EVANESCENT WAVES*†

by

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Abstract

Some recent developments in the treatment of evanescent waves are reviewed. Such new methods as evanescent wave tracking, complex ray, and complex-source-point techniques are discussed and illustrated by examples, which include Gaussian beams, shadow formation due to evanescent fields, propagation on curved dielectric layers, and modal fields in graded-index films and fibers.

Summary

In the theory of wave propagation, evanescent fields have played a secondary role since they are usually overshadowed by the dominant effects of non-evanes-fields. Although evanescent waves must be included in complete representations of arbitrary fields, they contribute generally in the near zone of sources (actual, or induced as on an obstacle or scatterer), but are negligible in the far zone. An exception occurs when the evanescent fields represent the entire field contribution; although exponentially small, they must then be explicitly accounted for in the field description. Representative of this circumstance, and most familiar to specialists in guided wave theory, are the evanescent fields exterior to slab or rod dielectric surface wave structures, or the fields excited on the optically thinner side of an interface between two media by a totally reflected field incident from the optically denser side. Evanescent fields also occur on the "dark" side of caustics formed by a guided mode in an inhomogeneous duct or by a focused incident field in a homogeneous or an inhomogeneous medium.

With the development of laser sources and their application to integrated and fiber optics, and also for applications in microwave acoustics, Gaussian beams have assumed an important role as collimated fields that are coupled into transmission systems comprised of bulk media and guiding regions. Gaussian beams have usually been treated by plane wave spectral analysis, which obscures the fact that they are actually evanescent fields. Stimulated primarily by the importance of Gaussian beam propagation, guiding, and diffraction, evanescent waves have recently been studied from a more general viewpoint than heretofore. This general study has, in turn, clarified certain properties even of the more conventional evanescent wave fields.

The conventional view of evanescent waves is associated with modal fields that belong either to a discrete or continuous spectrum. For dielectric guiding structures, the discrete modes decay in a direction transverse to a preferred guiding axis; the guide axis is specified to follow a coordinate parallel to the boundaries. In plane wave spectral or other eigenfunction representations of general fields, evanescent (below cutoff) modes decay along a selected guiding direction. In either event, the modal character ascribes to these fields global properties that pertain to the entire waveguide cross section or to the entire axial domain of evanescent decay. Consequently, the treatment of evanescent fields has conventionally taken place within the framework of guided mode theory.

The modal view of evanescent fields is unnecessarily restrictive. For non-evanescent fields it has long been recognized that modal representations are not the most useful formulations of certain field problems. Thus, in the range of short wavelengths in a free space or large-waveguide environment, ray-optical representations describe the field more compactly and with deeper physical content[1,2]. Such ray-optical formulations are based on the local character of short-wavelength propagation and permit the tracking of fields in terms of local plane waves along ray trajectories that may intercept boundaries, scatterers, and other perturbations in the local propagation environment. Such local tracking is not possible for modal fields because of their inherent global character.

The established versatility of ray (i.e., local wave tracking) methods for non-evanescent fields has motivated the study of similar methods for evanescent fields. These developments, which include evanescent wave tracking, complex ray, and complex source techniques are reviewed in the present paper and applied to Gaussian beam propagation and diffraction, guided mode propagation in dielectric layers, and mode propagation in graded-index films and fibers.

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References

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