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A New F.D.T.D. Algorithm for the Study of Ferrite with a Negative Effective Permeability

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Abstract: Ferrite materials are used in many microwave devices (circulators, isolators ...) which work in a frequency range where the effective permeability μ_{eff} of the ferrite can be either positive or negative. Many authors [1], [2] and [3] have applied the F.D.T.D. method to the study of saturated ferrite when μ_{eff} is positive. The behaviour of the material is completely different when its effective permeability becomes negative [4]. In this paper a new 2D F.D.T.D. algorithm is developed to study ferrite when μ_{eff} is negative. It is validated by computation of resonant frequencies and fields patterns of a ferrite resonant structure.

1. THEORETICAL STUDY

The F.D.T.D. method applied to ferrite consists in a discretization and resolution in time domain of the two curl's Maxwell equations and of the equation of motion of the magnetic moment. The classical discretization scheme (Fig 1) is due to YEE. In isotropic medium, H_x is calculated at (A) point versus B_x and H_y at (B) point versus B_y . In anisotropic ferrites we need B_x and B_y at the same point (A) to calculate $H_x(A)$. The approximation $B_y(A) = B_y(B)$ is done and gives good results when $\mu_{\text{eff}} > 0$ but is not accurate enough when $\mu_{\text{eff}} < 0$. This is the reason why another scheme is presented (Fig 2) in this paper.

Figure 1: YEE scheme

Figure 2: NEW scheme

With this scheme, H_x and H_y are calculated at the same points, chosen at the center of 4 domains Ω_i included in the mesh. H components are determined versus B_x and B_y known and constant in each domain Ω_i . $H_x(A)$ and $H_y(B)$ are deduced by a linear interpolation from H_{xi} and H_{yi} previously calculated.

2. RESULTS

Validations are done by computation of resonant frequencies and fields patterns of a resonant structure made of a cylindrical ferrite resonator centered in a metallic cavity. The results obtained by the two schemes are compared to those given by an analytical method [5]. The characteristics of the structure are: radius of ferrite 15mm, radius of cavity 45mm, Ferrite: $\epsilon_r = 14$, $4\pi M_s = 900$ G, $H_i = 200$ Oe. Figure 3a presents the evolution of E_z versus frequency calculated by the two F.D.T.D. schemes. A good agreement appears when $f > 3$ GHz ($\mu_{\text{eff}} > 0$), there is an important difference in the amplitude of fields for $f < 3$ GHz ($\mu_{\text{eff}} < 0$). In order to explain this phenomena, fields patterns are presented on Fig 3b and 3c. Fig 3b is the comparison between analytical results and the YEE F.D.T.D. algorithm results. A great dispersion appears in the F.D.T.D.

computation showing the bad accuracy of this method. On Fig 3c fields are calculated using the new F.D.T.D. scheme and are compared to analytical results [5]. A good agreement appears showing the best accuracy of the new scheme.

3. CONCLUSION

A new F.D.T.D. algorithm has been presented to study ferrite when their effective permeability is negative. It has been validated on a two dimensional structure. It seems more accurate than the classical YEE scheme to treat mediums with high anisotropy. The application of this algorithm to three dimensional problems is now under consideration.

Figure 3a: Evolution of E_z versus frequency

Figure 3(b)(c): Fields patterns: Comparison between FDTD and Modal method TM110 $F=2.32\text{GHz}$ $\mu_{\text{eff}}=-1.12$

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