International Journal of Science and Research (IJSR)
ISSN: 2319-7064
Impact Factor 2024: 7.101

LTE-based Broadband Antenna for Vehicular Applications

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Abstract: ***Vehicle consists of antennas for various applications. Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2X) are one of the most recent applications. This new technology can significantly enhance efficiency of travel, reduce traffic incidents and improve safety. In this paper, an LTE-based broadband omnidirectional planar antenna suitable for vehicular communication is presented. The design is intended for roof mount position on vehicles for public and domestic transportations. The proposed antenna consists of four printed arc dipoles that form a circular loop for horizontal plane omnidirectional radiation. A feeding network which consists of four baluns and an impedance matching circuit is designed to excite the four arc dipoles. By introducing small defects, slots and t-shaped design on the arc dipole and feeding network, respectively, improve the impedance matching. Experimental results show that the presented broadband antenna have good omnidirectional performance over 10 dB return loss bandwidth. The proposed broadband antenna covers 1.64-2.13 GHz at -10 dB for LTE bands. A prototype antenna was fabricated and tested for input reflection coefficient. Simulated and measured results for the broadband antenna element is presented.***

Keywords: Broadband antennas, LTE, V2V and V2X communications, vehicle antennas.

1. Introduction

The automotive industry has increased its interest immensely in wireless technologies. It is well known that antennas are key components to assure a reliable wireless communications link. Modern vehicles may contain multiple antennas covering different frequency bands for different wireless applications. In addition to the existing applications, modern vehicles will include Long-Term Evolution (LTE) and Vehicle-to-Vehicle and Vehicle-to Infrastructure (V2X) technologies. LTE will provide high data rates for several applications such as Internet connectivity [1].

LTE radio can be efficiently used for vehicular communication because of its inherent radio capabilities. LTE band is progressively being recognized by various operators to support LTE services in various regions. LTE is commonly advertised as 4G LTE, is a standard for wireless communication of high-speed data for mobile communications and data terminals. It is based on the GSM/EDGE and UMTS/HSPA network technologies, having upgraded capacity and speed using a different radio interface together with core network improvements [2]. There is a considerable interest which describes approaches to the problem of producing high data performance multifrequency designs. Therefore, a lot of research is conducted on designing antennas capable of covering different frequency bands and fitted in the same module [3]- [6]. Similarly, several horizontal polarized omnidirectional antennas were proposed [7]-[9]. Various antenna for the LTE and V2X applications has been presented in the reported research [12-16]. The major problem for a HP omnidirectional antenna is to enhance its bandwidth while keeping a simple configuration.

In this paper an LTE-based broadband omnidirectional antenna is proposed for vehicular communication. This antenna covers LTE band from 1.66-2.08 GHz. The antenna consists of four printed arc dipoles excited by a broadband feeding network. The feeding network consists of four broadband baluns and an impedance matching circuit. Different shape of defects, slots and t-shaped design on the arc dipole and feeding network improves the antenna impedance matching. A prototype of the designed antennas was fabricated and evaluated for the input reflection coefficient and omnidirectional radiation performances. The measurement and simulation results have been presented and discussed in the paper.

2. LTE Broadband Antenna Design

Fig. 1 depicts the geometry of the proposed antenna. As can be seen the antenna consists of four arc dipoles which are excited by a broadband feeding network. Each dipole has a length of about a half wavelength ($\lambda/2$). The feeding network is consisting of four broadband baluns and an impedance matching circuit. Matching circuit connects four broadband baluns to a 50 Ohm coaxial line at the center of the antenna. This type of balun has been widely used in broadband dipoles [10]. The four arc dipoles form a circular loop for horizontal plane omnidirectional radiation. The arc dipoles are printed on one side of a FR4 substrate with substrate thickness, t = 1 mm, relative permittivity, ε_r = 4.6, and loss tangent, δ = 0.0245. The feeding network is printed on the other side of the same substrate. In order to minimize the feed cable related issues, the antenna is fed through an SMA connector placed feeding network. A copper sheet of 0.015 mm thickness is used in fabrication of the prototype antenna. The overall size of the designed broadband antenna is 90 x 90 x 1 mm^3. This antenna is designed for the vehicular applications at the LTE bands, which covers the frequency range of 1.66-2.08 GHz.

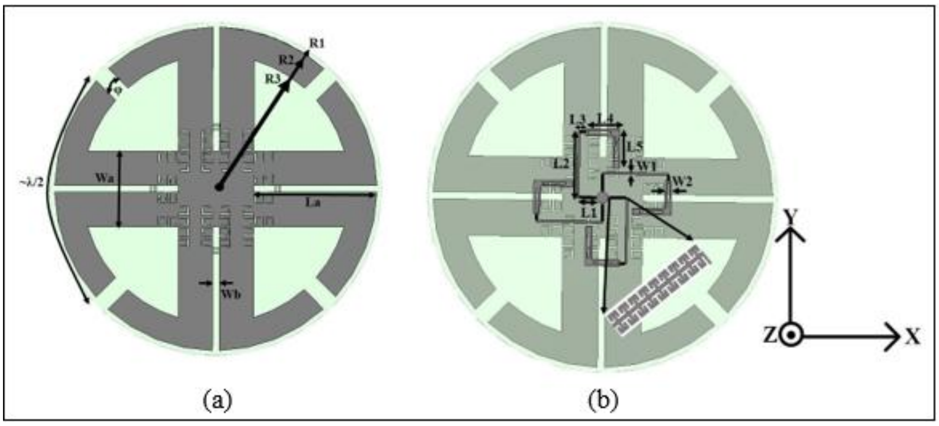


Figure 1: Antenna Geometry (a) Front View, (b) Back View.

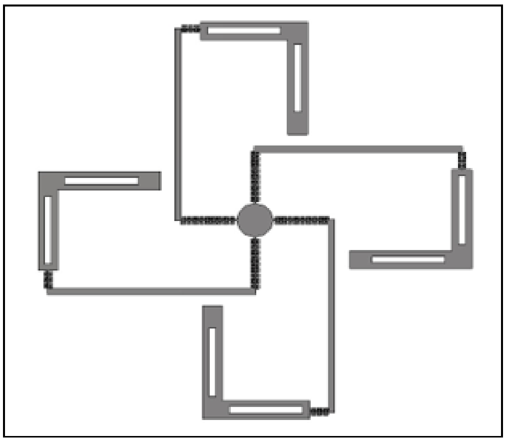


Figure 2: Feeding network for the proposed LTE-based broadband antenna.

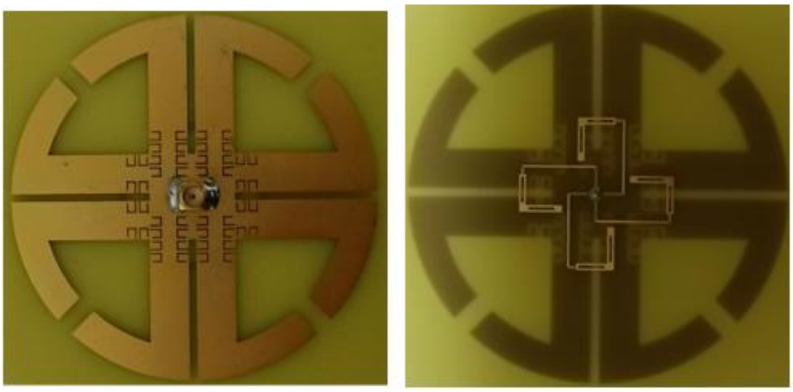
Fig. 2 illustrates a simple circuit for the feeding network on the other side of the substrate. The broadband balun for each arc dipole is 50 Ohm lumped impedance since the input impedance was designed to be 50 Ohm. The dimensions of the feeding network is given in Fig. 1(b). The theoretical analysis of the broadband balun and matching network can be found in [7], [10]. However, the antenna impedance matching is improved by introducing defects on the arc dipoles. Similarly, investigations show by making slots on the four baluns and t-shaped defects on the feeding lines further improves the impedance matching. In addition to that due to these defects the proposed broadband antenna is miniaturized. The omnidirectional antenna is simulated and optimized using CST microwave studio [11]. The optimized geometric parameters (in mm) are summarized in Table I.

Table 1: Optimized geometric parameters

Parameter	Value	Parameter	Value
R1	45	L1	5
R2	47	L2	19.25
R3	39	L3	2
W1	0.5	L4	8
W2	1.8	L5	13
Wa	20	La	33
Wb	1.8	ϕ	4.6 degree

3. Results and Discussions

The proposed antenna has been fabricated using the photolithography technique. A prototype of the fabricated broadband antenna is depicted in Fig. 3. The return loss of the antenna is measured using vector network analyzer. Comparison of the measured and simulated return loss for the optimized broadband omnidirectional antenna is shown in Fig. 4. It can be noticed that both the simulated and measured return loss plots are in good agreement while in measured result slightly occupying more bandwidths compare to simulations. The bandwidth of the proposed antenna has been calculated for -10 dB return loss. On the other hand, some discrepancies may occur in the impedance matching due to assembling and manufacturing process. Therefore, the proposed broadband antenna covers 1.64-2.13 GHz at -10 dB for LTE bands. The design is intended for roof mount position on vehicles and suitable for vehicle communication on the LTE bands.



(a) (b)

Figure 3: Photograph of the fabricated LTE-based broadband antenna, (a) Front view, (b) Back view

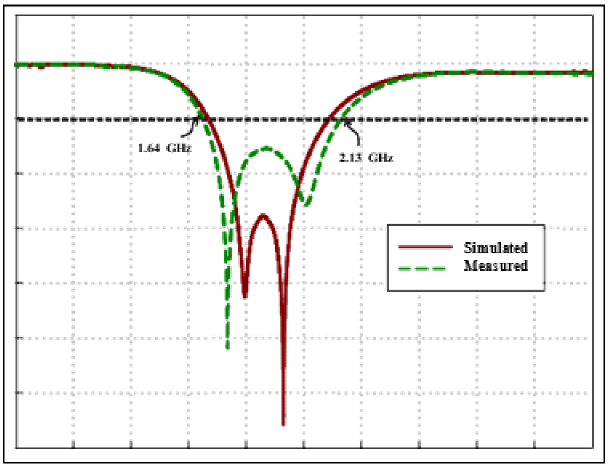
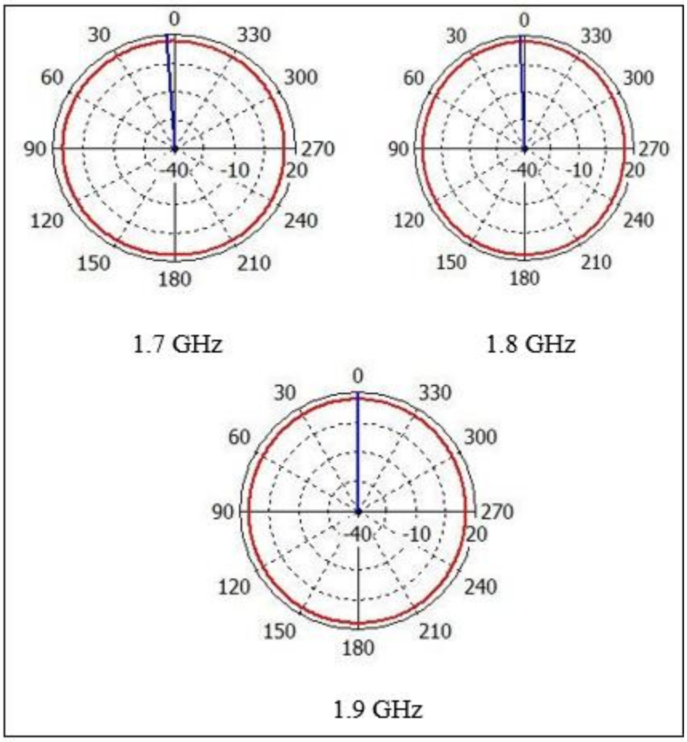


Figure 4: Measured and simulated return loss of the proposed broadband antenna

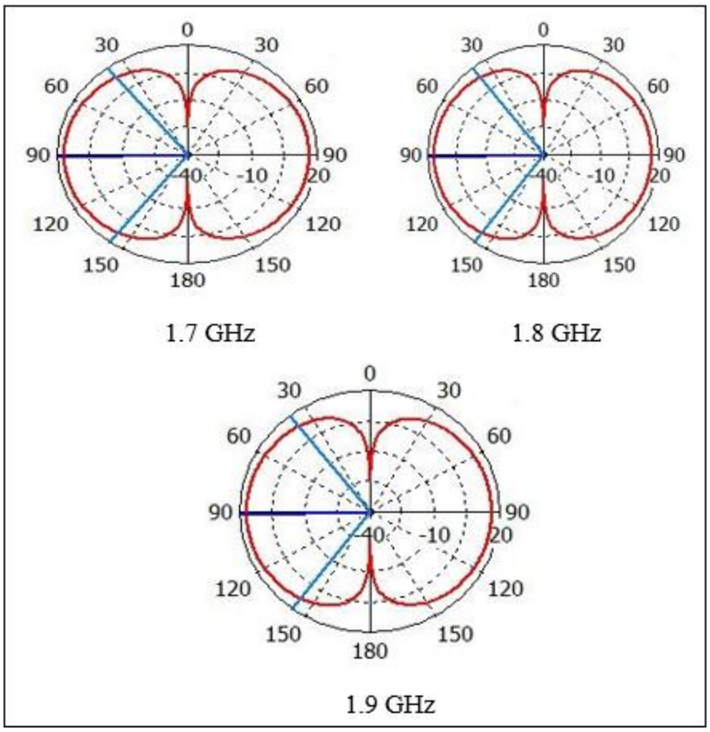
Table 2: Simulated gain and efficiency of the proposed antenna

Frequency (GHz)	Gain (dB)	Efficiency (%)
1.7	1.85	82
1.8	1.84	79
1.9	1.78	90
2.1	1.58	93

The polar radiation patterns of the broadband antenna are computed at 1.7 GHz, 1.8 GHz, and 1.9 GHz. These patterns are shown in Fig. 5 on *XY and XZ* planes. At all the frequencies, radiation patterns of the proposed broadband antenna are omnidirectional. The patterns show reasonable gain in the operating frequency bands. To analyze the proposed designed antenna, the simulated peak gain values and total efficiencies at the aforementioned frequencies are given in Table 2, respectively. The gain and total efficiency of the proposed broadband antenna at different frequency bands are quite reasonable. The gain is observed in between 1 and 2 dB. The efficiency of the proposed antenna is increases with the operating frequency bands.



(a) XY-Plane radiation pattern



(a) XZ-Plane radiation pattern

Figure 5: Simulated polar radiation pattern of the proposed broadband antenna at different frequencies.

4. Conclusion and Future Work

LTE based broadband omnidirectional antenna is presented for vehicular applications. The proposed broadband antenna consists of four printed arc dipoles. A broadband feeding network has been utilized to feed the four arc dipoles. The total size of the broadband antenna is 90 x 90 x 1 mm^3. A prototype of the proposed antenna has been successfully designed, fabricated, and measured. The designed antenna is simulated using a CST microwave simulator and then realized on a low cost widely available FR4 dielectric substrate material with 4.6 relative permittivity and 1 mm thickness. Measured results shows that the omnidirectional antenna covers 1.64-2.13 GHz at -10 dB for LTE bands for return loss greater than -10 dB.

Further work will be placing the two or multiple antennas within line, parallel and perpendicular to check their mutual coupling, respectively. In addition to that the envelope correlations and the multiplexing efficiencies of the prototypes may be necessary to fully analyze the behavior of the two antennas in a MIMO system.

References

[1] E. Condo Neira, J. Carlsson, K. Karlsson, E. G. Strom, “Combined LTE and IEEE 802.11p antenna for vehicular applications,” 9th European Conference on Antennas and Propagation (EuCAP), pp.1- 5, 13-17 April 2015.

[2] A. K. Arya, N. V. Anh, R. S. Aziz, B-Y. Park, S-O. Park, “Dual Polarized Dual Antennas for 1.7–2.1 GHz LTE Base Stations,” IEEE Antennas and Wireless Propagation Letters, vol.14, pp.1427-1430, 2015.

[3] B. Sanz-Izqierdo and R. Leelaratne, “Evaluation of Wideband LTE Antenna Configurations for Vehicular Applications,” Loughborough Antennas & Propagations Conference (LAPC), Loughborough, UK, Nov. 2013.

[4] E. Gschwendtner and W. Wiesbeck, “Ultra-Broadband Car Antennas for Comunications and Navigation Applications,” IEEE Transactions on Antennas and Propagation, vol. 51, pp. 2020-2027, Aug. 2003.

[5] R. Leelaratne and R. Langley, “Multiband PIFA Vehicle Telematics Antennas,” IEEE Transactions on Vehicular Technology, vol. 54, pp. 477-485, March 2005.

[6] A. Thiel, L. Ekiz, O. Klemp, and M. Schutz, “Automotive Grade MIMO Antenna Setup and Performance Evaluation for LTECommunications,” International Workshop on Antenna Technology (iWAT), Karlsruhe, Germany, March 2013.

[7] X. L. Quan, R. L. Li, J. Y. Wang, and Y. H. Cui, “Development of a Broadband Horizontally Polarized Omnidirectional Planar Antenna and its Array for Base Stations”, Progress In Electromagnetics Research, Vol. 128, 441-456, 2012.

[8] C.-C. Lin, L.-C, Kuo, H.R. Chuang, “A Horizontally Polarized Omnidirectional Printed Antenna for WLAN Applications,” IEEE Transactions on Antennas and Propagation, vol. 54, no. 11, pp.3551- 3556, Nov. 2006.

[9] H. Nakano, R. Satake, J. Yamauchi, “Realization of a horizontally polarized, low-profile, omnidirectional antenna with an EBG reflector,” European Conference on Antennas and Propagation (EuCAP), Proceedings of the Fourth, pp.1-5, 12-16 April 2010.

[10] R. L. Li, T. Wu, B. Pan, K. Lim, J. Laskar, and M. M. Tentzeris, “Equivalent-circuit analysis of a broadband printed dipole with adjusted integrated balun and array for base station applications,” IEEE Transactions on Antennas and Propagation, vol. 57, 2180- 2184, July 2009.

[11] CST Microwave Studio. Available: https://www.cst.com/.

Paper ID: SR25507233407 DOI: https://dx.doi.org/10.21275/SR25507233407

[12] Q. Wu, Y. Zhou and S. Guo, "An L-sleeve L-monopole antenna fitting a shark-fin module for vehicular LTE WLAN and car-to-car communications", IEEE Trans. Veh. Technol., vol. 67, no. 8, pp. 7170-7180, Aug. 2018
[13] B. Feng, J. Chen, S. Yin, C.-Y.-D. Sim and Z. Zhao, "A tri-polarized antenna with diverse radiation characteristics for 5G and V2X communications", IEEE Trans. Veh. Technol., vol. 69, no. 9, pp. 10115-10126, Sep. 2020.
[14] Y. Cui, R. Li and P. Wang, "Novel dual-broadband planar antenna and its array for 2G/3G/LTE base stations", IEEE Trans. Antennas Propag., vol. 61, no. 3, pp. 1132-1139, Mar. 2013.
[15] J.-K. Che, C.-C. Chen and J. F. Locke, "A compact four-channel MIMO 5G sub-6 GHz/LTE/WLAN/V2X antenna design for modern vehicles", IEEE Trans. Antennas Propag., vol. 69, no. 11, pp. 7290-7297, Nov. 2021.
[16] B. Feng, B. Yang, C. -Y. -D. Sim, L. Deng, Z. Zhou and X. Ding, "A Compact Vehicle-Mounted Garden-Themed Artistic Antenna With Isolation Improvement for 2G/3G/LTE/5G Sub-6-GHz/WiFi/Bluetooth Communications," in IEEE Transactions on Vehicular Technology, vol. 72, no. 4, pp. 4851-4862, April 2023.