Adiabatic Mode Formulation for Conical Metahorn

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Corrugated horn antennas and dielectric loaded horns are the most currently used feeders for reflector antennas. These types of antennas guarantee symmetric radiation properties and low cross polarization for an efficient illumination of the reflector. It was demonstrated that appropriate anisotropic Impedance Boundary Conditions (IBCs) at the horn walls are required in order to achieve low cross polarization patterns with axial symmetry (Minnett, Thomas, IEEE TAP, vol. AP-14, 1966). “Artificial” horn walls have therefore to be engineered to realize the required surface impedance characteristics; corrugations or dielectric loads are the known and largely used implementation of these synthetic walls.
The advent of Metasurfaces (MTSs) and their increasing comprehension has inspired the possibility of realizing the walls for symmetric pattern horn antennas with these artificial composite structures. The interior walls of metallic horn antennas can be coated with a dielectric material with a sub-wavelength printed metallic texture on top. The MTS walls can be modelled in terms of an equivalent impenetrable tensor impedance and engineered to obtain exactly the required IBCs. Moreover, the resulting structures, that we can denote as “MetaHorns”, are compact and easy to manufacture, coming up as an attractive alternative to expensive and bulky corrugated horn antennas or heavy and lossy dielectric loaded horns.

In recent studies, conical horns with MTSs as walls have been demonstrated to provide satisfactory radiation characteristics (Wu, Scarborough, Werner, Lier, Shaw, IEEE TAP, vol. 61, Issue 10, 2013).
From a computational point of view, a quasi-analytical modal analysis has the advantage of being extremely cheap, with respect to full-wave analysis of IBCs, that can be very expensive.
The objective of this work is to present a modal field-based approach for the analysis of a low cross polarization conical MetaHorn, whose sidewalls are described through equivalent surface impedances. The proposed method overcomes the intrinsic non-separability problem in conical geometries with arbitrary IBCs, using an adiabatic local approximation for the description of the modal field.
The quasi-analytical method has the advantage to give a physical insight on MetaHorn behavior; it can in fact provide an initial hint both for the appropriate surface impedance profile needed to achieve low cross polarization, and for the synthesis of the MTS unit cells. The developed approach is therefore an efficient starting point for design of low cross polarized MetaHorns with symmetric radiation pattern, and can be used in support of optimization algorithms and full wave simulations for refined antenna synthesis.