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Design Of A Compact Ultra-Wideband Microstrip Antenna for Millimeter-Wave Communication

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***Abstract*—In this paper, a planar compact ultra-wideband microstrip antenna is proposed for millimeter-wave communication. The proposed single antenna element has 93.78% fractional bandwidth (covered band of 23.5 GHz to 65 GHz). The simulated radiation efficiency is greater than 93% and a peak gain of 5.6 dBi, with less than 3 dB variation in the whole band. The return loss of the single element antenna is well below -10 dB in the proposed band. The unique contribution of the proposed antenna design lies in its huge operation bandwidth (41.5 GHz) with a very simple structure. The proposed ultra-wideband antenna is suitable for many mmWave applications such as ISM band at 24 GHz, the upper region of K-band, Ka-band (27-40 GHz), mmWave 5G communication (26 GHz, 28 GHz, 38 GHz), as well as 60 GHz high-speed wireless communication (IEEE 802.11ad).**

Keywords—5G, microstrip antenna, mmWave, ultra-wideband

I. INTRODUCTION

Millimeter-wave (mmWave) technology has evolved rapidly over a couple of decades due to the demand of high data rate and to accommodate high throughput for fifth-generation (5G) wireless communication. The exceptional advantages of mmWave communication over the existing wireless technology are prominent in academia as well as industries [1]. MmWave bands such as 26 GHz, 28 GHz, and 38 GHz are proposed for 5G [1], whereas Wireless Gigabit Alliance (WiGig IEEE 802.11ad) has motivated researchers to use 60 GHz band for extremely high-speed (Wi-Fi) wireless communication [2]. Since the integration of systems and multiple applications on a single user platform is already in trend, thus an ultra-wideband (UWB) antenna encompassing the required multi bands for a compact RF circuitry is highly desirable [3]-[6].

This paper presents, for the first time a compact (8 mm × 4.6 mm) UWB microstrip antenna designed for mmWave communication covering a wide spectrum of 41.5 GHz with fractional bandwidth (FBW) of 93.78%. To the authors' knowledge, this is the highest reported bandwidth for below 65 GHz band microstrip antennas with such a compact size (less than 9 mm^2). The proposed antenna covers the complete mmWave band for 5G, ISM band at 24 GHz, UWB automotive radars in Ka-band, and 60 GHz WiGig communication.

II. ANTENNA DESIGN

The design of the proposed single element antenna is shown in Fig. 1. The antenna is designed using Rogers 5880 substrate having dielectric constant of 2.2 and height of 0.254 mm. The antenna consists of a set of rectangular box-type structure connected to the main feed line. The closed rectangular structure on the antenna is responsible for the wideband response. Additionally, to improve matching, an additional stub with length of 0.6 mm was added to the feed line which resulted in increased bandwidth and improved reflection coefficient. Finally, the position and length of the stub as well as size of the rectangular box were optimized to get an efficient reflection coefficient and to further enhance the bandwidth. Likewise, the ground plane was truncated to an optimized value which also has a significant effect in wideband response. The overall size of the antenna is quite compact with the dimensions of 8 mm × 4.6 mm.

III. SIMULATED RESULTS

The proposed antenna model was designed and simulated in CST Microwave Studio. The reflection coefficient is shown in Fig. 2, which is below -10 dB through the whole operational bandwidth. The antenna achieves a moderate average gain of 3.9 dBi, with a peak gain of 5.66 dBi at 64

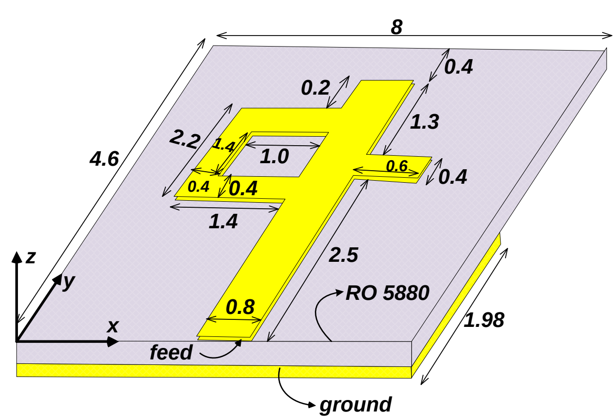

Fig. 1. Prototype of the proposed planar UWB antenna (dimensions in millimeter)

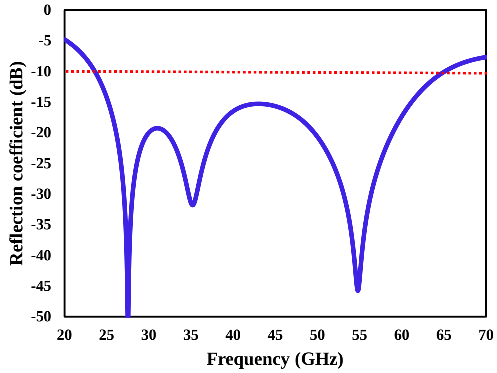

Fig. 2. Simulated reflection coefficient of the proposed single antenna element.

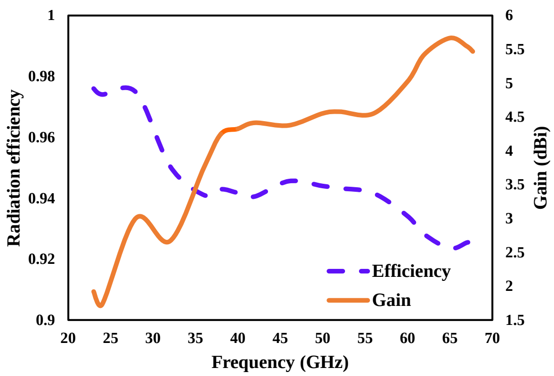

Fig. 3. Simulated gain and radiation efficiency of the proposed single antenna element.

GHz, whereas it is well above 3 dBi from 33.3 GHz to 65 GHz, with the gain variation of less than 3 dB from 27 to 65 GHz. The antenna is more than 92.4% efficient throughout the operational band, with the radiation efficiency greater than 94.17% from 23.5 to 55 GHz. The maximum radiation efficiency of 97.47% is obtained at 28 GHz. The radiation patterns are shown in Fig. 4 which are stable and directional. Performance comparison of the proposed work with other UWB mmWave antennas is summarized in Table I.

In addition to single element design, an 8-element linear array (1×8) with optimized 4.8 mm center-to-center element spacing was also simulated. The array configuration provides a high gain 0f 12.03 dBi to 18 dBi from 24 GHz to 60 GHz. The simulated radiation efficiency remains above 93% in array configuration throughout the bandwidth. The half-power beamwidth varied from 9º to 30º for phi = 0º plane and 50º to 157º for phi = 90º plane (from 24 GHz to 60 GHz).

Finally, the array radiation patterns, scanning performance, and the beamforming capabilities of the proposed antenna are not included in this paper due to brevity. However, they are anticipated to be included in a more detailed work in future along with the fabricated prototypes of the single element as well as the array, together with measurements.

IV. CONCLUSION

In this paper, the design of a planar compact UWB antenna is proposed which covers a wide frequency spectrum (23.5 to

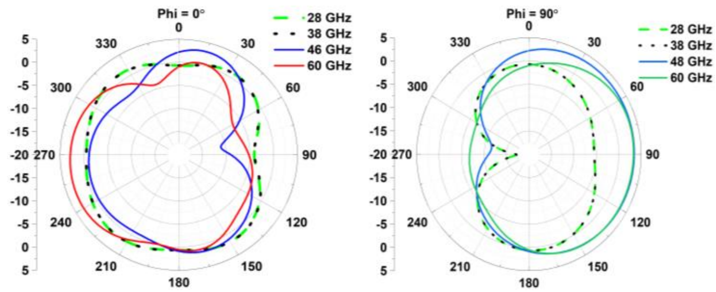

Fig. 4. Radiation patterns for the proposed single antenna element for phi = 0º (left) and phi = 90º (right).

TABLE I. PERFORMANCE COMPARISON OF THE PROPOSED WORK WITH OTHER RELATED WORK

Ref.	Covered Band (GHz)	FBW (%)	Peak Gain for Single Element (dBi)	Single Element Size (mm × mm)
[3]	26.5 - 38.2	36.2	5.8	10 × >10
[4]	16 - 40	85.7	5.5	30 × 20
[5]	23.41 - 33.92	35.53	5.7	9 × 5
[6]	23 - 33	35	5.4	6 × 5
This work	**23.5 - 65**	**93.78**	**5.66**	**8 × 4.6**

65 GHz) with impedance bandwidth of 93.78%, the peak gain of 5.66 dBi, and radiation efficiency greater than 93% with a single antenna element throughout the proposed band. The achieved bandwidth is the highest to date among mmWave antennas with such a compact size. The array performance of the antenna is also good with peak gain of 18 dBi for 1 × 8 array. The proposed UWB antenna is suitable for mmWave 5G communication, ultra-wideband applications in Ka-band, 24 GHz ISM band, and 60 GHz WiGig communication.

REFERENCES

[1] Wang, Xiong, Linghe Kong, Fanxin Kong, Fudong Qiu, Mingyu Xia, Shlomi Arnon, and Guihai Chen. "Millimeter wave communication: A comprehensive survey." *IEEE Commun. Surv. Tutorials*, vol. 20, no. 3, pp. 1616–1653, 2018.

[2] Hansen, Christopher J. "WiGiG: Multi-gigabit wireless communications in the 60 GHz band." IEEE Wireless Communications 18, no. 6, pp. 60–61, 2011.

[3] Ta, Son Xuat, Hosung Choo, and Ikmo Park. "Broadband printed-dipole antenna and its arrays for 5G applications." IEEE Antennas and Wireless Propagation Letters 16, 2017.

[4] Awais, Muhammad, Arslan Riaz, and Wasif Tanveer Khan. "An Ultra-wideband (16 40 GHz) mmWave Antenna for Automotive Radar and 5G Applications." In 2019 IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting, 2019.

[5] Ullah, Hidayat, and Farooq A. Tahir. "A high gain and wideband narrow-beam antenna for 5G millimeter-wave applications." IEEE Access 8, 2020.

[6] Parchin, Naser Ojaroudi, Ming Shen, and Gert Fralund Pedersen. "UWB MM-Wave antenna array with quasi omnidirectional beams for 5G handheld devices."IEEE International Conference on Ubiquitous Wireless Broadband (ICUWB), 2016.