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Modified e-slotted patch antenna for WLAN/Wi-Max satellite applications

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ABSTRACT

A low profile modified e-slotted microstrip antenna is proposed for multiple wireless communication applications. The performance of antenna is measured in terms of return loss, current distribution. The effect of variation of height of substrate on antenna impedance bandwidth is also studied. The antenna with overall size 30×50×.8m.m.^{3} resonates at eight frequencies which covers some important applications like GPS, wireless local area network (WLAN), worldwide interoperability for microwave access (WiMax), Satellite communication etc. The proposed antenna structure offers great advantages due to compact size, simple structure and multiple applications. The multi band antenna was designed and optimized using ansoft HFSS v13 simulator. The simulated result is good agreement with measured result.

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1. INTRODUCTION

The rapid progression of wireless system accelerate interest in multiband, low cost, light weighted, compact patch antennas however the conventional microstrip antennas suffer with several limitations such as narrow bandwidth, low gain and low efficiency. To overcome these limitations many researchers worked on it since the 1980s [1-5], still the research is in process to design compact size, multiband and high gain patch antennas. Now a days it is desirable to design an antenna which integrate as many applications such as GPS, wireless area network (WLAN) Wi-Fi, Wi-Max, RFID, into a single device. For this reasons many designs like dual band F-shape printed monopole antenna [5], multi band slot antenna [6], defected ground (DGS) multi band patch antenna [7], triple band e-shape patch antenna [8], stub loaded multi band slotted antenna [9], tri-band microstrip antenna [10] and triple band fractal microstrip antenna [11] have been proposed. Compact multiband monopole [12] had small size of 30×34×.8m.m.^{3} but the design is complex in structure and the maximum antenna gain is -1 dBi for 2 GHz, 1 dBi for 3.5 GHz, and 3.5 dBi for 5 GHz, e-slot antenna in [8] has maximum gain at two resonant frequencies is 1.5 dBi and total size of antenna is 80x100x1.6m.m^3., the dual band monopole antenna in [6] had size 35x40x1.6m.m.^{3} with gain 1.87 dbi at 2.45 GHz frequency and 2.88 dbi at 5.18 GHz. In regular microstrip antenna the dual, triple and multi band response are obtained with respect to fundamental and next higher order mode resonance frequency, but the radiation pattern characteristics not remains constant over two, three or multi frequencies [8].

2. METHODOLOGY

In this proposed work the multi band operation is obtained by slot cutting method, for the identical radiation pattern characteristic as we cut the slot on the patch the higher order modes is generated near to the fundamental mode which broaden the impedance bandwidth [9]. The location of the feed strip has a significant effect on impedance bandwidth and radiation characteristics. A single layer, compact multi band microstrip antenna is described. Parametric study of different parameters is also reported to obtain the best results. The proposed antenna is better than the work studied in literature which is shown with the help of Table 1.

Table1. Comparison with reference work

Ref. Ant.	No. of band	Antenna dimensions	Resonant frequency (GHz)	Total size
[6]	2	35×40× 1.6	2.45, 5.18	2240m.m.^{3}
[8]	3	80 × 100 ×1.59	.738, .922, .970	12720m.m.^{3}
[9]	4	80× 50 × 1.59	.667,.826,.889,1.081	6360m. m.^{3}
[13]	4	44× 56 × .8	1.575,2.45,3.5,5.2	1971.2m.m^3
[14]	3	85×85×1.57	2.1, 3.8, 5.3	11343.25 mm.
[15]	2	32× 30 × 3.175	1.56, 2.47	3048mm.$^{3048MM.}$
Proposed Antenna	8	30× 50 × .8	1.165, 3.665, 4.605, 5.095, 6.01, 6.835, 8.045, 8.81	1200m.m.^{3}

3. ANTENNA DESIGN

Figure 1 shows the structure of modified e-slotted patch antenna, which consists of a five horizontal rectangular slots, and one rectangular vertical slot on the radiating patch, the proposed antenna design printed on glass epoxy substrate of relative permittivity εr 4.4, loss tangent .0013 and substrate height (h) is .8m.m. A microstrip line feed technique is use for giving the input power, as depicted in Figure 1, the feed line has a width W_F = 3 mm to achieve an impedance of 50Ω. The side view of proposed design shown in Figure 2. Due to multiple slots antenna resonate at different frequencies , first band resonate at 1.165 GHz cover the frequency band of 1.02-1.31 GHz for GPS system, second band resonant frequency is 3.665 GHz cover the frequency band 3.63-3.7 GHz for, forth band resonant frequency is 4.605 GHz cover the band 4.57-4.64 GHz for, 5.095 GHz cover the band 5.06-5.13 GHz for IEEE WLAN standards, 6.01 GHz cover the band 6.36-6.46 GHz, 6.835 GHz, 8.045 GHz cover 8.01-8.08 GHz, 8.81GHz,cover 8.76-8.86 GHz. The dimensions of proposed design given in Table 2 are optimum dimensions to obtained multi bands.

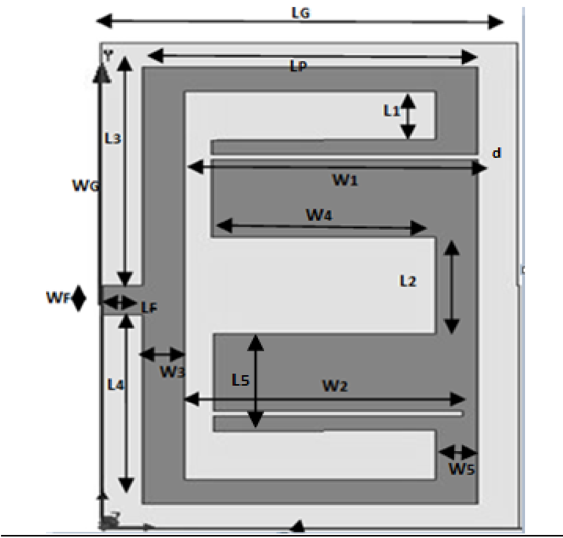

Figure 1. Top view of proposed design

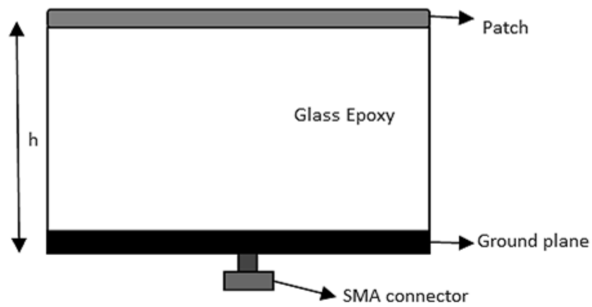

Figure 2. Side view of proposed design

Table 2. Optimum dimensions of proposed design (all units in mm)

Paramerters	L_G	W_G	L_P	L_1	W_1	L_2	L_3	W_2
Dimensions	30	50	26	5	21	10	22.5	20
Paramerters	W_3	W_4	L_4	L_5	W_5	D	W_F	L_F
Dimensions	3	16	19.5	10	3	.5	3	3

4. ANALYSIS OF PROPOSED DESIGN

Rectangular patch is considered as a parallel combination of R_1, L_1 C_1 as shown in Figure 3 according to cavity model, and the value of which are given as [16, 17]:

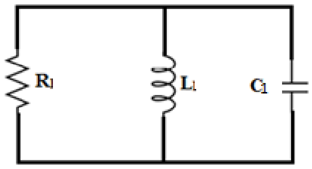

Figure 3. Equivalent circuit of rectangular patch

$$C_1 = \frac{\varepsilon_{eff}\varepsilon_0 L_P W_P \cos^{-2}(\pi y_0/W_P)}{2h} \quad (1)$$

$$R_1 = \frac{Q_r}{\omega C_1} \quad (2)$$

$$L_1 = {}^{1}/_{\omega^2 C_1} \quad (3)$$

$$Q_r = \frac{c\sqrt{\varepsilon_{eff}}}{8fh} \quad (4)$$

where C_1, R_1, L_1 are the fed rectangular patch antenna equivalent circuit parameters, Q_r is the total quality factor of the patch, f is the resonant frequency of the patch , L_P and W_P are the length and width of the rectangular patch, and h is the thickness of the substrate material, y_0 is the x co-ordinate of the feed point from the center.

Here $\omega = 2\pi f$ and ε_{eff} = effective permittivity of the medium which is given as [18, 19]:

$$\boldsymbol{\varepsilon_{eff}} = \frac{\boldsymbol{\varepsilon_r + 1}}{\boldsymbol{2}} + \frac{\boldsymbol{\varepsilon_r - 1}}{\boldsymbol{2}}\left(1 + {}^{10h}/_{W_P}\right)^{-\frac{1}{2}} \quad (5)$$

the resonant f of the fed patch is calculated as [20]:

$$f = \frac{c}{2L_P\sqrt{\varepsilon_{eff}}} \quad (6)$$

where c = velocity of light in free space.

The impedance of fed patch according to the equivalent circuit is given as:

$$Z_{F1} = \left(\frac{1}{\frac{1}{R_1} + \frac{1}{j\omega L_1} + j\omega C_1}\right) \quad (7)$$

micro strip line is considered as the parallel combination of strip inductance L_{L1} and the strip capacitance C_{L1} as shown in Figure 4 is calculated as [21-26]:

$$\boldsymbol{C_{L1}} = \sqrt{\boldsymbol{wW_f}}(\boldsymbol{130\,log(w/W_f) - 44})\boldsymbol{pF} \quad (8)$$

$$L_{L1} = h(40.5(w/W_f - 1) - 75\,log(w/W_f) + .2(w/W_f - 1)^2 nF$$

where W_f the width of feed strip, the microstrip line impedance Z_{L1} depends on strip inductance L_{L1} and strip capacitance C_{L1} is shown in Figure 4.

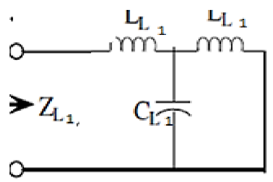

Figure 4. Equivalent circuit for microstrip feed

total impedance of the strip is given as:

$$Z_{L1} = j\omega L_{L1} + \frac{1}{j\omega C_{L1} + \frac{1}{j\omega L_{L1}}} \quad (9)$$

5. RESULT AND DISCUSSIONS

Figure 5 shows the measured result of S11 impedance bandwidth below -10 dB return loss of proposed design at h = .8m.m., and Figure 6 shows the comparison graph of measured result and simulated result of proposed design. The proposed design resonate at eight resonant frequencies, 1.165, 3.665, 4.605, 5.095, 6.01, 6.835, 8.045, 8.81 GHz in the simulated with the maximum return loss of -30 dB as shown in Figure 6. The effect of variation of substrate thickness (h) on number of resonant frequencies is also analyzed as shown in Figure 7.

The substrate thickness is varied from .8m.m. to 2m.m. at h=.8m.m. 1.2m.m. 1.6m.m. and 2m.m. from the simulated result it is observed that at h=.8m.m. antenna resonate at eight frequencies and maximum return loss -30 dB is achieved. While, at h = 1.2m.m. antenna resonate at six frequencies, at h = 1.6m.m. again antenna resonate at six frequencies, and h=2m.m antenna resonate at three frequencies so it is observed as we increase the substrate thickness less band is obtained. Figure 8 represents the current distribution on the patch at different resonant frequency and the magnitude of the current is given in the table attached. It can be easily concluded with the current distribution that current is concentrated near the slots which has a significant effect on the impedance bandwidth. Table 3 shows distribution of eight band of frequencies on which the proposed design resonates.

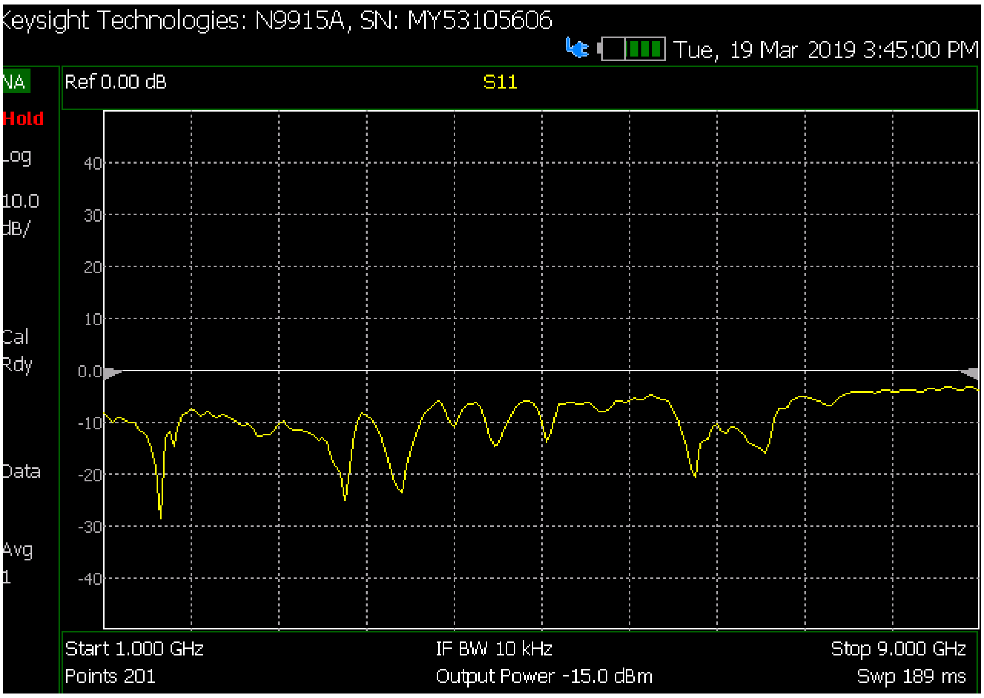

Figure 5. Measurement result of S11

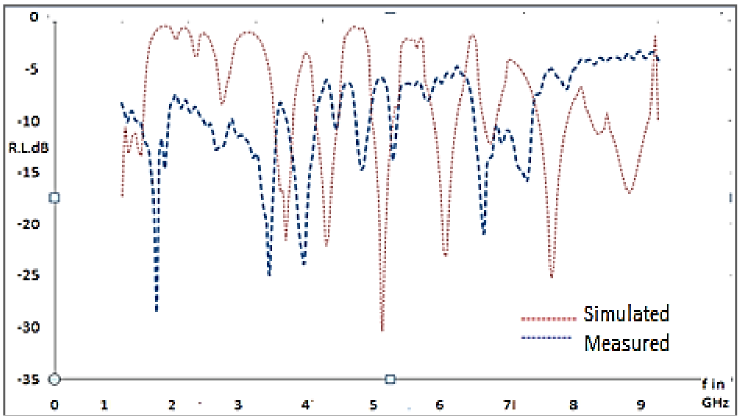

Figure 6. Simulated and measured results S11 of proposed design

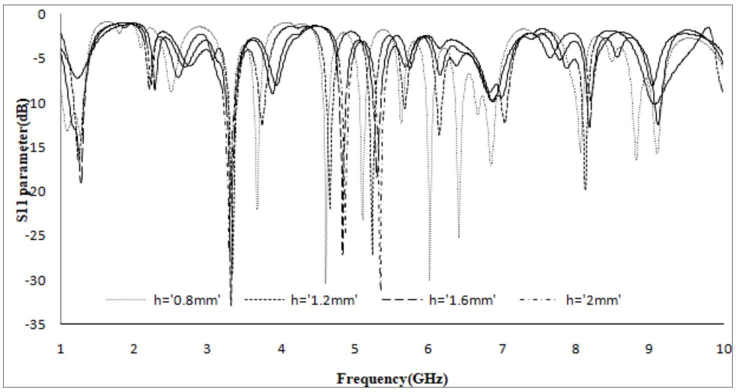

Figure 7. Simulated results of S11 at different thickness

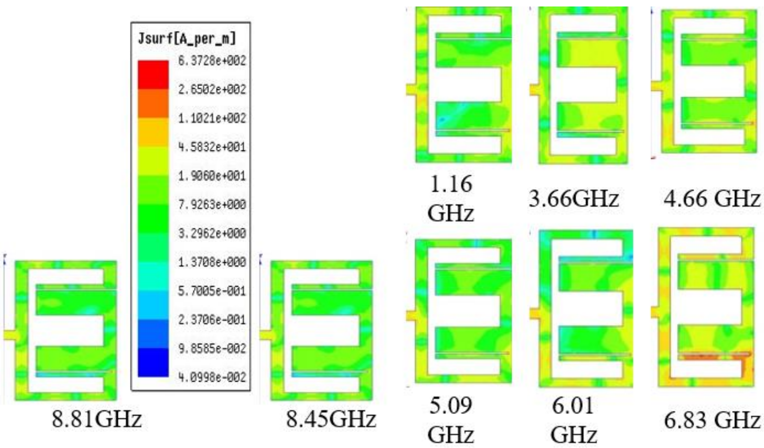

Figure 8. Current distribution on the patch at different frequencies

Table3. Distribution of frequency bands

Frequency band No.	F_L(GHz)	F_H(GHz)	F_c (GHz)
1	1.02	1.31	1.165
2	3.63	3.7	3.665
3	4.57	4.64	4.605
4	5.06	5.13	5.095
5	5.97	6.05	6.01
6	6.76	6.91	6.835
7	8.01	8.08	8.045
8	8.76	8.86	8.81

6. CONCLUSION

A low profile, multi band antenna is successfully designed for various applications with good current distribution. The antenna designed is simple in structure and compact in nature. Eight bands of frequency are achieved with a simple structure. Also the effect of substrate thickness is studied and best result is obtained at 0.8 mm thickness which is low. Mathematical analysis of the designed is presented, the simulated result of s11 is in good agreement with the measured result.The antenna is better than many antennas exists in size, in number of bands and current distribution.

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