Dual-Band Antenna Array for 5.9 GHz DSRC and 28 GHz 5G Vehicle to Vehicle communication

Sandhiya Reddy Govindarajulu, Rimon Hokayem, and Elias A. Alwan
Department of Electrical and Computer Engineering
Florida International University
Miami, FL, USA, 33174
sredd015@fiu.edu,rhoka001@fiu.edu, ealwan@fiu.edu

2020 IEEE International Symposium on Antennas and Propagation and North American Radio Science Meeting | 978-1-7281-6670-4/20/$31.00 ©2020 IEEE | DOI: 10.1109/IEEECONF35879.2020.9330220

***Abstract*— The Dedicated Short Range Communications (DSRC) band (5.85-5.925 GHz) allocated for vehicle-to-vehicle (V2V) communication provides limited opportunities for high speed data transfer. Alternatively, FCC plans to allocate millimeter-wave spectrum for 5G V2V communication. In this paper, we present a novel dual-band dual linearly-polarized antenna array for both DSRC and 28 GHz communications. For each band, we optimized antenna gain and number of elements to maximize range and data rate. The designed array has dual linear polarization and is fed with a simple quarter wave transformer. Due to large available connector's size, a Wilkinson power divider is designed to combine adjacent elements. Infinite array simulation show that the array is well matched (S_{11} < -10 dB) from 5.85 to 6.48 GHz, and from 17.29 to 29 GHz. The realized gain at both frequency bands is near-theoretical.**

Keywords*— *millimeter-wave, V2V, DSRC, dual-band array

I. Introduction

We witness a new wave of industrial revolution, where vehicles evolve from being docile and fully controlled by human beings to autonomous self-driving vehicles. Such development entails vehicles to be equipped with enormous number of sensors, cameras, and radar devices, to construct local view of the nearby objects. Autonomous vehicles cannot entirely depend on their own collected measurements alone. Therefore, the Federal Communications Commission (FCC) allocated 5.85 GHz - 5.95 GHz DSRC band for vehicle-to-vehicle (V2V) communication, where vehicles exchange their collected information between connected vehicles, to further improve the safety of the drivers [1].

Current V2V technologies require line-of-sight (LoS) communications for accurate positioning. This prevents detection of hidden vehicles and risks the safety of drivers. Furthermore, the links are lost during extreme weather conditions. This implies the need for additional connections to establish and secure the communication. Further, the allocated spectrum provides less opportunities for high data rate due to limited available bandwidth [2-3].

Alternatively, FCC plans to allocate bands in the millimeter-wave (mm-wave) spectrum for 5G V2V communication. The bandwidth availability in mm-wave implies high speed communication of at least 1Gbps. As such, improvement of positioning data collection and higher data rate for faster data sharing and processing [4]. Therefore, there is need to develop V2V radios for future mm-wave communication without sacrificing the well-established capabilities at 5.9 GHz. Recently, a dual-band transceiver architecture for both DSRC and 28 GHz communications was presented [5]. Link budget analyses showed that a dual-band array with at least 9×9 elements can effectively transmit information at a rate of 27 Mbps with coverage range of 867m at 5.9 GHz. Concurrently, a 9×9 dual-band array is able to achieve a high speed data rate of 1 Gbps across a range of 688m.

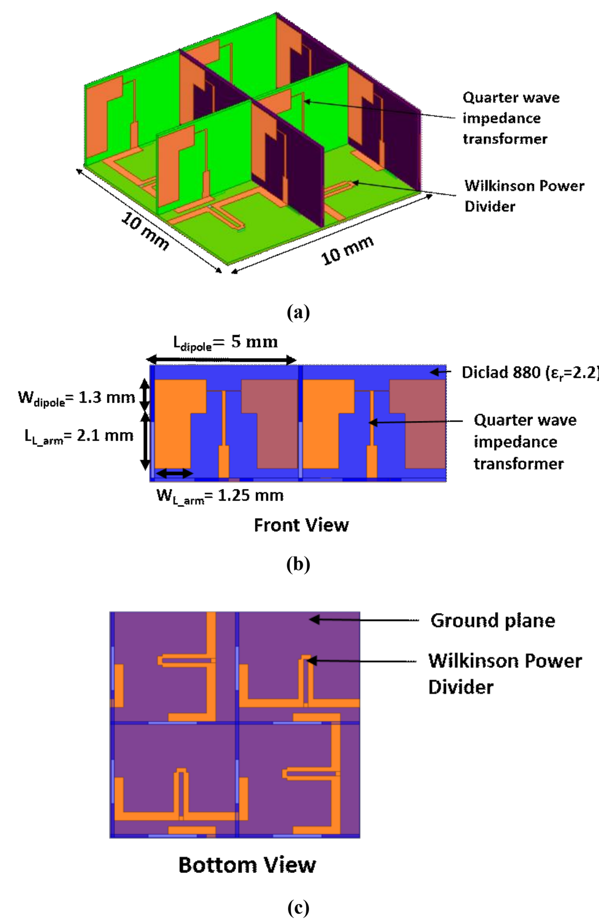

Fig. 1. (a) Dual-band dual linearly-polarized millimeter-wave array using dipole elements operating at 5.9 GHz and 28 GHz. (b) Dimensions of the dipole element. (c) A Wilkinson power divider is designed to combine adjacent cell to account for the connector's size.

In this paper, a dual-band dual linearly-polarized dipole array is designed and optimized for operation at both 5.9 GHz and 28 GHz. The array has dual-linear polarization and is fed with a simple quarter wave transformer. To account for fabrication tolerance, a Wilkinson power divider on the ground plane is designed to combine adjacent cells.

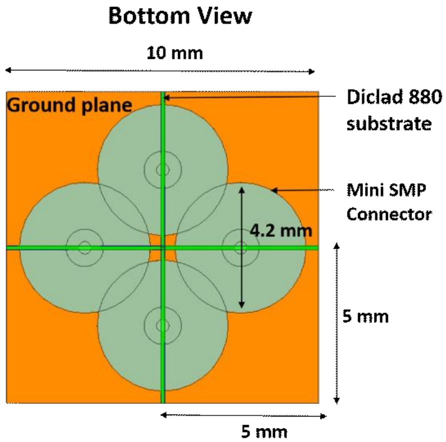

Fig. 2. Feeding challenges for millimeter-wave designs with connectors available on the market.

II. Array Geometry

We designed a simple dual-band dipole antenna array operating at both DSRC 5.9 GHz and 5G V2V 28 GHz, as illustrated in Fig. 1 (a). Each element consists of a dipole, quarter wave impedance transformer and the array is designed on an Arlon/DiClad 880 substrate, having a dielectric constant of 2.2, dielectric loss tangent tan δ=0.0009 and a thickness of 0.13 mm. The elements are placed cross-vertically over the ground plane, see Fig. 1 (a). Each unit cell is of 5mm×5mm×3.9mm. As shown in Fig. 1 (b), the width and length of the dipole arms are W_{dipole} = 1.3 mm and L_{dipole} = 2 mm and they are fed using a quarter wave impedance transformer. However, the size of existing connectors required redesigning the feed structure. Indeed, the smallest connector size on the market has a minimum diameter of 4.2 mm (mini SMP connector). With a 5mm×5mm unit cell, the connectors overlap with one another, as illustrated in Fig. 2. That is, given the available space of each unit cell, we proceed with a feed structure using Wilkinson power dividers on the ground plane, as shown in Fig. 1 (c). Consequently, two adjacent unit cells share the same feed.

Infinite array simulations using ANSYS HFSS v.19 show that the array is well matched (S_{11} < -10 dB) from 5.85 to 6.48 GHz (DSRC V2V), and from 17.29 to 29 GHz (5G V2V), as shown in Fig. 3. The 2×2 V2V dipole array's realized gain shows a near-theoretical value of -3.13 dBi at 5.9 GHz, and 10.39 dBi at 28 GHz (see Fig. 4).

III. Conclusion

In this paper, we presented a novel dual-band dual linearly-polarized V2V array design for both DSRC 5.9 GHz and 28 GHz communications. Notably, the implementation of a single platform for dual operation and dual polarization implies a significant reduction in the number of radios needed on a single vehicle. Future work includes the optimization of scanning performance and the implementation of a prototype for testing and measurements.

Acknowledgment

This research is supported by National Science Foundation (NSF) Award 1816112.

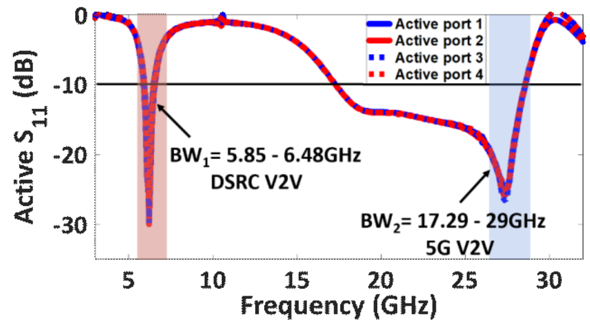

Fig. 3. Simulated S_{11} (dB) of the 2×2 dual-band dual-polarized V2V array.

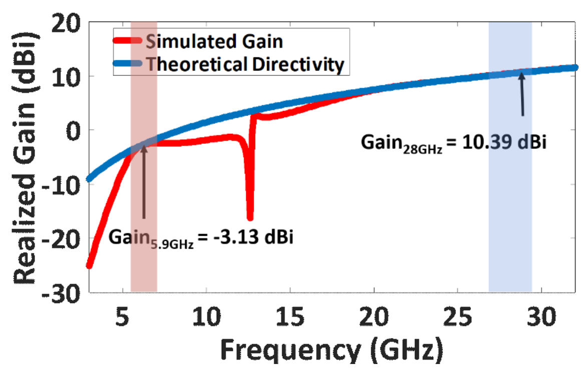

Fig.4. Simulated and theoretical realized gain of the 2×2 V2V array.

References

[1] Federal Communications Commission (FCC), https://www.fcc.gov/wireless/bureau-divisions/mobility-division/dedicated-short-range-communications-dsrc-service, April 11, 2017 [Jan. 12, 2019]

[2] O. K. Tonguz, "Red light, green light—no light: Tomorrow's communicative cars could take turns at intersections," in *IEEE Spectrum*, vol. 55, no. 10, pp. 24-29, Oct. 2018.

[3] J. B. Kenney, "Dedicated short-range communications (dsrc) standards in the united states," Proceedings of the IEEE, vol. 99, no. 7, pp. 1162–1182, July 2011.

[4] M. Marcus and B. Pattan, "Millimeter wave propagation: spectrum management implications," in *IEEE Microwave Magazine*, vol. 6, no. 2, pp. 54-62, June 2005.

[5] S. R. Govindarajulu and E. A. Alwan, "Range Optimization for DSRC and 5G Millimeter-Wave Vehicle-to-Vehicle Communication Link," 2019 International Workshop on Antenna Technology (iWAT), Miami, FL, USA, 2019, pp. 228-230.