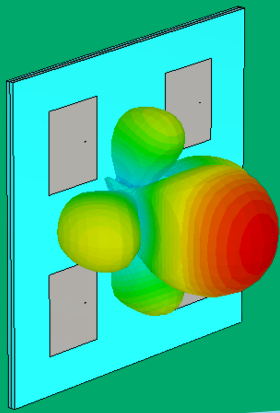

Characteristic Modes Special Interest Group

Quarterly Newsletter, Number 3, December 1, 2021

In This Issue:

Scholar Spotlight:

Teng Li received the B.S. degree and Ph.D degree from Xiamen University and Southeast University, China, in 2009 and 2015, respectively. From 2015 to 2019, he was a Post-Doctoral Fellow and a Research Fellow with Southeast University and National University of Singapore, respectively. From 2019 to 2021, he was an Alexander von Humboldt Scholar with the Karlsruhe Institute of Technology, Karlsruhe, Germany. Since 2019, he has been an Associate Professor with the State Key Laboratory of Millimeter Waves, Southeast University. His current research interests include metamaterials, metasurfaces, characteristic mode analysis, theory of antennas, pattern synthesis, AiP and AoC.

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Featured Article

"Characteristic Mode Inspired Dual-Polarized Double-Layer Metasurface Lens", *by Teng Li et al.*

Metasurface (MTS) lens is a kind of electromagnetic (EM) lens with a planar periodical-like structure. It can be implemented by PCB process featuring compact size, low profile, low weight, and low cost beyond the traditional EM lens. The surface processes a phase shift or time delay to the passing EM waves for wave-front manipulation. The phase shift range and the corresponding transmission amplitude of the MTS unit cell determine the efficiency of beam transformation. Multi-layer frequency selective surface (FSS) typed unit cell is generally employed for MTS lens design and at least three metal layers are required for 3dB full phase shift range (360°). But a single substrate layer (double metal layer) MTS lens is always desired for low cost and conformability.

The theory of characteristic mode has been successfully applied to analyze radiating problems, e.g. metasurface antenna design, and it is also powerful for scattering analysis. Inspired by this, this article explores using characteristic mode analysis (CMA) for a double layer MTS lens unit cell aiming to break through the phase shift limitation.

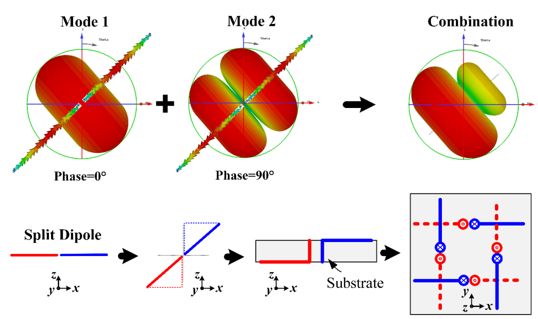

Figure 1: Characteristic mode inspired mode combination and evolution route of MTS lens unit cell.

Fig. 1 shows the modes combination and evolution route of the MTS lens unit cell. The idea starts from a split dipole where two significant modes are observed over the band of interest, named modes 1 and 2 with in-phase and anti-phase currents, respectively. If the dipole is positioned horizontally, only mode 1 is effectively excited by the normal incident plane wave and it appears as total reflection under periodic boundary. Mode 2 is quite promising for reflection elimination. It is found that the combined modal radiation pattern can be directional if these two modes are uniformly excited with a 90° phase difference and the dipole is rotated at a certain angle. Based on this finding, we developed the reflectionless split dipole-based unit cell by optimizing the rotation angle and dimensions. Because of these two modes, the transmission phase shift range is extremely extended beyond the double-layer FSS-based unit cell.

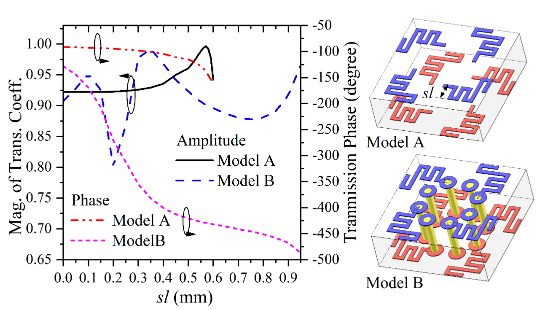

Figure 2: Configuration of proposed MTS lens unit cells and transmission response.

The planar implementation of the unit cell is depicted in Fig. 1 where the slant dipole arm is decomposed into horizontal and vertical stubs. In the PCB process, the vertical parts can be realized with plated through holes. Benefits from the simple structure, a dual-polarized MTS lens unit cell is feasible by rotating duplication of the dipole. Fig. 2 shows the final models and the corresponding transmission response. Two modes with and without vias are proposed where the phase range is further extended to 396° with transmission amplitude better than 0.8.

So far, the characteristic mode inspired MTS unit cell is suitable for high-efficiency lens design and the realized aperture efficiency is 45% with F/D = 0.86. For details, please refer to: T. Li, J. Sun, H. Meng, Y. Shen, S. Hu, W. Dou, Z. N. Chen and T. Zwick "Characteristic Mode Inspired Dual-Polarized Double-Layer Metasurface Lens," *IEEE Transactions on Antennas and Propagation*, vol. 69, no. 6, pp. 3144–3154, Jun. 2021, doi: 10.1109/TAP.2020.3046423.

News and Events

1. In the recent two-part paper (see Part I and Part II in arXiv), the authors (Gustafsson et al.) studied the scattering formulation of characteristic modes. This theory was originally proposed by Garbacz, and precedes the impedance-based approach of Harrington and Mautz. The impedance formulation, in conjunction with the method of moments (MoM), is the most common implementation of characteristic modes today, with little contemporary research involving the original scattering formulation. However, the scattering-based definition offers many advantages. For example, the scattering-based characteristic mode eigenvalue problem is uniquely defined for all MoM codes (EFIE, CFIE, PMCHWT,...) and it allows for the study of characteristic modes with arbitrary non-MoM EM solvers (e.g., FEM). The scattering approach also lends itself to powerful and fast eigenmode tracking methods.
2. Dr. Kapil Saraswat from Central University of Rajasthan is releasing an updated GUI version of his CM analysis program to the community working on CM analysis. The program can be downloaded from Sourceforge. It is a small package that can be used within the Windows operating system. The program has two modes, a GUI mode for the students and a simple to use and command-line mode for the advanced users. He is further improving the program by incorporating full-wave MoM solver, in-built meshing etc. A how-to-use video is also uploaded on his YouTube channel.

New Member Introduction

Bio: Ping Jack Soh (Member, IEEE) received his PhD degree from KU Leuven, Belgium. He is currently an Associate Professor in the Centre for Wireless Communications (CWC), University of Oulu, Finland. His research interests include antenna technologies focused on applications in wearable / body area communications; compact satellites; metasurfaces; 5G/6G communications; EM safety and absorption; and wireless techniques for healthcare. He is also an Associate Editor of the International Journal of Numerical Modelling: Electronic Networks, Devices and Fields (Wiley), and the recipient of the URSI Young Scientist Award in 2015.

View on CMA: *"CMA is a fascinating topic as it provides physical insights into radiating structures. Coming from an antenna design background, such technique enables a better understanding, and consequently a more efficient optimization in their design process. This is much needed in designing today's antennas which requirements are becoming increasingly complex and challenging. Besides the more direct goal of designing and optimizing in a much shorter time, my long-term vision is to be able to devise mechanisms to reconfigure wearable antennas which are affected by movements caused by the human body or mounting on different platforms. I believe CMA can be a useful tool to achieve this goal."*

Summary of CMA Research: *"I have been working with several postgraduate students in the past several years in applying CMA in the antenna design process for wearable and flexible antennas. The wearable antennas designed using this technique are made of flexible materials such as textiles, polymers, and liquid metals. We have been presenting results from our work in several journals, and annually in the European Conference on Antennas and Propagation (EuCAP), several of them in support of special convened sessions on this topic since 2018. "*

Resources

Open Source Tools for CMA:

- FEKO-student edition
- CM MATLAB Software
- Antenna Toolbox for MATLAB (AToM)

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

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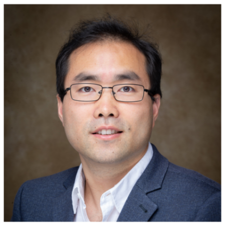

About CM-SIG: Characteristic Modes-Special Interest Group was initiated at the Special Session on CMs during the 2014, IEEE International Symposium on Antennas and Propagation in Memphis, TN, on 10 July 2014. CM-SIG was formed as a platform to promote technical activities in the field of CMs. For more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