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The Application of the FDTD Method to Aperture-Coupled Microstrip Antenna Array on LTCC at Millimeter-Wave

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Abstract. In this paper, The microstrip array antenna can be designed with a transmission line and matching circuit in the same substrate LTCC at 24 GHz for the SRR system. We achieved the proper impedance matching throughout the corporate feeding array configurations provides T-junction with slits. The return loss of single patch, 2×1, and 2×2 arrays using SEMCAD X tool are analyzed here. As a result, this paper is available for short range radar applications in the millimeter-wave band.

Keywords: SEMCAD X, T-junction power divider, LTCC systems, Short range radar system, Aperture-coupled 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 [1][2]. In recent years, the millimeter-wave radar systems in transportations are being used widely in automotive electronics sensors with the information and communication technologies [3]. In the center of these changes, it is an adaptive cruise control (ACC) system. Further automotive radar system (ARS) uses a millimeter wave sensor that can provide information about the environment around the front, rear and sides of the automobile to control the cruising car [4].

Further the technology of the structurally size has been applied in the system-on-package (SOP). This technology is mixed small power consumption of the active device component based on the silicon technology and the multi-layer substrate with the low temperature co-fired ceramic (LTCC)[5]. Therefore, this package technology of laminate is used in order to combine the antenna and the ARS into one. In this paper, we use a multi-layer LTCC substrate having a high dielectric constant. In addition, we design the aperture-coupled microstrip antenna (AMA) in order to improve the radiation characteristics. Also, we use the SEMCAD X tool[6] using the finite difference time domain (FDTD) method to analyze such structures[7].

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As a result, the proposed aperture-coupled MAA with slots in the patches of array element is well suited for the multi-layer packaging technologies for SOP.

2 Aperture-Coupled Microstrip Patch Antenna

Here we treat with a transmission line on LTCC substrate. The aperture-coupled microstrip single patch antenna used in this study is shown in Figure 1. In this configuration the antenna system is composed of a conductive thin metal plate and an air layer to minimize the reflected wave, the feed line for supplying a signal, the LTCC dielectric two layers for supporting a surface, a conductive ground plane that contains the aperture, the supporting LTCC dielectric four layers physically and the patch.

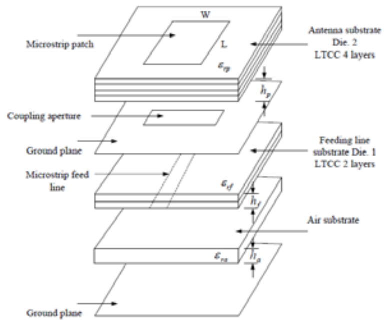

Fig. 1. Inset feed single patch antenna with U-shaped slots.

In general, the size of the patch is determined below half-wave by the fundamental resonance mode. In this case, the selected resonant frequency is 24 GHz. The LTCC dielectric substrate Die. 1 is Ferro A6S and it have the relative dielectric constant ε_{rp} = 5.9, the loss tangent tanδ = 0.002, and the thickness of the LTCC substrate two layers h_f = 0.2 mm. As shown in Figure 1, the substrate Die. 2 for a microstrip line is LTCC four layers and it is the relative dielectric constant ε_{rf} = 5.9, the loss tangent tanδ = 0.002, and a thickness h_p = 0.4 mm. Also the air layer with a thickness h_a = 1.6 mm to minimize the radiation of the strip line is added. The antenna arrays are designed starting from a single element to 2×2 antenna array using the transmission line model.

3 Results and Comparison

In this paper, we design and analysis of the microstrip line T-junction in the millimeter-wave band on the LTCC substrate. Figure 2 (a) shows the reflection coefficients S_{11} on the models of T-junctions. In Figure 2, these reflection coefficients S_{11} represents the best results when the 100 Ω-slit is added to the T-junction part.

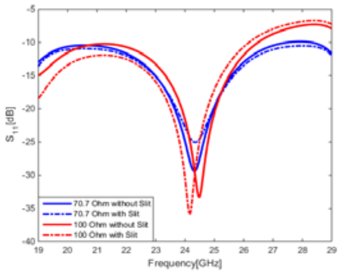

Fig. 2. The reflection coefficients S_{11} plots for T-junction without/with slit.

The variation of reflection coefficients S_{11} versus frequency of single patch antenna, 2 ╳1, and 2╳2 array antennas with feed network using T-junction dividers are shown in Figure 3. In particular, the band width is represented more widely in the 2╳2 array.

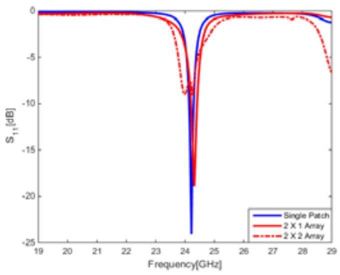

Fig. 3. The reflection coefficient curves for the single patch, 2╳1, and 2╳2 array.

Figure 4 presents the results of the normalized radiation patterns on the E_{Pi} and E_{Th} of the 2╳2 array antenn. It clearly depicts that by increasing the number of elements in the array, the gain and directivity increases with decrease in the beam width. The radiation patterns of the arrays are shown that the simulated gain is normalized at Φ = 90 degree for the operating frequency 24 GHz.

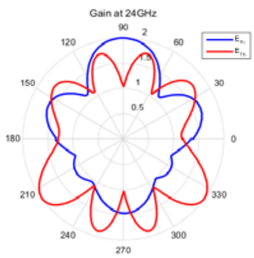

Fig. 4. The normalized radiation patterns of 2╳2 array antenna.

4 Conclusions

In this paper, we designed and interpreted the aperture-coupled MAA operating at 24 GHz for the SRR system. The MAA can be designed with a transmission line circuit and a matching circuit in the same substrate LTCC. Therefore it is easy to combine with the active elements of the SOP. Also, we use the SEMCAD X tool using the finite difference time domain (FDTD) method to analyze such structures. The radiation patterns of these designed arrays are very simple and high efficiency for the applications in the millimeter-wave. The optimum design parameters are used to achieve the compact dimensions and high radiation efficiency. As a result, this paper is available for SRR applications in the millimeter-wave band.

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