UWB Microstrip Patch Antenna with 5G Lower Band Notch Characteristics

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Abstract—For fifth generation (5G) lower band wireless application at a frequency of (4.5–5.5) GHz, recently ASEAN region countries have suggested 5G forums and band rejection antennas for 5G (4.5–5.5) GHz lower band. A UWB antenna has been constructed and suggested by use of the Roger RT5880 with defected ground on a rectangular radiating patch and a ring shape type of resonator (RSR) on ground plane to achieve the desired performance. It was decided to construct a band rejection within UWB antenna for 5G which included adding a rectangular slot on the radiating patch as well as placing RSR to the ground plane of the proposed antenna. The results support the theory that the antenna is capable of transmitting and receiving in the UWB except band notched bandwidth. Additionally, the results show that the antenna possesses good performance across the whole UWB spectrum with a gain of 4.6 dBi. This, in addition to its ability to support the lower 5G band notched, is why the suggested antenna is a good contender for future 5G wireless implementations within UWB bandwidth.

Keywords—UWB, band notched, 5G

1 Introduction

In the current and upcoming wireless applications, especially the two that major factors ultra-wideband (UWB) antennas are succeeding greatly. Additionally, there is a larger demand in modern times for wireless communication systems and UWB qualities like high data transfer rates, low costs, and low power use. Nowadays, antennas are no longer only needed for radio but may also be used for wireless devices with differing frequencies for different wireless applications and varied frequencies, which have bands are in high demand [1]. An antenna capable of operating in several bands is needed to meet the demand. A UWB antenna can be the solution to a growing antenna requirement. Antenna performance characteristics such as input impedance, gain, radiation pattern, surface current, efficiency and compact size, among others are required depending on the operating frequency of the bandwidth being used. In order to meet this increased capacity requirement to assist 5G extreme mobile broadband wireless application that require peak speeds of 10 Gbps and higher as well as edge speeds greater than 100 Mbps. With the availability of vast bandwidth at mmWave frequency the fifth generation EMBB standards can met by employing a straightforward signal interface as well as high-dimension phased arrays [2]. Because of the light weight, cost efficient, ease of manufacture and other characteristics, microstrip patch antennas are an excellent candidate for use in ultra-wideband wireless applications [3]. The main problem of UWB technology is to avoid licensed and non-licensed frequency spectrum existing wireless communication bands, like as Wi-MAX, WLAN, 5G lower band, FSS, X-band satellite application and so on. For the purpose of avoiding possible interference with existing bands, the researcher concentrated on developing UWB antennas with band notched capabilities [4]. Band notched ways include carving a slot on the radiating patch, while RSR at the bottom of an antenna's substrate to get the desired result.

The undesired bands are not receiving many rectangle patch antennas and this is most likely because of this type of antenna. In [5] the dimensions of the ground plane was relatively big therefore allowing for the use of a C-shaped resonator in the bottom plane. For UWB application, it provides a bandwidth range of (2.25–10.20) GHz; whereas for WLAN it offers a band-notch feature that is available from (5.16–5.85) GHz. For UWB bandwidth the VSWR not more than 2 and for stopband, more than 2 and it's about 7. RT 5880 substrate 0.8 mm thick, with 2.22 dielectric constant has been used in the design and simulation of HFSS software. UWB antenna has been experimentally shown in a paper on this topic [6], and a preliminary antenna concept contains an RPA with C-shape. A new resonance is aroused at higher frequencies when an S-shaped parasite structure is inserted into the rectangular slot which in turn encourages a higher-frequency response and the broad accessible bandwidth more than 135% increase. WLAN (5–6 GHz) band rejection was achieved by using the C-shaped rotating slot which is a part of the new design. In order to establish the real-world usefulness of the antenna design was combine simulated and measured results are shown. [7] is a planar monopole antenna that has band-stop capabilities and is sufficiently equipped for UWB application. The proposed antenna is made as a patch with a wafer-shaped and a bandwidth ranging from (2.6–11.7) GHz and wide frequency range. Because of the compactness and simplicity of the design a satisfactory band stop (5–6.20 GHz) is accomplished the vertical strip can be positioned correctly on any bottom edges of the radiating patch with goblet-shaped. This is achieved because of the design's simplicity and compactness. Being lightweight and radiative is made possible by high-efficiency mobile UWB systems. It is described in this paper [8] that a UWB antenna design and with this technology a monopole antenna with improved bandwidth and narrow band capabilities can be created allowing for greater efficiency. A competing antenna has taken over the usage of the reference antenna and is coupled to a microstrip feed line which has shape of a square patch for radiating applied to a FR-4. The substrate that the plane is on is usually referred to as ground. A partial ground is used on the top rim of the ground and below the feed line plane. The antenna feeds were embedded in a gap of 0.25 mm under the feed line and both C-shaped configurations were carved into the underside of the defected ground plane at that location. The narrowband notched extending from 6.26 to 7.28 GHz is generated in the C-face-to-face arrangement. A UWB antenna with a limited frequency range 5.15 to 5.85 GHz was demonstrated in this research article [9] by utilizing a W shape slot on the patch. The W-shape slot hexagon antenna's parameters are simulated using the HFSS which is available. Used with mobile devices such as USB the lightweight W Slot antennas can quickly and easily integrated. With the FR-4 substrate the antenna design that has been suggested and constructed. The UWB antenna with a low profile has been added to the list in [10]. Given that the suggested design has a monopole antenna the device will only radiate vertical waves whereas previously documented band notched UWB antennas radiate horizontally across the entire bandwidth. Because of the PDMS-conductive composite manufacturing process utilized this material is not only perfect for conformal applications but it also has exceptional adaptability and endurance. It was confirmed by doing an extreme bending test with various radiuses. After analyzing the result it was discovered that the bandwidth of (3.8–8.3) GHz and a notched (6–5) GHz. With the average gain 3.9 dBi in the rejection band across the entire bandwidth which declines −9.7 dBi and 3.9 dBi rising rejection indicates that the working bandwidth has been abandoned. UWB antennas are extensively employed as key equipment in high-speed wireless networking according to this paper [5]. This study suggests employing a Wi-Fi application that incorporates a metamaterial developed specifically for this work which includes an unique UWB monopole compact antenna with an exceptionally narrow bandwidth. The patch includes two rectangular slots and V-slot sandwiched in between. A UWB antenna has bandwidths ranging from (3.2–14) GHz while a band notched antenna offers bandwidth from (2.38–2.57) GHz. Intended UWB and Wi-Fi wireless connectivity is included in the calculated performance and profitability. This antenna is made and tested for quality assurance. Following the implementation of UWB and Wi-Fi applications, the simulated and estimated outcomes can be used to create an intelligent and applications for portable IoT. A new antenna architecture with an in-built changeable band rejection filtering feature for 5G / IoT wireless networks such UWB application was discussed in this study [2]. The suggested design for the use of steps that are constructed with optimally acceptable dimensions and angles as well as a new technique for changing the ground plane all of which are intended to ensure that the patterns of efficient radiation and the characteristic impedance have been obtained. Additionally, an omnidirectional H-field radiation pattern of a monopole antenna is obtained over the entire frequency spectrum of (3–11) GHz. This antenna is suited for wideband communication like 5G and frequency segments that run from (4.5–6.5) GHz which have notch bandwidth.

A number of previous studies such as the UWB antennas design with band stop technique have demonstrated that there are certain limitations to the research such as the need for a compact size antenna and a straightforward construction method. A UWB antenna, radiating patch can be modeled with a slot and RSR on the bottom is demonstrated in this research. This antenna also delivers 4.1 to 9.8 GHz bandwidth and band notching from 4.5 to 5.5 GHz for fifth generation wireless application [11], [12] which is a significant improvement over previous antenna. In the middle band the return loss is quite low and the effectiveness of the radiation is greater than 92%; however, in the 5 GHz frequency band, the return loss is close to 15 percent. It indicates that the performance of the antenna is extremely poor or non-existent when operating at band notched bandwidth. Antennas of this type can be used in a range of other countries that have proposed various frequency for 5G lower band applications including, Europe (3.4–5.8 GHz), China (3.3–3.6 GHz), Japan (4.4–4.9 GHz), Korea (3.4–5.7 GHz), and the United States (3.7–4.2 GHz) [2].

2 Antenna design

A microstrip patch (MP) is a small antenna, cost efficient and easy to manufacture antenna that meets all of the requirements for wireless applications. The suggested antenna's physical dimension is depicted in Figure 1 and the parametric dimensions are listed in Table 1. Design and fabrication of the proposed antenna have been completed on a 25×25 mm[2] Roger substrate with conductive material (Cu) thickness t = 35 μm and substrate height h = 0.25 mm, resonance frequency fr = 6.95 GHz, tanδ = 0.0009 and fed by a λ/4 microstrip line. In comparison to the radiating patch the bottom plane is on the other side. The antenna is fed via a microstrip feeding line technology which is advantageous due to its simplicity of development and matching. The patch has a rectangular shape and has a 14×18 mm[2] area. Its width and length are indicated by the letters W_p and L_p respectively. W_f and L_f represent the microstrip feedline's width and length and the width and length of the substrate are designated by W_s and L_s respectively. A consideration was given to the following formulas when designing the MP antenna [12].

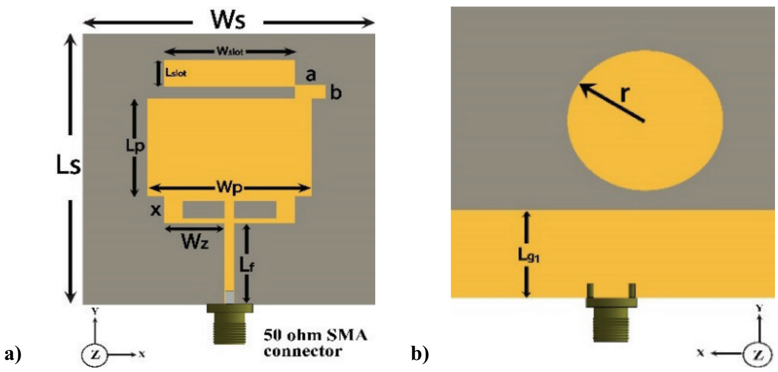


Fig. 1. Antenna's layout (a) front and (b) ground view [1]

$$W_p = \frac{c}{2f_r\sqrt{\frac{(\varepsilon_r+1)}{2}}} \tag{1}$$

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W_p}\right]^{-\frac{1}{2}} \tag{2}$$

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{eff}}} \tag{3}$$

$$\Delta L = 0.412h \frac{(\varepsilon_{eff} + 0.3)\left(\frac{W_p}{h} + 0.264\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{W_p}{h} + 0.8\right)} \tag{4}$$

$$L_p = L_{eff} - 2\Delta L \tag{5}$$

$$W_f = \frac{7.48 \times h}{e^{\left(Z_0 \frac{\sqrt{\varepsilon_r + 1.41}}{87}\right)}} - 1.25 \times t \tag{6}$$

$$L_f = 3.96 \times W_f \tag{7}$$

$$W_s = \frac{1.38 \times c}{f_r \sqrt{\varepsilon_r}} \tag{8}$$

There are three terms in this equation: C (light speed = 3×10^8 ms^{-1}), Z_0 (input impedance), and ε_{eff} (effective dielectric constant). Figure 2 illustrated the simulated result obtained after obtaining all parameter values. CST MWS 2021 was used to designed and simulated the proposed antenna for this purpose after obtaining all parameter values. Use a RSR with fractional ground (Lg1) and an inset on the patch to combine a slot and defecated ground plane create a band notched function from 4.5 to 5.5 GHz within a UWB antenna. The RSR is positioned on the bottom plane with the initial point of the proposed antenna being zero (0) and the location of RSR in the X-axis being 2.5 mm and the Y-axis being 2.7 mm beside a radii of 3 mm. With the help of the following equation [12,13], the band notched properties can be represented.

$$f_{notch} = \frac{c}{4L'\sqrt{\frac{(\varepsilon_r + 1)}{2}}} \tag{9}$$

$$L' = a + L_{Slot} \tag{10}$$

Here,
a = Length of the small slot
L_{Slot} = Width of the slot

Table 1. The proposed antenna has been optimized in its physical dimensions [1]

VARIABLE	LENGTH (mm)
Ws	25
Ls	25
Wp	14
Lp	18
Wf	0.8
Lf	10
Wslot	11.20
Lslot	2.50
a	2.66
b	1.28
X	2.50
Wz	5.20
Lg1	7.50
r	3

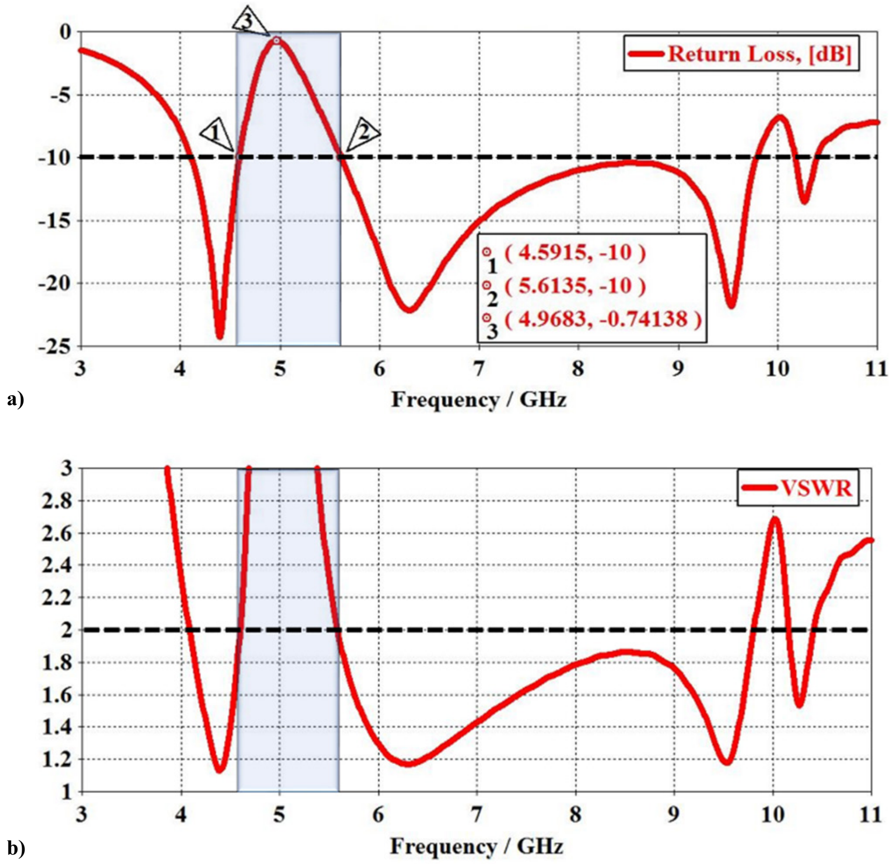


Fig. 2. Simulated return loss and VSWR [1]

Roger RT5880 is being used to design and test the antenna prototype. Different substrates of the suggested antenna were evaluated with regards to antenna performance and the effects of various substrates. Hence, Table 2 shows the different substrate speciation and antenna's performance as well in Figure 3. Furthermore, RT5880 substrate have excellent performance.

Table 2. The technical characteristics of various substrates

Parameters	FR4	RO3003	RO3200	RO4003C	RO6002
Relative permittivity	4.4	3	3.02	3.55	2.94
Thickness (mm)	1.6	1.52	1.32	1.52	0.508

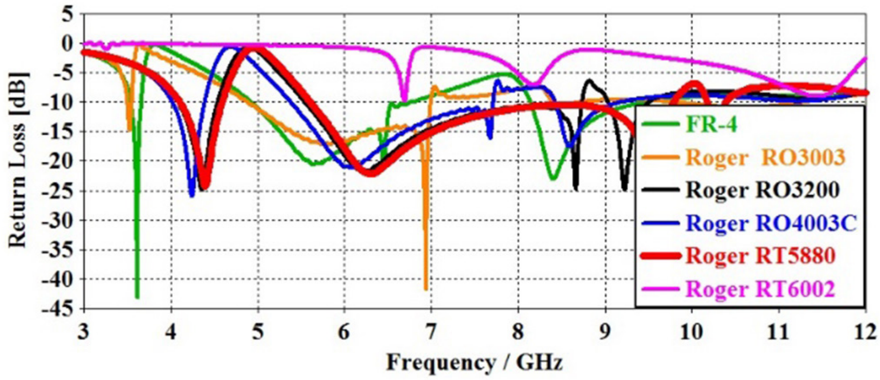
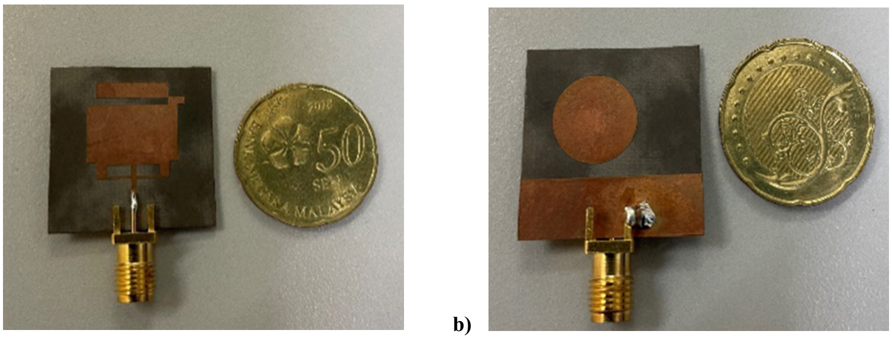


Fig. 3. Parametric study (S_{11}) of different substrate

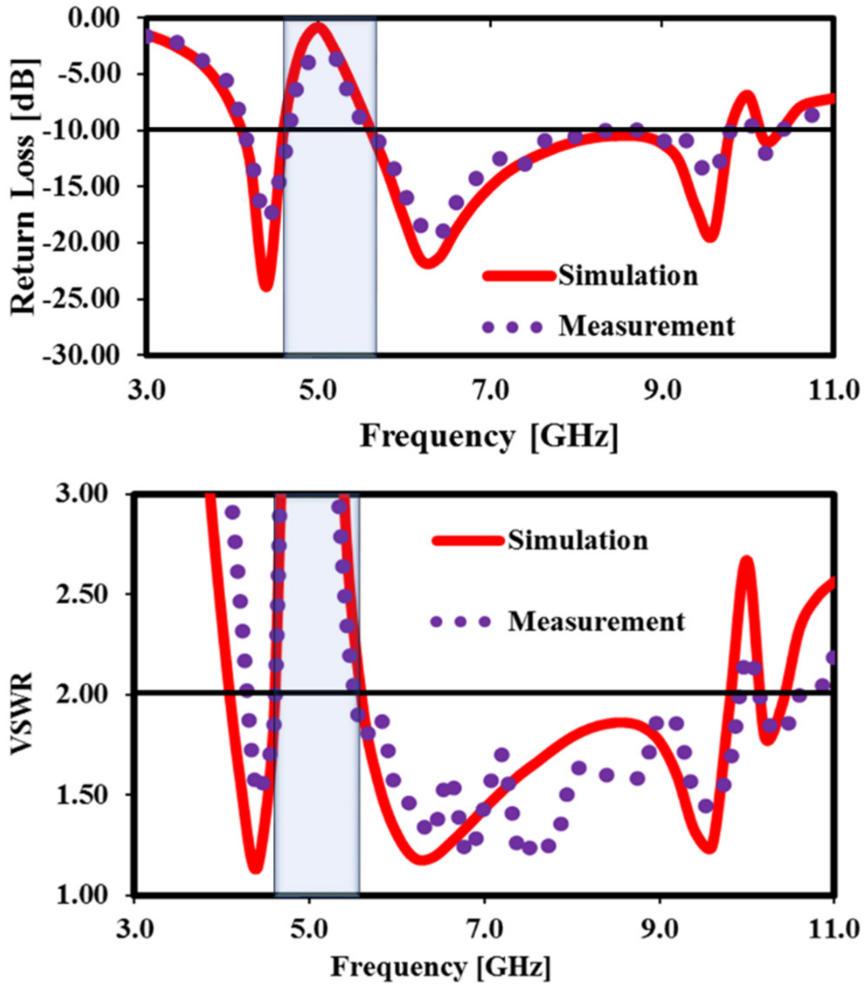
3 Result analysis and discussion

In Figure 4 illustrated the fabricated proposed antenna and this antenna is compact size which is comparable with a small coin. RT 5880 has been used for simulation and fabrication purpose. The simulated and measured results combinations show in Figure 5. Except for the notched from 4.5 to 5.5 GHz of the VSWR (Figure 5b), the UWB operating bandwidth from 4.1 to 9.8 GHz is lower than 2 except for the notched frequency. The intended antenna's surface current is shown in Figure 6. Figure 6(a, c) depict surface current distributions of the notched lower and higher frequency cuts accordingly. Based on this, it may be concluded that currents of 1578 A/m and 1114 A/m are present accordingly in the surface current accumulated. 5GHz radio frequency is the mid frequency band in the notched band and it has a significant on current 2564 A/m due to the RSR Figure 6(b), which concentrates on it. In contrast the mid frequency band of UWB bandwidth 6.95 GHz shown in Figure 6(d) has a low quantity of surface current (465 A/m) when compared to the other frequencies. From the surface current it can be seen that the band rejection is created as a result of the RSR and that the notched band has gathered a significant amount of surface current distribution. According to Figure 7 the proposed antenna's simulated radiation efficiency is outstanding. The best UWB efficiency was 98% when the average efficiency was 92%. However, the proposed antenna is incapable of performing at the band-notch frequency since the efficiency is less than 15%. 2-D polar pattern formed by the h-field of all monopole antennas is shown in Figure 8 which is the common among all of the monopole antenna's omnidirectional radiation patterns. Consequently 2-D polar patterns are more than adequate with the exception of the band notched frequency. As seen in Figure 9 the simulated gain illustrated that a maximum gain of 6.5 dBi at 9.4 GHz, minimum gain of 1.5 dBi at 5.1 GHz, and an average gain of 5 dBi across the band of 4.8 GHz. Group delay response illustrated in Figure 10(a). From this result the group delay fluctuated within 2 ns. As a result, the antenna exhibits linear phase response as well as excellent pulse handling performance. Figure 10(b) shows the input and output pulse, when it comes to input and output voltage the waveform responses exhibit nearly little dispersion.



a) b)

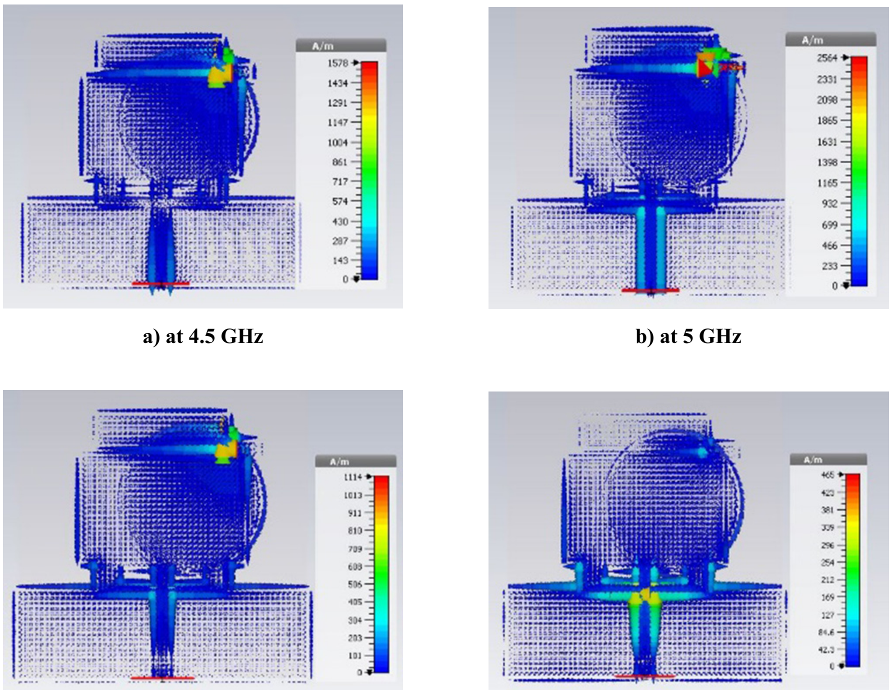
Fig. 4. Fabricated of proposed antenna



a)

b)

Fig. 5. Combination of simulated and measured (a) S_{11} and (b) VSWR



a) at 4.5 GHz

b) at 5 GHz

c) at 5.5 GHz

d) at 6.95 GHz

Fig. 6. Surface current distribution [1]

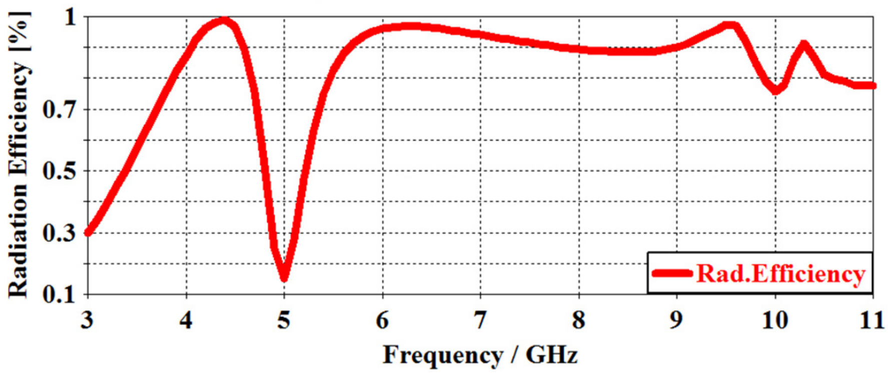


Fig. 7. Simulated radiation efficiency [1]

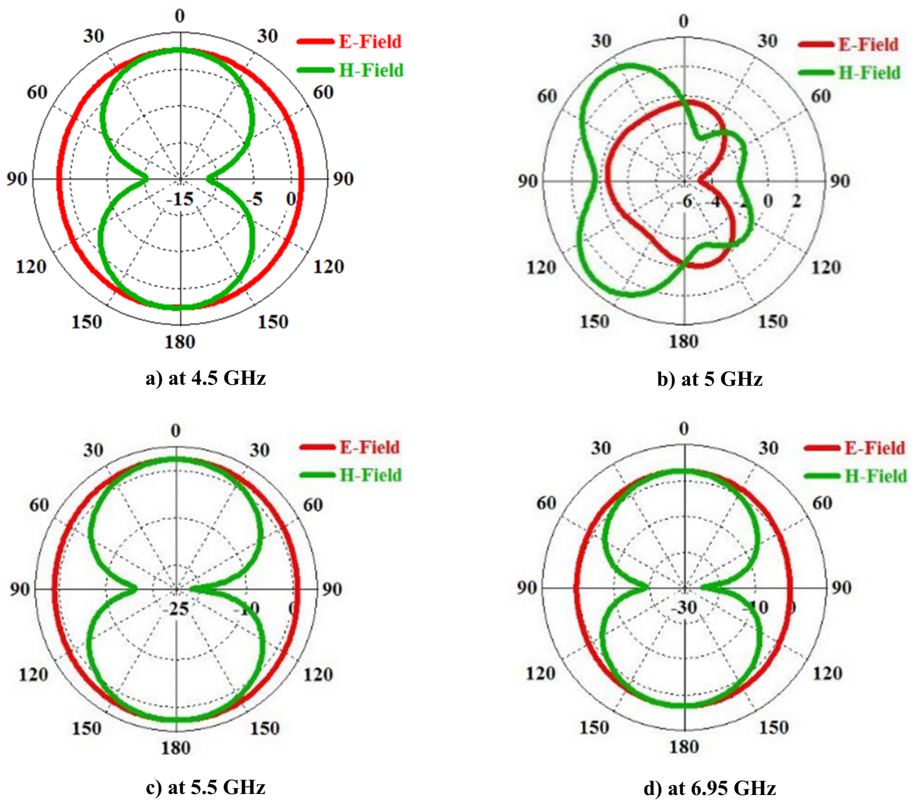


Fig. 8. Simulated 2-D polar radiation pattern [1]

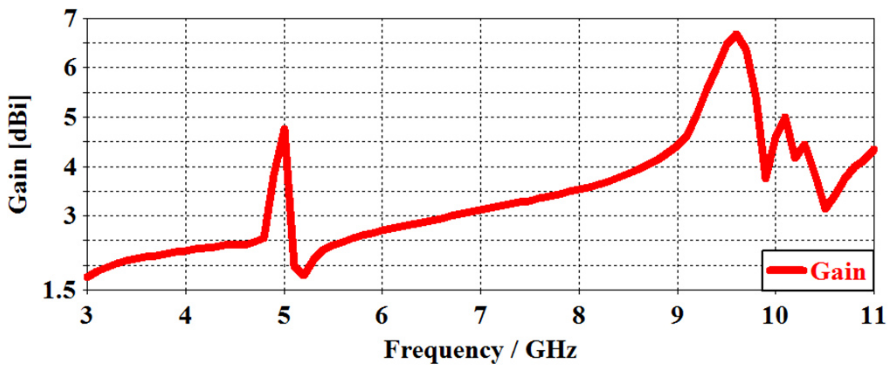
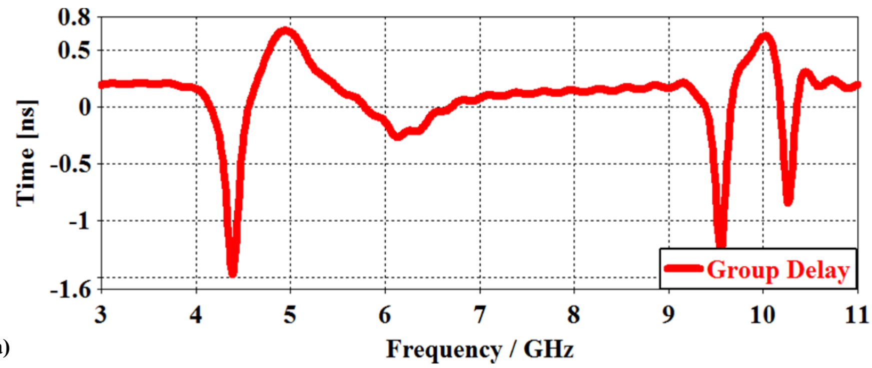
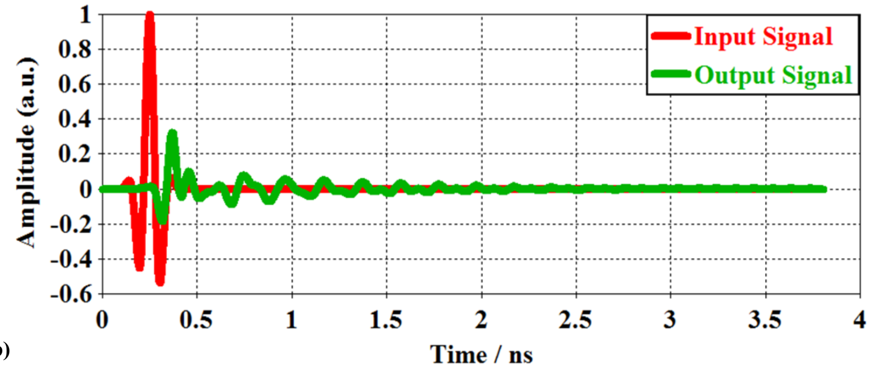


Fig. 9. Simulated gain [1]



a)



b)

Fig. 10. Simulated group delay (a) and input and output pulses

Table 3. Comparison of this research to previous literature about band-notched antennas [1]

Ref.	Antenna Size (mm^2)	UWB Bandwidth (GHz)	Relative Permittivity	Notched Bandwidth
[2]	30×30	3-11	4.4	4.5-6.5
[4]	27×33	3.2-14	4.4	2.38-2.57
[6]	55×48	2.25-10.20	2.2	5.16-5.85
[8]	20×33	2.6-11.7	4.4	5-6.2
[9]	23×35	2.7-14.10	4.4	6.26-7.28
[11]	70×68	3.8-8.3	2.77	5-6
This Work	**25×25**	**4.1-9.8**	**2.2**	**4.5-5.5**

4 Conclusions

A new UWB antenna has been introduced with a band rejection feature. In addition to being capable of operating over a wide range of frequencies this antenna provides outstanding band rejection in the lower band of 5G technology. Because of its small size, low overall return losses, and better antenna radiation patterns highly suited for use in ultra-wideband and band rejection wireless applications. Although this antenna has a straightforward design and is constructed of low-cost materials, it is incredibly adaptable and effective when compared to more sophisticated antennas of the same size.

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