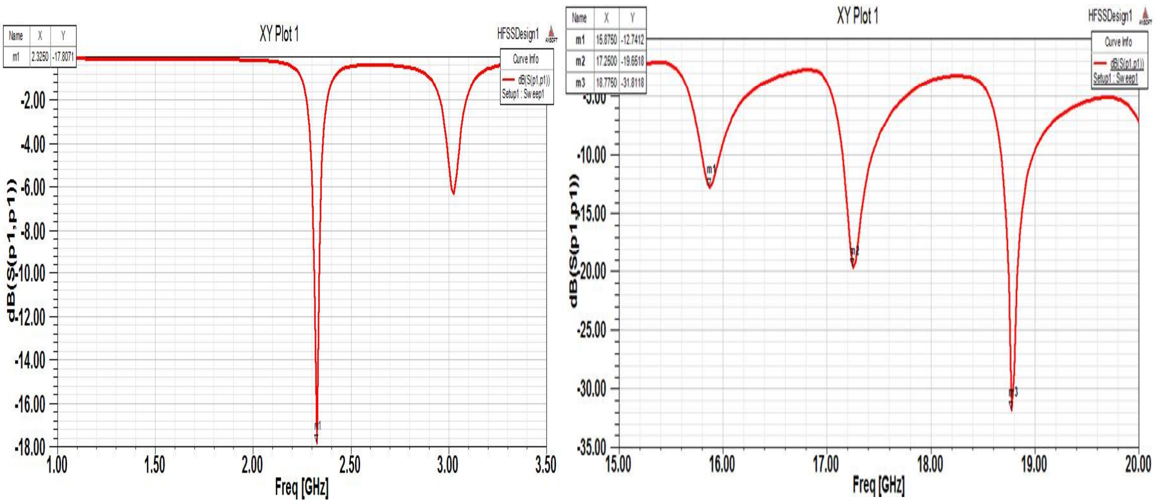
Tetrahedral meshing is selected for simulating the model. The characteristic impedance (Z_0) of the simulated design comes out to be 30Ω (approx) as shown in Figure 3. Theoretically, the value of Z_0 is 50 Ω that shows small existence of standing waves while propagation of RF signals.



(a) Meshing of Slot Antenna **(b) Meshing of U Slot Antenna**

Figure 3: Meshing diagram of Slot antennas.

To calculate the various parameters like s-parameters, VSWR, and radiation pattern by increasing the number of slots in patch has been taken that are shown in sequential manner. In Figure 4 shows the plot between return losses versus frequency. In figure 4(a) it can be seen that for basic slot antenna at 2.32 GHz, the return loss is -18 db. In case of modified U slot antenna figure 4(b), the return loss at different frequencies 15,17 and 18 GHz is -13,-19 and -31.52 dB respectively which is operating at three frequencies and useful for X and Ku band applications.



(a) Return loss of Slot Antenna **(b) Return loss of U-Slot**

Figure 4: Return loss vs Frequency of Slot antennas.

VSWR versus frequency plot for basic slot antenna shows that at 2.25 GHz, VSWR is 1.5 dB whereas for modified U slot shaped patch antenna it is 2 and 0.5 dB respectively as shown in figure 5.

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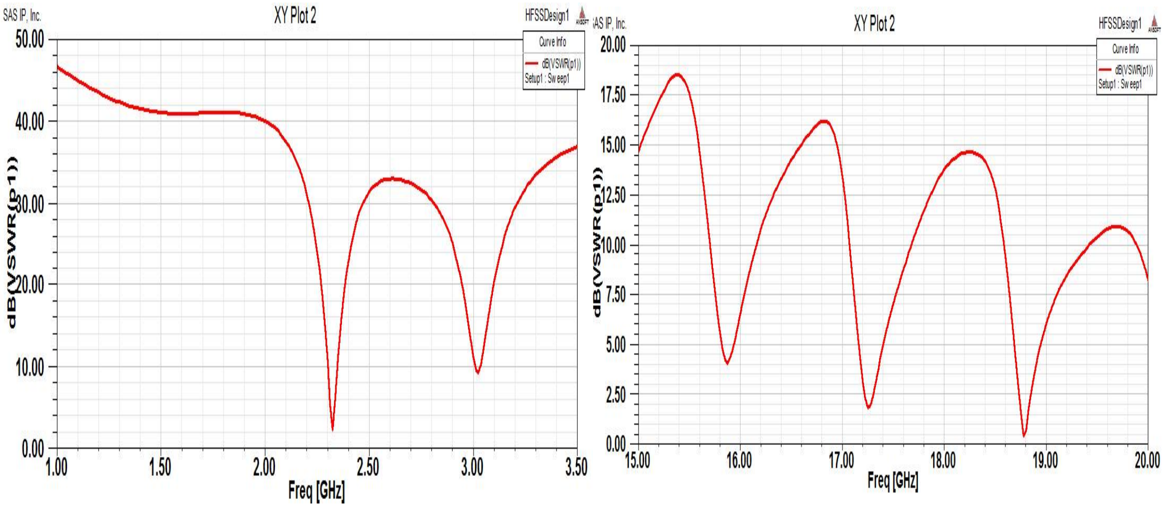
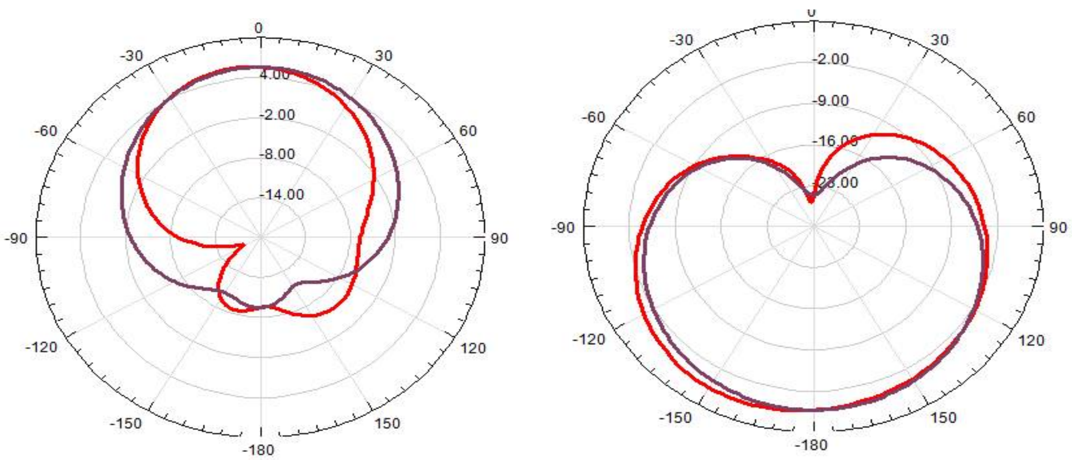


(a) VSWR of Slot Antenna **(b) VSWR of U-Slot**

Figure 5: VSWR vs Frequency of Slot antennas.

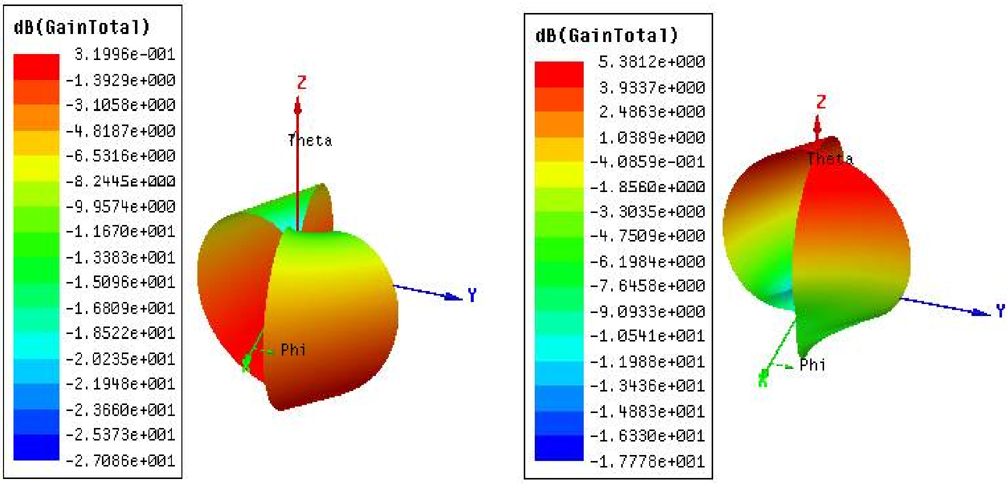
The radiation patterns of the proposed slot antenna and U- slot antenna at different resonant frequencies are depicted below in figure 6 correspondingly, which shows that the basic slot antenna is radiating mostly in broadside direction and modified U shaped slot antenna is unidirectional in nature.



(a) Radiation Pattern of Slot Antenna **(b) Radiation Pattern of U-Slot**

Figure 6: Radiation pattern of Slot antennas

The 3D polar plot of slot antenna and U- slot antenna is shown in figure 7 showing overall radiation characteristic. Maximum gain of 5.381dB is observed for U slot antenna and 3.199 dB is observed for basic slot antenna respectively.



(a) Gain of Slot Antenna **(b) Gain of U-Slot**

Figure 7: Gain of Slot antennas.

V.CONCLUSION

A basic slot and U slot antenna have been proposed and analyzed using proximity coupled feed technique. The Return loss -10 dB is achieved for both but U slot antenna showed better results. It can be determined that certain alterations in regular slot antenna can change the antenna performance. U slot antenna is more capable as compared to the simple slot antennas when compared on various parameters. Also U slot antenna is accomplished of operating at three different resonant frequencies which is making it very suitable for dual and triple band applications. The antennas hold their applications in satellite communication.

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