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

Sadeed Bin Sayed* (1), H. Arda Ulku (1,2), and Hakan Bagci (1)
(1) Division of Computer, Electrical, and Mathematical Sciences and Engineering
King Abdullah University of Science and Technology (KAUST)
Thuwal, Saudi Arabia
(2) Department of Electronics Engineering
Gebze Institute of Technology, Kocaeli, Turkey

Magnetization of a ferrite can be dynamically tuned using a biasing DC magnetic field. This makes ferrites a good choice of substrate for reconfigurable microwave devices and antenna designs. For example, antenna patterns and resonance frequencies can be shifted by adjusting the biasing DC magnetic field during the operation of the antenna or the device (A. Ustinov et al., Appl. Phys. Lett., 90, (031913), 2007).

The nonlinear relation between the magnetization vector and magnetic field intensity in ferrite materials is governed by the Landau-Lifshitz-Gilbert (LLG) equation. In electromagnetic solvers developed for characterizing ferrite-based devices, LLG equation is used either as an auxiliary relation to complement the Maxwell equations, or "converted" into a permeability tensor under a small signal approximation for linearization and inserted into the Maxwell equations. The former approach has been mostly used in time domain finite difference (FDTD) schemes (N. Dib and A. Omar, IEEE Trans. Microw. Theory Tech., 50, 1730-1736, 2002). On the other hand, the latter approach is usually preferred in frequency domain finite element (V. G. Kononov, et al., IEEE Trans. Antennas Propag., 57, 3402-3405, 2009) and volume integral equation (VIE) formulations (G. Kobidze and B. Shanker, IEEE Trans. Antennas Propag., 52, 2650-2658, 2004). It should be clear here that the former approach calls for a time domain solver because of the nonlinear relation between the magnetization and magnetic field intensity.

In this work, a marching on in time (MOT) scheme for solving coupled LLG and time domain volume integral (TDVIE) equations, which are expressed in terms of unknown magnetic field intensity and flux density, is proposed. The proposed scheme discretizes the LLG equation and TDVIE separately. The field intensity and flux density are expanded using half and full Schaubert-Wilton-Glisson (SWG) basis functions in space and polynomial temporal interpolators in time. The resulting coupled system of the discretized LLG equation and TDVIE is integrated in time using an explicit $PE(CE)^m$ scheme to yield the unknown field intensity and flux density expansion coefficients (H.A. Ulku, et al., IEEE Trans. Antennas Propag., 61, 4120-4131, 2013). Explicitness of time marching allows for incorporation of the nonlinearity as a function evaluation on the right hand side of the coupled system of equations. Therefore, the resulting MOT scheme does not call for Newton-like nonlinear solvers.

Numerical examples, which demonstrate the applicability of the proposed MOT scheme in analyzing electromagnetic interactions on ferrite-based antennas and microwave devices, will be presented.