Characteristic Modes for Modulated Metasurface Antennas

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Modulated metasurface (MTS) antennas mostly consist of circular apertures with a diameter of several free-space wavelengths (λ_0). They are excited by means of a cylindrical surface-wave (SW) launched by a point-source feeder. Typically, MTS antennas comprise several tens of thousands of subwavelength patches printed on a grounded slab. The dimension of these patches is normally between $\lambda_0/6$ and $\lambda_0/10$, and they can present even smaller features, such as slots. Therefore, the number of degrees of freedom required in a conventional method of moments (MoM) framework is extremely large, and renders the analysis of MTS structures computationally intensive. In addition, the need of a very fine mesh worsens the condition number of the MoM impedance matrix, and one has to combine iterative solvers with efficient preconditioners to reach convergence in a reasonable number of iterations. These are the reasons why, even when fast methods are applied it is difficult to reduce the computation time in such a way that more than a few parameters of the modulation are optimized.

On the other hand, the small dimension of the patches allows for a homogenization of the MTS, thus legitimating the use of a sheet transition impedance boundary condition (IBC) to represent the layer of patches. In addition, the effect of the grounded slab can be efficiently accounted for using appropriate Green's functions. In such context, two different sets of entire-domain basis functions have been recently proposed for a compact representation of the currents on circular MTS apertures. First, Gaussian Rings Basis Functions (GRBFs) were described in (D. González-Ovejero and S. Maci, *IEEE Trans. Antennas Propag.*, 2015, 63.9: 3982-3993). GRBF's closed-form spectra allows one to carry out a closed-form evaluation of the MoM impedance matrix using the spectral-domain approach and an asymptotic expansion, but they are just quasi-orthogonal. Conversely, the Fourier-Bessel Basis Functions (FBBF) described in (M. Bodehou et al., *NEMO* 2017, Seville, pp. 158-160) are strictly orthogonal on the circular aperture and div-conforming, but they do not allow a closed-form MoM matrix evaluation. More importantly, both families of basis functions represent the global evolution of the surface current density in an effective manner, which results in a significant reduction in the number of unknowns, if compared with sub-entire domain basis functions, like Rao-Wilton-Glisson functions defined on triangular domains.

Nowadays, the trend is to move up in frequency to satisfy the bandwidths required in modern communications systems, and to allocate in portable devices electrically large apertures with high gains and/or multibeam capabilities. Hence, despite the great performance shown by GRBFs and FBBFs, there is still an interest in further reducing the number of degrees of freedom in the MoM analysis of MTS antennas. In this regard, the adiabatic Floquet-Wave expansion described in (Minatti et al., *IEEE Trans. Antennas Propag.*, 2016, 64.9: 3896 - 3906) provides an accurate description of the aperture fields with a limited number of modes. Indeed, such Floquet modes (see an example of -1 indexed mode in Fig. 1) can be regarded as characteristic basis for MTS antennas. In this work, we explore the potential of Flat-Optics derived modes for carrying out an accurate analysis of MTS, further reducing the number of basis functions required in GRBFs and FBBFs analysis.

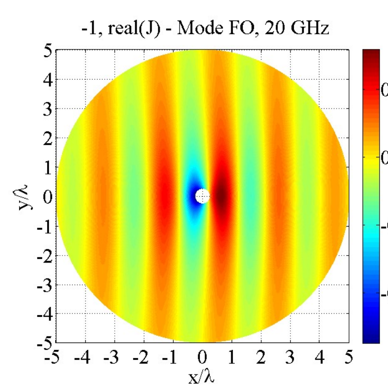

Fig. 1. Flat optics -1 indexed mode for a circular MTS aperture with $5\lambda_0$ radius.