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Study of a Circular Monopole Antenna with T-shaped Slot in the Patch for Ultra Wideband (UWB) Applications

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ABSTRACT: This paper presents a study of a novel monopole antenna for ultra wideband (UWB) applications. Printed on a dielectric substrate FR4 and fed by a 50 microstrip line, a planar circular monopole has been demonstrated to provide an ultra wide 10 dB return loss bandwidth with satisfactory radiation properties. A T-shaped slot, cut in the radiating patch, increase the impedance bandwidth of the proposed antenna up to 131%. The parameters which affect the performance of the antenna in terms of its frequency domain characteristics are investigated. The proposed antenna is optimized by ANSOFT High Frequency Structure Simulator (HFSS). Details of the proposed antenna design and simulated results is described and discussed.

KEYWORDS: UWB antenna, monopole antenna, T-shaped slot, circular patch, partial ground plane.

1 INTRODUCTION

Since the Federal Communication Commission (FCC) first approved rules for the commercial use of ultra-wideband (UWB) in 2002 [1], [2]. Both the feasible design and implementation of UWB system have become a highly competitive topic in academy and industry communities of telecommunications. In particular, as a key component of the UWB system, an extremely broadband antenna, which has attracted significant research power in the recent years [3], will be launched in the frequency range from 3.1GHz to 10.6GHz [4], [5]. Challenges of the feasible UWB antenna design include the UWB performances of the impedance matching and radiation stability, the compact appearance of the antenna size, the low manufacturing cost for consumer electronics applications [6].

Ultra-wideband (UWB) technology is one of the most promising solutions for future communication systems due to its high speed data rate and excellent immunity to multi-path interference. UWB antenna design has some challenges including the ultra wide band performance of impedance matching and radiation stability [11], [12], [13], compact antenna size, and low manufacturing cost for consumer electronics application [7].

Conventional UWB antennas in the geometry of either log periodic or spiral tend to be dispersive. They usually radiate different frequency components from different parts of the antenna, which distorts and stretches out the radiated waveform [8]. Recently, several broadband monopole configurations, such as circular, square, elliptical, pentagonal and hexagonal, have been proposed for UWB applications [9], [10]. These broadband monopoles feature wide operating bandwidths, satisfactory radiation properties, simple structures and ease of fabrication.

In this paper, a novel design of printed circular monopole fed by microstrip line is proposed and investigated. The ultra wideband antenna is obtained by inserting T-shaped slot in the radiating patch. The antenna design was performed using the HFSS software. The simulation results show that the ultra wideband antenna covers frequency band 2.76 – 13.18 GHz (S11 < −10 dB). The paper is organized in the following sections. Section 2 describes the proposed antenna design. Section 3 analyzes the characteristics of the antenna. Section 4 summarizes and concludes the study.

2 ANTENNA DESIGN

The geometry of the proposed UWB antenna with partial ground plane is illustrated in figure 1. The antenna is fed with a 50 Ohm microstrip line, imprinted on the FR4 substrate with thickness 1.6 mm, relative permittivity of 4.4 and loss tangent 0.02. The shape of the radiating element is circular with a radius of R. The T-shaped slot is embedded on the radiating patch. The design and study of the proposed antenna with a bandwidth of operation below - 10dB, which extends from 2.76 to 13.18 GHz, are presented. The antenna parameters are summarized in table 1.

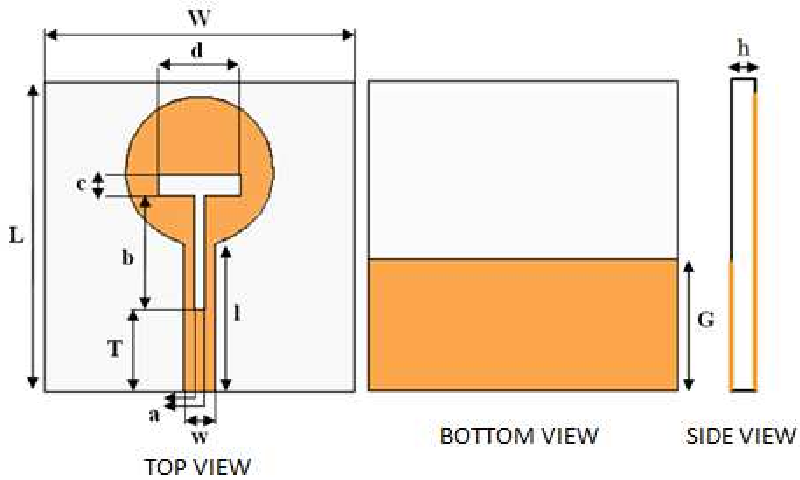


Fig. 1. The geometry of the proposed UWB antenna

Table 1. Parameter's values of the proposed antenna

Parameter	W	L	w	l
Dimension (mm)	30	30	3	14.5
Parameter	G	R	a	c
Dimension (mm)	12.8	7.2	1	2

3 SIMULATED RESULTS

The proposed antenna presents a reflection coefficient of -10 dB over the entire frequency band (2.76-13.18 GHz). The influence of the slot sees itself clearly in the improvement of the adaptation and also at the level of the bandwidth. However, compared with the antenna without slot, whose coefficient reflection is upper to -10 dB in the frequency band (8.8-10.2 GHz), this antenna presents one better adaptation. A maximal coefficient reflection of - 18dB with the frequency of 3.61 GHz is obtained. The bandwidth obtained for a coefficient of reflection of -10dB is from 2.76 to 13.18 GHz.

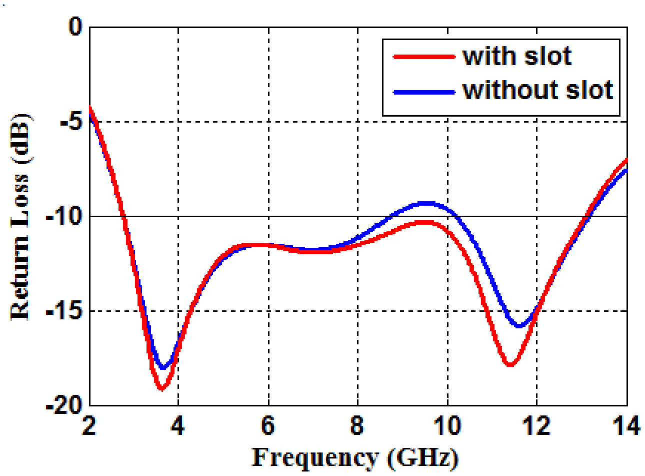


Fig. 2. Simulated return losses of the proposed antenna with and without T-shaped slot

Fig. 2 shows the return loss of the proposed antenna with and without T-shaped slot. We note that the ultra-wideband antenna has a bandwidth impedance between 2.76 GHz and 13.18 GHz, and Two resonance modes are observed, one centered around 3.61GHz and the other around 11.35GHz. The results are obtained with the optimal parameters shown in the table1.

3.1 Effect of T Parameter

The coefficient of reflection of the antenna for various values of the parameter T is shown in fig. 3. In this part of the study, only the position of the T-slot will be changed. The other parameters of the slot remain fixed. We noticed that with the decrease of the parameter T the bandwidth of the frequency is increased to 131 %, then an improvement in the adaptation in all the frequency bands.

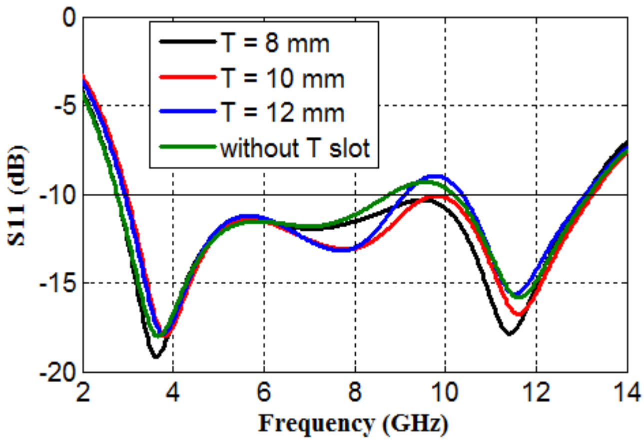


Fig. 3. Simulated reflection coefficient curves for different T values

3.2 Effect of b , c and d Parameters

Fig. 4, fig. 5 and fig. 6 show the simulated reflection coefficient of the proposed antenna for various values of the dimensions of the T-shaped slot. In order to study the influence of dimensions of the slot on the characteristics of the antenna and in particular the coefficient of reflection, we will vary the length and the width of the slot noted b, c and d respectively. First of all we vary the parameter b (fig. 4), we noticed that the bandwidth widens with the increase of the parameter b. For b = 12 mm the bandwidth is increased up to 125 %. For the second parameter c (fig. 5), we noticed that with the increase of parameter c the adaptation of the proposed antenna improves for the first frequency of resonance, On the other hand, when c decreases the adaptation is improved for the second resonance frequency. For the study of the parameter d, we showed that this played parameter an important role in the improvement of the adaptation (fig. 6), the adaptation improves in all of the bandwidth when d = 8 mm.

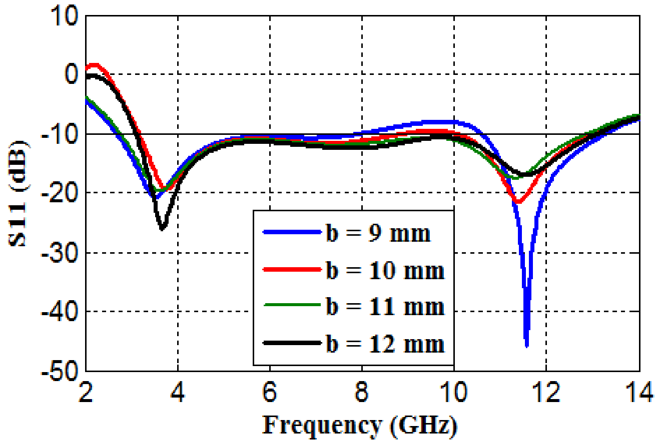


Fig. 4. Simulated reflection coefficient curves for different b values

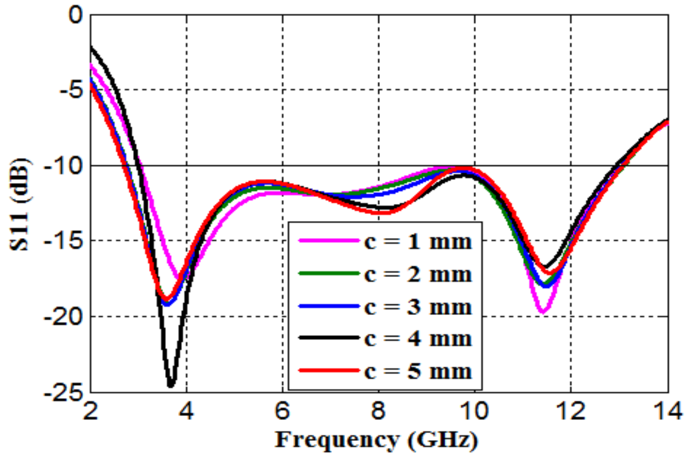


Fig. 5. Simulated reflection coefficient curves for different c values

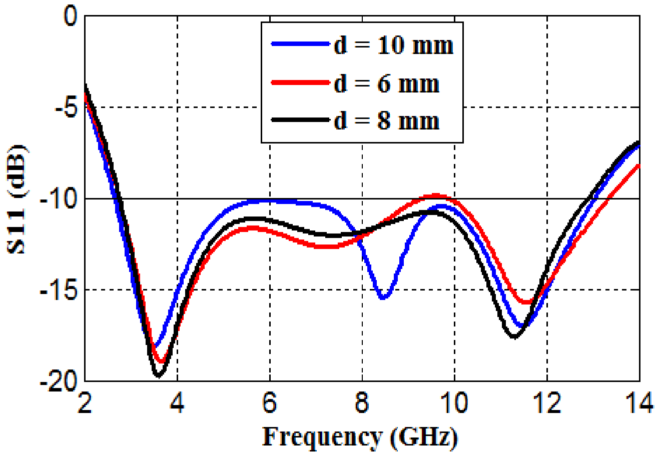


Fig. 6. Simulated reflection coefficient curves for different d values

3.3 Current Distribution

Fig. 7 shows the current distribution simulated on the radiating element with the slot and the ground plane in two resonance frequencies 3.61 GHz (fig. 7 (a)) and 11.35 GHz (fig. 7 (b)) respectively. One can notice that for the two frequencies of resonance, the distribution of the current surface is mainly concentrated on the line of feeding. At the level of patch the distribution of current surface is important in the inferior edges of the second frequency of resonance. On the other hand, for the first frequency of resonance the distribution of the surface currents decreases in the level of the patch. We can notice also that for the partial mass plan the current distribution is important for the first frequency of resonance and less important for the second frequency of resonance.

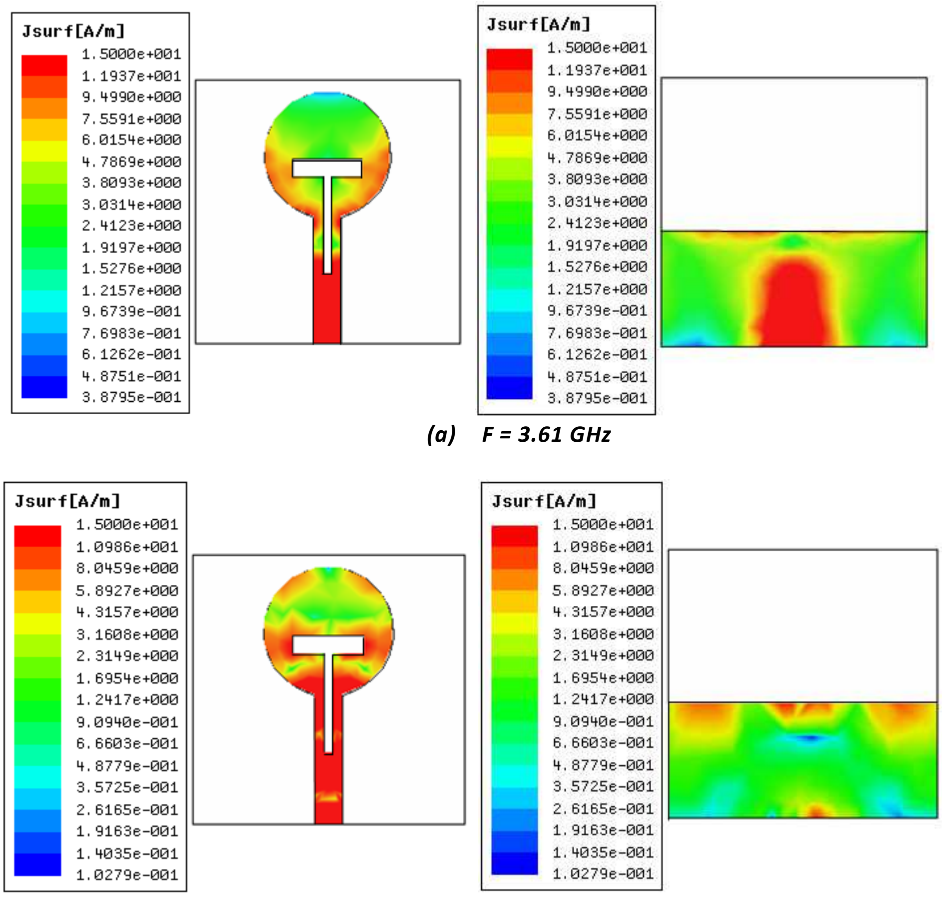


Fig. 7. Simulated current distributions on the monopole and the ground plane, (a) f = 3.61 GHz and (b) f = 11.35 GHz

3.4 Gain and Radiation Pattern

Fig. 8 shows the antenna peak gain in the frequency bands of 2-14GHz for the proposed UWB antenna. We observe that the significant antenna gain increase at 3.61GHz and 11.35GHz indicate the effect of band function clearly.

Two principal planes are selected to present the radiation pattern of the proposed antenna. These are called E plane (φ = 0) and the H plane (φ = π/2). Fig. 9 shows the radiation patterns in the H-plane and E-plane of the proposed antenna at frequency 3.61GHz and 11.35GHz. We can observe that the radiation pattern in the E-plane is omnidirectional for 3.61GHz and nearly omnidirectional for 11.35GHz. While in H-plane, the radiation pattern is bidirectional.

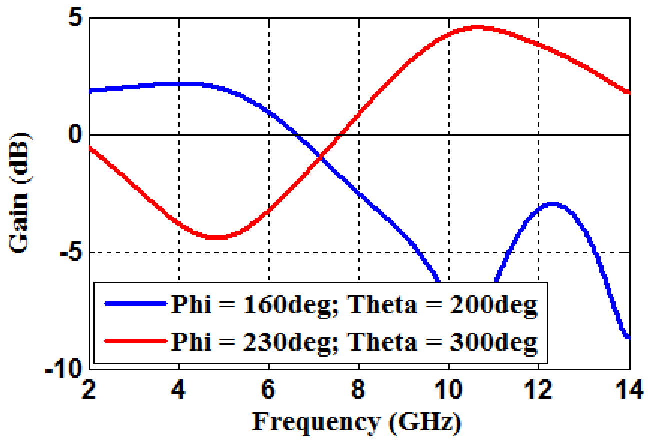
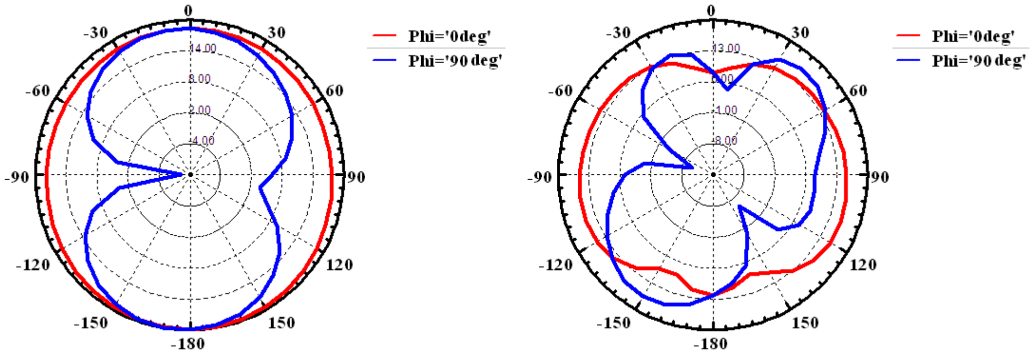


Fig. 8. Simulated gain of the proposed UWB antenna

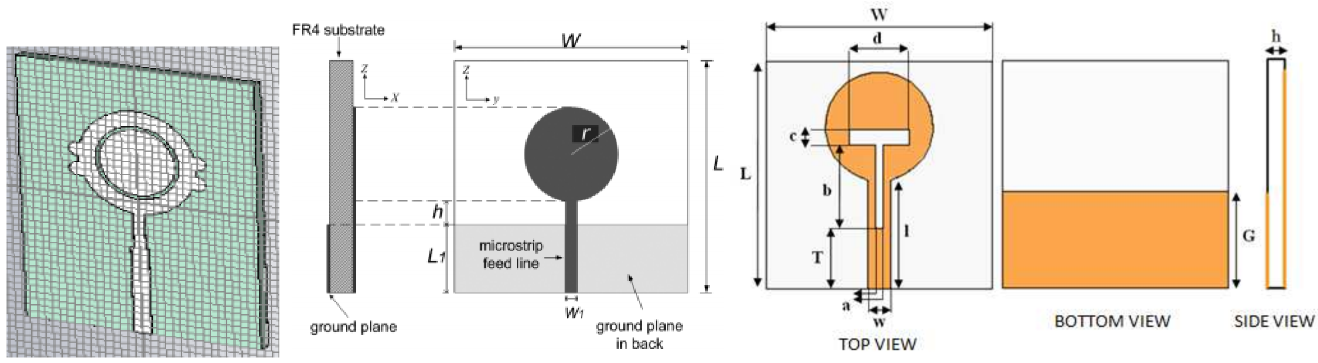


(a) F = 3.61 GHz **(b) F = 11.35 GHz**

Fig. 9. Simulated radiation patterns of the proposed antenna, (a) f = 3.61 GHz and (b) f = 11.35 GHz

3.5 Comparison between Recently Developed Antennas and the Proposed Antenna

Fig. 10 shows the geometries of reference antennas and proposed antenna, these antennas are of shape circular and characterized by the impression on the substrate FR4.



(a) **(b)** **(c)**

Fig. 10. Geometry of the reference antennas and the proposed antenna, (a) [11], (b) [12] and (c) proposed antenna

Table 2 presents a comparison between the performances of some recently developed UWB antennas and the proposed antenna. The proposed antenna shows wide impedance bandwidth and compact size.

Table 2. Comparison between recently developed antennas and the proposed antenna

Antenna	UWB (GHz)	L (mm)	W (mm)	h (mm)
Proposed antenna	2.76 – 13.18	30	30	1.6
[11]	3.1 – 10	40	30	1.59
[12]	2.69 – 10.16	50	42	1.5
[13]	2.6 – 10.6	42	42	1.5

4 Conclusion

A new compact planar circular ultra wide band antenna for UWB applications have been proposed and discussed. The circular patch antenna ring ultrawide-bandwidth between 2.76 GHz and 13.18 GHz, with the impedance bandwidth 131%. The result of the simulated S11, gain and radiation pattern for the proposed antenna shows good performance.

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