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Design Of L-Slotted Dual Band Z-Shape Patch Antenna Useful For Wireless Applications

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Abstract- A Z-Shape dual band antenna is proposed in this paper. The Antenna consist of three L-Shape Slots being cut in the patch, and is being fed with coplanar waveguide, which ultimately radiates electromagnetic waves, and determines the radiation pattern of the antenna. The Z-shape patch has been provided Perfect E Boundary, which in turn results in better gain and return loss characteristics. The two resonant frequency of the antenna are 1.40Ghz and 1.68Ghz, which gives 0.18Ghz and 0.16Ghz bandwidth, and a gain of 18.3db at the solution frequency of 0.95Mhz. The frequency domain characteristics of the antenna has been studied, and performance of the antenna has been thoroughly investigated by simulating it with the help of High Frequency Structure Simulator(HFSS) software.

Keywords- Patch Antenna, Z-Shape Patch, Wireless Applications, Dual-Band Patch Antenna, L-Slot Antenna, Microstrip Antenna, HFSS

INTRODUCTION

Wireless Communication is more preferred these days compared to wired communication because of its flexibility, ease and durability. A patch antenna is a low profile antenna(called as rectangular microstrip patch antenna), which can be scaled on a flat surface, and usually consist of a patch of metal put on another large sheet of metal popularly known as the ground plane. Slots are being cut in patch antennas because slotted antennas provide greater control of radiation pattern, and has many advantages such as robustness, design simplicity and convenient adaptation. In slotted antennas, radiation arises by excitation of the slots, and protruding components are absent, which proves to be of greater advantageous than other antennas especially when these antennas are being mounted in the aircraft.

When E & H vectors are being replaced by H & -E vectors, the slots produce fields, that are much similar to the field of a sheet like dipole, and the input impedance of a slotted antenna can be as high as $10^3\Omega$, and the characteristic impedance of the cable can be in between 50 and 75Ω range. In this paper, a patch antenna having dual bands has been presented, which consists of a Z-Shape patch in which three L Shape slots are being incorporated in order to have better impedance matching and in turn better radiation characteristics. A rectangle shaped ground plane along with a co-planar waveguide transmission line is provided in order to provide necessary excitations to the antenna. The optimized values of length and width of the slots are taken, and these slots are used to enhance the upper frequency of the band, and improving the lower frequency along with impedance bandwidth. Good Bandwidth is achieved in dual resonant frequencies of 1.40Ghz and 1.68Ghz with S11<-10db. The simulation results are being obtained, and radiation pattern, return loss, VSWR, Gain and other properties are being studied. Design details of the proposed antenna along with results and detailed explanations are given and discussed in this paper.

ANTENNA DESIGN

In the proposed antenna, the ground plane and Z-Shape parasitic strip are on the same side of the substrate. The Z-shape Patch has been designed by cutting two rectangle shape slots having length of 35mm and width of 8mm The antenna has been fed with a coplanar waveguide transmission line having width of 3.8mm, and length of 41mm. Three L-Shaped slots are further being cut in the three sections of Z-Shape patch having width of 5mm each. The substrate used here is FR4 epoxy, and is having relative permittivity of 4.4, and di-electric loss tangent of 0.02, and mass density of 1900. The Antenna is provided with Perfect E excitation since it forces the H field tangential component to be on same side, and also models perfectly conducting surface of a structure. Current path induces from two resonant frequencies, which in turn creates dual resonant modes. The Gain achieved at the solution frequency of 0.95Mhz is 18.3 db, and S11 achieved at both the resonant frequency is -18.74db, -22.34db.

"Fig. 1" denotes the general geometry of the proposed antenna, and "Fig. 2" denotes the Z-shape patch incorporated with three L-shape slots which are identical to each other in dimension. The simulation process was carried in HFSS software, and various characteristic plots of the antenna are being depicted below.

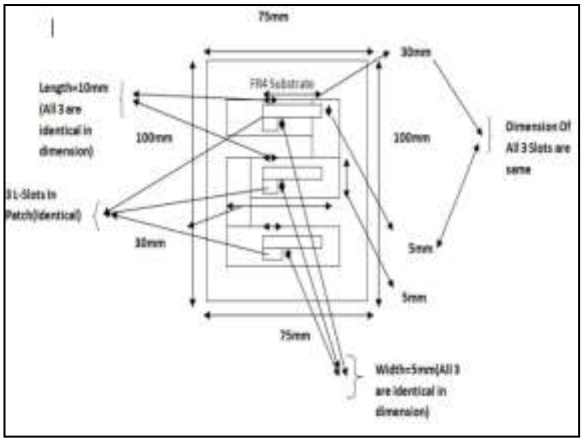


Fig. 1: Geometry Of The Patch And Substrate

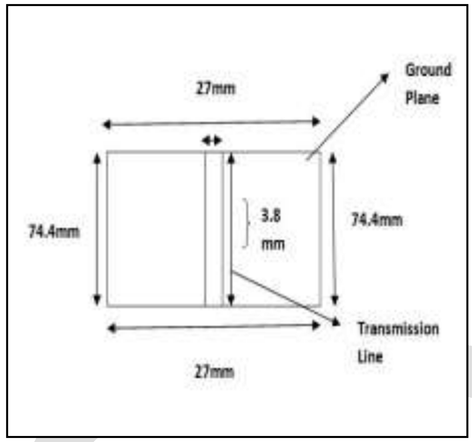


Fig. 2: Ground Plane Geometry

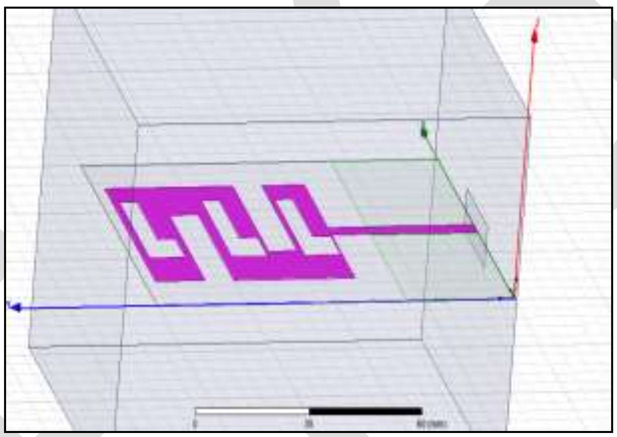


Fig. 3: Simulated Antenna(Proposed)

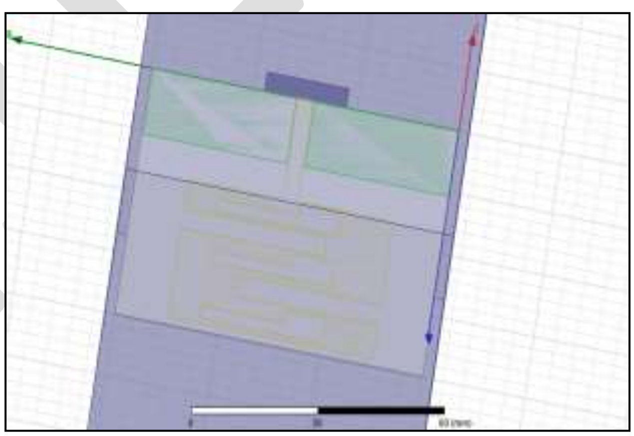


Fig. 4: Simulated Antenna(Top View)

Dimensions of the proposed antenna are clearly indicated in "Figure 1". The substrate that is being chosen is FR4 Epoxy having the following properties:

- **Relative Permittivity:** 4.4
- **Di-Electric Loss Tangent:** 0.02
- **Lande G Factor:** 2
- **Mass Density:** 1500

The ground plane dimension is (74.4 x 27mm), and the co-planar waveguide transmission line is incorporated by cutting the middle portion of the ground plane having dimensions equal to that of the transmission line. L-shape slots are being used here because presence of slots in any antenna confirms a roughly Omni-directional radiation pattern, and ensures linear polarization along with various design variables that can be helpful to tune performance of the antenna.

Operating Range Of The Antenna:

The Proposed antenna operates within the frequency band of wireless communications viz. F1= 1.40GHz, and F2=1.68GHz.

GOVERNING FORMULAS AND VARIABLES

- **Effective Di-electric Constant is given by:**

$$\varepsilon_{eff} = \frac{(\varepsilon_r + 1)}{2} + \frac{(\varepsilon_r - 1)}{2}\left[1 + 10\frac{H}{W}\right]^{-\frac{1}{2}}$$

- **Length Of The Patch is calculated by the formula:**

$$L = \frac{c}{2f\sqrt{\varepsilon_{eff}}} - 2\Delta L$$

- **Notations Used:**
  - ε_R= Relative Permittivity.
  - L= Length, f= Working frequency, c= Velocity of light
  - W= Patch Width(W=C/2f$\sqrt{\varepsilon_R}$) [Non-Resonant]
  - Length Of The Patch Antenna is calculated as:

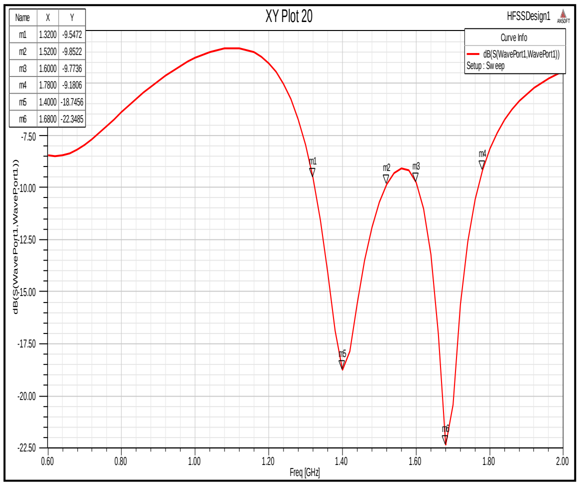
$$\Delta L = 0.412h\frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)}$$

- **Effective Length L_{eff} is given by:** [$Leff= c / 2f0 \; x \sqrt{\varepsilon_{Reff}}$]

OBSERVATION AND RESULTS

Return Loss And VSWR Graph:

- The return loss graph of the proposed antenna is shown in the "fig. 5" below. The two resonant frequencies are 1.40GHz and 1.68GHz yielding S11(F1)= -18.74db, and S11(F2)= -22.34db. The VSWR Graph is shown in "fig. 6", and it can be seen that highest VSWR(Voltage Standing Wave Ratio) is achieved at 1.10GHz, and value of VSWR at two resonant frequency of 1.40GHz and 1.68GHz is 2.01db and 1.32db respectively.



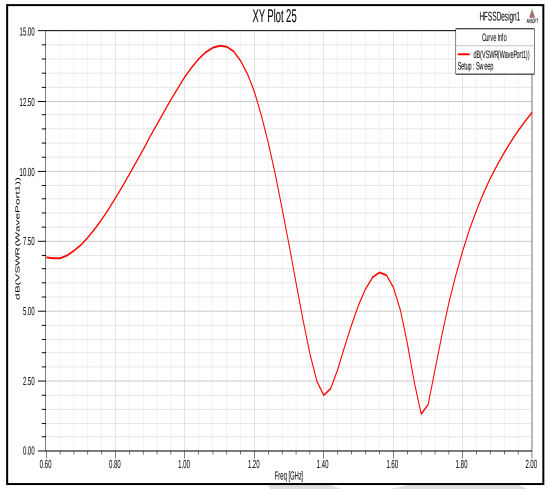


Fig. 5: Return Loss Of The Proposed Antenna

Fig. 6: VSWR Of The Proposed Antenna

- From the graph, it can be clearly seen that highest return loss is being found at 1.12GHz, and lowest return loss is being found at 1.68GHz. Bandwidth is being calculated from return loss graph are 0.18 GHz(at F1), and 0.15GHz(at F2).

3d Polar Plot:

- 3d Polar Plot graph is shown in "Fig 6". Data table has also been shown in "Fig. 7", which clearly depicts db[reTotal V] corresponding to various values of theta from -180 to +180.

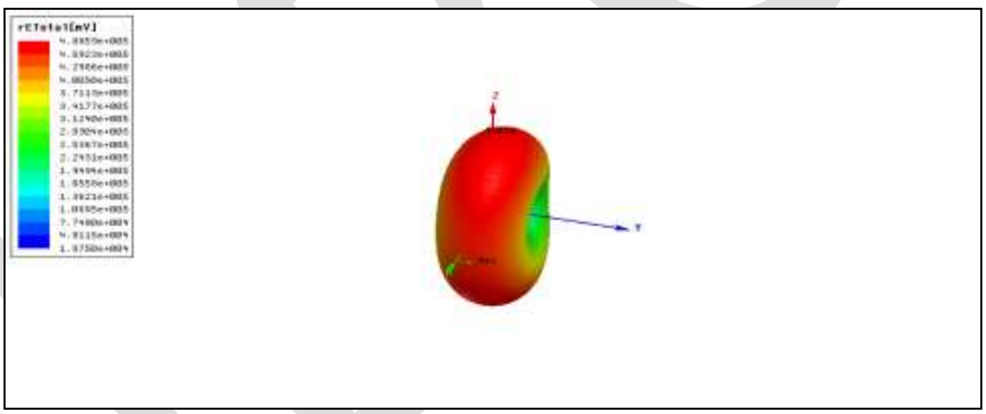


Fig. 6: 3d Polar Plot Of The Proposed Antenna

Data Table 2 — HFSSDesign1

	Theta [deg]	dB(rETotal) Setup : LastAdaptive Freq='0.95GHz' Phi='0deg'	dB(rETotal) Setup : LastAdaptive Freq='0.95GHz' Phi='5deg'	dB(rETotal) Setup : LastAdaptive Freq='0.95GHz' Phi='10deg'	dB(rETotal) Setup : LastAdaptive Freq='0.95GHz' Phi='15deg'	dB(rETotal) Setup : LastAdaptive Freq='0.95GHz' Phi='20deg'	dB(rETotal) Setup : LastAd... Freq='0.95GHz'...
1	-180.000000	53.331276	53.331276	53.331276	53.331276	53.331276	53.331276
2	-175.000000	53.177553	53.161932	53.146940	53.132718	53.119408	53.107158
3	-170.000000	52.993618	52.961375	52.929335	52.897834	52.867243	52.837969
4	-165.000000	52.781398	52.731724	52.680820	52.629252	52.577681	52.526856
5	-160.000000	52.543673	52.475982	52.404703	52.330641	52.254768	52.178214
6	-155.000000	52.284053	52.198004	52.105199	52.006658	51.903638	51.797635
7	-150.000000	52.006932	51.902448	51.787370	51.662875	51.530431	51.391825
8	-145.000000	51.717420	51.594701	51.457035	51.305673	51.142179	50.968487
9	-140.000000	51.421254	51.280775	51.120658	50.942117	50.746659	50.536175
10	-135.000000	51.124680	50.967192	50.785209	50.579793	50.352219	50.104104
11	-130.000000	50.834307	50.660823	50.457998	50.226625	49.967571	49.681929
12	-125.000000	50.556938	50.368718	50.146486	49.890667	49.601559	49.279495
13	-120.000000	50.299369	50.097898	49.858070	49.579868	49.262898	48.906543
14	-115.000000	50.068168	49.855133	49.599851	49.301827	48.959909	48.572411
15	-110.000000	49.869447	49.646706	49.378393	49.063542	48.700241	48.285712
16	-105.000000	49.708620	49.478172	49.199482	48.871157	48.490600	48.054023
17	-100.000000	49.590181	49.354137	49.067899	48.729737	48.336504	47.883596
18	-95.000000	49.517506	49.278056	48.987224	48.643063	48.242067	47.779099
19	-90.000000	49.492693	49.252077	48.959679	48.613476	48.209835	47.743430
20	-85.000000	49.516470	49.276941	48.986031	48.641785	48.240686	47.777585
21	-80.000000	49.588152	49.351948	49.065555	48.727225	48.333790	47.880619
22	-75.000000	49.705678	49.474991	49.196070	48.867497	48.486643	48.049686
23	-70.000000	49.865709	49.642653	49.374035	49.058857	48.695173	48.280160

Fig. 7: Data Table Of The Proposed Antenna

- **Note:** Values of db[rETotal] is shown for only few values starting from -180 degree to -70 degree.

Radiation Pattern:

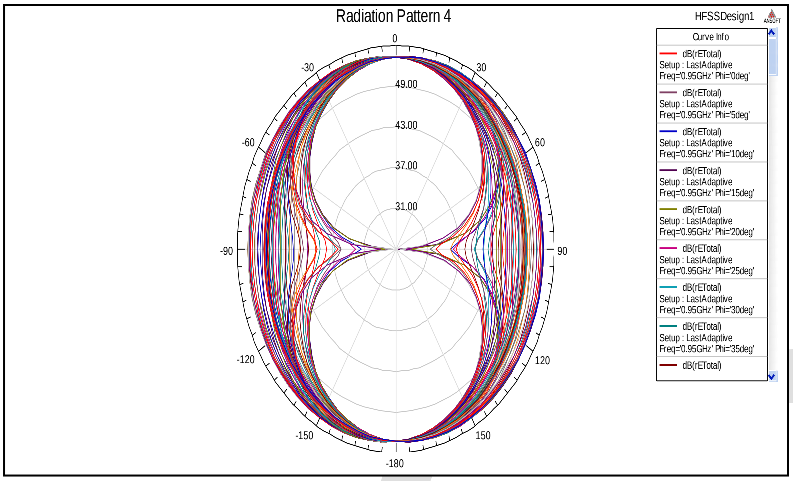


Fig. 8: Radiation Pattern Of The Proposed Antenna

- From the radiation pattern shown in "Fig 9", it is quite evident that there is sufficient cross polarization in the higher band, and because of this, the proposed antenna can receive large distance signals effectively.

CONCLUSION

A L-Slotted Z-shaped patch Antenna is presented in this paper. The Antenna operates in two resonant frequency bands viz. 1.4GHz and 1.68GHz, giving bandwidths of 0.18GHz and 0.15GHz. Gain, Radiation efficiency and other characteristics of the antenna are quite satisfactory, and the frequency domain study and numerical analysis of this antenna is being done in detail. The proposed antenna is having good impedance matching, and 96.61% radiation efficiency, which no doubt makes it suitable for establishing effective wireless communication.

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