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Design of hexagon microstrip antenna for vehicle-to-vehicle communication

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Abstract

Considering the shortcomings of the existing vehicle-to-vehicle (V2V) communication antennas, this paper proposes a regular hexagon broadband microstrip antenna. By loading shorting pins and etching V-shape slots with different size at each angle of the regular hexagon patch, it realizes impedance matching and obtains better impedance bandwidth. The simulated results show that the relative bandwidth of this antenna reaches 35.55%, covers the frequency band of 4.74 GHz to 6.79 GHz. The antenna acquires an omni-directional radiation pattern in the horizontal plane whose out of roundness is less than 0.5 dB. In addition, the antenna is manufactured and tested, whose tested results are basically consistent with simulated results. Because the height of antenna is 3 mm, it is easy to be hidden on roof of a vehicle for V2V communication.

Keywords regular hexagon, microstrip antenna, shorting pins, V-shape slots, omni-directional radiation pattern, V2V communication

1 Introduction

With the development of wireless communication technology, all kinds of wireless communication equipment are widely used to bring great convenience for people's works and lives. For example, global system for mobile communication (GSM), long term evolution (LTE) etc, make interpersonal communication more convenient. Wireless fidelity (WiFi) makes people connect to the Internet faster, and the real-time understanding things are surrounding. Recently, people pay close attention to the communication between vehicles. It can provide real-time traffic information to drivers so as to effectively relieve traffic congestion and avoid traffic accidents. In July 2010, IEEE modified the IEEE 802.11 standard with IEEE 802.11p, the frequency band of 5.85 GHz~5.925 GHz is used for wireless access in vehicle environments (WAVE) and dedicated short range communications (DSRC) [1] which includes the V2V communication and the vehicle-to-infrastructure (V2I) communication [2]. Therefore, the frequency range of the V2V communication is defined as 5.85 GHz~5.925 GHz.

Most of automotive antennas are designed for applications of low frequency, such as frequency modulation and amplitucle modulation (FM/AM) radio, GSM [3], global position system (GPS) [4]. Among them, the 2.45 GHz bluetooth transmission [5] which is installed on the vehicle is the application on relatively high frequency. In general, very few researches of the automotive antennas which are operated on 5 GHz are carried out. As the vehicle communication becomes a hot topic and gets extensive attention of people, a lot of antenna structures are proposed for the V2V communication. Klemp et al. designed an antenna array consists of four antenna elements which load shorting pins at the center of each circular patch [6]. Varum et al. designed two square printed monopole antennas which can be installed on the vehicle [7]. Westrick et al. designed a monopole antenna with eight parasitic elements [8]. The antenna attains an omni-directional radiation pattern which causes more effective application in the V2V communication. Aloi et al. proposed a linear polarization antenna in the form of the multiple planar monopole

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antenna and it is used to realize the V2V communication [9]. Bras et al. designed printed loop antenna with periodical capacitive loading [10], which is used for taxis communication. These antennas are simple with easy to be installed, but their operating bandwidths are relatively narrow. Moreover, some antennas possess the disadvantage of higher manufacturing cost and larger overall size.

Because of microstrip antenna with small volume, light weight, low profile, easy integration and good concealing, it has far-ranging application prospect in the field of automotive antennas. A low profile and low cost regular hexagon microstrip antenna is proposed to get rid of disadvantages of the existing V2V communication antennas. This antenna achieves good impedance matching and broad bandwidth by loading shorting pins and etching V-shape slots. What's more, an omni-directional radiation pattern can be obtained. The proposed antenna is simple structure and small size, which is suitable for V2V communication.

2 Antenna design and analysis

In this paper, the basic structure of the proposed wideband microstrip antenna is shown in Fig. 1.

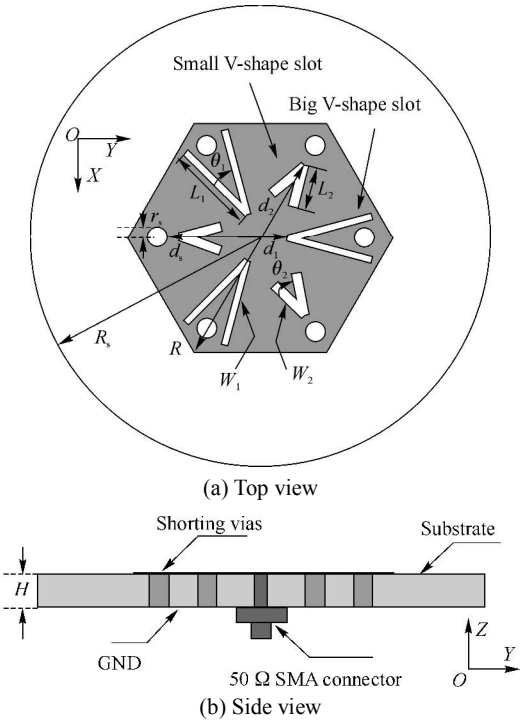

Fig. 1 Structure of proposed antenna

Wideband microstrip antenna is composed of a center-fed regular hexagon microstrip patch antenna, six shorting pins, and two sets of V-shape slots with different size. Six shorting pins are placed on the six angles of the regular hexagon patch to realize conductive connecting between the patch and ground. It is equivalent to introduce parallel inductance between the patch and ground [11]. Adjusting the size and location of shorting pins, d_s and r_s, can effectively decrease input impedance and obtain wide impedance bandwidth. In order to further improve impedance matching and reduce the size of the antenna, two sets of V-shape slots with different size are etched on the regular hexagon patch, which is equivalent to introduce the capacitive reactance and inductive reactance [12]. Selecting the appropriate positions and lengths of two sets of V-shape slots, d_1, d_2, L_1 and L_2, makes the antenna get a better impedance matching. It also gives larger impedance bandwidth.

The proposed antenna is printed on FR4_epoxy substrate with dielectric constant $\varepsilon_r = 4.4$, loss tangent $\tan\delta = 0.02$ and thickness $H = 3$ mm. At the center of this antenna, the coaxial probe with 50 Ω sub miniature version A (SMA) connector is used to excite the antenna proposed. This antenna obtains omni-directional radiation pattern in the horizontal plane and conical radiation pattern in the vertical plane. Through the simulation software high frequency structure simulator (HFSS), the detailed dimensions of proposed antenna are shown in Table 1.

Table 1 Detailed dimensions of the proposed antenna

Parameter	Value	Parameter	Value
R_s /mm	30.0	L_1 /mm	7.50
R/mm	15.0	W_1 /mm	0.45
H/mm	3.0	d_1 /mm	3.00
d_s /mm	10.9	L_2 /mm	5.50
r_s /mm	1.1	W_2 /mm	0.45
θ_1 / (°)	30	d_2 /mm	8.50
θ_2 / (°)	30		

3 Simulation analysis and measured results

3.1 Parameters optimization analysis

As stated previously, the location and size of shorting pins, the positions and lengths of V-shape slots might influence the input impedance and impedance bandwidth. Hence, the situation of the impedance matching and parameters of V-shape slots are going to be analyzed.

Fig. 2 shows the input impedance of the antenna without/with shorting pins and V-shape slots. In Fig. 2, it is observed that the resistance and reactance of the input