DESIGN AND SIMULATION OF A L AND U-SHAPED SLOT COMPACT PLANAR MONOPOLE ANTENNA

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ABSTRACT

This paper presents the design of a new compact antenna structure for multiple incorporating operation service. The proposed antenna is suitable to operate at three different frequency bands, 3.9839 GHz (3.9165 GHz – 4.0340 GHz), 4.4271 GHz (4.3830 GHz – 4.4800 GHz), and 9.8442 GHz (7.0435-11.6715) with a return loss less than -10dB. The antenna structure includes a CPW fed line, the technique used to enlarge the frequency bands is the slots technique i.e. L and U-Slots and in the same time we have developed a new antenna structure which operates in various wireless communication applications. The antenna parameters have been investigated and optimized by using HFSS tool. Simulated results show that the proposed antenna with compact size of 15X15X1.6 mm has good radiation characteristics and operating in specific microwave applications.

Keywords: L-Slot, U-Slot, Monopole antenna, Compact, HFSS

1. INTRODUCTION

In Recent years, the technologies of wireless communication systems have been rapidly increasing for greater capacities broadband service to support wireless devices and be operational in many frequency bands and in many applications. In order to respond to the rapidly increasing demands, an antenna should be operational in multi-frequency bands [1-2]. Therefore, the development of planar antennas with a broadband or multi-frequency operation capacities, low cost, small size, low profile ,high efficiency and flexibility have become an attractive and a real challenge research in recent years [3-4].

To achieve such antennas for the specific applications, there are some methods and techniques used for designing microstrip antennas that operate in wide and multi frequency bands. In [5], a symmetrical ground plane is used to obtain multiband operations which cover various wireless applications. In [6], the use of metamaterials for the antennas design yields to multiband characteristics. In [7], they have demonstrated the multiband operation by using fractal geometry. Some monopole antennas with slot loading, such as circular ring slot [8], square ring slot [9], rectangular slot [10-12], are reported, providing multi-frequency band. In this paper, a novel coplanar waveguide-fed multiband monopole antenna with simple structure, small size and wide frequency bands is presented. The coplanar waveguide mechanism, geometry radiator patch and slot techniques also have many advantages over microstrip type to efficiently control the characteristics of the impedance bandwidth of the operating frequency and to ease the integration with active and passive devices for Wideband or multiband applications.

2. ANTENNA GEOMETRY

The schematic configuration of the proposed microstrip-fed planar monopole antenna for triple-band operation is shown in Fig. 1. The antenna consists of a rectangular radiating patch with a pair of symmetrical L- and U-shaped slots, a feed line, and a ground plane. The design of the proposed antenna is based on a microstrip-fed monopole antenna that is low-profile and simple, but it has relatively large dimensions with a quarter guided-wavelength at first resonant frequency and does not satisfy all the requirements for wideband applications. The proposed antenna is fed by a microstrip line partially backed by a ground plane to provide the connection of the antenna to an external circuit. It is also expected that the far-field radiation patterns of the antenna will be omnidirectional since the patch with the slots is small and it is not backed by the ground plane. Based on this design
formulation, the optimized dimensions of the proposed antenna including the size of the substrate and the ground plane are obtained using a parametric study. Extensive simulation including reflection coefficient $S_{11}$, surface current distributions, and gain has been performed using the Ansys simulation software High Frequency Structure Simulator (HFSS). The proposed antenna is imprinted on FR4 substrate with permittivity of 4.4, a loss tangent of 0.024, and thickness of 1.6 mm. $L_{\text{sub}}=15\text{mm}$, $W_{\text{sub}}=15\text{mm}$, $L_{\text{g}}=15\text{mm}$, $L_{\text{p}}=10\text{mm}$, $W_{\text{p}}=7.5\text{mm}$, $L_{1}=1.5\text{mm}$, $L_{2}=4\text{mm}$, $L_{h}=6.5\text{mm}$, $U_{1}=0.5\text{mm}$, $W_{1}=0.5\text{mm}$, $W_{2}=0.3\text{mm}$, $W_{3}=0.2\text{mm}$, $L_{f}=7.2\text{mm}$, $W_{f}=2\text{mm}$, $g=0.6\text{mm}$.

3. RESULTS AND DISCUSSIONS

Figure 3: Reflection coefficient of the antenna iterations

The goal of this study is to design a new compact antenna structure for multi frequency wide band microwave applications. The design evolution of the proposed antenna is presented in Fig.2 the conception of the planar antenna with multi frequency operation capabilities is due to the multiple resonances introduced by the combination optimization of the geometry antenna, cutting notched and slot shaped on the radiator patch technique and CPW-feed line width. Therefore, Fig 3 shows the simulated return losses for successive cases of the conception of the final tri-band antenna. We can clearly see that the proposed antenna is designed through three steps. Firstly, for a reference rectangular plane, the geometry radiator patch was modified to further improvement of the bandwidth of the antenna as exhibited in Fig 2. Secondly by adding a three parallel slot shaped on the radiator patch, the dual-band antenna is obtained. At the end, the final tri-band antenna is achieved by using slanted rectangular slots with an angle of 45°. Thus, the matching input impedance of the final antenna structure is achieved respectively in frequency bands.

Fig 4 shows the parametric analysis of the reflection coefficient of the antenna with change in ‘g’ i.e $g=0.2\text{mm}$, $0.4\text{mm}$, $0.6\text{mm}$, $0.8\text{mm}$. When $g=0.6\text{mm}$, we got optimized results with good return loss.

Figure 4: Parametric analysis with change in ‘g’

Fig 5 shows the parametric analysis of the reflection coefficient of the antenna with change in ‘w3’ i.e $W_{3}=0.1\text{mm}$, $0.2\text{mm}$, $0.3\text{mm}$. When $W_{3}=0.2\text{mm}$, the return loss is better when compared to other values of $W_{3}$. Frequency Bands are 3.9839 GHz (3.9165 GHz - 4.0340 GHz), 4.4271 GHz (4.3830 GHZ - 4.4800 GHz), and 9.8442 GHz (7.0435-11.6715).

Figure 5: Parametric analysis with change in ‘w3’

Figure 6: VSWR of the antenna

Figure 7: Input impedance smith chart

Figure 8: Gain of the antenna
The radiator patch antenna and the feeding are implemented on the same plane, only one layer of the substrate with a single side metallization. The dimensions of the designed antenna are 15x15x1.6 mm. All the design and simulated results are performed by using HFSS tool. After many optimizations of the antenna geometry, the parameters of the final structure. Fig 6. illustrated the simulated Voltage Standing Wave Ratio (VSWR) versus frequency of the final proposed antenna structure. It is noticed that the VSWR less than 2 for the frequencies throughout matching bands. The variation of the antenna gain versus frequency is shown in Fig 8. The radiator patch antenna and the feeding are implemented on the same plane, only one layer of the substrate with a single side metallization. The dimensions of the designed antenna are 40 x 36 mm2. All the design and simulated results are performed by using HFSS. After many optimizations of the antenna geometry, the parameters of the final structure are presented in Table 1.

It can also be seen from Fig. 9 that the proposed antenna provides omnidirectional radiation patterns in the –plane and bidirectional patterns in the –plane over the desired operating bands. For further examining of the whole proposed antenna, the excited surface current distributions on the patch are provided. The simulated current distribution of the antenna at the three resonant frequencies is shown in Fig. 10. From this simulation, it is found that for the lowest frequency band a large surface current density is observed along the gap in between the symmetrical U-shaped slots. For the second and the highest frequency bands, the current distributions are concentrated around the symmetrical L- and U-shaped slots.

Figure 9: Radiation patterns at resonant frequencies

Figure 10: Surface current distribution of the antenna
### Table 1: Antenna Parameters

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max U</td>
<td>0.00175352 (W/sr)</td>
</tr>
<tr>
<td>Peak Directivity</td>
<td>2.43759</td>
</tr>
<tr>
<td>Peak Realized Gain</td>
<td>2.20359</td>
</tr>
<tr>
<td>Radiated Power</td>
<td>0.00904003 (W)</td>
</tr>
<tr>
<td>Accepted Power</td>
<td>0.00999798 (W)</td>
</tr>
<tr>
<td>Incident Power</td>
<td>0.01 (W)</td>
</tr>
<tr>
<td>Radiation Efficiency</td>
<td>0.904185</td>
</tr>
<tr>
<td>Front to Back Ratio</td>
<td>1.33583</td>
</tr>
</tbody>
</table>

### 4. CONCLUSION

In this study, we have designed and validated a new low cost printed multi-band antenna structure, suitable to operate in wide frequency bands. As described in this paper conception, optimization and simulation results are performed by using HFSS electromagnetic simulator. The slots technique used in this work is a simple way to optimize and to control the frequency band. The proposed antenna is composed of a pair of symmetrical L- and U-shaped slots inside the rectangular patch that enables proper adjusting of the resonant bands. The proposed antenna can be an excellent choice for multiband applications due to its small size, simple structure, good multiband characteristics, and omnidirectional radiation pattern over the aforementioned bands.

### REFERENCES


