SIW Feed Patch Antenna for 28GHz mm-Wave Pre-5G Applications

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Abstract— **In this paper, a beam steering capability with a newly modified single two port and series fed 2x2 port patch antenna arrays are designed with an operating frequency of 28-GHz for millimeter wave applications. Using high-impedance microstrip lines, the patches are connected to each other in a symmetric 2D format. By optimizing the length of the substrate the gain can be increased. The frequency range of this design varies from 26.5GHz to 29.5GHz and it has a center frequency of 28GHz. Here, a gain of 10.2dB is obtained. An efficient method to increase the gain and efficiency using SIW (Substrate Integrated Waveguide) has been used. SIW for a single feed is designed and a gain of 14.86dB is obtained. By comparing the results of single feed with and without using SIW, the former design provides best gain and efficiency. The use of additional integrated circuits to improve the gain and performance are allowed. The simulated results and discussions are presented.**

Keywords—5G, 28 GHz, SIW, microstrip array antenna, millimeter-wave application.

I. INTRODUCTION

Due to the higher bandwidth for wireless communications, lots of researchers and industries are becoming more and more interested in millimeter (mm)-wave spectrum[1].In spacecraft, satellite, and missile applications of high performance, where size, weight, cost, performance, ease of installation, and aerodynamic profile are constraints, the requirement is based on low-profile antennas. For example, the mm-wave communication has become one of the most attractive techniques in next generation of the International Mobile Telecommunications (IMT) (5G) [2]–[4]. A newly modified single two port antenna and series fed 2x2 port antenna are designed with beam steering capability [5]-[8] Presently there are many other government and non government applications, such as mobile radio and wireless communications, that have similar specifications. To meet these requirements, in advanced radars and emerging biomedical and satellite communications, microstrip antennas can be used [6]-[8]. These series fed structure of the antenna enhances the efficiency of the antenna [9]. These antennas are conformable to planar and nonplanar surfaces, simple and inexpensive. An improved impedance and radiation characteristics have been produced from the 2x2 series fed patch antenna [10], [11]. Finally, in [12] to decrease the cost with reduced number of phase shifters, this series fed antenna was proposed.

From the above deliberations, the main objective is to provide 2-D series fed antenna with reduced number of feed ports and phase shifters. In this paper the patches are connected to impedance transformer. The design of the 2x2 antenna provides increased gain and efficiency while comparing to single feed patch antenna. Next a new method of using SIW has been proposed [15]. The slot used to feed and increases the gain and efficiency. The use of SIW also leads to reduce the number of feeds that results in high gain.

II. SUBSTRATE INTEGRATED WAVEGUIDE

Many types of antennas are investigated for mm-wave applications. For an mm-wave band, the cost and efficiency of the antenna are significant. But the microstrip feeding line for an mm-wave band is not appropriate because of undesired radiations with increasing frequency. So Substrate Integrated Waveguide has been introduced to solve these problems. The SIW has many merits such as characteristics of rectangular waveguide, low loss, simple fabrication process, easy integration with other circuits, and low manufacturing cost, where the conventional printed circuit board (PCB) can be used. The SIW has been considered as an attractive choice for mm-wave applications.

III. DESIGN OF SERIES FEED PATCH ANTENNA

A. Single port feed antenna

A substrate named Duroid substrate with relative permittivity ε_r = 2.2 and thickness of about 0.25mm is used. The dimensions of the substrate and ground are 11.47mm. The length and width of the patch is of 3.47mm. Two symmetric feeds with single patch is shown in Fig. 1 with the feed dimensions of 0.05mm and 1mm respectively. And in second method optimization is used to get good performance.

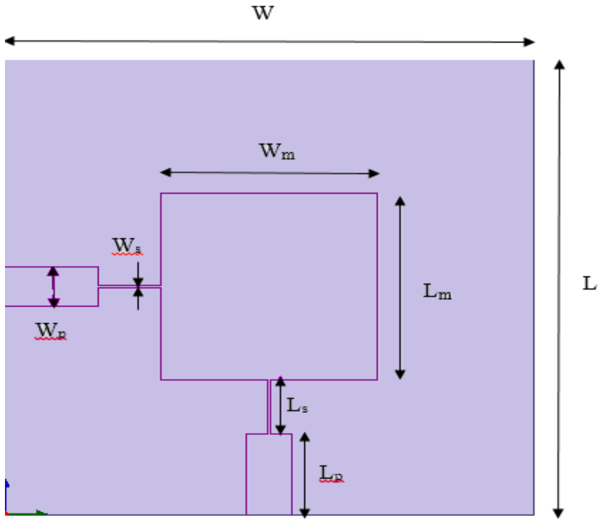

Fig.1 Single patch with two series feed patch design.

By optimizing the length and width of the substrate preferred S_{11} has been obtained. The design parameter of single patch with two series feed is shown in Table 1.

Parameters	Values
L	11.47mm
W	11.47mm
L_m	3.47mm
W_m	3.47mm
L_s	1mm
W_s	0.05mm
L_p	1.5mm
W_p	0.72mm

Table 1

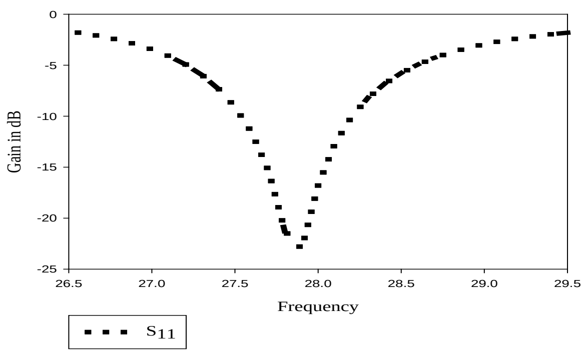

Fig. 2 S_{11} single patch with two series feed.

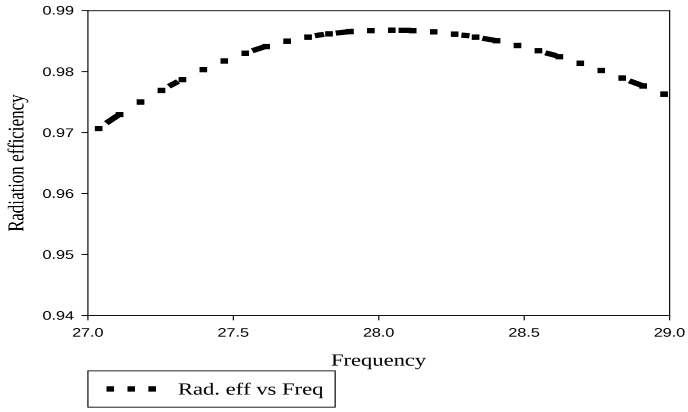

Fig. 3 Radiation efficiency of single patch.

The efficiencies are observed from many simulations from the antenna having reduced length and width to a particular extent. The radiation efficiency of the antenna gained is 98.6%.

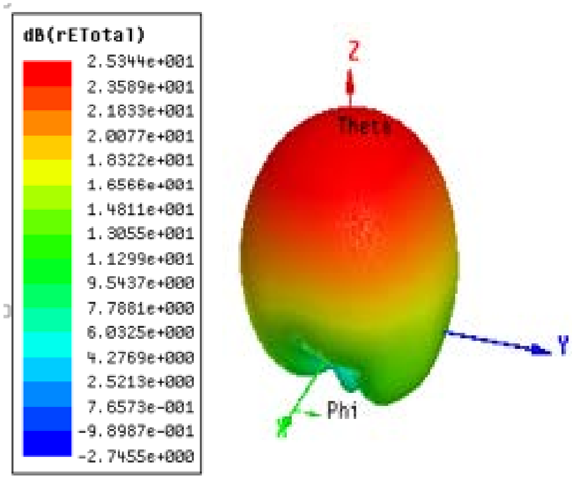

Fig. 4 3D Radiation pattern of single patch with two series feed.

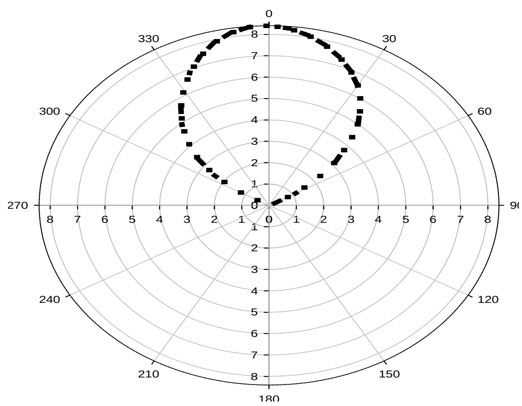

Fig. 5 Gain of single patch with two series feed.

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Gains are observed from many simulations from the antenna having reduced length and width to a particular extent. The gain of the antenna obtained is 8.4dB.

B. 2x2 series fed patch antenna

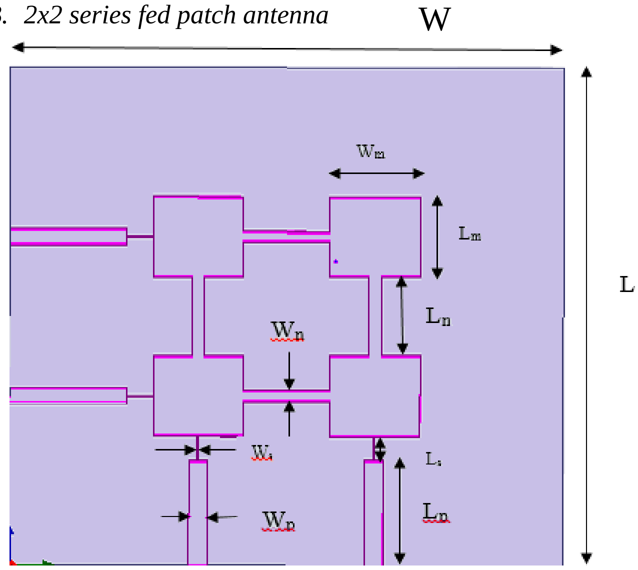


Fig. 6 2x2 series feed patch antenna design.

The dimensions of the substrate and ground are 19.47mm with 0.035mm thickness. The length and width of each patch is of 3.47mm.Symmetric feeds with 2x2 patch is shown in Fig. 6 with the feed dimensions of 4.5mm.

Parameters	Values
L	20.24mm
W	20.24mm
L_m	3.47mm
W_m	3.47mm
L_s	1mm
W_s	0.05mm
L_p	1.5mm
W_p	0.72mm
L_n	3.3mm
W_n	0.5mm

Table 2

By optimizing the length and width of the substrate preferred S_{11} has been obtained. The design parameter of 2x2 two series feed patch antenna is shown in Table 2.

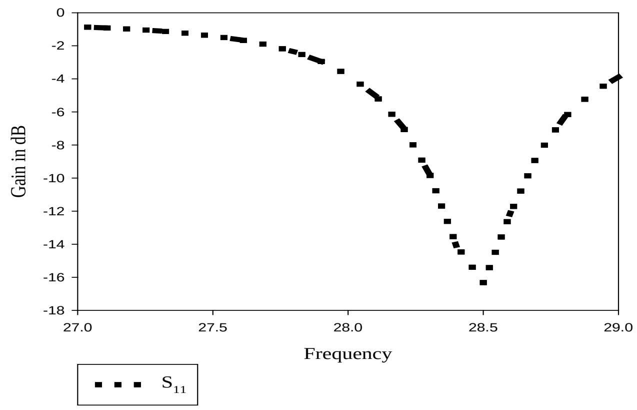


Fig. 7 S_{11} of 2x2 series feed patch antenna.

By reducing the length and width of the substrate preferred S_{11} has been obtained. The frequency ranges from 26.5GHz to 29.5GHz and it is centered at 28GHz.

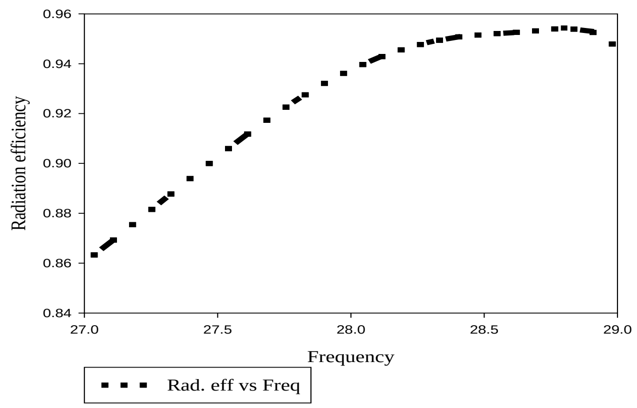


Fig. 8 Radiation efficiency of 2x2 series feed patch antenna.

Radiation efficiencies are observed from many simulations from the antenna having reduced length and width to a particular extent. The radiation efficiency of the antenna gained is 95.4%.

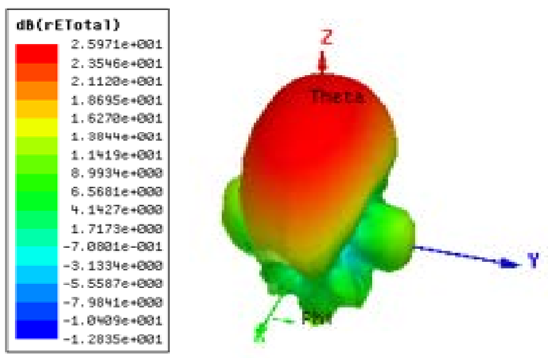


Fig. 9 3D Radiation pattern of 2x2 series feed patch antenna.

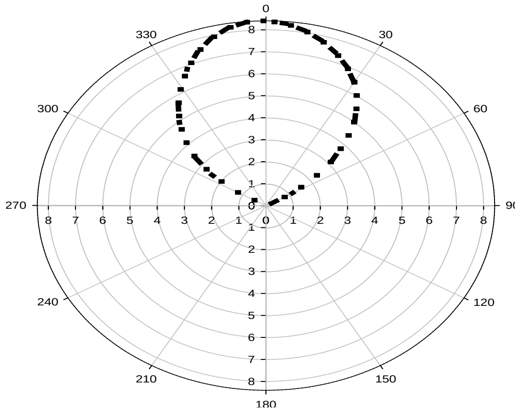


Fig.10 Gain of 2x2 series feed patch antenna.

While comparing all the gains of 2x2 patch antenna it is concluded that by reducing the length and width of the substrate the gain can be increased. The gain of the antenna obtained is 10.21dB.

IV. Design of SIW Feed Patch Antenna

One of the important factors to improve antenna array performance is to reduce side-lobe levels. Various types of pattern synthesis such as binomial distribution, Dolph–Chebyshev distribution, and Taylor distribution have been widely used to reduce the side-lobe level of an array beam-pattern. Here a chain of cylinders have been introduced in the design to increase the gain and to reduce the side-lobe levels. The radius of the SIW is 0.2mm and the space between each cylinder is 0.4mm. The design of the SIW feed antenna is given below:

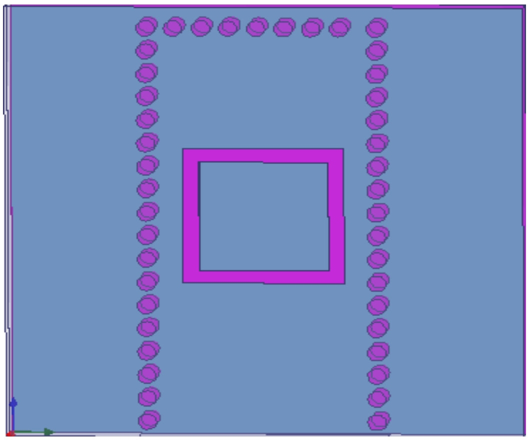


Fig. 11 SIW single patch antenna design.

The dimensions of the substrate and ground are 11.47mm with 0.035mm thickness. The length and width of patch is of 2.8mm and of slot is 4.5mm.

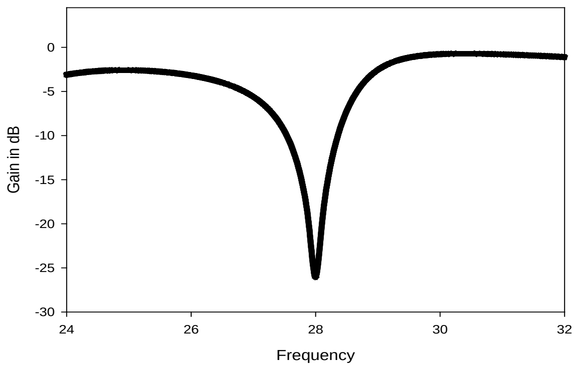


Fig. 12 S_{11} of SIW series feed patch antenna.

By reducing the length and width of the substrate preferred S_{11} has been obtained.

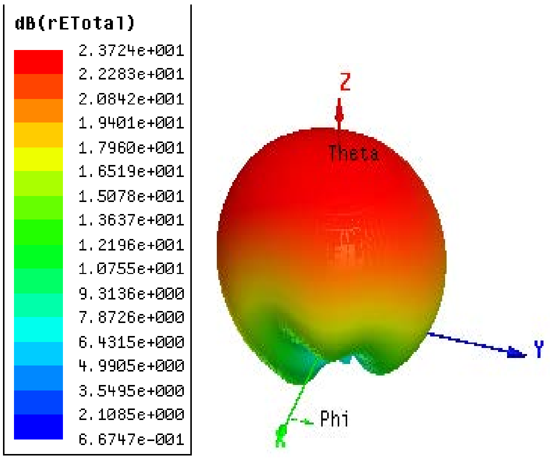


Fig. 12 Radiation pattern of SIW series feed patch antenna.

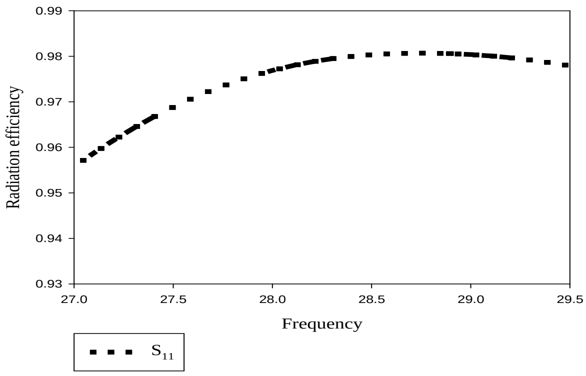


Fig. 13 Radiation efficiency of SIW series feed patch antenna.

Radiation efficiencies are observed from many simulations from the antenna having reduced length and width to a particular extent. The radiation efficiency of the antenna gained is 97.4%.

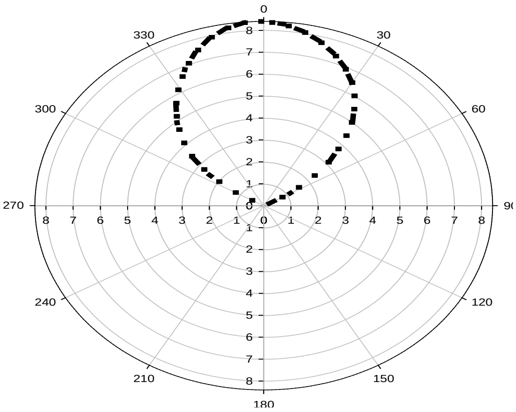
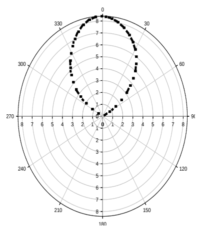
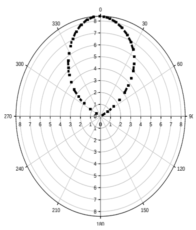
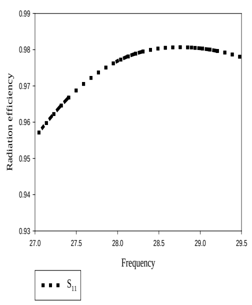
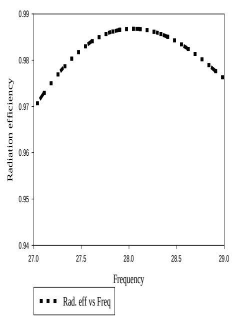


Fig.10 Gain of SIW series feed patch antenna.

While comparing all the gains of SIW series feed patch antenna it is concluded that by reducing the length and width of the substrate the gain can be increased. The gain of the antenna obtained is dB.

V. Comparison of Series Feed and SIW Feed Patch Antenna

By comparing the results of series feed and SIW feed patch antennas, it is clearly shown that the gain and the radiation efficiency of SIW feed provide improved results with perfect impedance match.

Parameter	**Single feed**	**SIW feed**
Gain	 10.21dB	 14.86dB
Efficiency	 95.4%	 97.82%

VI. Conclusion

It is concluded that from the proposed work, desired gain improvement had been obtained by using single two port and 2x2 port antennas. The S11 parameter was assigned from 26.5GHz to 29.5GHz and it is centered at 28GHz. Finally, antenna gain of 8.4dB for a single two port microstrip antenna and also a gain of 10.21dB for a 2x2 series-fed patch antenna array have been developed. The efficiency has been improved further by SIW feed patch antenna and a gain of 14.86dB has been obtained from the design. From the result, it has been identified that SIW technique provides high gain than 2x2 port series fed patch antenna by using various feeding techniques in 5G communication.

References

[1] M. Fakharzadeh, M. R. Nezhad-Ahmadi, B. Biglarbegian, J. Ahmadi-Shokouh, and S. Safavi-Naeini, “CMOS phased array transceiver technology for 60 GHz wireless applications,” IEEE Trans. Antennas Propag., vol. 58, no. 4, pp. 1093–1104, Apr. 2010.

[2] Y. Niu, Y. Li, D. Jin, L. Su, and A. V. Vasilakos, “A survey of millimeter wave (mm-wave) communications for 5G: Opportunities and challenges,” 2015 [Online]. Available: http://arxiv.org/abs/1502.07228

[3] O. M. Haraz, A. Elboushi, S. A. Alshebeili, and A. R. Sebak, “Dense dielectric patch array antenna with improved radiation characteristics using EBG ground structure and dielectric superstrate for future 5G cellular networks,” IEEE Access, vol. 2, pp. 909–913, 2014.

[4] A. Bisognin et al., “Differential feeding technique for mm-wave series-fed antenna-array,” Electron. Lett., vol. 49, no. 15, pp. 918–919, Jul. 2013.

[5] K. Zhao et al., “mmWave phased array in mobile terminal for 5G mobile system with consideration of hand effect,” in Proc. 81st IEEE VTC Spring, 2015, pp. 1–4.

[6] D. Ehyaie and A. Mortazawi, “A 24-GHz modular transmit phased array,” IEEE Trans. Microw. Theory Tech., vol. 59, no. 6, pp. 1665–1671, Jun. 2011.

[7] D. Ehyaie and A. Mortazawi, “A new approach to design low cost, low complexity phased arrays,” in IEEE MTT-S Int. Microw. Symp. Dig., 2010, pp. 1270–1273.

[8] E. Topak, J. Hasch, C. Wagner, and T. Zwick, “A novel millimeter wave dual-fed phased array for beam steering,” IEEE Trans. Microw. Theory Tech., vol. 61, no. 8, pp. 3140–3147, Aug. 2013.

[9] F.-Y. Kuo and R.-B. Hwang, “High-isolation X-band marine radar antenna design,” IEEE Trans. Antennas Propag., vol. 62, no. 5, pp. 2331–2337, May 2014.

[10] T. Yuan, N. Yuan, and L.-W. Li, “A novel series-fed taper antenna array design,” IEEE Antennas Wireless Propag. Lett., vol. 7, pp. 362–365, 2008.

[11] Y. Chong and D. Wenbin, “Microstrip series fed antenna array for millimeter wave automotive radar applications,” in Proc. IEEE MTT IMW, 2012, pp.1–3.

[12] A. Abdellatif, S. S. Naeini, and M. Mohajer, “Novel low cost compact phased array antenna for millimeter-wave 3D beam scanning applications,” in Proc. IEEE APSURSI, Jul. 2014, pp. 1145–1146.

[13] Q. Liu, J. Shen, H. Liu, and Y. Liu, “Dual-band circularly-polarized unidirectional patch antenna for RFID reader applications,” IEEE Trans. Antennas Propag., vol. 62, no. 12, pp. 6428–6434, Dec. 2014.

[14] L. Chiu, Q. Xue, and C. H. Chan, “Dual-fed patch antenna with distorted patch mode for balanced circuits,” Microw., Antennas Propag., vol. 4, no. 7, pp. 809–816, 2010.

[15] Seong-Jin Park et al, “Low side lobe Substrate-Integrated-Waveguide Antenna Array Using Broadband Unequal Feeding Network for Millimeter-Wave Handset Device”, 2016.