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A compact ultra-wideband (42-54 GHz) mm-Wave Substrate Integrated Waveguide (SIW) cavity slot antenna for of future wireless communications

Najib AL-Fadhali, Huda A Majid, Rosli Omar, Mohd Hezri Mokhtar, S. M. Shah, Z. Z. Abidin, S. H. Dahlan, M. K. A. Rahim, Najmaddin Abo Mosali, B.A.F Esmail

Abstract: A compact and robust ultra-wide-band SIW antenna technology is presented. The proposed antenna applies for 42 - 54 GHz applications such as 5 G and future WLAN. The SIW is designed with specific slot configurations. The simulated results show that the SIW antenna resonates throughout the bands of 42 to 54 GHz, making this new antenna cover all applications within this range. The reflection coefficients in all ranges from 42 to 45 GHz are below 10 dB. The antenna achieves good efficiency and gain as well.

Index Terms: UWB, mm waves, future wireless communications. SIW, cavity slot antenna.

I. INTRODUCTION

Integrated substratum waveguide (SIW) built in a metalized planar substratum through two parallel rows of thru-holes as shown in Figure 1 ends with an attractive transmission shape due to its simplicity of manufacture and the ability to integrate planar with active circuits [1]. An enormous amount of researches have been conducted in recent years to improve the efficiency of microwave and millimetre wave elements using minimal effort and low - cost technologies. These include the Substrate Integrated Waveguides (SIWs), initially presented as laminated waveguides as in indicated in the study of [1 - 4], which can be easily executed using the creation of regular Printed Circuit Boards (PCBs). Since the presentation of SIWs or laminated waveguides, various components, interconnections and circuits based on SIW were created and their merits justified in comparison to their counterparts in the milled waveguide or transmission line.

According to [5], SIW interconnects provide an excellent Electromagnetic Interference Insulation (EMI) for a broadband bandpass signalling medium, while conventional planar transmission lines are known as the bottleneck performance in broadband systems because of their limited bandwidth and high-frequency losses. Similarly, in the study of [6], revealed the electric field distribution in a SIW fills the volume within the waveguide interconnection and surface currents propagate on the larger cross-section of the waveguide walls, leading to low losses and the demand for multiband and compact electronic systems continually increases. This requires the use of SIW technology in highly integrated system applications in the future. The SIWs formed the foundation for designing many circuit components as a new signal transmission instrument. Components like resonator cavities and filters utilizing microstrip, stripline or milled -waveguide technology, the SIW platform is now being redesigned. As per [7, 8], stated that other components based on SIW, such as waveguide cavities, have been integrated directly into the PCB platform, enabling for substantial cost reductions in microwave oscillators development and mass production. The high-quality factor in the cavities of the waveguide makes the coupling frequency excellent choice. In the study of [9], investigated that, reconfigurable antenna provides a system with compactness and flexibility. A large number of reconfigurable antennas capable of switching between narrowband. The SIW technique is a new emerging application and integration technique for microwaves, millimetre waves and wireless components. Modern trends in research into future wireless sensor networks based on SIW technology and the use of advanced SIW structures based on environmentally friendly technologies and materials. As per [20] the SIWs configurations allow for the realization of conventional rectangular waveguides in form of planar shape conducted in dielectric substrates by employing double rows of metal vias connecting the patch to the ground plane. SIW technology enables active components, passive structures and antennas to be integrated into a single substrate to avoid transitions and minimize parasitic effects and losses. According to the system on the substrate approach, all wireless systems can be easily integrated into the SIW technique. The technology of SIW combines the benefits of conventional microstrip patch such as low

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Najib AL-Fadhali, Faculty of Electrical and Electronic Engineering, University Tun Hussein Onn Malaysia, Batu Pahat, Malaysia

Huda A Majid, Faculty of Engineering Technology, University Tun Hussein Onn Malaysia, Batu Pahat, Malaysia

Rosli Omar, Faculty of Electrical and Electronic Engineering, University Tun Hussein Onn Malaysia, Batu Pahat, Malaysia

Mohd Hezri Mokhtar, Faculty of Engineering Technology, University Tun Hussein Onn Malaysia, Batu Pahat, Malaysia

S. M. Shah, Faculty of Electrical and Electronic Engineering, University Tun Hussein Onn Malaysia, Batu Pahat, Malaysia

Z. Z. Abidin, Faculty of Electrical and Electronic Engineering, University Tun Hussein Onn Malaysia, Batu Pahat, Malaysia

S. H. Dahlan, Faculty of Electrical and Electronic Engineering, University Tun Hussein Onn Malaysia, Batu Pahat, Malaysia

M. K. A. Rahim, Faculty of Electrical Engineering, Universiti Teknologi Malaysia, Johor Bahru, Johor, Malaysia

Najmaddin Abo Mosali, Faculty of Mechanical and Manufacturing Engineering, University Tun Hussein Onn Malaysia, Batu Pahat, Malaysia

B.A.F Esmail, Faculty of Electrical and Electronic Engineering, University Tun Hussein Onn Malaysia, Batu Pahat, Malaysia

weight, a high degree of miniaturization, low cost and easy for fabrication while the metal waveguides characterized by high power handling, full shielding and low losses. It has several advantages compared to open planar lines or solid metal waveguides. First, it provides electromagnetic interference-free design, as it is a closed configuration like a wave guide. The common circuit board (PCB) technology can also be easily integrated into planar substrates. [2]

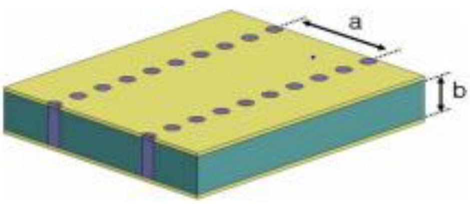


Figure1: Structure of SIW [2].

Finally, the current spreading structure endows high - quality resonance factor with integrated high - performance resonators [3]. Several SIW, microstrip and coplanar transitions [4, 5] have been investigated for integrated SIW applications. Major knowledge has been gathered that over the past decade 60-GHz MMW channels have been accumulated A lot of work has been done on developing MMW communication networks for various applications[6]. In 2001, the Federal Communications Commission (FCC) allocated 7 GHz in the 57–64 GHz band for unlicensed use. Combined with advances in wireless communication technology, the opening of this large chunk of once perceived for expensive point-to-point connections, the free spectrum revived interest in this portion of the spectrum. In this specific region of the spectrum, the opportunities immediately seen include wireless personal area networks of the next generation [7]. The unlicensed 60 GHz band has appeared as a worldwide short-range wireless process option such as WLAN with a data rate of about 1.5 Gb / s allowing uncompressed video signal transfer between a video player and a TV to be a good choice for roughly 60 GHz unlicensed band application [8,9]. In this frequency band [10], [11], different antenna designs were presented. Because of its ease of manufacture, small size, planar structure and lightweight, SIWs are very attractive for millimetre applications, many papers have been published to design microstrip antennas working in the 60-GHz group lengthways with efforts to build impedance transmission capacity [12, 13]. These structures are either muddled or lossful due to the expansion of materials and the conventional planar encouraging used to couple the vitality to the MPA, for example, microstrip lines and coplanar waveguides. These structures suffer from conductive and radiation misfortunes on the mm-wave recurrence band, which decrease the general proficiency of radio wire radiation, particularly in receiving wire exhibit applications [14]. SIW is a planar formed rectangular waveguide utilized in many microwave and mm-wave [15, 9] and radio recurrence (RF) circuits, demonstrating coplanar joining, minimal effort points of interest, high power dealing with.

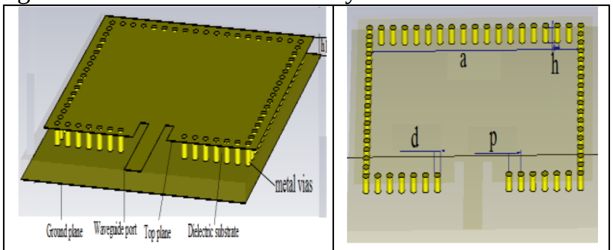
In this paper, the SIW structure is presented as a new antenna with ultra - wide 50 - 60 GHz band covers the improvements of radiation efficiency in the 60-GHz band due to the traditional planar feeding structure.

Due to its multifold, the 60-GHz band is attractive. Furthermore, data or bandwidth rates are never enough, while the remote sight and sound circulation advertise is expanding consistently, while UWB is a progressive power – a constrained band innovation allotted by FCC for its phenomenal 3.1– 10.6 GHz unlicensed framework data transmission. UWB radio's low discharge and hasty nature lead to expanded correspondence security and the infiltration of the divider makes UWB frameworks appropriate for unfriendly indoor conditions [16]. With low - cost and low - control battery - driven segments, the UWB motivation radio can possibly be actualized. UWB can give remote high - speed mixed media and is appropriate for WPANs. Moreover, a standout amongst the most troublesome issues for UWB is that it is hard for real nations to accomplish universal coordination of operational range. Furthermore, IEEE standards are not accepted throughout the world. However, spectrum allocation does not appear to be a problem for WPANs with 60 GHz. This is one of the reasons why 60-GHz MMW is popular. Another concern is interference between systems. The UWB band includes the 2.4 and 5 GHz groups utilized for dynamically positioned WLANs, intensifying and disturbing corresponding impedance. There is additionally this issue of framework impedance in Europe and Japan. Administrative bodies in these regions ensure current remote frameworks working in various areas as required by UWB execution. Global harmonization is possible around 60 GHz, but the regional UWB radio station is almost impossible to operate in another area [17].

Like the UWB microwave radio, the 60-GHz radio is reasonable for high data and short separation executions however is less inclined to meddle with the framework than the UWB. Numerous applications can be found in local locations, workplaces, meeting rooms, passages and libraries [18]. For home applications, it is, thusly, reasonable for sound/video transmission, work area association and cell phone support. Wireless backhaul and wireless, multi-point desktop connections, wireless docking station, Gigabit Ethernet, file transfer, high - definition video streaming and ad hoc networks are judged by the interest shown in 50 to 60 GHz applications by many driving CE and PC organizations. These three applications are viewed as best in class, including video gushing, record exchange and remote Gigabyte Ethernet applications [19].

II. ANTENNA DESIGN & ANALYSIS

The schematic of the proposed antenna appears in Figure 2.which demonstrates the position of the different slots that were investigated in the designed antenna, slots in the front, the distance between the consecutive vias, the diameter of via, length and width of the antenna layers.



(a) (b)

Figure 2: Configuration of the SIW synthesized by metallic via-hole arrays (a) shows the top and bottom plane while (b) shows the dimensions of vias' array

Arrangement of the SIW composed by metallic by means of via-hole arrays as said before, SIW is made out of two parallel varieties of through via holes delimiting the TE10 wave spread zone, as its cutoff frequency is just branded with the width an of the waveguide as long as the substrate thickness or waveguide height 'h' is smaller than 'Wsiw'. Parameter 'Wsiw' between the two arrays decides the spread steady of the central mode, and parameters of through via holes 'D' and 'p' are set to limit the radiation loss and in addition the the return loss [20]. Despite the fact that SIW can be described by by propagation constant, waveguide mode, cutoff frequency and guided wavelength like a regular rectangular waveguide, it ought to be noticed that SIW has some unpleasant physical qualities as compared with traditional rectangular waveguides. Primary, the SIW's geometrical parameter 'Wsiw' is substantially bigger than 'b' in light of the fact that there is a physical constraint to build the substrate thickness 'b'. Second, the comparable waveguide width of SIW, aeff isn't the same as 'Wsiw'. Along these lines, numerous trials and reforms have been led to confirm estimation of aeff. One empirical condition to ascertain aeff is given by [16, 17].

$$a_{eff} = a - 1.08\frac{d^2}{p} + 0.1\frac{d^2}{a} \dots\dots\dots\dots\dots\dots\dots (1)$$

Whenever d/p < 1/3 and d/a < 1/5. SIW can be displayed by rectangular waveguide with a comparable width and keeps up radiation losses at an insignificant level, when its geometry parameters meet, the metalized by means of via hole measurement is

$$d < (\Lambda_g/2) \quad \dots\dots (2)$$

The distance among the via holes is

$$p < 2d \quad \dots\dots (3)$$

The dimensions of SIW designed using the related equations which adopted from recent literature review while the length/width of the designed slots were based on parametric study.

Figure 3 shows the design of the UWB SIW antenna after several parametric studies to check the effective length of the designed slots until the optimum position, length and width of the proposed slots are obtained.

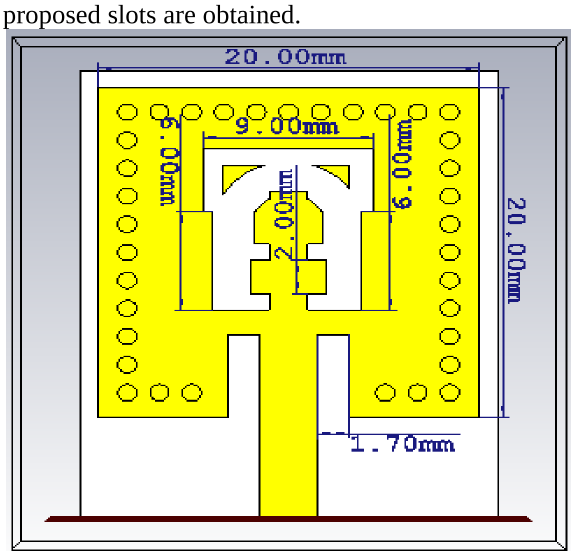


Figure 3: the SIW antenna structure

The dimension of the substrate used is shown in figure 4

The UWB SIW antenna involves of a radiating element in the form of in front slot antenna, fed by a strip line to match the impedance to produce the best return loss at the wanted frequency. The antenna is built on Rogers RT5880lz (lossy) with a dielectric constant of 1.96, the thickness of l.27 mm, and loss tangent of 0.0009. Parameters used in the design are given in Figure 4 and Table 1. Figure 4 shows the dimensions of the ground and substrate in more details as shown below.

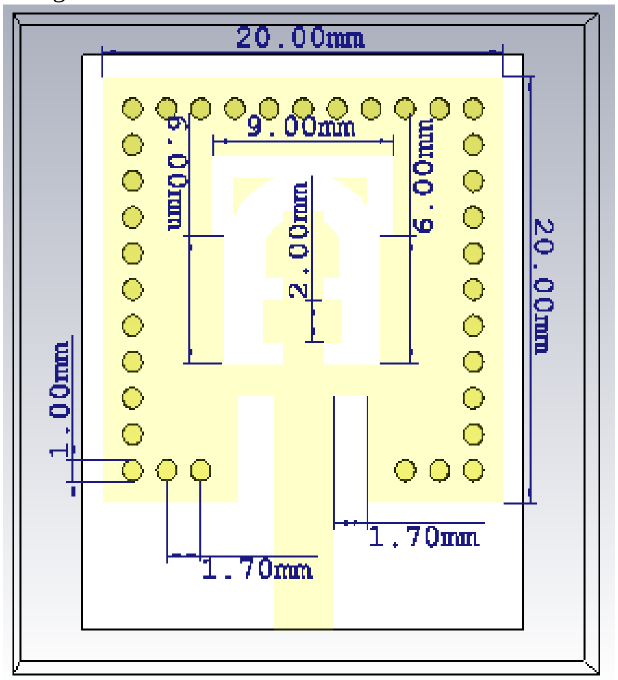


Figure 4: The substrate structure

Table 1: The dimensions of ground and substrate

Type	W (mm)	L (mm)	H (mm)
Ground	22	27	0.35
Substrate	22	27	1.27
The via diameter (d) =1 mm		The distance between 2 consecutive vias = 1.7 mm	

The antenna design and analysis has been done utilizing CST program. The geometry comprises of slots formed space and slots structure to understand the effectiveness of slots in terms of resonant frequency.

III. SIMULATION RESULTS AND DISCUSSIONS

Performance of the proposed antenna was researched by utilizing the CST Microwave Studio programming. The streamlined measurement appears in Table 1.Reflection coefficient (dB) demonstrates that almost in all range from 42 to 54 GHz achieved lower than - 10 dB, so in this condition make this antenna more reliable and robust to serve the application of future wireless communications. Figure 5: shows the resonant frequency of UWB which covers the whole range from 42 GHz to 54 GHz

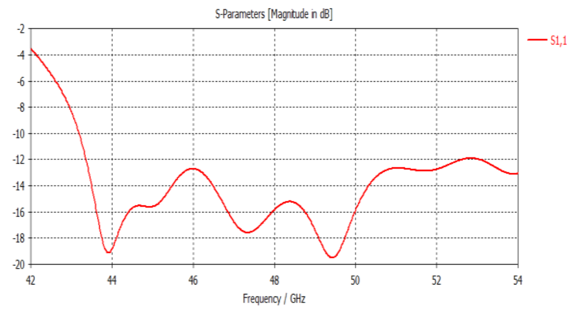


Figure 5: The resonant frequency of UWB based SIW antenna

The distribution of the UWB SIW antenna's E - field shows that it resonates from the slots and vias wall confining the electromagnetic energy within the cavity as shown in Figure 6. The current distribution in the slot was studied to determine the maximum current in the slot.

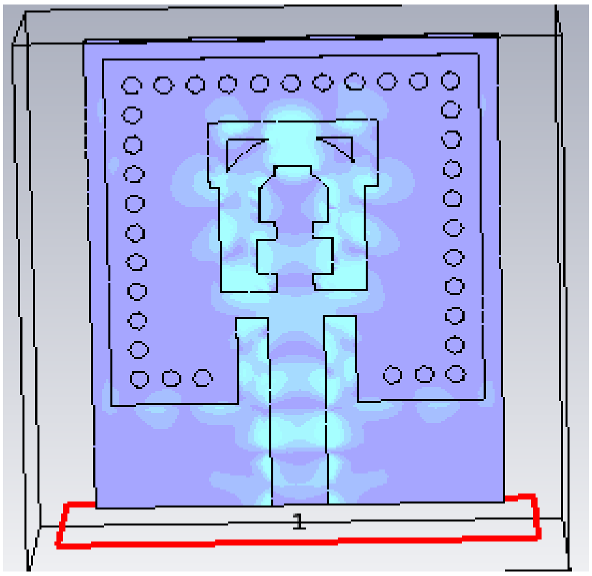
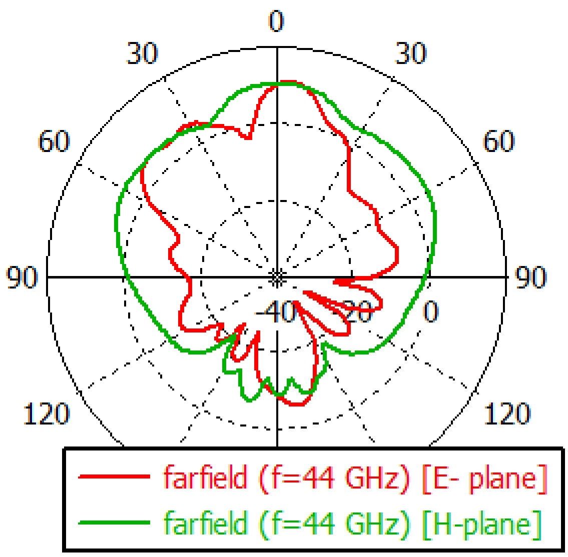
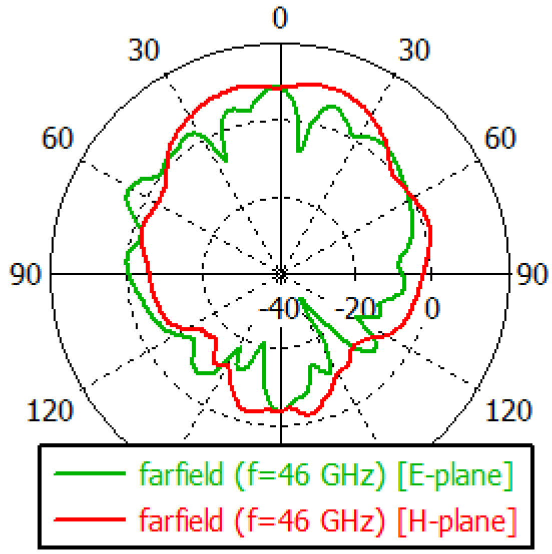
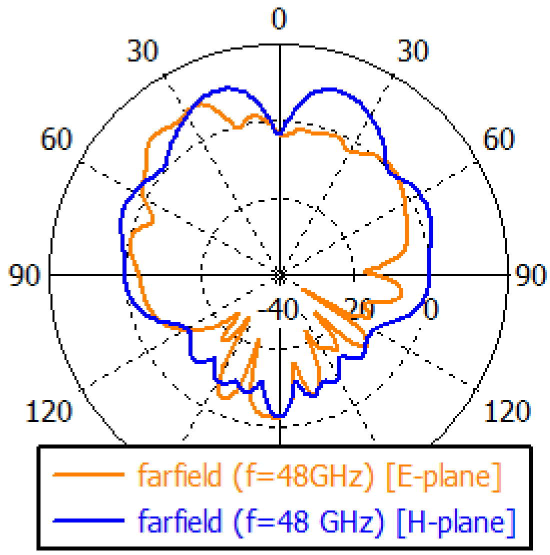


Figure 6: the radiating from slots

The radiation patterns observed in resonates frequency of (44 GHz, 46 GHz, 48 GHz, 50 GH) are shown in figure 7.







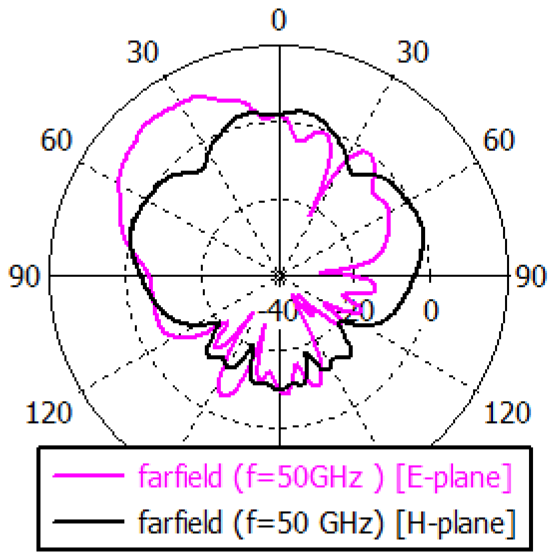


Figure 7: the radiation patterns of selected frequencies

IV. Conclusion

Ultra-wideband SIW cavity slots antenna is presented in this paper. a novel antenna design base on SIW including an intelligent slots for antennas resonating in an ultra wideband that covers from 42 GHz to 54 GHz. The designed antennas expected to support the applications of future wireless communications systems such as future WLAN and satellite systems. It is simulated in CST Microwave Studio programming and the author recommends improving the results of this study to obtaining more deep below of reflection coefficients. In future, real-time implementation, fabrication and measurements will be done.

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