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Frequency notched wide slot antenna for UWB/2.4 GHz WLAN applications

Abstract A compact frequency notched microstrip slot antenna for ultra-wideband (UWB)/2.4 GHz-band wireless local area network (WLAN) applications is proposed. The antenna is similar to a conventional microstrip slot antenna; however, by introducing a cross wide slot and a meandered-slotted stub, both compact size and frequency notched function can be achieved. It has been studied both numerically and experimentally for its impedance bandwidth, surface current distribution, radiation patterns, and gain. As will be seen, an operation bandwidth of over 4.6:1 ranging from 2.39 to 11.25 GHz for return loss lower than −10 dB having a frequency notched band ranging from 4.75 to 5.85 GHz has been achieved, and good radiation performance over the entire frequency range has also been achieved.

Keywords printed slot antenna, frequency notched, ultra-wideband, 2.4 GHz-band WLAN

1 Introduction

Recently, there is considerable interest in developing such high data rate systems known as UWB communication systems. To avoid interfering with the neighboring communication systems such as 5 GHz-band WLAN systems, UWB antenna with frequency notched function is desirable, and some design schemes have been reported recently [1−3]. Printed wide slot antennas, including coplanar-waveguide-fed and microstripline-fed slot antennas, are attractive, compact, integrable UWB antennas, and thus, several attempts have been made to increase their operation bandwidth [4−9]. Also, by employing fractal tuning stub [10], U-slotted tuning stub [11], or fractal-shape wide slot [12], frequency notched function may be introduced.

However, the operation bandwidth of most of these printed slot antennas is not more than 4:1, and these cannot get application in other communication systems at lower bands such as 2.4 GHz-band WLAN. To reduce the cost and complexity of compact equipments such as handsets, PC cards, and personal digital assistants (PDAs), it is necessary to develop compact ultra-wideband antennas for multiple applications.

In this article, a novel, compact ultra-wideband microstrip slot antenna with frequency notched function is proposed and investigated both numerically and experimentally. The antenna is similar to a conventional microstrip slot antenna, and by introducing a cross-like wide slot and a meandered-slotted stub, compact size and ultra-wideband performance of over 4.6:1 as well as frequency notched function can be achieved. As will be seen, an operation bandwidth of the antenna ranging from 2.39 to 11.15 GHz having a frequency notched band ranging from 4.75 to 5.85 GHz has been achieved, and relative omnidirectional and stable radiation patterns over the entire frequency range have also been achieved.

2 Description of the antenna

The schematic diagram of the antenna and its dimension parameters are shown in Fig. 1. The antenna is fabricated on a dielectric substrate with relative permittivity \( \varepsilon_r = 2.65 \), loss tangent \( \delta = 0.001 \), and thickness \( h = 1 \) mm. As seen in Fig. 1, its tuning stub has a rectangular shape of 11.8 mm width and 10.7 mm length with a meandered slot etched on it. The length of the meandered slot is \( L_c \). The antenna is fed by a microstrip line of 13.8 mm length and 2.8 mm width. The wide slot and tuning stub are positioned in such a way that the total antenna can be integrated with other microwave circuits easily. Parasitic tuning patches acting as reactance loading and compensation elements [13] are placed at the four corners of the slot to reduce the antenna’s size, and the total volume of the antenna is \( 34 \times 34 \times 1 \) mm\(^3\), which is smaller than that in Ref. [12]. It is observed that the size of the antenna is compact without greatly reducing the size of the ground plane and the length of the feed line. Hence, the antenna may be easier to operate and measure than that in Ref. [11]. The photograph of some antenna samples is shown in Fig. 2.
3 Numerical and experimental results

The input performance of the antenna is calculated with Zeland’s IE3D and measured with HP8720ET vector network analyzer (VNA). The measured and calculated results are provided in Fig. 3. It is observed that the measured results are in well accordance with the calculated result. It is seen that the impedance bandwidth for return loss of less than $-10$ dB ranges from 2.39 to 11.15 GHz, in which a frequency notched band ranging from 4.75 to 5.85 GHz is achieved.

The frequency notched characteristic of the antenna is investigated experimentally. The total length of the meandered slot is denoted as $L_s$. Four antennas, including three antennas with different $L_s$ and a reference antenna without meandered slot are fabricated and measured. By introducing a square ring resonator, the frequency notched function is obtained. As can be observed from Fig. 4, the measured central notched frequency is 5.05 GHz, 5.66 GHz, and 6.35 GHz when $L_s=20$, 26.5, and 31 mm, respectively. Thus, the frequency notched function can be controlled and adjusted by varying the value of $L_s$.

To determine the operation bandwidth of the antenna, the surface current distribution should be first simulated numerically. All simulation is accomplished by employing Zeland’s IE3D. The surface current distributions of the antenna at 3.5 GHz, 5.6 GHz, 6.3 GHz, and 9.4 GHz are shown in Figs. 5 (a)–(d), respectively. It is observed that the surface current distribution is relatively constant at 3.5 GHz, 6.3 GHz, and 9.4 GHz. Thus, relative radiation patterns may be achieved at these frequencies. At 5.6 GHz, the amplitude of current distribution near the meandered slot increases drastically. This phenomenon implies that the frequency notched characteristic is introduced by the meandered slot embedded in the tuning stub.

Based on the numerical results, the radiation patterns of the antenna are investigated in a chamber. Radiation patterns in the $zx$-plane and the $zy$-plane at 2.45 GHz, 3.1 GHz, 6.8 GHz, and 9.5 GHz are measured and displayed in Fig. 6. Like conventional wide slot antennas, the $zx$-cut plane radiation patterns are relative omnidirectional, whose non-circularity is about $3−6$ dB over the operation frequency band. The $zy$-cut plane radiation patterns show two nulls in the $+y$ and $−y$ directions, which are also similar to that of conventional wide slot antennas. The radiation patterns are relatively constant over the entire frequency range, as predicted from the calculated surface current distribution in Fig. 5. Thus, the
The operation bandwidth of the antenna can be determined to be the same as its impedance bandwidth. Furthermore, the good omnidirectional $zx$-plane patterns imply that it may be suitable for compact, omnidirectional applications.

Fig. 5 Calculated surface current distribution at four different frequencies

Fig. 6 Measured radiation patterns of the proposed antenna
Finally, the antenna gain is calculated, measured, and displayed in Fig. 7. It is observed that the measured results and the calculated result agree well with each other. At the 2.4 GHz-band, the antenna’s gain is about 1 dBi owing to the relative high return loss. At 3–5 GHz, the average measured gain is about 4 dBi. At 5–6 GHz, the measured gain is reduced sharply to –3 to –4 dBi owing to the frequency notched function. The average gain of the antenna above 6 GHz is sharply to –3 to –4 dBi owing to the frequency notched function at specified band have been achieved.

From these results, it is observed that both the relative constant gain and the frequency notched function at specified band have been achieved.

Fig. 7 Calculated and measured gain of the proposed antenna

4 Conclusions

A novel, compact frequency notched ultra-wideband microstrip slot antenna for UWB/2.4 GHz-band WLAN application has been presented with the calculated and experimental results. By incorporating a meandered slot into the antenna’s tuning stub, the frequency notched function has been achieved. From these results, good ultra-wideband with frequency notched characteristic is observed, and relatively stable and omnidirectional performance has been achieved. Thus, the proposed antenna may be useful for 2.4 GHz-band WLAN and UWB communication systems.

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References


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