A Modified Square Patch Antenna with Rhombus slot for High bandwidth

M.Ramkumar Prabhu, J.R.Arunkumar , A.Rajalingam, R.Anusuya

***Abstract:** In this the proposed patch antenna operates at 32 GHz which is among the projected 5G communication frequencies and has a novel geometry with rhombus-shaped slots. The first design in this work is a inset fed used conventionally in patch antenna. It has a quarter wavelength impedance matching line. The dimensions are determined according to the usual design considerations. Low return loss and high bandwidth requirements motivates us to modify the antenna design. Therefore, we add rhombus – shaped slots on the patch which leads to an additional increase in the system bandwidth as much as 52 MHz and a reduction in the return loss level up to 11.241 dB. The proposed patch antenna design is conjectured to be a suitable candidate to address the requirements of 5G communication systems. The operating frequency of the proposed antenna can be tuned by changing the geometrical dimensions from microwave to the THz region.*

***Keywords:** 5G, Rhombus, Patch antennas*

I. INTRODUCTION

Wireless communication technology has been an area with intense improvement and cutting edge development in the last decade. Starting with the first - generation communication systems all the way up to today's 4G LTE systems, there has been a rapid development and need to transfer not only voice data and text, but also live video streaming, GPS data and much more between the transmit and the receive devices [3].

The specific demand for faster communication will be the main focus in the near future. Based on Cisco Visual Networking Index (VNI) mobile data traffic grew 74 percent globally in 2015 and 4G technology traffic exceeded 3G technology traffic for the first time in 2015 [1]. In addition, VNI states that by 2020, more than three fifths of all devices connected to the mobile network will be hyper smart devices and there will be 11.6 billion mobile connected devices by 2020, including machine to machine modules [1]. Therefore efficient antenna designs are paramount to the design and development for the next generation communication systems. It is clear that millimeter wave (mm - wave) frequencies of unlicensed spectra will enable to utilize a vast amount bands [3]. To this end developments in the antenna technology become a central aspect in mm – wave system design. The microstrip patch [3], considering the width and length of the patch to be equal in dimension. Usually designers encounter a narrow bandwidth problem in patch antennas.

antennas are in particular importance thanks to their miniature dimensions which provides various surfaces, circuits and devices. A major short coming of such antennas, however, is their limited bandwidth. This disadvantage can be overcome with different techniques such as inset feeding [4] or etching different geometrical shapes to the ground plane which is called defected ground plane structure (DGS) [5]. There are also studies for efficient antennas with low return loss in wideband applications by etching circular slot on the circular patch [6].

There are myriad applications as well as various proposals to improve the bandwidth of patch antennas. However, there are few studies in the mm – wave microstrip antenna technology. In particular, in [7] the detailed design aspects for 5G frequencies have been discussed. In [8] it has been focused on orientation of phase array antenna for 5G applications. In addition, in [9] dual band printed mm – wave slot antennas are studied. [10] proposes an application for communication between vehicles in mm - wave radio channel. There is a clear need for an advanced microstrip antenna technology for mm – wave applications in order to facilitate high bandwidth and low return loss levels. GPS 4 anti jamming network is also analyzed [12] for smart antenna.

Following from that we propose a novel microstrip patch antenna design which is enabled by virtue of a simulated optimization of antenna geometry. In particular it is found that a rhombus shape opening carefully allotted on the antenna surface leads to a comparative reduction in the return loss level and provides a substantial increase in the system bandwidth. We focus on a square microstrip patch antenna resonating at 32 GHz. [2] states that a bandwidth increase of 1 GHz or more is likely to be obtained above 32 GHz. Following from [2] we initiate our optimization procedure by selecting a central frequency of 32 GHz. It will be shown in sequel that the optimization procedure that we follow will suggest that 32.2 GHz will manifest itself as a particularly suitable frequency for accomplishing high bandwidth and reduction in return loss.

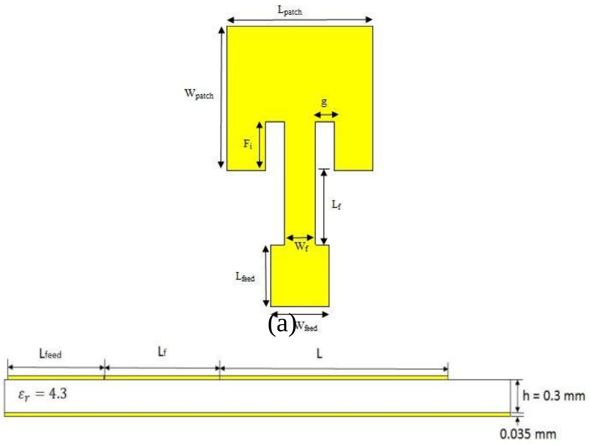
II. DESIGN

The design considerations have been made according to the steps of the design of rectangular microstrip patch antenna

Especially in millimeter wave bands this drawback becomes more important because the antennas should send the beams in definite directions with high efficiency so our objective is to improve the bandwidth with low return loss. For this purpose, a square microstrip patch antenna is designed with edge dimension 2.362 mm shown in Figure 1 from top and side. The patch is assembled on a FR 4 substrate with dielectric constant ε_r = 4.3 and dielectric loss tangent δ = 0.025.

We chose an FR 4 substrate because of being inexpensive, compatible with other circuits and being supplied easily. The substrate dimensions are W x L = 4.6 x 5.2 mm. The height of the [4].

So, the thickness of the substrate was chosen as h = 0.3 mm. The thickness of the metal is 0.035 mm.



(b)

Figure 1. Square inset fed patch antenna without slots (a) Top view, (b) Side view.

Antenna design parameters are summarized in Table 1. W_{subs} and L_{subs} show the width and the length of the substrate, respectively. According to the design method [11] the calculation on the dimensions of a square patch antenna is shown below.

$$W=L=C/2f_r \sqrt{} \varepsilon_r+1/2 \qquad \text{---- (1)}$$

Here W represents width of the patch, L represents length of the patch, c represents the speed of light, ε_r represents the dielectric constant of the substrate material and f_r represents the resonant frequency of the antenna. As seen from the formula (1) the patch dimensions define the resonant frequency. Because the proposed antenna has a square geometry there is no need to calculate the width and the length separately. Therefore, it can be concluded that this type of geometry is easier for having one calculation to adjust the resonant frequency.

Table 1. Geometrical dimensions of the proposed antenna

ε_r	W_{patch} (mm)	L_{patch} (mm)	h (mm)	W_{subs} (mm)	L_{subs} (mm)
4.320	2.362	2.362	0.320	4.600	5.200
F_i (mm)	g (mm)	L_f (mm)	W_f (mm)	L_{feed} (mm)	W_{feed} (mm)
0.800	0.320	1.210	0.510	1.000	0.955

The antenna is fed by an inset microstrip feed line of 75 Ω with the width W_{feed} = 0.955 mm and length L_{feed} = 1 mm. The feeding is not built on the patch edge. It is created in an interior point by using a rectangular notch with the dimensions F_i x g = 0.8 x 0.3 mm. F_i and g will affect the return loss and resonant frequency level, so the most suitable results should be found. In addition, the feed line is connected to the patch with a quarter wavelength impedance matching line. This line makes it easier to find the right dimensions for the feeding part. Additionally, by changing the value of W_f which is the width of the impedance matching line it is possible to get different resonant frequencies but at this time the return loss levels also change. We propose a square patch antenna with rhombus shaped slots to improve bandwidth and low return loss level with the edge dimension of a = 0.424 mm on it. This design is shown in Figure 2. The coordinates of the slots and the edge dimension effect on the resonant frequency and return loss level so an optimization should be carried out.

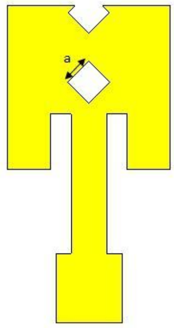


Figure 2. Square inset fed patch antenna with rhombus shaped slots.

III. RESULTS AND DISCUSSIONS

Computer simulation Technology is used to design and optimize a square patch antenna at 32 GHz. Reflection coefficient results $|S_{11}|$ without the rhombus shaped slots on the patch are shown in Figure 3 and the antenna resonates at near to 32 GHz with return loss -33.327 dB and a bandwidth of about 0.962 GHz.

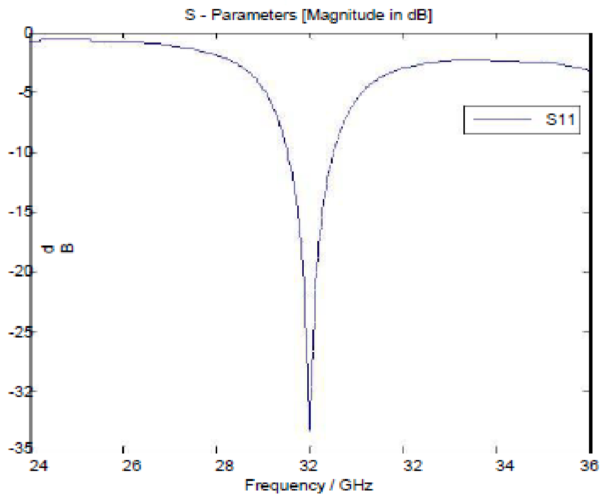


Figure 3. Return loss characteristics (S_{11}) vs frequency for the first design.

A rhombus shaped slot is proposed to increase the bandwidth and decrease the return loss. After these slots etched on the patch the $|S_{11}|$ results are as shown in Figure 4. There is a increase in return loss with the decrease of 11.241 dB as -44.059 dB and the bandwidth with the increase of 0.052 GHz as 1.008 GHz. But, the frequency of resonance is shifted to 32.216 GHz.

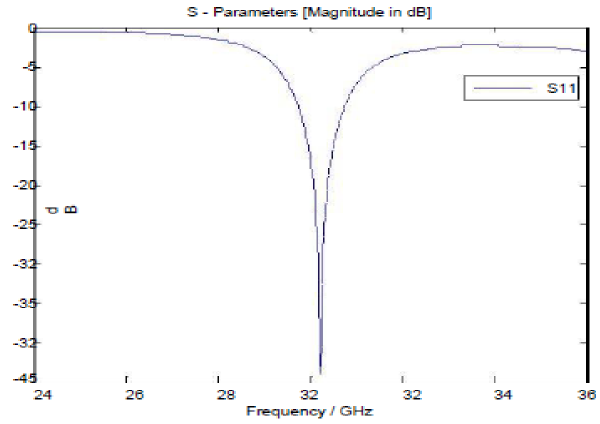


Figure 4. Return loss characteristics (S_{11}) vs frequency for the second design.

Figure 5 and 6 show the current densities on the square patch antennas with and without the slots, respectively. At the resonant frequency, it is clearly seen that the current density has increased on the antenna especially around the slot edges after the slots has been etched. It can be clearly concluded that the current density increases when surfaces are created along the edges of the patch antenna. Figure 7 and 8 show the radiation patterns at the resonant frequencies for the antennas with and without the slots, respectively. It is also clear that this novel design leaded to a decrease in the side lobe level from -8.8 dB to - 8.7 dB and to an increase in the main lobe level from 6.56 dBi to 6.6 dBi. These results can be taken also as advantages for this proposed patch antenna.

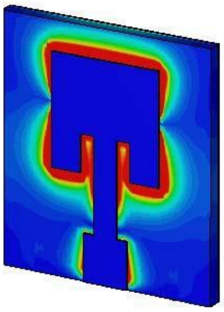


Figure 5. Current density distribution on proposed square patch antenna without slots.

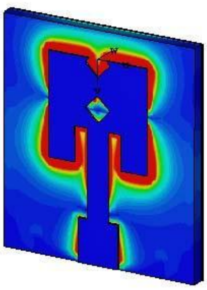


Figure 6. Current density distribution on proposed square patch antenna with slots.

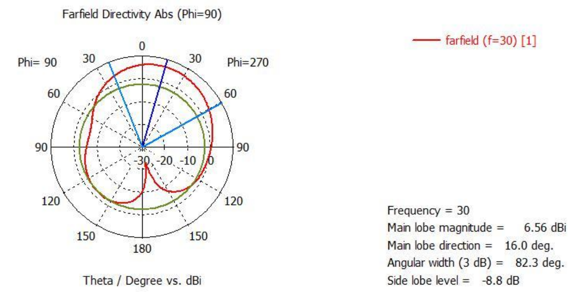


Figure 7. Square microstrip patch antenna without slot – Radiation pattern

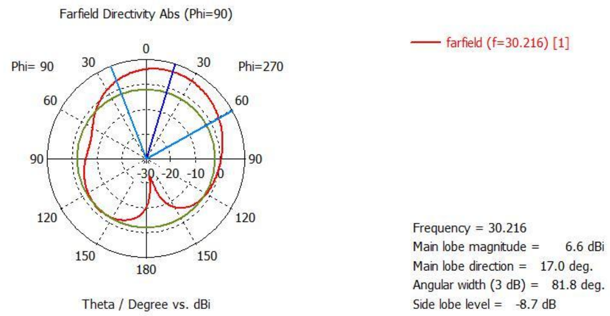


Figure 8. Square microstrip patch antenna with slot – Radiation pattern.

IV. CONCLUSION

A square microstrip patch antenna with a slot design to improve the radiation characteristics is presented. The operation frequency of the proposed antenna is 32 GHz . We perform the optimization of the slot coordinates and dimensions inorder to improve the return loss. From the experiments it is seen that lower retrun loss is obtained from the microstrip patch antenna with the rhombus slots. In order to obtain 5G and wireless application, the proposed patch can be used for future enhancement application purpose.

REFRENCES

1. Cisco, Visual Networking Index, White Paper, , February 2015.
2. Ericsson, White Paper, 5G Radio Access, April 2016.
3. M. Agiwal, A. Roy, N. Saxena, “Next Generation 5G Wireless Networks: A Comprehensive Survey”, IEEE Communications Surveys&Tutorials Vol. 18, No. 3, Thirdquarter 2016, February 2016, pp 1617 – 1655.
4. M. A. Matin, A. I. Sayeed, “A Design Rule for Inset – Fed Rectangular Microstrip Patch Antenna”, WSEAS Transactions on Communications, Volume 9 Issue 1, January 2010, pp 63 – 72.
5. A. Zaidi, A. Baghdad, A. Ballouk, A. Badri, “Design and Optimization of an Inset - Fed Circular Microstrip Patch Antenna Using DGS Structure for Applications in the Millimeter Wave Band”, International Conference on Wireless Networks and Mobile Communications (WINCOM), October 2016.
6. M. Ayyappan, B. Manoj, S. Rodrigues, “Low Return Loss Circular Microstrip Patch Antenna at 5.8 GHz for Wide – Band Applications”, International Conference on Electrical, Electronics and Optimization Techniques (ICEEOT), March 2016.
7. D. A. Outerelo, A. V. Alejos, M. G. Sanchez, M. V. Isasa, “ Microstrip Antenna for 5G Broadband Communications : Overview of Design Issues ”, 2015 International Symposium on Antennas and Propagation & USNC / URSI National Radio Science Meeting, July 2015.

8. L. C. Yu, M. R. Kamarudin, " Investigation of Patch Phase Array Antenna Orientation at 28 GHz for 5G
9. Applications ", 2016 International Electrical Engineering Congress (iEECON2016), Volume 86, pp. 47 - 50.
10. N. Ashraf, O. M. Haraz, M. M. M. Ali, M. A. Ashraf, "Optimized Broadband and Dual – Band Printed Slot Antennas for Future Millimeter Wave Mobile Communication", International Journal of Electronics and Communications, Volume 70, Issue 3, March 2016, pp.– 264.
11. M. G. Sanchez, M. P. Taboas, E. L. Cid, " Milimeter Wave Radio Channel Characterization for 5G Vehicle – To Vehicle Communications ", Measurment, Volume 95, January 2017, pp. 223 – 229.
12. H. Werfelli, K. Tayari, M. Chaoui, M. Lahiani, H. Ghariani, " Design of Rectangular Microstrip Patch Antenna ", 2nd International Conference on Advanced Technologies for Signal and Image Processing – ATSIP'2016, March 2016.
13. M.Ramkumar Prabhu & U.T.Sasikala, 2014. GPS- 4 Arrays Smart Antenna for Anti-Jamming in International Journal of Engineering Science Invention , Volume 3 Issue 4, April 2014, PP.29-41

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