Novel Planar Circulator Based on Magnetized Semiconductor Plasma

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Most nonreciprocal microwave devices use ferrite materials which are biased with a DC magnetic field. Classical ferrite components, such as isolators and circulators, operating above 40 GHz exhibit poor performance due to the upper limit of the saturation magnetization. Bandwidth and integration into the semiconductor-based MMICs are still issues of concern. The availability of spectrum near the 60-77 GHz range as well as the infrared region has increased the demand for improved performance of devices and systems. Fortunately, advancements in semiconductor material technology provide alternative materials for nonreciprocal devices. High mobility semiconductors act like solid-state plasmas, and when exposed to a DC magnetic bias, can be modeled as (gyroelectric) anisotropic material, or *magnetoplasma*. Magnetoplasmas have been reported in the design of nonreciprocal microwave devices at room and liquid nitrogen temperatures. They provide huge bandwidth, compatibility with MMICs, and the ability to work at much higher frequencies.

Among the reported devices, there have been very few cases where planar structures were considered at room temperature. We proposed a double-layer magnetoplasma slotline isolator utilizing thin n-InSb slabs based on the Field Displacement Effect (S. Alshannaq and R. Rojas, USNC/URSI, Boulder, CO, Jan 2008). In this work, we are extending the previous configuration to design a circulator at 77 GHz based on the same phenomenon and waveguiding structure. The wave is mainly propagating on one of the 120-degree-bent slot edges through an Edge-guided Mode. The design process goes from the 2-D cross-section to the final 3-D model through the optimization of many parameters; including the field displacement, the insertion loss and the bend curvature. Modeling and numerical simulations were carried out using a general Finite Element (FEM) code; both in 3-D as well as 2-D, where the eigenvalues and eigenmodes are computed. The final attenuation performance is given in terms of the applied magnetic bias.

To the best of our knowledge, this is the first reported magnetoplasma planar circulator working at room temperature. The unique design proposed here can be extended, by merging the isolator and circulator, to design a singe-pole double-throw (SPDT) RF switch, hence reducing losses, volume and weight. The fabrication of the above switch and circulator is now being carried out by the authors.