DESIGN AND ANALYSIS OF RECTANGULAR SLOT MICROSTRIP PATCH ANTENNA FOR MILLIMETRE-WAVE COMMUNICATION AND ITS SAR EVALUATION

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ABSTRACT

This paper presents the design and analysis of the compact patch antenna for 5G and future generation millimetre-wave communication system. The proposed design consists of FR4 substrate length, width, and height of 21.37 x 5 x 1.59 mm^3, besides two rectangular slots incorporated with a dimension of 0.2 x 2.6 mm^2 within the patch of 4.22 x 3.46 mm^2, to enhance the resonance frequency more accurate and one more square slot incorporated in to feed line with the dimension of 0.2 x 0.5 mm^2. The obtained return losses of the design is-21.25dB with gain and voltage standing wave ratio (VSWR) of 3.90dBi,1.18 by using a lumped port configuration. For the specific absorption rate (SAR) evaluation considered as a human head model in high-frequency structure simulator (HFSS) software, the obtained values are within the standard limit, the design covers the frequency range of 28GHz, this design may capable of 5G and next-generation wireless communication system application.

KEYWORDS

Patch antenna, SAR, Rectangular slot, Human head model

1. INTRODUCTION

There are tremendous changes has been observed in mobile communication since last few decades, the mobile devices and connections are not only getting smarter in their computing capabilities but also evaluating lower generation network connectivity technologies i.e.1G, 2G to higher generation technology (3G, 3.5G, and 4G or LTE) [1,2]. The first generation technology pertained to voice transmission services only were highly incompatible with related services it was introduced in the early 1980s[2], the second-generation wireless cellular mobile technology was planned for voice transmission with digital data transfer and the data transfer rate up to 64 kbps. This technology ahead of 1G services by providing the facilitate short message services (SMS) and lower speed data such as CDMA2000, the second generation technology deploying GSM services, Global system for mobile communication uses digital modulation schemes to improve the voice quality but network offers limited data services and the second generation carriers continued to improve the transmission quality and coverage, also, it began to offer text message services, voicemail, and fax service.

In the 2.5 generation technology introduced General packet radio services (GPRS)[1-3], it implies packet-switched data capabilities to existing GSM services and also it allows to user can send graphical data as packets, the importance of the packet switching increased with rising of internet and internet protocol (IP),3rd generation technology based on wideband wireless evolution intends to mobile telephone customer to use audio, graphics, and video application data transfer rate up to 200 kbps. This technology enhances the clarity and speed of the network up to megabits per second, for the Smartphone and mobile modems in laptop computers. Fourth-generation technology brought in Long Term Evaluation (LTE), this technology comes under 3GPP (Third Generation Partnership Project) Standard it fulfils (International Telecommunication Unit) ITU, (International Mobile Telecommunication) IMT -Advanced broadband network, the data transfer rate of the technology up to 1 Gbps and the 4G provides better than TV quality images, video-links. Furthermore, to enhance the data speed, it is predicted that the commercial deployment of fifth-generation (5G) systems will be approximately in the early 2020s [4]. To meet the increasing need for even higher data rates required in future applications (such as wireless broadband connections, massive machine-type communications, and highly reliable networks), the research activities on 5G mobile communication systems have started [5,6]. The microstrip antenna has several advantages compared to conventional microwave antennas some of them are lightweight, low volume and thin profile configurations, which can be made conformal, low fabrication cost, readily amenable to mass production, linear and circular polarizations are possible with simple feed, dual-frequency and dual-polarization antennas can be easily made, no cavity back is required, can be easily integrated with microwave integrated circuits [7].

In the existing present wireless communication world antennas are needed to assure some security of the human body from the electromagnetic radiation for that some of the protecting and guiding organization federal communication commission (FCC), European international electro technical commission (IEC) and IEEE 1528 has set the safety limit of 1.6W/kg absorbed by 1-gram tissue and 2W/kg for 10-gram of tissue.

2. DESIGN AND ANALYSIS OF THE PATCH ANTENNA

Geometry consists of FR-4 epoxy substrate dimensions of width, length and height are 5 x 21.37mm^2 x 1.59 mm with an epsilon value and the loss tangent of 4.4, 0.017. The design Fed by a microstrip transmission line, and the ground plane made of conducting material i.e., copper. The patch consists width and length of 4.22 x 3.46 with two rectangular slots dimensions of 0.2 x 2.6 mm^2, to enhance resonance one more square 0.2 x 0.5 mm^2 dimension feed slot incorporated to the patch. The considerable height of the patch is smaller than the wavelength of operation, the proposed design resonate frequency is 28 GHz, as per design the detailed dimensions are given in Table 1 with respective the Fig.1

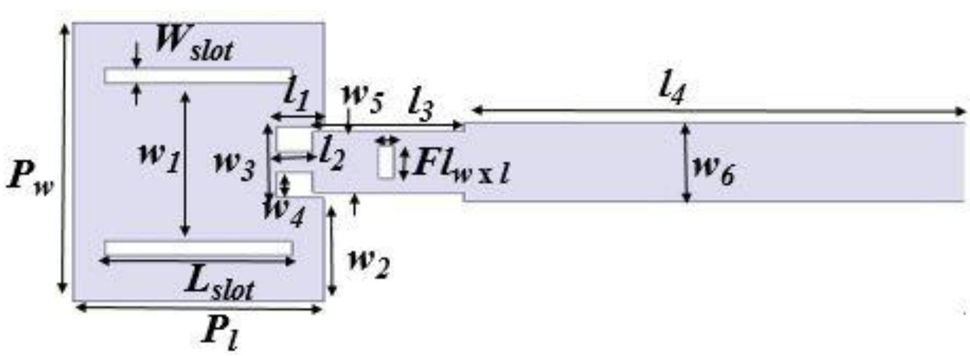

Figure 1: The geometry of the Rectangular Slot patch antenna

Table 1. Dimensions of the Rectangular slot Microstrip patch antenna

Parameters	Dimensions in (mm)
Substrate Width	5
Substrate Length	21.37
Height of Substrate (h_t)	1.59
Patch Length (P_l)	3.46
Patch Width (P_W)	4.22
Slot Width(W_{slot})	0.2
Slot Length (L_{slot})	2.6
Between Slot Distance (w_1)	2.4
Fedd line ($F_{wx\,l}$)	0.2,0.5
w_2, w_3	1.58,1.05
w_4, w_5	0.37,0.91
w_6	1.19
$l_1, l_2,$	0.65,0.50
l_3, l_4	2.1,8.37

3. MEASUREMENT ANALYSIS OF THE PATCH ANTENNA

To verify the design approaches, the proposed antenna fabricated and measured. The proposed microstrip patch antenna is designed in Ansys High-Frequency Structure Simulator (HFSS). The return losses and voltage standing wave ratio are measured in VNA as shown in Fig. 2 and Near field and the far-field radiation pattern is reported in Fig. 4, as shown in Fig. 2 the simulated and measured return loss plot which shows that resonance frequency of 28 GHz (7%)[8], which is in good agreement with the simulated results having a resonance at 28 GHz (6.7%). The little versions in simulated and measured results are due to the manufacturing allowance and binding of SMA connector using a conductive adhesive, return loss for covering 5G millimetre wave applications [9-28] is higher than −10dB. The proposed design antenna return loss is -22.21dB,as shown Fig.2, as well as section A and B, describes the effect of incorporated slots and the parametric analysis slot width, length variation with respective slot as shown Fig.3a,b.

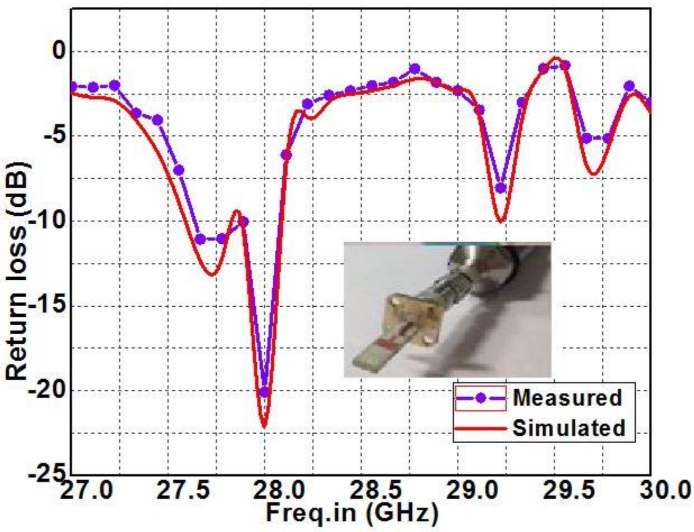

Figure 2: Return Loss of proposed antenna at 28GHz

A. Effect of Incorporated Slot

Incorporating the additional slots to patch the antenna behaviour has been changing i.e. enhancing the return loss and impedance matching, when there were no additional slots present on rectangle patch the antenna shows a non-resonance behaviour at the desired frequency, with increasing the additional slots on the rectangular patch to enhances the matching condition of the antenna, the patch resonating at 23 GHz to 25GHz to bring the response at the desired frequency at 28GHz.Further, one more slot incorporated on the rectangular patch. the slot width and length variations with respect resonance as given in section B

B. Parametric Analysis

Parametric analysis is one of the important analysis to determine the optimized results at desired resonance, the proposed antenna slot width variation from W_{slot}= 0.02 mm to 0.2 mm, slot length variation is L_{slot}= 1 mm to 2.6 mm from this observation resonance varies with respective return loss it is reported in Fig.3a, b.

As shown in Fig. 3a describes the variation of slots width with constant length of 2.6mm when increasing slot width values from 0.02mm to 0.2mm the resonance frequency shifts towards the desired response whenever increasing the further value of 0.2mm we acquired resonance at 28 GHz, as well as in the Fig.3b demonstrates the slot width keeping constant at 0.2mm, meanwhile slot length varies at 1mm to 2.6mm, from the 1mm to 2.2mm the resonance range from 27 to 30 GHz unmatching condition hence there is no desired response so that whenever increasing the further value of 2.6mm the resonance response and impedance matching was enhanced at 28 GHz.

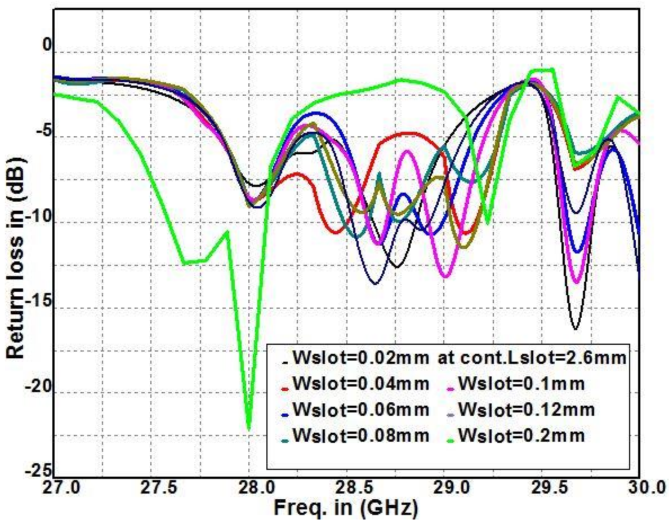

Figure 3(a) : slot width varies with constant slot length

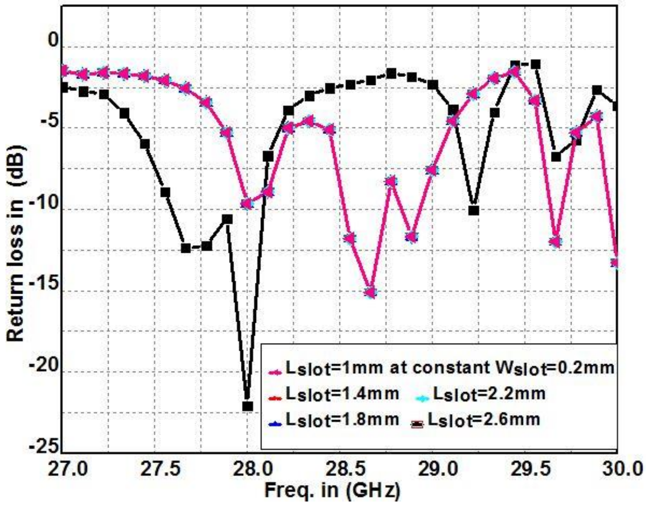

Figure 3(b): slot length varies with a constant slot width

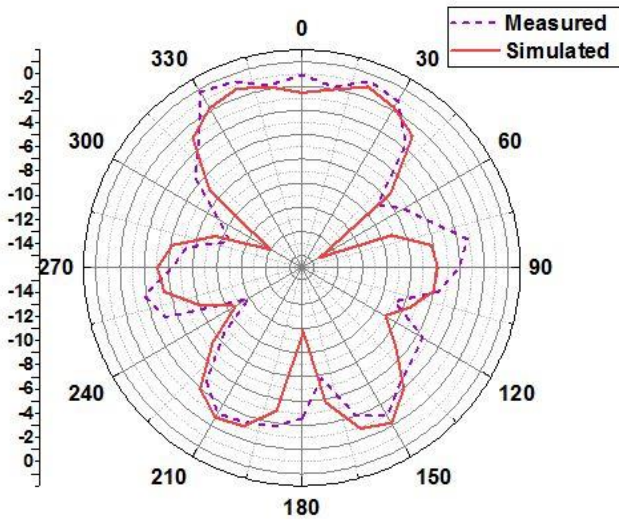

Figure 4(a): Measured and Simulated Radiation pattern

From the above plot, it describes antenna gain versus angle of phi in spherical coordinate from 0 to 360, this values on the perimeter of the circle while the values inside the circle such as -14dB to 0dB are radiation intensity values (gain), so we can observe that at phi =0 degrees simulated gain is approx. 3.9dBi and the measured value is approx.3dBi, both values should be quite similar at 28 GHz frequency.

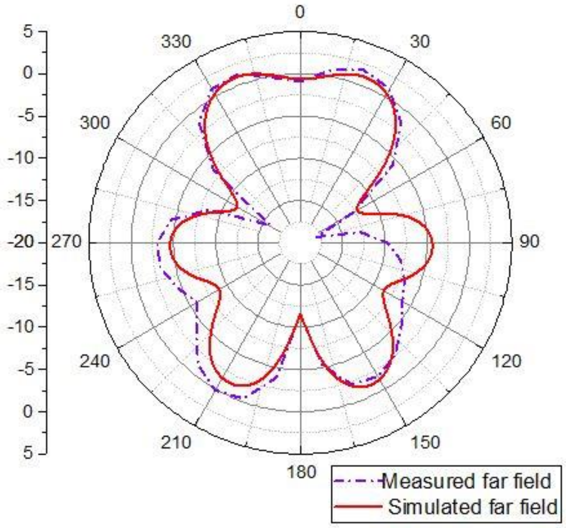

Figure 4(b): Measured and Simulated far-field Radiation pattern

As shown figure 4b demonstrate that the values on the perimeter of the circle are angle values from 0 to 360 degree for phi, while the values inside the circle such as -20 dB, -15 dB,-10dB,-5dB, 0dB, and 5 dB are the radiation intensity values (gain), the measured value is approx. 3.5dBi and simulated value approx. 3.9dBi at phi=0 degree, the high gain compact microstrip patch antenna reported in [29], both values are rather similar at 28GHz resonance, but phi at 75, degree radiation intensity of simulated value is -20dB and the measured value is approx.-17.5dB at phi 60 degree, same way phi at 300 degrees simulated value is -20 dB and the measured value is approx. -16.5dB, from this observation the both, are not identical but quite similar

Figure 5: A fabricated prototype of the proposed antenna

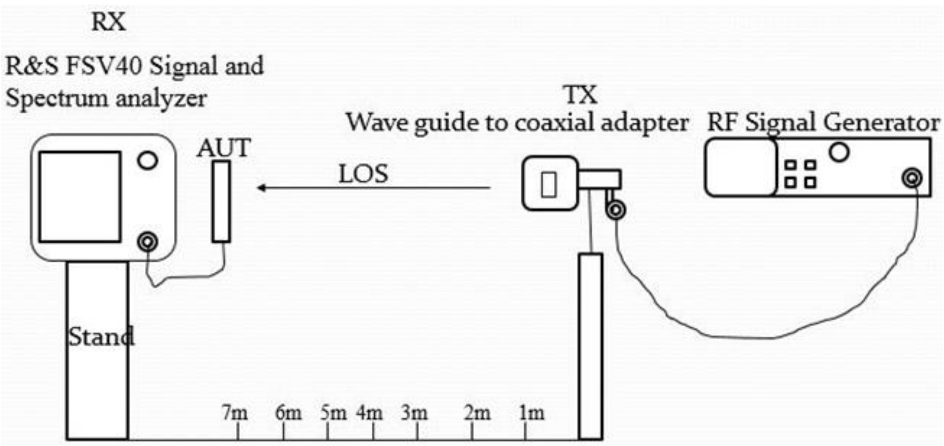

Figure 6: a prototype of the radiation pattern measurement setup

From the above figure, 6 reports measurement prototype of the radiation pattern, from the RF signal generator selected frequency of 28 GHz with 0 dB power and it fed up to waveguide adapter, it acts as a transmitter and the second end connected microstrip antenna to the 40 GHz R&S FSV40 signal and spectrum analyzer. In the antenna under test waveguide to coaxial adapter keeping constant microstrip antenna position changing with respective distance and phi, theta 0 to 360-degree rotation from 1 meter to 7-meter range. This experiment was done in an indoor environment with a noise level below -70 dBm (direct antenna gain method)

C. Specific Absorption Rate (SAR) Analysis

SAR is the unit of measurement for the RF energy absorbed by any biological tissue (human body) when we use wireless devices, SAR values are measured in W/kg. In this analysis, human head modal has been stimulated in HFSS software at the 28GHz, fed by monopole antenna with proposed design [24] .as per IEEE 1528

$$SAR = \frac{\sigma E^2}{M} \qquad (1)$$

Where σ is the conductivity of the tissue, E is the electric field, M is the mass density of the tissue

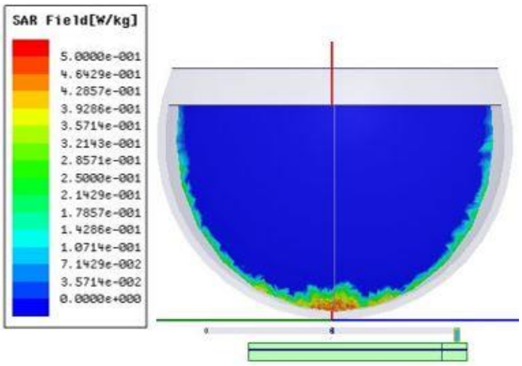

Figure 7(a): Simulated SAR of the proposed antenna with 1 gram biological tissue

As per IEEE/ANSI C63.19 standard, SAR safer limit value should be 1.6 W/kg for any 1g biological tissue, in the above figure describes SAR value with the limited about 0.5<1.6W/kg

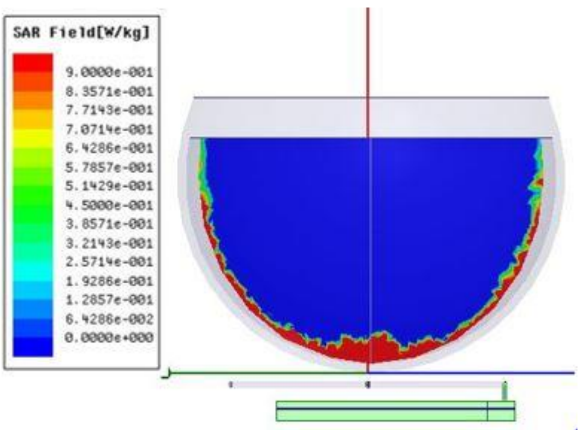

Figure 7(b): Simulated SAR of the proposed antenna with 10-gram biological tissue

As per the IEEE 1528 standard safer limit of SAR is 2W/kg for any 10g biological tissue, in the above figure demonstrates that the max value of SAR is within the limit of 0.9<2W/kg.

4. CONCLUSION

This paper portrays the rectangular slot microstrip patch antenna design and analysis has been investigated, various parameters in the design of the antenna are optimized and optimum design is reported. The proposed antenna return loss is -21.25 dB The VSWR of the antenna is 1.18 with 7% bandwidth. The intended antenna structure delineated a gain of 3.90 dBi and SAR investigated results for 1g,10g biological tissue limits are within standard range so, this antenna may find its suitability in future 5G-6G millimetre wave application.

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