International Journal of Emerging Engineering Research and Technology
Volume 8, Issue 4, 2020, PP 1-5
ISSN 2349-4395 (Print) & ISSN 2349-4409 (Online)

A Broadband Substrate Integrated Waveguide (SIW) Slot Antenna Design with WLAN Band-Stop Characteristic

Naser Ojaroudi Parchin*, Raed A. Abd-Alhameed

Faculty of Engineering and Informatics, University of Bradford, Bradford BD7 1DP, UK

***Corresponding Author:** Naser Ojaroudi Parchin, Faculty of Engineering and Informatics, University of Bradford, Bradford BD7 1DP, UK*

ABSTRACT

A new design of substrate integrated waveguide (SIW) slot antenna with band-notched function is introduced for ultra-wideband (UWB) communication systems. The SIW structure contains two parallel conducting plates connected by two rows of metallic posts. In order to match the antenna to a 50 Ω microstrip line, a proximity coupling has been used. The presented antenna has been implemented on a Rogers RT/Duroid 5880 substrate with 2.2 permittivity. By inserting two identical C-shaped slots in the ground plane, a new frequency resonance at the upper band can be excited and improve the antenna impedance bandwidth to cover the required UWB frequency spectrum. In order to create a band-stop function, an inverted E-shaped slot was cut at the radiating stub of the designed SIW antenna. It exhibits a UWB operating bandwidth of 3-11 GHz with a rejected frequency band at 5-6 GHz to suppress interference from wireless local area network (WLAN) systems. The presented SIW microstrip antenna offers various advantages such as low profile, easy fabrication, easy integration with circuits.

Keywords: *Band-notched antenna, SIW, slot antenna, UWB applications.*

INTRODUCTION

In recent years, a lot of attention is acquired by substrate integrated waveguide (SIW) technology owning to its high performance, ease of fabrication and potential to be integrated with circuit [1]. With emerging the SIW technology, a new horizon in the microwave and antenna engineering has been evolved. These structures synthesized on a planar dielectric with periodic arrays of metallic vias. This technology has desirable features such as low profile, low cost, and easily integrated with planar circuits maintaining the advantageous characteristics of conventional rectangular wave-guide. Using the concept of substrate integrated waveguide (SIW) technique gives us the ability to overcome some of the limitations we are dealing with in the microwave and antenna engineering, such as high price and heavy constructed structure with waveguide technology, which is the reason why it becomes popular in recent years. Slotted SIW antennas [2], leaky-wave SIW antennas [3], and SIW horn antennas [4].

For UWB systems, the band between 3.1-10.6 GHz is allocated by FCC (Federal communication commission) which has attracted the researchers from the academic and industrial background for current and future small range wireless applications [5-10]. Low-profile antennas with the low-cost fabrication process and also Omni-directional radiation patterns as well as a large bandwidth are desirable for UWB systems [11-15]. Recent works exhibit intensive research on UWB microstrip antennas due to features such as low cost, high data throughput, low power consumption, and small size [16-20].

In order to design an UWB antenna, there are certain challenges that antenna designers have to deal with. As the operating range of the UWB antenna is wide so there is a possibility of inter-ference of different frequency bands such as Wi-Max at 5.5 GHz and WLAN system at 5.2/5.8 GHz (5.15-5.35 and 5.725-5.825 GHz), and etc [21-26]. To mitigate this problem, rather than using an extra filter, UWB antennas with inherent band notch characteristics are deployed which reduces the area, complication, and cost of a UWB system. Recent work reports several UWB antennas with various band stop techniques are proposed to generate one or more notch bands [27-32].

In this paper, a new design of the SIW slot antenna with WLAN band-notched function for UWB applications. By cutting two C-shaped slots in the ground plane of the design, an extra resonance in the upper bands (10 GHz) was excited. Moreover, to create the desired frequency notched band, an inverted E-shaped slot is cut inside the rectangular radiating stub. The presented SIW antenna displays omnidirectional radiation patterns at different frequencies. In addition, Good VSWR characteristics are obtained in the frequency band of interest. for VSWR < 2, the antenna operates at 3-11 GHz with a notched band (at 5-6 GHz).

Design Details

Transparent schematic of the presented SIW antenna is plotted in Fig. 1. A proximity coupling has been employed to match the antenna to a 50 Ω microstrip feeding line. The proposed microstrip filter fabricated on a *Rogers* RT/Duroid 5880 substrate with a relative dielectric constant of 2.2 and has a very small size of 40×70×0.508 mm^3.

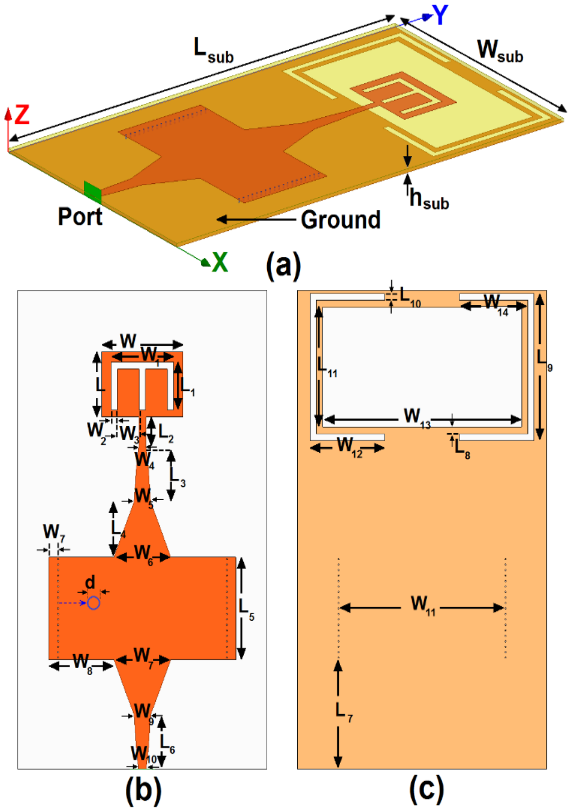

Fig1. *(a) Side, (b) front, and (c) back views of the proposed UWB-SIW antenna design.*

Table1. *Dimensions of the Design Parameters*

Param.	W_{sub}	L_{sub}	d	W	L	W_1
(mm)	40	70	0.8	13	9.5	10
Param.	L_1	W_2	L_2	W_3	L_3	W_4
(mm)	7	1	4.5	3.5	8	1.2
Param.	L_4	W_5	L_5	W_6	L_6	W_7
(mm)	8	2.5	15	9.1	8	9.1
Param.	L_7	W_8	L_8	W_9	L_9	W_{10}
(mm)	16.25	10.5	1	2.5	21.5	1.2
Param.	L_{10}	W_{11}	L_{11}	W_{12}	W_{13}	W_{14}
(mm)	1	26.6	17.5	12	32	11

Results and Discussions

The motive behind the proposed SIW slot antenna design is to achieve a broad impedance bandwidth with compact-size and capability of a band filtering characteristic. The simulated results are achieved using the An soft simulation software high-frequency structure simulator (HFSS) [33]. The configuration of the presented slot antenna was shown in Fig .1. Geometries for the ordinary SIW slot antenna (Fig. 2(a)), the antenna with a pair of C-shaped slots in the ground plane (Fig. 2(b)), and the proposed SIW slot antenna (Fig. 2(c)) structures are compared in Fig 2.

Figure 3 depict the impact of the embedded slot structures in the radiating stub and also ground plane of the proposed SIW antenna on the impedance matching and frequency behavior in comparison to the antenna without them. It can be clearly seen that by inserting a pair of C-shaped slot in the ground plane, a new frequency resonance at 10 GHz is achieved and hence the impedance bandwidth of the SIW design has been effectively improved. Furthermore, in order to generate a WLAN notched band function, the inverted E-shaped slot is cut at the rectangular radiating stub [34-37].

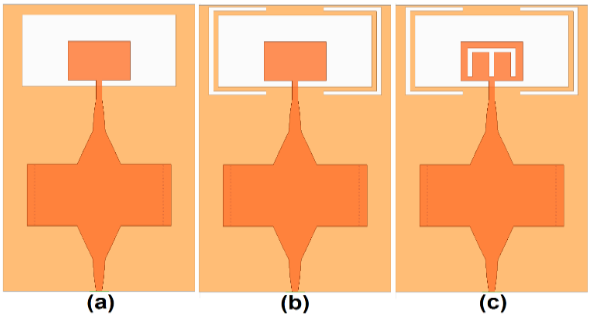

Fig2. *(a) Basic SIW antenna structure, (b) the antenna with two identical of C-shaped slots in the ground plane, and (c) the proposed SIW-UWB microstrip antenna.*

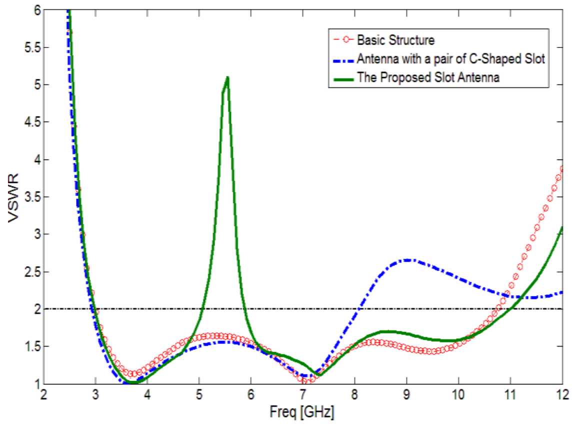

Fig3. *Simulated VSWR characteristics for the various antennas shown in Fig.2.*

In order to demonstrate the working technique of the SIW slot antenna, the surface current densities in the top and bottom layers are studied in Fig. 4. Figure 4 (a) illustrates the current distribution at the new resonance frequency (10 GHz) which improves the upper antenna bandwidth. It is clearly seen in Fig. 4 (a), that the current flows are extremely dominant around C-shaped slots which verifies its impact on creating the new resonance at 10 GHz and therefore improving the antenna upper bandwidth [38-40]. Figures 4 (b) studies the current distribution on the radiation stub of the antenna design at the notched frequency. As shown in Fig. 4 (b), at the notched frequency, the employed E-shaped slot is highly active in generating the first filtering band.

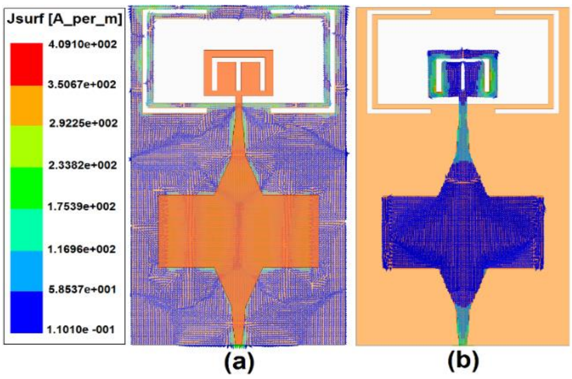

Fig4. *Simulated surface current distributions for the proposed (a) antenna in the ground plane at 13 GHz, (b) at the radiating patch at 5.5 GHz.*

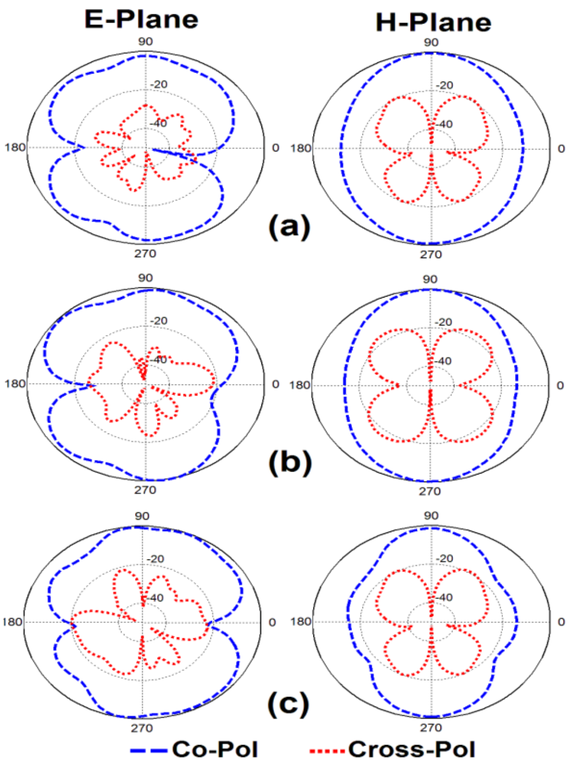

Fig5. *2D-polar radiation patterns of the antenna at (a) 4 GHz, (b) 7 GHz, and (c) 10 GHz.*

Figure 5 shows the radiation patterns of the antenna at selected frequencies including 3, 7, and 10 GHz. These three frequencies are chosen form the lower, middle, and upper frequencies, respectively. In this design, the xz plane is H-plane (φ=0º) and yz-plane is E-plane (φ=90º) for the proposed antenna. We can see that the antenna can give dumbbell-like radiation characteristics in E-plane and nearly Omni-directional patterns in H-plane [41-45].

Conclusion

A new SIW-based slot antenna design is presented to support the UWB frequency spectrum and suppres WLAN operation band. The antenna impedance bandwidth is from 2.9 to 11.1 GHz with a notched band of 5-6 GHz. The proposed SIW-UWB antenna provides good omni-directional radiation pattern even at different frequencies. It has a small size of 40×70mm^2. The presented SIW antenna offer many advantages including compact-size, easy fabrication, easy integration with circuits.

Acknowledgments

Authors wish to express their thanks to the support provided by the innovation programme under grant agreement H2020-MSCA-ITN-2016 SEC RET-722424.

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Citation: *Naser Ojaroudi Parchin, Raed A. Abd-Alhameed, "A Broadband Substrate Integrated Waveguide (SIW) Slot Antenna Design with WLAN Band-Stop Characteristic", International Journal of Emerging Engineering Research and Technology, 8(4), 2020, pp. 1-5.*