A Compact Four-element MIMO Antenna with High Isolation Based on EBG

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***Abstract* –Based on an electromagnetic band-gap (EBG) structure, the compact four-element MIMO antenna are proposed for 2.4 GHz band application, with antenna area of 0.72×0.72 λ^2 and high isolation level of -15 dB. To isolate the four elements in compact space, a concentric square ring mushroom EBG (CSR-EBG) which reduce cell size by 45% in comparison to the conventional EBG is designed. The effective arrangement and the optimal cell number of EBG structure is found through changing position and number of EBG cells inserted into the proposed antenna. Simulation results confirm the improvement of isolation between the antennas by 4 dB at the radiation frequency of 2.4 GHz without destroying the antenna operation performance when CSR-EBG is utilized.**

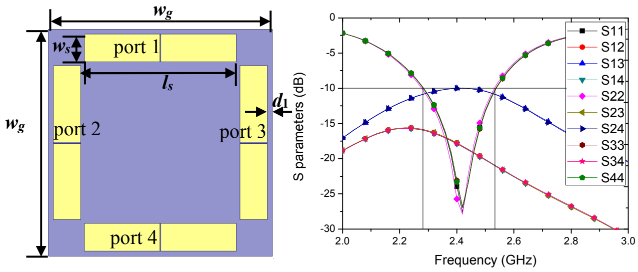
***Index Terms* — Compact MIMO Antennas, high isolation, EBG, mutual coupling**

1. Introduction

MIMO antenna with spatial, polarization, or pattern diversity is commonly utilized to ensure a reliable and broadband data transmission in modern telecommunication system. A sufficiently high capacity of the MIMO system can be achieved as long as no correlation exits between the diverse channels. It is stated in [1] that mutual coupling between multiple antennas can lead to channel correlation especially for closely spaced antenna elements, subsequently reducing their channel capacity. One of the frequently-used methods to reduce the coupling is the use of EBG structure. These periodic mushroom structures can prevent surface electromagnetic wave in certain frequency bands of interest. Thus the mutual coupling between antennas caused by this surface-wave can be reduced significantly. Single- and dual-layer EBG structure is employed successfully in two slot antennas [2] and two microstrip patch antennas [1] respectively. It can be seen that these antennas are diverse in space due to they are placed in parallel. In this paper, for a compact four-element MIMO antenna both with space and polarization diversity, a type of EBG structure with smaller unit-cell size is designed to improve isolation between the four antenna elements.

2. Antenna design

The compact four-element MIMO antenna, as shown in Fig. 1(a), is composed of four slot antennas sharing common ground and dielectric plate: two horizontal slot antennas excited by port 1 and 3, two vertical slot antennas excited by port 2 and 4. It can be seen that the multi-antenna system include polarization and space diversity both along two orthogonal direction to improve the system channel capacity. The intended radiation frequency of the antenna is 2.4GHz, and the structural parameters of the antenna are listed in table I. Where, h and ε_r are respectively the thickness and the dielectric permittivity of the substrate, and other parameters are marked in Fig. 1(a). The simulation of the antenna using Ansoft HFSS is created. The antenna is exited using four ideal lumped ports located at the center of the four slots. Fig. 1(b) shows the S parameters of the four ports. As expected, it can be seen that S_{13} and S_{24} are as high as 10 dB in the operation bandwidth due to the strong coupling between two parallel slots brought from the sharing ground.



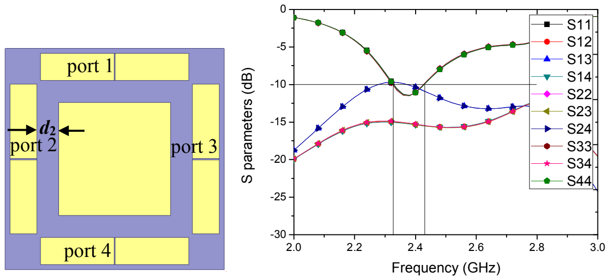
(a) (b)

Fig. 1. Top view and S parameters of the four-element MIMO antenna: (a) Top view of the antenna (b) S parameters

TABLE I
Antenna Parameters (Unit: mm)

w_g	w_s	l_s	d_1	h	ε_r
90	11	61	2	2	6.15

Slotting in the sharing ground is commonly used to reduce the interference between two parallel antennas. Fig. 2(a) presents the four-element MIMO antenna with center square slot based on this idea. The distance d_2 between the center square slot and each antenna is 9 mm, as shown in Fig. 2(a). However, from the simulated data shown in Fig. 2(b), the center square slot not only can't improve the isolation between antennas, but cuts down the operation bandwidth by 60% in comparison to the antenna without center slot. Thus, only slotting in ground can't reduce mutual coupling for the proposed four-element antenna. Next, the EBG structure is used to mutual coupling mitigation through inserting them into the center square slot, and some exploratory research about EBG design and arrangement can be made.

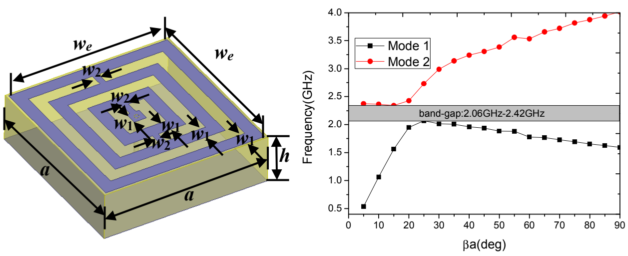


(a) (b)

Fig. 2. Top view and S parameters of the four-element MIMO antenna with center square slot: (a) Top view of the antenna (b) S parameters

3. EBG design

For a 2.4 GHz centered band-gap, a conventional mushroom lattice has unit-cell size of 10 mm according to the effective medium model [1]. In order to accommodate more mushroom unit-cells in the center square slot, the concentric square ring mushroom EBG structure (CSR-EBG) is employed because its increased inductive loading can further reduce the unit-cell size. The CSR-EBG structure is designed on the same substrate the proposed antenna used, as shown in Fig. 3(a). Table II lists the dimensions of the EBG structure, where each geometry parameter is defined in Fig. 3(a). Eigen-mode simulation of this CSR-EBG unit-cell is made in HFSS with a perfectly matched layer (PML) on top and period boundary conditions on each side. Dispersion diagram obtained in Fig. 3(b) shows that an omnidirectional band-gap extending from 2.06 to 2.42 GHz is created.



(a) (b)

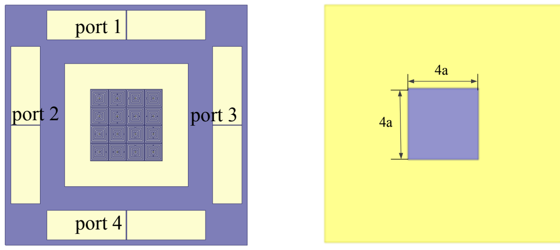
Fig. 3. Geometry and characteristic of the CSR-EBG unit-cell: (a) Geometry (b) dispersion diagram

TABLE II
The parameters of CSR-EBG unit-cell (Unit: mm)

a	w_e	w_1	w_2	g
5.5	5.3	0.4	0.2	a-w_e

4. Antenna with EBG

This CSR-EBG structure is used to develop the proposed four-element MIMO antenna. Several EBG arrangements with different spacing and number of EBG unit-cell are tried in simulation. The conclusions are found that with the increasing of the number of EBG unit-cell, the mutual coupling becomes weaker between two parallel slots but stronger between two vertical slots, and the optimal EBG unit-cell number is 4×4. The HFSS simulation model for the proposed antenna with CSR-EBG is shown in Fig. 5. From the figure we can see the mushroom patch and the ground of the EBG structure are metallized on the top and back side of the substrate respectively. Fig. 5 shows the simulated S parameters of the proposed antenna with CSR-EBG. This figure indicate that when the EBG is inserted into the center square slot, the mutual coupling between the parallel slots is reduced from -10 to -14 dB at 2.4GHz without cutting down the operation bandwidth of the proposed antenna.



(a) (b)

Fig. 4. The compact four-element MIMO antenna ports with CSR-EBG: (a) Top view (b) Back view

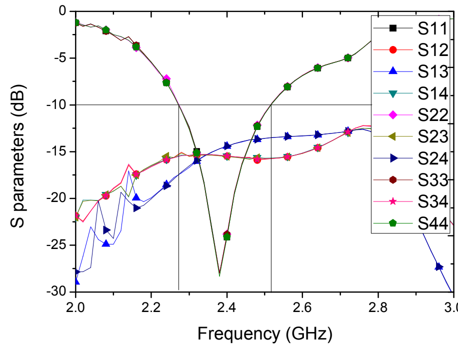


Fig. 5. S-parameters of the compact four-element MIMO antenna with CSR-EBG

5. Conclusion

A concentric square ring mushroom EBG structure is designed and used to develop a compact four-element MIMO antenna at 2.4GHz. It is can be shown that employing the 4× 4 CSR-EBG unit-cells reduces effectively the mutual coupling between the parallel antenna elements and maintain the antenna performance almost intact.

Acknowledgment

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References

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