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Printed G-Shaped Monopole Antenna For Wireless Sensor Networks

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Abstract

A G-shaped Microstrip Monopole printed antenna suitable for Wireless Local Area Network (WLAN) of monitoring applications is presented in this paper. The antenna is printed on FR4 substrate. The antenna has a Coplanar Waveguide (CPW) feed. The antenna performance parameters are measured at 2.4 GHz and 2.45 GHz. The measured results at the lower-range of ISM band (2.2144 – 2.687 GHz) show an enhancement of 26% with a bandwidth of 640 MHz (1.78-2.42 GHz) compared to simulated bandwidth of 472.6 MHz. The measured Voltage Standing Wave Ratio is below 2 with low radiation loss and less dispersion, showing consistent omnidirectional radiation pattern. The proposed antenna is compact and simple. The antenna is suitable for Wireless Sensor Networks Monitoring, Wireless Local Area Networks (WLAN) and other applications operate at 2.4 GHz for monitoring purposes.

Keywords: Compact Printed Microstrip, Printed G-shaped antenna, Printed Monopole antenna, Measured Bandwidth, Wireless Sensor Networks Monitoring.

Introduction

The wireless industry has experienced a massive evolution over the last two decades due to vast research activities. Antenna is a key component in a wireless communication system as no radio communication is possible without antennas.

A low-profile antenna is crucial in high-performance applications, where size, weight, cost, performance, and ease of installation, are all what are called the requisite constrictions. Microstrip antennas can be used to meet these requirements. These antennas are versatile in terms of resonant frequency, polarization, radiation pattern, and impedance when a particular patch shape and mode are selected. Such antennas are low profile, conformable in installations to planar and non-planar surfaces, simple, and inexpensive to manufacture using modern printed-circuit technology, mechanically robust when mounted on rigid surfaces, compatible with MMIC designs. Adaptive elements with variable resonant frequency, impedance, polarization, and pattern can be designed by adding loads between the patch and the ground plane.

In recent years, the telecommunication industry has seen an exceptional growth in technical advancements in the field of wireless communications, specifically, in the area of antenna designs. The performance of an antenna can be enhanced by logical modification of one or more antenna parameters, for example, gain, bandwidth, polarization, frequency, radiation pattern and impedance. These parameters decide the application domain of the antenna.

There is wide variety of antennas available in the market. (Of which, a patch antenna is an inexpensive to design and print due to its two-dimensional simple geometry). It provides a directivity of 6-to-9 dB. It has a very large effective area. It is widely employed in UHF band due to its reduced antenna size.

On the other hand, a Microstrip patch antenna suffers from narrow bandwidth, low gain, surface wave excitation, and inconsistent omnidirectional radiation pattern. In the past, a lot of research works were undergone to improve one of these drawbacks. From the literature it is observed that bandwidth enhancement can be achieved by increasing the thickness of substrate, but this leads to relatively large antenna dimensions. Alternatively, ferrite composition can be used but it is an expensive or appropriate selection of resonant frequency may combat narrow bandwidth issue. Over the recent past years in literature, several antenna designs have been reported for use in MIMO terminals.

A dual wideband symmetrical G-shaped slotted monopole antenna for Wireless Local Area Network (WLAN) and Worldwide Interoperability for Microwave Access (WIMAX) applications is presented in [1]. The dual band frequency operation is achieved by inserting a T-slot and an I–shaped strip on the combined G-shaped antenna, which covers both the WLAN and WiMAX applications at 2.4 GHz and 2.5/3.5 GHz. However these insertions did not help in impedance matching.

Another compact dual band U-shaped patch antenna for WLAN applications between 2.3 GHz and 2.5 GHz and 4.5 and 6.36 GHz is proposed [2]. The antenna had a good (omnidirectional) radiation pattern and a gain of 1.85 dB at 2.4 GHz.

Similarly, a circularly shaped patch antenna at 1.8 GHz with a height of 1.59mm, with FR4 substrate is proposed by [3]. The feeding arrangement is placed at an offset of 5 mm from the centre of patch, which helps in impedance matching. With this arrangement, there was a significant improvement of 24.5 dB recorded which is from 11.5 dB to 36 dB with the operating bandwidth of 60 MHz. The antenna gain increased by 3.8 dB.

In the same year, a rectangular Microstrip patch antenna with the idea of inserting a rectangular slot in the ground plane called RS-DGS was proposed [4]. The antenna is designed for WLAN at 2.4 GHz. By inserting a rectangular slot an enhancement in return loss of 18 dB is observed.

A dual-band E-shaped patch antenna to cover wider applications including WLAN is presented in [5]. The antenna has E-shape with a small trapezoidal structure that achieves wide bandwidth. The antenna is designed on a FR4 substrate with a dielectric constant of (εr=4.4) and a thickness of 1.6 mm. A 50Ω Microstrip feedline mechanism with a width of 3mm is used. The trapezoidal structure used is to achieve dual bands.

A microstrip patch antenna at 2.48□GHz band with a combined Electromagnetic Band-Gap (EBG) and Artificial Magnetic Conductor (AMC) structures is presented in [6]. Both structures have been combined with the same microstrip patch antenna. The prototype results show the improved bandwidth and better radiation properties.

An E-shaped patch antenna with rectangular cuts to enhance the return loss at a resonant frequency of 2GHz is presented in [7]. The antenna is designed on FR-4 substrate with a patch height of 1.6mm from the ground plane. The introduced rectangular cuts enhance a return loss of 6dB.

In this paper, a compact and simple G-shaped printed monopole antenna for MIMO-WLAN and other wireless applications in Single Input Single Output (SISO) and Multiple Input Multiple Output (MIMO) applications operating at 2.4GHz and 2.45GHz is presented. The antenna is constructed on a FR-4 substrate and has got a CPW feed. Furthermore, the measured VSWR is below 2 with a return loss of ≤ -10 dB with a consistent omni-directional radiation pattern. The proposed antenna geometry and the design steps are explained in Section II, the simulation results and the experimental results are presented in Sections III and Section IV respectively, and Section V is the conclusion.

Antenna Design and Geometrical Configuration

In this section, the antenna design and its dimensions are presented. The parameters of the proposed G-shaped antenna are calculated at 2.4GHz. These value are used in the design. The thickness of the substrate material is 1.6mm with a tangent factor of 0.025 while having a dielectric constant of ε_r=4.3.

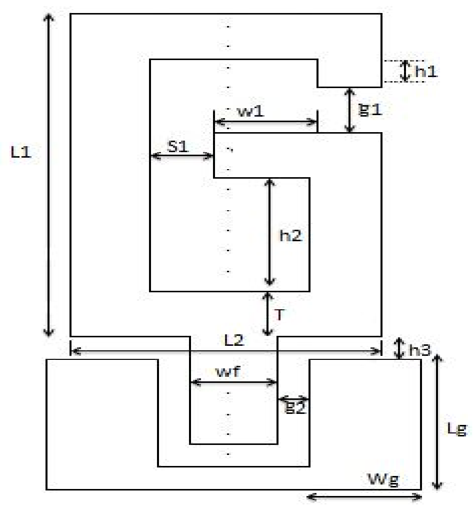

Figure 1: Geometry of the Proposed G-shaped Antenna

Usually the resonant length of the dipole should be less than half the wavelength in view of achieving a good performance of an antenna. The resonant length of the G-shaped dipole antenna is 28.396 mm. The proposed G-shaped antenna consists of two main strips, namely Width W1 and Length L1. The length L1 is 29 mm while the width W1 should be less than L1 and is approximated as 20mm as shown in Fig. 1.

Simulation Results

The antenna is designed and simulated at resonant frequency of 2.4 GHz.

Table I gives dimensions of the proposed G-shaped antenna

Table 1: Geometry of The Various Design Parameters of The Proposed Antenna

S.No	Parameters	Measurement in mm
1	H1	1.2
2	G1	10
3	W2	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	W1	20

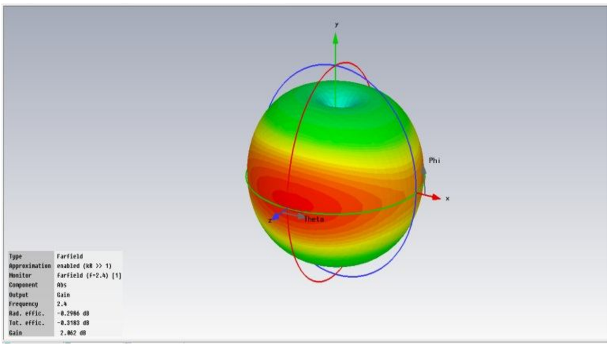

Figure 2: Simulated radiation pattern and gain of resonant frequency at 2.4 GHz.

Fig. 2 shows the simulated radiation pattern of the proposed antenna, which shows that the power-gained is radiated equally in all directions. Also, it could be observed that the gain is equal to 2.062 dB, which is sufficient for the proposed antenna to radiate in all directions. Fig. 3 shows the directivity of 2.361 dB, which fulfills the requirement of the WLAN applications as they need low directivity.

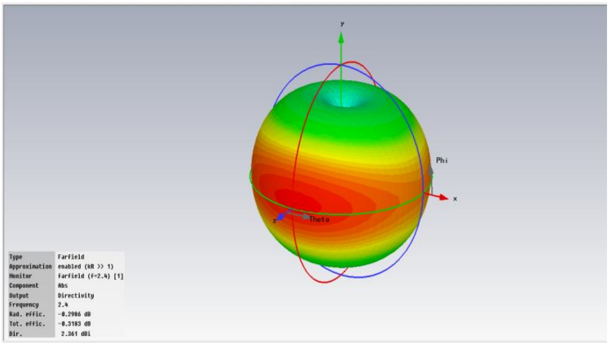

Figure 3: Simulated radiation pattern and directivity of resonant frequency at 2.4 GHz

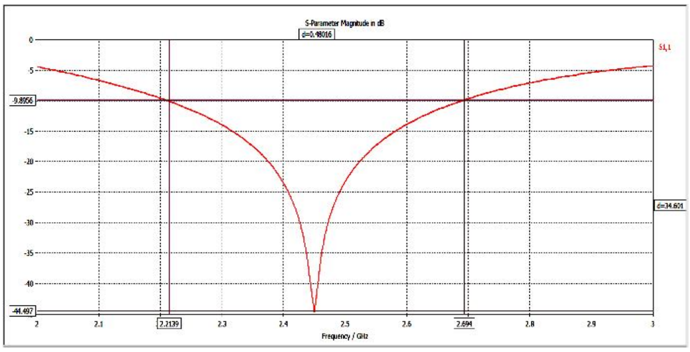

Figure 4: Simulated bandwidth of resonant frequency at 2.45 GHz

Return loss is the ratio of the power fed to an antenna to the power reflected back to the feed point. Thus, the power fed to an antenna should be absorbed rather than being reflected, which obviously produces a power loss. (However, the best value of return loss must be negative infinity if the power is absorbed and must be equal to zero if the power is reflected).

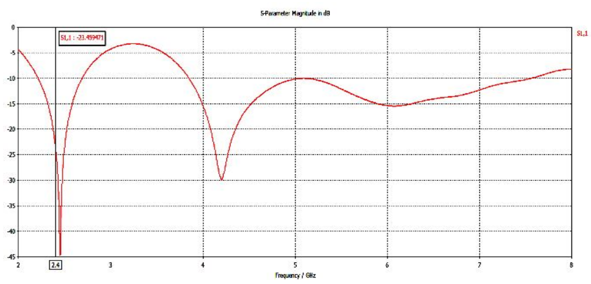

Figure 5: Simulated Return Loss

A bandwidth of 472.6 MHz at the resonant frequency of 2.45GHz at lower frequency range of ISM band is evident in Fig. 4. Return loss helps in determining the resonant frequency of an antenna. Fig. 5 shows a return loss of -23.5 dB at 2.4 GHz. However, the best return loss is -44.75dB at 2.45 GHz.

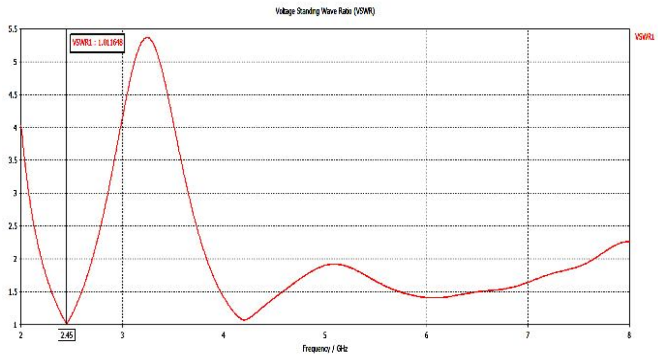

Figure 6: Simulated VSWR

The VSWR for an antenna should be a small value and possibly be near unity. Fig. 6 shows the simulated VSWR results. A VSWR of 1.011 at 2.45 GHz is evident. However a VSWR of 1.144 at 2.4 GHz is obtained from the figure.

Experimental Results

In this section, experimental setup and the measured results are presented. The antenna traces are prepared using a pcb trace maker. The conductivity of the board depends on the conducting material. Therefore, copper in reverse g-shape is used. Fig. 7 shows the reverse g-shaped antenna traces of the prototype for the proposed multi-band mimo antenna, which is fabricated according to the optimized dimensions for validating the simulation results.

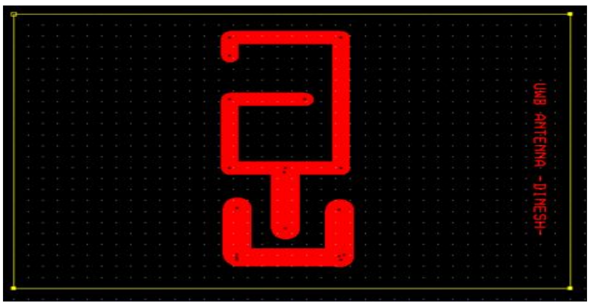

Figure 7: The Proposed Antenna Traces

After antenna traces, the ironing, printing, etching and finally the female SMA-connector mounting are all of antenna fabrication processes. Fig. 8 shows the proposed printed antenna.

The proposed antenna is tested using an Agilent Vector Network Analyzer (VNA). Fig. 9 shows the measured return loss obtained from the VNA. In the figure, a return loss of -12.728 dB at 2.4 GHz and -9.1109 dB at 2.45 GHz are evident.

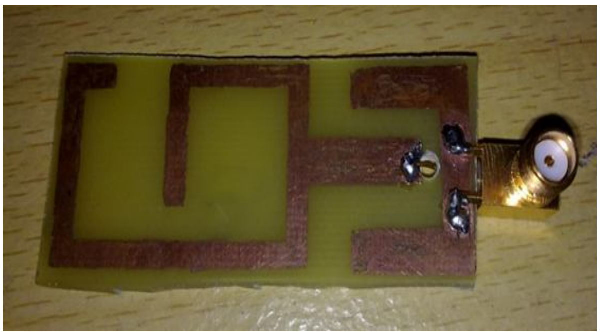

Figure 8: The Proposed Printed Antenna

Fig. 10 shows the measured Voltage Standing Wave Ratio (VSWR) with a range between 2 GHz and 6.2 GHz.

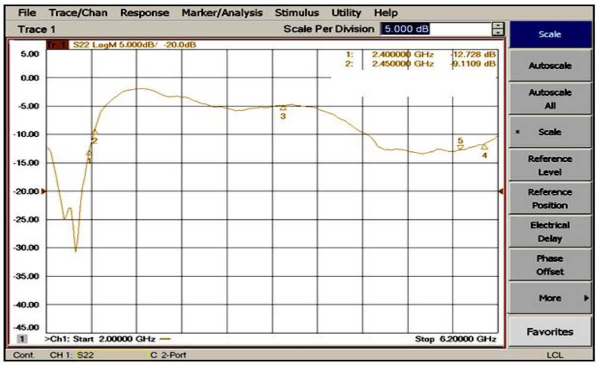

Figure 9: Measured Return Loss

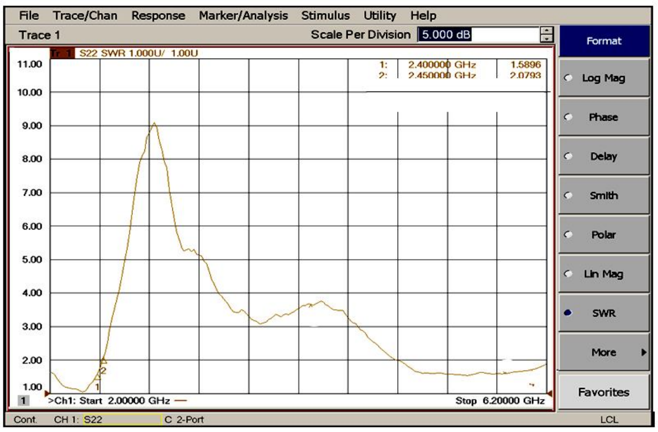

Figure 10: Measured VSWR Results

The measured VSWR at 2.4 GHz and 2.45 GHz are 1.5896 and 2.0793 respectively. The return loss results of the proposed antenna obtained from the simulation and the experimental setup are tabulated in Table II. The measured results of return loss given in the table are significantly higher than the simulated results. However these results fulfill the threshold value of return loss for various wireless communication standards.

Table 2: Simulated and Experimental Results of Return Loss

Frequency (GHz)	**Return Loss (dB)**	
	Simulated	**Measured**
2.4	-23.818761	-12.728
2.45	-44.74604	-9.1109

Table III compares the simulated and experimental vswr results of the proposed antenna at 2.4 Ghz and 2.45 GHz.

Table 3: Simulated and Experimental Results of VSWR

Frequency (GHz)	**VSWR**	
	Simulated	**Measured**
2.4	1.1442349	1.5896
2.45	1.0116480	2.0793

Fig. 11 and Fig. 12 show the measured radiation patterns obtained from a VNA at 2.4 GHz and 2.45 GHz respectively.

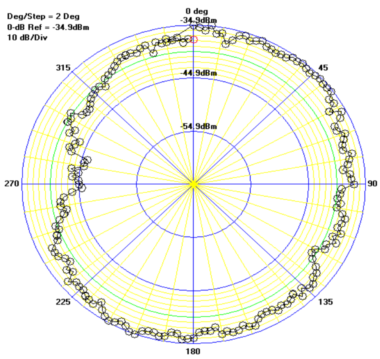

Figure 11: Measured Radiation Pattern at 2.4 GHz

The simulated and the measured radiation patters confirm that the proposed antenna has consistent omni-directional radiation pattern.

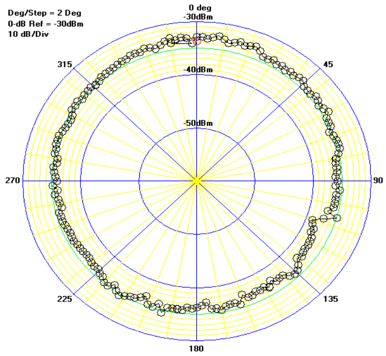

Figure 12: Measured Radiation Pattern at 2.45 GHz

Conclusion

In this paper, the simulated and the experimental results of a G-shaped monopole antenna with CPW feed at 2.4 GHz are presented. The measured results show a bandwidth of 640 MHz, which is 26 % higher than the simulated bandwidth of 472.6 MHz. The measured VSWR is at about 1.6 and the antenna exhibits consistent (omni-directional) radiation pattern. The proposed antenna is compact and simple. Hence, the antenna is suitable for Wireless Sensor Networks Monitoring and other applications operating at 2.4 GHz. Such antennas are with the features of low radiation loss, less dispersion, easy integration for monolithic microwave ICs besides having simple configuration of single metallic layer.

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