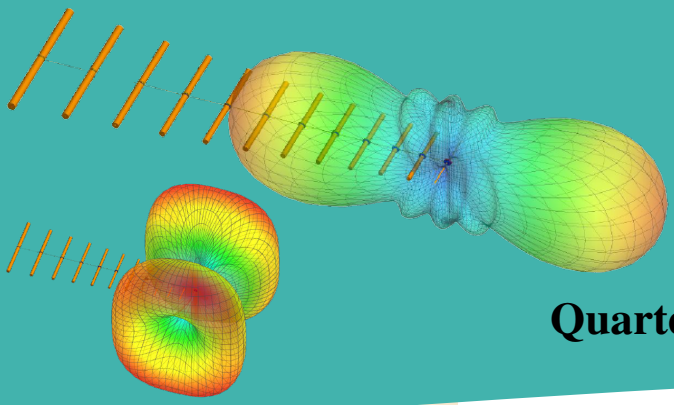

Characteristic Modes Special Interest Group

Quarterly Newsletter, Number 2, September 1, 2021

In This Issue:

Scholar Spotlight:

Fan Jiang received the bachelor's degree in electronic engineering from the University of Electronic Science and Technology of China, Chengdu, China, in 2014, and the master's degree in engineering from IMT Atlantique, Brest, France, in 2017. He is currently pursuing the Ph.D. degree with The Hong Kong University of Science and Technology (HKUST), Hong Kong, and the Southern University of Science and Technology (SUSTech), Shenzhen, China. His research interests include antenna design, pixel antenna, optimization techniques, and theory of characteristic mode.

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Featured Article

"Pixel Antenna Optimization Using *N*-port Characteristic Mode Analysis", *by Fan Jiang et al.*

Electromagnetic structures consisting of discrete sub-wavelength elements such as meta-atoms or pixels have many important applications. They include applications in technologies such as wireless communication where compact, reconfigurable and multimode antennas as well as reconfigurable intelligent surfaces or reconfigurable meta-surfaces are currently of significant interest.

This article explores the use of the theory of characteristic modes in the analysis of electromagnetic structures consisting of discrete sub-wavelengths elements and specifically pixel antennas. The key idea utilized in this article is the application of *N*-port characteristic mode analysis (CMA) to the analysis of the pixel structure to determine its fundamental resonance properties. *N*-port CMA has not been widely applied to electromagnetic design after it was first proposed in 1973 and this is in contrast to the resurgence in conventional or continuous CMA over the previous decade. An advantage of the *N*-port CMA approach is that it can be applied computationally efficiently to pixel antenna design so that only one full electromagnetic simulation is required in the entire optimization design process. This allows the process of antenna resonance optimization to be separated from impedance matching while remaining computationally efficient.

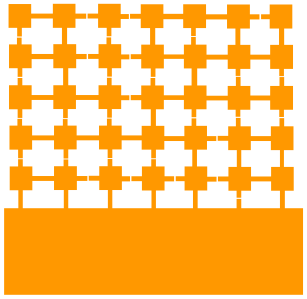

Figure 1: Optimized geometry of 5x7 pixel antenna using the proposed approach.

Pixel antennas consist of sub-wavelength elements denoted as pixels and the connections between pixels are leveraged to create desirable properties from the overall pixel structure. One reason pixel antennas have attracted attention is because of their potential for high antenna reconfigurability and straightforward optimization. There is a large body of research on the field of pixel antenna design and more generally they can be considered to be part of the subset of structures constructed from meta-atoms. A key challenge in the design of pixel antennas is finding the optimized set of pixel connections.

In this article the key to the application of *N*-port CMA to pixel antenna optimization was to first obtain the impedance matrix for all the internal ports (the ports formed by the potential connections between pixels) in the pixel antenna. *N*-port CMA could then be directly applied to this matrix to obtain the resonance properties (through its eigenvalues and eigencurrents) of any interconnected pixel structure. In particular modal significance was utilized in an objective function that was then optimized using the Genetic Algorithm. Furthermore, by leveraging previous work on pixel antennas the currents at the internal ports could also be used to efficiently evaluate radiation patterns for inclusion in the objective function. As a

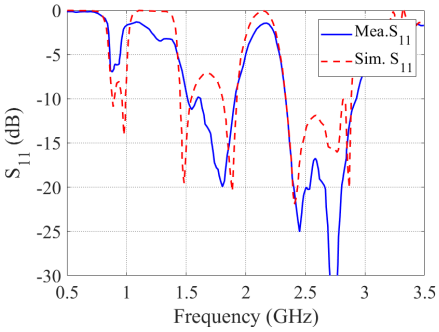

Figure 2: Measured and simulated S_{11} of the optimized tri-band 5×7 pixel antenna.

final step, separate from *N*-port CMA optimization, impedance matching is performed to extract the full bandwidth of the resonance structure found from the optimization. Simulation and experimental results are provided including a tri-band antenna design for GSM900 (880-960 MHz), DCS1800 (1710-1900 MHz) and IMT-E2600 (2500-2690 MHz) and a dual-band antenna design for GSM900 (890-960 MHz) and DCS + PCS + UMTS bands (1710-2170 MHz). The optimized geometry of a tri-band 5x7 pixel antenna using the proposed approach is as shown in Fig. 1. The measured and simulated S-parameters are shown in Fig. 2. More details are provided in our paper: F. Jiang, C. Chiu, S. Shen, Q. S. Cheng and R. Murch, "Pixel Antenna Optimization Using *N*-Port Characteristic Mode Analysis," in *IEEE Transactions on Antennas and Propagation*, vol. 68, no. 5, pp. 3336-3347, May 2020, doi: 10.1109/TAP.2019.2963588.

News and Events

1. Our proposal for a Characteristic Modes Convened Session at 2022 European Conference on Antennas and Propagation (EuCAP 2022) has been accepted! The title of the session is "Enhanced Capabilities of Characteristic Mode Analysis for Novel Applications" and the conveners are John Borchardt (Sandia National Laboratories, USA) and Chao-Fu Wang (National University of Singapore, Singapore). EuCAP 2022 will be held in Madrid Spain between 27 Mar – 1 Apr 2022.
2. The SIG is working on a special issue on characteristic modes for the IEEE Antennas and Propagation Magazine, which consists of a number of invited papers covering the main topics of characteristic mode analysis (CMA). These survey/review papers are led by senior members of our SIG, and efforts have been made to involve more coauthors with the relevant expertise. The special issue is planned for publication during 2022. This initiative is prompted by the large number of recent papers in CMA (e.g., 94 in IEEE Transactions on Antennas and Propagation between 2016-2020) and the desire to provide some directions to newcomers on this topic.

Resources

Open Source Tools for CMA:

- FEKO-student edition
- CM Matlab Software
- Antenna Toolbox for Matlab

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:

- Special issue on TCM in the July 2016 issue of IEEE transactions on Antennas and Propagation.

Past Issues of CM-SIG Newsletter:

- CM-SIG Newsletter

New Member Introduction

Bio: ZHAN ZHANG (Member, IEEE) received the B.S. degree in electronics and communications engineering from Jilin University, China, in 2002, and the Ph.D. degree in electrical engineering from Nanyang Technological University, Singapore, in 2010. She joined the Faculty of School of Electronics and Information Engineering, Beijing Jiaotong University, Beijing, China, in 2010, where she is currently an Associate Professor. Her current research interests include reconfigurable antennas and characteristic mode analysis.

View on CMA: *"CMA leads a path to the core of the problem. It can decompose the complex phenomena down into the most basic forms. It is far from enough to analyze the individual characteristics of each mode. It is also necessary to analyze the physical connection between them." . . . "We need to go deep into the physics of each mode and establish a mechanism to control them. In short, CMA still has a huge potential to be explored." . . .*

Contribution to CMA: *"We made some contributions on the reconfigurable pattern synthesis which avoids the dependence on the optimization process to explore the desired combination of modes. The inherent pattern and phase properties within different modes are leveraged to form such a combination, which offers a more physical understanding on the radiation mechanism. Based on that, we have proposed the design of a vertically polarized endfire antenna, an azimuth-pattern reconfigurable planar antenna, and a compact frequency scanning planar array."*

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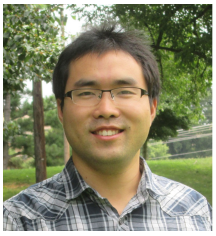

About CM-SIG: Characteristic Modes-Special Interest Group was initiated at the Special Session on CMs during the 2014, IEEE International Symposium on Antennas and Propagation in Memphis, TN, on 10 July 2014. CM-SIG was formed as a platform to promote technical activities in the field of CMs. For more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