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SEMICIRCULAR SLOT BASED UWB MICROSTRIP PATCH ANTENNA FOR VARIABLE BAND NOTCHED APPLICATIONS

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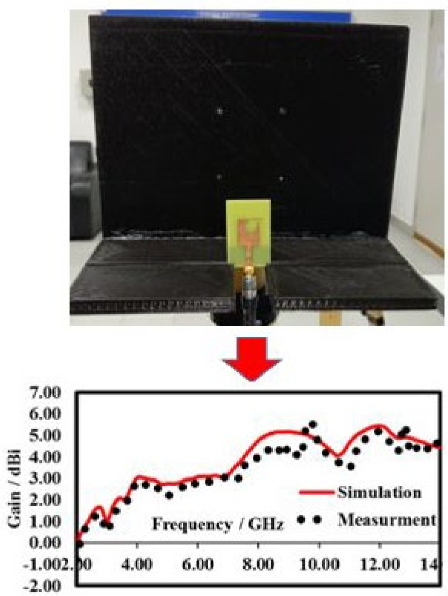
Graphical abstract



Abstract

The patch antenna with Ultra-Wide Band (UWB) characteristics is a promising candidate for wireless communication. It is a major research problem to mitigate electromagnetic interference (EMI) with narrowband technologies such as 5G lower band, Wi-MAX, WLAN and satellite band, which are all in the UWB region. This study describes a UWB antenna with variable band rejection that can be used to avoid interference with Wi-MAX and 5G lower band applications. The UWB characteristics of a simple rectangle patch antenna with a faulty ground structure has been designed for operational bandwidth (2.7–13) GHz. A novel method semicircular slot (SCS) at the radiation patch creates a band notched from (3.25–3.80) GHz and (3.4–4) GHz. Variable band rejection between (2.95–4.40) GHz can be achieved by adjusting the "Wa" values. When measured over the band rejection frequency, the return loss (S_{11}) and VSWR values are very close to 0 dB and larger than 2. The simulated and measured results such as return loss, VSWR, 2-D polar pattern and gain have almost similar agreement. The design of the suggested antenna is simple, compact and efficient for Wi-MAX application, this is an ideal UWB antenna with the band notch characteristics.

Keywords: UWB antenna, Semicircular slot, Variable band notched, 5G lower band, Wi-MAX

1.0 INTRODUCTION

Demand for wireless connectivity has increased, the demand for higher data rate and hence higher bandwidth and transmission frequencies [1]. The UWB frequency range is specified from (3.1–10.6) GHz according to the Federal Communication Board (FCC) [2], [3]. Although UWB technology offers numerous advantages, one challenge is to build an UWB antenna that is small, with appropriate impedance with good radiation stability and efficiency and a reduction of signal interference in the UWB frequency spectrum with achieve narrower bands [3]–[7]. The superimposed lower 5G frequency band (3.4–3.7) GHz [8], Wi-MAX (3.3–3.8) GHz, WLAN (5.15–5.825) GHz, X-band (7.9–8.4) GHz [9], [10] and ITU 8 GHz at (7.725–8.275) GHz operating connections [11]–[15] within the UWB bandwidth. In this article, a UWB antenna will be equipped with a variable band notch function with Wi-MAX (3.3–3.8) GHz and 5G lower band (3.4–4) GHz applications. The follows briefly review the literature for the shortcomings of past works.

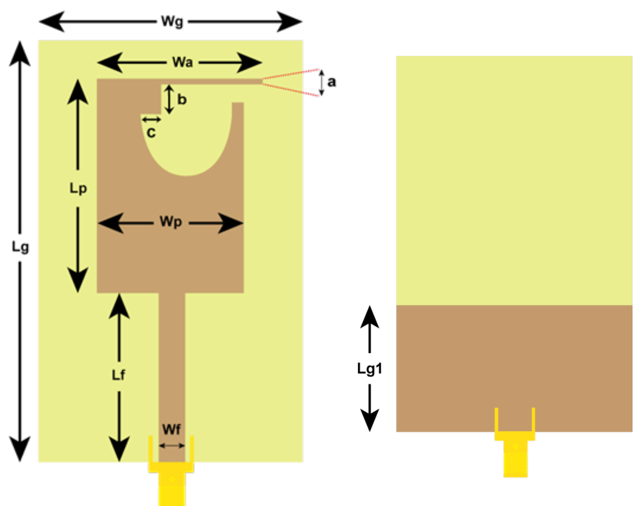
In [13], [16] a UWB antenna designed by using the FR-4 substrate with a single-band notched antenna was developed. A U-shaped slot is inserted into the circular patch for band notched in the Wi-MAX band. S_{11} result shows that the band entry created for the Wi-MAX application (2.3–3.8) GHz is (2.9–3) GHz to 4.0 GHz, but the effective band entry is (3.3–3.8) GHz. Moreover, (2.8–4.8) GHz is achieved by VSWR. Some essential parameters for the results are not presented in this study, such as radiation efficiency and gain plot. To conclude, the antenna does not supply band notched in Wi-MAX frequency band (3.3–3.8) GHz according to two important result parameters, namely: S_{11} and VSWR. In other works [17], [18] a single band notched (3.3–3.8) GHz antenna's designed to be centered on the FR-4 element. The band notched criteria obtained with the EBG structure and inserted in feed line. This antenna is large, and the construction of antenna is complicated enough to make it suitable for Wi-MAX frequency band effective. A new UWB hybrid dielectric resonator antenna is built, with a single-band rejection of (3.2–3.8) GHz in [16]–[18] antenna constructed using FR-4 low cost substrate element with height h=1.64 mm. It was found that the band notched frequency's radiation is not adequately received in the UWB frequency band after band stop. This antenna is simple system to build. An integrated electrically reconfigurable wireless microstrip antenna [16] which is a low-profile reconfigurable Wi-MAX band notched dual port MIMO antenna configuration for wireless communications has been presented. Although the antenna proposed shows good efficiency, the geometry of the antenna is complex. The complicated design of the antenna makes it very difficult to produce and commercially available. A half elliptical shape placed on V-shape slit provide UWB (2.7–14.7) GHz bandwidth and band stop functions for WLAN (5.15–5.825) GHz and 5G lower band (3.4–3.7) GHz [8]. FR-4 has been used for design simulated and fabricated purpose. Slot techniques [8], [11], [19] inspire to design a new UWB antenna which have excellent performance such as compact size, UWB bandwidth, gain, radiation efficiency, surface current and so on compare to the existing research work. Overall, this research work is compact size and size reduction almost 11% [12], maximum gain has been achieved 5 dBi which is comparatively [11] batter performance. Afterall this proposed antenna has been achieved variable band notched function. Wa= 12 mm has been performed (3.4–4) GHz notched bandwidth for 5G lower band application and Wa= 15 mm creates (3.25–3.8) GHz band notched bandwidth for Wi-MAX wireless communication purpose [20].

After reviewing previous works with UWB based frequency band antennas, some of the research gaps remain easy antenna design, compact antenna's dimension and efficient antenna efficiency in the design of efficient in UWB frequency band with band notch function of the Wi-MAX and 5G bands are presented here. A special type of SCS placed top on the radiating patch with partial ground plane (PG) provide UWB bandwidth with band rejection function for Wi-MAX (3.25–3.8) GHz and 5G (3.4–4) GHz wireless applications. The notched bandwidth shifted from (2.95–4.40) GHz by altering the "Wa" value i.e. notched bandwidth shifted from lower to upper frequency band.

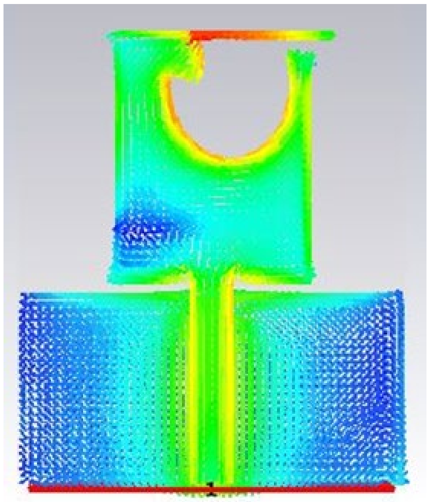
2.0 VARIABLE BAND NOTCHED (VBN-UWB)

A rectangular patch antenna (RPA) is constructed using the PCB-printed circuit board system, where FR-4 is used as a substrate and copper as a conductive patch layer comprising patch and ground thickness t=0.035 mm. FR-4 substrate height h=1.6 mm, relative permittivity=4.4, a loss tangent of δ=0.025. The width and length of the radiating patch Wp= 12.5 mm, Lp= 15 mm respectively. This antenna connected by a quarter-wave (λ/4) microstrip feedline with Wf width and length Lf. It is noteworthy that this traditional patch antenna has a narrow bandwidth of UWB and the ground length is reduced to Lg1=13 mm for obtaining a full UWB frequency range. The partial ground (PG) method UWB antenna achieved (2.7–13) GHz.

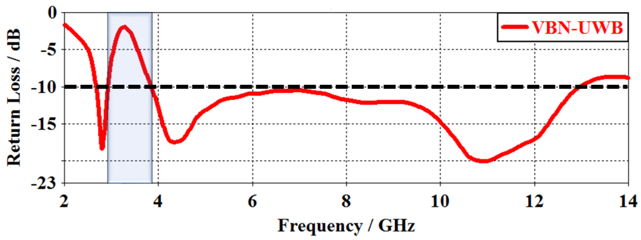
By inserting semicircular slots (SCS) in the radiating patch, the band rejection function is achieved. A compact size of proposed antenna 42×26 = 1092 mm^2 with Wp= 13 mm, Lp= 15 mm, Lf= 7.5 mm, Wf= 3 mm, a=0.6 mm, b= 2.5 mm and c= 2.23 mm. Which is the compact size compare to recent research work, [11] 1221 mm^2, [12] 2100 mm^2 and [13] 2000 mm^2. Figure 1(a, b) shows the physical layout of the proposed VBN-UWB antenna with surface current (Figure 1c) at 3.5 GHz. Due to SCS a huge amount of surface current i.e. 204 A/m accumulated. It is justified, due to the SCS top on the radiation patch, that band notched features are achieved. The certain parameters that are tailored to achieve the desired output by using CST MWS. It is noteworthy from Figure 1(d) that the (3.25–3.8) GHz antenna was rejected with S_{11} parameter notched value near to -1.8 dB. The band rejection bandwidth can vary from (2.95–4) GHz i.e. lower frequency to upper cut off frequency by changing "Wa" functions and "Wa" values from (8–18) mm, it notable that all cases "Wa" values satisfice the UWB bandwidth with band notched function. Thus, Wa=15 mm, 12 mm are optimized value that encompasses UWB bandwidth as well as Wi-MAX and 5G lower band applications. All "Wa" values are shown in Table 1 for a UWB bandwidth and S_{11} study in Figure 1(e). Figure 1(f) illustrated the S_{11} comparison between SCS and without SCS. From this S_{11} comparison it's clear that SCS creates a band stop function for avoiding the single interference.



(a) (b)



(c)



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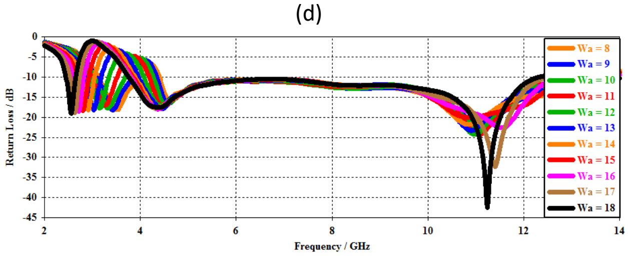

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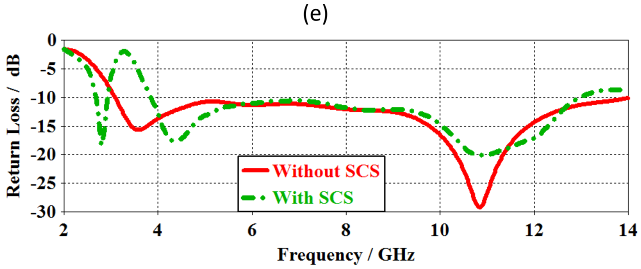


(f)

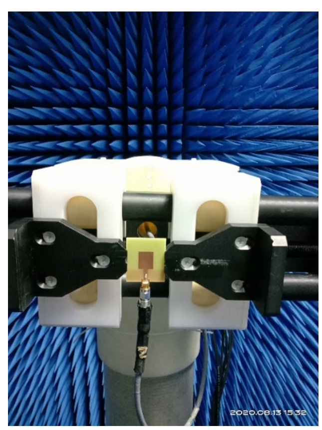
igure 1 Proposed VBN-UWB antenna layout (a,b), surface current at .5 GHz (c), S_{11} for Wa= 15 mm (d), parametric study S_{11} of different Wa alues (e) and comparison S_{11} between with SCS and without SCS (f) [20]

Table 1 Notched bandwidth performance with respect to different Wa values [20]

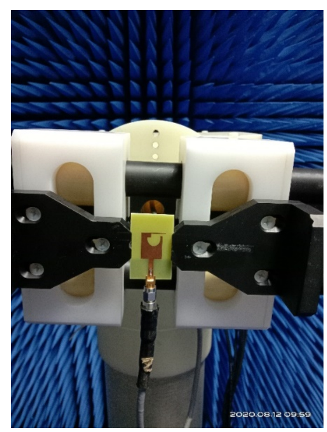
Value of Wa (mm)	Notched Bandwidth (GHz)	UWB bandwidth (GHz)
8	3.95–4.40	3.10–13.30
9	3.80–4.40	3.07–13.50
10	3.70–4.30	3.04–13.70
11	3.50–4.20	2.97–13.62
12	3.40–4.00	2.92–13.50
13	3.20–3.90	2.90–13.40
14	3.00–3.80	2.76–13.20
15	3.25–3.80	2.70–13.00
16	3.10–3.80	2.60–12.80
17	2.95–3.80	2.50–12.50
18	2.75–3.90	2.40–12.25

3.0 EXPERIMENTAL VALIDATION

Figure 2(a, b) shows the photography of testing antenna for Wa=15 mm. Figure 2(c,d,e) illustrated the comparison between simulated and measured S_{11} of PG-RPA (partial ground-rectangular patch antenna), S_{11} and VWSR of VBN-UWB antenna. The VSWR is found at less than 2, for the entire UWB (2.7–13) GHz and a higher than two at the notched frequency (3.25–3.8) GHz. Measured 2-D polar pattern illustrated in Figure 2(f). Usually, the antenna proposed is the h-field of the monopole antenna provided by an omnidirectional radiation pattern. So, the 2-D polar pattern, excluding the band notch frequency is more appropriate. Figure 2(g) illustrated the tested gain of the proposed VBN-UWB antenna. The maximum gain 5 dBi at 10 GHz and minimum gain near to 0 dBi at 3.5 GHz. Moreover, new research efforts have been used to compare the proposed VBN-UWB antenna's performance to previous work in Table 2.



(a)



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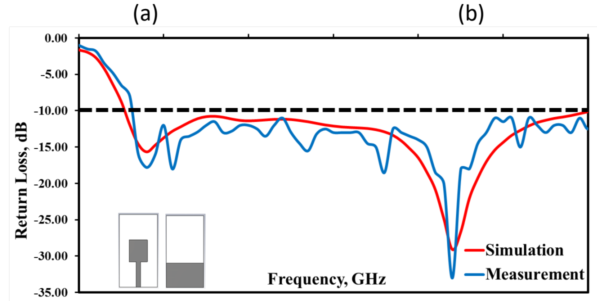

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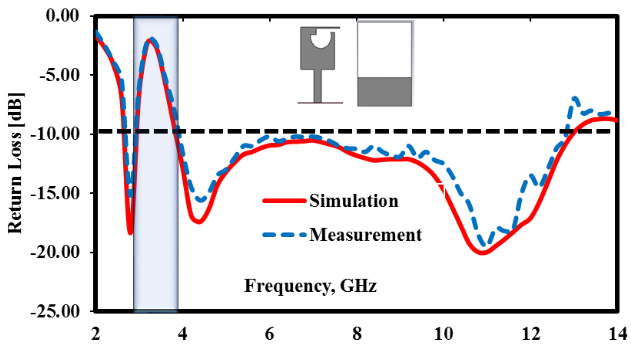

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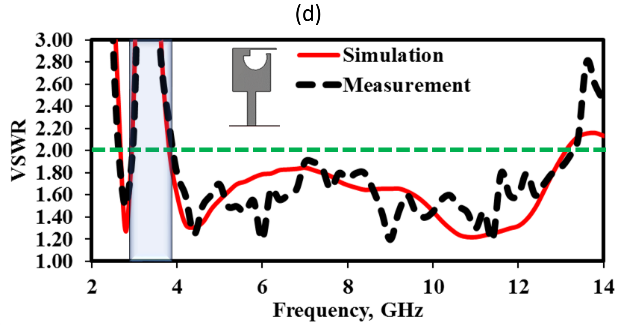

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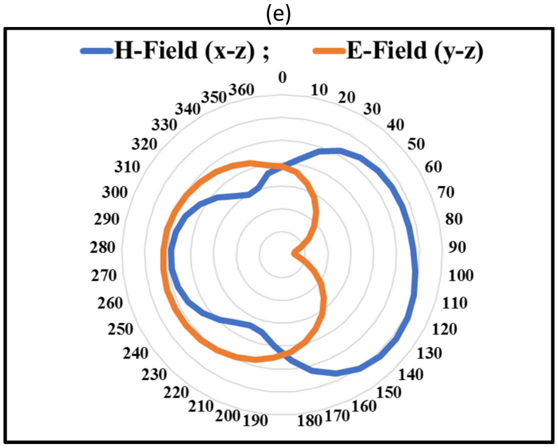

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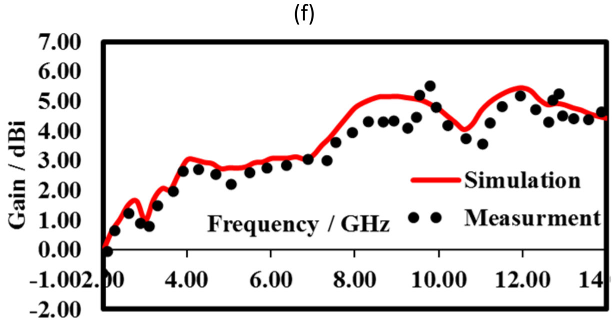

(g)

Figure 2 Testing of fabricated antenna (a, b), comparison between the simulated and measured S_{11} of partial ground rectangular patch antenna (PG-RPA) UWB antenna (c), S_{11}, VSWR (d, e), measured 2-D polar pattern at 3.5 GHz (f) and gain (g) of proposed VBN-UWB antenna

Table 2 Performance comparison of the proposed antennas with others recent research works [20]

Ref.	Dimension (L×W), mm²	UWB Bandwidth (GHz)	Band-Notched (GHz)	Variable Characteristic
6	75 × 10	2.70 – 14.70	5.15-5.83, 3.40-3.70	No
9	37 × 33	2.87 – 11.48	3.20 – 3.80	No
10	42 × 50	2.00 – 12.00	3.30 –3.80, 5.00 – 6.00	No
11	50 × 40	2.30 – 12.00	3.30 – 3.80	No
14	14 × 30	3.00 – 12.00	3.20 – 3.80	No
Our Work	**42 × 26**	**2.70 – 13.00**	**3.25 – 3.80, 3.40 – 4.00**	**Yes**

4.0 CONCLUSION

A UWB antenna has been suggested, designed, validated the simulated and measured results with variable band-notched function. The proposed antenna was designed on FR-4 substrate. A SCS produces band notched that can be used for Wi-MAX and 5G lower band wireless applications. The bandwidth can be changed by changing "Wa" and notched bandwidth moves lower cut of frequency to upper cut frequency, which is (2.95–4.4) GHz. With its basic configuration the antenna is best suited for Wi-MAX and 5G lower band notched applications.

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