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Design of small dual band microstrip antenna for broadband applications

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Abstract: In this article, a small dual band rectangular slot antenna for broadband application is presented. The antenna is being excited by capacitive coupled probe feed. The antenna consists of rectangular slot from the center of the patch. The rectangular slot is being used to obtain dual frequencies of 2GHz and 3.34GHz. Instead of a rectangular feed strip; antenna is excited by a triangular feed strip with same dimension. Triangular feed strip is used to obtain a broad band dual frequency range. The gain of the antenna obtained at particular frequency range is above 5dB so the antenna works well in the particular frequency. Along with Triangular feed slot is also being added in the patch. The size of the antenna is $100\times100\times1.6mm^3$with the ground of same dimension. The proposed antenna is simulated and optimized using IE3D simulation software.

Keywords: Return Loss, VSWR, FR4, Air Gap, SMA Connector

1. Introduction

Today as the research is increasing day by day, so in high performance application such as aircraft, spacecraft, satellite and missile applications, where size, weight, cost, performance, ease of installation and aerodynamic profile are constraints low profile antenna is used. Microstrip antenna is being designed to work in broadband as well as narrow and wideband frequency range [1, 2]. A slotted circular monopole antenna is presented [3] has spike shaped slots with square patch rotated around 45 degree to achieve a UWB applications.

Coplanar Capacitive coupled microstrip antenna [4] is used for wideband applications with impendence bandwidth of 50%.A printed Egg curved slot antenna[5]for wideband frequency range with gain of 4.1-5.1dBi. Many microstrip antennas which operate for dual and tri-band operation are being reported [6-11]. For example Bandwidth enhancement of printed slot antenna [6] having wideband of 2.80 to 11.81 GHz is reported. Antennas reported in [7] have a circular polarization with frequency ratio of 1.11. On the other hand antenna in [8] offers for ultra wideband frequency band from 840MHz to 960MHz and [9] offers for maximum antenna bandwidth.

Antenna reported in [12] offers for a dual band frequency range for a dual square ring slot. Polarization is also main characteristics in design of antenna. Antenna in [13] offers for circular polarization with (AR) below 2dB. Antenna proposed in [14, 15] have a slot along the patch to enhance for dual band operation. In the proposed antenna an air gap with dual band frequency with good bandwidth is being proposed

The basic geometry is shown in section 2. The design starts with the selection of center frequency and it may be scaled to any frequency of interest. Design and optimization procedure are shown in section 3. Section 4 showed the Experimental validation along with discussion. Conclusion of this study is shown in section 5.

2. Antenna Geometry

The proposed antenna has a rectangular slot in vertical direction from center of the patch. Substrate used for design is FR4 with dielectric constant of 4.4 and thickness of 1.6 mm with air gap of 7.5 mm. A long pin SMA connector is used to connect the feed strip which couples the energy to the patch by capacitive means. The detailed optimization procedure of the antenna and their optimum dimension characteristics are presented in section 3.

The antenna was designed to operate with center frequency of 2.4 GHz. Rectangular antenna with rectangular slot with all physical parameter is optimized with the IE3D, which is a method of moment (MOM) simulation software is shown in the Figure 1. The details dimensions of the optimized antenna are listed in Table 1.

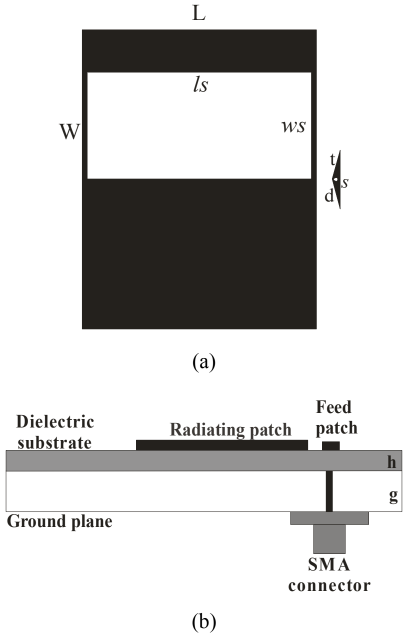


Figure 1. *Geometry of patch antenna. (a) Top view (b) Cross sectional view.*

Table 1. *Optimized dimensions of the proposed antenna.*

Antenna Parameters	Values with Air Gap(mm)
Length of radiator patch(L)	42.0
Width of radiator patch(W)	57.0
Length of feed strip(s)	11.1
Width of feed strip(t)	1.5
Separation between feed strip from the patch(d)	0.5
Air gap(g)	7.5
Slot length(*ls*)	40.0
Slot width(*ws*)	20.0
Slot position(*p*) (from center of patch)	10.0

3. Geometry Optimization and Discussions

In this section, study is being conducted to optimize the proposed antenna. The key design parameter used for the design are Air gap, distance between radiative patch and feed, slot position, sloth width, slot length. The details are given in following subsections.

3.1. Effect of Air Gap (g)

As shown in Figure 2, Air gap of antenna is being varied from 6.5 mm to 11.5 mm in steps of 1mm. Air gap (g) is used to maximize the antenna's bandwidth. Air gap of 7.5 mm is used to maximum bandwidth and maximum gain. As Air gap changes, there is shift in the resonance frequency of the antenna. The upper frequency goes on increasing as we increase the Air gap (g). From Figure 2, it may be noted that the upper and lower cut-off frequency varies accordingly as the air gap change. From Table 2 it may be noted that maximum bandwidth is obtained at 1.92-3.52 GHz frequency i.e 65% for the proposed geometry. As the Air gap goes on increasing the bandwidth of proposed geometry goes on reducing.

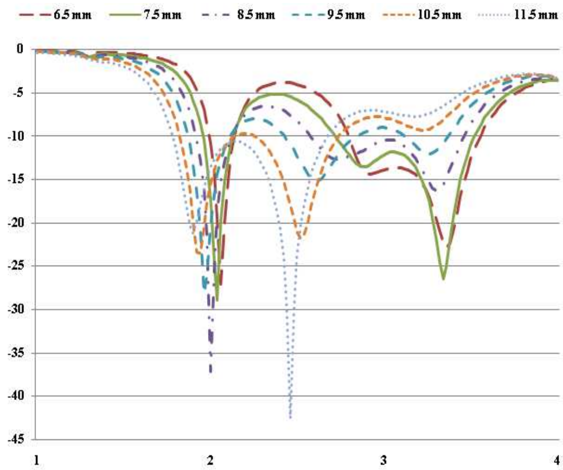


Figure 2. *Return loss characteristics for different Air Gap.*

Table 2. *Effect of Variation of Air Gap on bandwidth of proposed antenna.*

Air Gap(g) (mm)	6.5	7.5	8.5	9.5	10.5	11.5
Frequency range (GHz)	2-3.5	1.96-3.52	1.92-3.46	1.88-3.38	1.84-2.74	1.8-2.66
Bandwidth (%)	62.5	65.0	64.2	62.5	37.5	35.8

3.2. Effect of Distance between Radiator Patch and Feed Strip (d)

The distance between the patch and feed strip plays an important role in design of the antenna. It does not change the bandwidth of the antenna but shows a change in the depth of S_{11} parameter of the antenna. The distance between radiator and strip is change from 0.4 mm to 0.9 mm in steps of 1 mm each. The variation in S_{11} parameter of radiator patch and feed strip is shown in Figure 3. From Figure 3, it is clear that the lower cut-off frequency remains constant but the upper cut-off frequency changes. From Table 3 it is clear that the optimum result for the distance with maximum bandwidth of 65% is obtained at d=0.5mm.

Table 3. *Effect of variation of distance between patch and strip on bandwidth of proposed antenna*

Patch and feed distance (d) (mm)	0.4	0.5	0.6	0.7	0.8	0.9
Frequency range (GHz)	1.96-3.52	1.98-3.54	1.98-3.5	2-3.52	2-3.52	2.-3.54
Bandwidth (%)	64.1	65.0	63.3	63.3	63.3	64.1

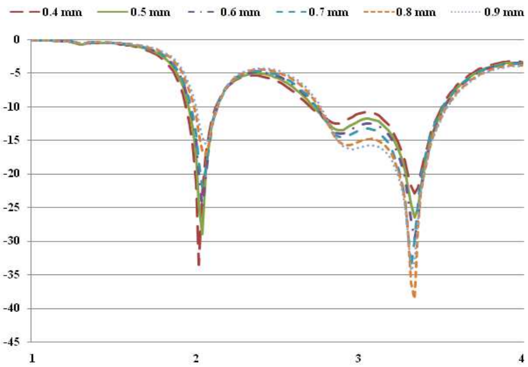


Figure 3. *Return loss characteristics for different feed strip distance.*

3.3. Effect of Slot Position (p)

Rectangular slot is being introduced from center of the patch at a position of 10mm to obtain maximum bandwidth. The slot position is varied from 8mm to 13mm in steps of 1mm. The optimized S_{11} parameter is being shown in the Figure 4. The slot is being introduced in vertical direction to obtain a dual band frequency range. From Figure 4, it is clear that the lower cut-off frequency of the geometry does not change but there is change in the upper cut-off frequency of the geometry. From Table 4, the optimum slot position having maximum bandwidth is obtained at p=10mm.

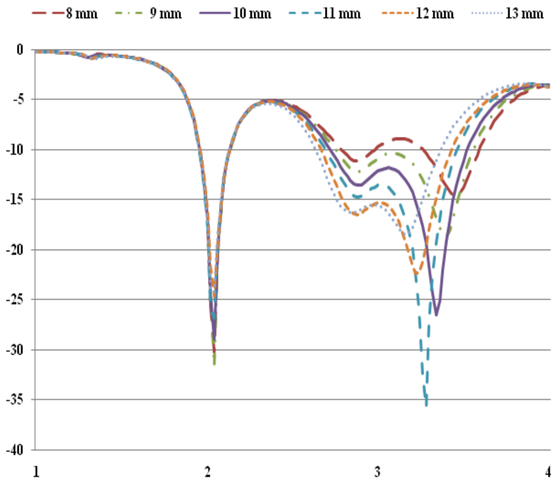


Figure 4. *Return loss characteristics for different slot position.*

Table 4. *Effect of variation of slot position on bandwidth of proposed antenna.*

Slot position(p) (mm)	8	9	10	11	12	13
Frequency range(GHz)	1.96-3.58	1.96-3.54	1.92-3.54	1.96-3.46	1.96-3.42	1.96-3.36
Bandwidth (%)	67.5	65.8	67.5	62.5	60.8	58.3

3.5. Effect of Slot Length (Ls)

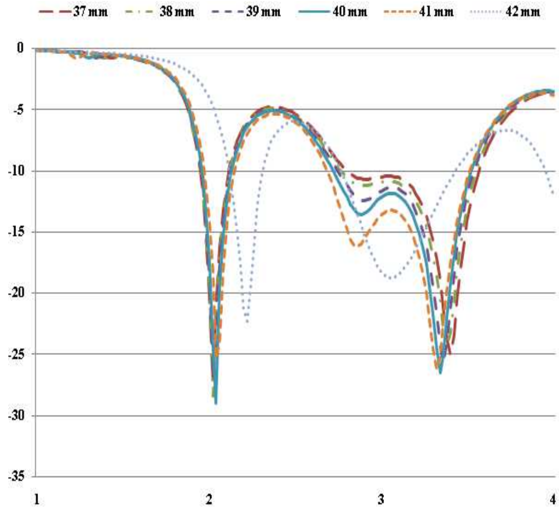


Figure 5. *Return loss characteristics for different length of slot.*

Keeping all the above parameter constant, slot length is varied from 37mm to 42mm in steps of 1 mm each. The S_{11} parameter of slot length variation is shown in Figure 5. From Figure 5, as we increase the length of the slot the upper cut-off frequency changes accordingly. As we increase the slot length above 41mm the bandwidth of the antenna reduces as shown in the Table 5. The maximum bandwidth is obtained at the frequency range of 1.96-3.52 GHz which is 65%. The optimum slot length is being obtained at *ls*=40mm without the shift in the resonance frequency.

Table 5. *Effect of variation of slot length on bandwidth of proposed antenna.*

Slot length(*ls*) (mm)	37	38	39	40	41	42
Frequency range (GHz)	1.96-3.51	1.96-3.52	1.96-3.5	1.96-3.52	1.98-3.5	2.12-3.42
Bandwidth (%)	64.6	64.6	64.2	65.0	63.3	54.2

3.4. Effect of Slot Width (Ws)

The slot width is being varied from 18mm to 21mm in steps of 1mm keeping above parameter constant. The S_{11}parameter change is shown in Figure 6.From Figure 6, it is clear that there is slight change in the upper and lower cut-off frequency of the proposed geometry. As *ws*=22mm shows for maximum depth in the return loss but there is slight shift in the resonance frequency of the antenna. From Table 6, it is being noted that the optimum slot width is obtained at *ws*=20mm without change in the resonance frequency having maximum bandwidth of 65%.

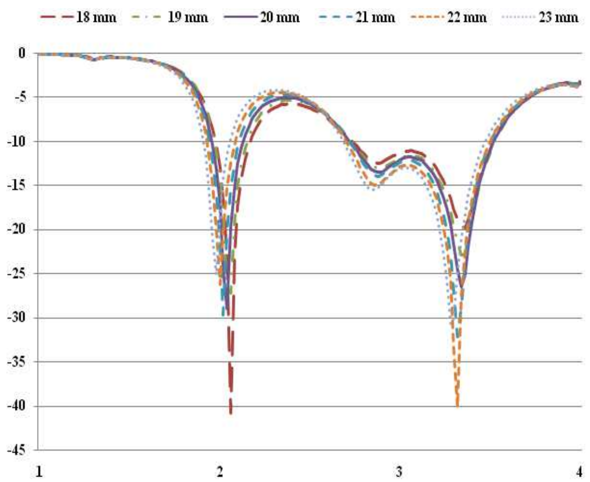


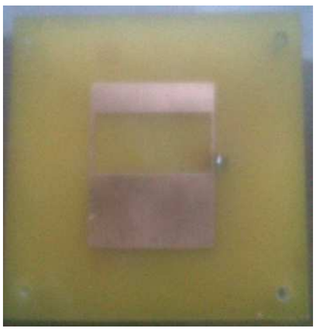
Figure 6. *Return loss characteristics for different width of slot.*

Table 6. *Effect of variation of slot width on bandwidth of proposed antenna.*

Slot width(*ws*) (mm)	18	19	20	21	22	23
Frequency range (GHz)	1.98-3.52	1.98-3.52	1.96-3.52	1.96-3.5	1.94-3.5	1.92-3.46
Bandwidth (%)	64.2	64.2	65.0	64.2	65.0	64.2

From all the cases studied, the optimum set of parameter are d=0.5mm, t=1.5mm, s=10mm, along with slot parameter p=10mm, *ls*=40mm and *ws*=20mm. As IE3D assumes infinite ground and substrate dimension the optimized geometry was resimulated using Ansoft HFSS v.13. Also, at both the resonant frequency, more than 5dB gain was observed. Detailed studies of parameter have been conducted for various designs.

4. Experimental Results and Discussions



(a)

(b)

(c)

Figure 7. *Fabricated prototype (a) Front side (b) Air Gap (c) Rear side*

The prototype antenna with dimension listed in Figure 1 with optimum parameter using IE3D presented in Table 1 was fabricated and tested. Return loss comparison is shown in Figure8.The substrate used for manufacturing is FR4 glass epoxy with dielectric constant of 4.4 and thickness 1.6 mm along with air gap of 7.5 mm. The substrate is assembled above copper ground plane of dimension 100×100×1.6 mm^3.A photography of the antenna is shown in the Figure7. S parameter comparison is shown in Figure 8. The pin of SMA connector is extended to reach the feed strip and is soldered there.

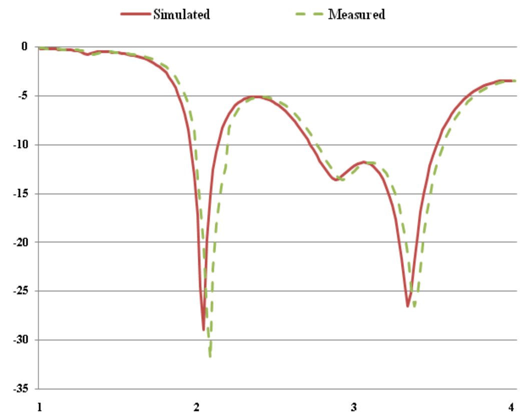


Figure 8. *Return loss characteristics of antenna shown in Figure 1 with stimulated and measured results*

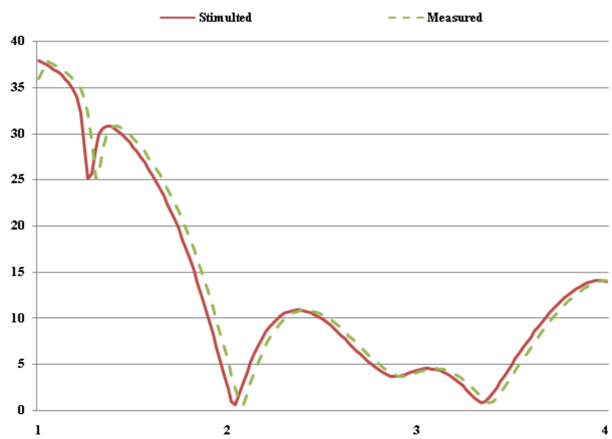


Figure 9. *VSWR Vs frequency of proposed antenna shown in Figure 1.*

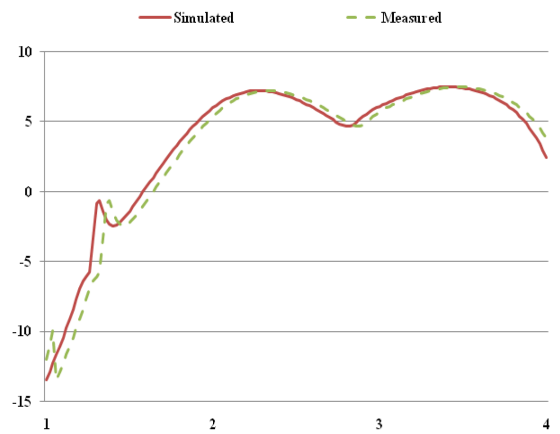


Figure 10. *Gain Vs frequency of proposed antenna shown in Figure 1.*

From Figure 8 it is clear that the proposed antenna has an operating frequency range at 2.4 GHz. The prototype antenna was tested for S11 using Agilent Technologies N9925A. From Figure 9 it is clear that VSWR of the proposed antenna is below 2 dB at the operating frequency 2.4 GHz. The gain of antenna is above 5dB at the operating frequency shown in Figure 10. The measured gain fairly agrees with the stimulated gain of the proposed antenna.

5. Conclusion

Rectangular slot antenna for broadband application with a finite ground is being presented. By varying the slot length and width dual band frequency is being achieved. The antenna presented here offers impedance bandwidth of 5.83 % and 33.3% in the frequency range of 1.96GHz to 2.1GHz and 2.72GHz to 3.52GHz respectively. The gain of the proposed antenna has value greater than 5dB. The proposed antenna is simple, easy to fabricate and need to investigate with less parameter. The Antenna presented here is suitable for Broadband applications.

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