Analytical Study of Non-Reciprocal and Unidirectional Leaky and Surface Waves on a Grounded Magnetized Plasma Slab

Xenofon M. Mitsalas[(1)], Theodore Kaifas[(2)], Elias Vafiadis[(2)] , George A. Kyriacou [(1)]
(1) Democritus University of Thrace, Department of Electrical and Computer Engineering, Microwaves Lab, Xanthi, Greece
(2) Aristotle University of Thessaloniki, Department of Physics, Thessaloniki, Greece

Leaky wave along with surface wave eigenmodes excited on a grounded magnetized plasma are considered. The structure of interest refers to magnetized semiconductors at cryogenic temperatures. A homogeneous magnetization is assumed with the DC-biasing magnetic field parallel to the substrate, but normal to the direction of propagation. While the characteristics of surface waves are extensively studied in the past and especially by Seshadri et al (S.R. Seshadri and W.F. Pickard "Surface Waves on an Anisotropic Plasma Sheath", IEEE Trans. on Microwave Theory and Techniques, pp. 529-541, 1964), the possibility of leaky waves is not well examined and constitutes the original contribution of the present effort. The characteristic equation is first obtained analytically and in turn investigated numerically. The important non-reciprocal and unidirectional propagation phenomena due to the non-even expression of the characteristic equation are verified regarding the surface waves while roots are then sought herein in the leaky modes regime. The conditions enabling backward waves and particularly their unidirectional nature are indeed challenging since they enable numerous novel applications, thus particular attention is devoted to them.

The propagation of electromagnetic waves within and around a dielectric slab including the radiation characteristics when leaky waves are excited has been extensively studied as it is involved in important practical applications. The majority of these investigations pertain to the case of a slab of isotropic dielectric. A complete survey of the relevant literature may be found in the work of Oliner and Tamir (A. Oliner and T. Tamir, "Backward waves on isotropic slab," J. Appl. Phys., vol. 33, pp.231-233, January, 1962) who have given a comprehensive treatment of the electromagnetic field of a source-excited, isotropic plasma slab. When ferrite or plasma materials are subject to constant magnetic field they exhibit anisotropic permeability $\bar{\bar{\mu}}_r$ and permittivity $\bar{\bar{\epsilon}}_r$ respectively. These tensors depend on both the biasing magnetic field and the operating frequency. This dependence enables their dynamic control through the dc current of an electromagnet which generates the biasing constant magnetic field H_{DC}. These features offered by ferrites are extensively used in microwave waveguides, stripline and microstrip devices.

Our previous effort directed toward the solution of a canonical problem of a grounded slab filled with anisotropic plasma. A lot of interesting phenomena regarding the excitation of surface and leaky waves in the grounded plasma region and the radiating space wave are involved in the scattered field expressions. Besides this, higher order modes of this grounded structure are expected to become leaky waves. These waves offer non-reciprocal features in their radiation mechanisms. All these type of modes are indeed involved in the mathematical formulation and are required for the evaluation of the field and especially the radiation of the structure. The study of all of those modes and particularly leaky waves constitutes the original contribution of the present effort.