U-Shape Wideband Slot Antenna for 5G Mobile Phone Applications

Basma M. Yousef*[1], Germien G. Sedhom[1], Alshimaa H. Ismail[1]

[1]Delta Higher Institute for Engineering and Technology,
Talkha, 35111, Mansoura, Egypt.
Emails: basmamyoused@gmail.com; germien_ggs@yahoo.com; eng.alshimaahamdy@gmail.com

Abstract

A new shape of slot antenna (U-shaped) is introduced in this paper. The proposed antenna is designed for use in mobile phone devices. This structure covers bands ISM/Bluetooth, WLAN, Wi-Fi, WiMAX, 5G applications, cellular communications, weather radar, surface ship radar, and some communications satellites. A U-shaped slot is cut on the ground plane. A coupling feed technique is used to feed the designed antenna. The proposed antenna is printed on a high-loss FR-4 dielectric substrate with $\varepsilon_r = 4.4$. The designed antenna achieves a very wide bandwidth (from 2.3GHz to 6.3GHz). A high gain (around 7dB) is also achieved. The design is simulated using CST software, and the results are verified by HFSS software.

Keywords: Slot Antennas; ISM/Bluetooth; WLAN; Wi-Fi; WiMAX; Cellular Communication; 5G.

1. Introduction

The antenna used for smart mobile phones is mandatory to have a wide bandwidth and a low profile. A small antenna always has a high return loss but a narrow bandwidth. It is difficult to strike a balance between wideband characteristics and antenna size minimization. There are other techniques for increasing antenna bandwidth with an impedance matching network, such as lumped components [1, 2], PIN diodes reconfigurable antenna [3, 4]. To increase the complexity of antenna design and fabrication, such as microstrip patches, slot antennas, and printed radiators, the lumped component technique is required. Slot antennas consist of a metallic ground plane with etched slots on it and a dielectric substrate, which makes them low profile, low weight, and compact in structure. Microstrip-fed slot antennas also have some distinct advantages, including lower cost, ease of fabrication, simple integration with circuit components, and a simple feeding structure [4]. These advantages make them suitable for printed circuit boards. On the other hand, it has a low gain relative to other types of antennas. This disadvantage can be compensated for by using it in an antenna array. To generate radiation, a microstrip line is used as an aperture coupled with the ground metallic plane. The microstrip line is assumed to be infinitely long and to be transmitting a quasi-transverse electromagnetic (TEM) signal.

In this paper, the proposed band is the S-band, which operates from 2.3 to 6.3 GHz. This band has several applications, such as weather, radar, surface ship radar, space shuttle, and mainly mobile and satellite communication [5]. One of the promising frequency bands are 2.4, 2.8 to 3.4, 3.6 to 4.5, and 5.8 GHz, which are mainly used in 5G communications [6]. The antenna configuration is presented

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in Section 3, and simulation results are discussed in Section 4. Finally, the conclusion is discussed in Section 5.

2. Related Work

Traditional designs, however, frequently have restricted bandwidth and poor gain, making it challenging to meet the needs of contemporary 5G communication systems. It is difficult to create small antennas with strong radiation performance and a wide bandwidth. Increased substrate thickness [7], aperture coupling feeding [8], multi-layer metallic-dielectric array radiator [9], double dipole with stubs [10], and fractal shape [11] are only a few of the several efficient ways of bandwidth optimization that have been vigorously advocated. In the meanwhile, a number of strategies for increasing antenna gain have been put forth, including the use of parasitic patches [12], shorted pins [13], array technology [14], and Fabry-Perot resonator cavities [15]. For mobile phone applications, a brand-new multi slot multiband printed monopole antenna is shown in [16]. The right design of the many slots used in the phone ground plan can provide the multiband capability. At the ground plane's edge, five symmetrical slots are carved to provide two broad frequency bands. The GSM900, UMTS, 2.4-GHz WLAN, and a portion of the GSM850 bands are all covered by the antenna's two large bands. Full-wave numerical simulations have been run to demonstrate the antenna's good radiation characteristics. For instance, Cao et al. combined two radiating edges of the primary radiation patch with two parasitic mushroom arrays to concurrently obtain a broadband impedance bandwidth of 41.8% (at 15.05 GHz) and a peak gain of 10 dBi [17]. But the majority of the aforementioned works have undesirable high operating bands, profiles, or polarisation levels.

3. Antenna design structure

The configuration of the proposed antenna is shown in Fig. 1. The antenna is designed on FR4 dielectric substrate with $\varepsilon_r = 4.4$ and thickness 0.8 mm. The total antenna size is $140 \times 60 mm^2$. The U-shape slotted antenna is inserted on the ground plane with a dimension of $45 \times 30 mm^2$. The microstrip feed line dimension is calculated to be matched with 50 Ω. Table 1 introduces all the dimensions of the proposed antenna. The antenna is created using CST software, and the results are validated using HFSS.

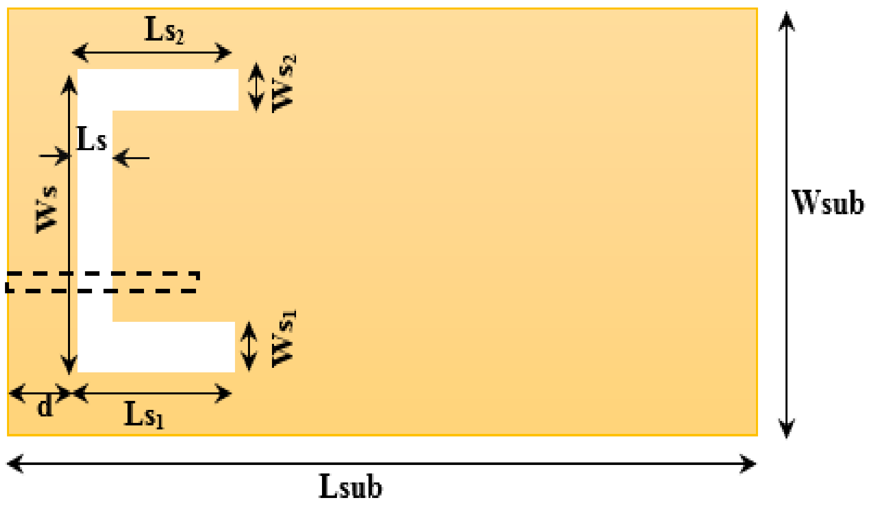

Figure 1: The complete antenna design

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Table 1: Dimension of antenna parameters

Parameter	Dimension [mm]	Parameter	Dimension [mm]
L_{sub}	140	W_{sub}	60
L_{feed}	21	W_{feed}	0.8
d_f	8	d	15
L_S	5	W_S	45
L_{S1}	30	W_{S1}	7
L_{S2}	30	W_{S2}	7

4. Results Analysis and Discussion

The return loss of the designed antenna is shown in Fig. 2. As shown, The -6dB bandwidth of the proposed antenna is started from 2.3 to 6.3 GHz with a total bandwidth of 4GHz. This bandwidth covers the mid band of 5G applications which widely used for the newest generation. A parametric study for each parameter is also studied individually. Some of these studies are discussed and displayed in this section. Figure 3 shows a parametric study result of three parameters WS1, WS2 and LS. In Fig. 3 (a), it shows the variation of results due to variation of WS1. The S11 is improved by increasing the WS1 but the resonance frequency is shifted. The value of WS1 is chosen to be 7mm. In Fig. 3 (b), it shows the variation of results due to variation of WS2. The value of WS2 is also chosen to be 7mm. The most effective parameter is shown in Fig. 3 (c); it is the variation of results due to variation of LS. The value of LS is chosen to be 5mm. In Fig. 4, radiation pattern of the designed antenna is presented at frequencies 2.4GHz, 3GHz and 5GHz. As shown in Fig. 5, the maximum overall gain of the frequency is introduced. The maximum achieved gain of the antenna is 7dB frequency 5GHz.

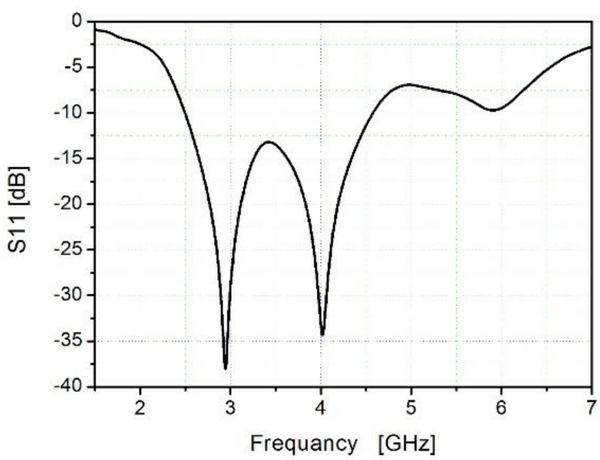

Figure 2: Return Loss of the proposed antenna.

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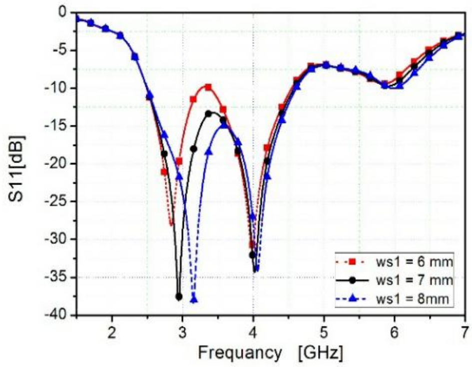
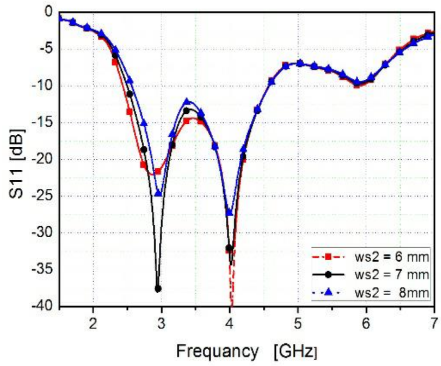
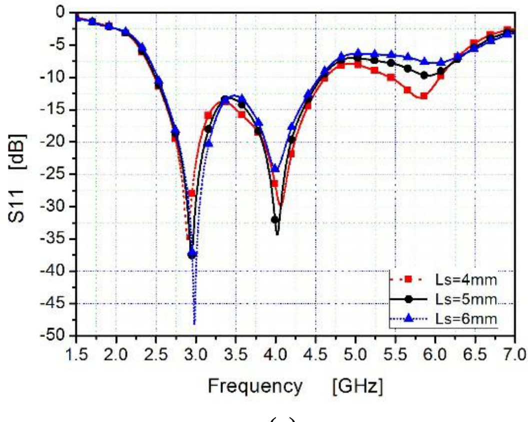


(a)



(b)



(c)

Figure 3: (a) Parametric study of W_{S1}, (b) Parametric study of W_{S2}, and (c) Parametric study of L_S.

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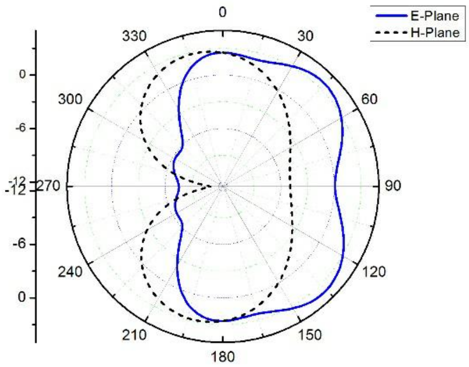
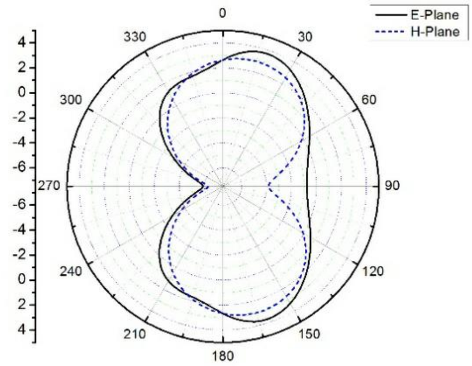
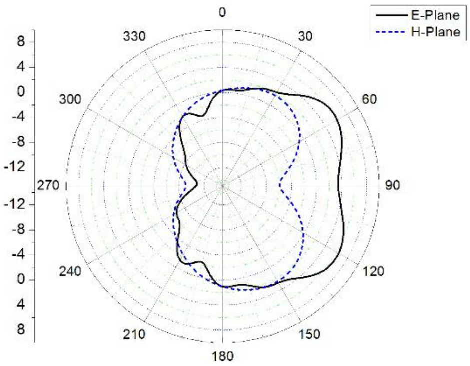


(a)



(b)



(c)

Figure 4: (a) E-plane and H-plane at 2.4 GHz, (b) E-plane and H-plane at 3GHz, and (c) E-plane and H-plane at 5GHz.

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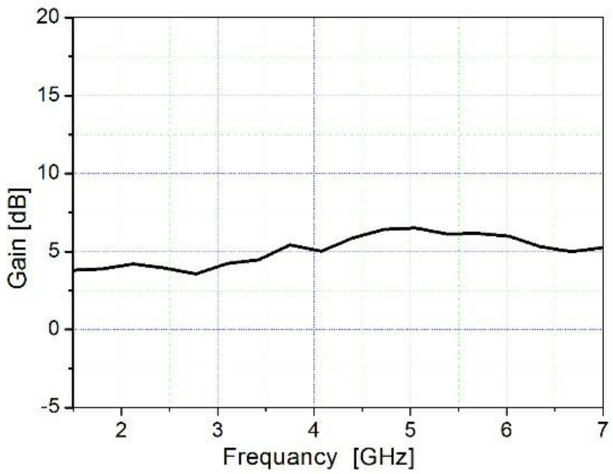

Figure 5: The maximum gain overall the frequency.

5. Conclusion

A wideband U-shaped slot antenna with a microstrip feeding line structure is proposed. The designed antenna has a low profile and a wide bandwidth, allowing it to be used in mobile communications. The designed antenna achieves a very wide bandwidth (from 2.3GHz to 6.3GHz). A high gain (around 7dB) is also achieved. Because of its very wide bandwidth, the structure can be used for many applications such as ISM/Bluetooth, WLAN, Wi-Fi, WiMAX, 5G applications, cellular communications, weather radar, surface ship radar, and some communications satellites.

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Conflicts of Interest: “The authors declare no conflict of interest.”

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