Leaky-Wave Antennas Using a Coated Cylindrical Structure

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In this paper, the radiation characteristics of planar and cylindrical dielectric structures excited by a line source are investigated and compared. The planar structure consists of a two-layer substrate/superstrate stack over a ground plane. The substrate is an air layer with thickness b and the superstrate layer is a dielectric with relative permittivity ϵ_r and thickness t. The cylindrical structure consists of a perfectly conducting cylinder surrounded by an air layer of thickness b that is in turn surrounded by a dielectric shell of relative permittivity ϵ_r and thickness t. It has been established previously that the planar configuration, when optimized properly, can achieve highly directive beams due to the excitation of leaky waves (i.e., it becomes a leaky-wave antenna). Our goal is to understand the radiation characteristics of the corresponding cylindrical structure and make a comparison between these two structures, in terms of the radiation characteristics and the waves that are guided by the two structures.

In the planar case the field due to the line source consists of a discrete spectrum of surface waves together with a continuous spectrum. The continuous spectrum in turn contains a discrete spectrum of leaky waves. The field is expressed as a line integral in the complex transverse wavenumber (k_t) plane. The integrand has poles and branch-point singularities on a two-sheeted Riemann surface. The poles are associated with the leaky (improper) waves and the surface (proper) waves. Integration around the branch cut forms the continuous spectrum.

In the case of the cylinder, we have a continuous spectrum in the lit region, plus azimuthally propagating creeping waves. The cylinder Green's function can also be expressed as a line integral in the complex k_t plane. In this case the integrand consists of combinations of Hankel functions of complex order $\nu = k_t(a+b+t)$ where a is the cylinder radius. There are no branch points in the complex ν plane.

The behavior of creeping-wave, leaky-wave, and surface-wave modes for a cylinder coated with a single layer has been recently investigated (Paknys and Jackson, IEEE Trans. AP, Mar. 2005). The observed similarities between leaky waves in the planar case and creeping waves in the cylindrical case suggests interesting possibilities for new designs of conformal antennas that exploit the leaky-wave behavior of azimuthally guided waves, and this will be explored.

The far-field radiation pattern for the line source inside of the two-layer cylinder can be computed from an eigenfunction series. The field on the outer surface of the dielectric shell can also be computed from the cylinder Green's function, so that the role of leaky waves in determining the far-field pattern may be explored. The radiation pattern from the pole waves can be determined, and this will aid the interpretation of the numerical results.