Modelling of Nonuniform Magnetisation of a Ferrite Loaded Waveguide

Harish V. Dixit[1], Aviraj Jadhav[1], Yogesh Jain[2], Alice Cheeran[1], Vikas Gupta[3], P. K. Sharma[2]

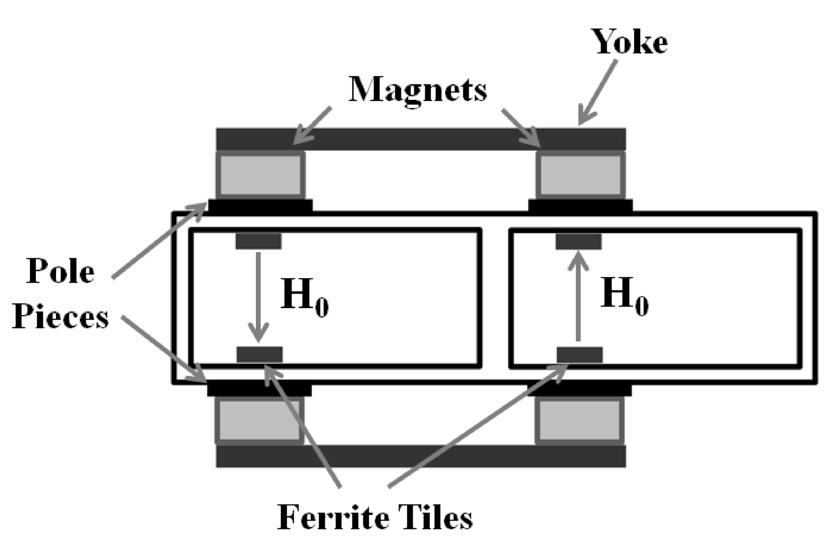
1. Veermata Jijabai Technological Institute, Mumbai, Maharashtra - 400019
2. Institute for Plasma Research, Gandhinagar, Gujarat - 382428
3. Vidyavardhini's College of Engineering and Technology, Vasai, Maharashtra - 401202

Introduction

The modelling of a ferrite material is conventionally carried out using the Polder permeability tensor which assumes that the ferrite is saturated by a uniform magnetic field. This assumption is often inaccurate due to the constraints imposed by boundary conditions which renders the magnetic field non-uniform. This work proposes to overcome this by determining the magnetic field through a magnetostatic solver and then computing the RF permeability of ferrite using its solution. A case study of a ferrite loaded nonreciprocal phase shifter is taken.

Polder tensor,

$$\begin{bmatrix} 1+X_{xx} & X_{xy} & 0 \\ -X_{xy} & 1+X_{xx} & 0 \\ 0 & 0 & 1 \end{bmatrix}$$



where,

$X_{xx} = X_{xy} = f(H_0)$

Boundary Conditions and Computational Methods

A Waveguide (WR-284) is loaded with a ferrite along a quarter of its broader dimensions. Magnets are placed over the ferrite tile to magnetise it in the transverse direction. Pole pieces are used to concentrate the magnetic field. The waveguide would be excited with a 3.7 GHz RF wave.

We first solve for the magnetic field in the ferrite material using the AC/DC Module . The magnetic field, no current physics is used.

$$\overline{H} = -\nabla V_m$$
$$\nabla \cdot \overline{B} = 0$$

Using the results thus obtained, The RF physics is solved to determine the non reciprocal behaviour.

$$\nabla \times \mu_r^{-1}\left(\nabla \times \overline{E}\right) - \kappa_0^2\left(\varepsilon_r - \frac{j\sigma}{\omega\varepsilon_0}\right)\overline{E} = 0$$

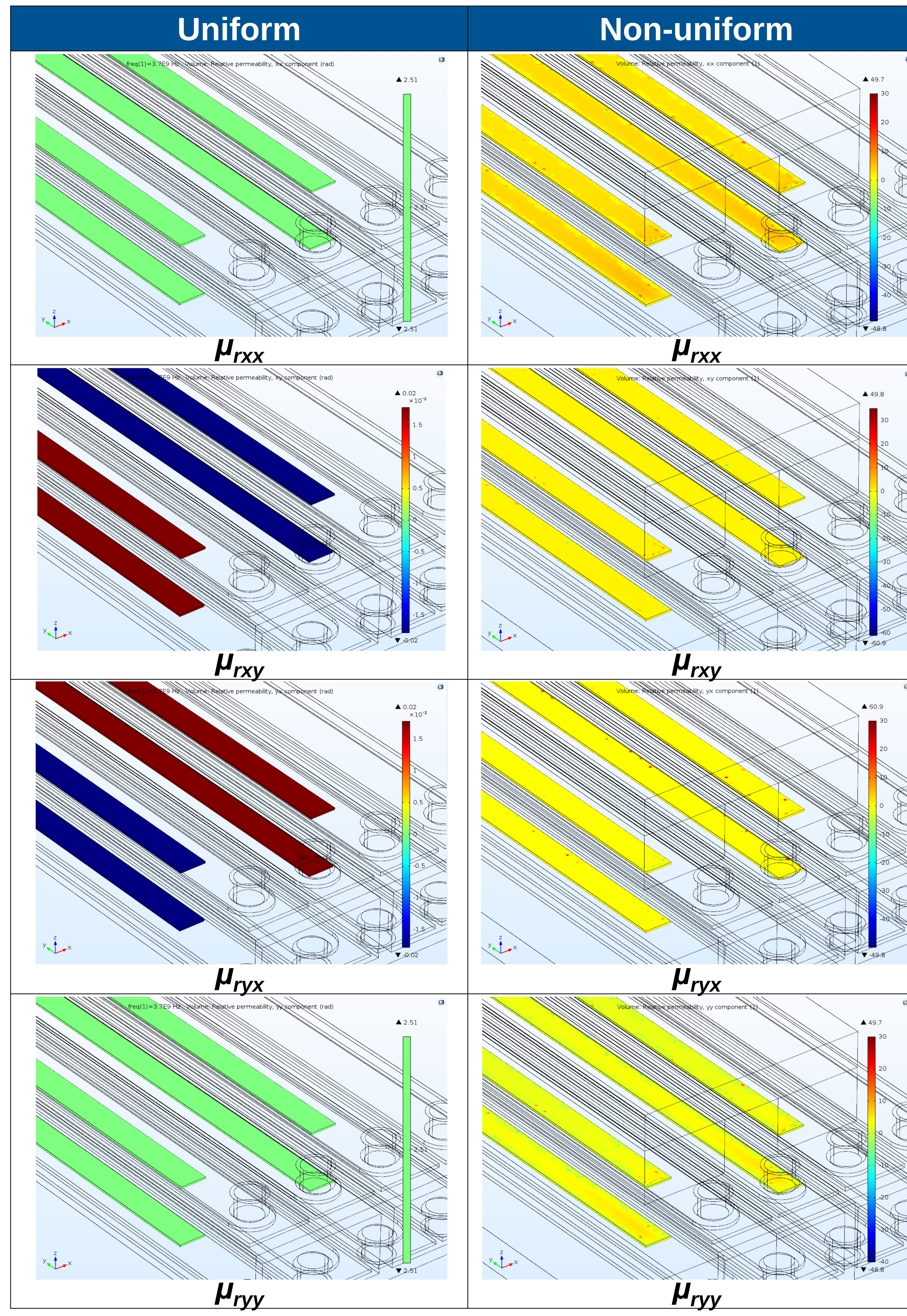
Study	I	II
Study Step	Stationary	Frequency Domain
Physics	Magnetic Fields, No Current (mfnc)	Electromagnetic Waves, Frequency Domain (emw)
Ferrite	$\mu_r = 200$	Polder Tensor
Magnets	Magnetisation (M) = 6555 Gauss	NA
Air	$\mu_r = 1$	$\mu_r = 1$

Results

Column 1 (uniform) determines the Magnetic Field due to polders permeability while Column 2 (non-uniform) determines the magnetic field due to proposed approach. Table 1 depicts the non reciprocal phase shift observed due to polders permeability and proposed method.

Results (Cont…) (Table 1)

Case	Magnetisation	Internal Magnetic Field	Differential Phase Shift
I	Uniform	1693	30^0
II	Non-Uniform	~1693	~54^0
III	Non-Uniform	~1948	~30^0



Conclusion

The proposed work has demonstrated the coupling of a magnetostatic solver with an RF solver. This method is effective to characterise the non uniform magnetisation of the ferrite tile.

References

1. B. Lax, K. J. Button, and L. M. Roth, 'Ferrite Phase Shifters in Rectangular Wave Guide,' *J. Appl. Phys., vol. 25, no. 11, 1954.*
2. P. J. B. Clarricoats, H. M. Barlow, 'Microwave Ferrites,' London: Chapman & Hall, 1961.
3. B. M. Dillon and A. A. P. Gibson, 'Microwave and thermal analysis of a high-power ferrite phase shifter,' *IEEE Trans. Magn. pp.* 1149–1152, Mar. 2002.

Excerpt from the Proceedings of the 2016 COMSOL Conference in Bangalore