Quad band-notched UWB antenna compatible with WiMAX/INSAT/lower–upper WLAN applications

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A simple design of multilayered quad band-notched ultra-wideband (UWB) antenna is presented. The antenna is compact in size, suitable for UWB applications, and exhibits quad narrow band frequency notches to suppress the interference of the nearby wireless communication systems within a UWB frequency range. The narrow band notches are realised by adding closed-loop ring resonators designed to cover the 3.3–3.7 GHz, 4.5–4.8 GHz, 5.15–5.35 GHz, and 5.725–5.825 GHz bands. The antenna has been fabricated and tested for demonstrating the desired characteristics.

Introduction: Recently there has been increasing demand for the designing of ultra-wideband (UWB) systems, and more particularly so after the release of the frequency band 3.1–10.6 GHz by the Federal Communications Commission (FCC). The main objective of UWB is the handling of high data-rates in the presence of wireless communication standards, which cause electromagnetic (EM) interference with the UWB systems, such as the worldwide interoperability for microwave access (WiMAX) system operating at 3.3–3.7 GHz, satellite communication systems such as the Indian national satellite (INSAT) system operating at 4.5–4.8 GHz, and wireless local area network (WLAN) system operating at 5.15–5.35 GHz and 5.725–5.825 GHz. Since antennas are essential components for a host system application, it is desirable to design UWB antennas that comprise narrow band notches within the UWB frequency range. The early work on frequency band-rejected UWB antennas was realised by utilising small strip bars [1], open-loop resonator [2], U-shaped slots [3], half-mode substrate integrated waveguide cavity [4] and pentagonal radiating patch with two bent slots [5]. In [1–3], however, the elements were developed on the same layer within the antenna radiator or on the back side of the same layer for generating single and/or dual frequency band-notched antennas. Therefore, owing to the space limitation, it is difficult to generate multiple band notches. On the other hand, in [4, 5], the designs have complicated structures leading to increased fabrication costs and antenna size, and difficulty in the integration with microwave integrated circuits.

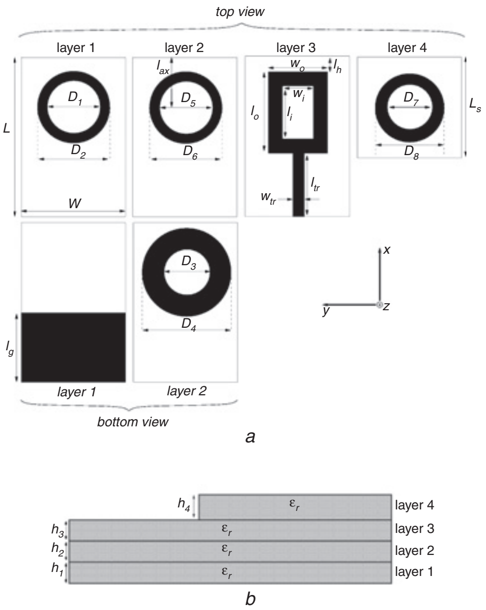

Fig. 1 *Structure of proposed antenna in four-layer configuration*

a 2D double-sided view of each layer
b Side view

The objective of this work is to present a simple and compact realisation with stable radiation performance of a quad band-notched planar antenna suitable for UWB applications. It will be shown that the proposed antenna in Fig. 1 possesses the desirable feature of compactness, while achieving an acceptable impedance bandwidth. Ring resonators have been utilised because of their narrow bandwidth, compact size and low radiation loss [6], essential to ensuring a relatively omnidirectional far-field radiation pattern (which is originally due to the actual antenna radiator).

Antenna configuration: The monopole UWB antenna illustrated in Fig. 1*a* is realised using a rectangular slot patch with a 50 Ω microstrip feedline. Four band notches within the UWB frequency range are achieved by vertically aligning four ring resonators (with their centres aligned along an axis) on multilayered planes. Here, each ring is responsible for creating a frequency band notch. The antenna is printed on four layers of Rogers substrate (RO4003) with a dielectric constant of 3.55 and a loss tangent of 0.0027. The thicknesses of the layers have been arbitrarily selected; the thickness of layers 1, 2, and 3 is set to be 0.508 mm and the top layer (layer 4) is set to be 0.8128 mm, as illustrated in Fig. 1*b*. The antenna is connected to a 50 Ω SMA connector between the feedline on the top side of layer 3 and the ground plane on bottom side of layer 1. The length of layer 4 (L_s) is implemented to be much shorter than the overall antenna length (L) as depicted in Fig. 1*a*, to make the connection through SMA connectors possible and to allow integration of RF front-ends. EM simulations are performed using ANSYS High Frequency Structure Simulator (HFSS) leading to the following optimal dimensions of the proposed antenna: $L = 33.5$ mm, $W = 30$ mm, $L_s = 19.7$ mm, $l_g = 12.1$ mm, $l_{tr} = 14$ mm, $w_{tr} = 3.5$ mm, $l_o = 17$ mm, $w_o = 11.2$ mm, $l_i = 10.6$ mm, $w_i = 4.8$ mm, $l_h = 2.5$ mm, $l_{ax} = 9.2$ mm, $D_1 = 10.2$ mm, $D_2 = 13$ mm, $D_3 = 4.8$ mm, $D_4 = 13.6$ mm, $D_5 = 8$ mm, $D_6 = 10.8$ mm, $D_7 = 11.2$ mm, $D_8 = 17.6$ mm.

In this design, the fundamental stopband centre frequency f_o corresponding to each ring is approximately given by

$$2\pi r = \lambda_g \tag{1a}$$

Therefore

$$f_o = \frac{c}{\pi D\sqrt{\varepsilon_{reff}}} \tag{1b}$$

where D is the mean diameter of the ring, λ_g is the guided wavelength, c is the speed of light in free space and ε_{reff} is the effective relative dielectric constant. The arrangement of the ring resonators could be either above and/or below the actual monopole antenna radiator. Each resonator in the structure resonates at different resonant frequencies by varying the mean diameter.

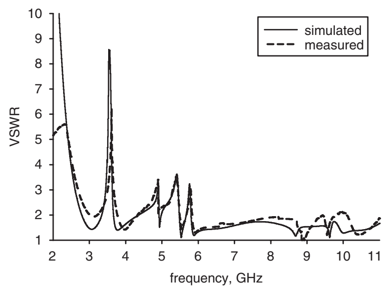

Fig. 2 *Measured and simulated VSWR characteristics of proposed antenna*

Results: Fig. 2 shows both measured and simulated VSWR characteristics of the proposed antenna. The frequency performance of the antenna demonstrates four rejection bands with VSWR > 2 covering all WiMAX, INSAT and lower/upper WLAN applications, while maintaining VSWR < 2 at out of the rejection bands. A very good agreement between measured and simulated results is observed. Slight discrepancies could be attributed to the effects of the SMA connector, which is not considered in our simulation. Measurements are carried out for the far-field radiation pattern on the quad band-notched UWB antenna in the custom built anechoic chamber with a quad ridged horn antenna as a reference. Figs 3*a* and *b* show the measured radiation patterns of the proposed antenna along the *yz*- and *xy*-planes at 4 and 7 GHz, respectively. The H-plane (i.e. *yz*-plane) patterns are almost omnidirectional for the two frequencies, in a manner similar to the conventional dipole antenna. On the other hand, the E-plane (i.e. *xy*-plane) patterns are relatively similar to those of a monopole. Fig. 4 shows the estimated antenna efficiency as well as the measured antenna gain. The gain was measured at the broadside direction as shown in Fig. 4, where two identical antennas are separated by a distance d of 0.98 m. The transmission coefficient S_{21} was measured and used to calculate the gain of the antenna. It is clearly evident that, at the notch bands, both the antenna efficiency and gain drop sharply.

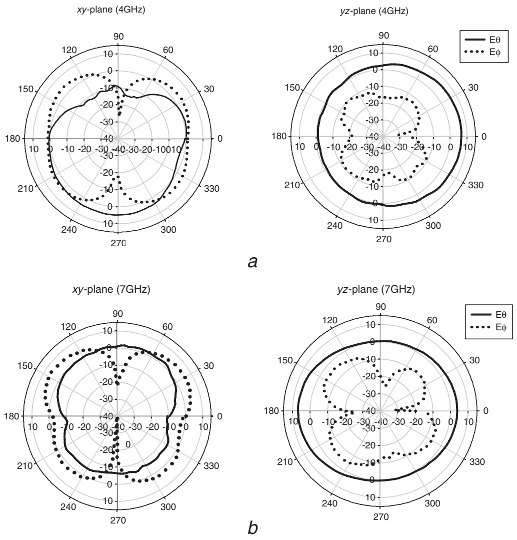

Fig. 3 *Measured radiation pattern of proposed antenna*

a At 4 GHz
b At 7 GHz

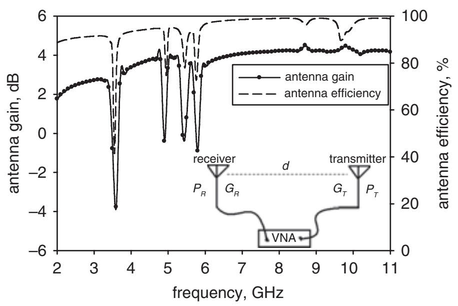

Fig. 4 *Estimated antenna efficiency and measured gain of proposed antenna against frequency*

Conclusions: A compact and simple multilayered quad band-notched UWB antenna for WiMAX, INSAT and lower/upper WLAN applications is proposed. The overall antenna dimensions 33.5 × 30 × 2.34 mm. Quad band-notched frequencies are realised by adding four ring resonators sharing the same vertical axial and implemented on multiple layers. Having the same vertical axis and allowing the possibility to arrange the ring resonators above and/or below the actual antenna led to straightforward fabrication. The antenna has been fabricated and measured for the purpose of validating our design. Finally, it is possible to conclude that the presented antenna is advantageous in modern multilayered circuits such as monolithic microwave integrated circuits (MMICs) and low-temperature co-fired ceramic (LTCC) technologies.

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