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Comments on and Corrections to "FDTD MODELING AND SIMULATION OF MICROWAVE HEATING OF IN-SHELL EGGS" by S. R. S. Dev, Y. Gariépy, V. Orsat, and G. S. V. Raghavan, in *Progress In Electromagnetics Research M*, Vol. 13, 229–243, 2010

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In the above paper [1], there are two classes of several errors. The first one is related to mistakes/misprints in equations and irrelevant references. The second one is assertions about innovations, which were claimed as "for the first time" in the literature. In addition to them, the commentators want to attract attentions of the readers with an additional part of comments in order to make more useful and better understanding of the work in [1]. All details about these issues are discussed at following parts:

1. Mistakes/Misprints in Equations and Irrelevant References:

- In Equation (1), ε must be ε_r. Otherwise, Equation (3) will not be true.
- In Equation (1), Maxwell's equations in the frequency domain must contain the induced current density term (loss term) for the investigated problem. Otherwise, the electromagnetic power cannot induce the heat in the object (egg) as formulated in Equation (13). Moreover, according to Reference [10] for Equation (1) in [1], the Maxwell's equations must contain the generalized current term which is appropriate to this comment. In fact, the frequency domain representation of the Maxwell's equations for simple medium is not necessary in this example [1].
- In Equation (2), $\mathrm{Re}\{\cdot\}$ operator must be written.
- Equations (7)–(12) have mistakes. In order to check the equations, let us first take time derivative of Equation (10), then substitute

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Equations (8) and (9) into Equation (10). Using the divergence relation for magnetic field, it is necessary to extract the wave equation for H_x component. However, Equation (6) cannot be true in the present form in order to obtain the wave equation. In this case, the dimensions (units) in Equations (7)–(12) will also be questionable. Therefore, in the scalar form of the Maxwell's equations, the presence of the coefficient $1/\sqrt{\varepsilon_0\mu_0}$ is problematic. Moreover, the Maxwell's equations in this form are not available in Reference [8] of [1]. It is also not clear what the usefulness of the proposed form of the Maxwell's equations. Furthermore, in Equation (6), another font for dielectric permittivity as ϵ_0 is used. As a last, after Equation (6), the value of it is miswritten in which true font should be used with the true value as $\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F/m}$. The corrected and common version of the scalar Maxwell's equations with the current density terms should be given by

$$\begin{aligned}
\frac{\partial D_x}{\partial t} &= \left(\frac{\partial H_z}{\partial y} - \frac{\partial H_y}{\partial z}\right) - \sigma E_x - J_x^{source} & \frac{\partial H_x}{\partial t} &= \frac{1}{\mu_0}\left(\frac{\partial E_y}{\partial z} - \frac{\partial E_z}{\partial y}\right) \\
\frac{\partial D_y}{\partial t} &= \left(\frac{\partial H_x}{\partial z} - \frac{\partial H_z}{\partial x}\right) - \sigma E_y - J_y^{source} & \frac{\partial H_y}{\partial t} &= \frac{1}{\mu_0}\left(\frac{\partial E_z}{\partial x} - \frac{\partial E_x}{\partial z}\right) \\
\frac{\partial D_z}{\partial t} &= \left(\frac{\partial H_y}{\partial x} - \frac{\partial H_x}{\partial y}\right) - \sigma E_z - J_z^{source} & \frac{\partial H_z}{\partial t} &= \frac{1}{\mu_0}\left(\frac{\partial E_x}{\partial y} - \frac{\partial E_y}{\partial x}\right).
\end{aligned}$$

- Reference [11] is irrelevant for Equation (14). This is the classical paper of Yee and is not related to the heat transfer Equation (14). There is no relation between them.
- Reference [8] in [1] is completely inadequate because it gives a Finite Difference Time Domain (FDTD) algorithm for narrowband structures. There is not this type of narrowband structure in the work of [1].

2. Assertions about Innovations

A subchapter was constructed for explanations about the innovations in paper [1]. However, these claims as emphasized "for the first time in the literature" are not true. Their accurate statements are:

- The first claim was the first usage of the coupled approach for the temperature and power distributions in [1]. However, this was given 16 years ago by Torres and Jecko, (Reference [2] in this paper). That work is really very detailed one about coupling phenomena and gives all necessary information for the FDTD implementation. The authors did not give the reference of the Torres and Jecko work. Therefore, the authors are not first in this topic.

- The second claim was first consideration about the dependency of dielectric properties on temperature of the material and frequency of the microwaves was taken into account. This is also not true. All these cases were covered in the Torres and Jecko work, (Reference [2] in this paper). The authors are not also first in this topic.
- The third claim was to introduce "a microwave heat generation factor". However, the meaning of it is not clear for the reader. It was only one time mentioned in [1]. Any explanation was not given for this factor.
- The last claim was to include the conduction, convection and radiation modes of heat transfer. This is inherent when one couples the heat transfer equation with the Maxwell's equations. Therefore, this was also included in the Torres and Jecko work, (Reference [2] in this paper).

All these comments show that the claimed innovations by the authors are not also true. 16 years ago, they were given in the Torres and Jecko work in details. We think that the authors should emphasize their investigated problem, not the applied method.

3. Additional Comments for Other Key Topics

In order to make more useful and better understanding of the work in [1], the commentators want to attract attentions of the readers for the following critical steps:

- The FDTD update equations must be given at least for the heat equation. It seems that none of the references in [1] and the paper itself also contain the FDTD heat update equations. This is an important weakness for the reader. We recommend the Torres and Jecko's work for this aim.
- The most critical step in the solution of electromagnetic power (energy) coupled heat transfer problems by the FDTD method is about the stability limitations. Because the Maxwell's equation is a hyperbolic type and the heat transfer equation is parabolic type differential equations, their FDTD stability criteria are completely different from each other. Therefore, the smallest one has to be used in the overall simulation. This is one of the most important FDTD limitations in this type of coupled (multi-physics) problems. There is no information given about this in [1].

- Another critical step in conjunction the Maxwell's equation with the heat transfer equation is implementation of boundary conditions for material modeling in the heat transfer equation. This is also very important and no information is given about this in [1].
- The averaging of the field in the FDTD calculations is also important for transforming the electromagnetic power into the heat transfer equation. This reduces the numerical errors and makes the solution closer to the physical reality. This is also not mentioned in [1].
- In Figures 6, 7 and 8, it is not explained which component of the electric field distribution is shown. It is also not clear that this is the total electric field variation or not.
- Before starting the FDTD calculations, it is better to check proper excitation of the cavity modes by the FDTD methods. Several TE and TM modes can be excited. Then, the numerical results can be checked in the sense of the field distribution and time response without the egg.

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