Calculation of Inductance of Sparsely Wound Toroidal Coils

A. Pokryvailo
Spellman High Voltage Electronics Corp., Hauppauge, NY, USA

Introduction: Analytical methods used for inductance calculation of toroidal coils yield large errors in the case of sparsely wound coils, especially when using low permeability cores.

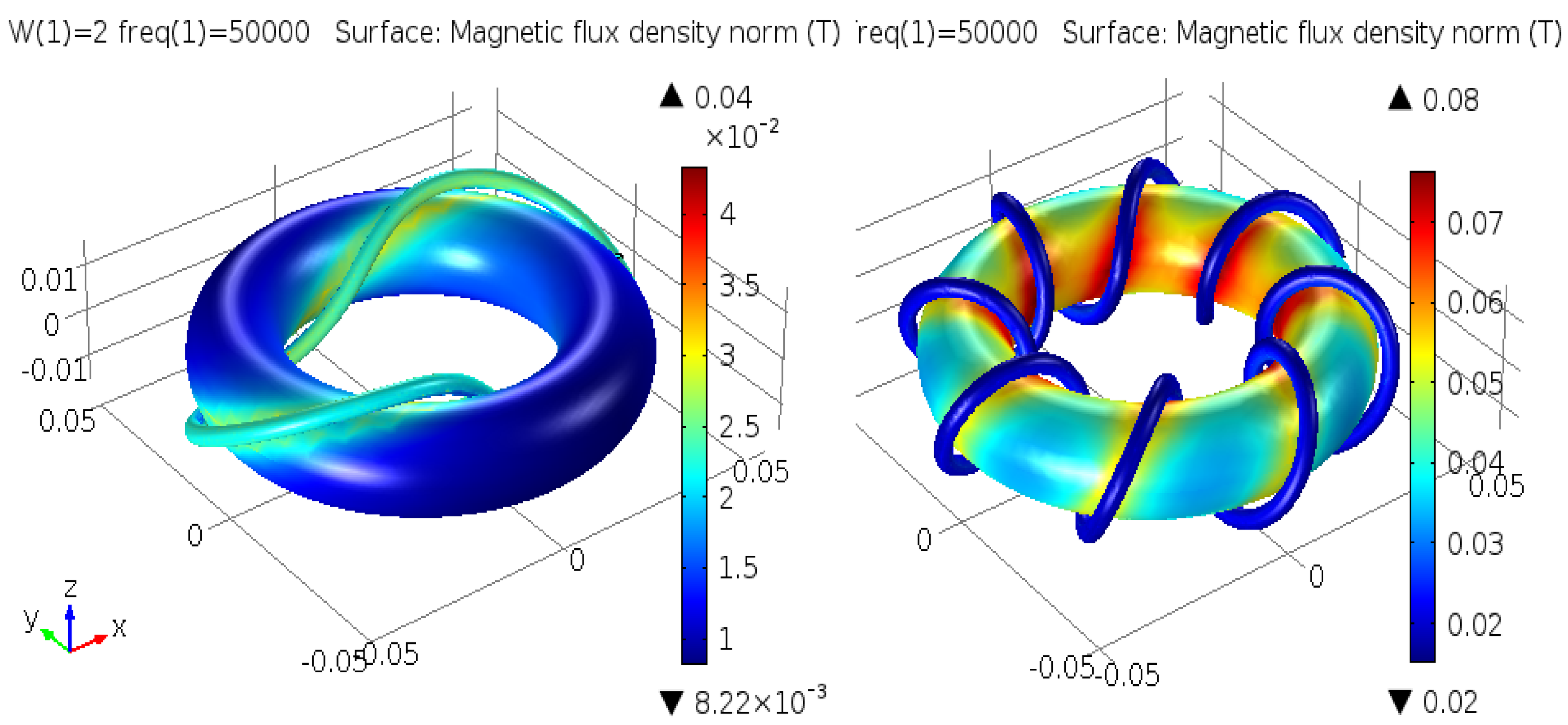

Figure 1. Flux density for two and eight turns. Winding current is 150 Arms for both cases.

Computational Methods: The problem was solved using the Magnetic Field Interface. The governing equations for the frequency domain are shown below:

$$(j\omega\sigma - \omega^2\varepsilon_0\varepsilon_r)\boldsymbol{A} + curl\boldsymbol{H} = \boldsymbol{J_e}$$
$$\boldsymbol{B} = curl\boldsymbol{A}$$

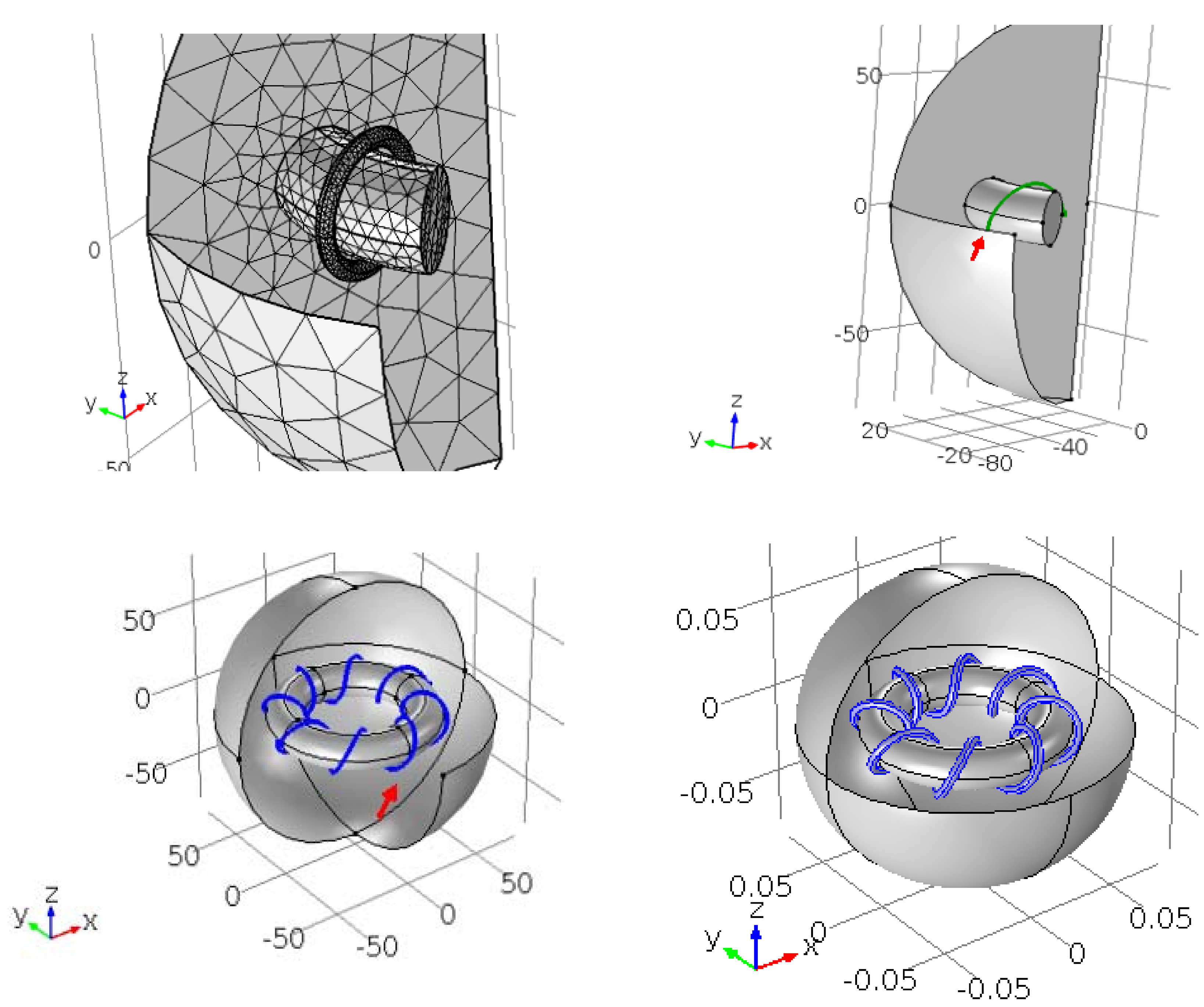

Figure 2. Different modeling approaches: a-discrete turns, b-filament (edge) current - taking advantage of symmetry; c-filament current, d-full-bodied winding – full space model.

Results:

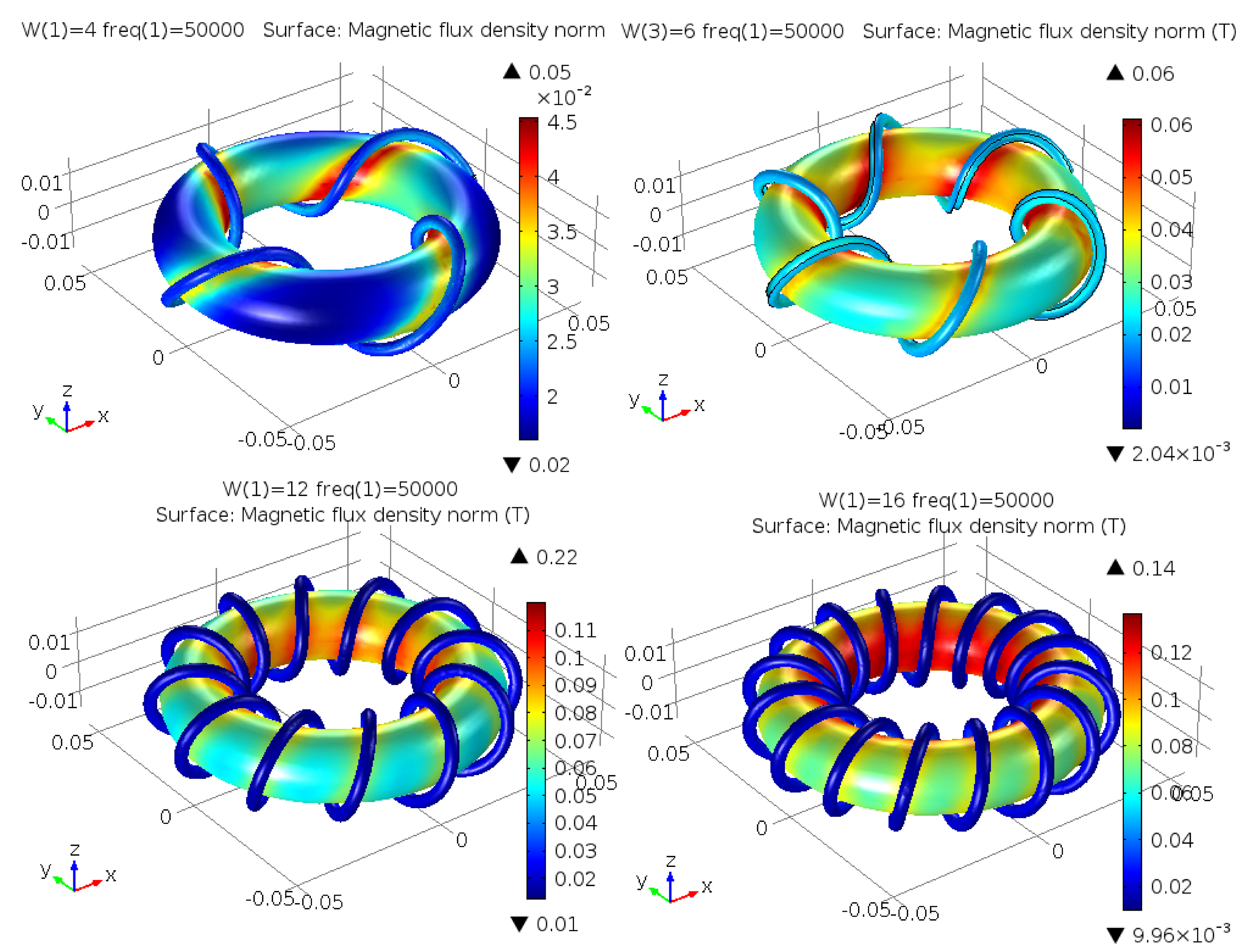

Figure 3. Flux density for W=4, 8, 12, 16. Winding current is 150 Arms for all cases. murel=10.

Table 1. Inductance, in H, full volume model, for different W and permeability, murel. Wire radius rwire=2 mm.

W	*murel*=1	*murel*=10	*murel*=100
2	1.94E-07	2.97E-07	9.89E-07
4	2.42E-07	5.46E-07	3.17E-06
6	3.22E-07	9.31E-07	6.99E-06
8	3.94E-07	1.50E-06	1.16E-05
12	6.38E-07	3.01E-06	2.64E-05
16	9.51E-07	5.14E-06	4.67E-05

Conclusions: For sparsely wound coils, dependence of inductance on number of turns is far from quadratic; wire inductance is a considerable factor, especially for low number of turns and slim cores; fringe field of a coil sparsely wound on a low-permeability core is low but not negligible.

References:

1. F.W. Grover, “Inductance Calculations”,Van Nostrand, 1946; Reprint: Dover, 2004.
2. “Micrometals Iron Powder Cores”, Catalog, Issue L, February 2007.
3. W. Frei, “Exploiting Symmetry to Simplify Magnetic Field Modeling”, Comsol blog, 2014.