IX-6. MICROWAVE FERRITES FOR PHASE SHIFTING APPLICATIONS

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Because of the trend in modern radars to the phased array type, a great deal of activity exists in the field of ferrite phase shifters. The desired high level of antenna performance has put stringent requirements on the phase shifting elements. Low insertion loss, ability to handle high peak and average power, temperature stability, and low switching time and switching energy are desired. Due to the large number of elements there are also considerations on cost, size, and reproducibility. These requirements lead to specifications which are an extensive test of the ingenuity of the element designer and frequently tax the state of the art in ferrite materials.

This paper will be a review of those microwave properties of ferrite materials pertinent to phase shifter performance and will present some new experimental results. The intrinsic properties will be described, compositions and their characteristics will be listed, and several examples of device performance and their relationship to intrinsic material properties will be given.

Because the phase shifters currently receiving attention operate with a low biasing field or in a latched state, the intrinsic properties that are important are those of a partially magnetized material. These intrinsic microwave properties can be described by a complex dielectric constant ϵ and a complex permeability tensor $\bar{\mu}$. Since ϵ shows very little variation with environmental parameters, the main concern will be with the performance of $\bar{\mu}$ as the material is magnetized and as temperature and power levels change. The dependence of $\bar{\mu}$ upon the ratio saturation magnetization to frequency will be treated as well. New results on the frequency dependence of the initial permeability and subsidiary absorption measurements as a function of sample shape and biasing field will be presented. The trade off between peak power and insertion loss will be considered.

The types of microwave ferrites in current usage can be divided into two structural classes, spinels and garnets. Within these classes a wide variety of compositions are possible. Those spinels which have found microwave usage are nickel ferrite with aluminum, zinc, and cobalt substitution, and magnesium manganese ferrite with similar substitutions. Among the garnets there is yttrium iron garnet with substitutions of the rare earth elements, aluminum, gallium, and indium. The properties of these compositions will be described and advantages and disadvantages of particular compositions will be considered. In addition some discussion will be given to new materials such as the calcium vanadium bismuth iron garnets.

From the intrinsic material properties it frequently is possible to understand device performance. The Faraday rotator phase shifter and the twin slab remanence phase shifter are two examples. In these two cases experimental data on intrinsic material properties and device performance will be given.