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ACTIVE UWB PRINTED ANTENNA WITH TUNABLE AND SWITCHABLE BAND-NOTCHED FUNCTIONS

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Abstract—A printed ultra-wideband (UWB) monopole antenna with both tunable and switchable band-notched characteristics is proposed. An embedded resonant slot loaded with a varactor and a pin diode controlled by DC signal through one common bias network is employed to tune and switch the notch band. In the "all-pass" state when the two diodes are partially turned on, the power consumption of this active antenna is only 2.4 μW. Measured return loss, radiation pattern, gain and group delay of the introduced antenna are presented in this paper.

1. INTRODUCTION

Since the Federal Communications Commission (FCC) authorized the unlicensed use of UWB devices for commercial applications, a great deal of research on UWB technology has been done. UWB antennas, as a key component of UWB communication systems, have attracted more and more attentions. Printed UWB antennas have been considered as excellent candidates for UWB applications, because of their low profile, light weight, and easily fabricated properties [1–3].

Over the UWB band, there are many narrow bands, such as WiMAX, WLAN, HYPERLAN/2, etc. To avoid interference between UWB system and narrow band systems, narrow-band interference mitigation must be considered in UWB system design. Realizing a band-notched behavior in antenna itself is a feasible method to decrease complexity of UWB system, compared to that with an extra filter. One of the usual strategies to provide this feature is to introduce a slot or strip in the antenna [4–7].

Since interferences from narrow-band systems vary with environment, tunable notch band within the pass-band of a UWB antenna is

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required. However, after fabrication it is difficult to adjust the notch band frequency, because it depends on the physical length of resonant slot. A slot loaded with different capacitors has been employed to realize tunable band-notched behavior [8, 9]. Electronically tunable behavior can be achieved by using a slot or strip loaded with a varactor [10, 11]. Moreover, band-notched feature could cause distortion of a part of the UWB spectrum and decrease the data rate of UWB system. Therefore, it is necessary to turn off the filtering function, if there is no interferences from narrow band systems in the antenna environment. A slot loaded with a PIN diode or MEMS has been proposed to achieve switchable band-notched characteristic [12–15]. An antenna with both tunable and switchable notch bands has been realized in [16] by using six pin diodes. However, the notch band is discretely tunable.

In this paper, a printed UWB antenna with both tunable and switchable band-notched behaviors is presented. The notch band frequency can be fine-tuned continuously. This feature can be achieved easily by loading a varactor and a pin diode across a loop slot. These two diodes are controlled by a common bias network. The maximum power consumption of this active antenna can be as low as 2.4 μW, when the two diodes are partially on. The antenna was designed and optimized using CST Studio.

2. ANTENNA DESIGN

The proposed antenna is illustrated in Figure 1. It is fabricated on a high-frequency substrate Ro4350B ($\varepsilon_r = 3.48$) with thickness of 0.762 mm, width of 30 mm, and length of 35 mm. A 50-Ω microstrip transmission line with width of 1.67 mm is adopted to feed the radiating patch. To achieve optimum impedance matching over UWB band, a staircase rectangular patch on the front side of the substrate and an open slot on the ground are adopted. A loop slot embedded on the patch is loaded with a pin diode and a varactor on the top and bottom side, respectively. The varactor used in this design is SMV1405-079LF from Skyworks Solutions Inc., with tunable capacitance from 0.63 to 2.67 pF over a 0 to 30 V reverse bias voltage range. It can afford a maximum forward current of 20 mA. The pin diode adopted is SMP1345-079LF also from Skyworks Solutions Inc., with capacitance of 0.18 pF under a 5 V reverse bias voltage. It can afford a maximum reverse bias voltage of 50 V. The cathodes of the varactor and pin diode are connected to the copper inside the loop slot which is connected to the DC bias circuit on the backside through a via hole. Therefore, these two diodes are parallel connected in the same direction and can be controlled by a DC signal through the common bias network conveniently, as shown in Figure 1.

Under different reverse bias voltages, capacitance of the varactor changes, and a shift of resonant frequency of the slot is observed, while the pin diode is switched off with slight influence on the resonant frequency characteristic due to its small capacitance. Under a slight forward bias voltage, the two diodes are partially turned on. In this case, the loop slot is split by these two diodes into two short slots of high resonant frequency beyond the UWB band that we concern about. Therefore, the notch band disappears.

As shown in Figure 1, a 22 nH inductor, LQW18AN22NG00 from

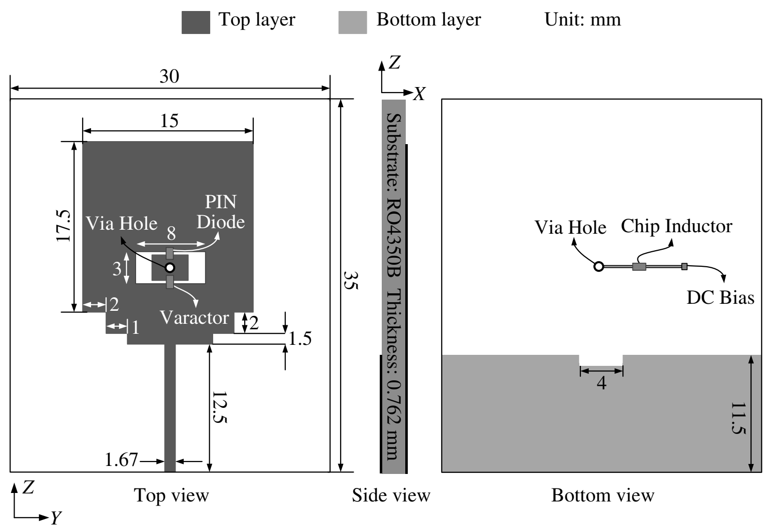
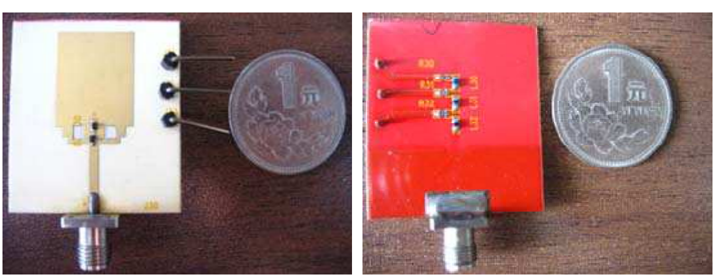


Figure 1. Geometry of the proposed antenna.



(a) (b)

Figure 2. Photograph of the fabricated active antenna. (a) Top view. (b) Bottom view.

Murata Manufacturing Co., Ltd., is mounted on the back side of the substrate to isolate RF signal from DC bias lines as a RF choke without significantly affecting the omnidirectional radiation pattern of the UWB antenna. A photograph of the fabricated active UWB antenna is shown in Figure 2. As shown in Figure 2(b), three parallel bias networks with 36 nH, 22 nH and 8.7 nH inductor respectively are fabricated on the back side. According to the measured results, the bias network with the inductor at 22 nH is matched to the notch band and provides the best performance of the antenna. In practical active UWB antenna applications, a capacitor of proper value as a DC block and a DC return path are necessary. In this design, for convenience we used a Bias-T test accessory from Agilent Technology to avoid the influence of DC bias current on RF signal.

3. MEASURE RESULTS AND DISCUSSION

The return loss of the antenna has been measured using Agilent N5230A vector network analyzer. Figure 3(a) shows the measured return loss for different reverse bias voltages. By tuning reverse bias voltage from 0 to 30 V, the capacitance of the varactor changes from 2.67 to 0.63 pF, a drift of the notch band edge from 4.7 to 6.8 GHz is observed. The measured return loss of the antenna under various forward bias voltages is shown in Figure 3(b). By increasing the forward bias voltage from 0.2 to 2 V, the two diodes are turned on gradually. It is observed that notch band exists until the forward bias voltage rises to 0.6 V. If the forward bias voltage continues to increase to 2 V, the two diodes are completely switched on, but the return loss of the antenna is almost unchanged compared to that under 0.6 V bias voltage. The currents of whole bias network for corresponding bias

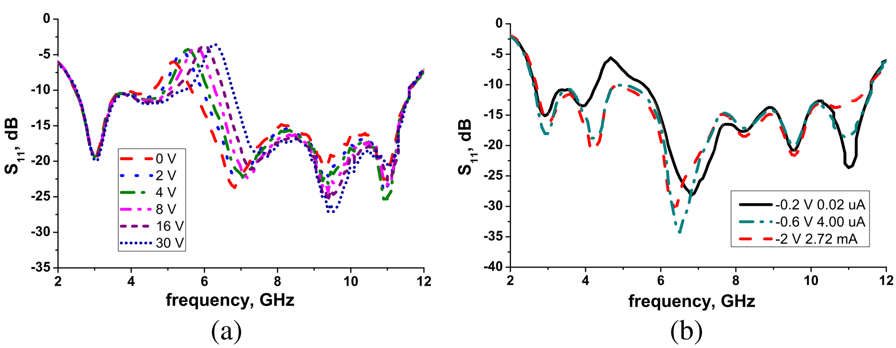


Figure 3. Measured return loss of the proposed antenna for different (a) reverse and (b) forward bias voltages.

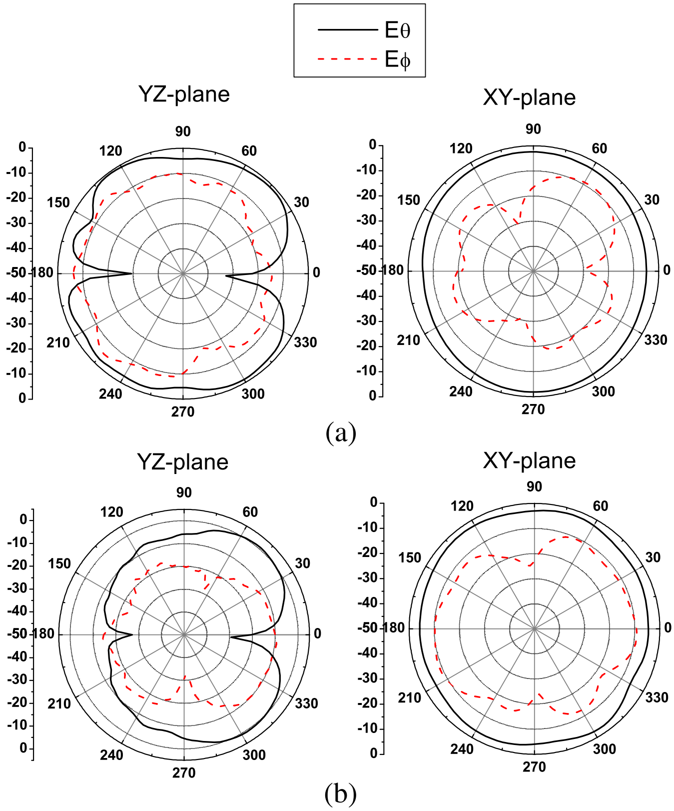
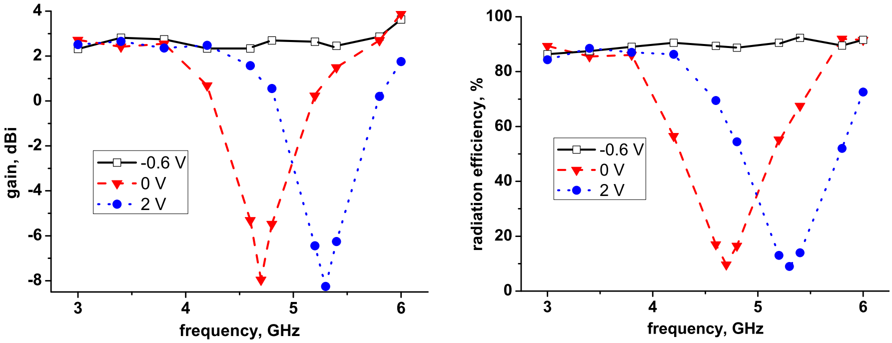


Figure 4. Measured radiation patterns of the proposed antenna in YZ- and XY-plane at (a) 4 GHz and (b) 6 GHz respectively.

voltages are also shown in Figure 3(b). By operating the two diodes with 4.00 μA bias current which corresponds to 0.6 V bias voltage, the power consumption can be reduced to only 2.4 μW which is much lower than 1.1 mW mentioned in [16].

The measured radiation patterns at 4 and 6 GHz in XY- and YZ-planes are shown in Figures 4(a) and 4(b), respectively. The antenna presents a stable omnidirectional pattern in XY-plane. The influence of the isolation circuit on the radiation pattern can be ignored. The measured gain and radiation efficiency of the proposed antenna under −0.6, 0 and 2 V bias from 3 to 6 GHz are shown in Figures 5(a) and 5(b), respectively. Although they do not cover the whole UWB band (3.1–10.6 GHz), the notch band that we concern about is located in the measured band. It is clear that the gain and radiation efficiency



(a) (b)

Figure 5. (a) Measured gain and (b) radiation efficiency of the proposed antenna under -0.6 V, 0 V and 2 V bias voltages.

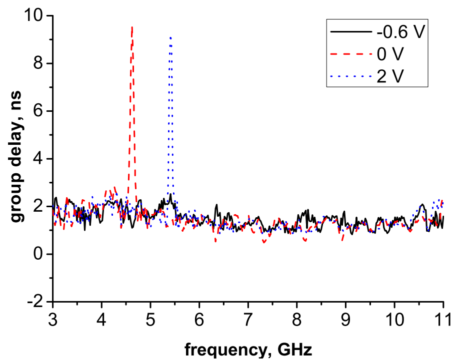


Figure 6. Measured group delay of the proposed antenna under -0.6 V, 0 V and 2 V bias voltages.

of the proposed antenna under 0 and 2 V bias drop sharply at about 4.7 and 5.3 GHz. The gain suppression is approximately 10 dB. It also can be seen that the gain of the antenna under -0.6 V bias is flat and doesn't have a notch. Figure 6 reveals the group delay for -0.6, 0 and 2 V bias which indicates the time signal distortion introduced by antenna. The group delay is measured by using two identical face to face active antennas with a distance of 200 mm. It is observed that the group delay for -0.6 V bias is nearly flat in the whole UWB band, and the group delays for 0 and 2 V are also flat except the notch frequency at 4.7 and 5.3 GHz, respectively. This result demonstrates that the antenna introduces a small time signal distortion as desired in UWB antennas.

4. CONCLUSIONS

A compact UWB printed antenna with both tunable and switchable band-notched behaviors has been realized by etching a resonant slot loaded with a varactor and a PIN diode. By changing the control signal through one common bias network, the notch band can be tuned and switched off conveniently. The power consumption is only 2.4 μW when the antenna presents an "all-pass" state and the two diodes partially turned on. These characteristics make the antenna an excellent candidate for ultra-low power UWB applications in complex electromagnetic environment.

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