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Design & Realization of Tri-Band Monopole Antenna for Wireless Application

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Abstract: A design of a compact printed microstrip G-shaped monopole antenna is proposed covering a frequency range of wireless local area network (WLAN) and the World wide Interoperability for Microwave Access (Wi-MAX). The antenna is simulated and its performance is analyzed by measuring various antenna parameters such as bandwidth, directivity, gain, radiation pattern and return loss. The antenna is constructed of a Flame Retardant 4 (FR4) dielectric substrate. The overall dimension of the radiating patch is$46 \times 25 \times 1.6\text{mm}^3$. The tri band performance can be achived by tuning the length and width of the resonating patch. The antenna has a G-shaped resonating element which is designed for the three resonance frequencies at 2.4 GHZ, 4.5 GHz and 6.45GHz. IE3D method of moments based simulation software is used for design and analysis of the antenna.

Keywords: Monopole Antenna, Microstrip G-Shaped antenna, Tri-Band, Bandwidth, Radiation Pattern.

I. INTRODUCTION

Designing a antenna for multi-band operation with ease of fabrication compact size low cost and a large bandwidth is a challenging task. Even though the telecommunication industry has grown at a remarkable rate in improving the performance of antenna. In recent decade, different techniques have been proposed providing dual triple or quad band performance such as triangular patch [], inverted F [], parasitic element[], E shaped [], H shaped[], U shaped[10]. Even the position and the type of feed such as defected ground[], Coupling fed plate and coplanar waveguide (CPW)[] are used to further increase the antenna parameters. A tri-band G-shaped printed monopole antenna is proposed operating in the band of frequency ranging from 2GHz to 7.5GHz which is suitable for Worldwide Interoperability Microwave Access (WiMax) and Wireless Local Area Network (WLAN) applications. The essential parameters for the design of a printed monopole antenna are:

Operating Frequency: The operating frequency for the ISM Band ranges from 915MHz,2.4GHz and 5.8GHz. Hence we design a antenna with a resonant frequency of 2.45GHz and 4.5GHz. Dielectric Constant of Substrate: Dielectric material that will be used for the antenna is glass epoxy Flame Retardant 4 (FR4) substrate with a dielectric constant of 4.3. There is a significant reduction in the dimension of the antenna with the use of high dielectric constant.

II. METHODOLOGY

1) Hardware Implementation: If the desired parameters and results are obtained then further implementation can be processed on a double sided copper clad in future. Result Analysis: Obtain the results for the antenna and analyze whether the desired parameters are achieved as per the software simulation results

A. Dimensions: Equation for lower edge frequency is used to calculate the dimensions of the microstrip in accordance with the required resonant frequency, bandwidth and gain.
B. Design of Antenna: MGRID – Layout editor for the construction of a geometry and post processor for current display and pattern calculation is used to design the antenna according to the dimensions and parameters calculated.
C. Simulation: IE3D: Electromagnetic simulation engine for numerical analysis to obtain parameters such as current distribution, radiation pattern, gain vs frequency plot, VSWR etc.
D. Hardware Implementation: If the desired parameters and results are obtained then further implementation can be processed on a double sided copper clad in future.
E. Result Analysis: Obtain the results for the antenna and analyze whether the desired parameters are achieved as per the software simulation results .

III. ANTENNA DESIGN GEOMETRY

Designing steps for a microstrip antenna are as follows:
Step 1: Define basic parameters.
Step 2: Draw the geometry with respect to the dimensions calculated.
Step 3: Define port to the antenna.
Step 4: Electro-magnetic Simulation.
Step 5: Current Distribution and Radiation Pattern Calculation

The geometry of the proposed tri-band G-shaped monopole antenna is shown is Fig.1 and Fig.2 The G-shaped antenna consist of two main strips L1andW1. The substrate for the antenna is FR-4 with dielectric constant 4.3 and the loss tangent of 0.02.
Calculation of length of antenna starts with calculating quarter wavelength.

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$$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{2.4 \times 10^9} = 1.25 \times 10^{-1}\text{m} = 125\text{mm}$$

The actual electromagnetic signal propagation speed is given by.

$$\upsilon = \frac{c}{\sqrt{\varepsilon_{eff}}} = \frac{3 \times 10^8}{4.3} = 1.45 \times 10^8\ \text{m/s}$$

Where ε_{eff} is the effective dielectric constant of the substrate used for designing antenna at the operating frequency of 2.4GHz. Assuming resonant length of the of the dipole is 0.47 times the wavelength, the resonant length of the dipole is calculated as follows:

$$r_L = 0.47 \times \lambda = \frac{1.45 \times 10^8}{2.4 \times 10^9} = 0.2839 \times 10^{-1}$$

Thus, the resonant length of the proposed antenna is 28.39mm. Dimensions of the proposed antenna considering the resonant length are $46\text{mm} \times 20\text{mm} \times 1.6\text{mm}$.

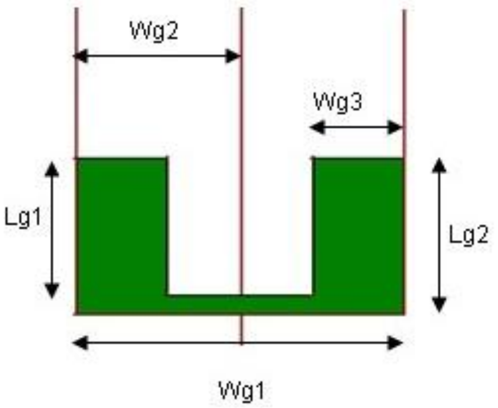

Fig.1 Geometry of the ground plane for proposed antenna

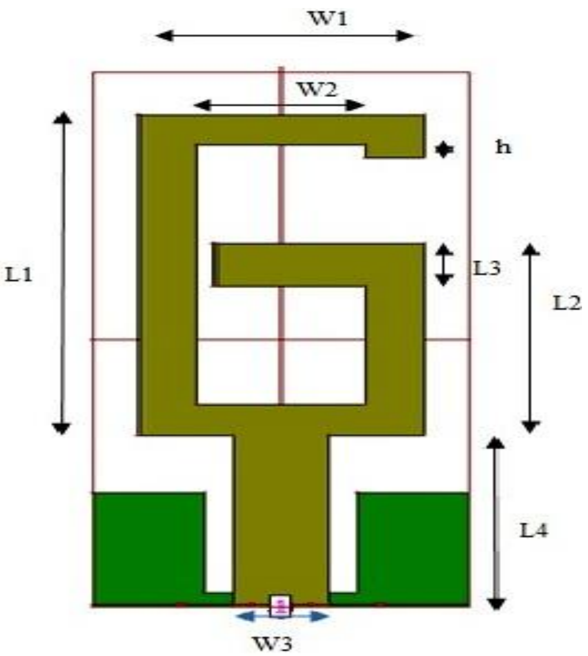

Fig.2 Geometry of proposed G-shaped Antenna

TABLE 1
Dimensions of proposed G-Shaped antenna

Sr. No.	Parts	Measurements in mm
1	h	1.2
2	L1	30
3	W1	15
4	L2	18
5	W2	11
6	L3	4
7	L4	16
8	W3	5
9	Lg1	10.75
10	Wg1	20
11	Wg2	1.5
12	Lg2	14
13	Wg3	6

IV. RESULT

The proposed G-Shaped monopole antenna is simulated at lower frequency range , mid frequency range and higher frequency range of ISM band. The following results were obtained for the various parameters such as bandwidth, gain(S21), radiation pattern, return loss (S11) and voltage standing ratio (VSWR)

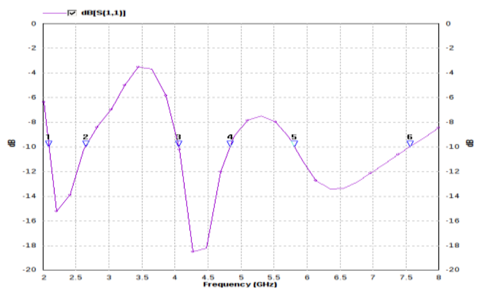
Fig.3 Simulated return loss plot

At lower frequency range of ISM band from 2.12GHz to 2.67 GHz a return loss of -10dB is obtained with a center frequency of 2.4GHz and bandwidth of 548MHz as shown in Fig. 3 At the mid frequency range of ISM band from 4.03GHz to 4.85GHz a return loss of -10db is obtained with a center frequency of 4.45GHz and the bandwidth of 801MHz is observed in fig.3. Bandwidth obtained in this range is suitable for Bluetooth, Wi-Fi and WLAN applications. Fig.3 shows return loss of -10dB over the higher frequency range of ISM band ranging from 5.62GHz to 7.46GHz with a center frequency of 6.26GHz and a bandwidth of 1.84GHz. This bandwidth with a return loss of -10 dB satisfies the standards for Wi-Fi and HYPERLAN.
The voltage standing wave ration (VSWR) is used to determine the impedance matching of an antenna with a transmission line. The value of VSWR should be small as possible and must be near unity, The VSWR for the

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proposed G-Shaped tri-band antenna is shown in Fig. 4. The VSWR value is less than 2 for the three center frequencies from 2GHz to 8GHz. These VSWR values show that the proposed antenna delivers high power. VSWR for the centre frequency of lower frequency range and mid frequency range is lower than 1.5 and it is above 1.5 but below 2 for the the higher frequency range.

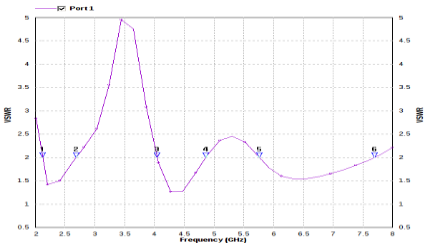

Fig. 4 Simulated plot of VSWR

The radiation pattern as shown in following figures shows that the antenna radiates in all direction and forms an omnidirectional radiation pattern. Directivity can also be extracted from these radiation patterns. The result shows the directivity of 2.214 dBi for 2.4GHz , 2.804 dBi at 4.45GHz and 5.237 at 6.26GHz is achieved for the proposed antenna as shown in Fig.

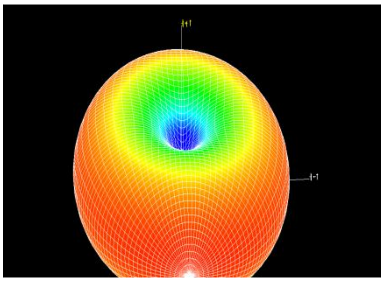

Fig. 5 Simulated radiation pattern at 2.4GHz

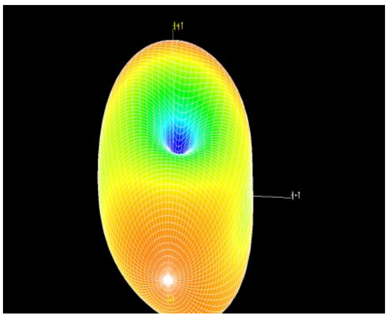

Fig. 6 Simulated radiation pattern at 4.45GHz

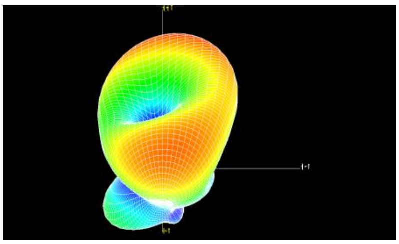

Fig. 7 Simulated radiation pattern at 6.45GHz

Evaluation of three bands namely lower band, mid band and higher band of the proposed G-Shaped antenna is shown in the Table II . It is clearly evident from the Table 2 that the proposed antenna design is adequate for WLAN, Wi-Fi, Bluetooth, and HYPERLAN and other wireless applications.

TABLE 2
Evaluation of performance of proposed antenna

Parameters	Lower Frequency Band	Middle Frequency Band	High Frequency Band
Frequency Range	2.12GHz to 2.67GHz	4.03GHz to 4.84GHz	5.62GHz to 7.46GHz
Center Frequency	2.4GHz	4.45GHz	6.26GHz
Bandwidth	584MHz	801MHz	1.84GHz
Applications	ISM Band		

V. CONCLUSION

This paper presents a tri-band G-Shaped Monopole patch antenna. The proposed antenna can be easily designed to operate in the lower frequency range of 2.12GHz to 2.67GHz , mid frequency range of 4.03GHz to 4.8GHz and a higher frequency range of 5.62GHz to &.46GHz with the center frequency being 2.4Hz, 4.5GHz and 6.26GHz respectively. Thus the proposed antenna is suitable for use in wireless application in ISM Band.

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