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A Dual Band Hexagonal Shape Printed Monopole Antenna for GPS and WiMAX Applications

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***Abstract*— This paper introduces a hexagonal shaped patch antenna with two rejected bands that is designed and simulated for wireless communication systems. The proposed antenna is aimed to produce two different operating frequency bands on a single radiating patch, which can offer a potentially compact design for dual-frequency antennas. The desired dual band operation was obtained by proper loading for a hexagonal shaped patch antenna. The antenna consist of a truncated hexagonal patch with a feed line, printed on a 1.6 mm thick of FR4 epoxy dielectric substrate with permittivity ε_r= 4.4. Return loss of less than -10 dB or VSWR of 2 can be achieved for the desired 1.57 and 3.5 GHz frequency band respectively. The antenna gain increases almost linearly from 1.89 dB at 1.57 GHz to around 3.87 dB at 3.5 GHz. These characteristics make the designed antenna suitable for GPS L1 band and WiMAX applications. The CADFEKO and MATLAB are used to design and simulate the antennas behavior over the different frequency ranges.**

***Key words* – Hexagonal Shape Monopole Antenna, GPS, WiMAX, CADFEKO, MATLAB.**

1) INTRODUCTION

Microstrip antenna are used in communication systems owing to their advantages such as low profile, conformability, low manufacturing cost and easy association with other circuit components [1]. Microstrip or patch antennas are becoming increasingly useful because they can be printed directly onto a circuit board. Patch antennas are low cost, have a low profile and are easily fabricated.

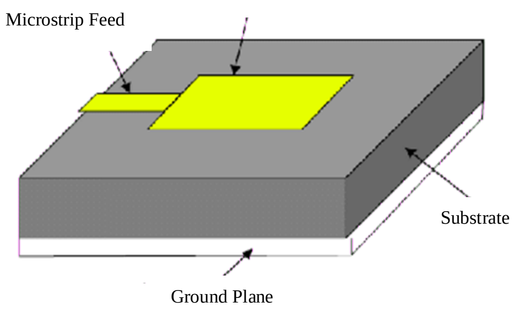

Fig.1. Simple Rectangular Microstrip Patch Antenna

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Simple microstrip antenna is shown in Fig.1, fed by a microstrip transmission line. The patch antenna, microstrip transmission line and ground plane are made of high conductivity metal (typically copper). The patch is of length L, width W, and sitting on top of a substrate (some dielectric circuit board) of thickness h with permittivity ε_r. The thickness of the ground plane or of the microstrip is not critically important. Typically the height h is much smaller than the wavelength of operation, but not much smaller than 0.05 of a wavelength. [2]

The advantages of printed microstrip antenna are light weight and low volume, low profile planar configuration which can be easily made conformal to host surface, low fabrication cost, hence can be manufactured in large quantities, supports both, linear as well as circular polarization. Along with the advantages this type of antenna has certain disadvantages as well such as low bandwidth, lesser gain and low efficiency which influence the capability of this antenna [1]. Various researches are being done by the researchers to overcome these disadvantages by using different patch geometry such as using E shaped patch, U shaped patch, L shaped patch etc. Other methods to overcome these disadvantages includes use of different dielectric materials ,use of substrate of different thickness, cutting various notches and slots in the patch geometry, antenna array etc. for improving the performance which make this antenna suitable for different applications such as cellular phones, pagers, radar systems, and satellite communications systems. [3]

In this research work, the hexagonal shaped patch antenna is designed to achieve sharp frequency.

The paper is divided in four sections. Section 2 explains the design and configuration of the proposed antenna. In section 3, parametric analysis and optimization of the antenna is done and simulation results are also discussed. Section 4 gives the conclusion of this work.

2) ANTENNA DESIGNING PARAMETERS

There are three important parameters of the micro strip patch antenna such as resonant frequency (fc), height of dielectric substrate (h) and relative permittivity of the dielectric substrate (ε_r). All of the parameters in a rectangular patch antenna design control the properties of the antenna. First, the length of the patch L controls the resonant frequency. The length of the longest path on the micro strip controls the lowest frequency of operation. Second, the width W controls the input impedance and the radiation pattern.

The wider the patch becomes the lower the input impedance is. The permittivity ε_r of the substrate controls the fringing fields - lower permittivity have wider fringes and therefore better radiation. Decreasing the permittivity also increases the antenna's bandwidth. [5]

The proposed antenna is done application a FR4 substrate, generally acclimated to accomplish printed ambit boards with array (h) of 1.6 mm and about permittivity of 4.4, which makes it simple and bargain to manufacture.

The length and width of the substrate can be calculated by using design equations (1) through (12). [1]

$$L_g = L + 6h \tag{1}$$

$$w_g = w + 6h \tag{2}$$

Where, $L = L_{eff} - 2\Delta L$

For partial ground plane:

$$w_{pg} = \frac{1.38c}{f_r\sqrt{\varepsilon_{eff}}} \quad \text{and} \tag{3}$$

$$l_g = \frac{0.36c}{f_r\sqrt{\varepsilon_{eff}}} \tag{4}$$

Length extension ΔL can be calculated as

$$\Delta L = 0.412\left(\frac{\varepsilon_{re}+0.3}{\varepsilon_{re}-0.3}\right)\frac{\left[\frac{w}{t}+0.264\right]h}{\left[\frac{w}{t}+0.8\right]} \tag{5}$$

The effective length is

$$L_{eff} = 0.5\frac{\lambda}{\sqrt{\varepsilon_r}} \tag{6}$$

And the effective dielectric constant is

$$\varepsilon_{re} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r+1}{2}\left[1+\frac{12h}{w}\right]^{-0.5} \tag{7}$$

The patch width will be

$$w = \frac{c}{2f_0\sqrt{\frac{\varepsilon_r+1}{2}}} \tag{8}$$

The hexagonal patch side length s will be calculated using effective radius of circular.

$$\pi a_e^2 = \frac{3\sqrt{3}}{2}s^2 \tag{9}$$

Effective Radius of Circular is

$$a_e = a\left\{1-\frac{2h}{(\pi a\varepsilon_r)}\left(\ln\frac{\pi a}{2h}+h+1.7726\right)\right\}^{\frac{1}{2}} \tag{10}$$

$$w_f = \frac{w_m}{h} = \frac{8e^A}{e^{2A}-2}; \quad \text{for } A \geq 1.52 \tag{11}$$

where,

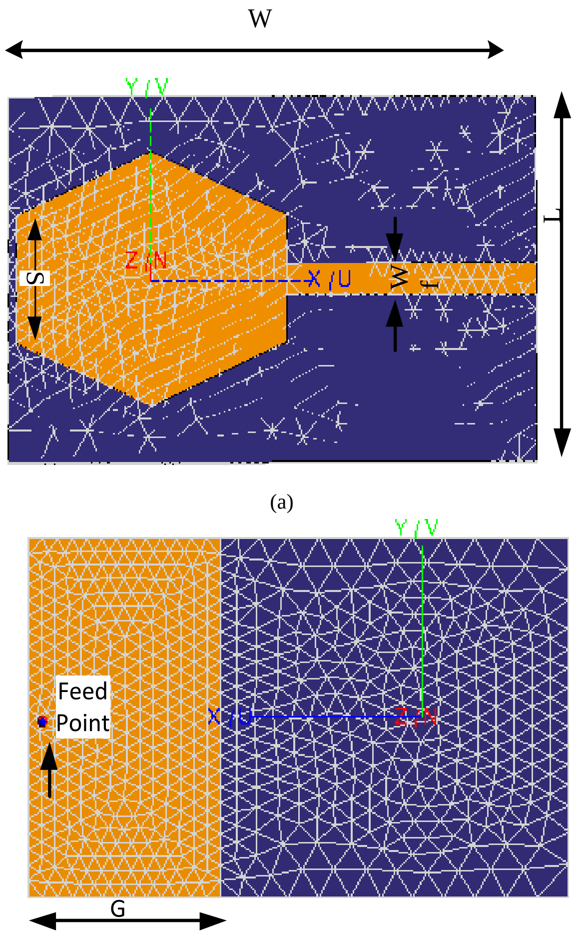
$$A = \frac{Z_0}{60}\sqrt{\frac{\varepsilon_r+1}{2}} + \frac{\varepsilon_r+1}{\varepsilon_r}\left(0.23+\frac{0.11}{\varepsilon_r}\right) \tag{12}$$

The calculated antenna parameters are shown in Table.1.

Table 1. Dimensions of the Designed Hexagonal Antenna

Parameters	Hexagonal shape Antenna
Hexagonal Side Length	18mm
Substrate Corner	(-18,8,0) (0,16,0) (18, 8,0) (18, -8,0) (0,-16,0) (-18,-8,0)
Substrate Width &Length	W_g = 70 mm, L_g= 46 mm, W_f = 2, g = 0.2 mm W_{pg} =70 mm, L_g= 23 mm
Substrate Height &Thickness	h = 1.6 mm, t = 0.75
Dielectric constant	ε_r = 4.4

The geometry of the proposed dual-band antenna for 1.57 GHz GPS L1 band and 3.5GHz WiMAX band with its connected is depicted in Fig.2.



(b)
Fig.2. FEKO modal of hexagonal antenna
(a) Top View (b) Bottom View

3) Simulation Results

The performance of the Hexagonal shape antenna has been investigated by using FEKO. The Fig.3 and Fig.4 shows the simulated S parameters results and VSWR of the designed antenna. The reflection coefficients of the desired 1.57GHz and 3.5GHz are below -10dB and the VSWR of these two bands are between 1 and 2.

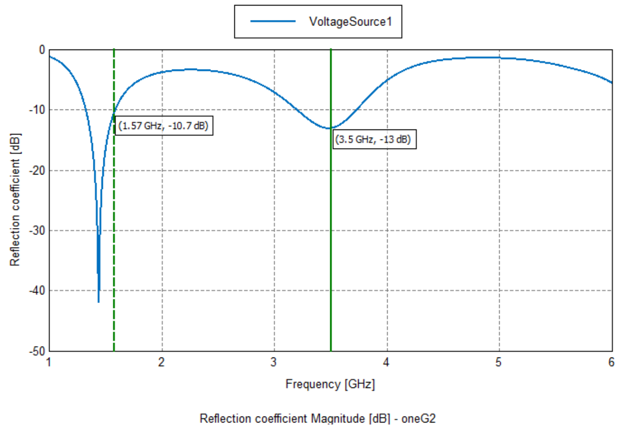


Fig.3. S-parameters curve for dual band hexagonal strip monopole antenna using FEKO

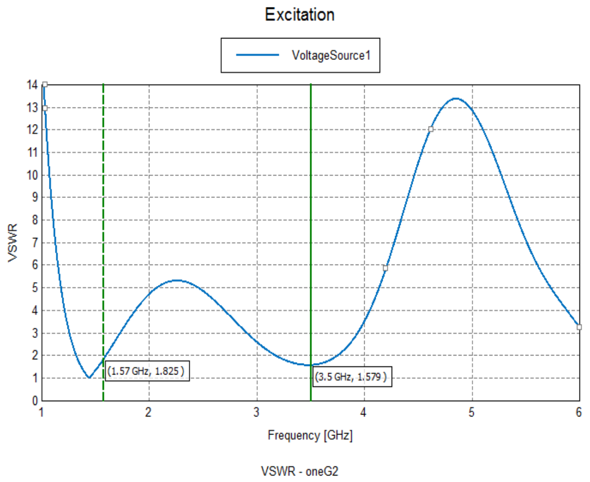


Fig.4. .VSWR curve for dual hexagonal strip monopole antenna using FEKO

The impedance of the antenna is approximately matched with 50 Ω feed line as shown in Fig.5. The gain curve is plotted in Fig.6. . It can be observed that for two applications the gains are 1.89dBi and 3.87dBi respectively.

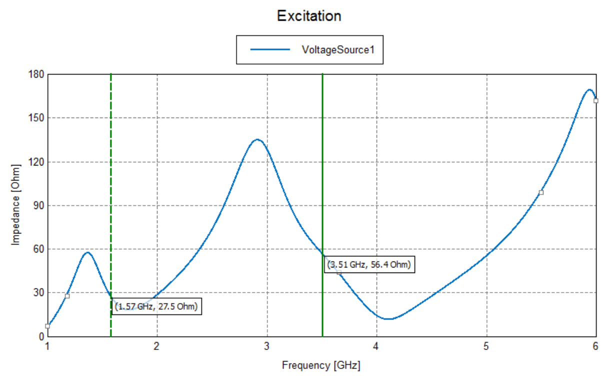


Fig.5. Impedance curve for dual band hexagonal strip monopole antenna using FEKO

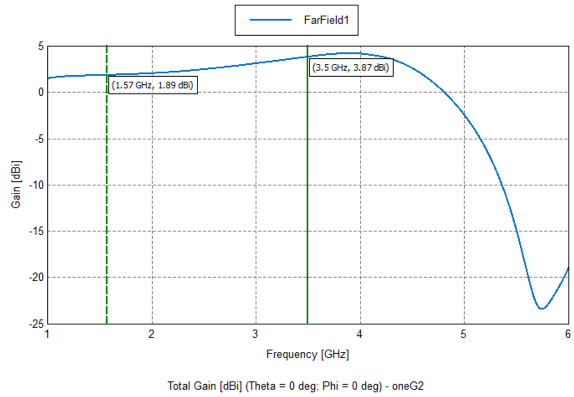
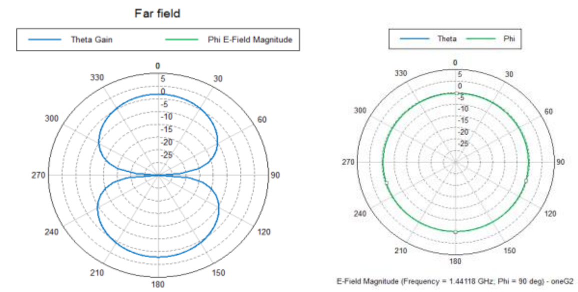
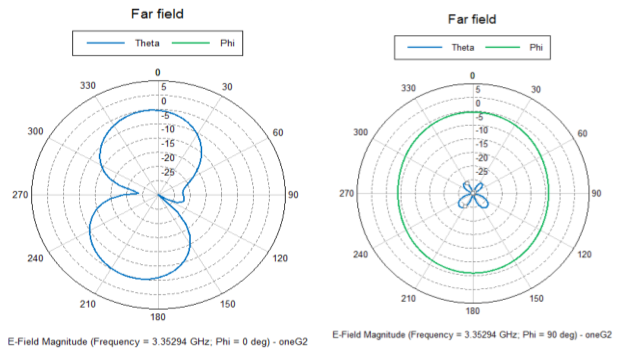


Fig.6. Gain curve for dual band hexagonal strip monopole antenna using FEKO

The FEKO computed far-field are simulated directive gain patterns of two bands in both Y-Z- and X-Z-planes are shown in Fig.7 (a) and (b). According to the results satisfactorily omni-directional patterns are obtained.



(a)



(b)

Fig.7. Simulated radiation patterns for dual band hexagonal strip monopole antenna using FEKO

(a)1.57GHz GPS-L1 band (b) 3.5GHz WiMAX band

4) Conclusion

Design of Hexagonal shape monopole microstrip patch antenna is presented in this paper. The hexagonal patch antenna is dual band antenna and resonant at 1.57 GHz frequency with a -10.7 dB with a gain of 1.89 dBi and 3.5GHz with a -13dB with a gain of 3.87 dBi respectively. By adding feeding line in the patch, the bandwidth of antenna is wide achieved and performance of antenna also improved. A novel low-profile, low-cost monopole-type microstrip antenna for GPS L1 band and WiMAX operation are designed and simulated in this paper. The antenna possessed stably omnidirectional patterns, good gain figures and acceptable radiation efficiency values over the respective frequency range.

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