Nonreciprocal devices based on magnetoplasmons in semiconductor materials

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The constant improvement in the quality of semiconductor materials (substrates and thin films) has opened the door for the development of devices operating at microwave, millimeter and sub-millimeter wavelengths. For many years, nonreciprocal devices such as phase shifters, isolators and circulators have been built with ferrites. Such designs can provide broadband performance up to around 40 GHz. Above this frequency, ferrite devices are limited to narrow bandwidth operation because the maximum saturation magnetization of ferrites available is about 0.5T. Fortunately, high mobility semiconductor materials are now available and become nonreciprocal when a DC magnetic field is applied.

The semiconductor material can be modeled as plasma in the frequencies of interest and a variety of interesting EM propagation phenomena can be observed, especially when a DC magnetic field is applied. In this talk we will concentrate on the excitation of magneplasmons and electrostatic waves in planar transmission lines and waveguide structures. These structures are simulated with 2-D and 3-D Finite Element computer codes. A transverse resonance method for anisotropic non-reciprocal structures has also been developed by these authors to analyze waveguide structures. Complex propagation constants and the corresponding modes are obtained by solving appropriate eigenvalue problems. Dispersion relationships, S-parameters, effect of the permittivity, magnetic bias and physical dimensions of the waveguide structure in the non-reciprocity as well as physical interpretation of the results will be presented

The proposed devices achieve non-reciprocity or unidirectionality due to the semiconductor magnetoplasma effect. For this purpose, waveguides and planar transmission line structures are implemented by using high electron mobility semiconductor substrates like gallium arsenide (GaAs). Under the influence of the static magnetic field bias, a gyroelectric effect is induced due to the cyclotron motion of nearly free electrons. This leads to a non-diagonal macroscopic permittivity tensor and consequently, this property yields field configurations or modes in a waveguide that are different for forward and reverse propagation. This field displacement effect can cause unequal phase propagation (β) constants as well as attenuation constants (α) in the forward and reverse directions. In this paper, field displacement effects of different planar transmission line structures and waveguides will be investigated, and different design approaches using this phenomenon will be proposed. We also will show preliminary results of the behavior of "electrostatic" or electro-kinetic waves in various waveguide structures.