Compact Super Wideband Monopole Antenna with Switchable Dual Band-Notched Characteristics

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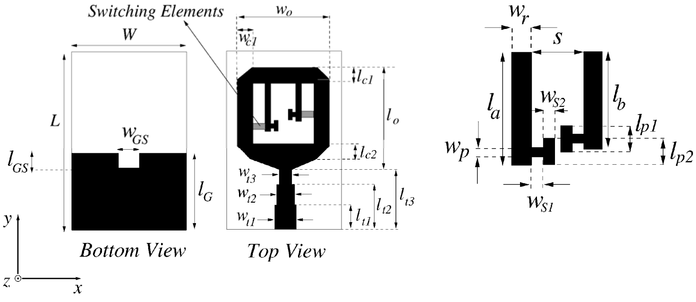
***Abstract* — A Compact implementation of a microstrip monopole antenna for the future super wideband (SWB) communications is proposed. The proposed antenna possesses an excellent impedance bandwidth performance over a broad frequency range (3 to 33 GHz) with switchable dual band-notch characteristics. The notch bands were realized using bandstop resonators to reject lower and/or upper WLAN applications (5.15 to 5.35 GHz and 5.725 to 5.825 GHz, respectively). The proposed resonators with open circuit stubs allow operation at low frequencies while maintaining a compact size. Switching elements were incorporated into the design to provide the switching functionality of the notch bands. Full-wave EM simulations were performed for demonstrating the proposed antenna operation.**

***Index Terms* — Bandstop resonators, monopole, super wideband (SWB) antenna, switchable band-notch.**

I. Introduction

In 2002, the Federal Communication Commission adopted a first report and order regarding the use of ultra-wideband (UWB) [1] transmission systems that regulated the frequency band of 3.1 to 10.6 GHz for UWB communications. As a result, focus on designing UWB components, particularly monopole antennas, has been the subject of research and development over the past decade. UWB monopole antennas have the potential to support very high data rates over distances up to ten meters and lower data rates over longer distances [2]. The high data rates with low power consumption characteristics make UWB an attractive option for short range wireless communication systems. Although UWB communications have a vast potential in the near future, the increasing applications of wireless personal area networks (WPANs) are demanding a super wideband (SWB) bandwidth to cover both short-and long-range communications [3-5]. The SWB antennas operate in overlaps frequencies allocated for diverse wireless communication standards such as Local Area Networks (WLANs) which operate at 5.15 to 5.35 GHz and 5.725 to 5.825 GHz for lower and upper WLANs, respectively [6]. One way to prevent unwanted interference signals is by introducing a single notch-band from 5.15 to 5.825 GHz [7]. However, such notch-band unnecessarily blocks usable frequencies from 5.35 to 5.725 GHz. In order to take advantage of the available spectrum, antennas need to employ narrow notch bands to reject only the undesired frequency bands [8]. As well, antennas exhibiting switchable narrow notch bands become more important for future cognitive radio systems.



(a) (b)

Fig. 1. Physical structure of the proposed SWB antenna (a) top and bottom view; and (b) its bandstop resonators (zoom view).

To this end, the objective of this paper is to present a simple and a compact realization of a switchable dual-band notched planar antenna suitable for UWB and SWB applications. It will be shown that the proposed antenna in Fig. 1 possesses the desirable feature of compactness while achieving an acceptable electrical performance through using microstrip line transitions as a matching network for broadband impedance bandwidth [9] and the ground cutout [10]. Bandstop resonators with the proposed shapes have been utilized for generating the dual rejection band characteristics. Moreover, simplified mechanical switching elements are simulated for demonstrating the switching functionality of the antenna rejection bands.

The rest of this paper is arranged as follows: Section II describes the proposed antenna configuration. In Section III, parametric studies and antenna results are discussed, while conclusions are given in Section IV.

II. Antenna Configuration

A. Antenna Implementation

The geometry of the proposed antenna is shown in Fig. 1. The antenna is supported by a 1.524 mm thick Roger's[1] RO4003C substrate with a dielectric constant of 3.55, a loss tangent of 0.0027, and a copper cladding thickness of 17 μm. The antenna is fed by a 50 Ω microstrip line. The basic shape of the antenna radiator is a rectangular patch. However, triangular sections have been removed from the four outer corners of the antenna and a rectangular metal segment has been cut at the middle of the antenna radiator. These modifications lead to a size reduction compared to the

[1] http://www.rogerscorporation.com

conventional microstrip monopole antennas. Antenna broadband matching is very challenging to achieve in practice. Problems associated with one port designs include reduced radiation performances with increased ringing in the time domain due to multiple reflections along the feed-line, which limits the impedance matching up to nearly 11 GHz. In this paper, the impedance bandwidth is improved by introducing impedance transitions between the microstrip feed-line and the antenna radiator [9]. Moreover, it was found that the majority of the electric currents are concentrated around the metal arms of the antenna radiator, thus, the effect of the ground plane can be reduced [11]. Here, a slit in the ground plane centered underneath the microstrip feed-line was incorporated into the design. Those techniques have been applied to increase the upper cutoff frequency from 11 to 33 GHz.

B. Dual-Band Notch Formation

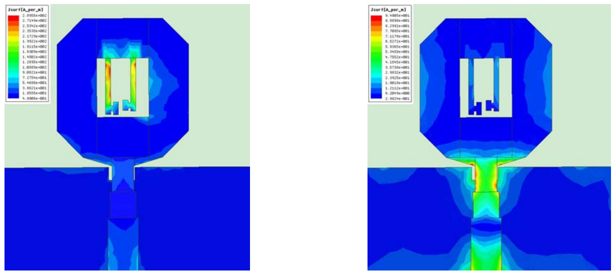
In order to obtain the desired dual-band notch response, bandstop resonators with open circuit stubs were placed at the center of the rectangular antenna radiator. The bandstop resonators can be seen in Fig. 1(a), and an enlarged, detailed view is shown in Fig. 1(b). Each resonator is responsible for generating a band notch as determined by their separate resonate frequencies. It is worth mentioning that the small segment/stubs (i.e., l_{p1}, l_{p2}) attached to the bandstop resonators, provides more freedom in tuning the rejection bands, especially at low frequencies. Due to the proximity of the two band notches, there is a considerable coupling between the two resonators. This means parametric studies or optimization is required to achieve the optimal performance.

C. Switching Elements

For demonstrating the switching capability of the proposed antenna, simplified switching elements have been realized by short-circuiting the bandstop resonators to the antenna radiator using rectangular metallic segments as depicted in Fig. 1(a). This represents the on state of the switch while an open-circuit resonator represents the off state of the switch. Practically, the switching elements can be realized using simple mechanical switches.

III. Results and Discussion

In this section, with the aid of ANSYS-HFSS[2], full-wave EM simulations have been carried out for providing a better understanding of the bandstop resonators and antenna operation. Simulated impedance bandwidth and far-field radiation pattern are discussed. The proposed antenna (Fig. 1) was designed using the substrate parameters provided in the previous section and simulated using HFSS leading to the antenna optimal dimensions as listed in Table I. Fig. 2(a) depicts the simulated current distribution of the proposed antenna at the notch frequency (i.e., 5.3 GHz) while Fig. 2(b) shows the current distribution at out of the rejection bands that is arbitrarily selected to be 8 GHz. It can be observed that the electric currents concentrate around the bandstop resonators at the notch frequency while weak electric currents appear at 8 GHz. In other words, the bandstop resonator has a significant effect on the antenna performance which is described by the frequency rejection band. Fig. 3 shows the variation of the VSWR against frequency for different bandstop segment lengths. For convenience, the resonators lengths were fixed (i.e., l_a = l_b = 6.5 mm). As expected, increasing the resonator length leads to a negative shift in the resonant frequency. The microstrip feed-line transitions as well as the antenna radiator and bandstop resonators, were


(a) (b)
Fig. 2. Simulated current distributions at: (a) the lower WLAN notch frequency (5.3 GHz); and (b) out of the rejection bands (8 GHz).

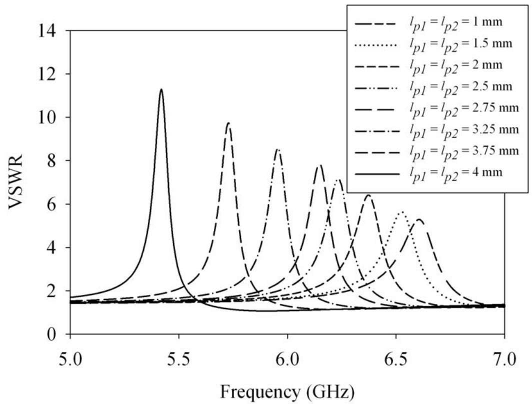


Fig. 3. Simulated VSWR response against frequency by varying the bandstop resonator's length of Fig. 1(b).

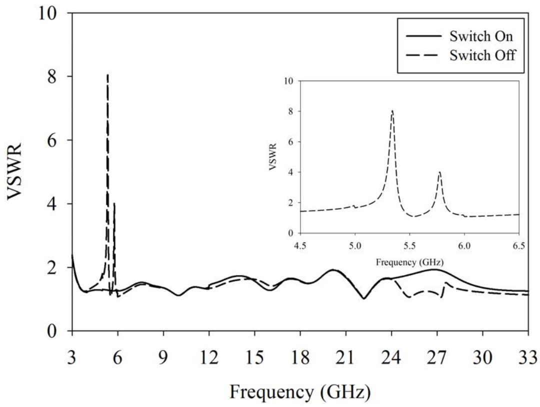
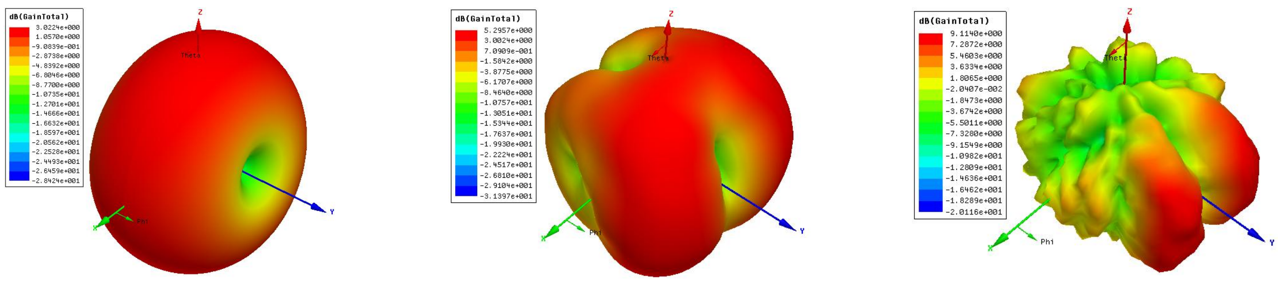


Fig. 4. Simulated VSWR response against frequency of the proposed antenna with switch on/off.

2 ANSYS High Frequency Structure Simulator (HFSS), ver. 13.0, 2011.



(a) (b) (c)

Fig. 5. Simulated 3D far-field radiation pattern of the proposed antenna at: (a) 4 GHz; (b) 9 GHz; and (c) 15 GHz.

TABLE I. ANTENNA DESIGN PARAMETERS

Symbol	Value (mm)	Symbol	Value (mm)
L	32	w_{t1}	3.5
W	30	w_{t2}	3.0
l_{GS}	1.5	w_{t3}	2.5
w_{GS}	3.0	w_r	0.6
l_G	12.3	w_n	0.3
w_p	15.2	w_{S1}	0.3
l_p	16	w_{S2}	0.6
l_{c1}	3.0	l_a	6.5
l_{c2}	3.0	l_b	6.1
w_{c1}	4.6	l_{n1}	1.2
l_{t1}	6.5	l_{n2}	1.5
l_{t2}	9.5	S	2.3
l_{t3}	13.5		

adjusted to achieve the best electrical characteristics resulting in the simulated performance shown in Fig. 4. At the off state, the frequency performance of the VSWR response demonstrates two rejection bands with VSWR > 2 covering all of lower and upper WLAN applications, while maintaining VSWR < 2 out of the rejection bands. The response at the on state has a smooth impedance bandwidth with VSWR < 2 over the broad frequency range. Fig. 5 depicts the simulated far-field radiation patterns of the proposed antenna at 4, 9, and 15 GHz, respectively. The H-plane (i.e., XZ-plane) patterns are almost omnidirectional for the two low frequencies, in a manner similar to the conventional dipole antenna. The E-plane (i.e., XY-plane) patterns are relatively similar to those of a monopole. Omnidirectional pattern allows user mobility and freedom in the transmit/receive position.

IV. CONCLUSIONS

A compact implementation of an SWB monopole antenna with switchable dual-band frequency notches is introduced. Dual-band notches were achieved by introducing two bandstop resonators with open circuit stubs within the antenna radiator area. The switching mechanism was modeled by using rectangular metallic segments for switching between the notch bands on/off states. Simulation results have been carried out using HFSS for providing a better understanding of the antenna mechanism. The proposed antenna exhibit a dual-band notches covering both lower and upper WLAN applications and exhibits an omni-directional radiation pattern. Compared to the conventional designs, the proposed antenna suitable for low cost fabrication, straightforward printed circuit board integration, and possesses an excellent broadband impedance bandwidth.

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