An Unconditionally Stable Time-Domain Solver Unifying Electrodynamics and Micromagnetics

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A multiphysics simulation algorithm is proposed for the first time, to accurately model the dynamic interaction between micromagnetics and electrodynamics, by solving dynamic Maxwell's equations and Landau-Lifshitz-Gilbert (LLG) equation simultaneously. The favorable performance of the new modeling is realized by two unique features:

1. Unconditional stability due to the incorporation of a modified alternating-direction-implicit (ADI) finite-difference-time-domain (FDTD) method. Therefore, the model can handle structures with fine details and drastically different spatial scales between spintronics and electromagnetic wavelength.
2. The boundary conditions of magnetic flux density ($\vec{B}$) and magnetic field intensity ($\vec{H}$) are handled jointly for the first time, to include the demagnetization effect on the material interface.

The accuracy of the modeling has been validated by the simulated dispersive permeability of a magnetic thin film with a 2 μm-thickness, using a time-step size 5000 times larger than the Courant-Friedrichs-Lewy (CFL) limit. As shown in Fig. 1, the match between the modeling and the theory validates the unconditional stability of our model, with the time step size determined by sampling rate limit only. Moreover, as an example of potential application of the algorithm, the effect of high permeability in platform effect elimination is explored. Fig. 2 shows an electric current sheet source close to perfect electrical conductors loaded with 2 μm-thick magnetic thin films, which exhibit an enhanced surface resistance by three orders of magnitude higher than that without magnetic thin film. Our code offers the ease of addition of desired physics, such as nonlinearity, exchange field, anisotropy, magnetostriction, magneto-electric coupling, and so on.

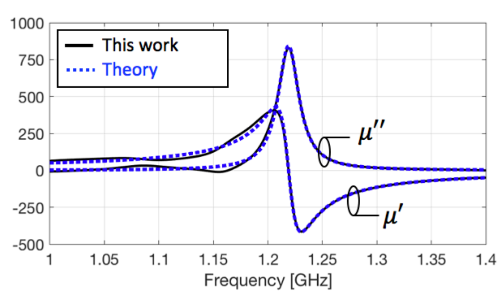

Fig. 1. Dispersive permeability of thin-film YIG

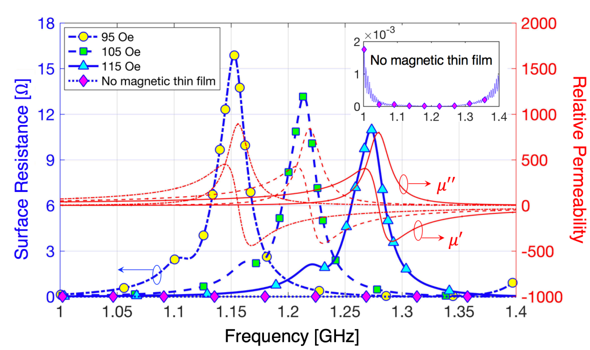

Fig. 2. Surface resistance of ferrite-loaded current source