

Ultra-Wideband Microstrip Antennas with WLAN Band-Notch Capability

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Abstract— The presented paper exhibits the design configuration of Microstrip Line (MS)-fed and Co-Planar Waveguide (CPW)-fed symmetrical staircase shaped, planar monopole Ultra Wideband (UWB) antennae with WLAN band rejection characteristic having sized $30 \times 30 \times 1.6 \text{mm}^3$. The staircase pattern in the radiating patch and the feed line's U-shaped slot are used to achieve the UWB and notch the 5GHz WLAN band, respectively. For the MS-fed antenna with partial ground plane, a slot is introduced in the ground which is used for impedance matching and it enhances the effect of WLAN band-notch as well. The proposed antennae have achieved the 3.1GHz-10.6GHz UWB frequency range. In between this UWB range, the 5GHz WLAN band (5.15GHz-5.35GHz and 5.725GHz-5.825GHz) is notched effectively to avoid interference with UWB. FR4 substrate, having relative permittivity of 4.4 and thickness of 1.6mm, is used to print these antennae. Moreover, the fabricated prototype antennae show good simulation and measurement results.

I. INTRODUCTION

In 2002, Federal Communication Commission (FCC) allocated a bandwidth of 7.5GHz to Ultra WideBand (UWB) applications having frequency range from 3.1GHz to 10.6GHz [4]. The licensing of UWB has made a great influence on this technology's commercial success. Various antenna types have been proposed and used for the UWB amongst which the Microstrip patch antennas are most widely used because of their many striking features as they are economical, low profile, light weight and their fabrication simplicity [2]. Despite the progresses in designing patch antennas for UWB, narrow bandwidth, radiation losses and low gain are still the issues lingering ever since UWB's licensing. To cater these issues, different antenna design techniques have been adapted to achieve the maximum out of microstrip patch antennas to implement Ultra WideBand. Some of the significant

techniques include stacking [3], slot compact design [5], aperture coupling [3], thickening the substrate and parasitic patch [6].

With the progressions in the development of antennae for UWB applications, the interference problems in the frequency bands caught developers' attention. The Wireless Local Area Network (WLAN) technology has substantial share in the electromagnetic interferences with the applications related to UWB. After extensive research several techniques have been adopted to counter WLAN band's interference in the UWB which include a CPW resonant cell in feed-line [14], a rectangular stub fixed on a round ring [7], a dual band-notch CPW-Ground-fed UWB antenna by fractal binary tree slot [16], insertion of slots in the ground plane [10][12][17], CPW-fed C-shaped slot antenna [8], wide slot antenna [9], T-shaped notch square monopole antenna [15], an U-shaped slot antenna [18][11] and E-shaped slot rectangular slot antenna [13].

In this paper, the design configurations of a Co-Planar Waveguide (CPW)-fed and a Microstrip Line (MS)-fed planar monopole staircase antennae with WLAN notch band characteristic are presented. The WLAN band notch is achieved by subtracting a U-shaped slot in the feed-lines of the antennae. The stair-case structure of both the antennae covers the UWB range of 3.10GHz to 10.6GHz while the U-shaped slot in the feed-line prevents the interference with WLAN systems. The detailed parametric analysis in term of Voltage Standing Wave Ratio (VSWR) has been presented for the proposed antennae. Furthermore, gain, current distribution and radiation pattern plots of the proposed antennae are also presented. The proposed paper is formulated to describe the CPW-fed and MS-fed antennas' geometry in section 2, modeling, parametric analysis and results are presented in section 3 while section 4 concludes the paper.



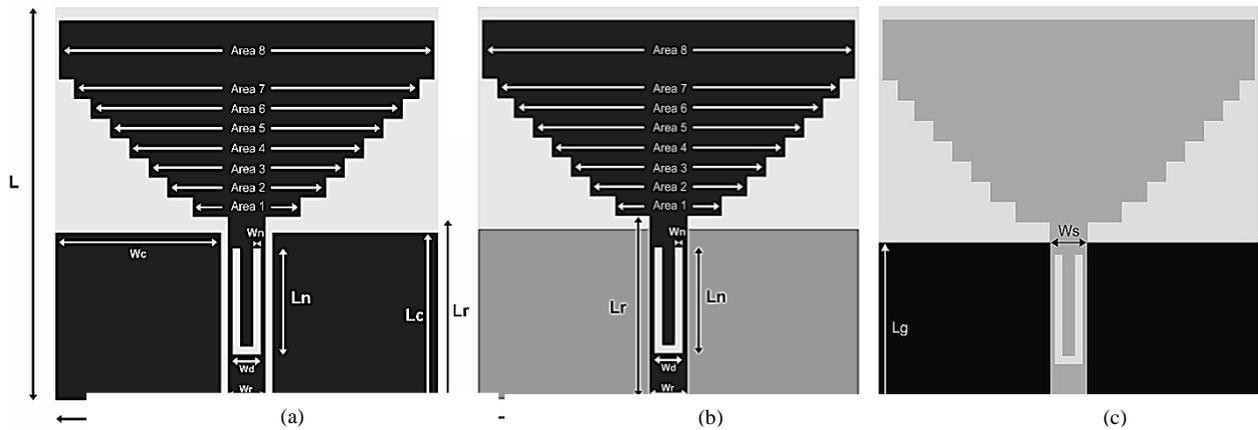


Fig. 1. (a) CPW-fed antenna (front) (b) MS-fed antenna (front) (c) MS-fed antenna (back)

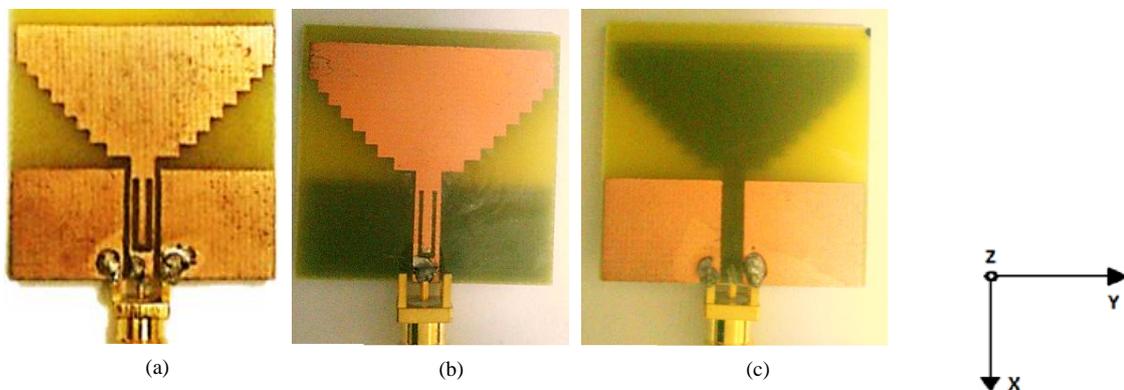


Fig. 2. Prototype (a) CPW-fed antenna (front) (b) MS-fed antenna (front) (c) MS-fed antenna (back)

TABLE I, DESIGN PARAMETERS OF THE PROPOSED CPW-FED AND MS-FED ANTENNAE

PARA	SIZE(mm)	PARA	SIZE(mm)	PARA	SIZE(mm)	PARA	SIZE(mm ²)	PARA	SIZE(mm ²)
L	30.0	Ln	8.1	Wc	13.0	Area 1	8.4 x 1.5	Area 5	21.4 x 1.5
W	30.0	Wn	0.6	Lg	12.3	Area 2	12.4 x 1.5	Area 6	24.4 x 1.5
Lr	14.0	Wd	2.2	Wg	13.55	Area 3	15.4 x 1.5	Area 7	27.0 x 1.5
Wr	3.0	Lc	12.8	Ws	2.9	Area 4	18.4 x 1.5	Area 8	29.4 x 4.5

II. BAND NOTCH ANTENNAE GEOMETRY

Figure 1(a-c) shows the geometric representation of the proposed CPW-fed and MS-fed UWB antennae with WLAN band-notch. The antennae are designed using FR4 substrate with thickness 1.6mm, relative permittivity 4.4 and loss tangent 0.02. Both antennae are square-shaped and compact in size each having dimensions 30x30mm². The patch of each antenna comprises of 8 symmetric staircase rectangles in ascending order from the top edge of transmission line.

An increase in the bandwidth is observed while truncating the patch which successively helps to achieve the Ultra WideBand. The introduction of a 2.9mm wide slot in the ground plane ‘Ws’ in the MS-fed antenna plays a vital role to achieve the desired results. The dimensions of the CPW-fed antenna’s ground are 12.8x13.0mm² having identical shape on either side of feeding line. The U-shaped slot is added at 3.5mm from the bottom end of the transmission line for both the antennae. Simulation of the proposed

antennae is done using 50Ω SMA (Sub-Miniature version A) connector in order to increase the precision of the simulated results. Table I shows the dimensions of both the antennae.

III. ANTENNA MODELING AND RESULTS

This section includes the results and analysis of various parameters of the proposed CPW-fed and MS-fed UWB antennae with WLAN notch. The results of the VSWR, current distribution, gain (dBi) and radiation pattern are discussed. The Ultra Wideband (3.1GHz-10.6GHz) is achieved by adding each 'Area' step to the patch whereas the WLAN (5.15GHz-5.35GHz and 5.725GHz-5.825GHz) band-notch is achieved by adding a U-shaped slot in the transmission line of both antennae.

A. CPW-fed UWB Antenna with WLAN Band-Notch

Figure 1(a) shows the design configuration of the proposed CPW-fed UltraWide Band Antenna with WLAN band-notch. The proposed antenna with U-shaped slot in the transmission line has $VSWR < 2$ between 2.858GHz and 14.538GHz with an exception from 5.124GHz to 5.938GHz in which the $VSWR > 2$ which covers the entire WLAN band range i.e. 5.15GHz-5.35GHz and 5.725GHz-5.825GHz. Figure 3 shows the Frequency vs VSWR plots of the CPW-fed antenna. From the figure it can be seen that without the addition of the U-shaped slot, the antenna has $VSWR < 2$ from 2.688GHz to 17.506GHz with more than 146% fractional bandwidth covering the entire UWB.

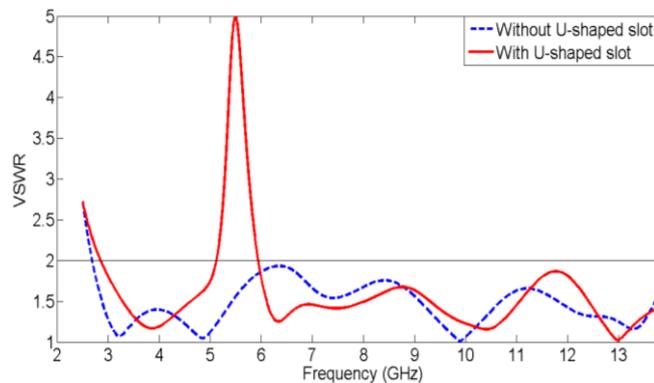


Fig. 3. Frequency vs VSWR with and without U-shaped slot

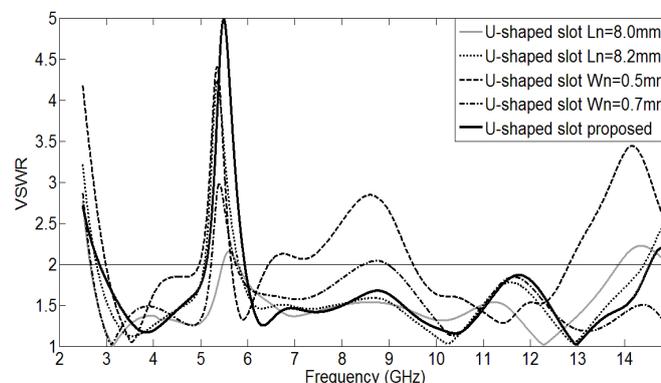


Fig. 4. Frequency vs VSWR Parametric analysis

The parametric analysis of the band-notched antenna is presented in fig. 4. It can be seen from the figure that the

desired results are obtained when the width of U-shaped slot, W_n , and the Length of U-shaped slot, L_n , are kept to be 0.6mm and 8.1mm, respectively. In all the other geometric variations, either the UWB range is disturbed or the WLAN frequency rejection is very poor.

B. MS-fed UWB Antenna with WLAN Band-Notch

The design configuration of the proposed MS-fed Ultra WideBand Antenna with WLAN band-notch is presented in fig. 1(b-c). All the parameters of the MS-fed antenna are similar to those of the CPW-fed antenna except the feeding technique and the change in the ground planes. The proposed antenna with U-shaped slot in the transmission line has $VSWR < 2$ between 2.948GHz and 11.762GHz with an exception from 5.086GHz to 5.950GHz in which the $VSWR > 2$ which successfully notches the entire 5GHz WLAN band range. Figure 5 shows the simulated and measured Frequency vs VSWR plots of the CPW-fed antenna. From the figure it can be seen that without the addition of the U-shaped slot, the antenna has $VSWR < 2$ from 2.734GHz to 12.526GHz with an exception from 5.876GHz to 6.714GHz which leads to the conclusion that the U-shaped slot in the MS-fed antenna does not only reject the 5GHz WLAN band but it also helps in impedance matching for the 6GHz-7GHz band for the MS-fed UWB antenna with WLAN band-notch.

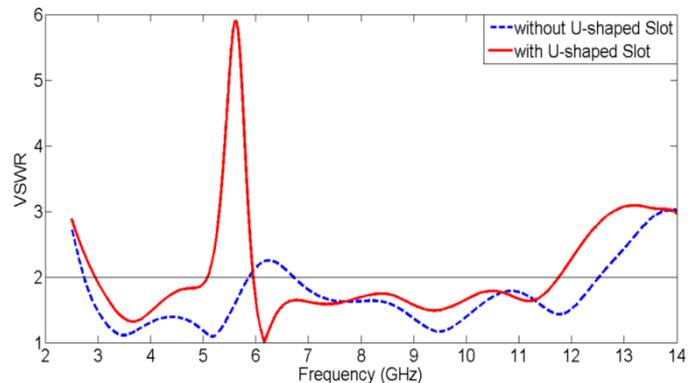


Fig. 5. Frequency vs VSWR with and without U-shaped slot

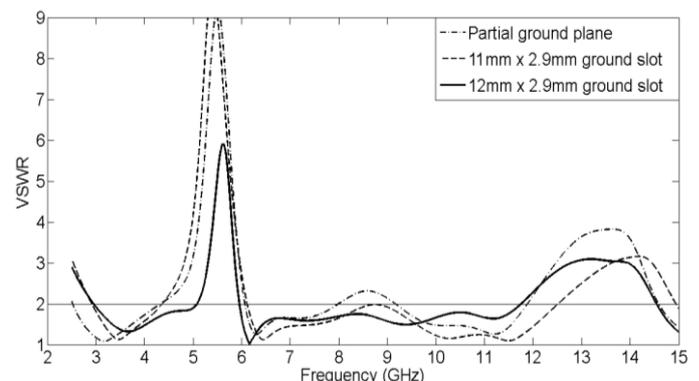


Fig. 6. Frequency vs VSWR Parametric analysis

The parametric analysis of the MS-fed 5GHz band-notched antenna is presented in fig. 6. It can be seen from the figure that the desired band is rejected when a slot of dimensions $12 \times 2.9 \text{mm}^2$ is subtracted from the ground plane of this antenna. For a slot with dimensions

11x2.9mm², even though the notch peak is very high, there is a loss in the efficient utilization of the bandwidth. The same problem persists with the partial ground plane without any slot and, apart from that, it does not operate in the entire UWB i.e. VSWR>2 from 7.996GHz to 9.158GHz.

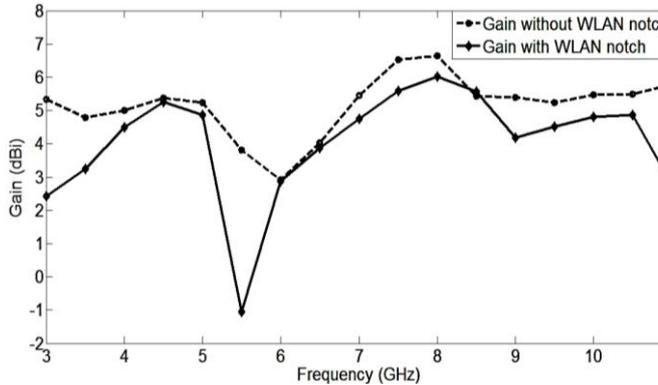


Fig. 7. Gain CPW-fed UWB with and without WLAN notch

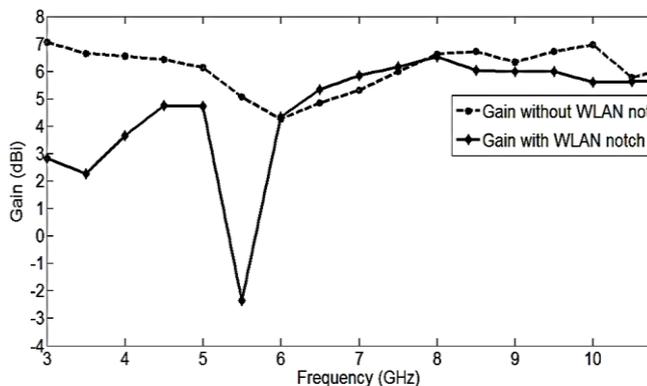


Fig. 8. Gain MS-fed UWB with and without WLAN notch

The gain plots are shown in fig. 7 and fig. 8. From the graphs of both antennae it can be seen that the gain has dropped drastically between 5GHz-6GHz frequency range after the addition of U-shaped slot in the transmission line. Figure 10(a-d) show the radiation characteristics of the proposed planar monopole antennae. The proposed antennae have a bi-directional dumb-bell shape in the xz-plane throughout the UWB range and an omni-directional pattern in the yz-plane which remains constant throughout the antennas' operating range. Figure 11(a-d) depict the current distribution pattern of the CPW-fed and MS-fed UWB band-notched antennae, respectively. In fig. 11(b) and fig. 11(d) it can be seen that the current is normally distributed from transmission line to patch and ground plane whereas it is accumulated around the U-shaped slot in the transmission line at 5.5GHz in fig. 11(a) and fig. 11(c) further verifying the WLAN band rejection.

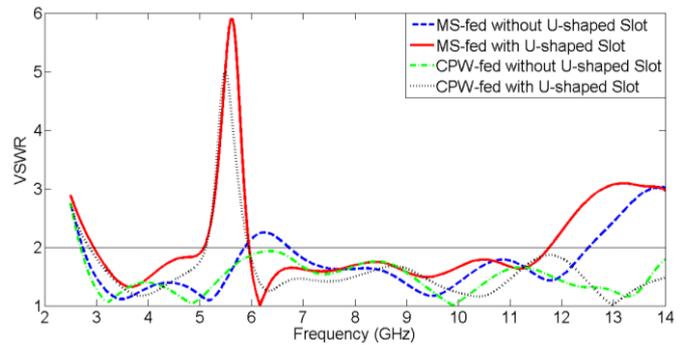
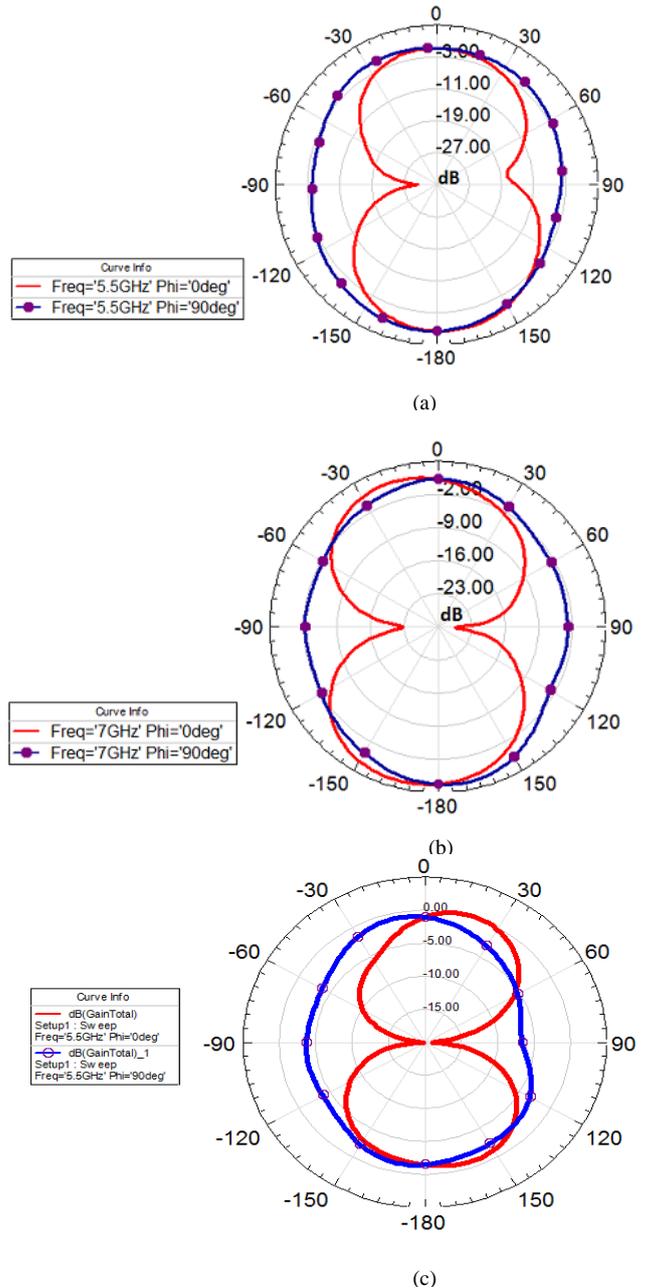


Fig. 9. Freq vs VSWR comparison of MS-fed and CPW-fed antennae



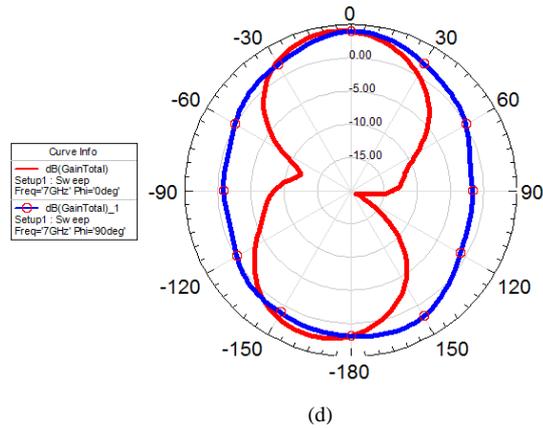


Fig. 10. Radiation Pattern with U-shaped slot (a) CPW 5.5GHz (b) CPW 8.0GHz (c) MS 5.5GHz (d) MS 8.0GHz

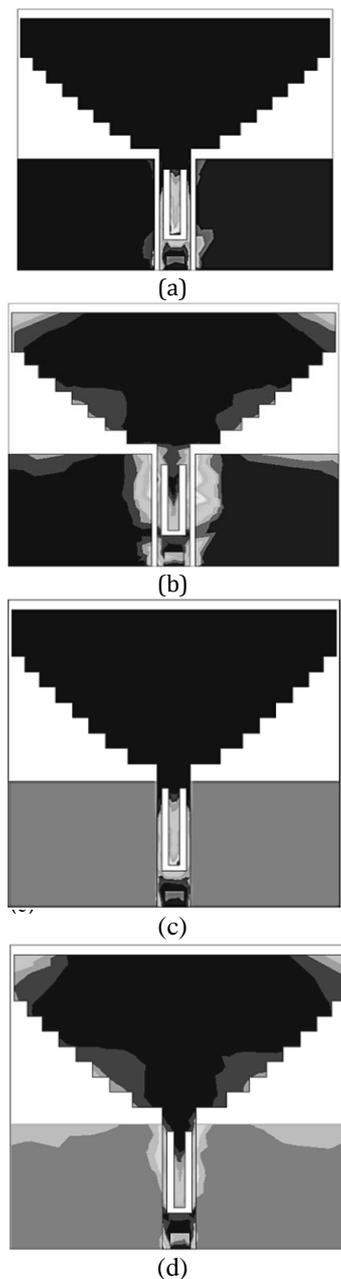


Fig. 11. Current Distribution with U-shaped slot (a) CPW 5.5GHz (b) CPW 8.0GHz (c) MS 5.5GHz (d) MS 8.0GHz

TABLE II. PARAMETERS OF THE PROPOSED ANTENNAE AT 5.5 GHz

PARAMETER	CPW-FED WITHOUT BAND-NOTCH	CPW-FED WITH BAND-NOTCH	MS-FED WITHOUT BAND-NOTCH	MS-FED WITH BAND-NOTCH
MAXIMUM U (W/SR)	0.37358	0.10071	0.23266	0.045723
PEAK DIRECTIVITY	3.6513	5.8663	2.6787	2.0932
RADIATION EFFICIENCY	1.3889	0.34172	1.1253	0.5268
FRONT TO BACK RATIO	1.5629	1.8375	1.759	2.0204

IV. CONCLUSION

In this paper, a Co-Planar Waveguide-fed and a Microstrip Line-fed planar monopole antennae are presented which operates in the UWB range (i.e. 3.10GHz-10.6GHz) and efficiently notch the WLAN band (i.e. 5.15GHz-5.35GHz and 5.725GHz-5.825GHz) which causes interference due to operating power differences. UWB is achieved by using staircase design and the WLAN band is notched by embedding a U-shaped notch in the feed line. The bandwidth and radiation characteristics of the CPW-fed antenna are better than that of the MS-fed antenna. The notching characteristics and the gain of the MS-fed antenna are comparatively better than that of the CPW-fed antenna.

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