Full-wave synthesis procedure for the design of innovative metasurface devices

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In the last few years, artificial surfaces, or metasurfaces (MTSs), have proved to be a versatile platform for the design of a number of electromagnetic devices, including planar lenses, leaky wave antennas and metascreens. In particular, modulated MTS antennas have emerged as a promising class of radiating structures characterized by low profile, low weight, small losses, simple feeding structure and high flexibility in pattern shape and polarization (G. Minatti *et al*., "Modulated metasurface antennas for space: Synthesis, analysis and realizations," *IEEE Trans. Antennas Propag*., vol. 63, no. 4, pp. 1288–1300, Apr. 2015).

The design of MTS devices is conveniently based on an equivalent impedance model. This model, which results from the homogenization of the artificial surface, allows one to significantly simplify the structure description, while retaining a high accuracy. Starting from this assumption, a rigorous procedure for the design of modulated MTS antennas was proposed in G. Minatti *et al.,* "Synthesis of modulated-metasurface antennas with amplitude, phase, and polarization control," *IEEE Transactions on Antennas and Propagation*, 64(9), pp. 3907-3919, 2016. This procedure applies to MTSs realized by using subwavelength patches of different size/dimensions printed on a grounded slab, illuminated by a transverse magnetic point source. It is based on a field representation in terms of adiabatic modes, relying on a local Floquet mode expansion, and it allows for the control of the amplitude, phase and polarization of the radiating aperture field.

More recently, an alternative approach to the design of MTS antennas, directly based on the electric field integral equation (EFIE), was proposed (M. Bodehou *et al.* "A Quasi-Direct Method for the Surface Impedance Design of Modulated Metasurface Antennas," in *IEEE Transactions on Antennas and Propagation*, vol. 67, no. 1, pp. 24-36, Jan. 2019). In this approach, the desired surface currents are first decomposed into a set of orthogonal entire-domain basis functions and a similar representation is considered for the MTS sheet impedance to be designed. The coefficients of the latter representation are then obtained by solving an inverse problem derived from the EFIE. A key point for the design procedure is the knowledge of the spectrum of the desired currents, including its invisible part. The adiabatic model can provide useful information on the currents' invisible spectrum. On the other hand, the approach based on the EFIE is more general than the one based on adiabatic modes, since it does not rely on the hypothesis of a local sinusoidal modulation. For this reason, it may lead to a larger class of metasurface antenna solutions.

This work examines the differences and similarities between the two design approaches, investigates the possibility to use the adiabatic mode model to improve the a priori knowledge of the invisible part of the spectrum and explores the applicability of the EFIE-based procedure for the design of innovative electromagnetic devices. Different examples and numerical results will be shown at the conference.