Isolation-enhanced Four-element MIMO Antenna System Using Mushroom

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***Abstract*—In this paper, double-layer mushroom walls are vertically positioned in between a four-element substrate integrated waveguide (SIW) cavity-backed slot (CBS) MIMO antenna system for the inter-element isolation enhancement. A piece of mushroom wall comprises two printed circuit boards (PCB), two identical patches of mushroom cells are symmetrically printed onto both the surface of the PCBs, the shared ground is sandwiched in between, and a vias connecting the patches to the ground. Using the band-gap characteristics of the mushroom walls, the four-element SIW CBS MIMO antenna system, wherein the edge-to-edge distance of the antenna elements is 0.024 λ (λ is the wavelength in free space at 2.42 GHz), achieves extremely high isolation of 40 dB between the elements throughout the operating frequency bandwidth of 2.396 GHz–2.445 GHz, the envelope correlation coefficient (ECC) is lower than 0.02 across the operating bandwidth accordingly.**

Key words—Isolation, mushroom, MIMO, substrate integrated waveguide (SIW), cavity-backed slot (CBS) antenna.

I. Introduction

The multiple-input-multiple-output (MIMO) system performance can be greatly improved with the increasing number of the antennas in the terminals of the transceivers. As an example, a 4 × 4 MIMO antenna system has been integrated into IEEE 802.11n for the further requirement of larger channel capacity [1]. However, the inter-element isolation of the MIMO antenna system becomes poorer because of the closer positioning of the antenna elements, which leads to the degradation of the MIMO system performance [2]. Therefore, the enhancement of the inter-element isolation of the antenna system is very critical for the design of the MIMO system.

With the increasing demand of larger capacity of the MIMO communication system, the issue of the inter-element isolation enhancement of the four-element MIMO antenna system has been drew more attention. They include the adoption of the decoupled networks [3], the introduction of the split ring resonator (SRR) structure [4], and the utilization of the planar mushroom structure [5]. However, in order to further increase data transfer rate and efficiency of the MIMO system, an ultra high isolation between each antenna elements, for example, larger than 40 dB, is required to be achieved for industrial application.

In this paper, a four-element SIW CBS MIMO antenna system loaded with vertically double-layer mushroom walls is proposed to control the space-wave coupling for realizing ultra-high isolation of 40 dB over the operating band range of2.395 GHz–2.45 GHz. The mushroom wall structures are crossed in between the four-element CBS antenna system. Part of space field is trapped in the mushroom structure, which greatly enhances the inter-element isolation of the four-element MIMO antenna system.

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II. Antenna and Mushroom Wall Configuration

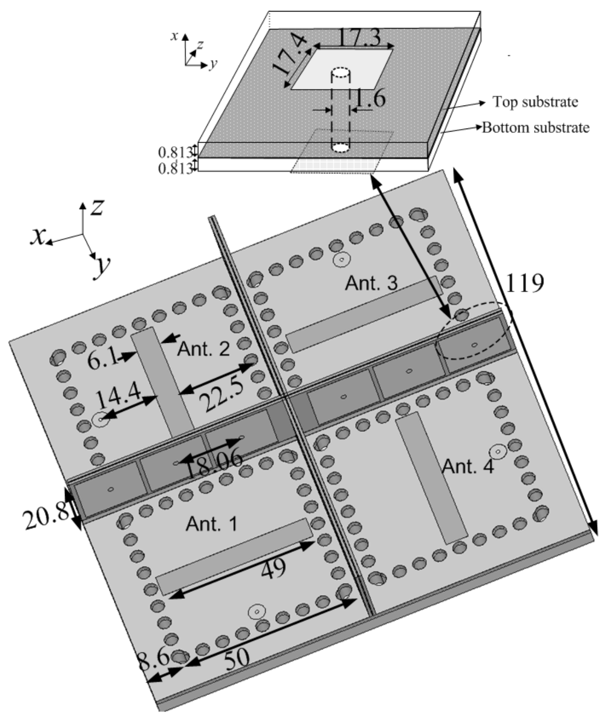

Fig.1. Configuration of the four-element SIW CBS antenna system with mushroom wall as well as mushroom cell. (Unit: mm)

The geometry of the four-element SIW CBS antenna system with mushroom wall is shown in Fig. 1, wherein the two piece of mushroom walls are symmetrically crossed in between the four-element CBS antenna system. The adjacent antenna elements are orthogonal positioned and fed by the coaxial probe, separately. The SIW CBS antenna is fabricated on a single-layer Rogers 4003C substrate with a thickness of 1.524 mm, $\varepsilon_r = 3.55$, tanδ = 0.027, and the mushroom structure is fabricated on a double-layer Rogers 4003C substrate with a thickness of 0.813 mm. The overall size of the antenna system is 119 mm× 119 mm× 20.8 mm.

III. RESUTLS

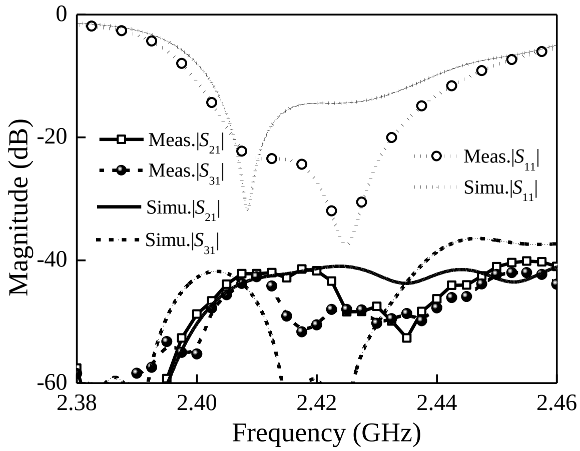

Fig.2. Measured and simulated *S*-parameters

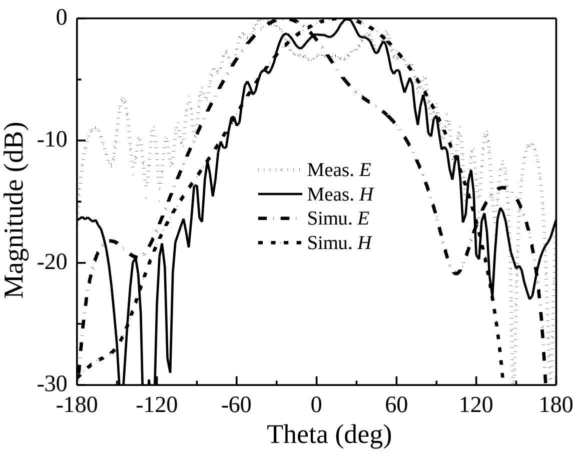

Fig. 3. Measured and simulated radiation patterns of the four-element antenna system (Antenna 1@2.42 GHz).

The *S*-parameters of the four-element CBS antenna system with mushroom walls is shown in Fig. 2. Because all the slot antenna elements are fully symmetrically distributed, the reflection coefficient of each element of the four-element antenna system is identical. Thus, only the reflection coefficient of the Antenna 1 is presented. It can be seen that the -10-dB reflection coefficient bandwidth is 2.396 GHz–2.445 GHz.

Because of the symmetrical distribution of the antenna elements, the isolation between the adjacent elements along the horizontal and vertical lines is the same. In addition, the isolation between the elements along the diagonal lines is the same as well. For brevity, only the $|S_{21}|$, $|S_{21}|$, $|S_{31}|$ and $|S_{41}|$ are presented. As shown in Fig. 2, the isolation between all the adjacent antenna elements is less than -41 dB over the operating band of 2.396 GHz–2.455 GHz.

The far-field pattern of the Antenna Element 1 at 2.42 GHz is shown in Fig. 3. The maximum bore-sight gain is 4dBi at 2.42 GHz. The beam squinting is attributed the adding of the mushroom wall, and the deflections of *H*- and *E*-planes pattern are about ±22° from boresight.

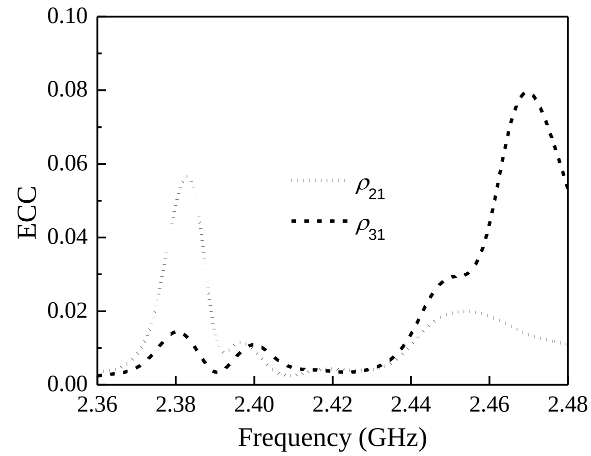

Fig. 4. Calculated ECC of the four-element antenna system.

The enveloped correlation co-efficient (ECC) (ρ_{ij}) among the four-element antenna system with the mushroom wall can be calculated according to the measured far-field [2]. Similar to the *S*-parameters of the antenna system, $\rho_{21}=\rho_{32}=\rho_{43}=\rho_{41}$, and $\rho_{31}=\rho_{42}$. For brevity, only ρ_{21} and ρ_{31} are presented here. It can be seen that the ECC is always below 0.02 over the whole the operating bandwidth.

IV. CONCLUSION

A double-layer mushroom wall has been proposed to enhance the inter-element isolation of the four-element MIMO antenna system. It not only blocks the space wave propagation from the antenna elements but also concentrates part of fields at the operating frequency as well. The measured results validate the technology is feasible and efficient to enhance the isolation of the multi-element MIMO antenna system.

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