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Design of Multi-Band Microstrip Patch Antenna

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ABSTRACT: The current work represents a dual-band microstrip-fed patch antenna in which the radiating structure is formed with a pair of inverted L-shaped patches and ground plane and patch is being modified to a shape. Both of the radiating patch and the modified ground plane are perfectly electric conductors. The patch is printed on a easily available Epoxy Glass (FR-4) substrate with thickness 1.6 mm, relative permittivity 4.4, and loss tangent 0.0024. The proposed microstrip patch antenna (MPA) design is capable of generating two distinct operating bands with 10-dB return loss as follows 3.22–
3.60 GHz and 4.94–8.54 GHz with adequate bandwidth of 380 MHz and 3.6 GHz, respectively. The impedance bandwidths are wide enough to cover the required bandwidths of 3.22– 3.60 GHz, 5.2–5.45 GHz, 5.71–5.825 GHz for wireless local area network, 3.3–3.5 GHz for multiple input multiple output, 5.25–5.85 GHz for world- wide interoperability for microwave access, 5.640–5.672 GHz for uplinks and 5.831– 5.850 GHz for downlinks of Amateur Satellite, and 5.91GHz wireless access in the vehicular environment (WAVE-IEEE 802.11p). Proposed MPA was simulated using Computer Simulation Technology Microwave Studio V9 based on the finite integration technique with perfect boundary approximation and effect of using different substrate materials was studied. Finally, the proposed antenna with optimal parameters was fabricated and some performance measurements were taken to validate towards simulation results. The design procedure to achieve the desired performance are presented and discussed

Key words: microstrip patch antenna, defected ground structure, multi-band, inverted dual L-shaped patches.

I. INTRODUCTION

The design of a microstrip patch antenna is one of the most exciting developments in electromagnetic history because of its noteworthy features which are not commonly exhibited in other antenna configurations including ease of fabrication, good radiation control, low cost of production, low profile, lightweight, simple, and cheap to fabricate using modern day printed circuit board technology, consonant with microwave and mm-wave integrated circuits, and ability to conform to planar and non-planar surfaces. These features are largely responsible for the success of Microstrip Patch Antenna as a viable topic for new researches. The performance and operation of a microstrip patch antenna is driven mainly by the geometry of the printed patch and the material characteristics of the substrate onto which the antenna is printed. Recently, the ability to integrate more than one communication standard into a single system has become an increasing demand of a modern portable wireless communication device. Also, a modern antenna requires not only the function of providing a dual or multiband operation but also a simple structure, compact size, high gain, and easy integration with the system circuit. Dualband multifrequency systems combining various IEEE 802.11a/ b/g standards are becoming more attractive [1]. A dual-band/ wideband antenna is a key component for such

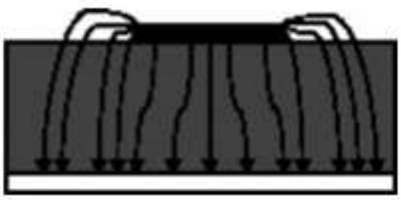

Figure 1 Electric field lines [2]

In this article, a high-gain dual-band MPA having multi-frequency operations formed with a pair of inverted L-shape patches printed on a FR-4 substrate with defected ground structure is

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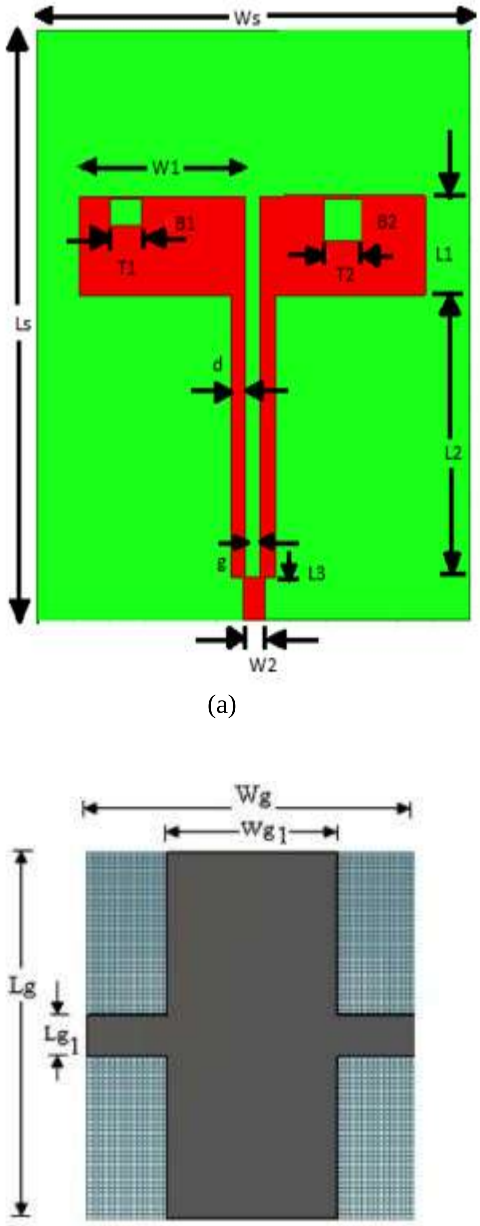
presented for satisfying different wireless communication standards simultaneously. The constructed antenna has two inverted dual L-shape patches separated by a small gap “g”. These design skills are introduced to approach the excitation of dual- resonant modes because of two current paths accompanied with stable radiation communication systems [1–12]. Such dual- band antennas with mono feed have been proposed in various configurations [1,3– 5,7,8]. These antennas either provide insufficient coverage at the unique resonating frequencies or they cannot be easily integrated in portable devices [1,8]. Furthermore, the gains of reported singlefed dual-band antennas are lower than 6 dBi [1– 9] and they face difficulty to meet the requirement for applications such as long range communications or point-to-point communications devices running on battery. The main of the present work was to achieve high gain of wireless local area network (WLAN) antenna. Also, the size of antennas proposed in [10–14] is very large and complex which reduces an antenna’s application in wireless communication. characteristics over the entire operating band. The performance of the proposed antenna is simulated using commercial software High frequency Structure Simulator (HFSS) and the prototype of the antenna is manufactured and measured. From the measured results, the proposed antenna shows two operating frequency bands with 10-dB return loss as follows 3.22–3.60 and 4.94– 8.54 GHz with adequate banwidth of 380 MHz and 3.60 GHz, respectively The obtained bandwidth of
3.60 GHz (4.94–8.54 GHz) for the upper resonating band is quite higher than the existing dual/multiband antenna designs and all this is because of the defected structure embedded in the ground plane which makes it suitable to be used in various wireless communication systems.



(a)

(b)

Figure 2 Antenna configuration of the proposed antenna (a) Front view - Radiating structure (b) Back view - shape ground plane[18]WLAN/world-wide interoperability for microwave access (WiMAX)/Amateur Satellite (AMSAT)/wireless access in the vehicular environment (WAVE).

Both the inverted L-shape patches and -shape ground plane play a very vital role to reject the interferences in desired frequency bands. The proposed antenna design has been studied thoroughly and fabricated, and the details of simulated and measured results are presented and discussed.

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II. ANTENNA DESIGN

MPA consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side as shown in Figure 2. Dielectric constant of the substrate (fir) is typically in the range 2.2 < ir)< 12 [15]. The radiating patch and the feed lines are usually photoetched on the dielectric substrate. MPAs radiate primarily because of the fringing fields between the patch edge and the ground plane as shown in Figure 1 [16,17]. Figure 2 shows the geometry of the proposed antenna capable for dual-band operational characteristics. In our present design structure, the antenna is etched on both sides of FR-4 substrate with relative dielectric constant 4.4, thickness 1.6 mm, loss tangent 0.0024, and a total area Ls 3 Ws 5 70 3 60 mm2 . Also, the substrate used is having the metal thickness of 0.07 mm. The radiating structure consists of a two inverted L-shape patches located symmetrically along the center line and separated by a small gap "g" [Fig. 2(a)]. The dimensions of wide vertical and horizontal arms of L-shape patches are denoted as L1 and W1. The symbol L2 represents the length of narrow arm of L-shape patches and "d" represents the width of narrow strips. Notice that, there is a symmetrical DGS having wide vertical arm with dimensions Lg 3 Wg1 5 70 3 31 mm2 and narrow horizontal arm withdimensions Wg 3 Lg1 5 60 3 8 mm2 printed on the back of the substrate. This -shape ground plane [Fig. 2(b)] is responsible for bandwidth enhancement of the upper resonating band. For perfect radiation characteristics, the positions, lengths, and widths of a pair of inverted L-shape patches and DGS were adjusted carefully. The gap "g" between two inverted L-shape patches also plays a major role in the successful excitation of two appropriate desired resonating frequency bands.

TABLE 1 Optimal Parameters of the Proposed

parameters	unit (mm)
WS	60
LS	70
L1	11.7
L2	33.5
L3	5
W1	23
W2	3
Lg1	8
Wg1	31
g	2
d	2
T1	3.25
T2	5
B1	4.5
B2	5

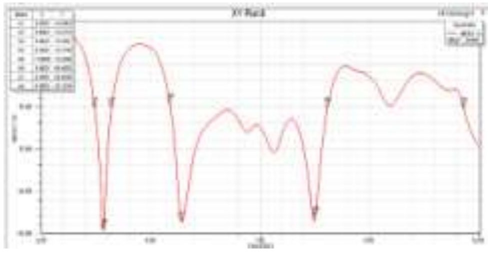

Figure 3 Simulated return loss curve of proposed antenna.

The front and back view of proposed antenna has been shown in Figures 2(a) and 2(b), respectively.

Return Loss and VSWR

To investigate the performance of the proposed antenna configuration, the commercially available simulation software, HFSS 15.0.0 based on finite integration technique was used for the required numerical analysis and optimization of geometrical parameters. To simulate the antenna, transient solver was chosen. During simulation, hexahedral mesh cell with 20 lines per lambda was selected. The geometrical parameters were adjusted carefully after performing a number of experimental iterations by using the option of parameter sweep in transient solver. Finally, the optimal parameters obtained for the proposed configuration are presented in Table 1. Return loss is a convenient way to characterize the input and output signal sources. S11 represents how much power is reflected from the antenna. If S11 5 0 dB, it shows that all power is reflected from the antenna and nothing is radiated. Figure 3 shows the simulated return loss of proposed antenna with the optimized parameters which confirms dual-band operation at desired bands with reasonable bandwidth. As can be well- verified from this figure, the antenna shows a return loss of -23 and -24 dB at strong resonating frequencie 5.25 GHz, respectively. A 50-ohm microstrip line is used to feed the patch for impedance matching. The simulated impedance bandwidths of the two distinct operating bands with 10-dB return loss are about 380 MHz (3.22– 3.60 GHz) and 3.60 GHz (4.94–8.54 GHz).

Another parameter that is used to judge the performance of any antenna is its voltage standing wave ratio (VSWR) measurement. For an ideal match, the VSWR should be 1 which means no reflections. In our present design structure, it turns out to be 1.6 and 1.9 that is, VSWR < 2 and the impedance transformations ratio is 1:1.9 at 5.25 GHz. These values indicate that the antenna is very well-matched to a 50-ohm line allowing maximum power to be coupled through the line to the antenna allowing for the best results.

Effect of Dielectric Constant

The dielectric constant is varied from 4.3 to 4.7. The return losses with variation offir are depicted in Figure 4. As the fir increases, the first and the second resonant frequencies are shifted to the left and return loss value decreases for the lower band. So the FR-4 substrate with dielectric constant 4.4 is preferred to cover the WLAN/multiple input multiple output frequency bands.

2.3. Current Distribution Results

To explain more details on the excited resonant modes of the proposed antenna, the simulated current distribution at resonant frequency of 5.25 GHz are shown in Figures 5 From the figure, it can be noticed that DGS was responsible for enhancing the impedance bandwidth for the upper band resonating at 5.25 GHz and inverted L-shaped patches fed by a microstrip line were responsible for resonance at 3.48 GHz. Further, a gap between a pair of L-shaped patches also play an important role in the sufficient excitation of two resonant modes covering WLAN/MIMO/WiMAX/AMSAT/ WAVE wireless communication standards.

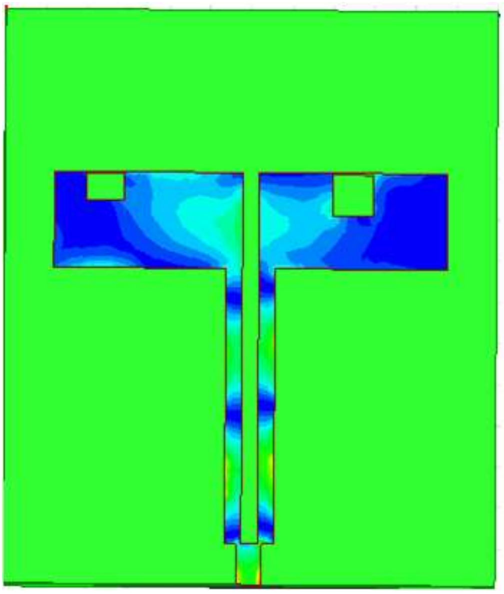

Figure 5 Surface current distribution of the proposed at (5.25)

III. CONCLUSION

Band MPA formed with a pair of inverted dual L-shaped patches and -shaped ground plane is presented that is suitable for WLAN/MIMO/WiMAX/ AMSAT/WAVE and other long-distance communication applications. The frequency bands with return loss below 210 dB cover 3.22–3.60 and 4.94–8.54 GHz with maximum gain values of 6.1 and 8.0 dB in the lower and higher frequency bands, respectively, thus making the proposed antenna appropriate for high-gain applications. The microstrip line feeding method enables direct feeding of the structure without using complicated impedance transformer or microstrip taper. The fabricated prototype on measurement shows reasonable impedance bandwidths of around 380 MHz (3.22–3.60 GHz) and 3.60 GHz (4.94–8.54 GHz) in two operating bands. Slight discrepancies between simulated and measured results are observed which may be mainly due to errors in fabrication process and possible presence of interference and noise. In this specific antenna structure, DGS has been incorporated which is actually responsible for the wide impedance bandwidth of 24% from 4.90 to 8.54 GHz. Taken as a whole, the performance of the antenna meets the desired requirements in terms of return loss, high gain, and VSWR at the two operating frequencies. From this article, it can be concluded that the performance of the microstrip antenna depends heavily on the dimensions of the inverted dual L-shaped patches and DGS been used. The type, thickness, and dielectric constant of substrate also contribute in the antenna performance. The proposed antenna production costs are reduced because of using a FR-4 dielectric substrate. It is seen that the proposed antenna having simple structure achieved very good performance and can be constructed with a lower cost. Hence, the proposed dual-band design will meet the requirements of various wireless communication standards with smaller size and can be easily integrated to microwave circuits for practical wireless applications.

IV. ACKNOWLEDGMENTS

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