A 77 GHz Series-fed Leaky-Wave Antenna for Automotive Radar System

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***Abstract*-A 1.5mm × 28mm patch leaky-wave antenna (P-LWA) with a high gain and a large beamwidth in H-plane is proposed for 77GHz automotive radars. Four slots were etched on the driven patch to satisfy the beamwidth requirement in H-plane,which acts as the array element. The simulation results show that the proposed antenna can achieve an impedance bandwidth of 1.3% (76-77GHz) and a maximum realized gain of 15.23dBi. Besides, the proposed antenna can offere an HPBW greater than 118.07° in the H-plane.**

***Index Terms*– 77 GHz Antenna, Patch Leaky-Wave Antenna (P-LWA), Automotive Radar System.**

I. Introduction

With the booming rise of industrial technology and automobile automation [1], millimeter-wave radars have attracted considerable interests and has been applied in many different fields. The 24 GHz and 77 GHz bands are mainly two frequency bands of the Millimeter-wave radars. As a result of spectrum regulations and standards developed by the European Telecommunications Standards Institute (ETSI) and the Federal Communications Commission (FCC), the 24 GHz band will be phased out starting in 2022. In the future, the 77 GHz radar will become more important more widely used.

The antenna in different positions plays different important roles in the field of automotive radar in various scenarios. For example, in roof positions, antennas can be used as a Global Positioning System (GPS) [2] or frequency modulation (FM) radio [3], [4].In front and back bumper positions, antennas generally act as radar sensors [5].On the reverse mirror, antennas are being used in large numbers to provide a 360° radar sensor view for autonomous driving [6][7].Recently, even more antennas in different positions will be required.

In this paper, a series-fed patch array antenna was presented, which operates at 77 GHz for an automotive radar system. It exhibits the merits of wide beamwidth, compact size and high gain.

II. ANTENNA DESIGN

A. Antenna Configuration

The antenna is printed on a Rogers RO3003G2 (εr = 3.07, tan δ = 0.0013) substrate with a thin thickness (h= 0.127 mm). Fig. 1 depicts the configuration of the patch element and its specific geometrical parameters of this element is given by Table 1.

Fig. 2(a) shows the geometry of a 1.5mm × 28mm series-fed linear patch array antenna. Fourteen patch elements are utilized to form the patch array, and the gap between them is W, which is a half wavelength in free space. In order to obtain better antenna performance, four slots are etched on the patch to obtain wider H-plane beamwidth. In addition, an impedance matching stub is placed in front of the first element to realize better impedance matching.

TABLE I
PARAMETERS OF THE PATCH ELEMENT

Par.	Value(mm)	Par.	Value(mm)
L	3	W	2
L1	1.5	W1	0.05
L2	0.15	W2	0.475
L3	0.05	W3	0.8
L4	0.5	W4	0.05

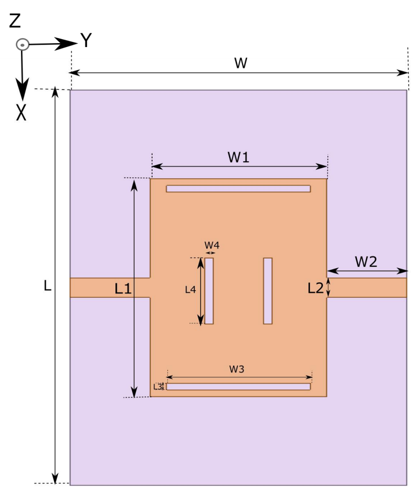
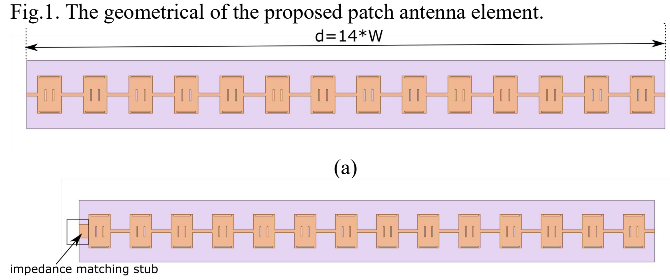


Fig.1. The geometrical of the proposed patch antenna element.



(a)

(b)

Fig. 2. The geometry of the proposed patch antenna array. (a) the original antenna array, (b) the antenna array with impedance matching stub.

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B. *Antenna Theory*

Based on the theoretical analysis of LWA, the performance of the patch element and the relevant formula of the the phase constant (β) and the attenuation constant (α) are given below.

$$\beta = \mathrm{Im}[\operatorname{arccosh}(\frac{1-S_{11}S_{22}+S_{21}S_{12}}{2S_{21}})/W] \tag{1}$$

$$\alpha = \mathrm{Re}[\operatorname{arccosh}(\frac{1-S_{11}S_{22}+S_{21}S_{12}}{2S_{21}})/W] \tag{2}$$

As shown in Fig. 3, the phase constant and attenuation constant of the element are given. The attenuation constant curve barely fluctuates over the entire band. What's more, the smoothness of the phase constant curve implies the effective elimination of open-stop band (OSB). As can be seen from Fig. 4, the simulated |S11| is less than -10dB from 76GHz to 77 GHz. With these measures, a P-LWA with good performance can be designed.

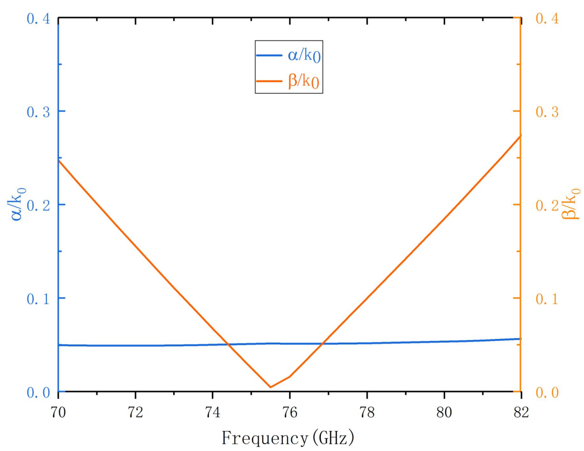

Fig.3. The normalized phase constant (β) and the normalized attenuation constant (α).

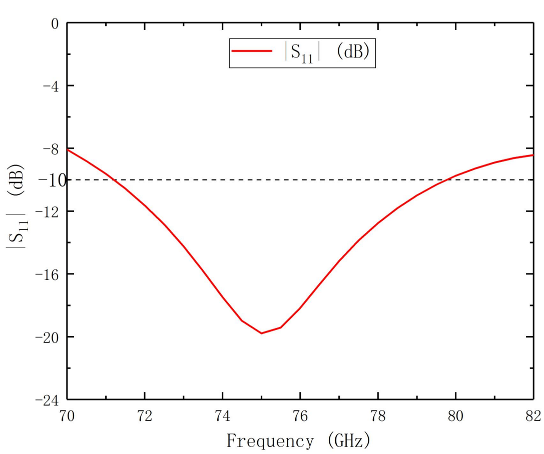

Fig. 4. The simulated |S11| of the proposed patch element.

Fig. 5 shows the simulated |S11| of the P-LWA antenna with and without the impedance matching stub. As can be seen, the proposed P-LWA antenna with the impedance matching stub can achieve good impedance matching in the operating band from 76 to 77GHz, making it suitable for mm-Wave sensors.

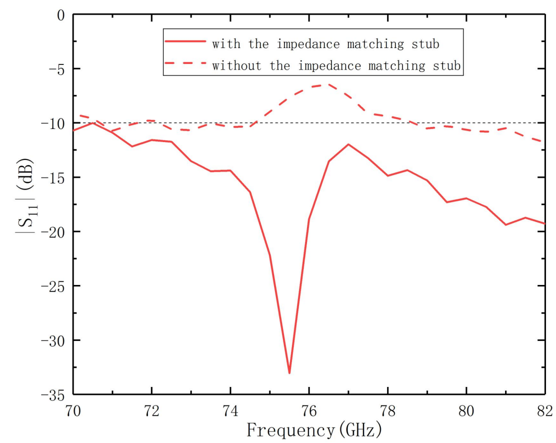

Fig. 5. The simulated |S11| of the P-LWA with and without the impedance matching stub.

Fig.6 shows the comparison of the H-plane pattern of the patch element with and without the slots. Fig.6 clearly depicts that the H-plane beamwidth is greatly improved by employing the four slots.

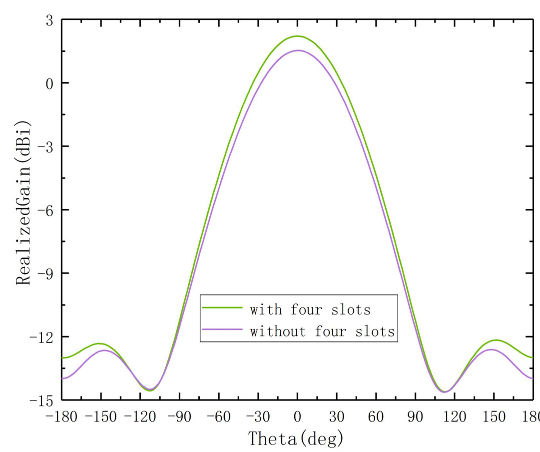

Fig. 6. Comparison the patch element of XZ plane (H-plane) radiation patterns with and without four slots.

III. Results and Discussions

As can be seen from Fig. 7, antenna gain can reach more than 13.5 dBi in the whole operating band (from 76GHz to 77GHz). Moreover, the antenna array radiates waves in the broadside direction over the whole working band.

Fig. 8 shows the H-plane radiation patterns of the patch with and without parasitic loop at 76.5 GHz. As can be seen, the P-LWA with the parasitic loop can achieve a wide HPBW of 118.07° in H-plane and the antenna without the parasitic loop can obtain a HPBW of 89.78° in H-plane. By comparison, it is found that about 28.29° optimization is achieved.

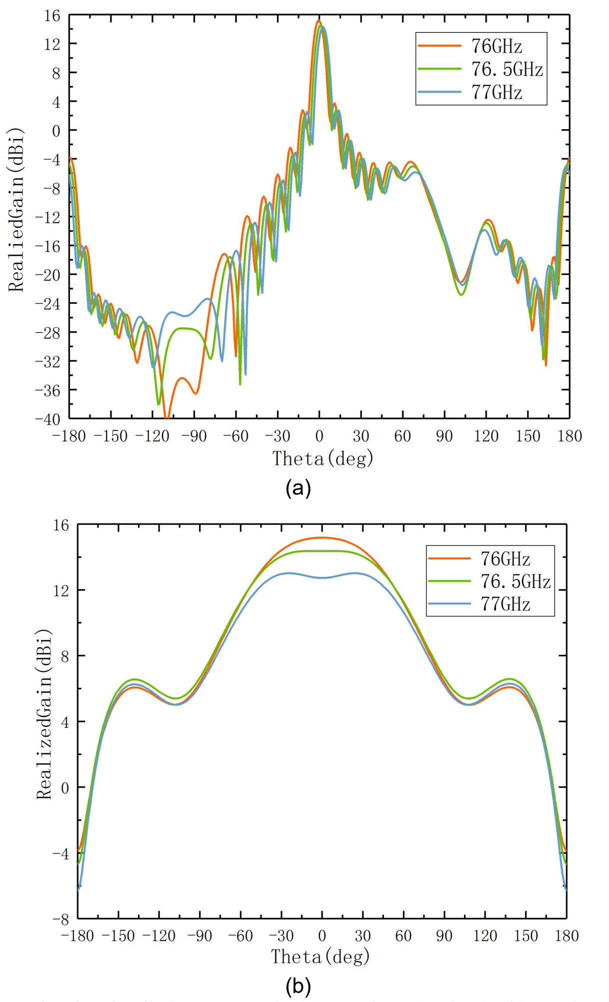

Fig. 7. Simulated radiation patterns in (a) YZ plane (E-plane), (b)XZ plane (H-plane)

IV. CONCLUSIONS

A series-fed P-LWA with fourteen patch elements is presented in this paper for automotive radar system. To cover the 1 GHz bandwidth of the 77 GHz radar and achieve good H-plane beamwidth, the P-LWA is designed with four slots and an impedance matching stub. The simulation results indicate that the performance of the proposed P-LWA can fulfill the requirement of 77 GHz automotive radar system.

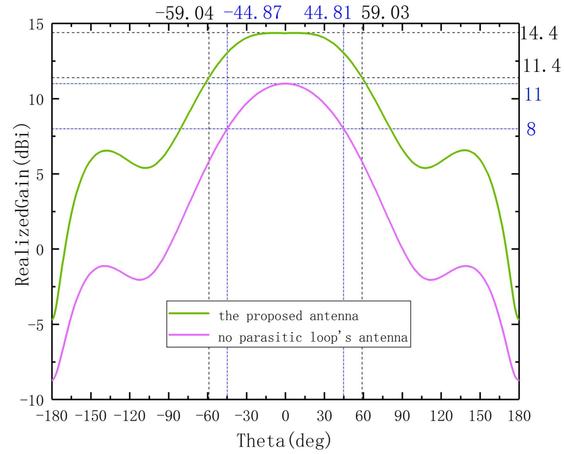

Fig. 8. Comparison the P-LWA antenna of XZ plane (H-plane) radiation patterns with and without four slots.

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