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New single layer wideband rectangular patch antenna

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A simple single layer wideband rectangular patch antenna with double U- shaped slot is presented. The antenna gives impedance bandwidth (–10 dB return loss) of 45% (3.125 GHz) with average gain of about 6.45 dBi over the entire band of operation and peak gain of 9.25 dBi. Air substrate of thickness 4.5 mm is used. The antenna is on single layer having single feed and simple structure; it also has a small size and small height. The proposed antenna has many advantages in terms of simplicity, gain, bandwidth and height as compared with other reference antennas. Both simulated and experimental results are presented. The radiation patterns are stable across the bandwidth.

1 Introduction

Microstrip antennas have been popular because of compactness, low cost, light weight, thin profile and compatibility with integrated circuitry etc. The main disadvantage of a conventional microstrip antenna is its low impedance bandwidth of about 1-2% which can be increased up to 6-7% using thick substrates. But many current applications, as in telecommunication or radar systems, require much larger bandwidth. A popular method of increasing impedance bandwidth is defining U-slot on the patch. A single U slot [1] has achieved impedance bandwidth upto 47% using a nonstandard probe as thick as having radius of 3mm. Although another such patch antenna with repetition of the U slot pattern has been reported to achieve impedance bandwidth upto 44%, it also used a similarly thick probe [2]. There is little practical relevance of these works since the thick probe used is nonstandard and hence is not readily available. By using the method of stacking substrates, the size of probe had been reduced [3], for which impedance bandwidth of 44.7% with peak gain of 10 dB and average gain of 3 dB had been reported. But such stacking enhances complexity of the structure and makes fabrication more difficult. In this article simulated and experimental studies on a new single layer double U-slot rectangular broadband patch antenna with air dielectric is reported. The antenna has impedance bandwidth of 45% (3.125 GHz), peak gain is 9.25 dBi and average gain of 6.45 dBi with good radiation patterns. The advantages of this antenna compared to the others as reported are usage of conventional thin probe (standard SMA connector) and no requirement of stacking, as also much higher value of average gain over the entire bandwidth. The IE3D simulation software based on Method of Moments (MoM) is used for simulation and Agilent's E8363B PNA series Network Analyzer is used for measurements. Anritsu 37269D Vector Network Analyzer is used for radiation pattern measurement. Simulated and experimental results are presented. Comparison table for the antenna developed with other reference antennas is also provided.

2 Antenna design

The double U-shaped slot rectangular microstrip antenna studied has got patch dimensions of 44 × 18 mm^2. The dimensions of the U-slot are as shown and the patch height is 4.5 mm above ground plane. The antenna geometry is shown in Figure 1(a, b). The patch is fed by a conventional 50Ω SMA coaxial probe

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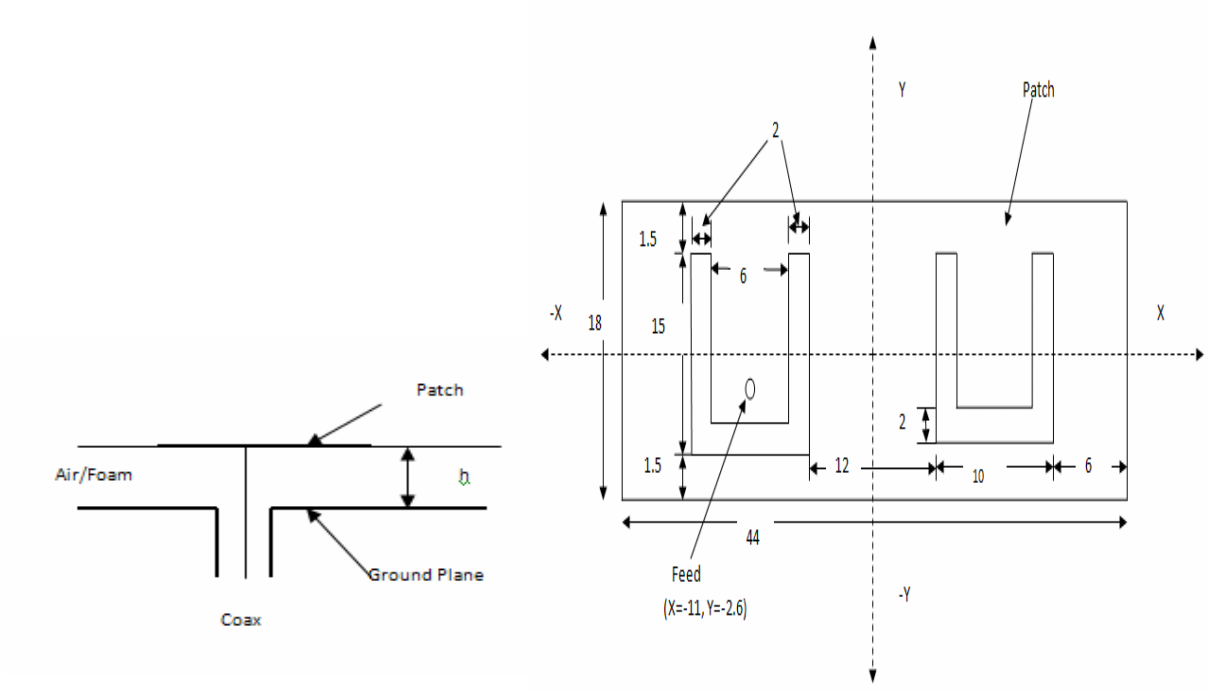
having inner conductor of radius 0.6 mm and foam ($\varepsilon_r \approx 1$) is used between the patch and ground plane to support the patch. The design is optimized thorough parametric studies involving extensive computer simulation. The ground plane size is taken to be about three times the patch size during fabrication and measurements for realization of semi-infinite extent of it.



a. b.

Fig. 1. Double U shaped slot antenna a. side view (h = 4.5 mm) a. Top view (dimensions are in mm)

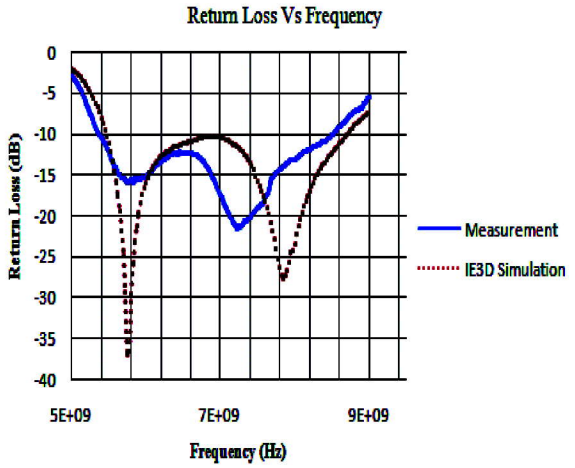
3 Results and Analysis

The antenna simulation is performed using Method of Moment (MOM) based IE3D simulator. Infinite ground plane is considered to ensure faster convergence. Simulation results give impedance bandwidth of 45.5% (5.475-8.7 GHz) around the centre frequency. Experimentally measured results show impedance bandwidth of 45% (5.375-8.5 GHz) around the centre frequency. The experimentally measured radiation patterns at three frequencies in the operating frequency band viz. 5.34 GHz, 7.0 GHz & 8.56 GHz are also reported. The simulated average gain of the antenna is about 6.45 dBi over the entire band and the peak gain is 9.25 dBi. Simulated results for gain and cross polar discrimination also shown. All the simulated and measured results for return loss, gain and radiation patterns are shown in Figure 2. (a-h). It is obvious that the simulated and measured results are closely matching with each other.

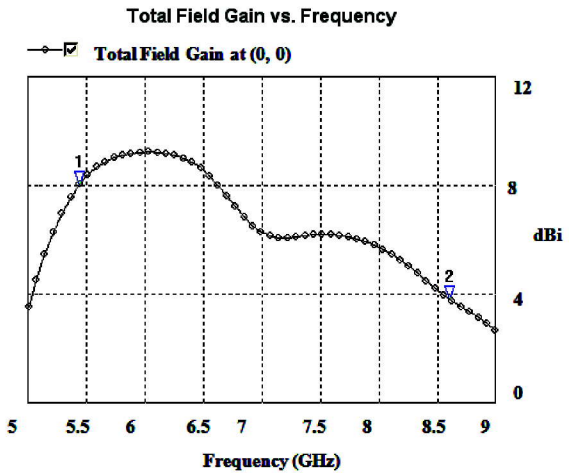
The polarization characteristics of the antenna are also studied. The simulated results for co and cross polarized components of radiation at three different frequencies are shown in Figures 3 (a-c), which signify acceptable polarization purity.

The performance of the proposed double U- shaped slot antenna is compared to other reference antennas and is summarized below in Table 1.

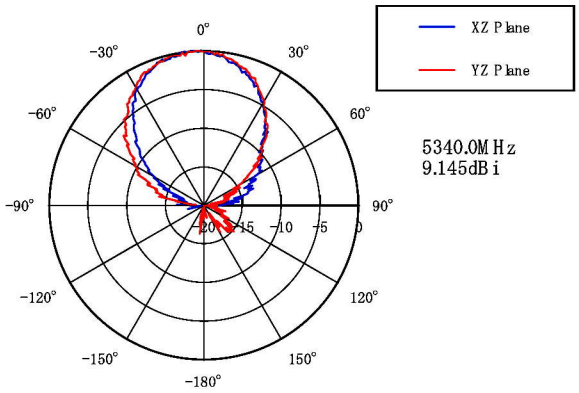
The comparison table shown above indicates that our proposed patch antenna with double U- shaped slot has many advantages over others in terms of gain, height, bandwidth and simplicity of structure. Its absolute bandwidth is significantly higher than other similar antennas. Moreover, its construction is


Return Loss Vs Frequency
Return Loss (dB)
0
-5
-10
-15
-20
-25
-30
-35
-40
5E+09
7E+09
9E+09
Frequency (Hz)
Measurement
IE3D Simulation

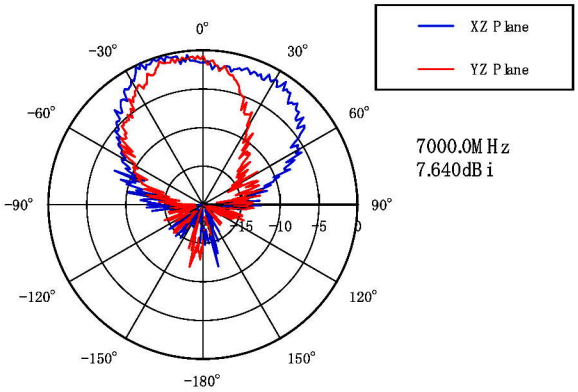
a.


Total Field Gain vs. Frequency
Total Field Gain at (0, 0)
12
8
4
0
dBi
1
2
5
5.5
6
6.5
7
7.5
8
8.5
9
Frequency (GHz)

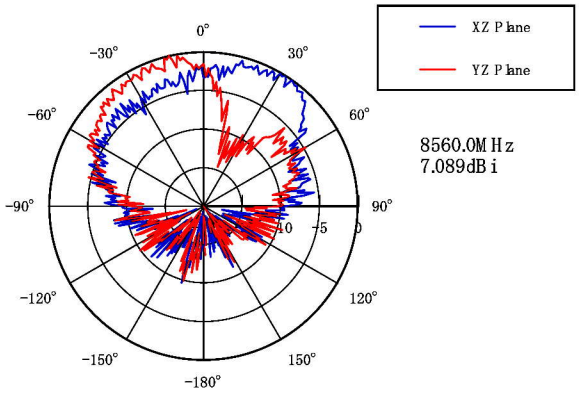
b.


XZ Plane
YZ Plane
5340.0MHz
9.145dBi

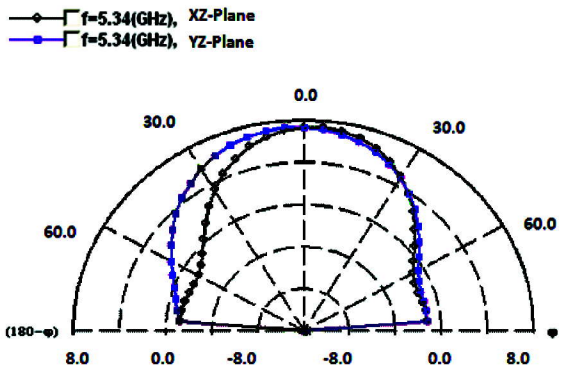
c.


XZ Plane
YZ Plane
7000.0MHz
7.640dBi

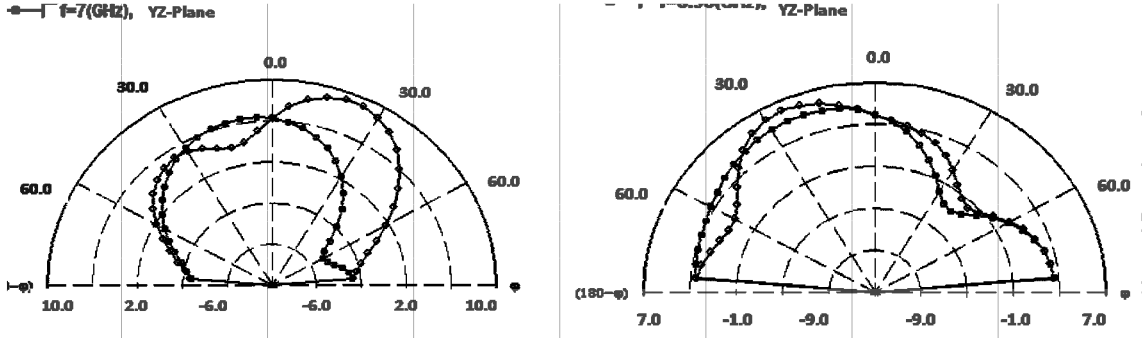
d.


XZ Plane
YZ Plane
8560.0MHz
7.089dBi

e.

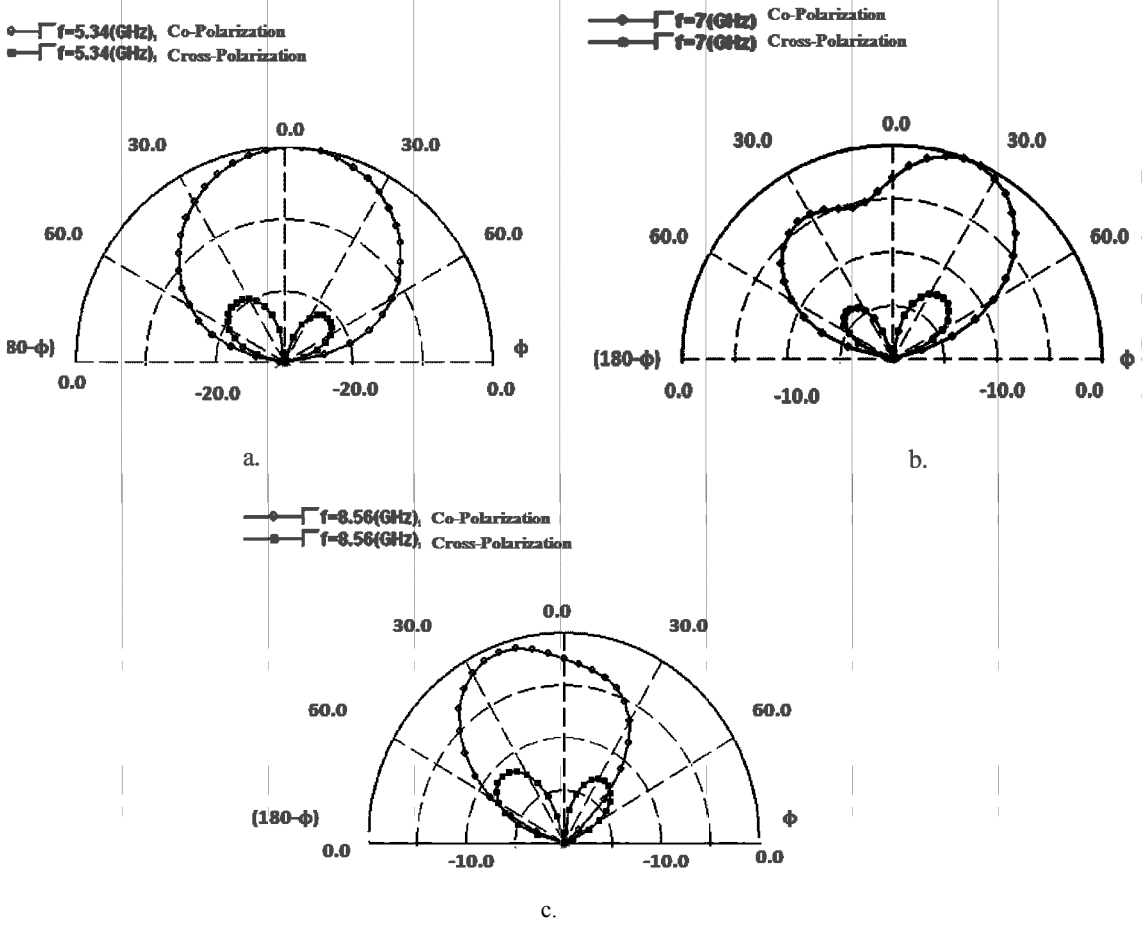

f=5.34(GHz), XZ-Plane
f=5.34(GHz), YZ-Plane
0.0
30.0
30.0
60.0
60.0
(180-φ)
8.0
0.0
-8.0
-8.0
0.0
8.0

f.



g. h.

Fig. 2. a. Return loss vs frequency plot; b. Simulated Gain vs frequency plot; (c-e). Experimentally measured radiation patterns at 5.34 GHz, 7 GHz and 8.56 GHz respectively; (f-h). Simulated radiation patterns at 5.34 GHz, 7 GHz and 8.56 GHz respectively



a. b.

c.

Fig. 3 (a-c). Simulated Co and Cross polarized simulated radiation fields at 5.34 GHz, 7 GHz and 8.56 GHz, respectively

very simple and it is very easy to fabricate since it uses a single air layer as substrate. The practical antenna is fabricated with foam (dielectric constant ≈ 1) as spacer. Another advantage of this antenna is its low height, reducing the aerodynamic drag for airborne applications considerably.

Table 1. Comparison of different broadband patch antennas

Antenna	Peak, Avg. gain	Height h (mm), Probe radius r (mm)	BW in %, Absolute Frequency range)	Comments
Ref.[1]	Not mentioned	h = 27, r = 3	47%, 812-1282 MHz = 470 MHz	Single layer, ε_r = 1 and thick probe
Ref.[2]	Not mentioned	h = 16.5, r = 3	44%, 1.2407-1.9406 GHz = 0.6999 GHz	Single layer, ε_r = 1 and thick probe
Ref.[3]	10 dBi,3 dBi	h = 10, r = 0.6	44.7%, Not mentioned	Stacked patch and small probe
Double U-shaped slot – our antenna	9.25dBi, 6.45dBi	h = 4.5, r = 0.6	45% , 5.375-8.5 GHz = 3.125 GHz	**Much smaller height, standard thin feed probe, single layer, ε_r= 1, better avg. gain**

The small discrepancies between measured and simulated results are in all likelihood due to imperfect fabrication of the patch and inexact positioning of the probe feed.

4 Conclusion

The simulated and measured results reported in this article show that the new double U- slot single air layer wideband rectangular patch antenna is small in size and height and easy to fabricate. It uses only a standard SMA connector. Its impedance bandwidth is 45%, peak gain is 9.25 dBi and average gain is 6.45 dBi with good radiation patterns. Its average gain over the entire band of operation is much higher than other similar antennas reported earlier without compromising the bandwidth. In fact, the absolute bandwidth of 3.125 GHz is orders greater than that of other similar antennas. This gain enhancement is caused probably by the additional directive radiation from the double slots which add up to the patch radiation.

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