Series Feed Broadband Patch Array Antenna Design for Vehicle Collision Warning Radar System

Kuan-Hsun Wu, Ding-Bing Lin, Chung-Wei Wang
Department of Electronic and Computer Engineering
National Taiwan University of Science and Technology
Taipei, Taiwan
davidwu917@gmail.com, dblin@mail.ntust.edu.tw,
ot2133951@yahoo.com.tw

Hsi-Tseng Chou
Graduate Institute of Communication Engineering
National Taiwan University
Taipei, Taiwan
chouht@ntu.edu.tw

***Abstract*— In this paper, a 77GHz Vehicle Collision Warning Radar System short-range antenna is proposed. The operating frequency range is 77GHz to 81GHz, which is realized by the two actual substrates of RO4835 and RO3003, respectively. A patch array antenna is used as the basic structure of this system with multilayer board design technique for smaller size. Main beam is not offset by feeding on intermediate position of the array. We introduce two and three vias in parallel as the feeding in this system for enhancing bandwidth by decreasing overall equivalent inductance. The reflection coefficient reaches below -10 dB for automotive radar allocation of the 79GHz frequency band. The antenna gain reaches 14.2dBi, and the radiation efficiency reaches more than 85%.**

Keywords—Patch Array Antenna; short-range antenna; Vehicle Collision Warning Radar; Broadband

I. Introduction

With the development of technology, the rapid development of the modern automobile industry, people's demand for automobile is getting higher and higher. Therefore, the Advanced Driver Assistance System (ADAS) is one of the most important technologies for implementing smart vehicles. The technical growth is not simply derived from the driver's requirements for driving safety.

According to the World Radiocommunication Conference (WRC-15), the allocation of the 79 GHz frequency band provides a globally harmonized regulatory framework for automotive radar [1]. The millimeter-wave radar plays an important role for automotive radar [2]-[8]. It has strong signal penetration and high accuracy of distance detection, which is used in long distance systems, such as automatic braking system, front collision warning system, active distance control cruise system. Since it has wider bandwidth operating at millimeter-wave frequency band, it can recognize the type of pedestrians and be more conducive to system and interface integration due to higher resolution. Compared to general microwave radar, millimeter-wave radar can detect farther distances, faster speeds, larger angles. In this paper, a series-fed microstrip patch array antenna is proposed for automotive radar.

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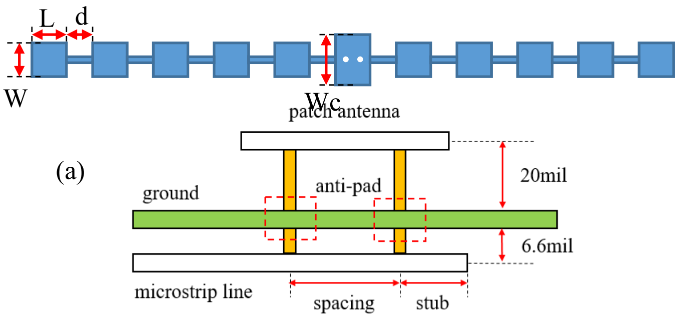
The overall structure has three layers with multiple vias as the feeding point to broaden bandwidth. We design it in different circuit materials RO4835 and RO3003, which is flexible and applicable in industry.

II. Array Antenna Design and Measurement

A. Microstrip Patch Array Design

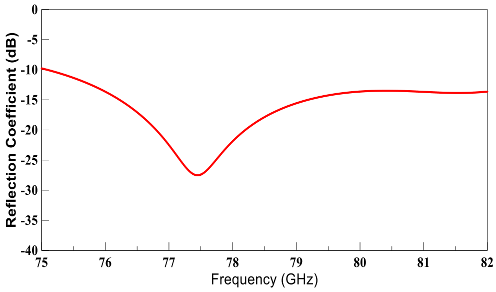
In this section, we propose a series-fed microstrip patch array antenna with three different types. The first presented microstrip patch array antenna is implemented on 20 mil thick Rogers RO4835 substrate with relative permittivity of 3.66 as shown in Fig. 1. We introduce two vias in parallel as the anti-phase feeding point, as shown in Fig. 1. By this way, the overall equivalent inductance is reduced and then enhance the bandwidth.



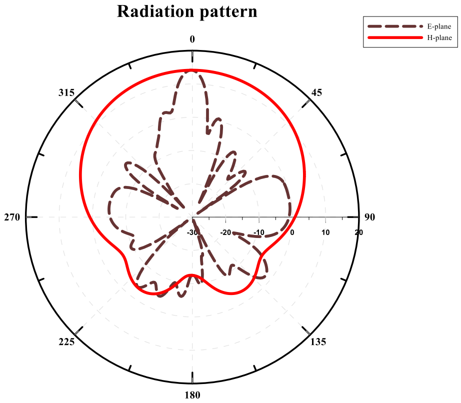
(b)

Fig. 1. Patch array antenna fed with 2 vias on RO4835 substrate

The physical dimensions are: L=0.97 mm, W=1.18 mm, Wc=1.3 mm. The simulated return loss is below -10 dB from 75.1 GHz to 82 GHz, as shown in Fig. 2 (a). The simulated radiation patterns in E- and H-plane are shown in Fig. 2 (b) with peak gain value of 14.1 dBi at center frequency 77 GHz.



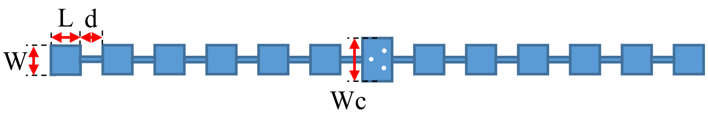
(a)



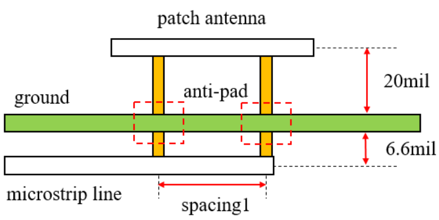
(b)

Fig. 2. The simulated (a) return loss and (b) radiation patterns.

The second presented microstrip patch array antenna is similar to the first one with the difference that we change two vias into three vias for the feeding and reduce the stub on the bottom layer. The bandwidth is enhanced by more than 0.1GHz to cover the whole band compared to the previous case. It shows that we improved it by introducing an additional via, which is equivalently reduce the overall inductance.



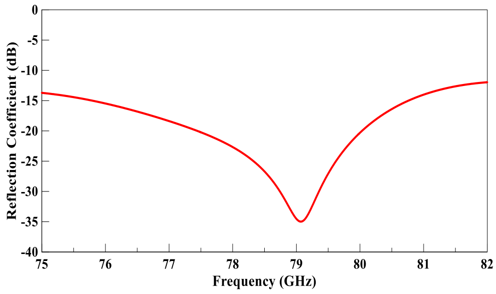
(a)



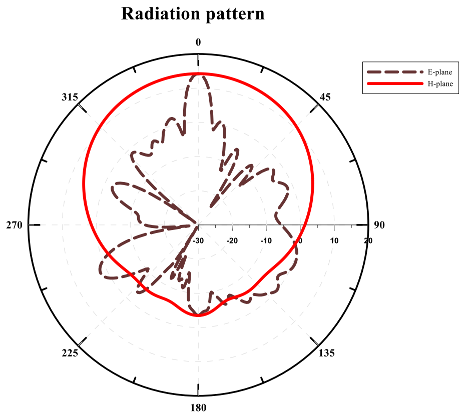
(b)

Fig. 3. Patch array antenna fed with 3 vias on RO4835 substrate

The physical dimensions are: L=0.93 mm, W=1.1 mm, Wc=1.4 mm. The simulated return loss is below -10 dB from 75 GHz to 82 GHz, as shown in Fig. 4 (a). The simulated radiation patterns in E- and H-plane are shown in Fig. 4 (b) with peak gain value of 14.24 dBi at center frequency 77 GHz.



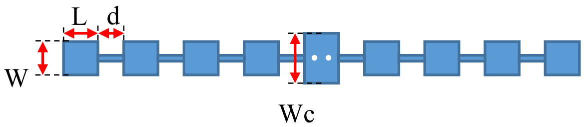
(a)



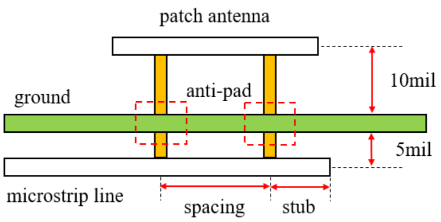
(b)

Fig. 4. The simulated (a) return loss and (b) radiation patterns.

The third presented microstrip patch array antenna is implemented on 10 mil thick Rogers RO3003 substrate with relative permittivity of 3. The structure is similar to the first one with the difference of circuit material, as shown in Fig. 5. RO3003 is more difficult to fabricate, so only 10 mil substrates can be used as the first layer thickness. The bandwidth is narrower compared to the first case.



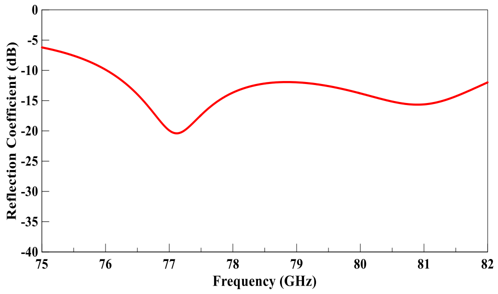
(a)



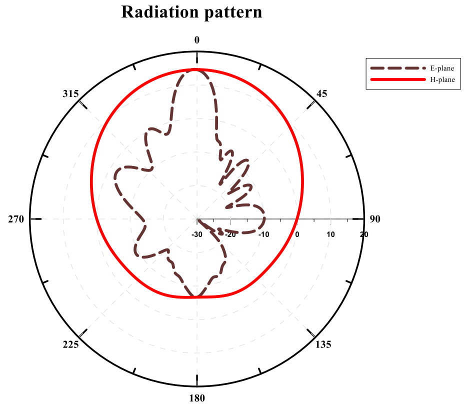
(b)

Fig. 5. Patch array antenna feeding with 2 vias on RO3003 substrate

The physical dimensions are: L=1.1 mm, W=1.16 mm, Wc=1.2 mm. The simulated return loss is below -10 dB from 76.1 GHz to 82 GHz, as shown in Fig. 3 (a). The simulated radiation patterns in E- and H-plane are shown in Fig. 3 (b) with peak gain value of 14.7 dBi at center frequency 77 GHz.



(a)



(b)

Fig. 6. The simulated (a) return loss and (b) radiation patterns.

B. Measurement And Discussion

Radiation patterns is measured in a spherical far-field 3D antenna measurement system in National Taiwan University of Science and Technology. The measurement setup is shown in Fig.7. We measure three kinds of presented microstrip array antenna.

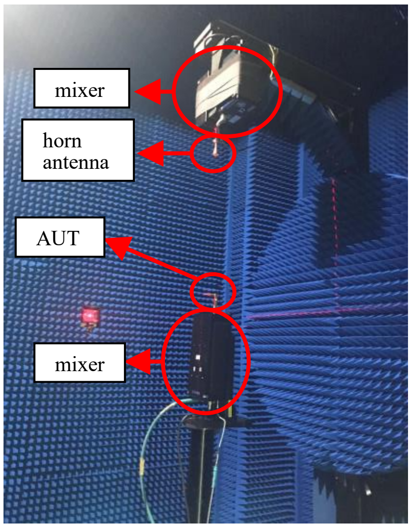


Fig. 7. measurement setup

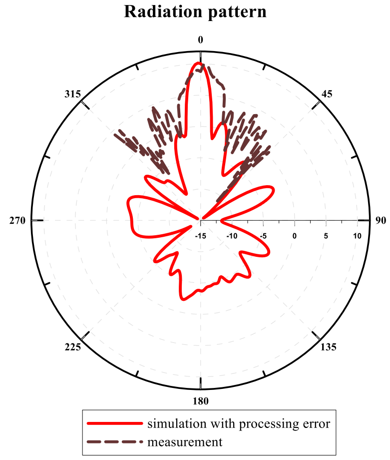


Fig. 8. Results of feeding with 2 vias on substrate RO4835

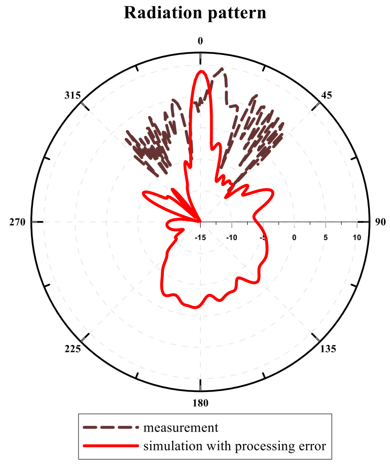


Fig. 9. Results of feeding with 3 vias on substrate RO4835

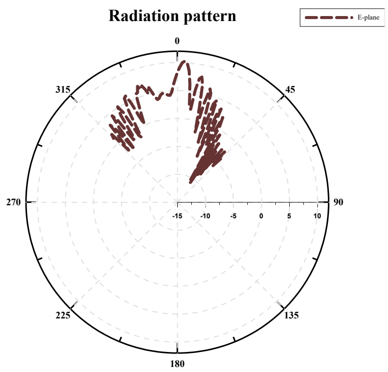


Fig. 10. Results of feeding with 2 vias on substrate RO3003

Result shows that measured gain is 9.84 dBi with 2 vias feeding on substrate RO4835, another is 9.66 dBi with 3 vias feeding on substrate RO4835, and the other is 10.29 dBi with 2 vias feeding on substrate RO3003, as shown in Fig.8, Fig.9, Fig.10, respectively.

The reason of loss compared to the simulation is because of the glue between each layer, which is IT-180TC with 10mil thickness, relative permittivity 4 and loss tangent 0.02.

Furthermore, the measurement setup requires the use of 1.0mm connector, which we have to adjust the trace of microstrip line on the bottom layer, causing mismatch to the feeding.

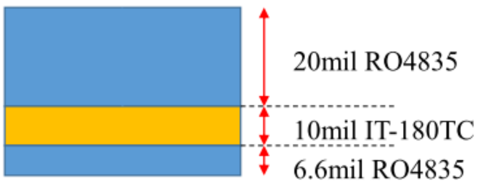


Fig. 11. Fabricated glue IT-180TC between layers

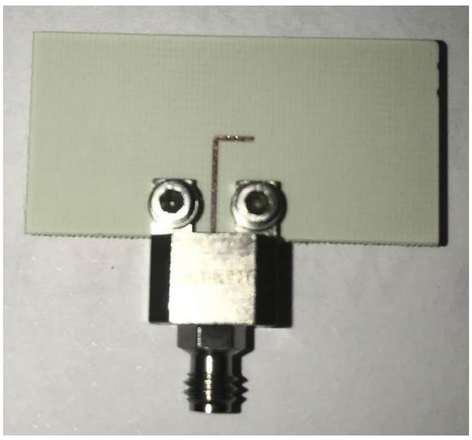


Fig. 12. Microstrip line feeding with 1.0mm connector

We validate it by putting IT-180TC and the 1.0mm connector on simulation, as shown in Fig.8, Fig.9, Fig.10, respectively as well. We observe that the trend of simulation with processing error meets the measurement result.

III. Conclusion

A short-range array antenna of the vehicle anti-collision radar is proposed with the substrate RO4835 and RO3003 generally used in industry. The feeding is fed by two or three vias for wide-bandwidth application, which makes the array antenna operating at required frequency band from 77 GHz to 81 GHz. With the reflection coefficient reaches below -10dB, the radiation efficiency reaches more than 85%. Although the antenna is sensitive to other unwanted factors, the simulation still shows the performance we achieve. Hence, the fabrication of array antenna will be studied for more suitable design, and the measurement result is expected for meeting the simulation.

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