A Compact Elliptical Slot UWB Antenna with Extra Bands for Bluetooth, GSM, and GPS

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Abstract

a compact size and lightweight planar ultra-wideband (UWB) antenna with an omnidirectional radiation pattern and a stable gain in the frequency range 3.1-10.6 GHz is proposed and investigated. The antenna consists of an elliptical shaped slot which is fed by a 50-Ω microstrip line that is beveled and has fork-shaped is designed. Attaching two inverted U-shape strips at the upper part of the slot, two additional bands are realized covering GPS, upper part of GSM (1770–1840 MHz), and Bluetooth (2385–2490 MHz) bands. The calculated return loss, omni-directional radiation pattern, and peak gain are in good agreement with the measurement results. The antenna can provide high-performance wireless communications over different frequency bands. This structure has a compact size (27×24 mm^2), is lightweight, and can be easily fabricated. According, the proposed antenna is expected and normal to be a good candidate in various applications in portable and lightweight communication system.

Keywords— ultra-wideband, lightweight, multi-band, slot.

I. INTRODUCTION

UWB communication systems become one of the most expanding technologies in recent years [1]. Among planar printed antennas for portable communication systems, printed slot antenna is one of the most suitable candidates for UWB applications. UWB systems have advantages as low cost, low loss and ease of fabrication which made them a good candidate for remote sensing application and environment security [2]. Size reduction and bandwidth enhancement are highly required for printed slot antennas in order to facilitate their use in the compact UWB communication systems.

In recent years, several papers such as [1], [3], reported printed microstrip-fed slots on the ground plane of the antennas in different shapes to obtain UWB performance [4]. These configurations may be comprised of a square, hexagonal, or inverse cone slots which are fed by a microstrip fork shaped feed [4, 8]. Furthermore, due to the increasing demands for adding extra bands within the UWB applications in modern wireless communication systems, different methods are proposed for implementation of these structures [9].

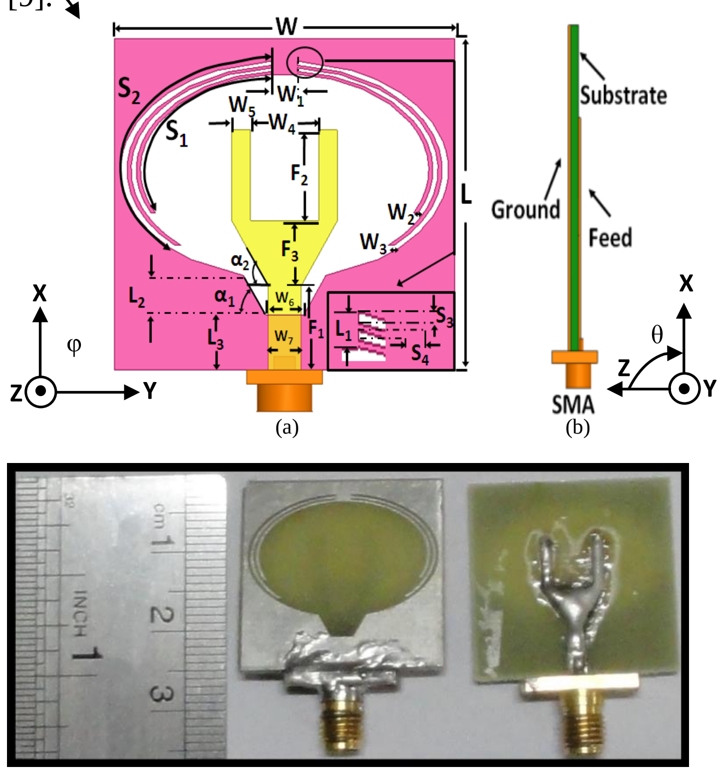

Fig.1. The configuration of our proposed antenna (a) front view, (b) side view, and (c) the fabricated UWB antenna with two extra bands.

In [1] and [3], Multiband performance is achieved by employing three L-shaped or elliptical-shaped strips in the ground plane of the antenna, respectively. Furthermore, by using inverted U-

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shaped strip, two extra bands are added to the UWB antenna [10]. However, the entire spectrum of UWB communication is not cover by the proposed structures in [1], [3], and [10].

This paper first describes the design procedure of a UWB microstrip based slot monopole antenna that covers the 3.1-10.6 GHz band. The structure consists of an elliptical slot connected to a trapezoidal slot in the ground plane. The slots are fed by a 50Ω microstrip-fed feed line placed on the top side of the substrate.

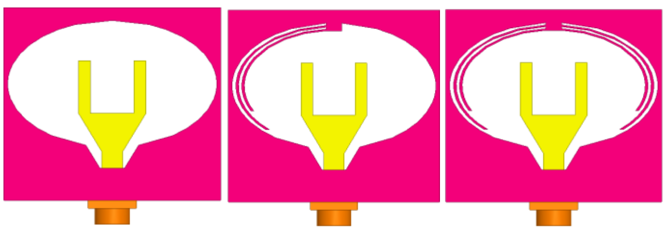


Fig. 2. Configuration of the printed UWB antenna. (a) Antenna I: initial UWB antenna. (b) Antenna II: UWB antenna with two strips added in one side, and (c) antenna III: UWB antenna with strips that are placed symmetrically on both sides of the elliptical slot.

TABLE I
DESIGN PARAMETERS OF THE GROUND PLANE For THE MULTIBAND ANTENNA

Antenna Parameter	Value	Antenna Parameter	Value
W	27 mm	S_1	17 mm
W_1	2 mm	S_2	21.2 mm
W_2	0.35 mm	S_3	0.3 mm
W_3	0.48 mm	S_4	0.3 mm
W_4	5.4 mm	F_1	6 mm
W_5	1.5 mm	F_2	6.5 mm
L	24 mm	F_3	4.7 mm
L_1	1 mm	H	1.6 mm
L_2	2.8 mm	α_1	60°
L_3	4 mm	α_2	60°

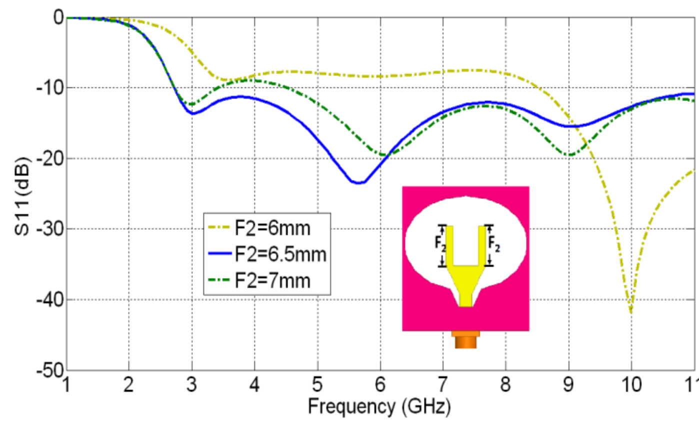


Fig. 3. Simulation results for reflection coefficients of the UWB slot antenna for three different values of "F_2".

The feed line is beveled and is fork-shaped with two fingers. In the next step, two quarter-wavelength strips are added to the elliptical slot on the ground plane, to achieve a UWB antenna with two extra bands covering GSM and Bluetooth bands. The comparison of the proposed antenna with that of [4] reveals that tuning the frequency of extra band is implemented in the proposed structure. This capability can be exploited for unwanted frequency rejection or noise reduction. Furthermore, higher gain and more stable radiation pattern are achieved compared to [10, 13] and [12], respectively. Also, a size reduction is obtained compared to [1], [3], [4], [10] and [11].

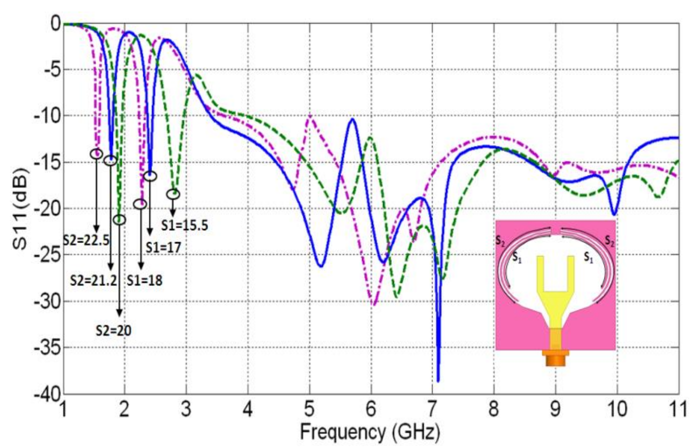


Fig. 4. Simulation results for reflection coefficients of the proposed antenna for different values of S1 and S2; these parameters are used for length of edges of inverted U-shaped strip. Other values of this simulation are shown in Table I. The inset shows the antenna structure.

II. Antenna Design

The configuration of the proposed antenna, side view, and the realized structure are shown in Fig. 1(a), 1(b), and 1(c), respectively. The antenna is fabricated on a FR4 substrate with substrate transverse dimensions of (27×24 mm^2) and a thickness of 1.6mm^2. The relative permittivity of the substrate is 4.4, and it has a loss tangent of 0.02. In the bottom side of the substrate, an elliptical slot is fabricated and a trapezoidal slot is designed for matching impedance. Two U-shaped strips are added to the perimeter of the elliptical slot to create two extra bands.The feed line is a 50-Ω microstrip transmission line. The feed is beveled by the angle α_2, and is fork-shaped with two fingers. Parameters for the structure are shown in Table I. These parameters are optimized to achieve return loss less than -10dB in the UWB communication band. Fig.2. shows three antenna designs, (I) is a UWB antenna, (II) is the same UWB antenna which is modified with adding two strips in one side, and (III) in which similar strips are placed symmetrically on both sides of the elliptical slot to improve the impedance matching level of the resonances.

III. RESULTS

The return loss of UWB antenna is shown in Fig.3. It is demonstrated that the bandwidth is controlled by the length of two-finger fork-shaped feed shown by F_2 parameter. As can be seen in this figure, the bandwidth of the proposed antenna can be controlled with the length of the finger, which is one of the advantages of this structure compared to [4]. Obviously, Fig.3 shows that by increasing the length of fork fingers, the bandwidth is increased. The effect of length for inverted U-shaped strips is shown in Fig. 4. Here, the frequency of extra

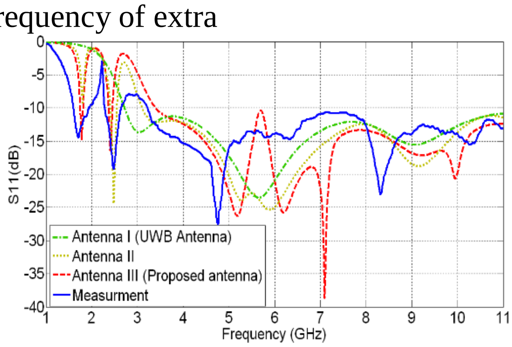
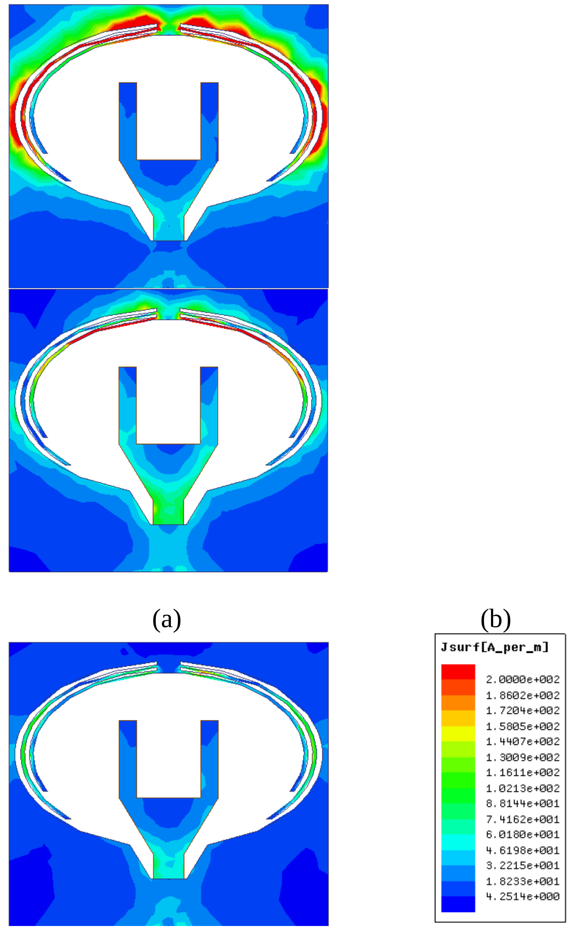


Fig. 5. Reflection coefficient of the antennas. Dash-dotted line, dotted-line and dashed-line are used for reflection coefficient of antenna I, antenna II, and antenna III, respectively. Solid line corresponds to the Measurement results.



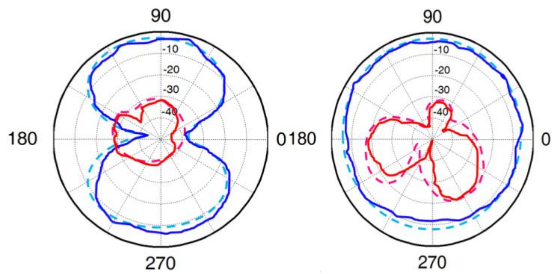
(a) (b)

(c)

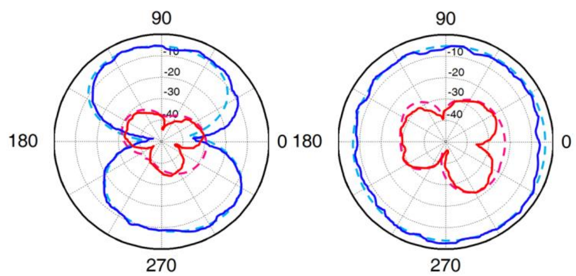
Fig. 6. Simulation results for current distributions on the multiband slot antenna at the frequencies of (a) 1.7GHz, (b) 2.4GHz, and (c) 5.8GHz.

bands can be controlled by tuning the length of each strips. Therefore, one can simply add the desired extra operating frequencies to the UWB antenna by simply choosing the proper strips lengths. Other shown parameters of the added strips can be determined by optimization methods.

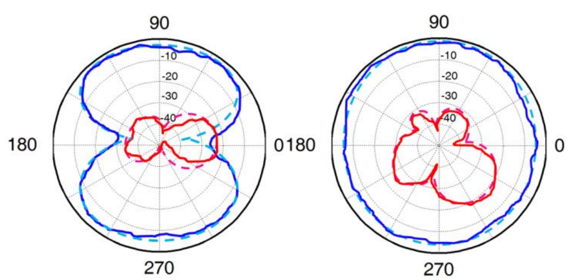
The reflection coefficients of the mentioned antennas are shown in Fig. 5. Since the presence of the strips make the area of the elliptical slot smaller, it is expected that the performance of antenna will be degraded for lower frequencies. Therefore, if the area of elliptical slot is increased and two strips are added, then two extra bands in addition to the entire UWB band coverage can be obtained. In other words, the UWB printed slot antenna with two inverted



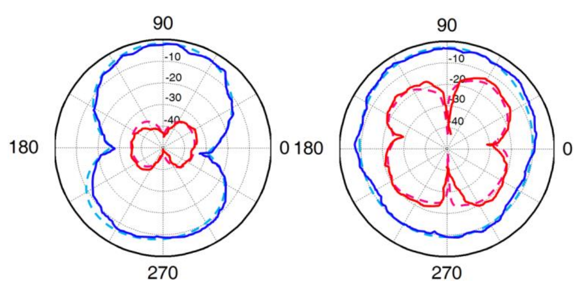
E-plane (a) H-plane



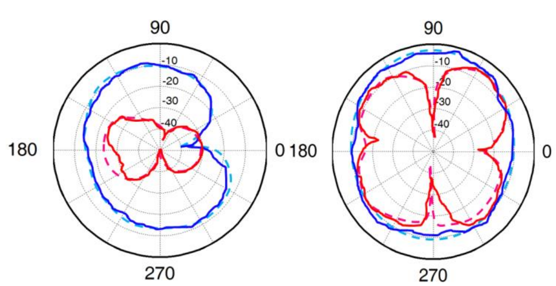
E-plane (b) H-plane



E-plane (c) H-plane



E-plane (d) H-plane



E-plane (e) H-plane

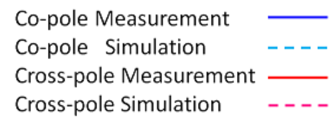


Fig. 7. Measured radiation and simulation Co- and cross-polar radiation patterns at (a) 1.7 GHz, (b) 2.4 GHz, (c) 3.5GHz, (d) 5.8 GHz, (e) , and 8.3 GHz frequencies in E-plane and H-plane.

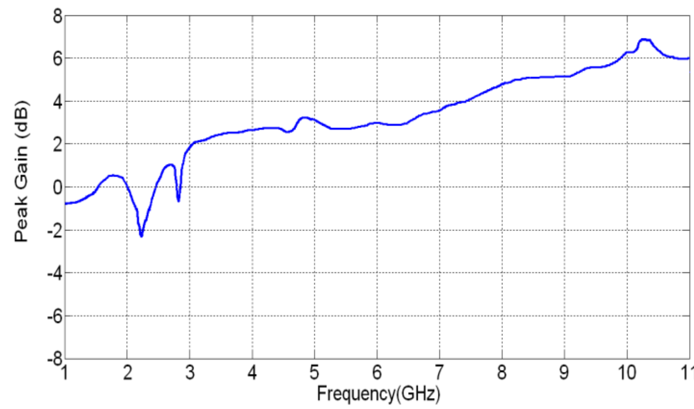
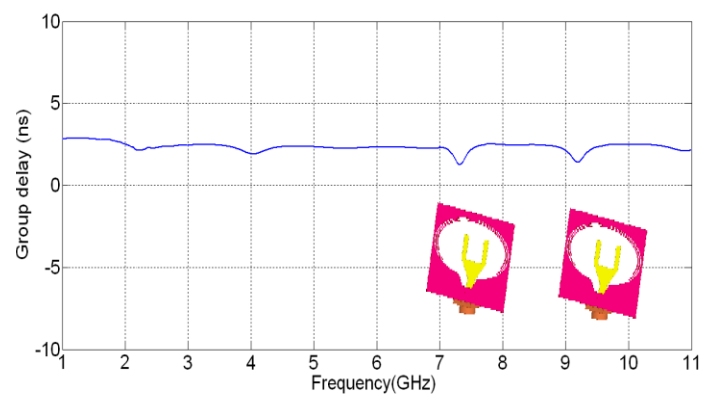
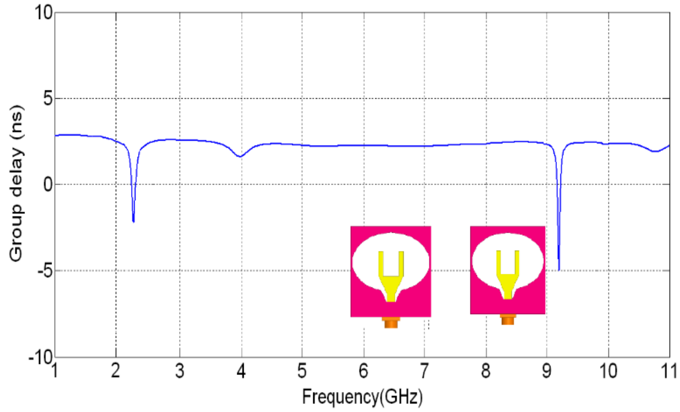


Fig. 8. Measured peak gain of the proposed antenna.



(a)

U- shaped strips covers the whole of the UWB band (3.1–10.6 GHz) as well as two extra frequency bands. To describe working principle of the antenna, current distributions for different frequencies are shown in Fig. 6. It can be seen that the current is mainly present on the longer and shorter strips at frequencies of 1.7 GHz, and 2.4 GHz, respectively. Beyond



(b)

Fig. 9. Simulation results for group delay of the proposed antenna, (a) face-to-face and (b) side-by-side configurations.

the extra bands, the amplitude of current is reduced on the strips, as shown in Fig. 6(c) for 5.8 GHz. It is seen that the surface current distribution on the strips at the extra bands is similar to that of a quarter-wavelength open stub where the current is maximum at the connection point of the strip to the ground plane and is minimum at the other end. The simulation and measurement results of both co-pol and cross-pol components are shown in Fig. 7. In this figure, the normalized radiation pattern in the E-plane and H-plane are demonstrated for frequencies of 1.7GHz, 2.4GHz, 3.5GHz, 5.8GHz and 8.3GHz. This figure confirms that the radiation patterns are stable at different frequencies. Also, it can be seen that the antenna has an omnidirectional radiation pattern in H-plane for the mentioned frequencies. Similar to other planar UWB antenna [4], the cross-pol component for the proposed antenna increases by frequency, as shown in Fig.7. Furthermore, regarding the mentioned radiation pattern, the corresponding application of the antenna for each frequency can be found in [3].

The measured peak gain of the proposed antenna is shown in Fig. 8. As can be seen in this figure, the gain of the antenna is almost constant in GSM and Bluetooth while the gain decreases at notched frequency bands. The simulated face-to-face and side-to-side group delays of the proposed multiband antenna are shown in Fig. 9(a) and (b), respectively. It is shown that the group delays are constant over the operating frequency range and are improved compared to [1]. It is noteworthy that the smooth group delay of the antenna facilitates UWB pulse radiation without significant signal distortion.

IV.CONCLUSION

In this paper, we proposed a compact UWB antenna which is comprised of an elliptical slot, two strips, and a fork-shaped microstrip feed line. It is shown that by adding two U-shaped strips on the ground slot, two extra bands can be added. The proposed configuration covers GSM, Bluetooth and UWB communication bands. The antenna provides a stable and omni-directional radiation pattern. The flat group delay of proposed antenna facilitate multi-purpose and high-data rate applications.

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