# Rigorous Analysis of Sinusoidally-modulated Anisotropic Reactance Surfaces: Theory and Application to the Design of Modulated Metasurface Antennas

Francesco Caminita[1,2], Enrica Martini [1,2], and Stefano Maci[1]
(1) Dept. of Information Engineering and Mathematics
University of Siena, Via Roma, 56, 53100 Siena, Italy
(2) Wave Up Srl, Via Edimburgo, 6, 50126 Florence, Italy

Modulated metasurfaces (MTSs) have been recently proposed as a promising means to realize planar antennas characterized by low profile, low weight, simple feeding structure, reduced complexity and cost of manufacturing. In these antennas, a surface-wave (SW) excited by a primary source interacts with the modulated MTS and is gradually transformed into a leaky-wave (LW). This phenomenon can be accurately described by modeling the MTS through a modulated equivalent surface impedance. For an isotropic sinusoidally modulated impenetrable impedance, a rigorous analysis can be performed by applying the method described in A. Oliner and A. Hessel, *Antennas Propag., IRE Trans*., 7(5), 201-208, 1959, which provides complete information on the supported waves (both SW and LW). However, *anisotropic* modulated surface reactances are required in order to control polarization in modulated MTS antennas. For this kind of surfaces, no rigorous studies are available in the literature.

In this contribution, the general problem of a sinusoidally modulated anisotropic impedance is studied, and a rigorous solution is derived for the phase and attenuation constant as well as the polarization of the supported modes. The solution is obtained by first expanding the field in terms of TM and TE Floquet waves (FW); due to the nature of the impedance modulation, the $n$-indexed FWs couple only to modes with index $n$-1, $n$ or $n$+1. As a result, the problem reduces to the solution of an infinite set of linear equations in which each equation involves only five modes. Explicit expressions for the FW amplitudes and the determinantal equation for the propagation wavenumber along the surface are then expressed in a continued fraction form, which is rapidly convergent for all values of modulation. The analysis is performed both for an impenetrable reactance surface and for a penetrable reactance surface placed inside a generic dielectric stratification. This latter case represents an accurate model for MTSs consisting of a dense pattern of patches printed on a grounded slab.

The developed approach constitutes a valuable design tool, which makes it possible to exploit MTS anisotropy to control the polarization of the radiated field in modulated MTS antennas. In fact, the canonical problem of the 2D modulated reactance surface can be used to describe the local interaction between the exciting SW and the MTS. Examples of circularly and linearly polarized modulated MTS antennas, designed according to this principle and exhibiting high polarization purity, will be presented at the conference.