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Compact Monopole Antenna with Band Notching Characteristics

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Abstract: The rapid development in wireless technology has necessitated compact devices and these compact devices required miniature antennas for different applications. Many researchers carried out work to reduce size of antenna. There are different methods proposed by different researchers to reduce the size of the antenna without effecting the gain and bandwidth .The techniques used in the literature are using dielectric substrates with high permittivity, applying magneto inductive wave guide loading or using slots and notches on the patch of the antenna, embedding fractal slots but the simple method to reduce the size of the antenna is using Defective Ground Structure (DGS). In this study, two different Ultra Wide Band (UWB) monopole antennas are designed and their performance is compared by placing bevel slots on patch and without placing the bevel slots. Both the UWB Monopole antennas are operating in the frequency band of 2.4-12 GHz with band notching from (5.1-5.9 GHz) is designed. Performance evaluation of this antenna is carried out using HFSS software. The results are presented and discussed. The designed antenna with bevel slots on patch is fabricated and tested for return losses and VSWR and the results are compared.

Key words: Band notch (DGS), Bevel slots, returns loss, UWB, evaluation

INTRODUCTION

FCC allocated 3.1-10.6 GHz frequency spectrum for commercial applications. UWB technology has tremendous advantages like extremely fast data rates at short transmission distances, low power dissipation. Generally UWB antenna operates in the frequency band of 3.1-10.6 GHz. To avoid interference with existing WLAN application band notching is desired. Many researchers have developed UWB monopole antennas with slots in patch and slots even in ground plane (Thomas and Sreenivasam, 2010; Nasir *et al.*, 2014; Hsu and Chang, 2006; Zhang *et al.*, 2008; Wu *et al.*, 2008; Wu *et al.*, 2007; Hong *et al.*, 2007; Gao *et al.*, 2006; Naser-Moghadasi *et al.*, 2009; Reddy *et al.*, 2014; Nguyen *et al.*, 2012). In this study monopole UWB antennas are designed by taking defective ground plane. To get good impedance bandwidth slots aremade in ground plane as well as in patch. To avoid interference with the existing frequency band a viahole is placed on the feed line.

MATERIALS AND METHODS

First the rectangular patch antenna is designed using the design equations mentioned in the literature (Balanis, 2015). The width of the rectangular patch:

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\epsilon_r + 1}} \quad (1)$$

Where:

c = Velocity of e m wave in free space
ϵ_r = Relative permittivity of substrate

$$\text{Length of the patch } L = L_{eff} - 2\Delta L \quad (2)$$

L_{eff} is the effective length of patch and:

$$L_{eff} = \frac{c}{2f_r\sqrt{\epsilon_{eff}}} \quad (3)$$

ϵ_{eff} is effective dielectric constant given by:

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left[1 + \frac{12h}{W}\right]^{-0.5} \quad (4)$$

The difference in length ΔL can be estimated from:

$$\frac{\Delta L}{h} = 0.412\frac{(\epsilon_{eff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\epsilon_{eff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \quad (5)$$

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Table 1: Dimensions of monopole antenna

Parameters	Dimensions (mm)
Height or thickness of the substrate (h)	1.6
Length of the patch (L)	13.8
Width of the patch (W)	16
Radius of cylindrical monopole r	2.547
Length of the full ground plane (L_g)	27
Length of the partial ground plane (variable)	8.5
Width of the ground plane (W_g)	28
Length of the feed line (L_f)	9.5
Width of the feed line (W_f)	2.8
Gap between ground plane and patch (g) (variable)	0.6
Width of the Slot (Sw)	2
Length of the Slot (S_L)	10
Width of Bevel slot (W_b)	1
Length of Bevel slot (L_b)	1
Bevel slots length in groundplane	2.2
Bevel slot width in groundplane	5.5
Radius of via. hole	0.9

The ground plane dimensions are taken as:

$$L_g \geq 6h+L \quad (6)$$

$$W_g \geq 6h+W \quad (7)$$

To design the monopole antenna equating the area of the planar rectangular patch antenna to that of cylindrical wire of radius r and height h = L:

$$2\pi rh = L * W$$

Radius of the cylindrical monopole will be:

$$r = \frac{W}{2\Pi} \quad (8)$$

The lower resonant frequency of the rectangular monopole antenna is given by:

$$f_L = \frac{7.2}{L_f+r+g} Hz \quad (9)$$

L_f is the length of 50 Ω feed line and g is distance between ground plane and patch. Using the above expressions the dimensions are calculated and are presented in Table 1.

Antenna 1: Rectangular monopole antenna with rectangular slot in patch, slots in DGS and a via hole.

Antenna 2: Rectangular monopole antenna with rectangular and bevel slots in patch, slots in DGS and a via. hole. The structure of antenna 1 and 2 are shown in Fig 1 and 2.

In both the designs arectangular slot of 10×2 mm is placed at a position of 12 mm distance from feed point and

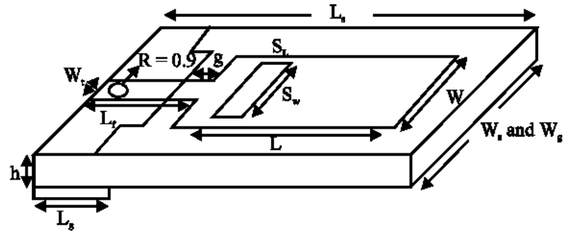

Fig. 1: Structure of antenna1

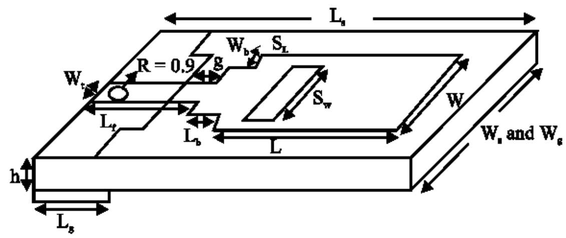

Fig. 2: Structure of antenna 2

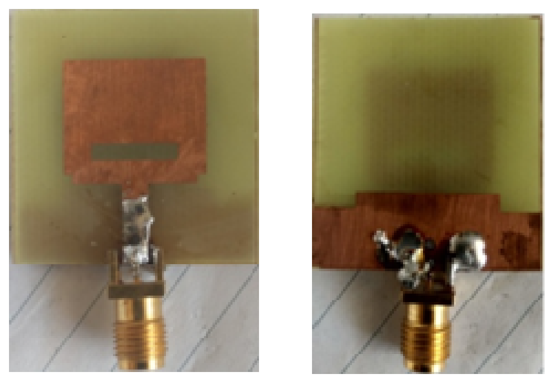

Fig. 3: Fabricated antenna 2

bevel slots of dimensions 1×1 mm are made on patch to get good impedance bandwidth. Finally, a hole of 0.9 mm radius is made on feed line to get band notching characteristics.

The antenna 2 is fabricated on the FR4 substrate and the fabricated antenna front view and back view is shown in Fig. 3a, b.

RESULTS AND DISCUSSION

The antenna performances of both the antennas are evaluated through HFSS Software. In antenna1the slot position is varied from 10-16 mm, the return losses gain and VSWR are measured and results are presented in Table 2.

It can be inferred from the above table that slot at position 12 mm from feed point gave better performance. Placing the via h ole of radius 0.9 mm it is found that band

Table 2: Effect of slot position on band notching without bevel slots for antenna1

Slot position from feed (mm)	Frequency GHz with return losses <-10 dB (without bevel slots)	Frequency GHz with VSWR is <2 (without bevel slots)	Gain dB at 7.5 GHz (without bevel slots)
10	2.2-7.2	2.2-7.2	3.3201
11	2.2-11.9	2.2-12.7	3.7832
12	2.2-15	2.2-15	3.2103
13	2.2-4.9, 6.1-15	2.4-7.5	1.4122
14	2.3-5, 6-12.9	2.3-11.8,14-15	0.9962
15	2.3-5, 6.2-12.6	2.3-12, 13.1-15	-0.0896
16	2.3-4.8, 6.3-12.7	2.3-4.9, 6.1-13.3	-1.3606

Table 3: Frequency vs. gain at different frequencies for antenna 1

Frequency (GHz)	Notching frequency band	Gain (dB)
3.1	5-5.8	-5.0035
3.5	5-5.8	-3.5114
4	5-5.8	-1.8644
4.5	5.2-5.7	-0.5634
5	5-5.8	0.4388
5.5	5-5.9	0.9917
6	5-5.9	1.4608
6.5	5-5.8	1.9901
7	5.1-5.8	2.4603
7.5	5.1-5.7	2.9672
8	5-5.8	3.2103
8.5	5-5.7	2.8233
9	4.8-5.9	1.5669
9.5	4.9-5.8	-1.6182
10	4.8-6	-4.0483

Table 4: Effect of bevel cut dimensions on antenna parameters slot at 12 mm, Lg = 8.9 mm

Bevel cut size mm (on both sides)	Frequencies GHz where <-10 dB return loss	Frequencies GHz where VSWR<2	Gain at 8 GHz
2	2.2-4.7, 6.3-15	2.2-4.9, 6.2-15	3.3822
1.5	2.3-4.9, 6.1-15	2.3-5.2, 5.8-15	3.3987
1	2.3-4.9, 6-13.6	2.2-5.2, 5.8-14.2	3.2592
0.5	2.3-11.1, 14-15	2.3-11.5, 13.6-15	3.0155

notching characteristics are obtained. The variation of gain at different frequencies are observed and reported in Table 3.

The performance of antenna 2 is evaluated through simulation. To improve the performance parameters bevels slots are made on the patch and the effect of bevel slots on performance parameters is studied. For antenna 2 with the slot position at 12 mm on patch, bevel slots and a via. hole is made on patch. The antenna is fabricated and the antenna performance parameters are measured and reported in Fig. 4-6.

The effect of bevel slots on performance parameters of the antenna is shown in Table 4 and 5. From the above table it is observed that when the bevel slot dimensions are at 1×1 mm better results are obtained.

From the table when the slot position is at 12 mm better results are obtained. Finally, variation of gain at different frequencies is observed and it is shown in Table 6.

From the above Table 6 it is observed that maximum peak gain is obtained at 8 GHz for antenna 2 and the gain is reducing at notching band.

Table 5: Variation of slot position on antenna parameters

Slot position from feed (mm)	Frequency GHz with return losses <-10 dB (without bevel slots)	Frequency GHz with VSWR is <2 (without bevel slots)	Gain dB at 7.5 GHz (without bevel slots)
10	2.1-7, 9.6-12.1	2.1-7.1, 9.6-12.2	3.6154
11	2.2-12, 14.2-15	2.2-12.4, 13.6-15	3.5977
12	2.2-4.9, 6-13.6	2.2-5.2, 5.8-15	3.2592
13	2.2-4.9, 6.1-15	2.2-5.1, 5.9-15	1.8920
14	2.3-5, 6-12.9	2.3-11.8, 14-15	0.9962
15	2.3-5, 6.2-12.6	2.3-12, 13.1-15	-0.0896
16	2.3-4.8, 6.3-12.7	2.3-4.9, 6.1-13.3	-1.3606

Table 6: Variation of gain at different frequency for antenna 2

Frequency	Gain
3.1	-4.9400
4	-1.8000
5	0.4721
6	1.9671
7	2.5400
7.5	3.0600
8	3.2592
9	1.8099
10	-3.7700

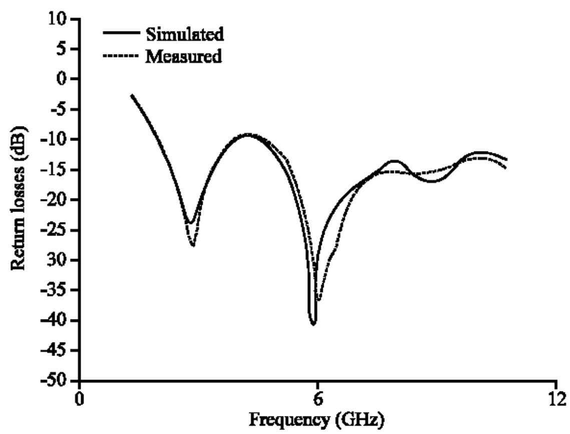

Fig. 4: Simulated and measured Frequency vs. return losses for antenna 2

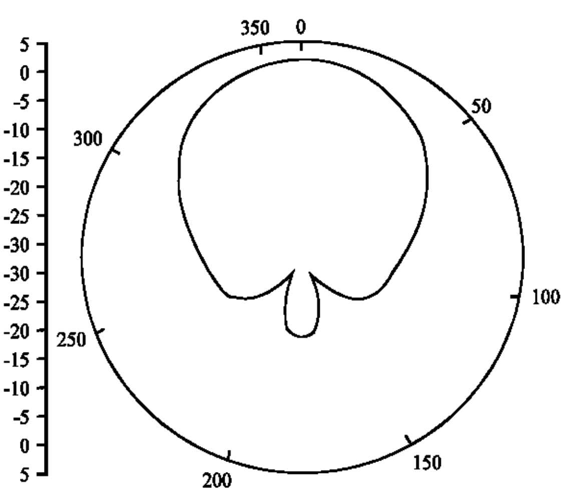

Fig. 5: Simulated radiation pattern at 8 Ghz for antenna 2

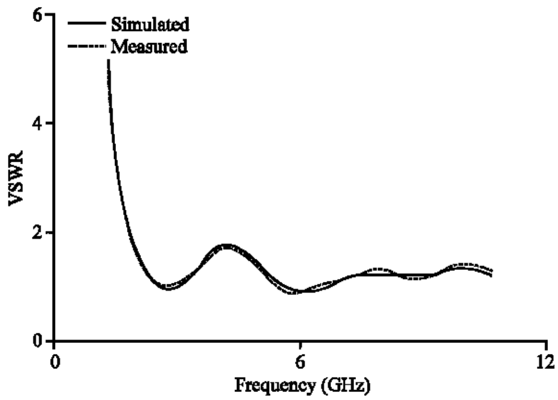

Fig. 6: Simulated and measured VSWR for antenna 2

A compact UWB antenna operating in the frequency band from 2.4-12 GHz with band notching over the frequency range 5.1-5.9 GHz is simulated and tested. The effect of slot position and the dimensions of the bevel slots DGS is studied and the performance is compared with and without bevel slots on patch. It is observed that the shape of the radiation pattern is uniform throughout the frequency band and a maximum gain of 3.31 dB is observed at 7 GHz. The notched band is used by existing WLAN applications. The simulated and measured return losses and VSWR are compared they are in line.

CONCLUSION

A compact UWB antenna with band notching characteristics from 5.1-5.9 GHz is achieved. The proposed antenna can be used for the UWB applications. The proposed antenna will eliminate interference from the existing WLAN systems.

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