Properties of 2D Periodic Leaky Wave Antennas at Microwave and Optical Frequencies

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Two-dimensional (2D) periodic leaky-wave antennas can be formed by a periodic arrangement of metal patches on a grounded dielectric layer, excited by a simple source such as a horizontal magnetic dipole in the middle of the structure. The dipole source launches a radially-propagating (cylindrical) TM_0 surface wave, guided by the grounded substrate. This surface wave becomes a leaky wave due to the periodic patches, which perturb the surface wave and enable radiation from a higher-order space harmonic (Floquet wave). Such structures, although extremely simple in construction, at microwave frequencies can produce very narrow beams at broadside. The beamforming is by means of a cylindrical leaky wave that propagates outward from the source. The leaky wave propagates anisotropically, having a complex wavenumber that varies with the angle of propagation, since the periodic metal patch structure has periodicity on a rectangular lattice. Although a narrow pencil beam at broadside can be created, the beam is asymmetric, being narrower in the E plane than the H plane. One of the goals of this investigation is to characterize the wave propagation and radiation characteristics of these types of 2D periodic leaky-wave antennas, and to show how the beam properties can be optimized.

The phenomenon of directive beaming at optical frequencies using a periodically corrugated plasmonic metal (e.g., silver) film is an interesting phenomenon that can be explained and studied in terms of leaky plasmon waves. The structure usually consists of a periodic set of grooves surrounding a subwavelength aperture in a thin silver film. At optical frequencies the silver has a negative permittivity due to plasmonic behavior, allowing for the guidance of a plasmon wave (similar to the TM_0 surface wave that propagates on a grounded substrate layer at microwave frequencies). The grooves perturb the cylindrically propagating plasmon wave that is launched by the subwavelength aperture, which can be approximately modeled as a magnetic dipole. Therefore, the structure has a physical principle of operation similar to the periodic metal-patch LWA at microwave frequencies. The theory developed for the microwave LWA discussed above will be applied to the plasmonic directive-beaming structure to illustrate its fundamental principle of operation, and to show how it can be optimized.

The analysis of these structures will be done using spectral-domain methods as well as with commercial full-wave simulators. Results will be presented to explain the basic wave-propagation and radiation characteristics, and to illustrate the optimization of these structures.