Canonical Solution for Surface Wave Coupling to Metasurfaces

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In this presentation, we will discuss surface-to-propagation waves conversion, one of the classical problems in antenna theory. Conventionally, such conversions are performed by leaky-wave antennas, however, surface waves along periodically modulated open or partially open waveguides cannot be entirely converted into propagating waves along a particularized direction. Even in case of perfect matching of the antenna feed, parasitic radiation into unwanted directions always takes place. It is of fundamental and practical importance to find and explore possibilities for perfect and full conversion of a surface-bound mode to propagating plane waves and vice versa. Recently, new means for enhancement of conversion efficiency have been proposed for the case of *one* TM-polarized surface wave and TE-polarized homogeneous plane wave, where polarization transformation is applied to prevent field and power interference of propagating and surface waves with each other (S.N. Tcvetkova, D.-H. Kwon, A. Díaz-Rubio, S.A. Tretyakov, arXiv:1706.07248v1). However, even in this case the most desirable lossless and reciprocal solution is found by using an approximation, which imposes some important limitations on the size of the structure, which should be electrically very long. Here, we explore canonical exact solutions for full conversion between *one* TM-polarized surface wave and *one* TE-polarized *inhomogeneous* plane wave. We show that theoretically ideal surface-wave antenna performance is possible within this new scenario.

As a mode-converting device we consider an impenetrable periodic metasurface, which can support only two Floquet modes, 0 and -1, which correspond to a surface wave and an inhomogeneous plane wave (namely, a leaky wave), respectively. The surface wave in this case is a plane wave attenuating along the normal to the surface with the propagation constant along the surface larger than the free-space wavenumber. Both surface and propagating waves have the same attenuation constant along the surface to ensure that all the power from the surface wave is converted to the leaky one (and vice versa in the reception regime). Solving the corresponding boundary problem we find the surface impedance profile of a metasurface which performs perfect conversion from the surface wave into a propagating inhomogeneous plane wave and vice versa. The results show that this surface is lossless and reciprocal. Applying all the conditions in the numerical full wave analysis, a stable to the mesh density result of 99,7% conversion efficiency over twenty periods of the metasurface was obtained.

This solution can be considered as a canonical one. It is important to note that the exact solution of the boundary value problem for an impedance surface does not include any higher-order Floquet modes of the asymptotic expansion. It means that there is no energy stored by the higher-order modes: all the power carried by the surface wave is used for the leaky wave creation. Therefore, we expect that the found solution may lead to the minimum possible Q-factor and maximum group velocity for any leaky-wave antenna.