A Novel Design of Patch Antenna using U-Slot and Defected Ground Structure

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***Abstract*—A novel design of patch antenna is presented with double U slot structure on patch with ground irregularities. As a result tri-band response is achieved with gain reaching 0.785 to 3.75dB respectively and directivity of 5.5 to 5.6dBi. Coaxial cable is mounted with patch as medium of power. The antenna has shown minimum mismatch loss with 0 to 5% with high bandwidth response of 37 to 1200MHZ. The proposed antenna can be used for GSM, W-LAN, GPRS and other radio communication services systems.**

***Keywords*—multiband frequencies; directivity; gain; slots; Bandwidth; reflection coefficient**

I. Introduction

With rapid advancement in communication technology in modern era, antenna designers and researchers have been focused to new designs and structures. Patch antenna due to its low profile structures has been a prominent point of attention to communication technology. With their use as an array, resulting in powerful signals gain, bandwidth and directivity they have been frequently used for far in space communication and satellite systems. Regarding to reduction of size in patch structures and multiband response, several techniques have been proposed and implemented. Some of them are discussed.

With use of CSRR as defection of patch, size reduction was up to only 17% in [1] with altered radiation patterns. Use of synthetic magnetic conductors resulted with lowered gain at desired resonant frequencies [2].Using artificial magnetic conductors, nearly 40% of miniaturization is achieved at expense of efficiency [3]. Introducing incensement in electrical permittivity of a substrate, size reduction can be achieved but at the bandwidth gets worse [4]. Stack configuration with pi-shape fractal patch structure in [5] resulted size reduction with nearly diminishing gain. Hence Metamaterials, Stacked configuration, slotting techniques [6] [7] [8] [9] [10] size reduction and multiband response has been seen as very common topic among designers and researchers. In this paper, a novel design of patch antenna is presented. Two double U slots on patch and with help of ground irregularities, size reduction is achieved with multiband response which will be discussed below.

The antenna is designed in Computer Simulation Technology 2014. This paper is organized as following.

Starting from introduction, follows antenna design terminologies and slot method for size reduction. After result and discussion, Conclusion and Future work to be done is presented.

II. Antenna Design

The fundamental structure of patch antenna is presented in figure 1 which consists of ground, substrate and radiating patch.

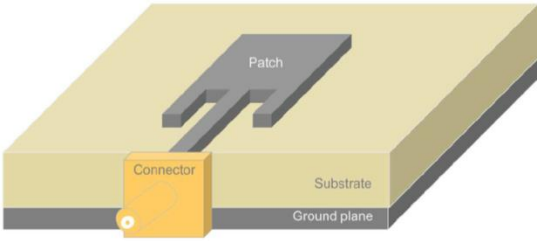

Fig. 1. Fundamental Patch Design

A. Substrate

Substrate plays a very important role in antenna performance parameters. Due to its moisture handling capabilities and commercially availability, FR4 with relative permittivity of 4.3 is selected [11].

B. Width

Antenna width is calculated using equation 1 [11] [12].

$$W = \frac{c}{2 f_0 \sqrt{\frac{(\varepsilon r+1)}{2}}} \quad (1)$$

Where c is the speed of light in free space.f_0 is the resonant frequency and $\boldsymbol{\varepsilon r}$ is the relative substrate permittivity.

C. Length

Patch length is calculated using equation 2 [11] [12].

$$L = L(eff) - 2\Delta L \quad (2)$$

Where

$$L(eff) = \frac{c}{2 f_0 \sqrt{\varepsilon_{(reff)}}} \quad (3)$$

And

$$\varepsilon_{(reff)} = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{4}\left(1 + \frac{12h}{W}\right)^{-1/2} \quad (4)$$

Where h is the height and W is the width of the patch. After deriving all the basic design parameters, patch antenna resonation at 4.5GHz is designed. The height of the patch and

ground is kept 0.787mm respectively. Substrate thickness is kept 1.6mm.

The table 1 below shows dimension of conventional patch antenna.

TABLE I. DIMENSIONS OF PATCH ANTENNA

Parameters	Values in MM
Patch Length	15.35
Patch Width	20.48
Patch height	0.787
Ground Length	27.35
Ground Width	32.48
Ground Height	0.787

The table 2 below shows of the U slots introduced in patch and ground plane.

TABLE II. DIMENSIONS OF U SLOTS IN ANTENNA

Parameters	Value in MM
Patch upper U slot length and width	6.0
U slot Thickness	1.0
Patch lower U slot length and width	12.0
Patch lower U slot width	6.0
Ground U slot length and width	24

The antenna after introducing slots in its structure showed multiband response with good gain, directivity and radiation patterns. The overall antenna design is shown in figure 2. The (a) part represents patch and (b) represents ground plane.

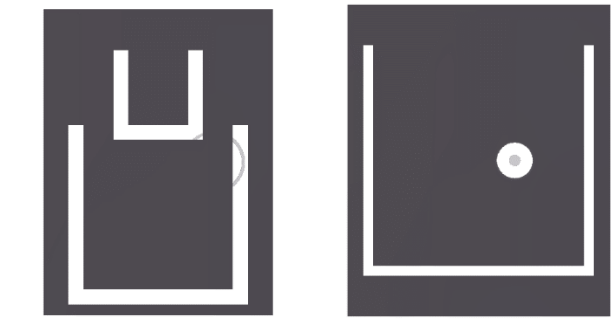

Fig. 2. (a) Frontal view of patch (b) Frontal view of Ground plane

We have used SMA connector for feeding antenna configuration as it is simply executed to 50 ohms of input resistance at required place in patch.

III. RESULTS AND DISCUSSIONS

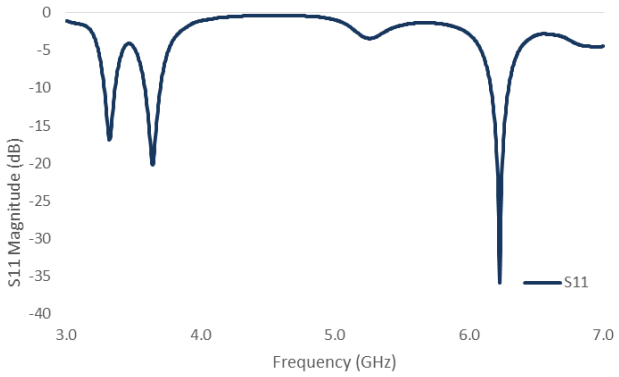

Fig. 3. Return loss graph of antenna

Figure 3 shows the return loss graph of proposed antenna. Resonation at 3 different frequencies, our proposed structure shows multiband response. The results are shown in table 3.

TABLE III. RETURN LOSS VALUES

Frequencies (GHz)	Return Loss
3.32	-19.50dB
3.64	-19.40dB
6.23	-35.79dB

As compared to the conventional antenna for 4.5GHz, the fundamental frequency of our proposed structure shifts down to 3.23GHz. Now the conventional antenna for 3.32 GHz of frequency would require dimensions of 22.18 x28.80 =638.74mm^2 while in our case it's just 15.35x 20.48 =314.368mm^2. So it shows that size is reduced in our proposed design up to 51% as our design is operating at 49% of conventional patch size with multiband response.

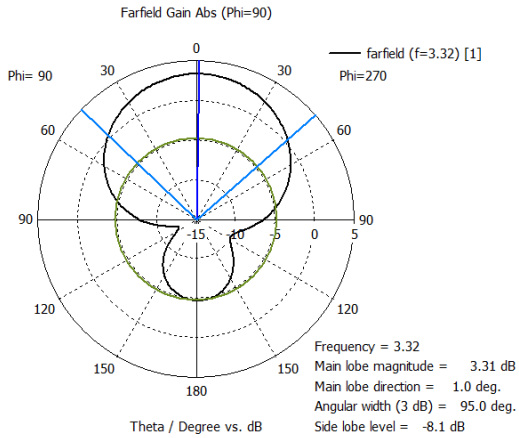

Fig. 4. 3.32GHz 1D Gain radiation pattern

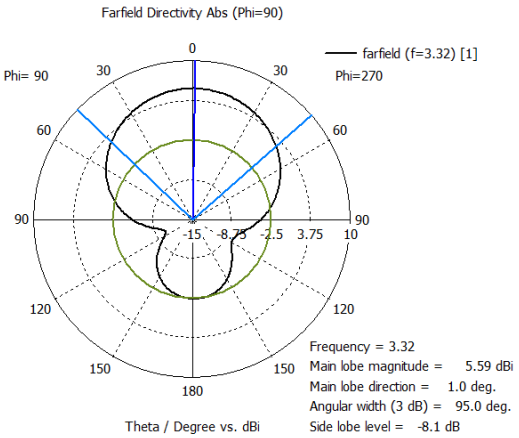

Fig. 7. 3.32GHz 1D radiation pattern of directivity

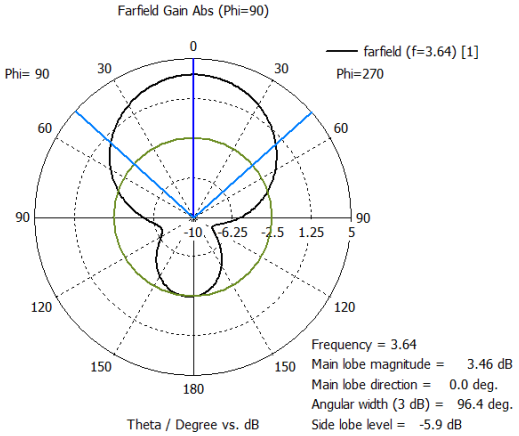

Fig. 5. 3.64GHz 1D gain radiation pattern

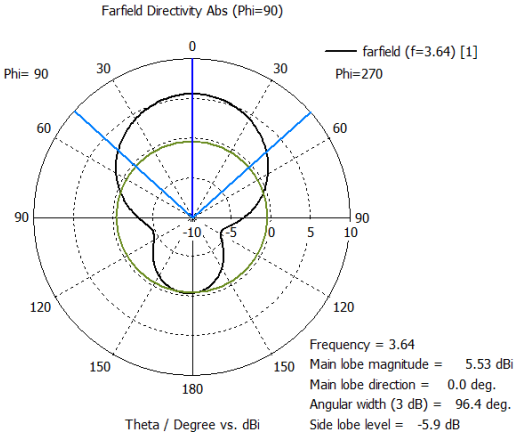

Fig. 8. 3.64GHz 1D radiation pattern of directivity

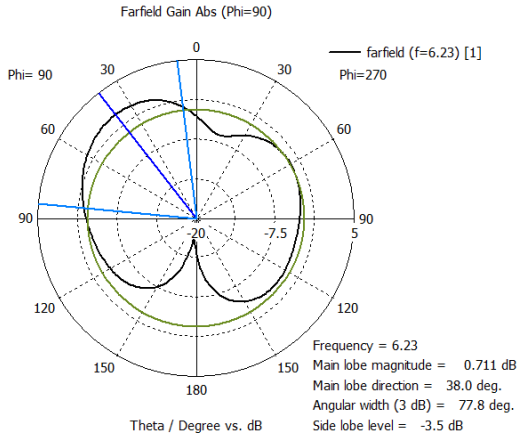

Fig. 6. 6.23GHz 1D gain radiation pattern

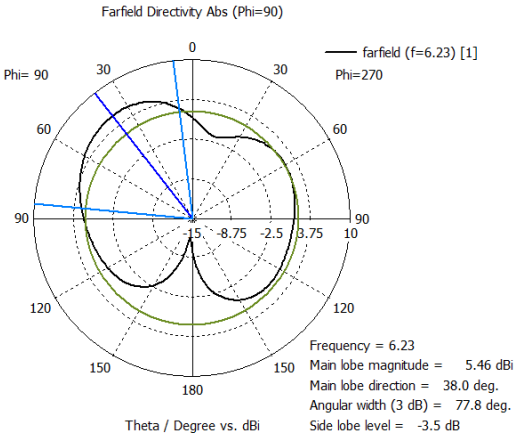

Fig. 9. 6.23GHz 1D radiation pattern of directivity

The radiation patterns of gain are presented in above and directivity are presented in below figures. In all resonating frequencies, there is minimum back lobe radiations better than [10]. The front lobe, back lobe, angular width and side lobe levels are mentioned in table 4 and 5.

TABLE IV. GAIN RADIATION PATTERN PARAMETERS

Frequency (GHz)	Main lobe Direction (Degrees)	Angular Width	Side Lobe Level (dB)
3.32	1.0	95.0	-8.1
3.64	0.0	96.4	-5.9
6.23	38.0	77.8	-3.5

TABLE V. DIRECTIVITY RADIATION PATTERN PARAMETERS

Frequency (GHz)	Main lobe Direction (Degrees)	Angular Width	Side Lobe Level (dB)
3.32	1.0	95.0	-8.1
3.64	0.0	96.4	-5.9
6.23	38.0	77.0	-3.5

From the results mentioned in table 4 and 5 it is cleared that radiation patterns obtained are far better than [9] [10] as antenna is conducting straight form origins. The VSWR ration also tends to be very satisfying in between range of 1 to 1.5 and ensuring no mismatch losses. The gain, directivity, bandwidth and VSWR are presented in table 6.

TABLE VI. ANTENNA PERFORMANCE PARAMETERS

Frequency (GHz)	Gain (dB)	Directivity (dBi)	VSWR	Bandwidth (MHz)
3.32	3.47	5.5	1.35	112.55
3.64	3.50	5.6	1.22	75.000
6.23	0.75	5.5	1.03	37.244

IV. CONCLUSION

A novel combination of U slot patch is presented. Our design showed multiband response with size reduction of 51% also the gain and directivity and other performance parameters have shown satisfied results with nearly zero percent mismatch losses. The proposed antenna can be used for GSM, GPRS, W-LAN and other radio satellite services.

V. FUTURE WORK

The design can also be implemented via other contacting schemes and in multiple input multiple output designs with stack configuration technique.

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