A Single Band Antenna Design for Future Millimeter Wave Wireless Communication at 38 GHz

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Abstract

In this proposed paper, a single band microstrip patch antenna for fifth generation (5G) wireless application was presented. 28, 38, 60 and 73 GHz frequency bands have been allocated for 5G mobile communications by International Telecommunications Union (ITU). In this paper, we proposed an antenna, which is suitable for the millimeter wave frequency. The single band antenna consists of new slot loaded on the radiating patch with the 50 ohms microstrip line feeding used. This single band antenna was simulated on a FR4 dielectric substrate have relative permittivity 4.4, loss tangent 0.02, and height 1.6 mm. The antenna was simulated by Electromagnetic simulation, computer software technology High Frequency Structural Simulator. And simulated result on return loss, VSWR, radiation pattern and 3D gain was presented. The parameters of the results well coherent and proved the literature for millimeter wave 5G wireless application at 38 GHz.

Keywords: Single-band antenna, rectangle and cylindrical slots, millimeter wave, 5G

Introduction

Communication system standards have been a challenge for modern wireless communications. As a trend, until now, fourth generation (4G) communication is already standardized. And next, the standard for 5G is just confirmed as the technology is to be matured. And it is estimated to be launched in 2020. As seen on Figure 1, some of the candidate bands are suggested for 5G communications in the frequency of 20 GHz to 50 GHz, which are called as millimeter wave band [1-3].

Millimeter wave band technology puts in the way easier and speeder data transfer and high capacity, high data rate and lower latency, which will be demanded by end user heartily in near future. Moreover, the technology brings flexible design to ensure the adaptability of 5G communication with advanced features for mobile [3].

Nevertheless, rapid development in wireless communications demand antenna design that can operate at millimeter frequency band in a compact size. To design a millimeter band antenna, increasing the bandwidth must be apart of to cover multiband applications [4-6]. Current research show that, bigger antenna than conventional is needed to cover 28 GHz millimeter wave frequency as unique frequency [7]. As for dual band antenna was designed, that can operate at two frequencies, which are 24.25 GHz and 38 GHz [8]. In this paper, a single band antenna was proposed for future wireless communication that can operate at 38 GHz.

Microstrip antennas, which was proposed, are suitable for global positioning system (GPS) and biomedical radiator. However, these antennas have a beneficial physical dimension including light weight, low cost and more. So, they are suitable for mobile radio and wireless communications as well, due to their planar configuration, easy integration ability into arrays [9-10]. Because low-profile antenna is required for these applications, microstrip antennas, which can be integrated within a given shape easily, are particularly suitable. Although several substrates can be applied to design a microstrip antenna, while applying 1 to 100 GHz frequencies, the dielectric constant should be selected within the range of $2.2 \leq \varepsilon_r \leq 12$.

So, in this paper, a new design of patch antenna was proposed to fulfil several requirements of the modern mobile wireless technology, especially the actual one, 5G. The paper is organized as follows; Section II describes the design of the proposed antenna. Section III presents the results and discussion in details. Lastly, section IV concludes the design with some prospective future agendas.

Antenna Design

The antenna was designed on a FR4 substrate with a thickness of 1.6 mm to operate at 38 GHz millimeter wave band frequency. As Nachabe et al. states that the antenna, printed on FR4 substrate, was found to perform well on millimeter wave technology [9]. Our proposed antenna was designed with 4.4 of dielectric permittivity. The front and side view of the antenna is illustrated in Figure 2. The proposed antenna specification is seen on Table I.

Parameter	mm	Parameter	mm
L_1	3.1	W_3	1.9
L_2	4.4	W_4	1
L_3	0.5	W_5	1
L_4	1.4	W_6	0.2
L_5	1.6	r	0.3
W_1	1	t	1.6
W_2	1		

Table 1. Dimension of proposed antenna.

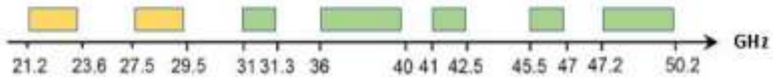


Figure 1. Candidate bands for 5G.

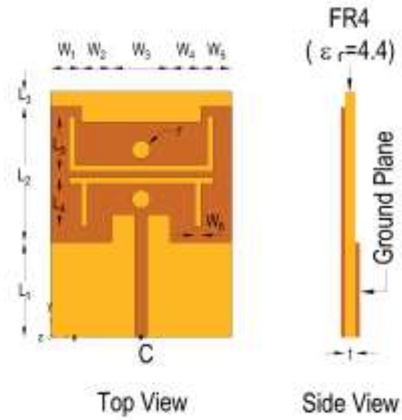


Figure 2. Structure of proposed single band antenna.

Results and Discussions

The performance of this single band slotted microstrip patch antenna was determined by HFSS software. The analysis was made on S-parameter, VSWR, E and H field radiation pattern and 3D radiation pattern with a frequency range of 20 to 50 GHz. This antenna shows resonance at single different band. The analysis is illustrated below with Figure 3 – Figure 6.

As seen on the Figure 3 of reflection coefficient that the propagating wave crossed the -10dB line twice within the range of 20 to 50 GHz. The resonance was approximately found at 38 GHz and the return loss is -24.35 dB. The corresponding 10 dB return loss bandwidth of the center frequency is 1.021 GHz. Proposed antenna has one resonant frequency at 5G band appeared in the range of 37.10 to 38.12 GHz. This resonant frequency along with its corresponding band and return loss is seen on Table II.

VSWR is used to measure the imperfections of the transmission line like VSWR represents the efficiency of transferring RF power into the load via a transmission line from the power source. On Figure 4, the VSWR parameter of the patch antenna were illustrated. The propagating wave intersected the 1 dB line at desired frequency. So, the VSWR value was found approximately 1 dB pointing out the good matching condition.

Resonant Frequency (GHz)	Band covered	Return loss (dB)	Bandwidth (GHz)
38	Ka	-24.35	1.021

Table 2. Return loss and bandwidth of the proposed antenna.

Resonant Frequency (GHz)	Directivity in E plane (dB)	Directivity in H plane (dB)
38	2.37	2.37

Table3. Directivity in E and H plane at operating frequency.

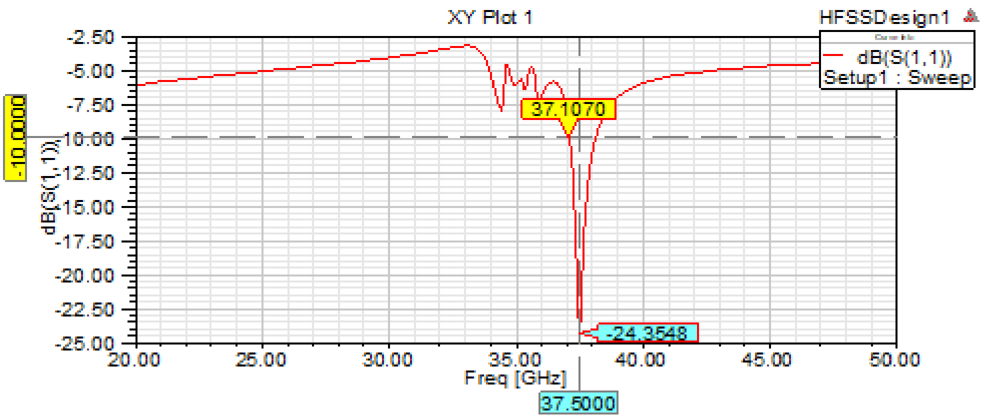


Figure 3. Reflection coefficient (S_{11}) of the antenna.

Directivity measures, how 'directional' an antenna's radiation pattern is. The directivity of the antenna at resonant frequency in E and H plane is seen on Figure 5 from the relevant pattern from φ= 0 and φ= 90 degrees. The directivity is shown on Table III at resonant frequency.

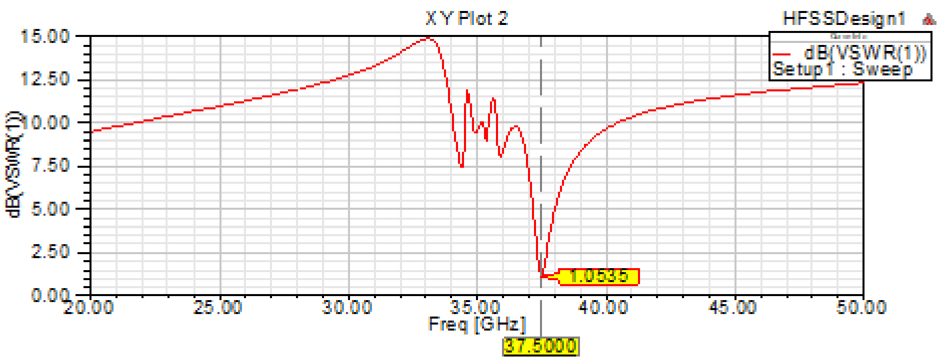
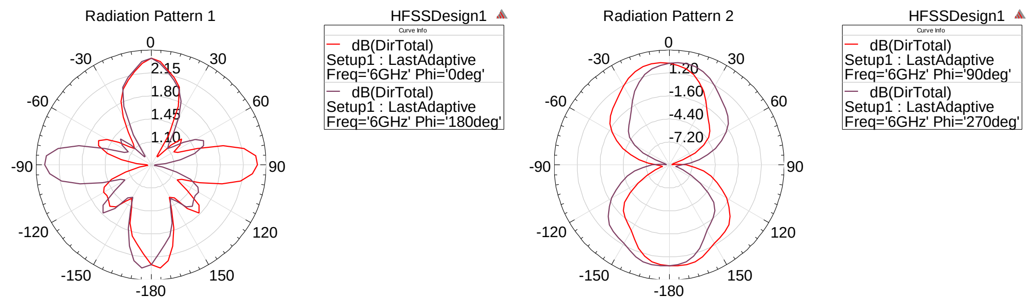


Figure 4. Voltage standing wave ratio of proposed antenna.

Microstrip patch antennas are used in a wide range of applications because of their advantageous features. But there are two major disadvantages are low gain and narrow bandwidth of antenna. Antenna gain describes, how much power is transmitted in the direction of an isotropic source. The gain of the antenna within the range of 20 to 50 GHz is seen on Figure 6, that is low at 38 GHz.



(a) (b)

Figure 5. Directivity at 38 GHz (a) in E-plane (b) in H-plane.

Figure 6. Gain of the patch antenna.

Conclusion

In this paper, a single band antenna was proposed, simulated and analyzed compatible with 5G application frequency. The simulation results proved, that it can operate at 38 GHz millimeter wave band compatible with the required 5G candidates band (20 GHz to 50 GHz). The simulation result was compared by several sizes of the antenna in order to achieve the best results especially in terms of frequency drop, gain and efficiency of the antenna. The antenna has a good result of return loss | S_{11}| of-24.35 dB at desired frequency and achieved a ultra wide bandwidth of 1.021 GHz.

Acknowledgments

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References

[1] Ojaroudiparchin, N., Shen, M., & Fr, G. (2015, November). Multi-layer 5G mobile phone antenna for multi-user MIMO communications. In Telecommunications Forum Telfor (TELFOR), 2015 23rd (pp. 559-562). IEEE.

[2] Gampala, G., & Reddy, C. J. (2016, March). Design of millimeter wave antenna arrays for 5G cellular applications using FEKO. In 2016 IEEE/ACES International Conference on Wireless Information Technology and Systems (ICWITS) and Applied Computational Electromagnetics (ACES) (pp. 1-2). IEEE.

[3] Haraz, O. M., Ali, M. M. M., Alshebeili, S., & Sebak, A. R. (2015, July). Design of a 28/38 GHz dual-band printed slot antenna for the future 5G mobile communication Networks. In 2015 IEEE International Symposium on Antennas and Propagation &USNC/URSI National Radio Science Meeting (pp. 1532-1533). IEEE.

[4] http://www.antenna-theory.com/basics/main.php

[5] Aziz, M. Z. A. A., Shukor, M., Suaidi, M. K., & Salleh, A. (2012). Design a 3.5 Antenna for Dual Band Application. International Journal of Emerging Technology and Advanced Engineering, 2(9), 486-492.

[6] Gai, S., Jiao, Y. C., Yang, Y. B., Li, C. Y., & Gong, J. G. (2010). Design of a novel microstrip-fed dual-band slot antenna for WLAN applications. Progress in Electromagnetics Research Letters, 13, 75-81.

[7] Morshed, K. M., Esselle, K. P., & Heimlich, M. (2016, April). Dielectric loaded planar inverted-F antenna for millimeter-wave 5G hand held devices. In 2016 10th European Conference on Antennas and Propagation (EuCAP) (pp. 1-3). IEEE.

[8] Daud, N. N., Jusoh, M., Rahim, H. A., Othman, R. R., Sapabathy, T., Osman, M. N., ... & Kamarudin, M. R. (2017, March). A dual band antenna design for future millimeter wave wireless communication at 24.25 GHz and 38 GHz. In Signal Processing & its Applications (CSPA), 2017 IEEE 13th International Colloquium on (pp. 254-257). IEEE.

[9] Nachabe, N., Luxey, C., Titz, D., Costa, J. R., Matos, S. A., Gianesello, F., & Fernandes, C. A. (2017, July). Low-cost 60 GHz 3D printed lens fed by a planar source with WR15 transition integrated on FR4 PCB. In Antennas and Propagation & USNC/URSI National Radio Science Meeting, 2017 IEEE International Symposium on (pp. 2671-2672). IEEE.

[10] Guneser, M. T., Seker, C. (2017, October). Design A Single Band Microstrip Patch Antenna At 28 Ghz For 5g Application. In International Conference Integrated innovative development of Zarafshan: achievements, problems, prospects on (pp. 180-184). Navoi, Uzbekistan.