

ULTRA WIDEBAND CPW-FED APERTURE ANTENNA WITH WLAN BAND REJECTION

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Abstract—In this paper, we present a new ultra wideband antenna design with band rejection for UWB applications. A CPW-fed circular patch radiates through a circular aperture, which ensures wideband impedance matching and stable omnidirectional pattern over an UWB frequency range, from 3 GHz to 10.6 GHz. In order to avoid interference

with WLAN applications, at 5.8 GHz, the antenna is slightly modified to reject undesired band. A semi-circular slot ring is etched on the circular patch at the notch frequency, which creates an open circuit and avoids impedance matching and current propagation. A prototype was fabricated and measured, and the obtained experimental results agree with simulations and show an omnidirectional azimuth pattern over the entire bandwidth.

1. INTRODUCTION

In modern communication systems, the need of exchanging huge quantity of information at high transfer rates tends toward UWB systems. Multimedia contents as video data or high resolution ranging, are critical in hostile environment, such as underground communication for mines; hence, security issues and economic context leads to high demand of low-cost and reliable UWB systems for underground communication [1]. US-FCC defines UWB to cover frequency bandwidth from 3.1 GHz to 10.6 GHz [2]. Planar antennas are suitable solutions to achieve low-cost and reliable radiating device for UWB systems, so some several work have been achieved in this area. A common approach is to use an UWB monopole with different shapes [3–6]; these monopoles are sensitive to ground dimensions. One solution is to take benefit from wideband feature of radiating apertures and combine it with planar technology to achieve UWB performance [2–8].

When used in confined areas such as underground communications, UWB systems can coexist with other communication systems. WLAN are commonly used for networking; these kinds of device, operate at central frequency 5.8 GHz, and create interference with UWB systems. In order to avoid this frequency overlapping, it is useful to exclude the undesired frequencies for UWB applications. Instead of burdening systems with filters, one may think of designing UWB antennas with band rejection at 5.8 GHz. One approach is to perturb the radiating element shape [9–11]. Other approaches suggest including stubs [12], slots [13–20], or SRR resonators [21–23] to the radiating element. Lee et al. [24] have chosen to perturb matching impedance and create an open circuit at the undesired frequency.

In this paper, a circular aperture antenna fed by a CPW line through a circular patch is considered. This configuration achieves UWB performances [8] with a stable omnidirectional azimuth radiation pattern over the entire bandwidth. We propose an approach to avoid interferences at 5.8 GHz by perturbing antenna impedance with a half circular ring slot that creates an open circuit at the undesired frequency

without perturbing antenna behaviour over the rest of the bandwidth. Experimental results are presented to validate our approach.

2. ANTENNA DESIGN

2.1. UWB Antenna Design

First, an UWB antenna was designed. The antenna layout is depicted in Figure 1. A circular patch is fed through a CPW line. This circular patch excites a circular aperture which is etched on the CPW ground plane. The antenna dimensions, defined in Table 1, are set in order to meet frequency bandwidth requirements. Considering a substrate of permittivity ϵ_r , and thickness h , one can derive a preliminary value of aperture radius with respect to the following equations [2, 20]

$$R_s \cong \frac{c}{4f} \sqrt{\frac{2}{1 + \epsilon_{reff}}}, \tag{1}$$

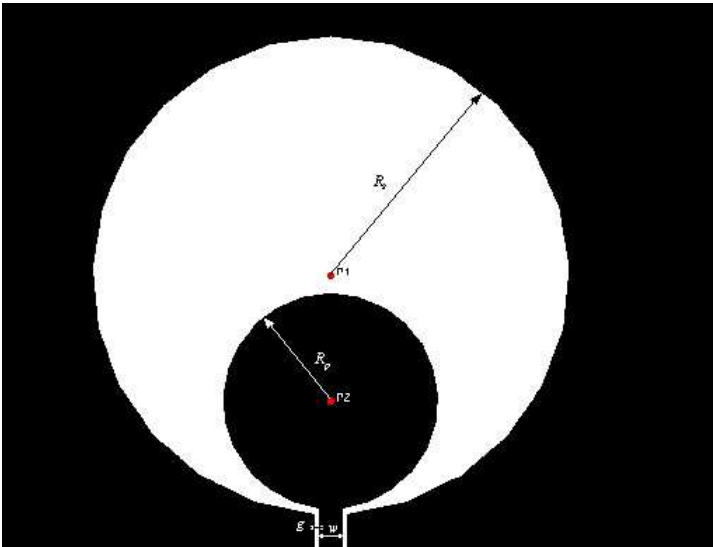


Figure 1. Antenna layout.

Table 1. Antenna dimensions.

Variable	R_s	R_p	R_n	P_1P_2	w	g	w_n
Dimension (mm)	20	9	6	10.5	2	0.35	0.25

where $\varepsilon_{\text{reff}}$ is the effective relative permittivity corrected considering substrate thickness, namely

$$\varepsilon_{\text{reff}} = \frac{1 + \varepsilon_r}{2} - \frac{1 - \varepsilon_r}{2} [1 + 12h/d]^{-0.5} \quad (2)$$

d is the antenna widest dimension; Equation (2) is simplified to be

$$\varepsilon_{\text{reff}} = \frac{1 + \varepsilon_r}{2} \quad (3)$$

The circular patch dimension is then considered with respect to the aperture radius as

$$R_p \cong \frac{R_s}{2} \quad (4)$$

The radiating element, namely the aperture, is chosen circular in order to achieve a wide bandwidth feature, so is the shape of the feeding patch. Let consider different antenna configurations: a slot fed through a simple rectangular stub, a circular monopole, and our circular slot with circular patch. The responses of the antennas are depicted in Figure 2. According to [4], UWB monopoles are sensitive to ground size while aperture structures are not.

Parametric study of this UWB is already discussed in [8]. However, it is worth to mention that wide bandwidth feature is achieved by the coupling between the patch and the ground plane which results in a wide impedance matching. Figure 3 shows that the real part of the antenna impedance fluctuates around 50Ω , while its imaginary part remains with small values and oscillates around zero;

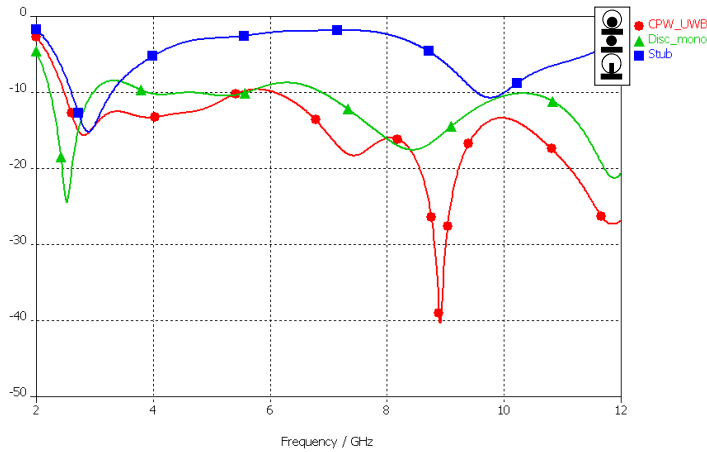


Figure 2. Various antenna shapes responses.

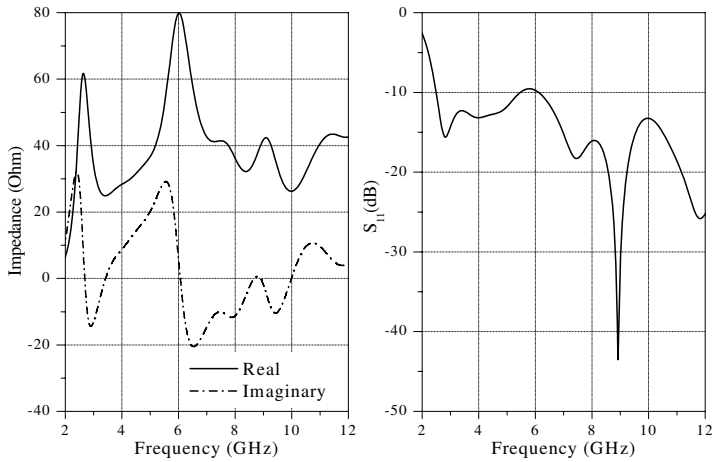


Figure 3. Antenna impedance matching.

this is mainly because a continuous coupling is obtained between the circular patch and the circular ground at different positions, and hence matching is achieved for different frequencies.

2.2. Notched Antenna Design

From the previously presented UWB antenna, we aim to achieve a design where a certain frequency bandwidth is rejected from the antenna frequency response. Instead of acting on antenna feed line, frequency notch is obtained by modifying the radiating element [24]. This modification should not perturb antenna normal behavior over its operating bandwidth but for a considered range of frequency. To do so, we have considered a circular ring slot etched on the circular patch. A half of ring is considered; its center is kept identical to the circular patch. Its diameter is considered so that the arc length is equal to the half wavelength at the notch frequency (Equation (5)).

$$R_n \cong \frac{c}{2\pi f_n} \sqrt{\frac{2}{1 + \varepsilon_{\text{reff}}}} \quad (5)$$

These parameters allow us to start investigating optimal values to design UWB antenna covering frequency range from 3.1 GHz to 10.6 GHz with a notch at 5.8 GHz to exclude WLAN band. The notched antenna is shown in Figure 4.

The slot is etched on the patch, its extremities are short-circuited, and the electric field is then relatively weak. Since, at



Figure 4. Notched antenna photograph.

the notch frequency, the slot length is more or less equal to the half wavelength, the arc center, which is close to the connection between the feed line and the patch, is then a quarter wavelength far from the extremities. Hence, through quarter wavelength impedance transformation materialized by the etched slot, the extremities short circuit becomes then an open circuit and the antenna impedance rises dramatically, as illustrated in Figure 5. The electric field is drastically important in this region, as illustrated by Figure 6.

The key parameters of the notch antenna are the slot length, related intrinsically to the arc radius and angle, the slot width and the arc position.

As described by Equation (5), the arc diameter permits to control the notch frequency since it is directly related to the slot length. In Figure 7, it is obvious how the notch frequency shifts towards lower values while the arc radius R_n increases. This notch frequency is also controlled by the slot arc angle. Figure 8 shows how this angle affects the notch frequency. The angle considered is complementary to π rad. The sharpest response is obtained for a half ring (plate angle arc), and

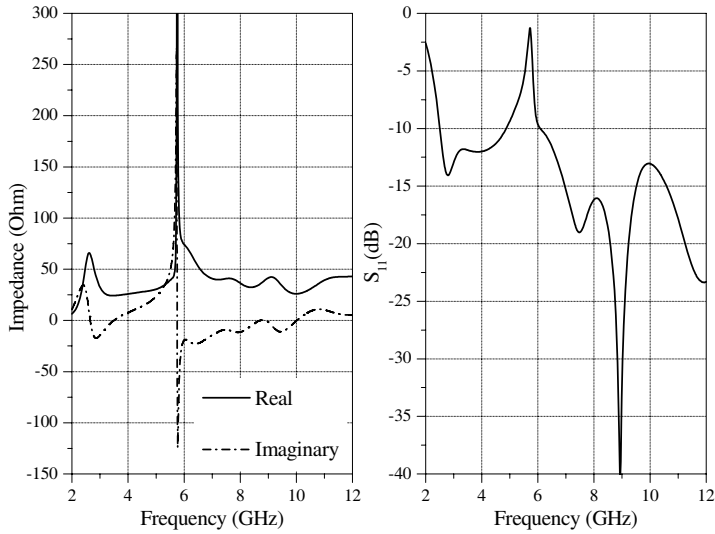


Figure 5. Notched antenna impedance matching.

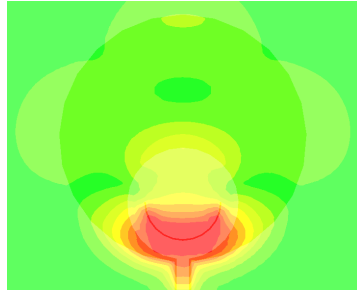


Figure 6. Electric field distribution at 5.8 GHz.

the frequency is set for a slot radius of 6 mm.

The slot width w_n defines the frequency rejection bandwidth (Figure 9); larger the slot, larger the bandwidth. On the other hand, it is possible to consider an offset between the slot center and the patch center off_n ; as presented in Figure 10, a large negative value (slot close to the feed line) perturbs the rejection bandwidth while a large positive value (far from the feed line) reduces the coupling effect and lowers the high antenna impedance at the considered notch frequency.

In the next section, a prototype of the antenna is measured and simulation and experimental results are then compared to the predicted ones.

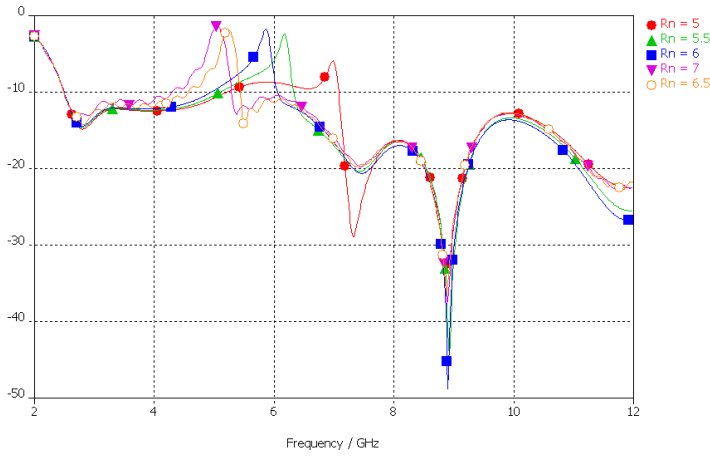


Figure 7. Effect of slot radius on notch frequency.

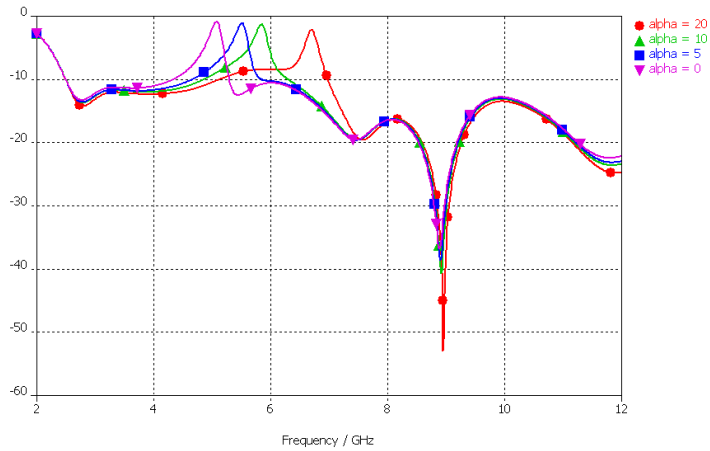


Figure 8. Effect of arc angle on notch frequency.

3. RESULTS AND DISCUSSION

A prototype of the antenna was fabricated, as shown in Figure 4. Simulations were carried out with two electromagnetic numerical tools: Momentum from ADS [25], and CST Microwave Studio [26]. The measurements of the proposed antenna were performed through Agilent 8722 ES network analyzer.

Figure 11 illustrates the antenna return loss. It can be observed

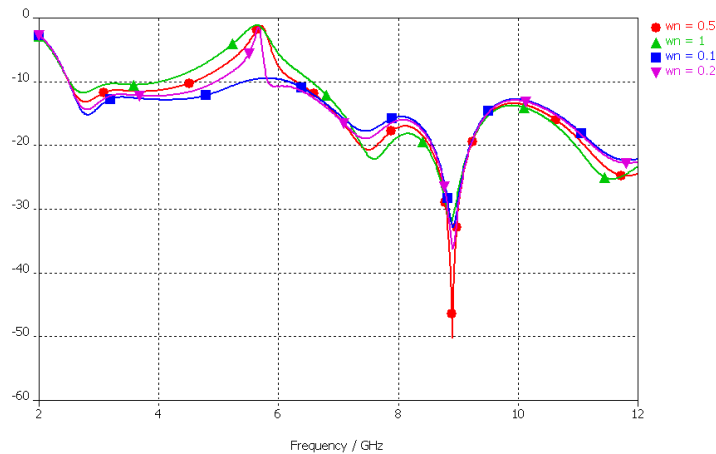


Figure 9. Effect of the slot width on the notch frequency.

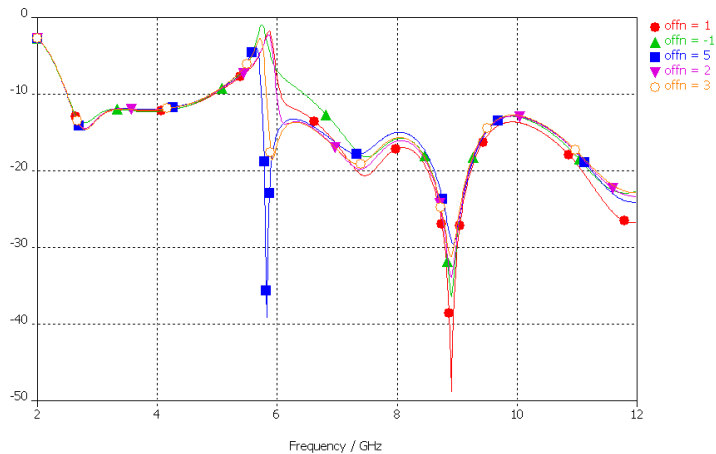


Figure 10. Effect of the slot arc center position offset on the notch frequency.

that experimental results agree simulated ones from both software tools. The experimental bandwidth starts at 3.1 GHz; then a rejection occurs between 5.7 GHz to 6.3 GHz for a return loss higher than -6 dB with a peak of -1.4 dB at 6.1 GHz. A slight deterioration happens around 9 GHz with a return loss of -7.9 dB which is still lower than -6 dB reference value. The antenna gain, depicted in Figure 12, raises from 4.6 dBi to 9 dBi over the frequency rang from 3 GHz to

10 GHz; around the notch frequency 6.05 GHz, the antenna gain drops to -0.5 dBi.

Antenna radiation patterns were measured over the UWB with

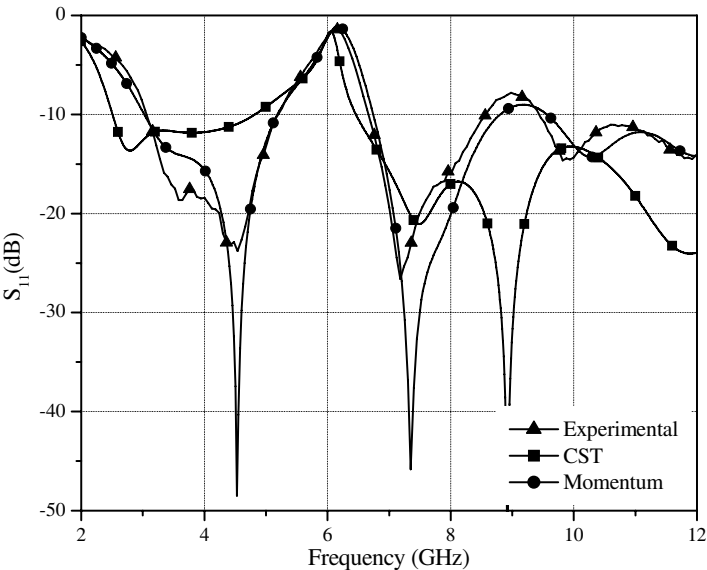


Figure 11. Antenna return loss.

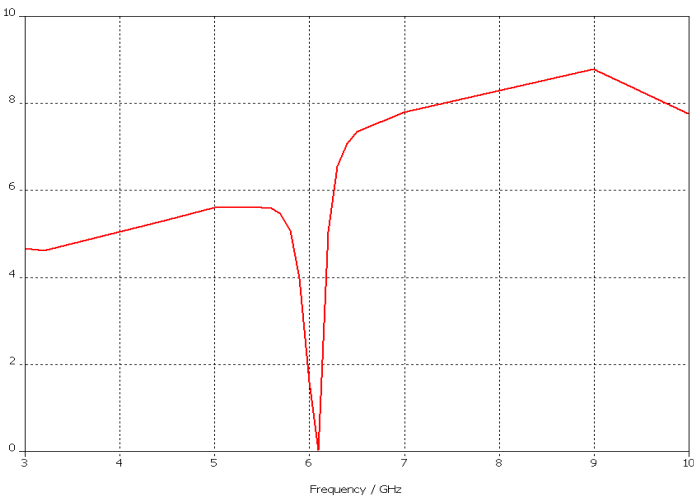


Figure 12. Antenna simulated gain.

the hybrid near-field/far-field antenna measurement system [27] in our facilities at RF Lab, INRS, in Montreal, Canada. Radiation patterns for different frequencies over the operating bandwidth in principal planes are shown in Figure 13 to Figure 17; specifically, radiation patterns at the notch frequency are plotted in Figure 15. It is worth to underline that the antenna keeps somehow an omnidirectional pattern in the H -plane. A good agreement between simulated and measured radiation patterns is observed.

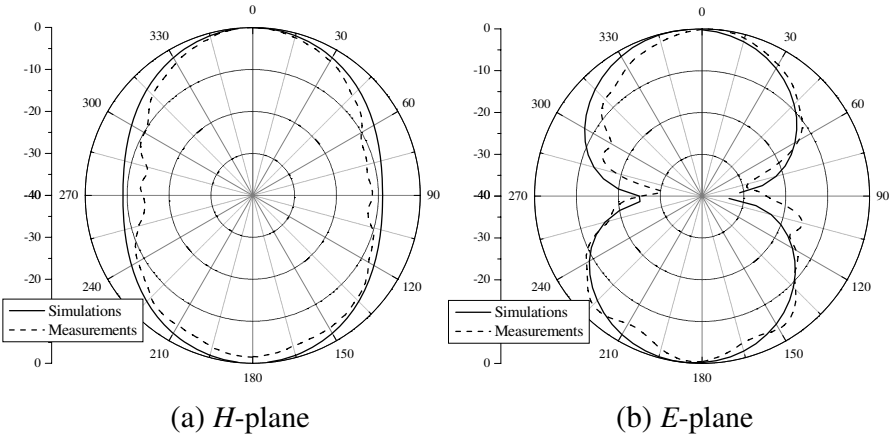


Figure 13. Radiation pattern at 3.5 GHz.

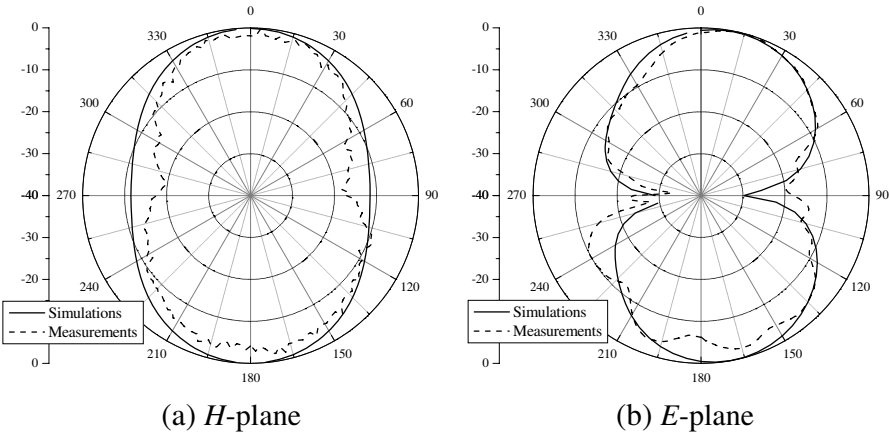


Figure 14. Radiation pattern at 4.5 GHz.

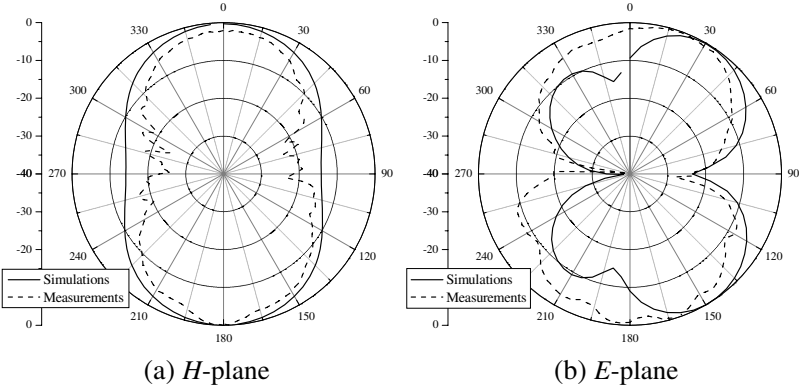


Figure 15. Radiation pattern at 6 GHz.

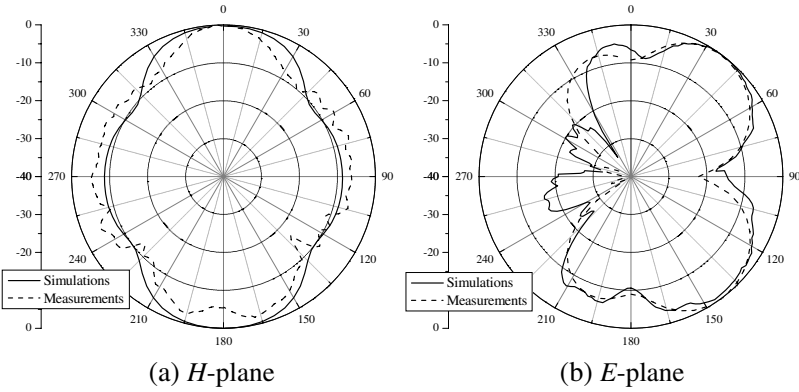


Figure 16. Radiation pattern at 7 GHz.

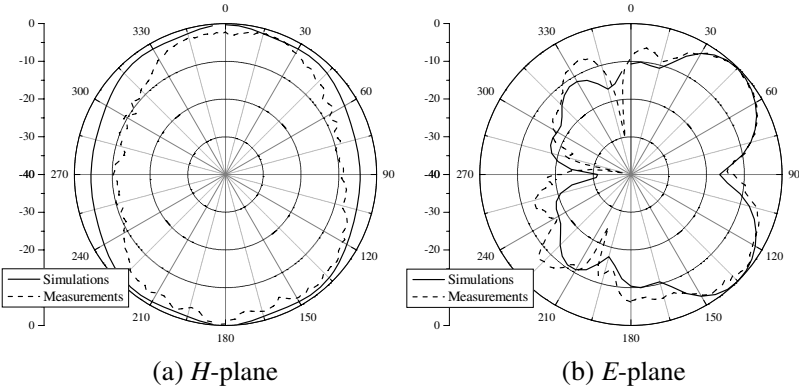


Figure 17. Radiation pattern at 9 GHz.

4. CONCLUSIONS

In this paper, an UWB antenna with a notch frequency has been designed to reject the undesired WLAN band. To achieve such a goal, a circular half ring slot has been introduced and etched on a circular patch. The patch feeds a circular slot, which ensures UWB features for the proposed antenna. The half ring slot creates an open circuit at the notch frequency, which increases the antenna impedance and produces a rejection band at this frequency. Measurements showed the antenna provide omnidirectional pattern in the azimuth plane over the entire UWB from 3.1 GHz to 10.6 GHz, ensuring a gain from 4.6 dBi to 9 dBi with a drop within the frequency notch bandwidth. These features make this antenna suitable for UWB communication systems and simplify these systems by rejecting unwanted frequency bands at the antenna level.

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