Design of Chassis MIMO Antenna Using Characteristic Mode Theory (Invited Paper)

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***Abstract*—In this paper, we propose a design method for a chassis MIMO antenna based on characteristic mode theory. Specifically, we provide a way to use a chassis with one axis of symmetry as a multiport MIMO antenna. The method utilizes a combination of characteristic mode and a mode-decoupling network, and suggests a way to design an inductive coupling element to excite specific characteristic modes while simplifying the mode-decoupling network.**

Keywords—Characteristic mode theory, MIMO antenna, mode-decoupling network.

I. Introduction

Much effort is currently devoted to designing a MIMO antenna in a limited space to increase the data rate of today's communication. However, there is a problem with designing a MIMO antenna in a limited space due to coupling and correlation between element antennas. To overcome this problem, a combination of characteristic mode theory (CMT) and a mode-decoupling network (MDN) is proposed, which enables us to utilize a chassis as a MIMO antenna with low coupling and low correlation between element antennas [1]. However, as the number of element antennas for MIMO increases, the MDN becomes more complicated to design. A simple MDN for multiport (>2 ports) MIMO antenna was implemented by using symmetric properties of a chassis [2]. This method, however, is applied only to structures with two orthogonal axis of symmetry, called biaxial symmetry.

In this paper, we propose a new design method for a multiport MIMO antenna using a chassis having one axis of symmetry, called bilateral symmetry. To reduce the complexity of the MDN, analysis of the bilaterally symmetric chassis is performed, and a suboptimal position of the inductive coupling element (ICE), which excites characteristic modes of the chassis, is suggested.

II. Characteristic Mode Theory

For a given chassis for the design of a MIMO antenna, there exist dominant orthogonal modes, called characteristic modes (CMs), which are derived using CMT [3]. When the individual dominant mode is used as an element antenna, a low correlated MIMO antenna is achieved owing to the orthogonal properties of CMT. To excite specific CMs, there are two options: one is capacitive coupling element, and an ICE [4].

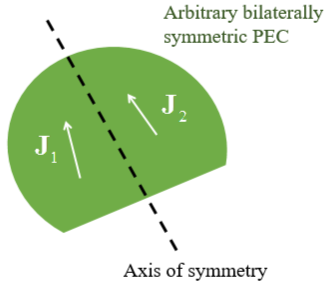

Fig. 1. Illustrative representation of bilaterally symmetric structure. $\mathbf{J}_1$ represents currents that flow on the left side of the axis of symmetry. $\mathbf{J}_2$ represents currents that flow on the right side of the axis.

For a chassis with bilateral symmetry, all characteristic modes are classified with even CMs and odd CMs with respect to the axis of symmetry [5]. Specifically, as shown in Fig. 1, total currents on the surface of a bilaterally symmetric perfect electric conductor (PEC) is divided into currents flowing on the left side of the axis, named $\mathbf{J}_1$, and current flowing on the right side, named $\mathbf{J}_2$. An even mode is defined as a mode whose currents satisfy $\mathbf{J}_1 = \mathbf{J}_2$. And an odd mode is defined as a mode whose currents satisfy $\mathbf{J}_1 = -\mathbf{J}_2$.

III. Proposed Method for the Chassis MIMO Antenna

Based on the characteristics of even and odd modes, we propose a multiport chassis MIMO antenna design method for bilateral symmetric structures. In particular, the characteristics of even and odd CMs provide independent excitation between even CMs and odd CMs. This independent excitation is achieved by putting coupling elements on the axis of symmetry. As an example, we used a slotted ICE. When we place the ICE for even CMs as shown in Fig. 2-(a), and for odd CMs as shown in Fig. 2-(b), each of them excites their own modes separately. The slot need not be rectangular as shown in Fig. 2, but one thing to keep in mind is that this slot should also be designed symmetrically with respect to the axis of symmetry. This also guarantees low coupling between ports of the ICE because they are virtually open to each other.

The independent excitation and the low coupling enables us to design a 2-port chassis MIMO antenna that has one port using the even CM and the other the odd CM. As shown in Fig. 3-(a), it is achieved without any MDN owing to the structural orthogonality mentioned above. Because an ICE has inductive

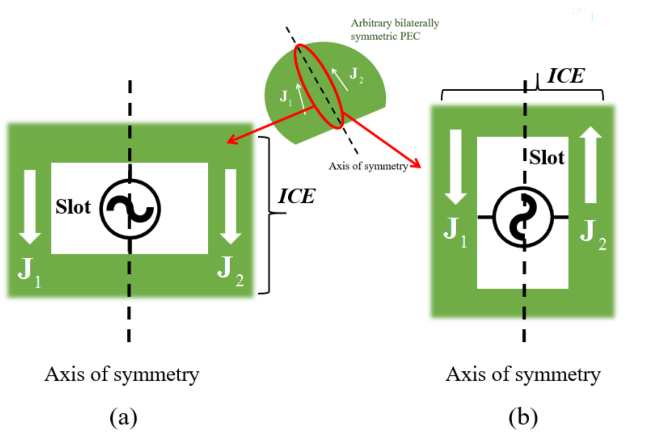

Fig. 2. Placement of an inductive coupling element(ICE). (a) ICE for exciting an even CM. (b) ICE for exciting an odd CM.

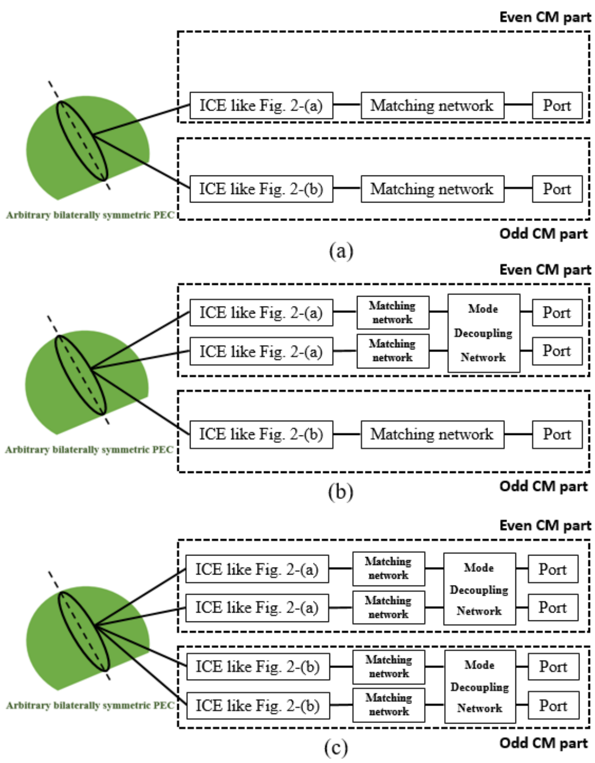

Fig. 3. Systematic configuration of the proposed chassis MIMO antenna. (a) A 2-port chassis MIMO antenna using 1 even CM and 1 odd CM, (b) A 3-port chassis MIMO antenna using 2 even CMs and 1 odd CM, (c) A 4-port chassis MIMO antenna using 2 even CMs and 2 odd CMs. CM, characteristic mode; ICE, inductive coupling element

input impedance, additional circuits are needed for input matching.

For an extension to a multiport MIMO, exciting multiple even modes or multiple odd modes should be done. However, our proposed method of placing the ICE on the axis does not guarantee independent excitation between modes in the same group. In general, modes in the same group have correlated current distribution around the coupling elements, except null points of the modes, so that coupling elements excite the same group of modes. These coupled CMs can be separated using a MDN, which is usually made with a rat-race coupler. The rat-race coupler provides not only separation of excitation between coupled modes in the same group, but also low-coupling between ports owing to directivity of the coupler. As shown in Fig. 3-(b), which is for a 3-port chassis MIMO antenna using 2 even CMs and 1 odd CM, the MDN exists in the even CM part between matching networks and ports.

In a similar manner, a 4-port chassis MIMO antenna using 2 even CMs and 2 odd CMs can also be proposed as shown in Fig. 3-(c). Compared to using a MDN for all 4 CMs, configuring the two MDNs for each of the modes in the same group reduces the complexity.

IV. Conclusion

The main idea of the proposed method is that coupling elements for exciting characteristic modes are placed on the axis of symmetry, which makes it simple to design a multiport chassis MIMO antenna including MDNs. The proposed method can be applicable to platform-mounted antennas for MIMO application, because most of the platforms are bilaterally symmetric.

Acknowledgment

This work is supported by a grant to Bio-Mimetic Robot Research Center funded by Defense Acquisition Program Administration, and by Agency for Defense Development (UD130070ID)

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