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Gain Enhancement of Microstrip Patch Antenna for 28 GHz 5G Applications

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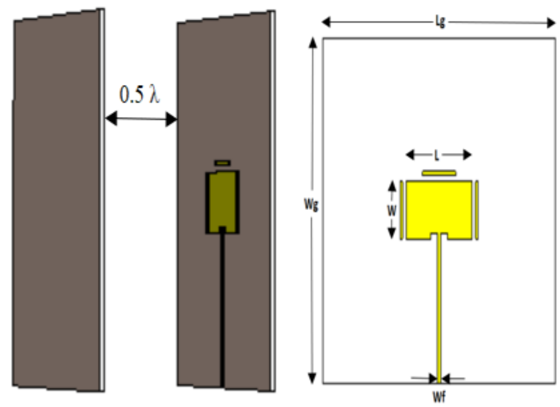
***Abstract*— In this article, the design of a rectangular patch antenna in the millimeter-wave range is presented. The antenna is placed on a Rogers TC600 substrate with a dielectric constant of 6.15. The antenna resonance is kept around 28 GHz. The proposed work enhances the gain by placing a superstrate at a specific distance from the radiator equal to 0.5 λ, which reflects the electromagnetic wave between the two substrates and, consequently, enhances the gain. As a result, the proposed method enhances the gain by approximately 2.27 dB, which suitable for automotive applications at mm-wave band.**

***Keywords*— Rectangular patch antenna; Millimeter-wave; Gain enhancement**

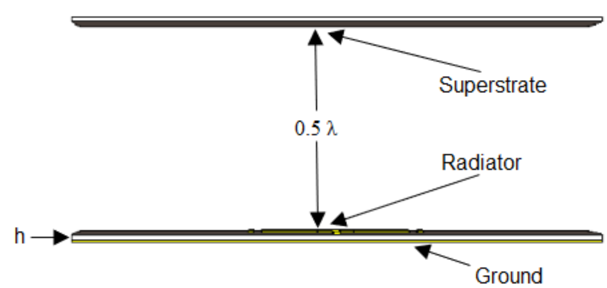
I. Introduction

Microstrip patch antenna (MPA) has been utilized for various wireless applications due to its lightweight, low cost, low profile, and easy fabricate features. However, significant disadvantages of these antennas with low profile include low gain and narrow impedance bandwidth, which limit its applications [1]. Over the years, some techniques have been proposed to enhance the gain. First, a simplest method to enhance the gain is to use antenna applications together with metamaterials [2-3]. In [4-5], the metal hole array is used as a wavefront conversion device to enhance the gain. Other techniques to improve the gain are by using the stacked patch configurations [6], increasing resonant frequency of the first-order mode without changing the size of the patch antenna [7-8], or aperture coupling feed [9]. However, these solutions led to the use of multilayer substrate, resulting in increased complexity and high fabrication cost. The typical low gain of a patch antenna can be enhanced by increasing the radiators elements, which is called an array [10].

Moreover, the gain enhancement attained by increasing number of elements which leads to metals losses. In this work, the gain of the design has been enhanced by placing the superstrate at a specific distance from the radiator. The recommended distance should be around 0.5 λ, where λ is the wavelength at the resonator frequency. The method of superstrate is affected by some parameters such as the distance between the radiator and the substrate, the thickness of the substrate, and the permittivity. To the best of our knowledge, the simulation gain for most of the patch antenna designs proposed in the open literature is between 5 and 7 dB. However, in our proposed design, a gain of 8.31 dB is achieved. The gain of the proposed design has achieved 8.31 dB, and thus, an improvement of 2.27 dB compares with the initial gain. This paper is organized as follows. In section II, the antenna design is presented, followed by section III, which contains results and discussion. Then, the paper concludes in section IV.



(a) Top and side view



(b) Cross-sectional view

Fig. 1. Geometry of the proposed antenna.

II. Antenna design

The antenna is designed and simulated in CST MWS studio 2019. A rectangular Patch antenna at 28 GHz connected by a transmission line is designed. The patch antenna acts as the radiator, and the three slots are placed beside the radiator to determine the resonant frequency at 28 GHz, which is the required frequency. In addition, two small squares were placed at the bottom of the patch antenna for antenna radiation. The radiator patch is located on the substrate which is located above the ground plane. The antenna is placed on a Rogers TC600 substrate with a dielectric constant of 6.15 and a thickness of 0.16 mm. Superstrate method is applied and a substrate with the same thickness and permittivity of the design substrate is located at a specific distance from the radiator equal to 0.5 λ in order to enhance the gain. The dimensions of the radiator patch *L* and *W* are kept 3.99 mm and 2 mm, respectively. The slots length and width are optimized as 0.15 and 2, respectively. Fig. 1. shows the proposed antenna layout in CST, and the design parameters are summarized in Table I.

Table I. Antenna design parameters.

Parameter	Value (mm)
Length of the ground plane and substrate (Lg)	14
Width of the ground plane and substrate (Wg)	12
Length of the patch (L)	3.99
Width of the patch (W)	2
Length of the slot (Ls)	0.15
Width of the slot (Ws)	2
Thickness of substrate (h)	0.16
Width of the feed (Wf)	0.18

III. Results and Discussion

The simulated results of the reflection coefficient (S_{11}) and gain are shown in Fig. 2. The results show that without the superstrate, a gain of 6.04 dBi is achieved. By adding a superstrate above the radiator, the gain improved to achieve 8.31 dBi, while most patch antennas at 28 GHz in the open literature achieve a maximum gain around 6.5 dBi. The superstrate boosts the gain improvement by almost 2.27 dBi. Enhancing the gain is required for most of mm-wave applications. In addition, Rohacell foam with a permittivity of 1.05 is used as a support between the radiator and superstrate.

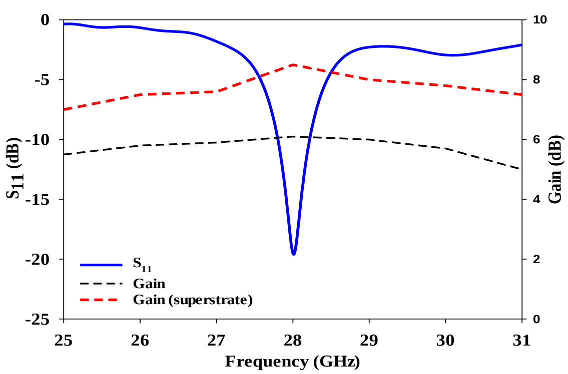
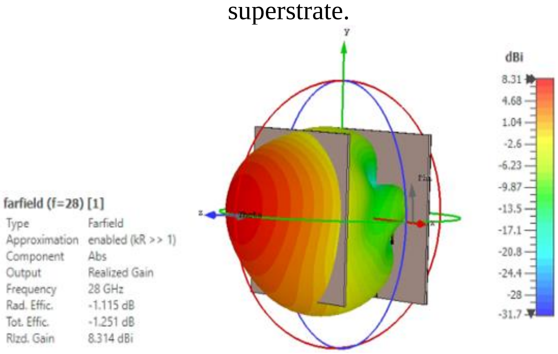
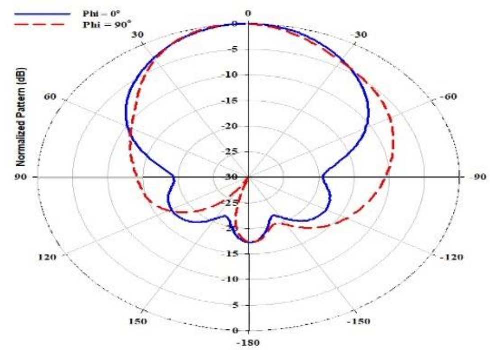


Fig. 2. Simulated return losses and gain with/without superstrate.



(a) 3D Radiation pattern



(b) H and E Radiation pattern

Fig. 3. shows the radiation pattern in (a) 1D and (b) 3D for the proposed antenna.

IV. Conclusion

In this paper, a rectangular patch antenna with slots was presented. The introduction of the superstrate is used for gain enhancement. The results demonstrated that the gain after placing the superstrate is improved from 6.04 dBi to 8.31 dBi, which translates to about 2.27 dBi enhancement. The proposed design is suitable for automotive applications operating at the V2X band that require a high gain to overcome the high atmospheric attenuation at the mm-wave band.

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