DESIGN AND OPTIMIZATION OF MICROSTRIP PATCH ANTENNA WITH DEFECTED GROUND STRUCTURE & CIRCULAR SLOT ON THE PATCH

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Abstract

A single feed compact rectangular micro strip patch antenna (MSA) for triple band application is presented in this paper. The proposed antenna has Circular slot on the patch and dumble shaped defected ground structure (DGS). To make the proposed antenna more efficient the optimization of the antenna design parameters have been done using HFSS's optometric. For the proposed antenna three resonant frequencies have been obtained at 2.33GHz, 7.60GHz and 8.53GHz with Bandwidth of 102Mz,130MHz and 127MHz return loss of -15.80db ,-18.77db and -36.57db respectively. The characteristics of the designed structure are investigated by using FEM based electromagnetic solver, HFSS. An extensive analysis of the return loss, gain and bandwidth of the proposed antenna is presented. The simple configuration and low profile nature of the proposed antenna leads to easy fabrication and make it suitable for the application in wireless communication systems. Mainly it is developed to operate in the WLAN, WiMAX & RADAR application.

Key Words: *Bandwidth, Return loss, Patch, DGS, RADAR*

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1. INTRODUCTION

Microstrip antennas are very attractive because of their low profile, low weight, conformal to the surface of objects and easy production. A large number of microstrip patches to be used in wireless applications have been developed [1-3]. Design of WLAN antennas also got popularity with the advancement of microstrip antennas [4-5]. Wireless local area network (WLAN) requires three band of frequencies: 2.4GHz (2400-2484MHz), 5.2GHz (5150-5350MHz) and 5.8GHz (5725-5825MHz). WiMax has three allocated frequency bands. The low band (2.5-2.69GHz), the middle band (3.2-3.8 GHz) and the upper band (5.2-5.8GHz).Tele communication via satellite and RADAR use the 4-8GHz band of frequency. The size of antenna is effectively reduced by cutting slot in proper position on the microstrip patch. The use of DGS for size reduction of microstrip antenna, although its application has been reported for harmonic reduction [6], cross-polarization suppression [7] and mutual coupling reduction [8] in antenna arrays etc. This paper presents the application of dumble shaped defected ground structure (DGS) in microstrip antenna for size reduction and to achieve useful multiband. While maintaining the antenna size, the broader operating bandwidth (BW) [9,10] is realized by cutting the slots of either half wave or quarter wave in length, having different shapes like U-slot, V-slot, L-slot, and a pair of rectangular slots inside the patch [11,12]. In this paper T-slot has been presented. The slot introduces a mode near the fundamental mode of the patch and realizes broadband response.

2. CONVENTIONAL MSA DESIGN, RESULTs & ANALYSIS

The design of the antenna is shown in figure 1(a). The antenna has 29mm x 25mm rectangular patch. The dielectric material selected for this design with $\varepsilon r = 4.4$ and substrate height =1.57mm. The antenna has been designed using the transmission line model. Where the transmission line model is most accurate To design the conventional rectangular micro strip patch antenna that operates at frequency around 2.45GHz, the dimensions can be found using [3]:

Step 1: Determination of the Width (W).The width of the Microstrip patch antenna is given by [3]
W = 37.26mm.
Step 2: Determination of effective dielectric constant (ε_{reff}). The effective dielectric constant is represented by [3]. By substituting $\varepsilon r = 4.4$, W = 36.26 mm and h = 1.57 mm, it can be determined that $\varepsilon_{reff} = 4.4$.
Step 3: Determination of the effective length (L_{eff}) The effective length is given by [3]. By substituting $\varepsilon_{reff} = 4.4$, c = 3×10^8 m/s and $f_0 = 2.45$ GHz, it can determine that
$L_{eff} = 29.126$ mm.
Step 4: Determination of the length extension (ΔL) [3]
The length extension may be represented by substituting $\varepsilon_{reff} = 4.4$, W = 36.26 mm and h = 1.57 mm, it can be determined that
$\Delta L = 0.01634$ mm.
Step 5: Determination of actual length of patch (L): The actual length is obtained by using expression
$L = L_{eff} - 2\Delta L$

By substituting Leff = 29.126 mm and ΔL = 0.01634 mm, the actual length can determined as
L = 29.093 mm

The actual length of the patch has been found using [3].

Now from the above calculated data antenna has been designed on HFSS 13.0. The design is shown in figure below:

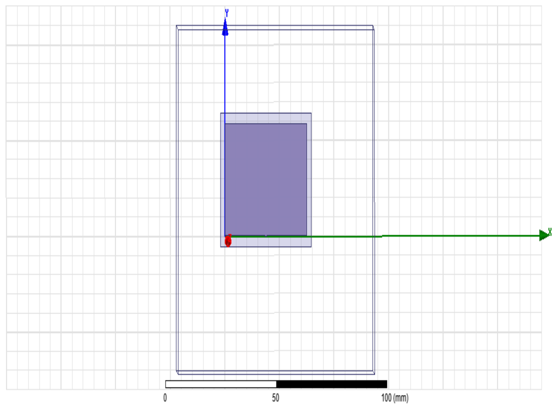

Figure 1(a): Conventional Microstrip Patch Antenna Design

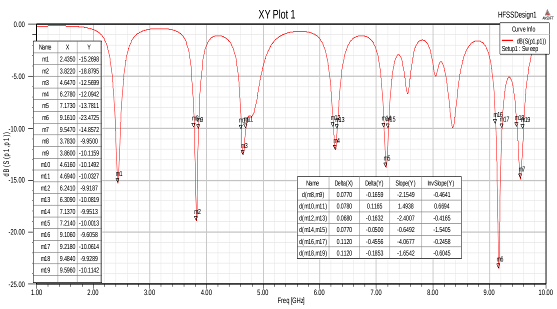

Figure 1(b): S-Parameter plot of the conventional Microstrip Patch Antenna

In the figure 1(b) the S-parameter plot of the MSA design of figure1(a) is shown and from the plot we can easily calculate the bandwidth as well as returnloss which are at 2.43GHz, 3.82GHz, 4.64GHz, 6.27GHz, 7.17GHz, 9.16GHz and 9.54GHz and bandwidth of 77MHz, 78MHz, 68MHz, 77MHz, 112MHZ and 112 MHz were obtained respectively. Due to the presence of the multiple bands as well as presence of so many numbers of varying amplitudes this antenna will consume too much power and hence will not radiate effectively on the particular selected band.

3. MSA with CIRCULAR slot and DGS- DESIGN, RESULTs & aNALYSIS

Now the patch antenna has been improved with the Circular slot on the rectangular patch which is shown in figure2 (a) and the ground have been made defected with the dumble shaped defected ground structure as shown in figure 2(b).

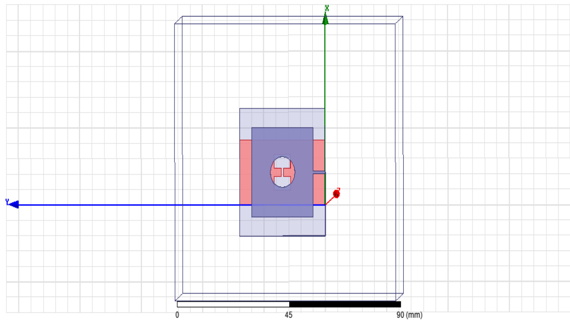

Figure 2(a): Simulated Design of Triple Band MSA (Front View showing Circular slot)

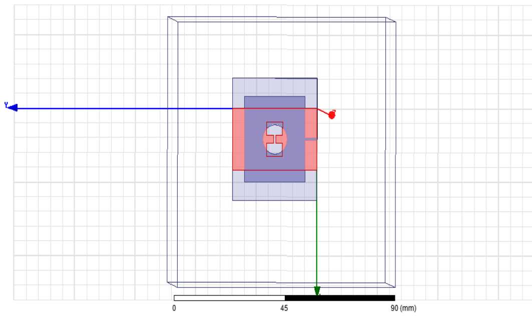

Figure 2(b): Simulated Design of Triple Band MSA (Back View showing DGS)

The fronts view of the antenna shows the Circular slot which is made by etching the patch. The defected ground structure has been made on the ground of the patch antenna which has dumble shape by etching the ground plane. The antenna parameter is given in table below:

Table 1: Dimensions of the Microstrip Patch Antenna

Variable	Value
Length of the Patch(lp)	25.054mm
Width of the Patch(wp)	29.036mm
Thickness of the Patch(t)	0.035mm
Width of the Ground(wg)	21.056mm
Length of the Ground(lg)	34.874mm
Width of the Substrate(ws)	41.456mm
Length of the substrate(ls)	34.874mm
Height of the Substrate(h)	1.57mm
Dimension of the symmetrical rectangular box on the ground	6.5mm,4.5mm
Dimension of rectangular box connector on the ground	2.5mm.1mm
Width of the feed Line(wf)	0.8mm
Radious of Circle on Patch	5mm

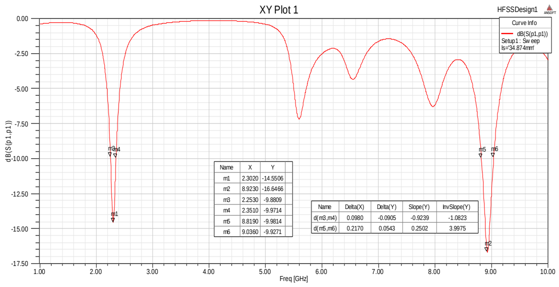

Figure 2(c): S-Parameter plot of the MSA with DGS and Circular Slot

In the figure 2(c) the S-parameter plot of the MSA design of figure2 is shown and from the plot we can easily calculate the bandwidth and returnloss which are (98MHz,-14.55db), (217MHz, -16.64db) at 2.30GHz and 8.92GHz respectively.

4. OPTIMIZATION OF MSA

To get the best possible result the antenna has been optimized in a number of ways. Here optimizations of the patch antenna is Discussed.

Width Optimization

Here the width of the microstrip patch antenna have been optimized, the width of patch (WP), the width of ground (wg) and the width of substrate (ws) have been simultaneously optimized.

Table2: Width optimization

Variation	wg	wp	ws
1	21mm	21mm	21mm
2	21mm	22mm	21mm
3	21mm	23mm	21mm
4	21mm	24mm	21mm
5	21mm	25mm	21mm
6	21mm	26mm	21mm
7	21mm	27mm	21mm
8	21mm	28mm	21mm
9	21mm	29mm	21mm
10	21mm	21mm	22mm
11	21mm	22mm	22mm
12	21mm	23mm	22mm
13	21mm	24mm	22mm
14	21mm	25mm	22mm
15	21mm	26mm	22mm
16	21mm	27mm	22mm
17	21mm	28mm	22mm
18	21mm	29mm	22mm
19	21mm	21mm	23mm
20	21mm	22mm	23mm
21	21mm	23mm	23mm
22	21mm	24mm	23mm
23	21mm	25mm	23mm
24	21mm	26mm	23mm
25	21mm	27mm	23mm
26	21mm	28mm	23mm

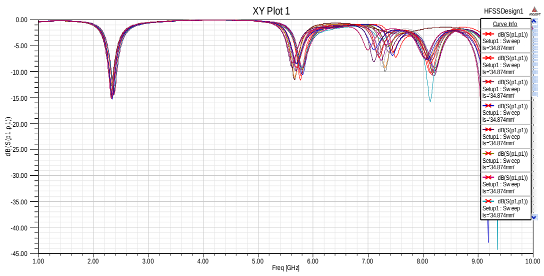

Figure 3(a): S-Parameter plot of the MSA with DGS and Circular Slot in Width Optimization

From this analysis the best width combination has been selected and now Radious of the circular slot on the patch have been optimized.

Radious Optimization

Now the Radious of the microstrip patch antenna have been optimized to get the best possible result.

Table 3: Radious Optimization

Variation	rad
1	2mm
2	3mm
3	4mm
4	5mm
5	6mm
6	7mm
7	8mm
8	9mm
9	1mm

Now the plots have been taken on all the variations and the obtained accumulated plot is shown in figure below:

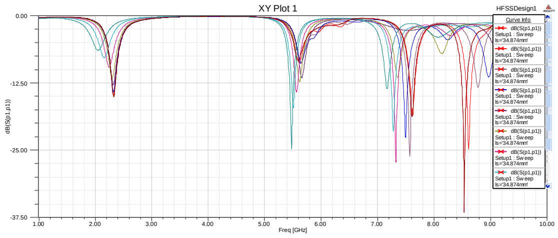

Figure 3(a): S-Parameter plot of the MSA with DGS and Circular Slot in Radious Optimization

5. OPTIMIZED MICROSTRIP PATCH ANTENNA RESULTs & ANALYSIS

Now the microstrip patch antenna has been optimized in all the possible ways to get the best possible results and final results are presented in this section.

Table4: Optimized dimensions of the proposed MSA

Variable	Value
Length of the Patch(lp)	25.054mm
Width of the Patch(wp)	21mm
Thickness of the Patch(t)	0.035mm
Width of the Ground(wg)	21 mm
Length of the Ground(lg)	34.874mm
Width of the Substrate(ws)	22mm
Length of the substrate(ls)	34.874mm
Height of the Substrate(h)	1.57mm
Dimension of the symmetrical rectangular box on the ground	6.5mm,4.5mm
Dimension of rectangular box connector on the ground	2.5mm.1mm
Width of the feed Line(wf)	0.8mm
Radious of Circle on Patch	1mm

Now figure below shows all the plots that have been taken.

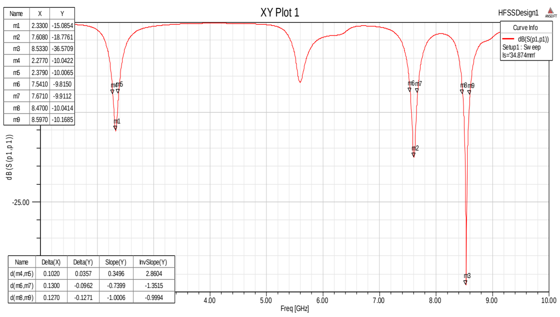

Figure 4(a): S-Parameter plot of the Optimized MSA with DGS and Circular Slot on the patch

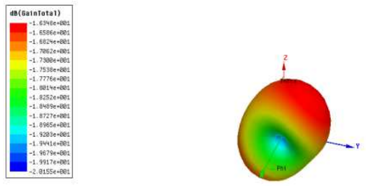

Figure 4(b): 3D-Polar plot of the Optimized MSA with DGS and Circular Slot on the patch

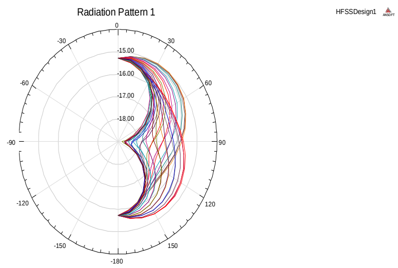

Figure 4(c): Radiation Pattern plot of the Optimized MSA with DGS and Circular Slot on the patch

In the figure 4(a) the S-parameter plot of the MSA design of figure4 is shown and from the plot we can easily calculate the bandwidth and returnloss which are (102MHz -15.08db),(130MHz -18.77db) & (127MHz -36.57db) at 2.33GHz,7.60GHz,8.53GHz respectively.

6. COMPARISIONS & CONCLUSIONS

Table5: Table of Comparisons

	Frequencies(GHz)	Returnloss(db)	Bandwidth (MHz)
Conventional Design	2.43GHz, 3.82GHz, 4.64GHz, 6.27GHz, 7.17GHz, 9.16GHz, 9.54GHz.	-15.26db, -18.87db, -12.56db,-12.09db, -13.78db,-23.47db, -14.85db.	77MHz, 78MHz, 68MHz, 77MHz, 112MHz, 112 MHz
Design With Circular Slot on the patch and DGS	2.30GHz, 8.92GHz	-14.55db,-16.64db	98MHz, 217MHz
Optimized Design	2.33GHz,7.60GHz,.8.53GHz	-15.08db,-18.77db, -36.57db.	102MHz, 130MHz, 127MHz

Now we have the results of both the conventional MSA as well as the Optimized MSA with DGS & Circular Slot. These results are presented in the table above

As we can easily analyze from the above table that the proposed Microstrip Patch Antenna will work in the frequency range of 2-8GHz. which covers the frequency of operation of WLAN, WiMAX, and wireless communication through satellite as well as the frequency of operation of RADAR- that's why it is multipurpose microstrip patch antenna.

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