ELECTROMAGNETIC RESISTANCE

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Abstract

Electromagnetic field can run engineer or electric machine as well put them to inconvenience. This paper presents calorimetric non-destructive test model using Electromagnetics module Comsol Multiphysics® computing and visualization tools for preliminary estimate in electromagnetic compatibility application field.

1. Introduction

Electromagnetic field (EMF) exists due to interpenetrations of variety fields in consequence of mater existence, its motion and its changes. High-frequency electromagnetic compatibility (EMC) is a part of machine characteristics that depends on machine construction. High-frequency EMC is measured in radio-wave bandwidth (100 kHz up to 1GHz) as well microwave bandwidth (1GHz up to 300 GHz). The EMC describes and measures:

- machine responsibility for correct running in external EMF interference conditions (machine resistance: susceptibility, sensitivity, sensitivity threshold, destruction threshold),
- what EMF does create the machine (machine is a source of interferences: energy parameters, frequency spectrum etc.).

The EMF is described via electric and magnetic parameters derived from Maxwell equations, other principles and relations. Exact processes are visualized in static or dynamic mode via scalars, vectors, phasors and tensors. Appliance of energetic balance equation and Poynting´s energetic theorem demands closed area that ensures energy balance. All the energy radiated inwards closed area changes to thermal energy into irradiation material. Absorbed energy P_a (1) can be measured also via calorimetric method using absorbing material capacity for heat in time dependence. In this case, equation (2) can represent thermal loses.

$$P_a = 0{,}556\varepsilon_r tg \frac{\sigma}{2\pi f \varepsilon_0} fE^2 .10^{-10} \tag{1}$$

$$Q = 4{,}18 c_s m \Delta T = P_a t \tag{2}$$

where: ε, σ, c_s, m – characteristics of absorption material, f – frequency of EMF,
E – electric field intensity, ΔT – temperature difference, t – irradiation period.

Shield and surface characteristics as well material quality and dimensions of high-frequency components (resonance circuits, carrier lines, measuring equipments etc.) have to be matched for frequency bandwidth on demand. Their quality coefficient q (3) should be maximized so the loses will reduce. Power losses are directly proportional to frequency and transmitted power.

$$q = \frac{\omega_0 P_{EMF}}{P_{loss}}, \qquad \text{or} \qquad P_{loss} = \frac{\omega_0 P_{EMF}}{q} \tag{3}$$

where: ω_0 – angular frequency of source, P_{EMF} – transmitted EMF power, P_{loss} – loss of power.

The equipment-under-test (EUT) can be considered as a non-matched resonance component by EMC valuation. The EMF energy can change to resistive surface / internal heating; it can permeate trough dielectric permeable materials or interfuse trough shield apertures into machine. The thickness and choice of high quality material bring significant decreasing of losses (EMF permeate specified depth of material). There can be used reflected or absorbing surface materials.

Interfused electromagnetic waves are reflected, combined and induced at internal surfaces, wirings and components. They create whirling currents, surface magnetism or microwave heating that can effect machine failures or malfunctions as long the EMF fades. The most sensitive electric components (e.g. low power input ports, micro-structured and integrated components, microwave and semiconductor components) can be damaged.

Measurement methods require consistent valuation of many tests (using few high-frequency sources, in all propagation directions). There are two method approaches:

- non-destructive methods; these methods test machine damping parameters without destruction. Often, machine damping parameters are measured via comparison inside- and outside-electromagnetic power parameters and Final damping characteristics are approximated with computing tools. Beyond all expectation, the results of non-destructive methods should be compared with some destructive tests.
- destructive methods; the EMC is measured up to destruction threshold. Although these methods have real unambiguous results, they have a disadvantage: by over-loading of destruction threshold, the machine destroys. It follows that these methods can be more expensive than non-destructive methods. Nevertheless, destructive methods can save lot of time, money or material at last.

Machine shield should prevent of unwanted EMF penetration in large frequency bandwidth. Usually, machine shields are made in Faraday cage design. Their EMC can be experimentally tested:

- in quasi-real conditions in limited space (microwave owen),
- in quasi-real opened area (fully-anechoic microwave damping chamber, transversal electromagnetic TEM waveguide).

2. Microwave owen model

The influence of EMF inside of closed area is simulated at the standard microwave owen base. A standard constant-wave source is connected to special all-metal structured box via microwave waveguide. Calorimetric parameters can be measured in the glass of water inside of the box.

The Electromagnetic Waves> Harmonic Propagation and Boundary Mode Analysis> TE Waves application modes are used for modeling in Electromagnetics modul, Comsol Multiphysics®. Simulations and real experiments verify assumption that EMF energy changes to the thermal energy via heating of water (Fig. 1). Electromagnetic field creates adequate resistive heating.

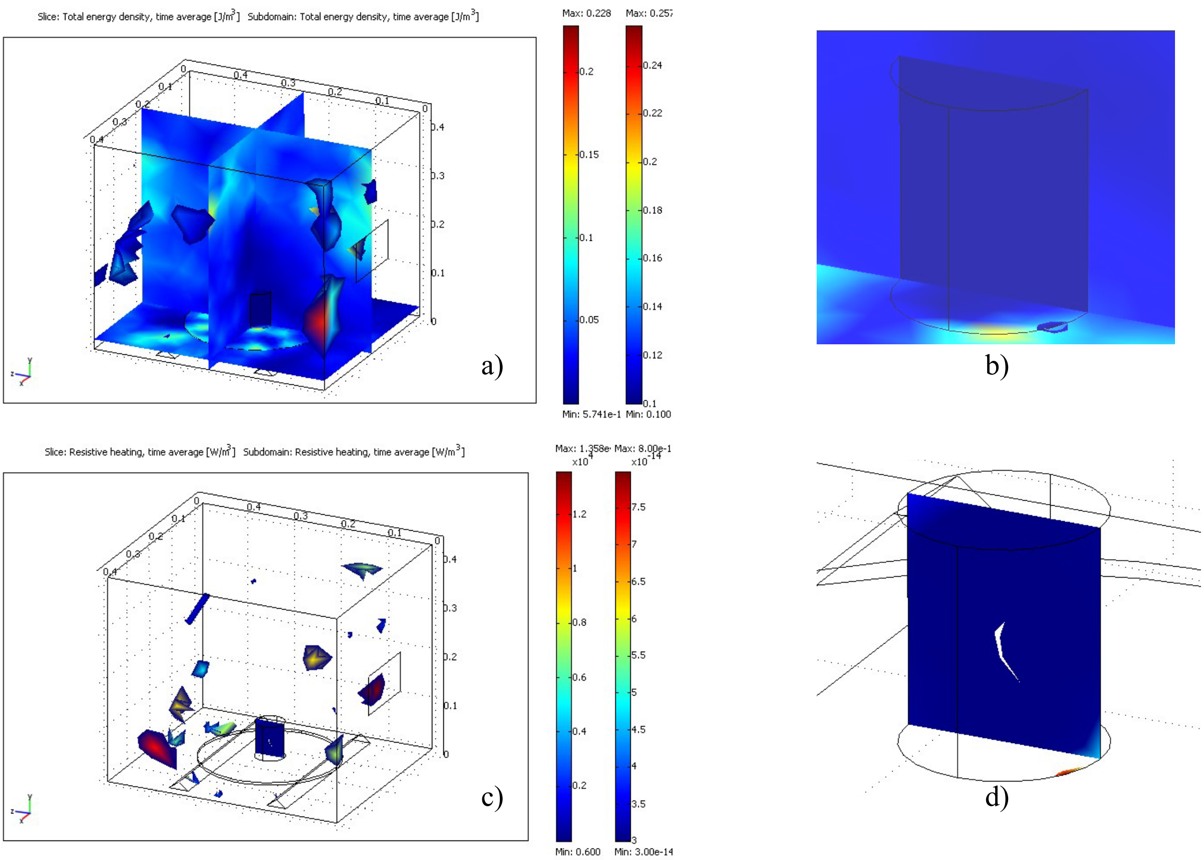

Fig. 1: Microwave owen model: a) total energy density, slice and subdomain plot; b) detail, slice plot; c) resistive heating, slice (left scale) and subdomain (right scale) plot; d) detail, slice plot

3. TEM model

The influence of EMF in opened area is simulated inside of anechoic area via gigahertz transversal electromagnetic waveguide with primary E-field. The horn aperture comes to the cubic-square box. Its aperture is closed by fully-anechoic microwave absorber. Both the horn and the box are made of special high-conductive copper. Their statures allow placing things, engineer or electric machines and measure calorimetric as well EMF parameters in the middle of cube box.

The Electromagnetic Waves> Harmonic Propagation and Boundary Mode Analysis> TE Waves application modes are used for modeling in Electromagnetics modul, Comsol Multiphysics® again. Microwave source is connected to the horn input via microwave waveguide R32 (a=72.14 mm, b=34.04 mm). The middle frequency $f_{mid} = 3e8/a\sqrt{2}$ is applied in the TE_{10} dominant mode. Following experiments show total energy density and resistance heating inside of waveguide and details at the EUT level.

First, glass of water collects the energy in the middle of cube box (Fig. 2). Even though the energy level heats the water at very low level due to opened area simulation, the results represent gradation in a few order.

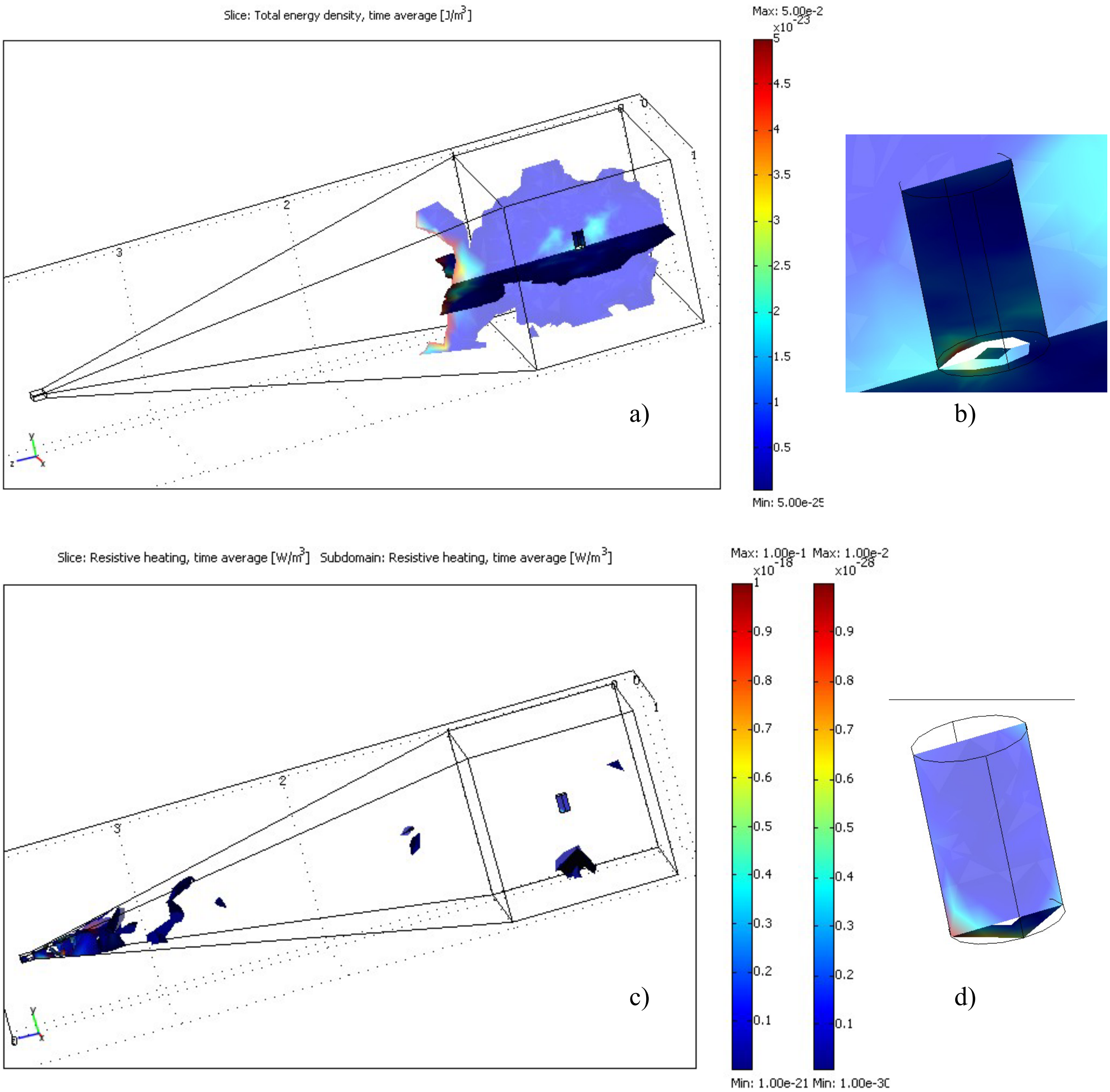

Fig. 2: TEM model, glass of water, slice plots: a) total energy density, b) detail;
c) resistive heating, slice plot of glass – left scale, subdomain plot of waveguide – right scale; d) detail

Next experiment shows EMF influence on electric device, circuit board (Fig. 3, 4) in the middle of cube box, slice plots. Both resistive heating and total energy density results are comparable to glass-of-water case.

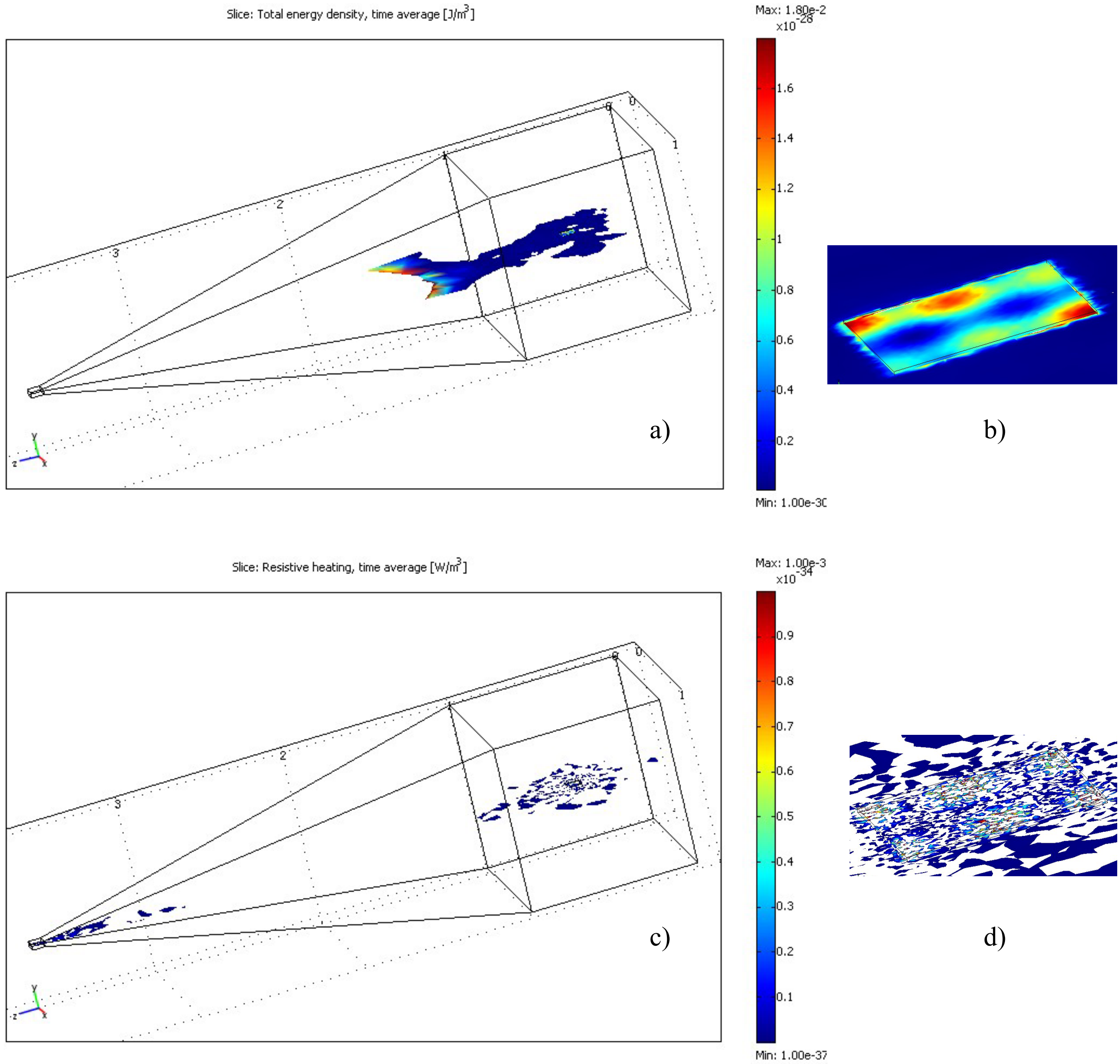

Fig. 3: TEM model, circuit board, horizontal, slice plots: a) total energy density; b) detail; c) resistive heating; d) detail

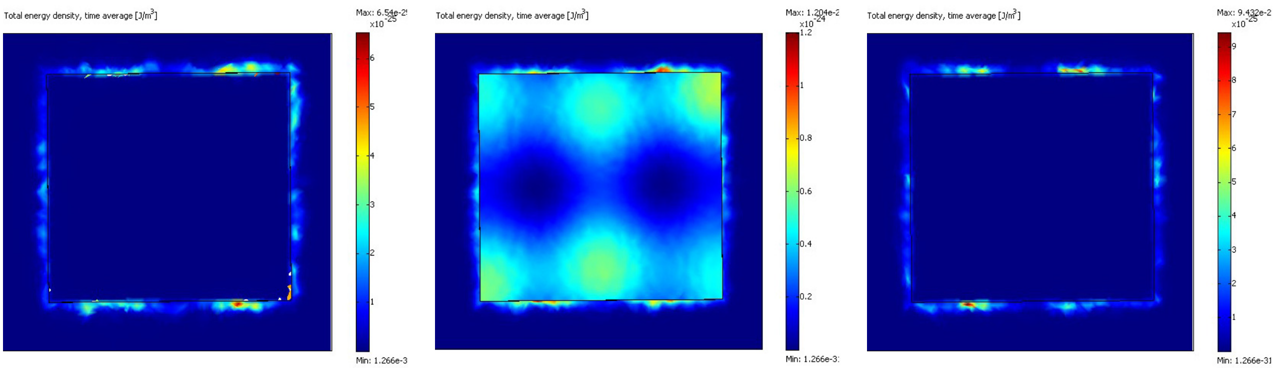

Fig. 4: TEM model, circuit board, vertical, total energy density, details: a) front; b) middle; c) back

Conclusion

Both electromagnetic and thermal energy form have influence on composite electronic machines. Comsol Multiphysics® has tools for non-destructive EMC valuation. Simulated microwave owen and TEM models were field tested. Output simulated results are comparable with real measurements.

In addition, Comsol Multiphysics® allows estimate sensitivity or destruction thresholds in EMF guidance conditions. Accurate modeling should raise prediction of critical vulnerable boundaries and weaknesses for components or composite machines as well self-resonance frequencies and angled reflector effect.

References

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