Design of an Aperture-Coupled Microstrip Array Antenna for Millimeter-wave Radar System

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Abstract. In this paper, we designed and interpreted the array antennas of the aperture-coupled microstrip operating in the millimeter-wave band for radar system. The microstrip array antenna can be designed with a transmission line circuit and a matching circuit in the same substrate. Therefore it is easy to combine with the active elements of the system. We add the slots to the patch to overcome it because general microstrip patch antennas have narrow band characteristics. We have designed the U-shaped slots in the patch. The substrate of patch for an aperture-coupled is used for general dielectric layer, and the substrate of transmission line for T-junction feeding is used FR4-epoxy. At this time, the analyzed center frequencies are 10 resonance mode from 24 GHz to 77 GHz at the 2×2 array. As a result, this paper is proposed the possibility of prototyping by design of multi-mode array antenna in the millimeter-wave.

Keywords. Patch antenna, Patch array antenna, Slot array antenna, Aperture-coupled antenna, Multi-band antenna

1 Introduction

The study on millimeter-wave antennas have evolved continuously over the past 30 years, with the rapid development of microstrip antenna theories and techniques. The microstrip antenna has been applied to many fields because it can be integrated a small weight and volume. In recent years, millimeter-wave systems in the transport sector are being used widely in the automotive electronics sensors with the information and communication technologies.

In the center of these changes, it is an Adaptive Cruise Control (ACC) system. The system is an active safety device that can predict the occurrence of an accident by sensing the external environment while driving car[1]-[3]. In recently, the development of automotive radar systems divided by a short distance SRR (Short Range Radar) and long distance LRR (Long Range Radar) are being developed. The SRR was used UWB of 24GHz band and 79GHz band, the LRR has been used for the 77GHz-band.

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Future of Automotive radar systems will be integrated into one radar system SRR and LRR. FMCW modulation is expected to be widely used in the integrated system[4].

This paper is designed and interpreted microstrip array antenna(MAA) of the aperture-coupled microstrip antennas operating in the millimeter wave band. In this technique the feed network is separated from the radiating patch by a common ground plane. Energy is electromagnetically coupled through an aperture in the ground. This aperture is usually centered with respect to the patch where the patch has its maximum magnetic field.

The MAA can be designed with a transmission line circuit and a matching circuit in the same substrate. Therefore it is easy to combine with the active elements of the system. Its main advantage is that it can be an overall design of the semiconductor integrated circuit.

We add the slots to the patch to overcome it because general microstrip patch antennas have narrow band characteristics. Also, it can be used to achieve dual or multiple frequency operation. The shape of slot selects a symmetric structure of the U-shape with a multi-band. As a result, this paper presents the possibility of a multi-band array antenna system implementations through the simulation results.

2 Analysis of Multi-band Array Antenna

The return loss of a single patch, 2x1 array, and 2x2 aperture coupled array with feed network using Wilkinson divider are displayed in Figure 1. The number of resonant band in single patch is 3, 2x1 array is 8, and 2x2 array is 10. And the bandwidth of the 24GHz is 2GHz, and the bandwidth of the 77GHz is approximately 4GHz.

The resonant frequency of the multi-mode is selected to adjust finely the length of the stub. In 2x2 array antenna, we are selected the length of stub as 0.5 mm to obtain the maximum number of resonance mode. The proposed geometry is simulated using HFSS tool software.

![Fig. 1. The return loss curves for single patch, 2x1 array and 2x2 array.](image-url)
Figure 2 presents the results of the radiation pattern at the center frequency of 24.4GHz and 77.6 GHz of the third-bands of a single patch antenna. Figure 3 presents the results of the radiation pattern at 25 GHz and 76 GHz of 8-band of $2 \times 1$ array antenna. Figure 4 presents the results of the radiation pattern at 24 GHz and 77 GHz of 10-band of $2 \times 2$ array antenna.

(a) Radiation pattern for 24.4 GHz antenna.  (b) Radiation pattern for 77.6 GHz antenna.
Fig. 2. The radiation patterns of single patch antenna.

(a) Radiation pattern for 25 GHz antenna. (b) Radiation pattern for 76 GHz antenna.
Fig. 3. The radiation patterns of $2 \times 1$ array antenna.
3 Conclusion

In this paper, we designed and interpreted the MAA of the aperture-coupled microstrip antennas operating in the millimeter-wave band. The MAA can be designed with a transmission line circuit and a matching circuit in the same substrate. Therefore it is easy to combine with the active elements of the system.

We add the slots to the patch to overcome it because general microstrip patch antennas have narrow band characteristics. Also, it can be used to achieve dual or multiple frequency operation.

The return loss of a single patch, $2\times1$, and $2\times2$ aperture coupled array with feed network using T-junction divider are analyzed here. The number of resonant-band in single patch is 3, $2\times1$ array is 8, $2\times2$ array is 10.

As a result, this paper is available to have multiple resonant mode in the millimeter-wave band. Also, this paper is required to extend over the $4\times2$ array antenna in millimeter-wave band.

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References


