Transient Analysis of Electromagnetic Wave Interactions on Magnetized Ferrites using Landau-Lifshitz-Gilbert and Volume Integral Equations

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1. Extended Abstract

Ferrites are often used as substrates in designs of reconfigurable microwave devices since their magnetization can be controlled using an external DC bias. Examples of such devices include circulators, isolators, phase shifters, and patch antennas with multi-mode operation points. Design of these ferrite-based devices calls for simulation tools capable of full-wave modeling of the (nonlinear) dynamics of the magnetization and its interactions with the electromagnetic fields.

The Landau-Lifshitz-Gilbert (LLG) equation describes the transient behavior of the magnetization in a ferrite material. For a full-wave electromagnetic characterization of a ferrite-based device, this equation needs to be coupled to the Maxwell equations. Frequency domain solvers linearize the LLG equation under a small signal approximation and "convert" the resulting equation into a frequency-dependent permeability tensor that is directly inserted into the Maxwell equations [1]. On the other hand, time domain finite difference (FDTD) schemes solve a coupled system of the LLG and Maxwell equations [2] and have the capability to fully model/capture the physics of the electromagnetic interactions on the device.

In this work, this approach is adopted within a time domain integral equation-based framework to benefit from the advantages of integral-equation based solvers over their differential-equation counterparts. The proposed approach solves the coupled system of the (lossy) LLG equation and the time domain volume magnetic field integral equations (TD-VMFIE) using an explicit marching-on-in-time (MOT) scheme. The unknown magnetic field intensity and the flux density in the LLG and the TD-VMFIE are discretized using half and full Schaubert-Wilton-Glisson (SWG) basis functions in space. Inserting these expansions into the coupled system and testing the resulting equations with the SWG functions in space yield a matrix system of equations, which is cast in the form of an ordinary differential equation (ODE) in time. This ODE is numerically integrated in time using an explicit predictor-corrector scheme [3] to obtain the unknown coefficients of the expansions. It should be noted here that the time retardation in the TD-VEFIE operator is accounted for using approximate prolate spherical wave (APSW) functions as an interpolator between time samples [4]. Additionally, the complex-exponent extrapolation scheme developed in [5] is used to ensure the stability while maintaining the causality of the time marching scheme. Numerical examples, which demonstrate the accuracy, stability, and applicability of the proposed MOT scheme in analyzing electromagnetic wave interactions on magnetized ferrites, will be presented.

2. References

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