A Novel UWB Antenna with Two Ultra Narrow and Closely Space Notched Bands

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Abstract. A novel compacting print planar monopole UWB antenna with two ultra narrow and closely space band-notched characteristics for low WLAN (5.15~5.35GHz) and high WLAN (5.725~5.825GHz) applications is presented. The antenna is one of the smallest UWB antenna found in the open literatures because of its overall size of 20×16×0.8(mm$^3$). Especially, by employing two open-circuited stub pairs (OCSPs), dual-band-notched characteristics are achieved. The notched bands is ultra narrow of 0.26GHz and 0.18GHz, respectively, to suppress the interferences of lower and higher WLAN band just enough. And the space between two notched bands is 0.53GHz. These features make a good proof that OCSP could reject narrow bands in both antenna and BPF.

1 Introduction

Ultrawide-band (UWB) wireless communications, which allow low power level and high data transmissions, have inspired great research interests for wireless communications applications in the 3.1~10.6GHz frequency band. This band is free, but there is a need to limit interference with other devices. When working indoors, the UWB band maximum radiation power is usually limited to -41.3dBm/MHz EIRP. This leads directly to the fact that it can only be used in short distance applications in radar sensing, locating, and communications.

In recent years, A lot of research work on UWB antenna design, such as TEM horn, ridged horn, Vivaldi, log-period, spiral antenna, sinous antenna, Sierpinski antenna, Fractal antenna, mono-cone, bi-cone, planar monopoles and planar dipoles, etc. Planar monopole antenna is one of the typical examples because of its low profile, small size and integratable [1-14]. Owe to these advantages, the planar monopole has a great potential in the area of handheld devices.

However, some existing wireless communication devices working in UWB band. These devices will cause interferences to these system such as IEEE802.11a (WLAN) in USA (5.15~5.35GHz and 5.725~5.825GHz). To minimize potential interference with WLAN applications, the UWB antenna with band-notched in these bands need to be designed. Nevertheless, almost all UWB antenna with band-notched presented in [1-13] reject the entire 5.15~5.825GHz band and then signals at 5.35~5.725GHz are also rejected (which are expected to accept). There are two notched bands of 3.4~4GHz and 5~5.9GHz in [1], two notched bands of 4.6~5.55GHz and 5.7~6.28 in [2], one notched band of 5.2~5.85GHz in [3], two notched bands of 3.59~3.68Hz and 5.1~5.89GHz in [4], one notched band of 4.8~6.2GHz in [5], four notched bands of 5~6.1GHz and others in [6], two notched bands of...
3.32~3.65Hz and 4.93~5.83GHz in [7], two notched bands of 3~3.9Hz and 5~6GHz in [8], one notched band of 5~6GHz in [9], three notched bands of 3.3~4.5Hz, 5.1~5.4GHz and 5.8~6.1GHz in [10], two notched bands of 3.3~3.8Hz and 5.1~6GHz in [11], one notched band of 4.6~6GHz in [12] and one notched band of 5.3~5.7GHz in [13]. It can be concluded from these literatures that there still are unwanted frequencies rejected in [2] which is the most narrow band notched UWB antenna.

In this paper, a novel monopole devices with two band-notched is presented. This work extends the embedded open-circuited stub (EOCS) [15] and with one-end-shorted parallel coupler [16], to a open-circuited stub pair (OCSP) which introduce ultra-narrow and closely space notched band. In Section 2, an annular ring shaped radiator is designed, and two OCSPs are straight printed on each side of the radiator to enable the rejection of both WLAN bands 5.15~5.35GHz and 5.725~5.825GHz with ultra narrow cutoff. Additional, for the understanding of the band-rejection mechanism of the stubs and radiating element, the evolution of the antenna design is described in Section 3. Comparisons between the ANSOFT FEM based HFSS V13 results and experiments for presented antenna are concluded in Section 4. Finally, a brief conclusion is proposed in Section 5.

2 Antenna Configuration

The presented antenna is printed on the substrate Rogers 5880 with \( \varepsilon_r=2.2 \) and \( h=0.762\)mm. The views of the presented are shown in Fig. 1(a), and the band-notched structure is shown in Fig. 1(b). The overall size of the presented antenna is 16×20(mm²), and it is through a microstrip line to achieve a 50Ω input impedance. Furthermore, in order to expand the impedance bandwidth, a tapered microstrip feed line is employed, and the details of the design is reported in [14]. The radiation portion of the antenna consists of an annular ring and two OCSPs.

With the aid of HFSS V13, the features and performance of the presented antenna could be studied. Therefore, by selecting the parameters, good impedance matching, radiation characteristics and desired band-notched can be achieved. The optimization are also shown in Fig.1. Based on model, some parameters are studied numerically in order to discovery the influence.

Fig.1. Geometry of the dual band-notched UWB antenna. (a) presented band-notched UWB antenna, (b) band-notched structure.

Following the ideas introduced in [15-16], the band-stoped characteristic is achieved by employment of the OCSPs rather than others band-notched structures presented in [1-13] because they reject narrow bands. The first OCSP with length of 10.1mm is printed at the right and left edges of the annular ring properly. Strong rejection is achieved when currents of OCSP flow in opposite direction from the current on the ring edges and reduce the radiated fields at 5.25GHz. And meanwhile, the current on the other non-resonant OCSP is small, and lower WLAN band is rejected. At 5.775GHz (centre frequency of higher WLAN band), the shorter OCSP with length of 9.2mm worked in turn as
abovementioned to achieve the band-notched characteristics in higher WLAN band. Generally, dual band-notched could be achieved together by optimizing the widths of the OCSPs and their separation gap in simulations. By the function of

\[ L = \frac{C}{4f_n \sqrt{\varepsilon_{\text{eff}}}} \]  

(1)

Where \( f_n \) is the centre frequency of notched band. The formula of determine \( \varepsilon_{\text{eff}} \) is

\[ \varepsilon_{\text{eff}} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \frac{1}{\sqrt{1 + \frac{12h}{W}}} \]  

(2)

3 Design Evolution

The basic structure of the UWB antenna without band-stopped characteristics is presented in [14], and the design evolution of the antenna presented in this paper is shown in Fig.2(a).

It begins with the design of Prototype A, a circular monopole antenna fed by microstrip line with overall size of 30×35(mm²). Because the current mainly concentrates on the periphery of the circular monopole antenna, the annular monopole antenna is formed by removing the central part of the monopole antenna (Prototype B). The inductive load is employed in Prototype C by lengthening microstrip line to touch the upper edge of the annular ring for size reduction. As a result, the overall size of Prototype C is 20×16(mm²). However, the bandwidth of this design is decreased with the employment of the inductive load.

Based on Prototype C, the microstrip line is replaced with tapered feed line for covering the entire band from 3.1GHz to 10.6GHz which allocated by FCC. By employing the tapered microstrip line, the S11<-10dB bandwidth of Prototype D could be expanded to beyond 40GHz [14]. The impedance bandwidth, radiation patterns and maximum realized gain are discussed in [14]. In this paper, two OCSPs are etched at the right and left edges of the annular ring to reject the expected bands (Prototype E) which is the presented antenna shown in Fig. 1. The simulated return losses of Prototype A to E is shown in Fig. 2(b). It can be concluded from this figure that the size reduction is achieved by loading an inductive load in Prototype C, the bandwidth is expanded by employing the tapered microstrip line in Prototype D, and the desired band is rejected by etching two OCSPs properly in Prototype E.
4 Results and Discussions

The presented antenna is subsequently fabricated with optimal parameters, and tested in a calibrated anechoic chamber by using Agilent E8363C Vector Network Analyzer (VNA) and a far field antenna measurement system.

The return losses of the presented antenna are shown in Fig. 3. All of them cover the frequency band of 3.1~10.6GHz and band-notched characteristics are achieved. Especially, the dual-band-notched is clearly achieved with S11 of -3.14dB (at 5.21GHz) and -3.37dB (at 5.78GHz). The frequency space of centre frequency between two notched bands is 0.56GHz, which is one of the most closely in the frequency space of presented antenna in open literatures. And the bandwidths of two notched bands are 0.26GHz and 0.18GHz, respectively, which are ultra narrow to cover the lower and higher WLAN bands just enough. Instead of the rejection in [1-13], the signal in the frequency of 5.35~5.725GHz could be received in this work. These results make a good proof that the OCSPs could introduce ultra narrow and closely space notched bands in both UWB antenna and BPF. Therefore, this band-notched structure is very suit for the suppression of narrow band communication systems.

Fig. 3. Simulated and measured return losses of the dual band-notched UWB antenna.

Fig. 4 shows patterns in E- and H-plane at different frequency of the presented antenna. It is observed that at lower frequency of 4GHz both E-plane and H-plane radiation patterns are omni-directional. The simulated and measured maximum realized gains of the presented antenna are shown in Fig. 5. Very sharp gain decreases occur in the vicinity of 5.25GHz and 5.77GHz bands.
Fig. 4. Patterns of the dual band-notched UWB antenna at different frequency (a) 4GHz, (b) 7GHz, (c) 11GHz.

Fig. 5. Maximum realized gains of the dual band-notched UWB antenna.

5 Conclusion
A new compacted printing antenna with band-notched characteristic used for UWB band has been studied in this paper. By employing two OCSPs, the ultra narrow and closely space dual-band-notched for applications of lower WLAN and higher WLAN are achieved. The patterns show good omni-directional through the entire UWB band. Therefore, the idea of band-notched structure from BPF in [15-16] could be used in antenna applications by slight changing.

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