Bandwidth Enhancement of CPW-fed G-shaped Monopole Antenna at 5.85 GHz for WiMAX

Ajmal Hussain Shah[1], Sathish Kumar Selvaperumal[2], and Surendran Subramaniam[3]
[1,2]Lecturer, School of Engineering, Asia Pacific University of Innovation & Technology, Kuala Lumpur, Malaysia
[3]Student, School of Engineering, Asia Pacific University of Innovation & Technology, Kuala Lumpur, Malaysia

Abstract—A modified Co-planar Waveguide based G-shaped Monopole Antenna at 5.85 GHz for WIMAX and other WLAN application is presented in this paper. Dielectric value, lengths and the ground plane on both sides of the strip of the existing G-shaped antenna have been modified. The proposed design has been simulated and analyzed at 5.85 GHz. An incredible bandwidth enhancement of 63.5% with 3.7129 GHz has been achieved compared to 12.6 % with 710 MHz bandwidth by the existing design. The antenna satisfies the radiating requirements with the gain of 4.334 dB and the directivity of 4.690 dBi. The return loss of -14.81 dB and the VSWR of 1.11 also achieved. In future, the antenna will be fabricated and tested, and the results will be compared.

Index Terms — G-shaped antenna, Monopole, Return loss, Bandwidth, VSWR, WIMAX.

1 INTRODUCTION

In recent years, there has been tremendous development in the wireless communication industry. Researchers from industry as well as from academic institutions are busy in carrying out research activities and providing sustainable solutions to the wireless industry. Antenna plays a vital role in communicating information in wireless communication. It is one of the fundamental parts of wireless communication equipments. It has made the radio wave communication to exist. Radio wave communication is impossible without these antennas. There has been continuous improvement in antenna design and development, and implementation due to high demand from the RF communication industry.

With the advancement in monolithic microwave integrated circuits (MMICs) technology, it is pretty easier to design a low profile and light weight antenna for wireless communication applications. Micro strip patch antennas with low profile and planar geometries are suitable for integration. However, there are two major disadvantages associated with patch antennas; low gain and a narrow bandwidth [1].

Recently many researchers have proposed various approaches to improve the gain and the bandwidth of micro strip patch antenna. Micro strip diamond slotted patch antenna with UWB characteristics has been proposed by the author [2]. Particle Swarm Optimization (PSO) based CPW-fed G-shaped planar monopole antenna for dual band operations for 2.4/5.8 GHz wireless local area network (WLAN) application is suggested. The PSO technique optimizes the antenna performance by selecting the most appropriate antenna configuration [6].

Low-profile antennas may be essential in high-performance aircraft, spacecraft, satellite, and missile applications, where size, weight, cost, performance, ease of installation and aerodynamic profile are constraints. With similar specifications, there are many other government and commercial applications such as mobile radio and wireless communications [7-10]. Wireless Local Area Network (WLAN) antennas cover wideband including IEEE 802.11 a, b, g and n which operates at 2.4 GHz (2.4 – 2.484 GHz) and 5.2/5.8 GHz (5.15-5.35 GHz / 5.725 – 5.825 GHz) [1-5]. However, the bands that are assigned for the Worldwide Interoperability Microwave Access (WiMAX) applications are based on the IEEE 802.16 standard which covers 2.5/3.5/5.5 GHz (2.5 – 2.69/ 3.4 – 3.69/5.25-5.85).

Micro strip antennas provide sustainable solution and fulfill these requirements. These antennas are very versatile in terms of resonant frequency, polarization, radiation pattern, and impedance when the particular patch shape and mode are selected. They are low profile, conformable to planar and coplanar surfaces, simple, and inexpensive to manufacture using modern printed-circuit technology, mechanically robust when mounted on rigid surfaces, compatible with Monolithic Microwave Integrated Circuit (MMIC) designs. Adaptive elements with variable resonant frequency, impedance, polarization, and radiation pattern can be designed by adding loads between the patch and the ground plane, such as Pin and Varactor diodes.

Due to advancement in monolithic microwave integrated circuits (MMICs) technology there has been a remarkable growth in wired and wireless communications. There has been a continuous enhancement in the design and development of the various antennas to improve various antenna characteristics such as gain, bandwidth, polarization, frequency, radiation pattern and impedance. These characteristics decide the application domain of the antenna.

Also, antennas designed using single radiating structure can resonate at dual frequencies. These structures have added advantage of acquiring less space and less cost economically. But not much analysis has been carried in the past but the trend has moved now. This may be due to the complexity in designing the feeding the network for the existing array type antennas. So, the requirement for dual band frequencies using a single structure arises due to the need of low cost antennas in applications such as vehicular-satellite communication system. These applications require isotropic patterns over the upper hemisphere which is best suited with the patch antenna characteristics.

The near future communication terminal antennas are required to operate at dual band or multi band apart from having light weight low profile antennas , single feed and flush mounted. Now a days antennas designed are expected to operate at various frequencies covering larger band to meet the growing needs of communication technology. Hence, S-shaped, rectangular, E-shaped, H-shaped antennas have been designed and simulated to show the various performances achieved. However, G-shaped antenna is the latest research type of patch antenna. Based on the recent G-shaped antenna designs literature have been carried.

The researcher proposed a Co-Planar Waveguide - fed planar monopole antenna in order to achieve a dual band using a G-shaped antenna for a WLAN application. In order to resonate at dual band, the researcher combined the two folder strips by resemble the G-shaped in turn feeding it by a coplanar waveguide transmission line. The researcher tried to print the deigned antenna on an FR4 microwave substrate of thickness 1.6 mm with the dielectric constant as 4.4. The dual resonant mode has been achieved by making the lengths of the two folded strips to be unequal, so that it provides two different current paths. So the two finite ground planes are considered to be equal. Thus, it has been identified that the dual band has been achieved by the current distribution control and by compensating the capacitive and inductive effects which are due to the electromagnetic coupling effects. This compensation effect has been overcome by grounding the finite planes. By considering all these aspects, the G-shaped antenna designed resonated at 2.43 and 4.3 GHz. However, the results obtained were the bandwidth improvement of 9.7% at 2.43 GHz and 62.8% at 4.3 GHz. Not much improvement in the other parameters has been achieved [11].

The patch antenna is selected for the design as it is very easy to build and is used for both planar antennas and microwave applications that are used in various communication industries. A patch is generally made up of a dielectric which is used to separate the conductive layer from the ground as shown in Figure 1.

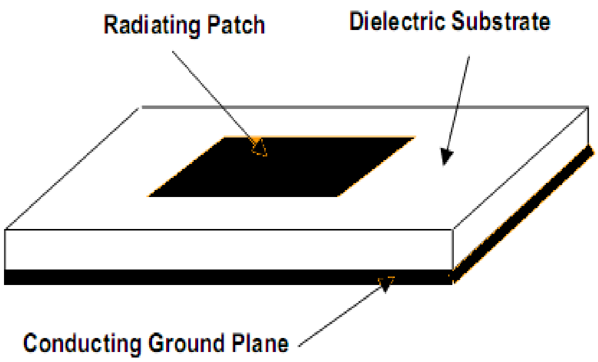

Fig. 1. Patch Antenna

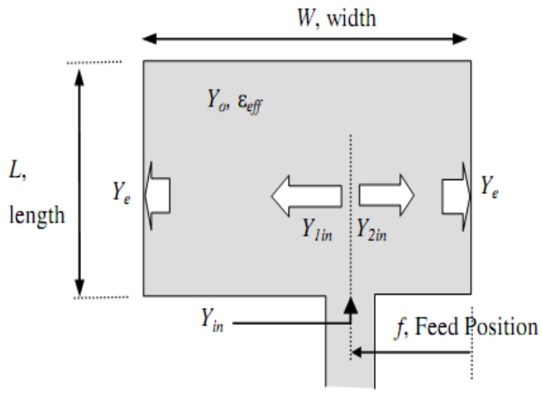

Fig. 2. Geometry of length and width

The general patch antenna design is shown in Figure 2 in which the length and width are the first two important parameters. The center frequency of a patch antenna is usually determined by the following formula.

$$f_c = \frac{1}{2L\sqrt{\varepsilon_0 \varepsilon_r \mu_0}}$$

Where, L is the length of the patch antenna and ε is the permittivity and μ is the permeability. Generally this equation determines the length of the patch antenna which is normally needed to be equal to one half of the wavelength on the dielectric material. The impedance is determined based on the width; if the width is decreased the impedance is increased and if the width is increased the impedance of the antenna decreases. This implies that the decrease in the input impedance to 50 ohms will broaden the patch antenna designed. This is a very important parameter to control the radiation pattern.

The proposed antenna design in this paper has been modified with the following novel contributions:

a. The length and width have been modified, and
b. The two ground planes have been joined by a strip.

The antenna dimensions or geometry have been obtained by examining the key antenna parameters carefully and finally the optimized values have been obtained as explained in the next section along with the enhancement in the bandwidth achieved.

2 ANTENNA DESIGN

As far as the geometry design of the proposed antenna is considered, it consists of two strips of Length L1 and Length L2 and a Co-Planar Waveguide (CPW) feeding line. The Capital "G-shaped" is obtained from a rectangular patch antenna. First the length and width of the rectangular patch antenna is assumed to be the Length L1 and Length L2 which form the three sides of the proposed Capital "G-shaped" antenna. While the fourth side of the rectangular patch antenna is modified with two vertical and one horizontal section to form the proposed Capital "G-shaped" antenna as shown in Fig. 1. The two vertical and one horizontal section is determined by Heights h1, h2, Gap g1, and Width W1 and Space S1.

Furthermore, the Capital "G-shaped" antenna is Centre fed from the bottom by a CPW feeding line with 50 ohms impedance. It has a width of Wf, with a gap g2 between the feeding line and the ground. The two equal ground planes which are finite are placed on either side of the feeding line and as a modification; they are connected together at the bottom as compared to [6,11]. The two ground planes are defined with dimensions of length Lg and width Wg and are situated symmetrically on either side of the feeding line. The distance between the Capital "G-shaped" structure and the ground plane is h3.

The substrate thickness to be 1.6 mm with dielectric constant of 4.3 and tangent factor of 0.025 is selected for the design. The following steps calculate the Length (L1) of the proposed strip.

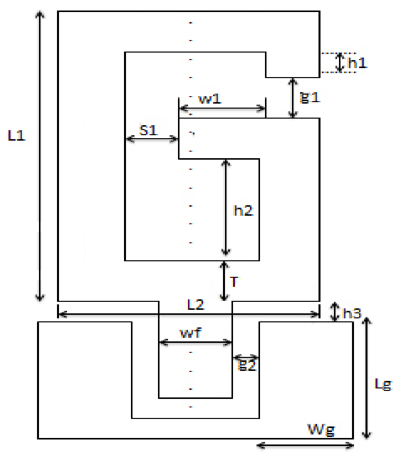

Fig. 1. Geometry of the Proposed G-shaped Antenna

Step 1:

The quarter wavelength can be computed using the following expression as follows:

$$\lambda = \frac{c}{f} = \frac{3X10^8}{2.4X10^9} = 1.25X10^{-1} m = 125\,mm$$

(1)

Thus from the above expression it is understood that the wavelength of the quarter wave is 125mm.

Step 2:

Considering the fact that the antenna is going to be printed on the substrate surface, then the resonant length will be influenced by the substrate's permittivity. In order to achieve the good performances, the resonant dipole needs to be designed slightly less than half a wavelength long. As an assumption, 0.47 times the wavelength is considered and hence the resonant dipole length is computed as follows:

$$r_d = 0.47\lambda = 0.47\frac{\upsilon}{f} \quad (2)$$

Where 'f' is the frequency and 'υ' is the actual propagation speed on the dipole radials which in turn depends on the substrate's effective dielectric constant.

The propagation speed is computed as follows:

$$\upsilon = \frac{c}{\sqrt{\varepsilon_{eff}}} \quad (3)$$

Where 'ε_{eff} ' is the substrate's effective dielectric constant.

Thus for 2.4 GHz, the propagation speed is computed as follows:

$$\upsilon = \frac{3X10^8}{\sqrt{4.3}} = \frac{3X10^8}{2.07364} = 1.45X10^8\, m/s \quad (4)$$

For the above speed, the resonant dipole length is computed as follows:

$$r_d = 0.47\frac{\upsilon}{f} = 0.47\left[\frac{1.45X10^8}{2.4X10^9}\right] = \frac{0.6815X10^8}{2.4X10^9}$$

$$= 0.28396X10^{-1} = 28.396\, mm \quad (5)$$

Step 3:

Thus the value of the resonant dipole length rd is assumed to be L1, which is the overall length of the Capital "G"- shaped antenna and hence L1 = 28.396 mm ≈ 29 mm.

TABLE I
GEOMETRY OF THE VARIOUS DESIGN PARAMETERS OF THE PROPOSED ANTENNA

Sno	Parameters	Measurement in mm
1	H1	1.2
2	G1	10
3	W1	10
4	S1	3.3
5	H2	10
6	T	3
7	H3	4.69
8	G2	1.35
9	Wf	4.75
10	Wg	5
11	Lg	10.75
12	L1	29
13	L2	20

TABLE I shows the various design parameters of the proposed antenna.

3 RESULTS AND DISCUSSION

The proposed Capital "G-shaped" antenna so designed is simulated to test its performance. The following parameters evaluate the performance of the proposed antenna.

a. Bandwidth
b. Directivity
c. Gain
d. Radiation Pattern
e. Return Loss
f. Voltage Standing Wave Ratio (VSWR)

Although the antenna is designed at 2.4 GHz but it resonates at a higher frequency as well, thus making it suitable for dual band. The designed antenna resonates at 5.85 GHz with a 10 dB bandwidth. Fig. 2 shows that the antenna operates on wide bandwidth; it provides a bandwidth of 3.7129 GHz (3.851 – 7.5639 GHz), which is 63.5 % with respect to the center frequency of 5.85 GHz. This wider bandwidth is useful to cover various WiMAX applications.

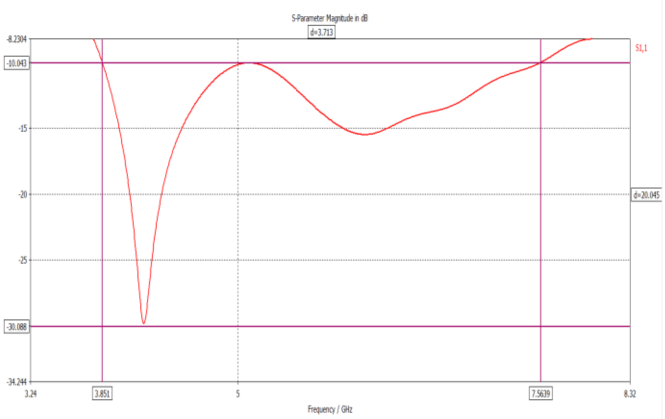

Fig. 1. Simulated bandwidth at 5.8 GHz resonant frequency

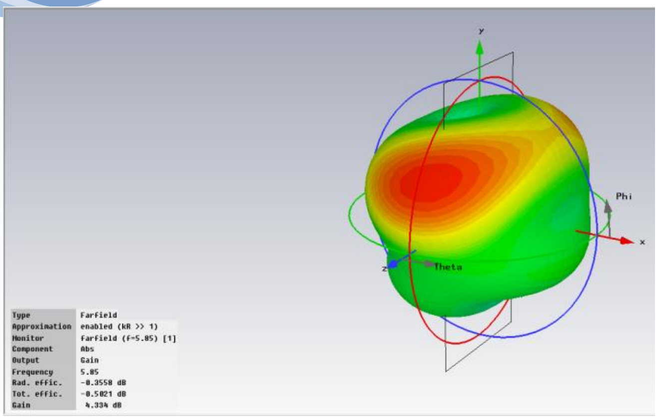

Fig. 2. Simulated radiation pattern ad gain at 5.85 GHz resonant frequency

Fig. 3 and Fig. 4 show the simulated results of the radiation pattern and the gain of the proposed design while Fig. 5 shows the directivity of the same. It is observed that the achieved gain is 4.334 dB while the directivity is 4.690 dBi. The results show that there is an improvemnet in the gain and the directivity and thus the power radiates in all directions.

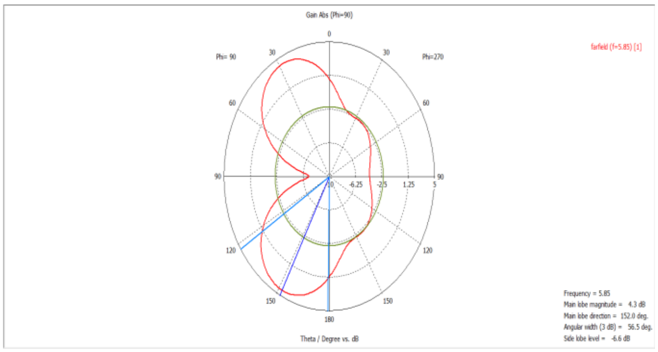

Fig. 3. Simulated gain at 5.8 GHz resonant frequency

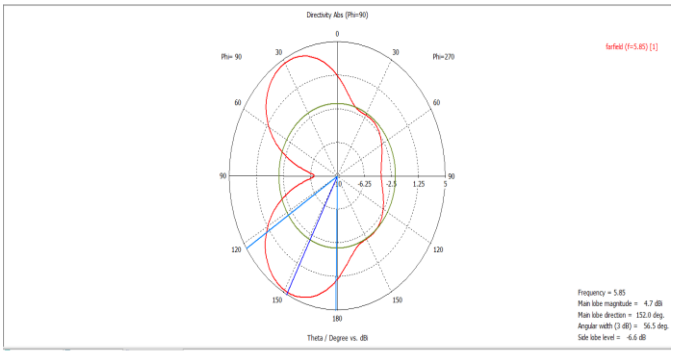

Fig. 4. Simulated directivity at 5.8 GHz resonant frequency

Fig.6 provides the return loss of -14.81 dB. This shows that the return loss is more negative and hence the power fed at 5.85 GHz is absorbed and less reflected. Fig.7 depicts the VSWR of 1.44489. The value is very close to unity, thus indicaties that there is a maximum power transfer to the load.

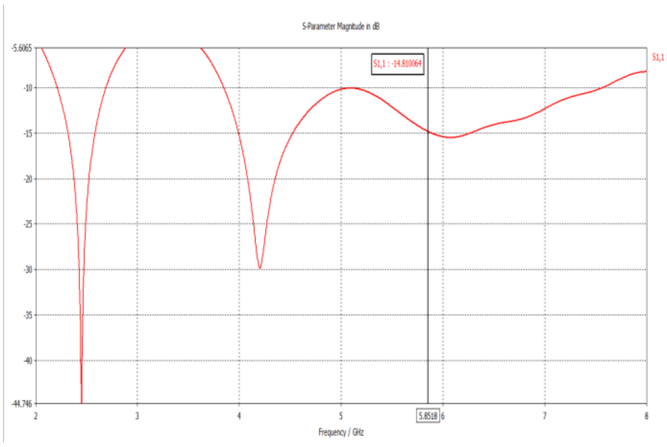

Fig. 5. Simulated Return Loss at 5.85 GHz resonant frequency

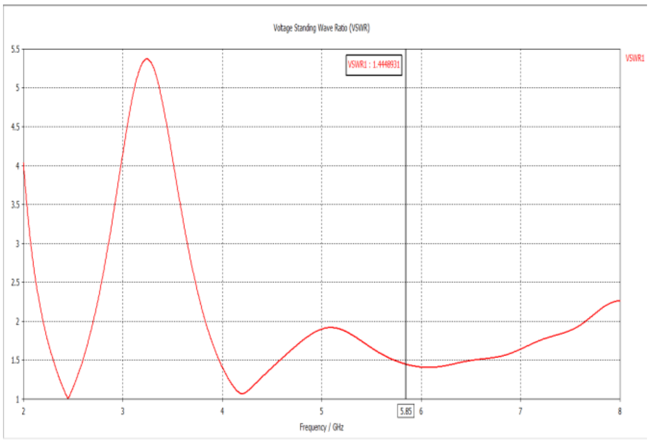

Fig. 6. Simulated VSWR at 5.85 GHz resonant frequency

The proposed G-shaped antenna's performance is evaluated at 5.85 GHz resonant frequency. The results are compared with the published results in the literature [11] and are presented in TABLE II.

TABLE II
PERFROMANCE EVALUATION OF THE PROPOSED AND EXISTING ANTENNA DESIGN AT 5.85 GHz

S.No	Parameters	Proposed Design	Existing Design [11]
1	Centre Frequency	5.85 GHz	5.85 GHz
2	Bandwidth	3.7129 GHz	710 MHz
3	Percentage Bandwidth of Improvement	63.5 %	12.6 %
4	Gain	4.334 dB	-
5	Directivity	4.690 dBi	-
6	Return Loss	-14.81 dB	-
7	VSWR	1.111	-

TABLE II shows that there is a remarkable improvement in the operating bandwidth and provides wide bandwidth as compared to the existing design published in the literature [1]. The bandwidth is improved by 63.5 % with 3.7129 GHz to that of 12.6 % with 710 MHz bandwidth published in the literature [11]. This improved bandwidth is more than sufficient for WIMAX and other WLAN applications.

Conclusion

A CPW-fed G-shaped monopole antenna with two modified vertical and horizontal patch sections for WIMAX and other WLAN applications is presented in this paper. The proposed antenna is simulated, and the results have shown that the antenna improves the antenna performances. The results show the remarkable bandwidth enhancement of 63.5% with 3.7129 GHz as compared to 12.6% with 720 MHz by the existing design. The antenna satisfies the radiating requirements with the gain of 4.334 dB and the directivity of 4.690 dBi. The return loss of -14.81 dB and the VSWR of 1.11 also achieved which validates that the maximum power is transferred to the load. The proposed antenna will be fabricated and tested and the results will be compared in future.

REFERENCES

[1] Bahadir Yildirim and Bedri A. Cetiner, " Enhanced Gain Patch Antenna with a Rectangular Loop Shaped Parasitic Radiator", Antennas and wireless propagation letters, IEEE, Vol 7, issue, 2008, pp: 229-232, 2008.

[2] Chia Ping Lee, Chandan Kumar Chakrabarty, "Ultra Wideband Microstrip Diamond Slotted Patch Antenna with Enhanced Bandwidth", Int. J. Communications, Network and System Sciences, pp: 468-474, 2011.

[3] Mouloud Challal, Arab Azrar and Mokrane Dehmas , "Rectangular Patch Antenna Performances Improvement Employing Slotted Rectangular shaped for WLAN Applications", IJCSI International Journal of Computer Science Issues, 2011.

[4] Mst. Nargis Aktar, Muhammad Shahin Uddin, Md. Ruhul Amin, and Md. Mortuza Ali, "Enhanced Gain and Bandwidth of Patch Antenna Using EBG Substrates", International Journal of Wireless & Mobile Networks, 2011.

[5] Nasimuddin and Karu P. Esselle , "A Low-Profile Compact Microwave Antenna With High Gain and Wide Bandwidth", IEEE Transactions on Antennas and Propagation, Vol. 55, no.6, 2007.

[6] Pavan Vishnukanth.K, S.Raghavan, "Design of an Optimal G-shaped Monopole Antenna Using Particle Swarm Optimization", in the 38th European Microwave Conference proceedings, Amsterdam, Netherlands, pp: 389 - 392, 2008.

[7] Pramendra Tilanthe, P.C.Sharma, "Gain Enhancement of Circular Microstrip Antenna for Personal Communication Systems", IACSIT International Journal of Engineering and Technology, Vol.3, No.2, 2011.

[8] R. C. Hadarig, M. E. de Cos, and F. Las-Heras , "Microstrip Patch Antenna Bandwidth Enhancement Using AMG/EBG Structures", International Journal of Antennas and Propagation, Article ID843754, 6 pages, 2012.

[9] Sushila Gupta, "Design a H shaped Patch Antenna for Wireless Communication", International Journal of Advanced Electrical and Electronics Engineering (IJAEEE), ISSN: 2278-8948, Vol.2, Issue-2, 2013.

[10] Teruhisa Nakamura and Takeshi Fukusako , "Broadband Design of Circularly Polarized Microstrip Patch Antenna Using Artificial Ground Structure With Rectangular Unit Cells", IEEE Transactions On Antennas and Propagation, 2011.

[11] Wen-Chung Liu and Chao-Ming Wu," Dual-band CPW-fed G-shaped Monopole Antenna for 2.4/5 GHz WLAN Application", Progress in Electromagnetics Research Symposium, March 26-30, Beijing, China,pp: 2232- 2236, 2007.