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Ultra Wideband Antenna with Controllable Rejection Band

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Abstract
An ultra wideband antenna with a circular structure that has a modified ground plane is presented in this article. By adding a U-slot in the conductor side of the circular patch, an ultra wideband antenna with a rejection band can be achieved. The U-slot parameters; length, width and gap are used to control the center frequency of the rejection band. Simulation for the regular circular patch shows that, the antenna impedance bandwidth covers the frequency range of 3.1–10.6 GHz. With controlling the U-slot parameters, the rejection band can cover the range from 5.4-6.8 GHz. The performance of the proposed antenna with U-slot and the regular circular patch antenna were measured and compared with the simulated results, good agreements were found.

Key-words: ultra wideband, microstrip, circular patch antenna, rejection band, U-slot, partial ground plane,

1. Introduction

Since the Federal Communication Commission (FCC) allocates the frequency band 3.1–10.6 GHz for commercial use, many antenna configurations have been designed for the ultra wideband antenna (UWBA) applications. The typical types are metal-plate monopole antennas with simple configurations [1]. Antenna design for ultra wideband applications is facing many challenges. One of them is to reduce the antenna dimensions as much as possible without affecting other frequency and time domain parameters. In ultra wideband radio applications, radiation performance of antenna is desired to be stable over the entire bandwidth (3.1–10.6 GHz). In addition, the gain and group delay are expected to be constant [2, 3]. By using planar structures for antenna design the volume of the antenna can be reduced. Various planar configurations such as circular, square, triangular, and elliptical have been proposed for ultra wideband applications [4–8]. Other structures such as coplanar waveguide [9], ultra wideband antenna (CPW-UWBA), and double sided printed antennas with a little higher gain [10] were given. However, it was noticed that, the WLAN band from 5.15 to 5.825 GHz is overlapped with the UWBA frequency band. To avoid the potential interference, some UWBA antennas having a frequency band notch function were designed. Fractal configuration [11] and planar monopole antenna with slot [12] are among the common designs. More articles were published to illustrate the idea for the ultra wideband antennas with a rejection band [13-16]. The UWBA system covers the frequency range from 3.1 to 10.6 GHz, and there are several narrow band services are overlapped with this band. To solve this problem, UWBA antennas had better built-in band-pass filter. This structure can reduce interference from nearby WLAN standard 802.11a, which has a frequency range of 5.15–5.825 GHz. A number of techniques have been recommended to getride from the band pass filter such as loading a pair of symmetrical open-ended slits on the radiating patch [17-18], inserting a pair of symmetrical parasitic strips [19], and embedding a $\lambda/4$ resonant circuit (small slot) on the feed line [20], can also lead to a band-notch function within the 5-GHz range.

In this article, the rejection band will be designed by using a U-slot in conductor side of the circular patch antenna that have partial ground plane. The effect of the U-slot length, width and gap on the position of the center frequency of rejection band are given. The regular circular patch antenna and that with U-slot were fabricated using the thinfilm technology and photolithographic techniques in the microstrip Laboratory at the Electronics Research Institute. Their performances were measured using the vector network analyzer (Agilent 8719ES). The measurement of the regular UWBA cover the frequency range (3-10.8GHz) with return loss less than (-10dB). The realized ultra wide band with U-slot achieves an ultra wide band from (3.0-10.15GHz) with reflection coefficient less than (-10dB) and has a rejection band that covers the range (5.23-6.17GHz).

2. Simulation Results

The ultra wideband antenna that consists of circular patch fed by a microstrip line, while the conductor in the ground plane under the antenna was etched partially is shown in Fig.1. After some trials using the IE3D simulator, the dimensions were obtained, Fig.1. The antenna is design on RT/Duriod-5880, Teflon substrate $(\varepsilon_r = 2.2, h = 1.5748, \tan\delta = 0.0009)$ and it was simulated using the IE3D readymade software package. The simulated return loss for this antenna is shown in Fig.2, where it gives an ultra wideband performance extended from 3.25-14.0 GHz with return loss (S_{11}) less than $(-12dB)$ overall the operating bandwidth. When a U-slot is etched from the conductor side of the patch antenna, Fig.3 the rejection band in the ultra wideband was achieved. The U-slot parameters which are, the width (W), the length (L) and the gap (s) have different impacts on the center frequency of the rejection band for the Ultra wideband antenna. Such effect will be described in details in the following sections.

2.1 The U-Slot width (W) effect

In this section, the effect of the U-slot width (W), Fig.3, on the performance of the rejection band center frequency of the Ultra wideband antenna is presented. After some trials using the IE3D simulator for different values of W, L, we nearly reach to the values that have an effect on the rejection band which are; at a constant U-slot length (L=16.0 mm) and U-slot gap (S=1.0 mm) then, by varying the U-slot width (W), the rejection band center frequency varies also. At L=16.mm, the lengths of the U-slot are around 1.219λ, 1.27 λ and 1.304 λ for the widths 4.0, 5.5 and 6.5 mm, respectively. The λ was calculated as normalized wave length at 6.85GHz which is the center frequency of the ultra wideband range. Figure 4 illustrates this effect on the center frequency of the rejection band at (W=4.0, 5.5 and 6.5 mm). From Fig.4, it is clear as the U-
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slot width (w) increases as the rejection band center frequency moves to lower value. So, as (W) varies from 4.0 mm to 6.5 mm, the rejection center frequency varies from 6.4 GHz to 6.2 GHz. The U-slot widths have nearly effect on the rejection band.

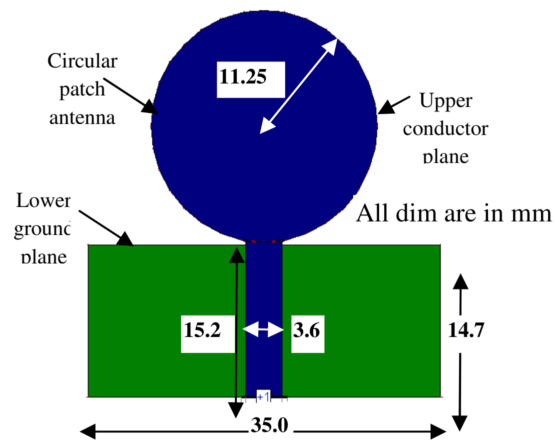


Fig.1 The UWBA configuration

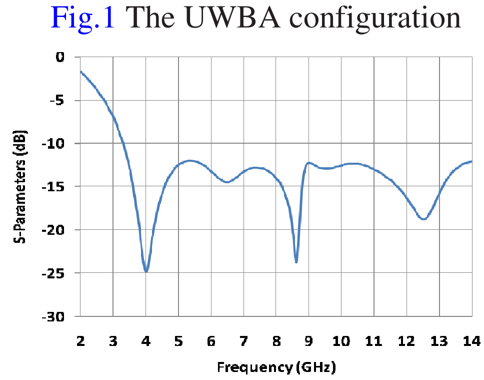


Fig.2 The simulated reflection coefficient ($|S_{11}|$ for the UWBA

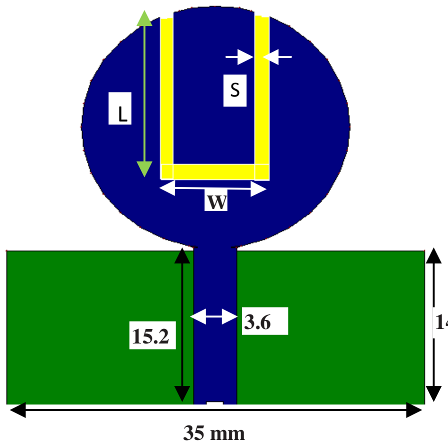


Fig.3 UWBA configuration with U-slot parameters

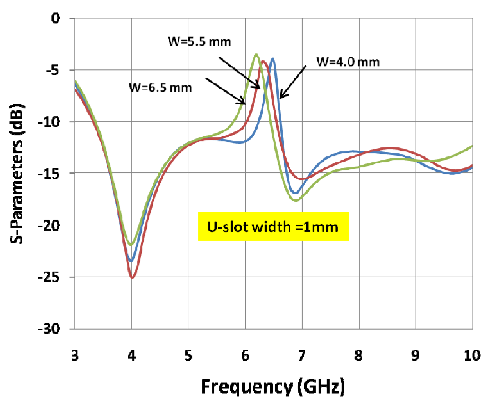


Fig.4 Variations of frequency against the U-slot width at L=16.0mm S=1.0mm

2.2 The U-Slot Length (L) effect

The variation of rejection band center frequency against the U-slot length (L) at a constant U-slot gap (S=0.5 mm) and U-slot width (W=6.5mm) is shown in Fig.5. It is clear that, as the slot length varies from 15.25 mm to 20.25 mm as the rejection band center frequency moves from 6.8 GHz to 5.4 GHz, respectively. The U-slot lengths (L) have a good impact on the rejection band center frequency and it covers a wide frequency range which makes the rejection band moves from 5.3 GHz up to 6.8 GHz when L varies from 21.25mm up to 16.25 mm. This range of variation nearly covers most of the WLAN band. A similar effect happened nearly, when the U-slot gap (S) has values 1.0 mm and 1.5mm and both of the performances are shown in Fig.6 and Fig.7, respectively. Form Figs.5-7, at constant U-slot length (L=19.25 mm), it is clear that as the U-slot gap (s) increases as the rejection band center frequency shift to upper frequency.

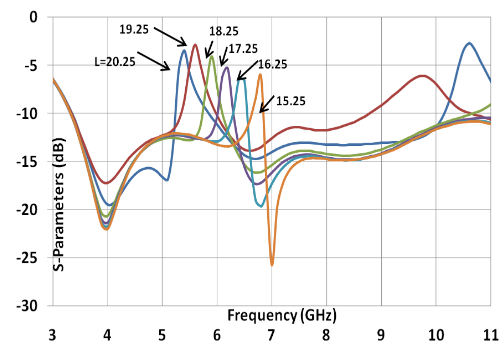


Fig.5 Variations of frequency against the U-slot height (L) at W=6.5mm and S=0.5 mm.

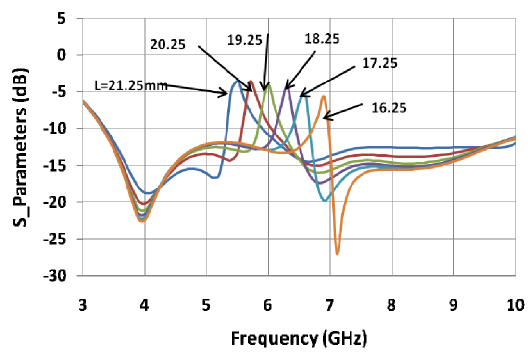


Fig.6 Variations of frequency band against the U-slot height at S=1.0 mm and W=6.5mm.

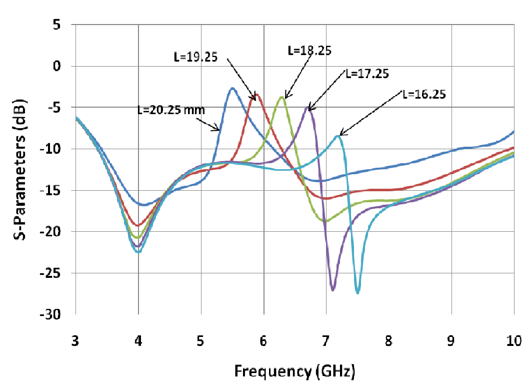


Fig.7 Variations of frequency band against the U-slot height at S=1.5 mm and W=6.5mm.

2.3 The U-Slot gap effect

The effect of the U-slot gap (S) on the rejection band center frequency is discussed. As an example, when the U-slot length (L) and the U-slot width (W) are adjusted to L=16.5 mm and W=6.5mm, respectively, the performance of rejection center frequency band against the U-slot gap (S) is shown in Figs.5-7. It is clear that, as the U-slot gap increases (from 0.5mm to 1.5mm) as the rejection center frequency band shifts to upper frequency values.

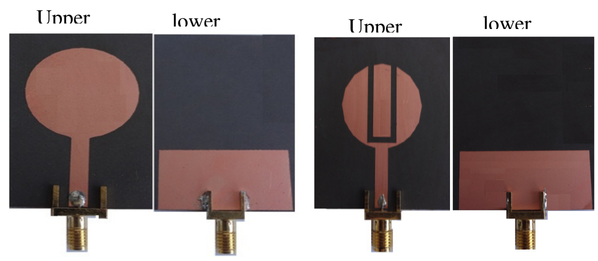
From the previous sections 2.1-2.3, it is clear that the main effect on the rejection band center frequency is the circumference (p) of the u slot which equals to(p= 4L+2W+2S), as this length increases as the frequency shift to lower value, because more the radiations happened around this circumference.

3. Fabrication and Measurements

Both of the conventional circular patch ultra wideband antenna and the ultra wideband antenna with U-slot were realized on the Teflon substrate material RT/Duriod-5880 $(\varepsilon_r = 2.2, h = 1.5748, \tan\delta = 0.0009)$ and fabricated in the microstrip Laboratory at the Electronics Research Institute using the thin film technology and photolithographic techniques. The photos of the upper and lower sides for the realized antennas are shown in Fig.8.

3.1 Measurement of the regular UWBA

The conventional ultra wideband antenna was measured and both of the simulated and measured results are shown in Fig.9. It is clear that, the measured return loss (S_{11}) is less than (-9.5 dB) over the entire band (3.0-10.8GHz). The current distribution for this antenna is shown in Fig.10 for different frequencies, where the current is concentrated around the edges of the circular patch and at the edges of the microstrip feed line, which means all the radiations comes from these sections. The polar plot for the E-field radiation pattern at the frequencies 3.3, 3.9, 6.4 and 12 GHz is shown in Fig.11, where the field is symmetrical for the frequencies 3.3 and 3.9 GHz, while there are a tilt angle for the H-plane at the frequencies 6.4 and 12GHz. There are back radiations in all cases which attributes to the partial ground plane.



(a) Conventional (b) UWBA with U-slot

Fig.8 The photos of the realized antennas

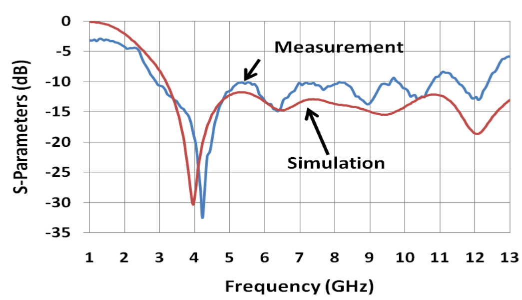


Fig.9 Simulated and measured performance for the regular UWBA

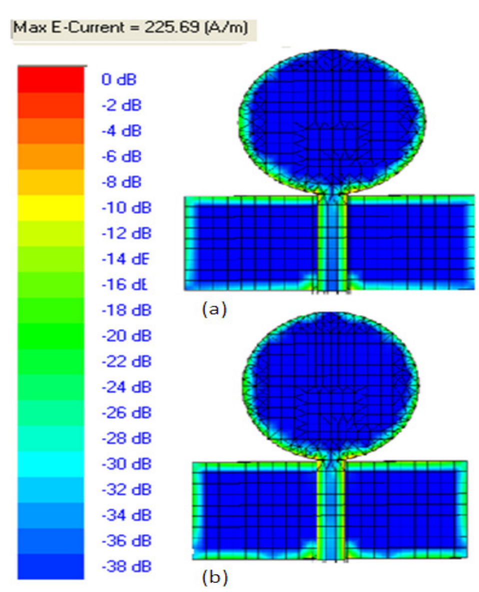


Fig.10 The current distribution for regular UWBA for each of
(a) At f= 3.9 GHz (b) at f= 6.4 GHz

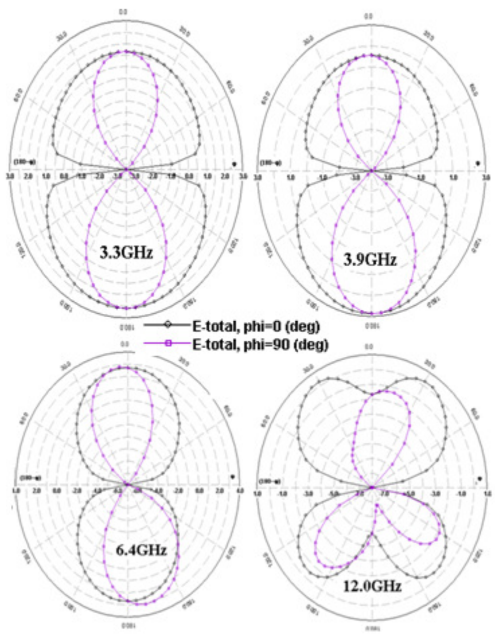


Fig.11 The regular UWBA radiation patterns at f= 3.3, 3.9, 6.4 and 12GHz

3.2 Measurement of UWBA with U-slot

The measurement result for the realized UWBA with U-slot is compared with the simulated results and both results are shown in Fig.12. The U-slot dimension for the U-slot antenna was (W=6.5 mm, S=1.5mm and L= 20.25mm). The antenna gives an ultra wideband performance that covers the band range from (3.0-9.5 GHz) with a rejection band having a center frequency of 5.5GHz, while the return loss (S_{11}) in the ultra wideband is less than $(-9.0dB)$. The current distribution for such antenna is shown in Fig.13, for the center frequency of the rejection band at 5.5GHz, and at the passband at 3.9GHz. At the rejection frequency (f=5.5GHz), the current was distributed around the microstrip feeder and at the lower part of the patch antenna around its edges, so a little radiation happened. For the frequency (f=3.9GHz) which is a radiated frequency, the current is distributed around each of the surface of the antenna, the partial ground plane and the U-slot. The polar plot for the E-field radiation pattern at F=5.5 and 3.9GHz is shown in Fig.14. At the rejection frequency (f=5.5GHz), the radiation is very low, where there is a radiation at the pass frequency f=3.9GHz. For both cases, the field is symmetrical for the E-total for $\varphi=0^o$ and there are back radiation for both cases which is due to the partial ground plane.

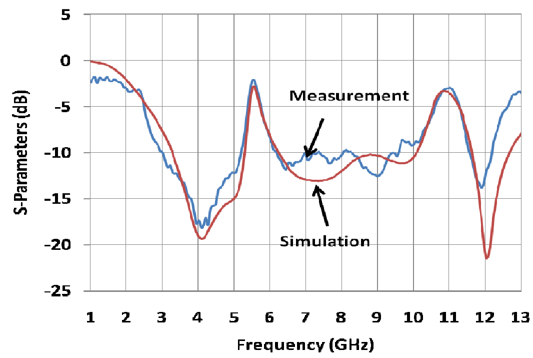


Fig.12 Simulated and measured performance for the UWBA with U-slot

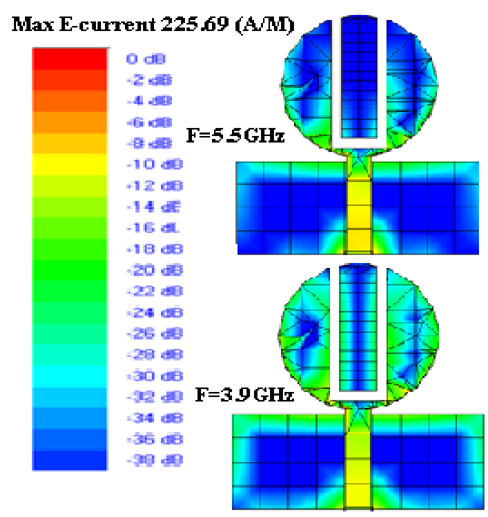


Fig13 The current distribution for the U-slot antenna

Conclusion

Each of the regular circular ultra wideband antenna and that with a rejection band using U-slot were designed and simulated. The effect of the U-slot parameters, such as length, width and gap were used to control the center frequency of the rejection band. Both antennas were realized and the measured results were compared with the simulated results, where a good agreement between both results was founded. The realized ultra wideband antenna with a U-slot achieved the ultra wideband performance and it had a rejection band with center frequency at 5.5GHz. The current distribution and the E-total field pattern were given, and the ultra wideband radiation has a symmetrical filed pattern with a little tilt angle which is due to the U-slot in the circular patch.

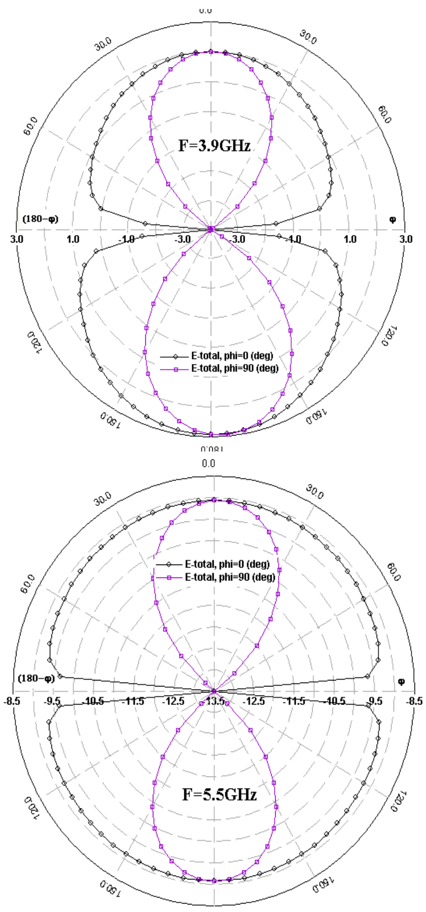


Fig14 The current distribution for the U-slot antenna

References

[1] K.-L. Wong, C.-H. Wu, and S.-W. Su, Ultra wide-band square planar metal-plate monopole antenna with a trident-shaped feeding strip, IEEE Trans Antennas Propag 53, PP.1262-1269, 2005.

[2] H. Schantz, *The art and science of ultra wideband antennas*, Artech House, Norwood, MA, 2005.

[3] H. Schantz, *Introduction to UWB antennas*, IEEE Conf. Ultra Wideband System Techno., 1–9, 2003.

[4] J. Liang, C.C. Chiau, X. Chen, and C. G. Parini, Study of a printed disc monopole antenna for UWB systems, IEEE Trans Antennas Propagation 53, 3500–3504, 2005

[5] X.H. Wu, Z.N. Chen, Comparison of planar dipoles in UWB applications, IEEE Trans Antennas Propag. 53, 1973–1983, 2005.

[6] C.C. Lin, Y.C. Can, L.C. Kuo, and H.R. Chuang, A planar triangular monopole antenna for UWB communication, IEEE Microwave Wireless Components Letters 15, 624–626, 2005.

[7] G. Lu, S.V. Mark, I. Korisch, L.J. Greenstein, and P.S pasojevic, Diamond and rounded diamond antenna for Ultrawide-band communications, IEEE Antennas Wireless Propagation Letters 3 , 249 –252, 2004.

[8] C.Y. Huang, W.C. Hsia, Printed elliptical antenna for ultra-wideband communications, Electron Letters 41, 2005.

[9] L. Seong, H. Park, K. Jong, and N.L. Jung, A novel CPW-FED ultra wideband antenna design, Microwave Optical and Technology Letters 44, PP.393-396, 2005.

[10] K. Kiminami, A. Hirata, and T. Shiozawa, "Double-sided printed bow-tie antenna for UWB communications", IEEE Trans Antenna and Propagation 45, PP. 152-153, 2004.

[11] W.J. Liu, C.H. Cheng, and Y. Cheng, Frequency notched ultra-wideband microstrip slot antenna with a fractal tuning stub, Electron Letters 41, PP.294-296, 2005.

[12] A. Kerkhoff and H. Ling, Design of a planar monopole antenna for use with ultra-wideband (UWB) having band-notched characteristic, IEEE Antennas Propagation Society International Symposium Digest, PP. 830-83, .2003.

[13] Movahedinia, R. ; Azarmanesh, M.N., Ultra-wideband band-notched printed monopole antenna, Microwave Antenna & Propagation, IET, Vol 4, Issue 12, PP.2179-2186, 2010.

[14] Mohammadian, N. ; Azarmanesh, M.-N. ; Soltani, S., Compact ultra-wideband slot antenna fed by coplanar waveguide and microstrip line with triple-band-notched frequency function , Microwave Antennas and Propagation, IET, Vol.4, Issue 11, PP.1811-1817, 2010.

[15] Li, T. ; Huo, F.-F. ; Zhai, H.-Q. ; Liang, C.-H. , Compact ultra-wideband antenna with sharp band-notched characteristics for WiMax and WLAN, Electronic Letters, Vol.48, Issue 22, PP.1380-1382, 2012.

[16] Bernety, H.M. ; Zakeri, B., A new partially grounded slotted ultra-wideband antenna with WLAN band-rejection, Telecommunications Forum (TELFOR), 2012., Serbia, Belgrade, Nov.20-22, PP.1153-1155, 2012.

[17] S.Y. Suh, W.L. Stutzman, W.A. Davis, A.E. Waltho, K.W. Skeba, and J.L. Schiffer, A UWB antenna with a stop-band notch in the 5 GHz WLAN band, IEEE/ACES International Conference, Wireless Communication Appl Comput. Electromagnetic, 1–5. 2005.

[18] K. Chung, S. Hong, and J. Choi, Ultrawide-band printed monopole antenna with band-notch filter, IET Microwave Antennas Propagation 1, 518–522, 2007.

[19] S.H. Lee, J.W. Baik, and Y.S. Kim, A coplanar waveguide fed monopole ultra-wideband antenna having band-notched frequency function by two folded striplines, Microwave Opt Technology Letters 49, 2747–2750, 2007.

[20] Y. Ding, G.M. Wang, and J.G. Liang, Compact band-notched ultra wideband printed antenna, Microwave Opt Technology Letters 49, 2686–2689.2007.