A Compact CPW-Fed Quintuple -Band-Notched Antenna for UWB Applications

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Abstract

In this paper, a compact coplanar waveguide (CPW)-fed quintuple-band-notched antenna for ultra-wideband(UWB) applications is presented. The voltage standing wave ratio (VSWR) results show that the proposed antenna exhibits good wideband performance over an UWB frequency range from 1.4 to 10.7 GHz with VSWR less than 2, except for five stop-bands at 2.1 to 2.6 GHz, 3.3 to 3.75 GHz, 5.15 to 5.85 GHz, 7.2 to 7.6 GHz and 8.15 to 8.52 GHz for filtering the worldwide interoperability for microwave access (WiMAX) systems, wireless local area networks (WLANs), downlink of X-band satellite communication system and ITU band signals, respectively. Good radiation patterns and gain characteristics are obtained in the whole UWB frequency range except the notched frequency bands. The simulation results were compared with the measured results and good agreement is obtained. The proposed antenna provides the simple structure and good characteristics and is suitable for UWB applications.

Keywords: UWB antenna, quintuple notched band, coplanar waveguide, interference.

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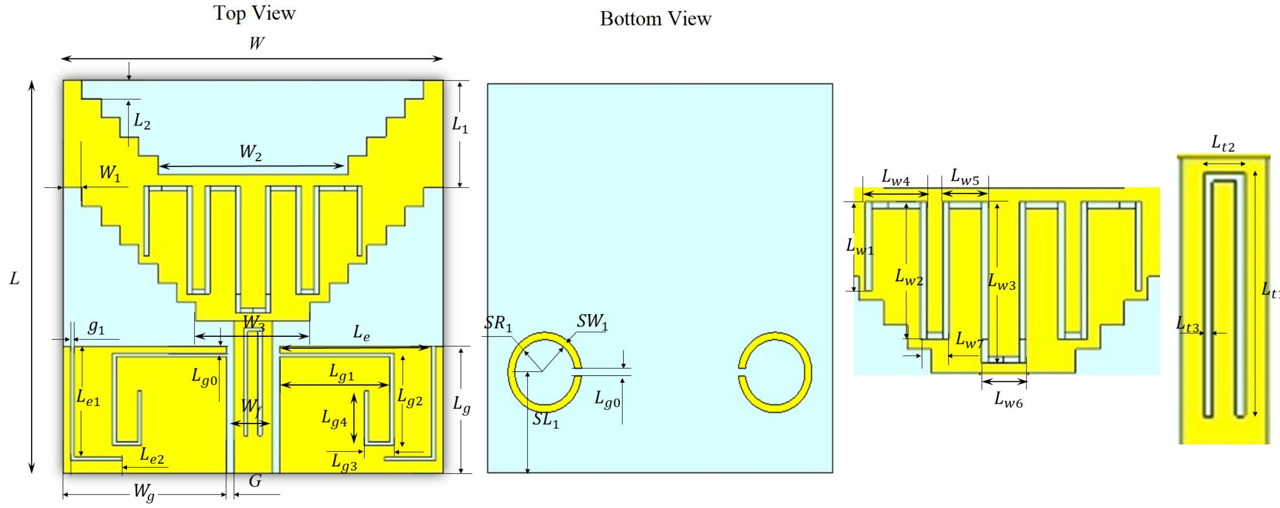
1 Introduction

There has been more and more attention in UWB antenna since the Federal Communication Commission (FCC) allocated the frequency band 3.1–10.6 GHz for commercial UWB systems [1]. The UWB antenna is a key part of UWB communication systems which has obtained a lot of attention because of its planar configuration, small size, light weight, easy realization, fast data transmission and low cost. UWB antennas with filtering properties are in great demand for many practical applications, due to the coexistence of UWB communication systems with other wireless standards, such as the WiMAX systems operating at the 3.35 GHz (3.3–3.4 GHz), 3.5 GHz (3.4–3.69 GHz) and 5.8GHz (5.725–5.85 GHz) bands, WLANs operating at the bands of 5.25GHz (5.15–5.35 GHz) and 5.75 GHz (5.725–5.825GHz), X-band downlink satellite communication system operating at the band of 7.25–7.75 GHz and International Telecommunications Union (ITU) operating at the band of 8.01–8.5 GHz, respectively. A stopband filter is embedded with the UWB antenna to avoid such interfering signals. However, the using the external embedded filters cause the increase of the total dimensions of the antenna, the complexity and cost [2]. To eliminate the interference, antenna filtering technique has become an excellent candidate for UWB devices due to its simplicity, effectiveness, easy integration into modern devices and low cost. In order to design UWB antennas with band-notched functions, methods of etching and adding various resonators on the radiating patch or on the ground plane or on the feed line have been widely used. The most popular method is etching various slots, such as C-shaped [3, 4], E-shaped [5-6], F-shaped [7], U-shaped [8], T-shaped [9, 10], inverted V-shaped [11], L-shaped [12], or SRR-shaped [13, 14] on the antenna structure. Another method is adding various parasitic elements [15, 16] and SRRs [17] on the antenna structure. In reference [18, 19], methods of etching slots and adding parasitic strips are simultaneously used for band-notched characteristic. In this paper, a novel CPW-fed planar UWB antenna with quintuple band-notched characteristics is proposed and investigated in detail. To realize a compact UWB system, CPW-fed monopole antenna is proposed, which has a UWB operating bandwidth with a quintuple notched frequency at 2.4GHz, 3.5 GHz, 5.6 GHz, 7.5 GHz and 8.2GHz. The prototype with optimal dimensions was fabricated and measured. A comparison between measurement and simulation results was done for the voltage standing wave ratio. The radiation patterns of the proposed antenna are also presented.

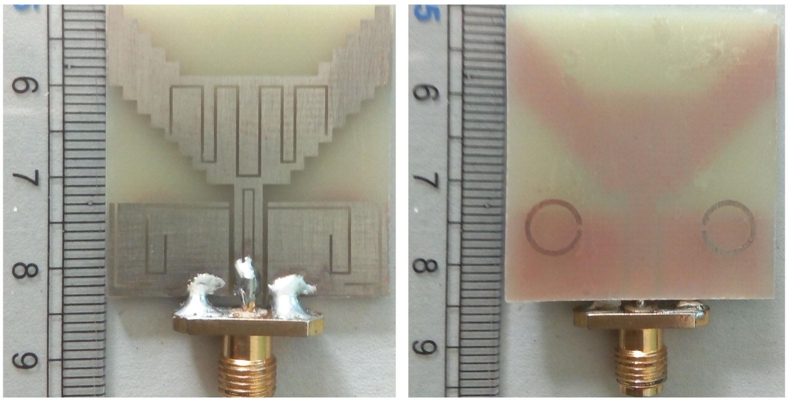
2 Antenna configuration

Fig. 1a shows the configuration of the proposed quintuple band-notched antenna. The proposed antenna is printed on an 0.508mm thick Rogers 4350B substrate with the relative permittivity of $\varepsilon_r = 3.66$ and loss tangent of $\tan\delta = 0.0037$. The antenna with new structure has a small size of $30\times31\times0.508\text{mm}^3$. Through simulations with the commercial software CST, the optimized parameters of the designed quintuple band-notched antenna are listed as follows: $L = 31$, $W = 30$, $W_1 = 1.5$, $W_2 = 15$, $W_3 = 9$, $L_1 = 8.5$, $L_2 = 1.5$, $W_g = 12.9$, $W_f = 3$, $g_1 = 0.3$, $L_{g0} = 0.5$, $L_{g1} = 9$, $L_{g2} = 7$,

$L_{g3}=2$, $L_{g4}=4$, $L_g=10$, $L_{e1}=9$, $L_{e2}=4$, $L_{w1}=5.5$, $L_{w2}=8.5$, $L_{w3}=10$, $L_{w4}=3.8$, $L_{w5}=2.8$, $L_{w6}=2.8$, $L_{w7}=1.8$, $SR_1=2.6$, $SW_1=0.6$, $SL_1=8$, $L_{t1}=8.2$, $L_{t2}=1.4$ and $L_{t3}=0.3$. Here all dimensions are in mm.



a



b

Fig. 1: *Geometry of the Proposed Quintuple Band-Notched UWB Antenna*
a : Structure of the Proposed Quintuple Band-Notched UWB Antenna
b : Photographs of the Proposed Quintuple Band-Notched UWB Antenna

3 Parametric Study

A parametric study of the proposed quintuple band-notched UWB antenna was done using the commercial software CST to obtain the optimized dimensions of a desired band-notched UWB antenna. While the relevant parameter is varied, the other parameters are not varied.

3.1 Controlling the first notched band

Figs. 2*a* shows the VSWR simulated while the parameter L_{w1} is being changed at the center frequency of the first-notched band near 2.4GHz. When the parameter L_{w1} increases, the center frequency of the first notched band shifts slightly towards lower frequency side: from 2.61 GHz for L_{w1} = 4.5 mm to 2.31GHz for L_{w1} = 6 mm. Therefore, the center frequency of the first notched band can be controlled by changing the parameter L_{w1}.

3.2 Controlling the second notched band

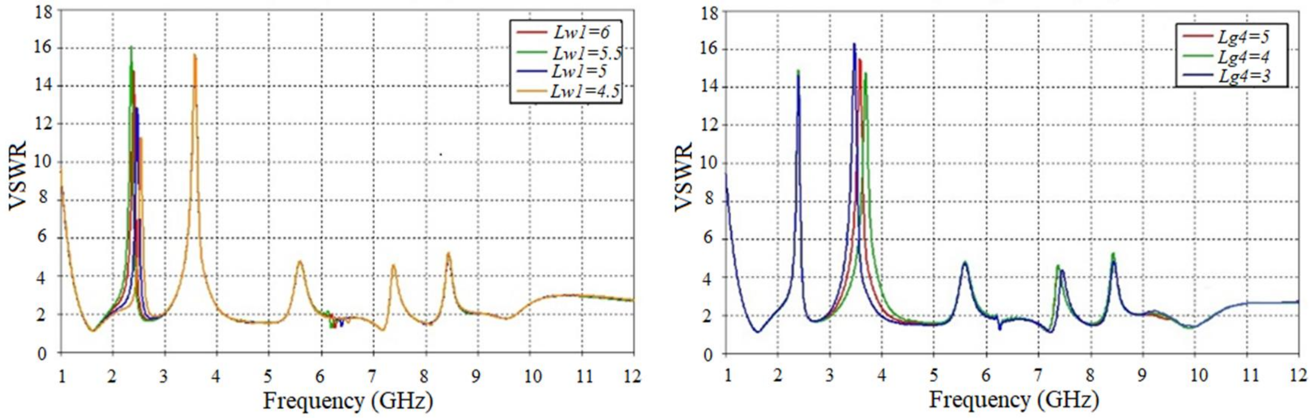
Figs. 2*b* shows the VSWR simulated while the parameter L_{g4} is being changed at the center frequency of the second-notched band near 3.5GHz. When the parameter L_{g4} increases, the center frequency of the second notched band shifts slightly towards lower frequency side: from 3.8 GHz for L_{g4} = 3mm to 3.4 GHz for L_{g4} = 5 mm. As a result, the center frequency of the second notched band can be controlled by changing the parameter L_{g4}.

3.3 Controlling the third notched band

Figs. 3*a* shows the VSWR simulated while the parameter L_{e2} is being changed at the center frequency of the third-notched band near 5.5GHz. Again, when the parameter L_{e2} increases, the center frequency of the third notched band shifts slightly towards lower frequency side: from 5.99 GHz for L_{e2} = 3 mm to 5.23GHz for L_{e2} = 5 mm. Therefore, the center frequency of the third notched band is mainly determined by the parameter L_{e2} .

3.4 Controlling the fourth notched band

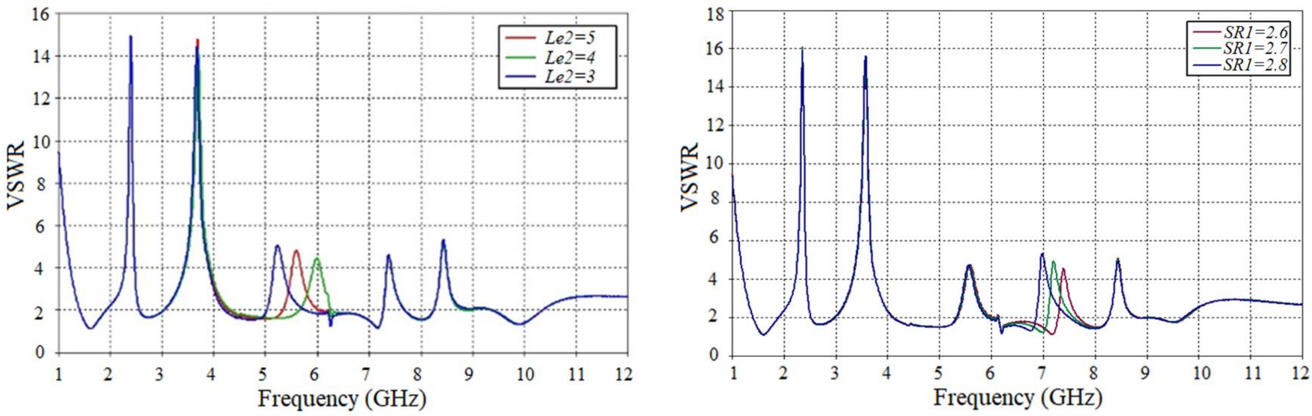
Figs. 3*b* shows the VSWR simulated while the parameter SR_1 is being changed at the center frequency of the fourth-notched band near 7.5GHz.



a *b*

Fig. 2: *The Simulated VSWR of the Proposed Antenna with Different Values of* L_{w1} *and* L_{g4}

a: L_{w1} , *b:* L_{g4}



a *b*

Fig. 3: *The Simulated VSWR of the Proposed Antenna with Different Values of* L_{e2} *and* SR_1

a: L_{e2} , *b:* SR_1

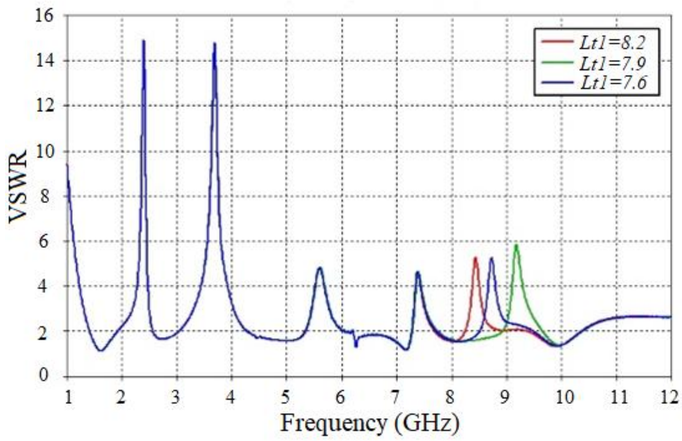


Fig. 4: *The Simulated VSWR of the Proposed Antenna with Different Values of* L_{t1}

When the parameter SR_1 increases, the center frequency of the fourth notched band shifts slightly towards lower frequency side: from 7.5 GHz for SR_1 = 2.6mm to 7.2GHz for SR_1 = 2.8 mm. Therefore, the center frequency of the fourth notched band is got by varying the parameter SR_1.

3.5 Controlling the fifth notched band

Figs. 4 shows the VSWR simulated while the parameter L_{t1} is being changed at the center frequency of the fifth-notched band near 8.2GHz. When the parameter L_{t1} increases, the center frequency of the fifth notched band shifts slightly towards lower frequency side: from 9.15 GHz for L_{t1} = 7.6 mm to 8.2GHz for L_{t1} = 8.2 mm. Therefore, the center frequency of the fifth notched band can be controlled by changing the parameter L_{t1}.

4 Results and discussions

The proposed quintuple band-notched antenna was successfully fabricated and measured. The photograph of the fabricated quintuple band-notched antenna was shown in Fig. 1*b* and the measurement was taken with an Agilent FieldFox N9918A vector network analyzer.

4.1 VSWR measurement

Fig. 5 shows the simulated and measured VSWR of the proposed antenna. It is shown that the proposed antenna exhibits five desired notched bands of 2.1 to 2.6 GHz, 3.3 to 3.75 GHz, 5.15 to 5.85 GHz, 7.2 to 7.6 GHz and 8.15 to 8.52 GHz and rejects the unwanted signals well, while maintaining wideband performance from 1.4 to 10.7 GHz for VSWR < 2.

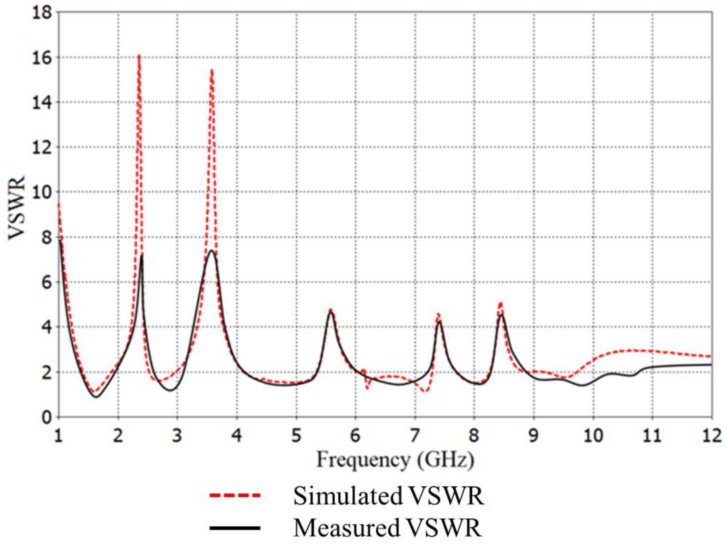


Fig. 5: *The Simulated and Measured VSWR*

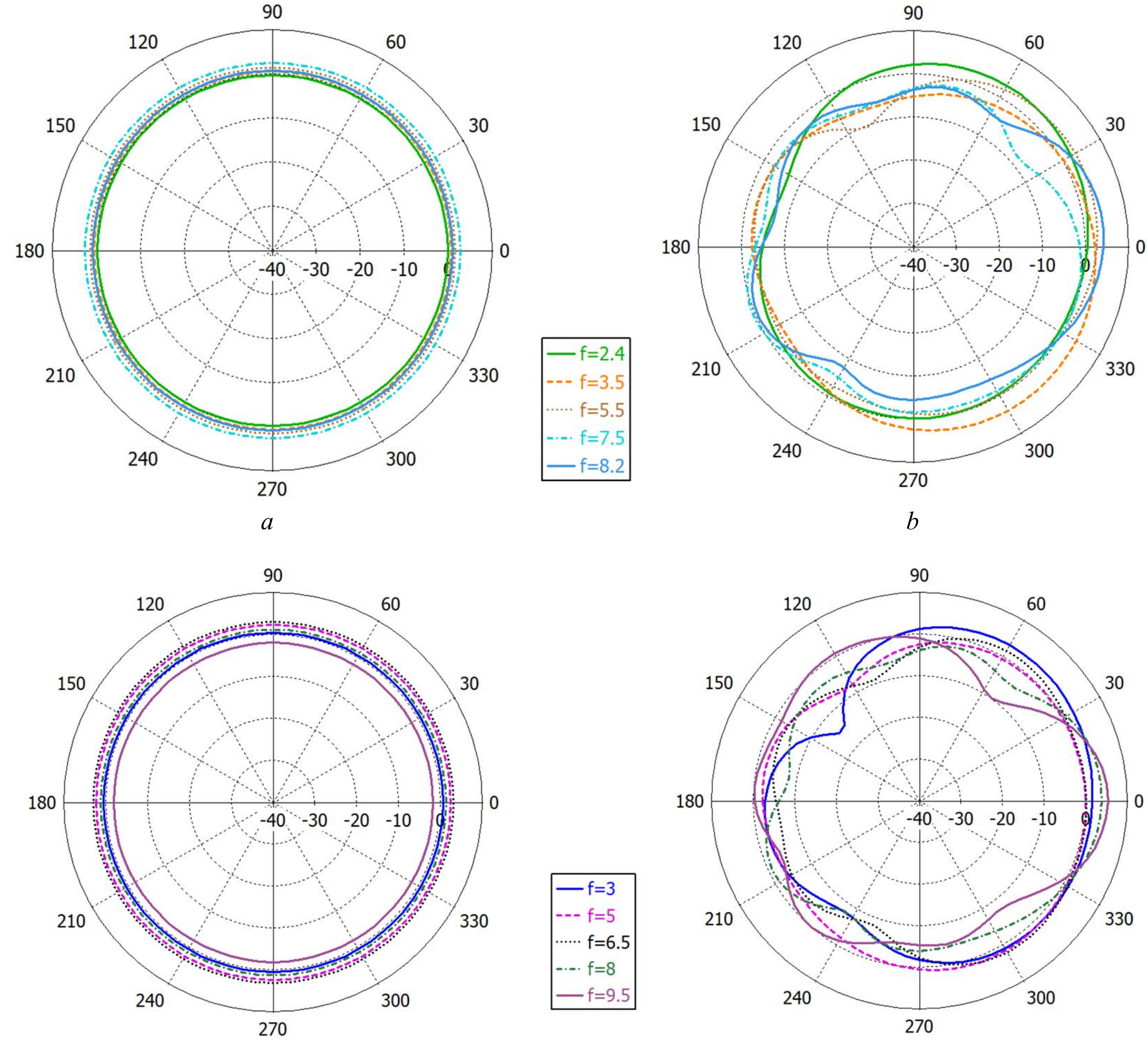
There is a little discrepancy between the measured and simulated results and it may be due to the tolerance in manufacturing, and the interference of the connector and feeding cable in the measurement.

4.2 Radiation Pattern

The radiation patterns of the *E*-plane and *H*-plane at the five notched frequencies of 2.4, 3.5, 5.5, 7.5, and 8.2 GHz and the passband frequencies of 3, 5, 6.5, 8, and 9.5 GHz are shown in Figs. 6*a–d*, respectively. At the passband frequencies out of the notched bands, it can be seen from Figs 6*c* and *d* that the radiation pattern in *H*-plane are almost omnidirectional and the radiation pattern in *E*-plane is monopole alike and it is suitable for the UWB communication applications.

4.3 Realized gain

Fig. 7 shows the realized gains of the proposed antenna with and without the band-notches. As was expected, it can be seen that there are five sharp decreases of the realized gain in the antenna in the vicinity of five notched bands. The energy in the five notched frequency bands is not radiated so that the radiation efficiency can drops in the five notched frequency bands. Thus, the realized gain decreases sharply in the five notched bands, which clearly indicates the quintuple band rejection functions of the proposed antenna. The results indicate that the annular-rings work effectively to ensure a quintuple band-notched characteristic for the UWB antenna.



a *b* *c* *d*

Fig.6: *Radiation Patterns of the Quintuple Band-Notched UWB Antenna*
a: H-Plane at the Stopband Frequencies, b: E-Plane at the Stopband Frequencies
c: H-Plane at the Passband Frequencies, d: E-Plane at the Passband Frequencies

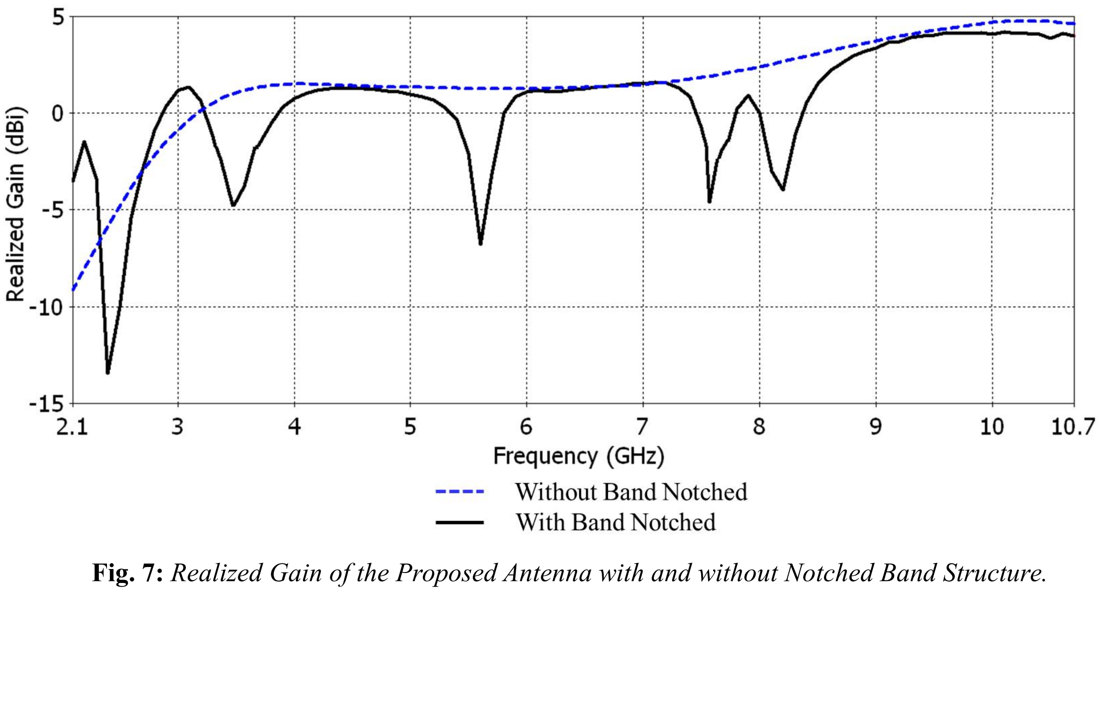


Fig. 7: *Realized Gain of the Proposed Antenna with and without Notched Band Structure.*

5 Conclusion

In this paper, a novel UWB antenna with quintuple band-notched characteristics has been proposed and analyzed. The proposed design is validated by the comparison between simulation and measurement results. The proposed antenna exhibits a good band rejection in the unwanted interference bands and has wideband performance from 1.4 to 10.7 GHz with VSWR less than 2. Also, the proposed antenna has shown good omnidirectional radiation patterns at the *H*-plane and acceptable gain. The proposed antenna is simple to design and fabricate and it provides us a flexible way to control the desired notch frequency. Therefore, the proposed quintuple band-notched UWB antenna can be successfully employed for UWB devices to avoid the unwanted electromagnetic interference.

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