SYNOPSIS:

Interest in phased array technology, well suited for tracking satellites, has grown in recent years. However, electronically steered arrays are expensive compared to reflector antennas and an important critical issue with phased arrays is the size and cost of the phase shifters. Ferrite phase shifters have been extensively used for phased arrays due to their low weight and small size. However, their extremely high cost and frequency limitations (up to 40 GHz) have prevented more widespread use in satellite communications, especially in millimeter wave devices. Recently, ceramic phase shifters have drawn much attention due to its relatively low cost and reliable performance. But due to larger size, complex impedance matching problem and frequency limitations of the ceramic material, semiconductor phase shifters are investigated in this article.

The proposed magnetized semiconductor phase shifter is a potential low cost and miniaturized phase shift section, to be used in micro/millimeter wave phased array antennas. The interaction of the EM wave with free carriers in a magnetically biased semiconductor produces gyroelectric cyclotron motion, dual to that of the gyromagnetic behavior in magnetized ferrite. So, design techniques of microwave ferrite phase shifters can be extended to semiconductor phase shifters operating at millimeter wave frequencies. But before doing so the modal characteristic of circular semiconductor waveguide, a typical geometry used in phase shifters, have to be fully evaluated. Thus, axisymmetric gyroelectric waveguide is characterized here for InSb and GaAs semiconductors at 77K. The information is presented in terms of signal frequency and the biasing magnetic field to permit direct comparison with the results of ferrimagnetic structures. The calculations assume that the gyroelectric properties of magnetized semiconductors are represented by the tensor permittivity derived from Drude model of cyclotron motion in plasma. In order to include the interaction of the electrons and lattice ions of the semiconductor medium, the concept of effective mass is introduced. Closed form techniques are used to derive the characteristic equation in terms of the propagation constant (β), biasing magnetic field (H_o) and signal frequency (f). Biasing-field/frequency cut-off chart is plotted to identify the lossy regions associated with two extraordinary wave resonance of the magnetized semiconductor material. The losses in these regions are proportional to collision frequency (ν_c), which in turn depends on the temperature. So increasing temperature from 77K leads to increased losses, resulting in broadening of the resonance regions. The phase constant associated with the circularly polarized waves of the dominant mode are calculated and displayed in the propagating plane. Finally, the phase shift per unit length of a magnetized semiconductor phase shifter is evaluated and compared with that of a ferrite phase shift device. The proposed device is miniaturized (1 mm in radius) and requires only a small biasing magnetic field (H_o=0.1 mT) to obtain a significant phase shift. Also the bandwidth of the magnetized semiconductor phase shifter was considerably higher than that of the ferrite phase shifter. The concept of Drude model of magnetized semiconductor, used in this article to theoretically fabricate the low cost and miniaturized InSb or GaAs phase shifter, is recently experimentally verified by Sloan and Davis.