Ferromagnetic Structures Using Landau-Lifshitz-Gilbert and Volume Integral Equations

PROBLEM DESCRIPTION
Nonlinear dynamics of magnetization inside ferromagnetic materials is governed by the Landau-Lifshitz-Gilbert (LLG) equation. A marching on in time (MOT) scheme for solving the coupled LLG and time domain volume electric field integral equations (TD-VEFIE) is developed. The proposed scheme is explicit and does not call for a Newton-like solver to account for the nonlinearities.

APPLICATIONS OF FERROMAGNETIC MATERIALS
- Isolator
- Microwave signal can be transmitted only in one direction
- Protection against reverse power flow
- Circulator
- Waves can only be transmitted in rotation
- Switch in between transmitter and receiver
- Phase shifter
- DC magnetic field to change the phase of the wave
- Phased arrays
- Reconfigurable Antennas
- DC magnetic field for dynamic tuning

ADVANTAGES
- Small signal approximation is not required
- Only scatterer is discretized but not the background
- Radiation condition is implicitly satisfied without using artificial absorbing boundary conditions
- Time step size is ideally independent of the spatial discretization

TD-VEFIE AND ITS DISCRETIZATION
\[ \partial_t H_{\text{m}}(r,t) = \partial_r (r \times L(r,t)) - \nabla \times \left( \mu_0 B(r,t) \right) \]

- Spatial discretization
  - Half and full SWG functions: \( t'_1(r) \)
    - Unknown coefficients: \( L(t), I(t) \)
  - Temporal sampling and interpolation using \( T(t) \)
  - MOT matrix equation

LLG AND ITS DISCRETIZATION
\[ \partial_t M_{\text{m}}(r,t) = -\gamma M_{\text{m}}(r,t) \times H_{\text{m}}(r,t) + \mu_0 \mu_s \partial_r B(r,t) \times H_{\text{m}}(r,t) \]

COUPLED SYSTEM
\[ \begin{bmatrix} G^{\text{m}} & 0 \\ -G^{\text{m}} & \mu_0 \mu_s \end{bmatrix} \begin{bmatrix} \partial_t L_i \\ \partial_t I \end{bmatrix} = \begin{bmatrix} Z^{\text{m}} L_i - \mu_0 \mu_s I_i + V_{\text{flad}}^{\text{m}} \\ H_{\text{m}} \mu_0 \mu_s I_i - M_i \end{bmatrix} \]

MOT SCHEME
Step 1: Compute the fixed part \( V_{\text{flad}}^{\text{m}} = \sum \varepsilon^{\text{m}} L_i - \sum \mu_0 \mu_s Z^{\text{m}} I_i \)
Step 2: Predict \( U_i = [L_i, I_i] \) using
\[ U_i^{n+1} = \sum_j \left( \rho_i \partial_j \gamma r_j + \rho_j \partial_i \gamma r_i \right)(U_i^{n+1} + I_{\text{tri}}) \]
Step 3: Evaluate \( \partial_t U_i \) by solving (1)
Step 4: Iterate until the solution converges
- Step 4.1: Correct \( U_i \) using corrector coefficients
- Step 4.2: Evaluate \( \partial_t U_i \) by solving (1)
- Step 4.3: Apply successive over relaxation
- Step 4.4: Check for the convergence

Ferromagnetic Scattering
\[ H_{\text{m}}(r,t) = \tilde{G}(t-r) \hat{e} \tilde{f}_0 \]

REFERENCES