A Dual-band WLAN/UWB Printed Wide Slot Antenna

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Abstract—This paper provides a dual-band printed wide slot microstrip-fed antenna. The proposed antenna consists of a U-shaped radiating patch, a T-shaped monopole path and a Pentagonal-shaped wide slot in the ground plane. The dual-band antenna can cover both 2.4 GHz (WLAN) and 3.1-10.6 GHz (UWB) frequency ranges. The antenna size is $28 \times 28 \times 1 \text{ mm}^3$ which fabricated on a FR4 substrate. The simulation and measured results of the proposed antenna are presented and show good agreement in reflection coefficient and radiation patterns.

I. INTRODUCTION

Ultrawideband (UWB) antennas for commercial systems such as indoor and hand-held wireless communication have developed since the Federal Communication Commission (FCC) allowed unlicensed operation between 3.1-10.6 GHz. Since then, the UWB radio system has received great attention from both the academic and the industry.

Design of a small-size antenna that covers the UWB frequency band and also be suitable for use with portable communication systems is highly desirable. Several papers have been published [1]-[4] that have used different shapes of printed microstrip-fed wide slot antennas to obtain UWB performance. Such antennas have great features such as being completely uni-planar, low profile, light weight, easy integration with active devices or monolithic microwave integrated circuits (MMICs), low cost, easy fabrication and stable radiation patterns across the operating band.

It is known that quarter-wavelength long strip can produce additional bands or notched bands, for a base radiating antenna [4]-[7]. In [4], by using a fork-shaped radiator and added several quarter-wavelength long strips, a UWB antenna with dual-band notched characteristics is given. In [6], at the corner of an UWB printed monopole antenna an L-shaped resonant element is added to integrate the Bluetooth band with the existing UWB. The overall size of the dual-band antenna is $42 \times 46 \text{ mm}^2$. Also, a dual-band notched behaviour with additional Bluetooth band on a base UWB antenna is presented in [7]. The antenna uses several parasitic strips on the ground plane to provide multi-band behavior and has dimension of $23 \times 28 \text{ mm}^2$.

Based on the present authors literature review, it seems that most of the works reported on dual band antennas, including the UWB band, are based on printed monopole antennas.

II. ANTENNA DESIGN

In this paper, a new method to design a dual-band printed wide slot antenna is presented. Slot antennas can be more desirable as they can provide a higher gain compared to monopole antennas. The key issue in the present design is to implement the extra band (outside the UWB band) without increasing the size of the original UWB band antenna. The simulation results of the proposed dual-band antenna show good agreement with measurement results. The simulations are carried out using the commercially available software package HFSS.

Fig. 1 Dual-band printed wide slot antenna

To design a UWB printed wide slot antenna which is fed by a microstrip line, the structure of Fig. 1 is considered that is simple and also has a few parameters. The dimension of the antenna is $28 \times 28 \times 1 \text{ mm}^3$ and is fabricated on FR4 substrate. The effective permittivity of the substrate is 4.4 and the loss tangent is 0.02. As shown in Fig. 1, the base radiating element is a simple rectangular patch with dimension of $12 \times 9 \text{ mm}^2$ in which a half ellipse is removed from its top side. The radiuses...
of the ellipse in X and Y direction are set at 5 and 8mm, respectively. It is noticed that if a simple Pentagonal-shaped slot is removed from the ground plane of the antenna structure, an omnidirectional radiation pattern and wide impedance bandwidth can be achieved. The dimension of the proposed base radiating patch mentioned above is so chosen to cover the UWB range. To excite the base radiating patch efficiently, the width of the feed line is kept at 1.86 mm that leads to 50 ohm input impedance for the U-shaped antenna.

To design a dual-band antenna which covers the UWB range, and also can operate at WLAN band (2.4 GHz), a quarter-wavelength long strip should be added to the initial U-shaped patch. Generally, it is desired that the overall dimensions of dual-band antenna to be kept fixed. Equation (1) shows the general formula to design a resonance strip in the printed wide slot antenna.

$$L_{total} = \frac{\lambda_g}{4}$$  \hspace{1cm} (1)

In this equation, $\lambda_g$ depends on the effective permittivity of the structure and is defined as below

$$\lambda_g = \frac{\lambda_0}{\sqrt{\varepsilon_{eff}}}$$  \hspace{1cm} (2)

$$\varepsilon_{eff} \approx (\varepsilon_r + 1)/2$$  \hspace{1cm} (3)

The exact equation to use for the effective permittivity is to include substrate thickness. But for the low thicknesses it can be shown that the effective permittivity is mostly dependent on the permittivity $\varepsilon_r$ as given in equation (3).

As shown in Fig. 1, to obtain the dual-band antenna, a T-shaped resonance path is required to be added to the base U-shaped patch. To keep the symmetry of the structure, the T-shaped strip is chosen. To operate at WLAN band, the total length of the resonance path is given by the equation (4)

$$L_{total} = L_1 + L_2/2 + L_3$$  \hspace{1cm} (4)

The final antenna parameters are as follows:

$W_f = 1.86$, $W = 12$, $W_{s1} = 24$, $W_{s2} = 14$, $L_f = 8$, $L_g = 7$, $L = 9$, $L_{s1} = 14$, $L_{s2} = 5$, $L_1 = 9$, $L_2 = 7$, $L_3 = 4.5$ mm.
III. RESULTS AND DISCUSSION

Fig. 2 shows the VSWR of the base U-shaped antenna. It is obvious that the simple U-shaped antenna operates over the 3-10 GHz for VSWR < 2. By inserting a T-shaped strip in the elliptical slot, a dual-band antenna can be achieved. Fig. 3 shows the VSWR of the proposed dual-band antenna. As shown, the antenna operates over 2.3-2.6 GHz and 3.3-10 GHz. Also, it is clear that good filtering behavior between two bands is provided by inserting the T-shaped path. Furthermore, good agreement between simulation and measurement results are clear.

The current distribution on the proposed dual-band WLAN/UWB antenna structure at 2.4 and 7 GHz frequencies are presented in Figure 4. As shown in Fig. 4(a), at 2.4 GHz frequency, the U-shaped patch is inactive with negligible current while on the added T-shaped strip maximum current is seen at the beginning and minimum current at the end of the path. The current distribution on the T-shaped strip confirms the equation (1) which predicts the length of the added strip. This verifies that the length of the strip is about quarter wavelength. Fig. 4(b) at 7 GHz frequency shows that most of the current is on the patch and the added T-shaped strip has no effect on the U-shaped patch and also on the UWB behaviour.

The total measured radiation patterns of the dual-band antenna in the E- and H-plane at 2.4, 4 and 7 GHz are presented in Fig. 5. As shown, the dual-band printed wide slot antenna has omnidirectional radiation patterns in the H-plane and stable figure eight radiation patterns in the E-plane. The radiation patterns in both E and H-planes are stable along the UWB range. Also, it is clear that the antenna has low cross-polarization over the dual-band coverage in both planes.

Fig. 6 shows the simulation results of the group delay for the proposed dual-band antenna when they are placed in front-to-front configuration with 30 cm spacing between two proposed dual-band antennas. As shown, the dual-band antenna provides consistent group delay over the UWB range which fluctuated within 0.5 ns. Although not shown here, it is seen that the side-by-side arrangement also provides flat group delay of less than 1 ns.

Fig. 7 shows the proposed dual-band WLAN/UWB antenna which has been fabricated and tested.

IV. CONCLUSIONS

In this paper, a new printed wide slot antenna structure is presented that provides dual-band operation over the WLAN at 2.4 GHz and UWB ranges (3.1-10.6 GHz). The U-shaped patch is considered for the UWB range while the added T-shaped strip is activated at the WLAN band. As shown, the length of added T-shaped strip should be about quarter-wavelength at the 2.4 GHz. The proposed antenna provides good VSWR over the two bands. The radiation patterns in both E and H-planes are good as well.

REFERENCES