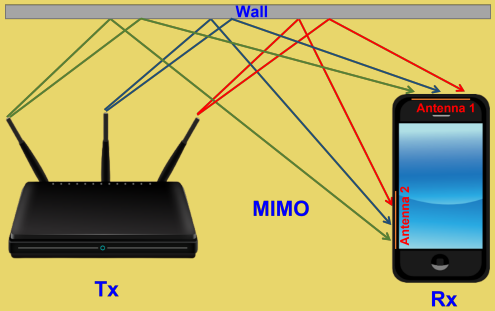

Characteristic Modes Special Interest Group

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In This Issue:

Scholar Spotlight:

Jiang-Feng Lin (S'16-M'18) was born in Shantou, Guangdong, China, in 1991. He received the B.S. degree in communication engineering from Beijing University of Posts and Telecommunications (BUPT), Beijing, China, in 2013, and the Ph.D. degree in electronic engineering from South China University of Technology (SCUT), Guangzhou, Guangdong, China, in 2018. He is currently a postdoctoral researcher with the University of Macau (UM), Macau SAR, China, under the support of UM Macau Talent Program. His research interests include characteristic modes theory, high-gain and/or wideband antennas, dual-beam antennas, MIMO antennas, and antenna decoupling.

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Featured Article

"Design of Low Profile Compact MIMO Antenna on a Single Radiating Patch Using Simple and Systematic Characteristic Modes Method", *by Jiang-Feng Lin et al.*

Recently, a mode cancellation method has been developed to enhance port isolation for multiple-input–multiple-output (MIMO) antennas. Different from the traditional modal method used to excite one single mode at one port, this method always excites a pair of modes, i.e., common/differential modes or even/odd modes at the same time. When one of the two ports is excited, modal fields of the two excited modes will cancel each other at the other port, leading to high port isolation.

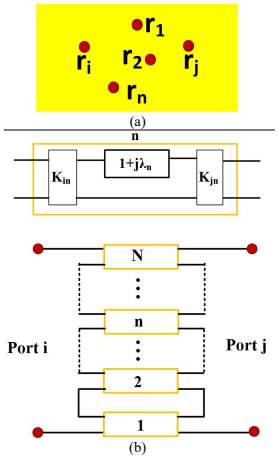

Figure 1: (a) Sketch of a single-patch antenna with several feeding ports. The red dots denote positions of ports. (b) Series-connected 2-port networks represent the topological relations of all the operating CM.

Based on Characteristic Mode (CM) analysis, this article extends the mode cancellation method limited by merely two modes and two ports toward more modes and more ports. As depicted in Fig. 1, every CM of the single patch antenna is modeled by a simple two-port network, where a modal impedance, $1 + j\lambda_n$, reflects its inherent property and two impedance inverters, $K_n(r_1)$ and $K_n(r_2)$, represent its input couplings with the two sources (current filaments). Then all the operating modes are involved by connecting all the two-port networks in series. It can be seen from this circuit model that port isolation and impedance matching are dependent on not only the eigenvalues of operating modes but also their input couplings. To get the desired eigenvalue, one can adjust the modal resonant frequency (ResF). To get the desired input coupling, one can place the source at the position where the modal electric field is equal to the desired value.

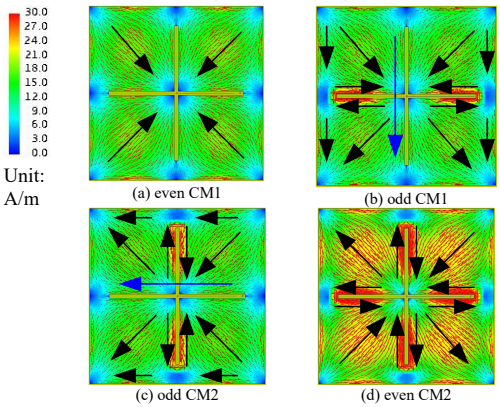

Figure 2: Current distributions of the four operating even/odd modes on the slots-loaded patch. The even and odd properties are determined according to distributions of modal electric fields underneath the patch diagonal.

To realize mode cancellation, both even and odd modes would be involved as operating modes. The CM-based cancellation method consists of three main steps. First, adjust all the desired even and odd modes to be equal in ResF through loading slots on the patch. Second, suppress unwanted modes without affecting desired ones by further loading shorting pins. Lastly, determine feeding positions carefully to obtain proper input coupling for each mode. Satisfactory port isolation and impedance matching could be achieved simultaneously and efficiently, getting rid of complicated decoupling structures or time-consuming optimization.

A 2-port and 4-port MIMO antennas are successfully designed for demonstration. As depicted in Fig. 2, two even modes and two odd modes are used as operating modes for designing the four-port antenna. Simulated results indicate that its adjacent- and diagonal-port isolations reach 32.0 dB and 19.5 dB, respectively. And they are larger than 28.5 dB and 19.4 dB within the 10-dB impedance bandwidth, respectively. The measurements of the fabricated antenna prototype validate the simulated results and the proposed CM-based cancellation method. Full details here.

News and Events

1. The next edition of the 1-week intensive course on CM under the umbrella of the famed European School of Antenna (ESoA) will be held in person in Hannover, Germany, with the confirmed dates of 5-9 June 2023. The event will be hosted by Dirk Manteuffel at the Leibniz University of Hannover and co-organized with UPV, CZT in Prague and Lund University.
2. Mahrukh Khan, Assistant Professor from The College of New Jersey has recently received a National Science Foundation (NSF) grant pertaining to her work on the CM.
3. Yikai Chen is spearheading a new special issue on CM in the Chinese Journal of Electronics, which is co-published by the Institution of Engineering and Technology (IET) Chinese Institute of Electronics. The journal publishes high-quality research papers on advances in electronics. The guest editorial team also includes Qi Wu, Chao-Fu Wang, and Simone Genovesi. The submission deadline is 31 July 2022. The Call for Paper is found here.

New Member Introduction

Bio: Dave J. Bekers (Senior Member, IEEE) received the M.Sc. degree in mathematics and the P.D.Eng. and Ph.D. degrees from the Technische Universiteit Eindhoven The Netherlands, in 1999, 2001, and 2004, respectively. Since November 2004, he has been with The Netherlands Organization (TNO), The Hague, where he first worked in (antenna) design, modeling, simulation, and optimization, and guided a few projects in the field of mm-wave and THz technology. In the past ten years, he worked mainly in the fields of radar signal processing and phased-array antennas, and side topics magnetic signatures and decision making.

View on CMA: The CMA formulations of Harrington and Mautz, and Garbacz and Turpin, have been definitely important for acquiring knowledge on various aspects of antenna design. Those formulations are however not the only ones. There is a wide variety of formulations as well as research on the phenomenology of the characteristic modes, eigencurrents, or whichever name one wants to use. That eigenmodes can be related to various wave phenomena on finite antenna arrays, including low-Q and high-Q resonances (super directivity), is already known for a few decades. Also, the modal decomposition of array eigenmodes into the modes of a single radiator is a powerful tool, both from the perspective of understanding wave phenomena and from a computational perspective (mutual coupling needs only to be taken into account for the dominant single-radiator modes, not for the higher-order ones). The decomposition also shows that arrays are entire objects rather than collections of separate elements, with the connected array being the physical realization of such an entire object.

Summary of CMA Research: *After my Ph.D. project and two conference papers, we wrote three journal papers (IEEE MTT, AP, and Radio Science) and a few more conference papers and abstracts between 2005 and 2009, in the fields of electromagnetics and reduced-order modeling. Then, in 2010, my former co-promotor Stef van Eijndhoven proved the countability of the spectrum of a microstrip dipole in our formulation. It took two years to get this proof published (in Proc. Edinburgh Math. Soc.). For about 5 years, I followed the CMA field hardly. Then, we revived our knowledge at TNO by literature research of the field, also for 3D antennas.*

Survey

We look forward to hearing your feedback and inputs on the CM Newsletter. Please take the time to complete the survey here: Take me to the survey.

Resources

Open Source Tools for CMA:

- FEKO-student edition
- CM MATLAB Software
- AToM Antenna Toolbox

Webinars:

- Our webinars on YouTube
- Our webinars on Bilibili
- Webinars from FEKO

Benchmarking Activity:

- Benchmarking in 2018

Available Courses:

- Courses offered by ESoA

Past Special Issues on CMA:

- July 2016 issue of IEEE Trans. Antennas Propag.
- April 2022 issue of IEEE Antennas Propag. Mag.

Past Issues of CM-SIG Newsletter:

- CM-SIG Newsletter

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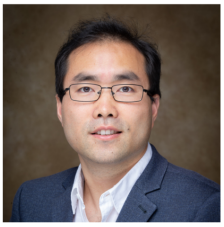

About CM-SIG: Characteristic Modes-Special Interest Group was initiated at the Special Session on CMs during the 2014, IEEE International Symposium on Antennas and Propagation in Memphis, TN, on 10 July 2014. CM-SIG was formed as a platform to promote technical activities in the field of CMs. For more information, please visit our website: http://www.characteristicmodes.org/.