A New Planar Monopole UWB Antenna with Quad Notched Bands

Xiu-Mei Zhang¹, Jun Ma¹, Cheng-Xiang Li¹, Ai-Sheng Ma¹, Qi Wang¹, and Ming-Xi Shao¹, ², *

Abstract—In this paper, a new planar monopole ultra-wideband (UWB) antenna with quad notched bands is investigated. The proposed antenna is composed of a circular-shaped radiating element, a 50 Ω microstrip feed line, a quad-mode stepped impedance resonator (SIR), and a partially truncated ground plane. By coupling a quad-mode SIR with an additional outer line beside the microstrip feedline, band-rejected filtering properties around the C-band (5.2/5.8 GHz) WLAN bands and X-band (7.6/8.2 GHz) satellite communication bands are generated. The measurement of voltage standing wave ratio (VSWR) is in agreement with simulation. The results show that proposed antenna not only retains an ultra-wide bandwidth but also owns quad band-rejections capability. The UWB antenna demonstrates omnidirectional radiation patterns across nearly whole operating bandwidth that is suitable for UWB applications.

1. INTRODUCTION

Ultra-wideband (UWB) radio technology has attracted much attention since the U.S. Federal Communications Commission (FCC) allocated a frequency range with a bandwidth of 7.5 GHz (3.1 ∼ 10.6 GHz) for unlicensed radio applications. Many applications have been developed based on UWB technology such as short-range broadband communication, radar sensing, and body-area networking [1]. It is a well-known fact that planar monopole antennas present attractive features, such as simple structure, small size, low cost, stable radiation patterns, and constant gain over the entire operating band. Owing to these characteristics, planar monopoles are attractive for use in emerging UWB applications, and research activity is increasingly being focused on them [2–5].

However, the existing wireless networks such as the wireless local area network (WLAN) for IEEE802.11a operating at 5.15 ∼ 5.35 GHz/5.725 ∼ 5.825 GHz and X-band (7.5 ∼ 7.7 GHz/8.1 ∼ 8.3 GHz) satellite communication systems (XSCS) signals can interfere with UWB systems, thus compact UWB monopole antennas with multiple notched-bands are emergently required to reject these unwanted interfering signals [6–11]. To achieve desired band-notched performance, slots, such as U-shaped, V-shaped ones, are usually inserted on the basic UWB monopole antenna in [7] and [8]; however, only one notched band is created. In [9] and [10], two notched bands can be introduced using defected ground structure (DGS); however, they are both based on a multi-layer structure that would increase fabrication cost and are hardly compatible with the existing microwave-integrated circuits. In [11], two notched bands can also be obtained, and these antenna structures are very simple and easy to fabricate; however, they use two or three single-mode resonators.

In this communication, a new, compact, planar UWB monopole antenna with quad band-notched function using quad-mode stepped impedance resonator (SIR) is proposed based on the previous works [12]. Firstly, the resonance properties of the quad-mode resonator are studied. Then, the quad notched-bands characteristic is achieved by putting the quad-mode resonator near the feed line.

Received 16 November 2018, Accepted 22 December 2018, Scheduled 7 January 2019
* Corresponding author: Ming-Xi Shao (elemingxishao@163.com).
1 Weifang University of Science and Technology, Shouguang 262700, China. ² China Agricultural University, Beijing 100083, China.
of the UWB antenna. To validate the design concept, a novel planar UWB monopole antenna with quad notched bands respectively centered at frequencies of 5.2 GHz, 5.8 GHz, 7.6 GHz and 8.2 GHz is designed and fabricated. The simulation and measurement show that the antenna achieves an ultra-wide bandwidth ranging from 2.8 GHz to 13.0 GHz and avoids the WLAN/XSCS interference. An omnidirectional pattern across the entire bandwidth in the $H$-plane of the antenna is achieved.

2. QUAD BANDS-NOTCHED UWB ANTENNA DESIGN

Figure 1 depicts the geometry of the proposed monopole UWB antenna with quad band-notched characteristics. It consists of the following major parts: the main patch with a feed, the quad-mode SIR on the front surface of the substrate, and a conductor ground plane in the back. It is printed on a Rogers 4350B microwave substrate of thickness 0.508 mm and relative permittivity 3.48. The quad notched-bands are realized by coupling the quad-mode SIR to 50 $\Omega$ microstrip feed-lines. The proposed planar UWB antenna has a circular patch with radius $R_1 = 7.5$ mm, which is fed by a 50 $\Omega$ microstrip line of width $w_0 = 1.1$ mm. In order to improve impedance matching performance, a rectangular slit is embedded in the ground plane, located under the microstrip feed line. The final optimized parameters of the planar UWB antenna are as follows: $w_1 = 20$ mm, $w_2 = 0.3$ mm, $w_3 = 1.6$ mm, $l_1 = 38$ mm,

\[
\begin{align*}
R_1 & \\
B & \\
B' & \\
\end{align*}
\]

Figure 1. Layout of the proposed UWB antenna with quad notched characteristics.

\[
\begin{align*}
R_1 & \\
B & \\
B' & \\
\end{align*}
\]

Figure 2. Geometry of the quad-mode stepped impedance resonator (SIR).
\( l_2 = 14 \text{ mm}, \ l_3 = 4.0 \text{ mm}, \ l_5 = 6.0 \text{ mm}, \ l_6 = 7.4 \text{ mm}, \ l_7 = 1.95 \text{ mm}, \ l_8 = 2.5 \text{ mm}, \ l_9 = 1.2 \text{ mm}, \ l_{10} = 2.7 \text{ mm}, \ r_0 = 0.1 \text{ mm}. \)

Figure 2 shows the geometry of the proposed quad-mode SIR. It consists of two half-wavelength SIRs and two short-circuited stubs on its center plane. Since the resonator is symmetrical to the B-B' plane, the odd-even-mode method is implemented.

Figure 3 shows the simulated current distribution on the surface of the resonator at four frequencies: 5.2, 5.8, 7.6 and 8.2 GHz. The figure shows that the current is more sparsely distributed as it nears the areas marked in blue, while its distribution grows denser in the red areas. Maximum and minimum values are set equal in order to allow an accurate comparison among Figs. 3(a)–(d).

![Simulated current distribution](image)

**Figure 3.** Simulated current distribution of the proposed structure at the four resonant frequencies: (a) 5.2 GHz, (b) 5.8 GHz, (c) 7.6 GHz, (d) 8.2 GHz.

3. MEASURED RESULTS

Finally, a novel UWB planar monopole antenna with quad band-notched characteristics is designed and fabricated. All simulations have been carried out using Ansoft HFSS 13.0 simulation software based on the finite element method (FEM). The normalized radiation patterns in the \( E- \) and \( H- \)planes are measured at 2.5 GHz, 4.0 GHz, 5.2 GHz, 5.8 GHz, 7.6 GHz, 8.2 GHz, and 10.0 GHz as in Fig. 4. It can be found that the antenna has good omnidirectional radiation patterns in the \( H- \)plane (dotted). The radiation patterns in the \( E- \)plane (continuous) are in symmetry.

Simulated and measured VSWRs of the UWB antenna are shown in Fig. 5 for comparison. We can notice that the UWB antenna possesses the impedance bandwidth from 2.8 GHz to 13.0 GHz for VSWR < 3 except in notched bands from 5.0 \( \sim \) 5.3 GHz, 5.7 \( \sim \) 6.0 GHz, 7.5 \( \sim \) 7.7 GHz, and 8.1 \( \sim \) 8.3 GHz, respectively. The central frequencies of the notched-bands are about 5.2 GHz, 5.8 GHz, 7.6 GHz, and 8.2 GHz. The notched-bands are very suitable to implement the rejection of 5.2/5.8 GHz (WLAN) signal and 7.6/8.2 GHz X-band satellite communication systems (XSCS) signal. The measured peak gain in the \( E- \)plane is given in Fig. 6. The proposed antenna exhibits four significant antenna gain
Figure 4. Measured radiation pattern of the UWB planar monopole antenna: (a) 2.5 GHz, (b) 4.0 GHz, (c) 5.2 MHz, (d) 5.8 GHz, (e) 7.6 GHz, (f) 8.2 GHz, (g) 10.0 GHz.
decreases at 5.2 GHz, 5.8 GHz, 7.6 GHz, and 8.2 GHz; this is indicative of the effect of the notched bands. The deviations of the measurements from the simulations are expected mainly due to the reflections from the connectors and the finite substrate. The overall size is about 20 mm × 38 mm.

4. CONCLUSION

In this work, a high-performance UWB planar monopole antenna, with quad band-notched characteristics, has been successfully implemented and investigated. The proposed antenna covers the frequency range for UWB systems, between 2.0 GHz and 11.0 GHz, with a rejection band around 5.2/5.8 GHz (WLAN) signal and 7.6/8.2 GHz X-band satellite communication systems (XSCS) signal. The introduced quad-mode SIR is simple and flexible for blocking undesired narrow band radio signals appearing in UWB. Using the advantage of small real estate, outstanding performance can be realised for broadband antennas, which are now widely demanded in UWB applications. The measured results show good performance in terms of reflection coefficient, antenna gain and radiation patterns. To summarise, because of its simple structure, compact size, and excellent performance, the proposed antennas are expected to be good candidates for use in various UWB systems.

ACKNOWLEDGMENT

This work was supported by the Weifang University of Science and Technology “13th five-year” Shandong University Science and Technology research platform project, and the research and development and demonstration of greenhouse intelligent water fertilizer integrated machine.

REFERENCES


