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Influence of the Magnetic Subdivision on the High Frequency Wave Propagation in Polycrystalline Soft Ferrites

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Abstract. In order to examine guided wave propagation in unsaturated ferrites, it seems reasonable to consider an alternation of layers with antiparallel magnetization in a rectangular waveguide. This approach is coherent with Schlömann's model which considers partially magnetized ferrites as an alternation of antiparallel coaxial cylinders. The state of magnetization will be changed by modifying the thickness of antiparallel layers. Globus model, that represents the partially magnetized material as a single grain subdivided into two domains with antiparallel magnetization, seems to be well adapted to express the "magnetization-field" relation.

1. INTRODUCTION

Due to their gyromagnetic properties, ferrites are being more and more used in microwave devices. Their utilization requires the knowledge of the permeability tensor that is usually established by empirical or physical models. Statistical or mixing laws have been used to modelize those heterogeneous materials. However, all these approaches do not really take the domain subdivision into account.

Taking inspiration from Schlömann's modelization, this paper presents the use of mode matching technique to simulate the wave propagation in non saturated ferrites. The magnetic state is determined by an extension of Globus model.

2. WAVE PROPAGATION IN UNSATURATED FERRITES: USE OF GLOBUS MODEL

2.1 Globus model

The calculation of the magnetization as a function of the field is the principal problem to establish a permeability tensor model. The Schlömann's subdivision into antiparallel domains allows to consider the use of Globus model.

In fact, Globus model postulates that the general magnetic behaviour of a polycrystalline soft ferrite is quite similar to that of a single grain subdivided into two antisymmetrical domains. These domains are separated by a 180° domain wall, whose position is changing in the grain with the magnetic field. A recent extension of Globus model [1] gives a good description of the magnetization curves and hysteresis loops. We propose to apply the results to the simulation of the wave propagation in an alternance of antiparallel layers in a rectangular waveguide, as presented below.

2.2 Wave propagation in heterogeneous anisotropic magnetic materials

In this section we examine the wave propagation in a non saturated ferrite that fills a rectangular waveguide. As a result of Schlömann's model [2], and according to Globus extension [1], the unsaturated ferrite can be assimilated to an alternation of respectively "up" magnetized layers (with a magnetization parallel to the external field) and "down" magnetized layers (with a magnetization antiparallel to the external field) layers. One considers a periodic alternation of layers in the guide. The motif is constituted by two thin layers assimilated to the Globus grain. Consequently, the volume of the layers is determined by the Globus model extension and describes the partially magnetized state. The approach with a lot of layers has the advantage to take interactions between the different grains into account.

Excitation at the guide input is a TE₁₀ mode. Thanks to the mode matching technique and the Floquet's theorem (that takes the periodicity into account), it is possible to determine the dispersion diagram of the structure for different magnetization states [3].

Figure 1: Common use of Globus modelization and Schlömann's representation to simulate wave propagation in non saturated ferrites

The dispersion diagrams for two different magnetization states ($M/M_s=0$ and $M/M_s=0.9$) are presented below (figure 2a). M_s is the saturation magnetization and M the partial magnetization. In the case of a totally demagnetized state (the motif is constituted of two layers with the same volume) it is possible to compare the results with Schlömann's model as shown on figure 2b. We notice that curves have the same shape, but are frequency shifted. This could be explained by the different geometry of the two modelizations. Yet this check constitutes a validity for the presented method.

Figure 2: Dispersion diagrams in non saturated ferrites

3.CONCLUSION

The combination of Globus model and TE₁₀ wave propagation in a magnetic periodic medium leads to the determination of dispersion diagrams in partially magnetized ferrites. Examination of the inverse problem makes it possible to determine components of the permeability tensor. The presented configuration considers only domains with a rectangular geometry, but it is possible to introduce more realistic structures. The treatment consists in using a spatial discretization method, such as FDTD. This method is based on discretization of Maxwell's and magnetic moment equations, and would be particularly well adapted to describe the physical subdivision in magnetic domains of the partial magnetization state [3].

Références

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