International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-9 Issue-2, December, 2019

SSR Based Slotted Patch Antenna with Integrated Wave Guiding structure for 5G Application

Rajeev Dandotia, Ranjan Mishra, S M. Bhaskar, Raj Gaurav Mishra, Piyush Kuchhal

***Abstract:** An electrical small microstrip patch antenna with guided SIW slotted configuration is investigated in this paper. In the proposed design the primary antenna patch includes a slotted SRR configuration which later converted into concentric SRR slotted configuration. Here the antenna patch with concentric slot contributes dual-band resonance. The impedance matching at both the resonance is improved with guided SIW slotted structure. The proposed antenna patch incorporates a slot inside the concentric slot to correct the pattern asymmetric. The proposed antenna shows resonance at 28 GHz and 37.5GHz for mmWave 5G applications. The proposed antenna is implemented with a physical dimensions of 4.7mm ×2.7mm × 0.8mm.*

***Index Terms:** Microstrip antenna, 5G application, Slotted Patch, Frequency, Impedance.*

I. INTRODUCTION

In recent days, the development of the wireless technology developed many wireless standards which targets to integrate many more standards into one platform [1]. With this, the development Mobile communication system has been rapidly grown-up. Starting from the GSM era to the LTE-Advanced and 5G enjoyed a massive focus and research interest. To confirm compact-full implementation wireless communication terminal Microstrip antennas are one of the ultimate choices and has been widely adopted in different application such as Wireless Local Area Network (WLAN), Global Positioning System (GPS), Wi-Max, Mobile communication bands (LTE, LTE-A) [2]. Superior to the microstrip technology planar Inverted-F antenna (PIFA) has been investigated multi-band mobile communication system. The PIFA antennas are widely adopted for multi-band mobile communication also easy to integrate and easy of fabrication [3]-[4]. In further analysis these antennae extends its tremendous application implementation sub 6GHz 5G communication. Now the technology look forward to integrate multiple communication career into single terminal where the multiband antenna with LTE and 5G-NR band play a significant role [5].

In this work, a compact multi-resonance microstrip antenna is proposed for millimeter wave 5G application. The proposed antenna geometry comprises of concentric SRR slots with transmission line excitation. The SRR slot-based structure contributes dual-band resonance at millimeter wave 5G spectrum (28GHz/38GHz). Here a guided SIW slotted structure is introduced at the transmission feed line to further enhance the impedance matching. The proposed SRR based slotted SIW shows a symmetric radiation characteristic at both plain. However, a center slot is used to correct the antenna main beam squint. The antenna is implemented on a low dielectric, low loss roger's substrate which realize a better result.

The proposed antenna is structured to give a better reading experience. The design flow of the dual band 5G mmWave antenna is presented in Section 2. The antenna validation through experimental analysis is presented section 3. In section 4 the proposed work is summarized.

II. ECONFIGURATION OF PROPOSED ANTENNA

The proposed multi-band 5G antenna is designed based on the guided transmission line technique. In which the antenna patch is having a radiating patch geometry implemented on the top side of the substrate along with a transmission line excitation and ground plane is designed on the bottom side of the substrate.

Configuration of the 28GHz/38GHz 5G antenna

The proposed antenna is design on a Roger's RT/Duroid 5880 with dielectric constant (εr) of 2.2, substrate thickness (hs) of 0.8mm, and loss tangent (tan δ) of 0.0009. The proposed antenna incorporates a single-layer, single dielectric design methodology. In the beginning stage a simple rectangular patch geometry is designed to resonate near 30 GHz. To resonate in millimeter wave frequency band near 30GHz, the length and width of the antenna is determined from the given equation as presented in equation (1) and (2).

Revised Manuscript Received on December 30, 2019.
* Correspondence Author
Rajeev Dandotia, Research Scholar, Department of Electrical & Electronics Engineering, School of Engineering, University of Petroleum & Energy Studies, Dehradun , India. rajeevdandotiya@gmail.com
Ranjan Mishra, Department of Electrical & Electronics Engineering, School of Engineering, University of Petroleum & Energy Studies, Dehradun , India. rmishra@ddn.upes.ac.in
Raj Gaurav Mishra, Department of Electrical & Electronics Engineering, School of Engineering, University of Petroleum & Energy Studies, Dehradun , India. rgmishra@ddn.upes.ac.in
S. M. Bhaskar, Scientist G, GoI, New Delhi, India.
Piyush Kuchhal, Department of Physics, School of Engineering, University of Petroleum & Energy Studies, Dehradun , India pkuchhal@ddn.upes.ac.in

$$Wp = \frac{c}{2kf_r}\left(\sqrt{2/\varepsilon_{reff.} + 1}\right) \quad ...(1)$$

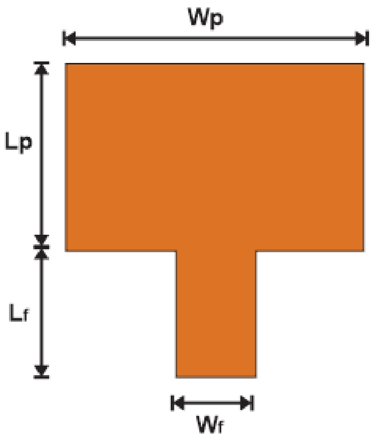
$$Lp = \frac{1}{k}\left(\frac{c}{2kf_r}\right) \quad ...(2)$$

where,

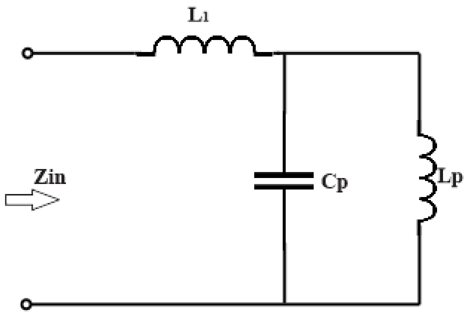
$$\varepsilon_{reff.} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left\{1 + 12\frac{h}{W}\right\}^{-0.5}$$

$\varepsilon_{reff.}$ is the effective dielectric constant
fr is the desired resonance frequency
k is the constant correction factor

The primary antenna patch of the proposed antenna incorporates edge excitation through a transmission line feed. The discussed primary antenna patch is illustrated in Figure 1(a). As shown, the patch is designed with a width (W_p) and a length (L_p) whereas the feedline is designed with a length (Lf) and width of (W_f). The length of the patch is optimized to acquire resonance at 30GHz. In the same manner the feed line width is optimized to realize a better impedance matching at the desired resonance.



(a) Antenna 1



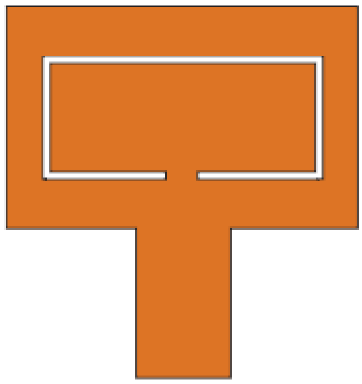
(b) Equivalent circuit.

Fig 1 Primary antenna design

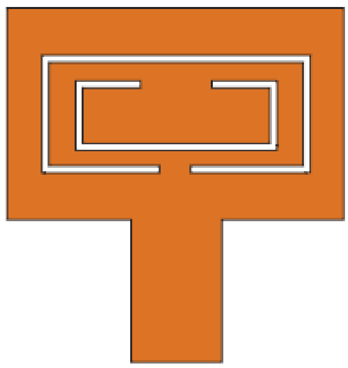
The designed primary patch can be analyzed as a lumped circuit equivalent, where the designed patch is represented as its equivalent inductance(L), capacitance (C) and resistance(R). The equivalent lumped circuit of primary patch is demonstrated in Figure 1(b). In which the equivalent resistance of the microstrip patch is ignore in this high frequency analysis. As the conductive loss due to patch is much less. The inductance of the patch is represented as (Lp), capacitance (Cp) and the microstrip fed line is represented as Li. Considering the lumped element the input impedance of the patch can be determined using the below equation (3).

$$Zin = jwL_i + jwC_p + \frac{1}{jwL_p} \quad ....(3)$$

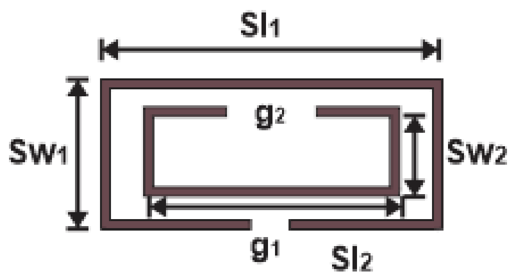
The primary patch is investigated with slotted configuration to realize the first order miniaturization which reduce the required patch size hence demonstrate the compactness. Here, Rectangular Split Ring (RSR) slot is introduced in the radiator patch as shown in Figure 2 (a). In the next step, the antenna radiator is introduced with another rectangular split ring slot. The designed radiator patch with both RSR contributes a concentric slot configuration as shown in Figure 2 (b). The concentric RSR slot demonstrate the second order miniaturization and enhances the efficiency and radiation performances. This is due to the extra number of edges caused by the concentric RSR slot. The concentric slot configuration is discussed in detail at Figure 2 (c).



(a) Antenna with one SSR slot



(b) Antenna with 2 SSR slot



(b) RSR configuration

Figure 2 Primary antenna design

In Figure 2(c), the designed concentric RSR is having a outer slot length of Sl1 and a width of Sw1. Wherein the inner slot is having length Sl2 and width sw2. To realize the rectangular ring as split ring, the outer and inner ring is made open with a gap of g1 and g2 respectively. The physical dimensions of the proposed 5G antenna is mentioned in Table 1 as mentioned below.

Table 1: Physical design parameter of the 5G dual-band antenna

Parameters	Values
Dielectric constant	2.2
Loss tangent	0.009
Substrate height	0.8mm
Patch Length	2.7mm
Patch Width	4.7mm
Feed Length	1.35mm
Feed width	1.1mm

The realization of iterative antenna design was carried out and the resonance characteristics at each instant is recorded. The S-parameter response of all antenna configuration is plotted in figure 3.

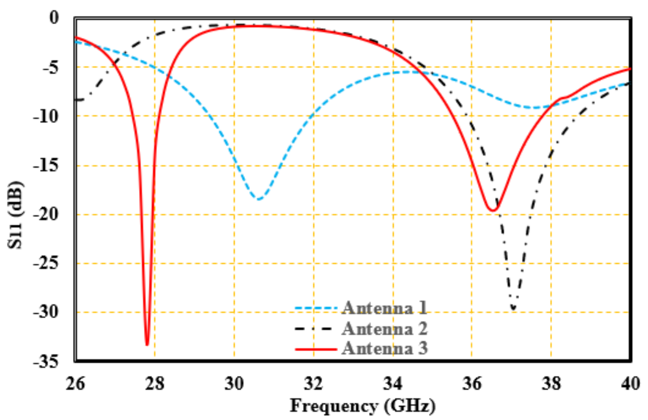


Figure 3. S-parameter result of different antenna configuration

The antenna 1 shows a single band resonance at 30.6 GHz with a return loss of 18dB. To acquire multiband response an RSR slot is implemented on the antenna aperture as shown in antenna 2. Antenna 2 with single RSR slot shows a dual band resonance. However, the matching at first resonance is poor and the point of resonance is shifted towards lower resonance. Further another ring is introduced in the center of aperture which gives perfect dual-resonance at 28 GHz and 38GHz. At both the resonances the matching is very good as shown in figure 3.

Analysis of Guided SIW structure

The designed antenna structure (Antenna 3) is introduced with guided SIW slots which guides the EM signals to the antenna apertures and hence improves the performance of the antenna. Basically, the proposed model yields better impedance matching at both the resonances.

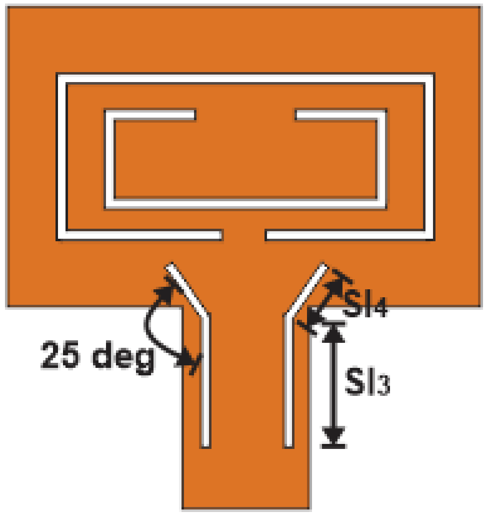


Figure 4. Proposed antenna with guided SIW structure

The presented antenna in figure 4 shows a better impedance matching and resonance tuning to meet the design requirement. The S-parameter result of the antenna with and without guided SIW slot is shown in Figure 5. Including the SIW in structure the antenna is fine tuned to 28 GHz with improved return loss of 32dB.

The simulated performance of the proposed multi-band 5G antenna is verified through experimental analysis. The detail experimental analysis is shown in next subsection.

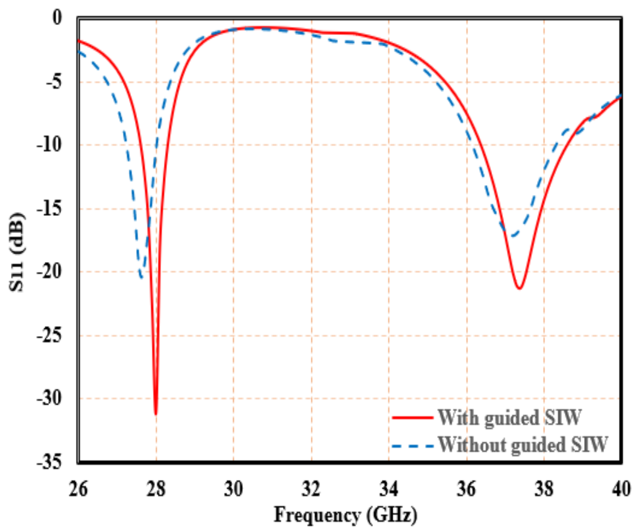


Figure 5. S-parameter with and without SIW implementation

Measurement results

The proposed antenna is fabricated on a Rogers 5880 dielectric substrate as considered in the design. The antenna geometry is converted into photographic film which is pasted on the dual-copper cladded substrate. Then the antenna is etched with chemical solution. The fabricated prototype of the proposed antenna is shown in Figure 6.

Retrieval Number: B3842129219 /2019©BEIESP
DOI: 10.35940/ijeat.B3842.129219
Journal Website: www.ijeat.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

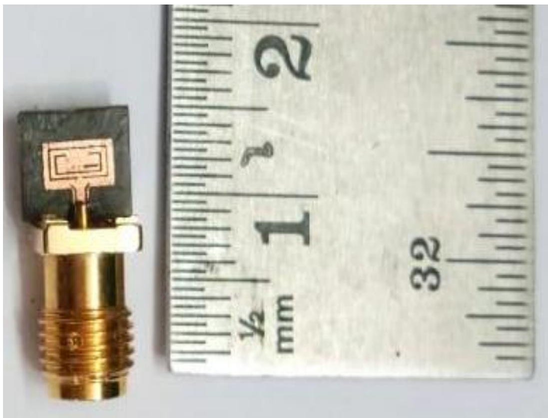


Figure 6. Fabricated prototype of the proposed antenna

The fabricated antenna prototype is tested using a Vector Network Analyzer (VNA). It has been realized the tested S-parameter response of the antenna is closely matched with the simulation results. The antenna compare S-parameter result is plotted in Figure 7.

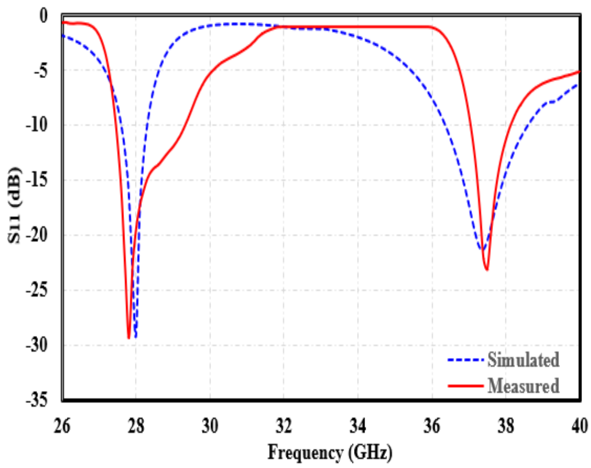
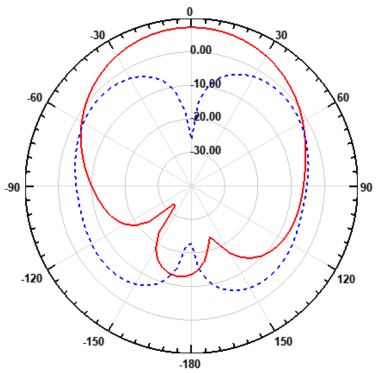


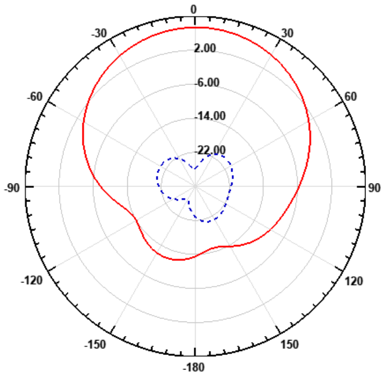
Figure 7. S-parameter response of the final prototype

The measured S-parameter results shows the first resonance at 28 GHz and second resonance at 38 GHz with a very small deviation from the simulated results. Also, the impedance matching at both the resonance are better than 29dB and 21dB respectively.

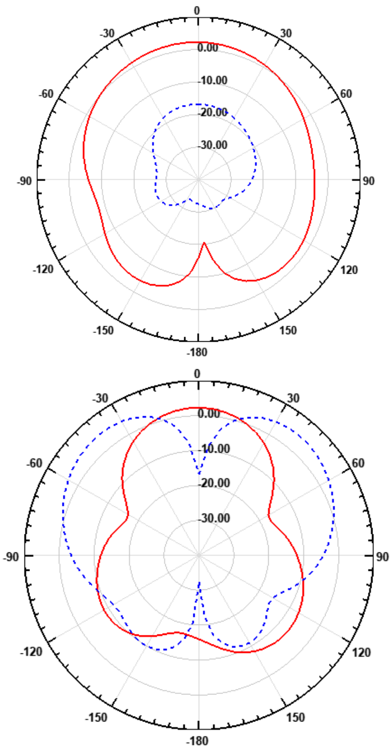
Moreover, the radiation characteristics of the antenna at both the resonances are observed and plotted in Figure 8.

Here, the antenna far-field behavior at both the plane (E-Plane and H-Plane) are observed. In each plot both co-polarization and cross polarization response are realized.





(a) 28 GHz



(b) 38 GHz

Figure 8. Radiation Pattern at each resonance

NOTE: The E-plane pattern are plotted in top side of the figure and H-plane pattern at the bottom side.

III. CONCLUSION

In this work, a multi-band 5G antenna with concentric RSR slotted configuration is investigated. The proposed electrical small antenna with concentric RSR shows the first resonance at 28 GHz with > 800MHz bandwidth and second resonance at 38 GHz with > 1GHz of bandwidth. The antenna shows an improved impedance bandwidth of better than 20dB at both the resonances with guided SIW slotted configuration.

The antenna shows improved gain response upto 5 dBi with the asymmetric slotted configuration.

Retrieval Number: B3842129219 /2019©BEIESP
DOI: 10.35940/ijeat.B3842.129219
Journal Website: www.ijeat.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

The proposed antenna shows an symmetric radiation pattern at E-plane with good cross polarization level better than -20dB. With these viable performances the proposed antenna claims its efficient application in millimeter wave 5G communication bands.

REFERENCES

1. R. Mishra, An Overview of Microstrip Antenna, HCTL Open International Journal of Technology Innovations and Research (IJTIR), Volume 21, Issue 2, August 2016.
2. Y. F. Cao, S. W. Cheung and T. I. Yuk, "A Multiband Slot Antenna for GPS/WiMAX/WLAN Systems," in IEEE Transactions on Antennas and Propagation, vol. 63, no. 3, pp. 952-958, March 2015.
3. C. H. Chang and K. L. Wong, "Printed λ/8-PIFA for penta-band WWAN operation in the mobile phone," IEEE Trans. Antennas Propag., vol. 57, no. 5, pp. 1373 - 1381, May. 2009
4. C. Rowell and E. Y. Lam, "Mobile-Phone Antenna Design," in IEEE Antennas and Propagation Magazine, vol. 54, no. 4, pp. 14-34, Aug. 2012.
5. K. L. Virga and Y. Rahmat-Samii, "Low-profile enhanced-bandwidth PIFA antennas for wireless communications packaging," in IEEE Transactions on Microwave Theory and Techniques, vol. 45, no. 10, pp. 1879-1888, Oct. 1997.
6. A. Alieldin et al., "A Triple-Band Dual-Polarized Indoor Base Station Antenna for 2G, 3G, 4G and Sub-6 GHz 5G Applications," in IEEE Access, vol. 6, pp. 49209-49216, 2018.
7. Y.-C. Lee and J.-S. Sun, "Compact Printed Slot Antennas for Wireless Dual- and Multi-Band Operations," Progress In Electromagnetics Research, Vol. 88, 289-305, 2008.
8. Z. Chen, Y.-L. Ban, J.-H. Chen, J. L.-W. Li, and Y.-J. Wu, "Bandwidth Enhancement of LTE/WWAN Printed Mobile Phone Antenna Using Slotted Ground Structure," Progress In Electromagnetics Research, Vol. 129, 469-483, 2012.

AUTHORS PROFILE

Mr. Rajeev Dandotia is Ph D scholar in the Department of Electrical & Electronics Engineering, School of engineering at University of Petroleum and Energy studies, Dehradun, Uttarakhand. He has 13 years of experience in research and development. He has published 2 research papers in International conferences. His area of interest is wireless communication, antenna design, cyber platform.

Dr. Ranjan Mishra is currently working as an Associate Professor in the Department of Electrical and Electronics Engineering, School of Engineering at University of Petroleum and Energy Studies, Dehradun, Uttarakhand (India). He has around 19+ years of experience in academics and research. Dr. Mishra has received his Ph.D. in Microstrip Antenna Design from University of Petroleum and Energy Studies, Dehradun in the year 2016. Dr. Mishra is an author of 20 international refereed journal and international conference papers and 4 edited books.

Mr. Raj Gaurav Mishra is currently working as an Assistant Professor (Selection Grade) in the Department of Electrical and Electronics Engineering at the School of Engineering, University of Petroleum and Energy Studies, Dehradun, Uttarakhand (India). He is having around 12+ years of experience in academics and research. Prof. Mishra has received his M.S. in Space Engineering from the Department of Space Studies, Umea University, Kiruna, Sweden in the year 2007. Mr. Mishra is an author of 31 international refereed journal, international conference papers and book chapters, 1 Indian patent and 3 edited books.

Dr. S. M. Bhaskar is Scientist G in Government of India. He has 25+ years of experience in field of R&D. He is Ph.D in computer Science, M. Tech, MBA and cyber law expert. He is an author of 14 books, IGNOU course material and has published 30 papers.

Dr. Piyush Kuchhal received his M.Sc and Ph D in Physics from IIT Roorkee. He is currently working in UPES as Professor in Physics. He has published 50 scopus indexed papers journal and 12 patent. He has a vast teaching and research experience of 20+ years in the area of Microwave, Engineering electromagnetism and Photovoltaic Solar cell. He also published 30 papers in International conference and presided over many committees.