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DESIGN OF A BAND-NOTCHED MICROSTRIP CIRCULAR SLOT ANTENNA FOR UWB COMMUNICATION

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Abstract—In this paper, a novel band-notched circular slot (BNCS) antenna for ultra-wideband (UWB) communication is proposed. This antenna is comprised of a circular stub that excite similar-shaped slot aperture. The proposed antenna is designed on the RO4350B substrate with thickness of 500 μm and relative permittivity (ε_r) of 3.4 to operate in UWB band released by the US's Federal Communications Commission (FCC) in 2002 (i.e., 3.1–10.6 GHz). To reject the frequency band of 5.15–5.825 GHz, which is limited by IEEE 802.11a and HIPERLAN/2, an inverted-cup strip is parasitically attached to the feed layer. The size of our proposed antenna is $50 \times 50\,\text{mm}^2$, and this antenna has good radiation characteristics. Effects of varying the parameters of parasitic inverted-cup strip on performance of the proposed antenna have been studied. The antenna with optimal parameters obtained from parametric study is fabricated and measured. It is observed that the simulated and experimental results have good agreement with each other.

1. INTRODUCTION

The need of high-data-rates wireless communication becomes more and more urgent, and various solutions have been brought forward. Ultra-Wide Band (UWB) techniques have been paid the most attention for many advantages, such as higher data rates, immunity to multi-path cancelation, increased communications' operational security and

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low interference to legacy systems [1]. Transceiving antennas are the particularly challenging aspect of UWB technology. To satisfy such a requirement, various wideband antennas have been studied in literature (see [2–12] for example). In [2–10], some different kinds of ultra-wide impedance bandwidth antennas are investigated, i.e., planar monopole, printed monopole, and slot antennas. The studies of the CPW-fed and microstrip-fed circular and elliptical slot antennas for UWB applications are presented in [11, 12]. However, the UWB communication systems use the 3.1–10.6 GHz frequency band, which includes the IEEE 802.11a frequency band (i.e., 5.15–5.825 GHz). Therefore, UWB communication systems may generate interference with IEEE 802.11a. To overcome electromagnetic interference (EMI) between UWB systems and Wireless Local Area Networks (WLANs) based on IEEE 802.11a standard, many researchers have developed various UWB antennas by utilizing several techniques to achieve the band-notched characteristic [13–22].

In this paper, we propose a novel UWB band-notched circular slot (BNCS) antenna which covers the commercial UWB frequency range (i.e., 3.1–10.6 GHz), while rejecting the limiting band (i.e., 5.15–5.825 GHz) to avoid possible interferences with existing communication systems running over it. The band-notched property is achieved by utilizing a parasitic inverted-cup strip to the bottom layer of the antenna. The center frequency and bandwidth of the notched band are adjustable by varying the parameters of the parasitic strip. Effects of varying the parameters of inverted-cup strip on the performance of antenna have also been studied thoroughly. The numerical studies of the proposed antenna are performed by using the IE3D software which is based on the well-known method of moments [23]. Designed antenna with optimal dimensions was fabricated and measured. An extensive comparison between experimental and simulated results is made, which demonstrates good agreement over approximately the entire operating frequency range.

This paper is organized as follows. Section 2 presents the configuration of our proposed antenna. Parametric study of the proposed antenna is presented in Section 3. The simulation and measurement results accompanied with some discussions are presented in Section 4. Subsequently, Section 5 concludes the paper.

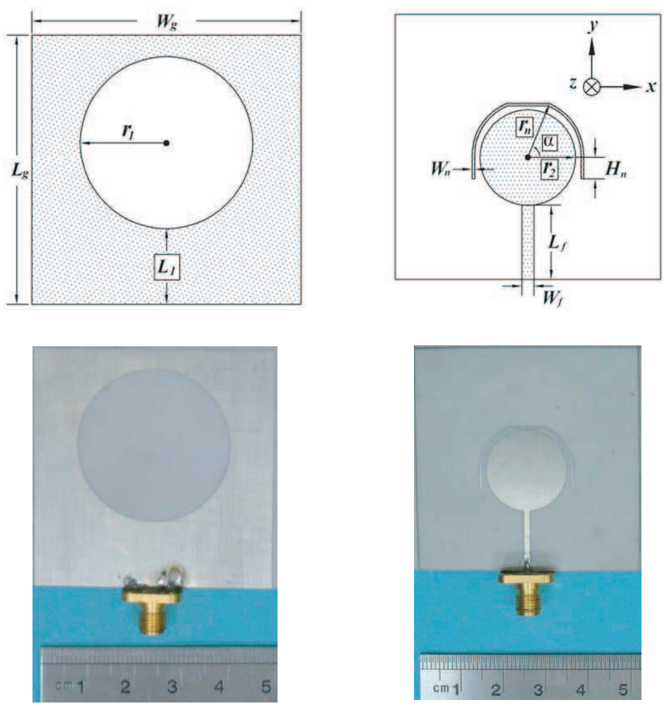
2. ANTENNA CONFIGURATION

The geometry and photograph of the proposed UWB band-notched circular slot (BNCS) antenna with its parameters are depicted in Figure 1. The antenna is located on x-y plane, and the normal direction is parallel to z-axis. The proposed antenna is printed on the RO4350B dielectric substrate with relative permittivity (ε_r) of 3.4, thickness of 500 µm, and ground plane size of $Lg \times Wg = 50$ mm $\times$ 50 mm. For this antenna, the radiation element consists of a circular slot with radius of r_1, which controls the lower edge of impedance bandwidth (see Figure 1(a)). As proposed in [12], the lower edge frequency of the −10 dB impedance bandwidth (f_l) can be estimated as:

$$f_l = \frac{30 \times 0.35}{2.25 \times r_1} \tag{1}$$

where f_l and r_1 are in GHz and cm, respectively. According to (1) and in order to get f_l around 3 GHz, $r_1 = 16$ mm is chosen.

The slot aperture of the proposed antenna is excited by a circular stub with radius of r_2, which is connected to the 50 Ω strip line with $W_f = 1.25$ mm (see Figure 1(b)). The band notched characteristics of antenna are achieved by attaching an inverted-cup strip to the circular



(a) Top layer (b) Bottom layer

Figure 1. Geometry and photograph of the proposed UWB BNCS antenna; (a) Circular slot. (b) Feed network with parasitic strip.

stub (see Figure 1(b)). Band notched characteristics can be controlled by proper adjustment of inverted-cup strip parameters.

3. PARAMETRIC STUDY OF THE ANTENNA

The effects of the parameters of parasitic inverted-cup strip on the antenna behavior are studied in this section. The principal parameters of the strip, which significantly affect the antenna performance are the dimensions of the strip and its distance from the feed network. Desired band-notched characteristics can be achieved by appropriate selection of these parameters.

The simulated VSWR of the proposed BNCS antenna for different values of *annular sector* (α) with $H_n = 4\,\mathrm{mm}$ and $r_n = 10\,\mathrm{mm}$ is plotted in Figure 2. As shown in this figure, it is seen that the notch frequency is shifted toward upper values, and the notch bandwidth of the proposed antenna is increased by increasing annular sector of the inverted-cup strip.

Figure 3 presents the simulated curves of VSWR for proposed BNCS antenna for different values of H_n with $\alpha = 67.5^\circ$ and $r_n = 10\,\mathrm{mm}$. In this Figure, it is seen that the notch frequency of the antenna is shifted toward lower values by increasing the length of H_n.

The effect of varying *inner radius of the annular strip* (r_n) on the performance of our proposed antenna is presented in Figure 4, with $H_n = 4\,\mathrm{mm}$ and $\alpha = 67.5^\circ$. By increasing r_n, we can see that the notch frequency of the antenna is shifted toward lower values, and bandwidth of the notch becomes wider.

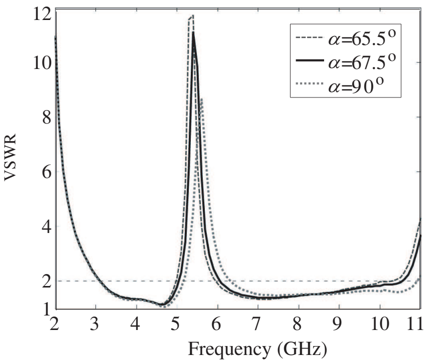


Figure 2. Simulated VSWR of the proposed UWB BNCS antenna as a function of *annular sector* (α).

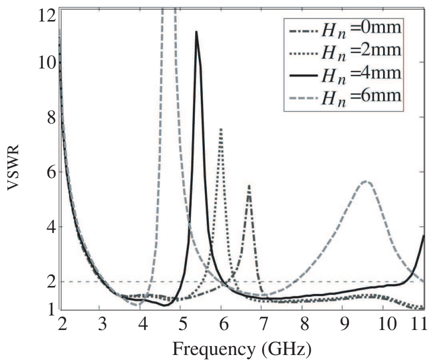


Figure 3. Simulated VSWR of the proposed UWB BNCS antenna as a function of H_n.

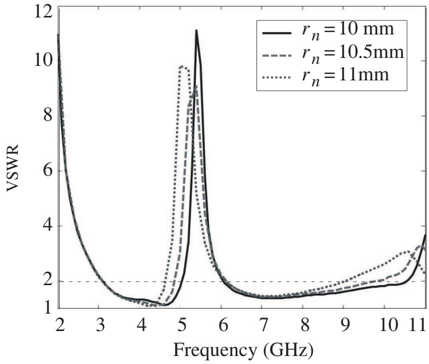


Figure 4. Simulated VSWR of the proposed UWB BNCS antenna as a function of *inner radius of the annular strip* (r_n).

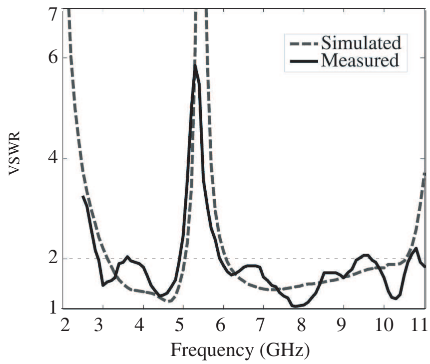


Figure 5. Simulated and measured VSWR of the proposed UWB BNCS antenna with dimensions of Table 1.

4. RESULTS AND DISCUSSION

Simulation and measurement results of VSWR, current distributions, input impedance, radiation patterns, and gain of the proposed antenna are investigated in this section. The simulations are performed by using the IE3D software which utilizes the method of moments for electromagnetic computations. The VSWR of the proposed antenna is measured by the Agilent 8722ES Network Analyzer, whereas the radiation patterns and gain measurements are performed in anechoic chamber of Antenna Laboratory of Iran Telecommunication Research Center (ITRC).

4.1. VSWR

The simulated and measured VSWR for designed BNCS antenna with dimensions indicated in Table 1 are illustrated in Figure 5. From this figure, we can see that the calculated bandwidth of our proposed antenna is from 3.08 GHz to 10.6 GHz for VSWR ≤ 2, with a notched

Table 1. Parameters of the proposed UWB BNCS antenna (see Figure 1).

Parameter	W_g	L_g	r_1	L_1	r_2	W_f	L_f	W_n	H_n	r_n	α
Value	50 mm	50 mm	16 mm	14 mm	9 mm	1.25 mm	14 mm	0.5 mm	12 mm	10 mm	67.5°

frequency band of 5.05–6.05 GHz for VSWR ≥ 2. By measuring return loss of the fabricated antenna, a frequency bandwidth of 2.85 GHz to upper 11 GHz and a 4.85–5.9 GHz notched bandwidth are achieved. Obviously, this measured frequency range covers commercial UWB band (3.1–10.6 GHz) and rejects the frequency band of IEEE 802.11a to overcome EMI problems between UWB systems and WLANs. As observed in Figure 5, there is a good agreement between expected numerical values and experimental results.

4.2. Current Distributions and Input Impedance

Figure 6 shows the simulated current distributions of our proposed BNCS antenna at frequencies of 4, 5.15, 8, and 10 GHz. As shown in Figure 6(b), the current is mainly distributed on the parasitic inverted-cup strip, which results in band-stop effect. In Figures 6(a), 6(c), and 6(d), weak current distribution on the parasitic inverted-cup strip is observed, which means that the parasitic strip is not a major contributor of antenna performance except for the notch frequency.

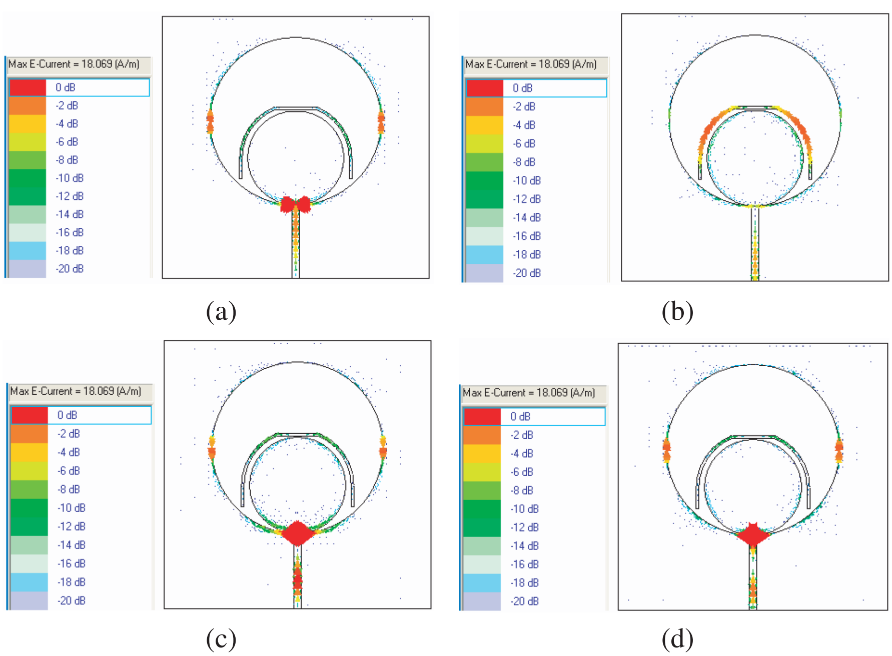


Figure 6. Simulated current distribution of the proposed UWB BNCS antenna at frequencies: (a) 4 GHz, (b) 5.15 GHz, (c) 8 GHz, and (d) 10 GHz.

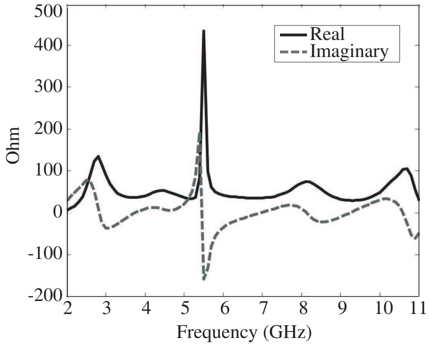


Figure 7. Calculated input impedance of the proposed UWB BNCS antenna.

Figure 7 shows the input impedance of the proposed antenna. It is seen that the antenna has high input impedance at notch frequency, which is produced by parasitic inverted-cup strip. This means that the strip prohibits the current flow at the notch frequency. This phenomenon is similar to the behavior of a quarter-wave open-circuited stub.

4.3. Radiation Pattern and Gain

The simulated and measured normalized radiation patterns of the proposed BNCS antenna in H-plane (or x-z) and E-plane (or y-z) at the frequencies of 4, 7, and 10 GHz are plotted in Figure 8. At lower frequencies, it is seen that our proposed design exhibits an omni-directional profile for the x-z plane and a bi-directional one for the y-z plane. With the increase of frequency, the proposed antenna becomes more directive, but remains nearly bi-directional. By comparing measured and simulated patterns of Figure 8, a good agreement is observed.

The calculated gain of the proposed antenna is illustrated in Figure 9. As shown in this figure, antenna gain decreases drastically at the notched frequency band of 5.45 GHz. However, stable antenna gain with a variation of less than 2.85 dBi is achieved in the desired UWB band except for the stop band.

The measured gain of the antenna at some frequencies is also depicted in Figure 9. The maximum gain obtained from measurements in desired frequency bandwidth is around 5.2 dBi, whereas in the notched bandwidth it shrinks to around -3.1 dBi.

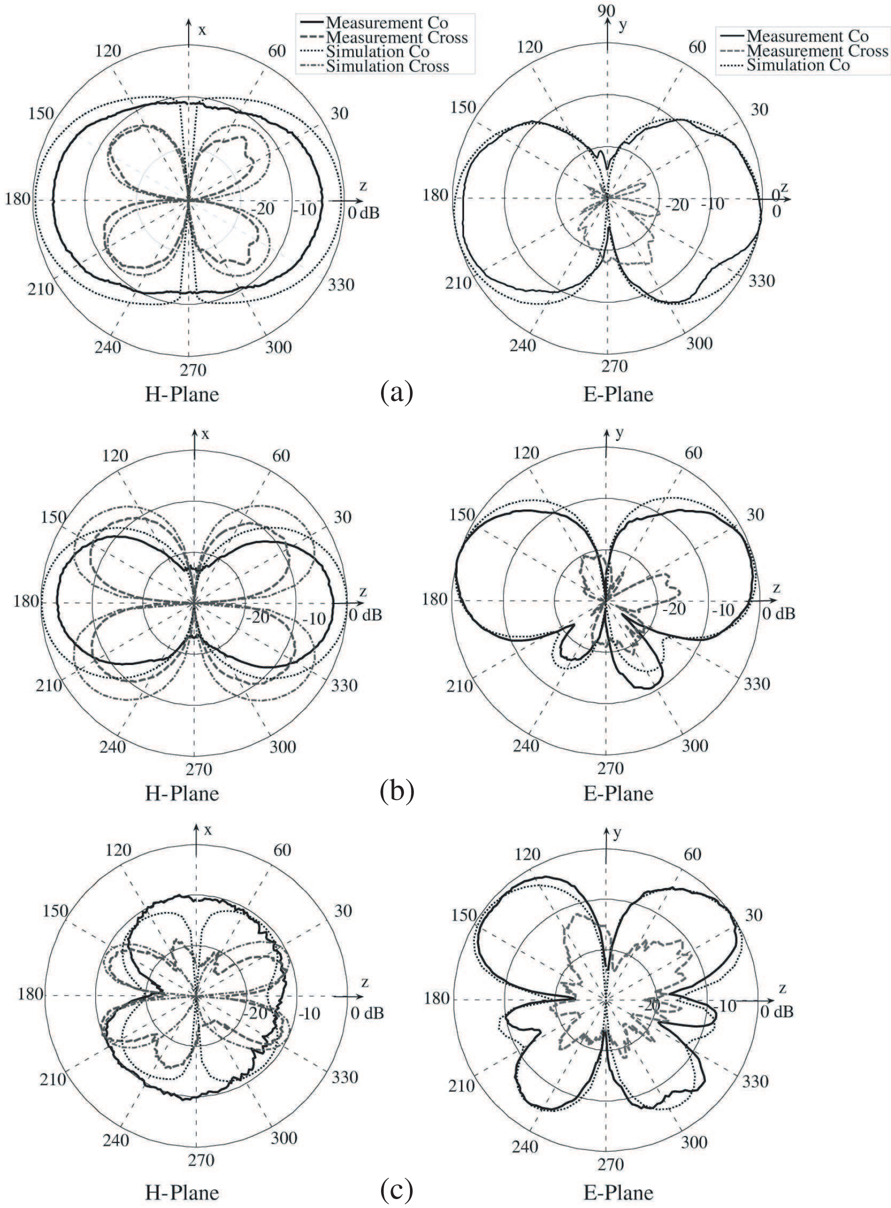


Figure 8. Simulated and measured radiation patterns of the UWB BNCS proposed antenna at frequencies: (a) 4 GHz, (b) 7 GHz, (c) 10 GHz.

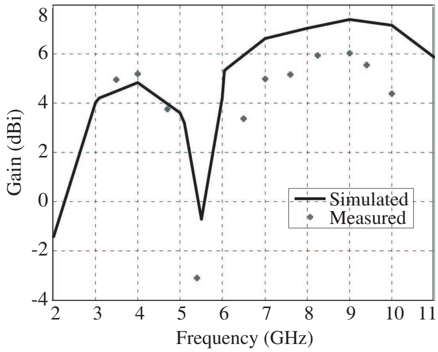


Figure 9. Simulated and measured gain of the proposed UWB BNCS antenna.

5. CONCLUSION

A novel UWB BNCS antenna is proposed in this paper. In order to obtain band elimination characteristic, the inverted-cup strip is parasitically attached to the feed layer of the proposed antenna. Band-notched characteristics can be controlled by adjusting inverted-cup strip parameters. Parametric studies of the antenna are also presented. The proposed antenna design with optimal dimensions is fabricated and experimented. The measurements show that VSWR $\leq$ 2 within the desired frequency bandwidth from 2.85 GHz to upper 11 GHz, whereas a notched bandwidth of 4.85–5.9 GHz is obtained with VSWR $\geq$ 2. Current distributions, input impedance, far-field radiation patterns, and gain of the antenna are also studied in this paper. Good agreement has been found by comparing the results from the measured data and simulated ones.

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