Split, Croatia, November 9-12, 2016

Training School on Electromagnetic modelling techniques for Ground Penetrating Radar

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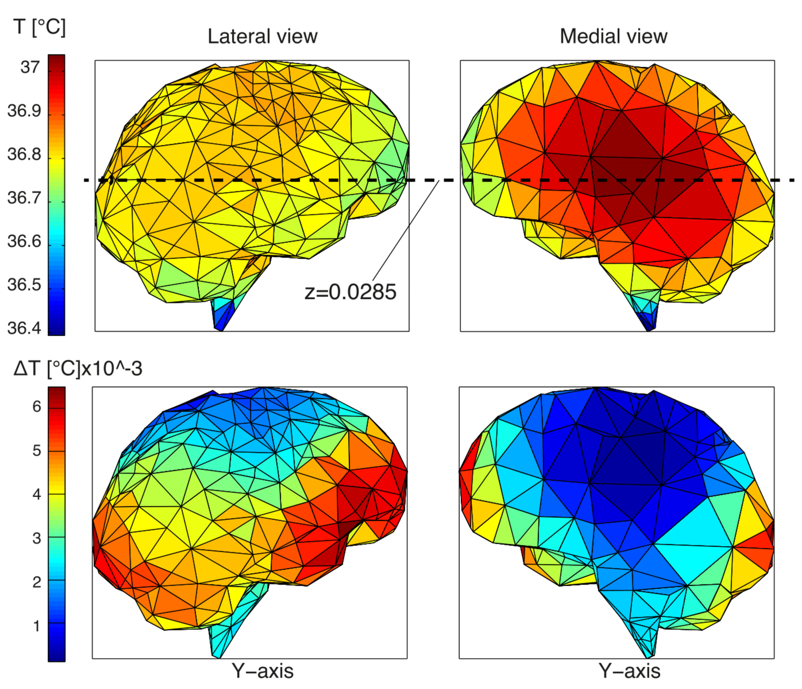
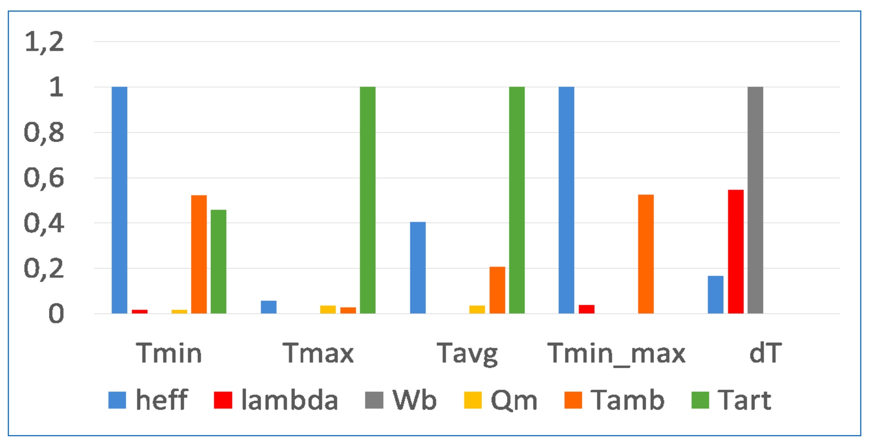
FESB, Split

Human exposure to electromagnetic fields

Stochastic sensitivity in thermal dosimetry for the homogeneous human brain model

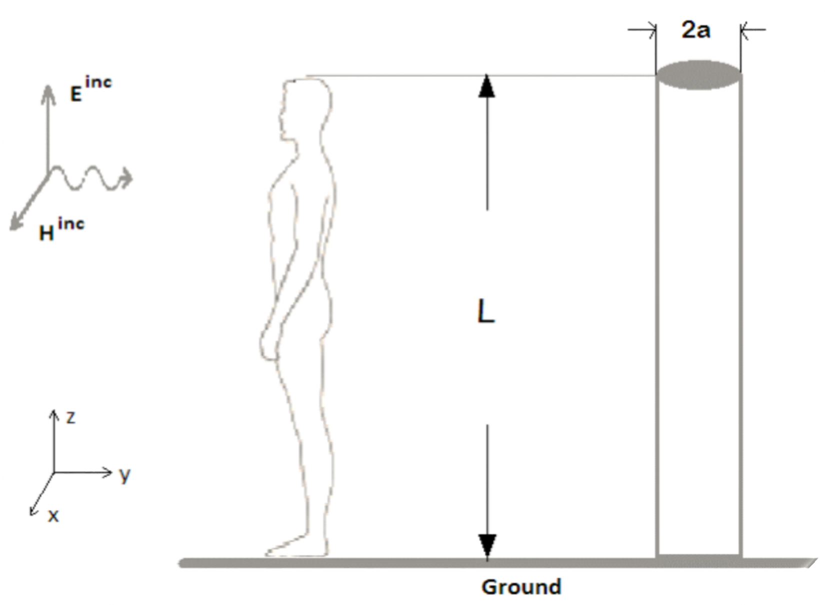




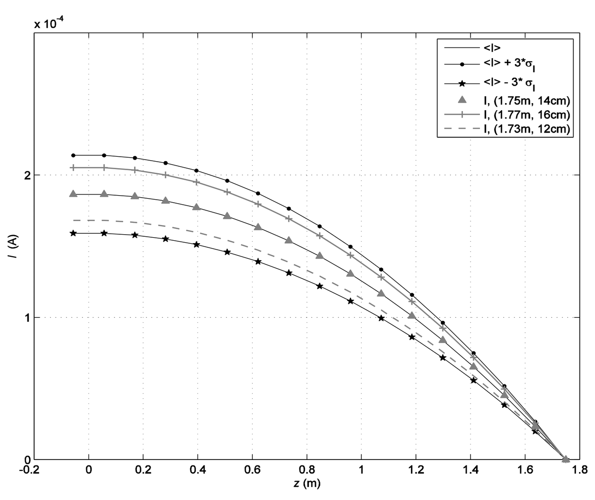
** This work was undertaken within the framework of COST Action BM1309 (COST EMF-MED) and ICES TC 95 SC6.*

- The **Stochastic Collocation** method is combined with the thermal part of the homogeneous deterministic electromagnetic-thermal **human brain model**.
- The aim is to investigate the influence of the thermal parameters on temperature rise which is a direct consequence of the brain exposure to the high frequency electromagnetic field.
- **Sensitivity analysis** excludes the less important parameters and can be used as a prior step of more complex experimental or computational models.
- Obtained **confidence margins** give more precise estimate if temperature elevation reaches the prescribed limits or not.

Deterministic-stochastic model of the human body exposed to ELF electric field



	Initial value	RV	Distribution
Body length (L)	$1.75\ m$	$\hat{u}_L$	$U[-2,2]\ cm$
Body radius (a)	$0.14\ m$	$\hat{u}_a$	$U[-2,2]\ cm$
Conductivity (σ)	$0.5\ S/m$	$\hat{u}_\sigma$	$U[-0.1,0.1]\ S/m$



- Human body is represented as **cylindrical antenna** illuminated by a low frequency electric field.
- The variability inherent to input parameters such as the height of the body, the shape of the body and the conductivity of body tissue, is propagated to the output of interest (induced axial current) by means of **Stochastic Collocation (SC) method**.
- The results point out the possibility of improving the efficiency in calculation of basic restriction parameter values in electromagnetic dosimetry.

Research activities comprise **deterministic** and in particular **stochastic** modelling in Computational Electromagnetics (CEM) mainly in the following applications:

- ✓ Bioelectromagnetism, human exposure to electromagnetic fields, biomedical applications of electromagnetic fields
- ✓ Electromagnetic compatibility of thin wire structures (GPR antennas, arbitrarly shaped wires)
- ✓ Magnetohydrodynamics and plasma physics: transport equations for magnetically confined plasma

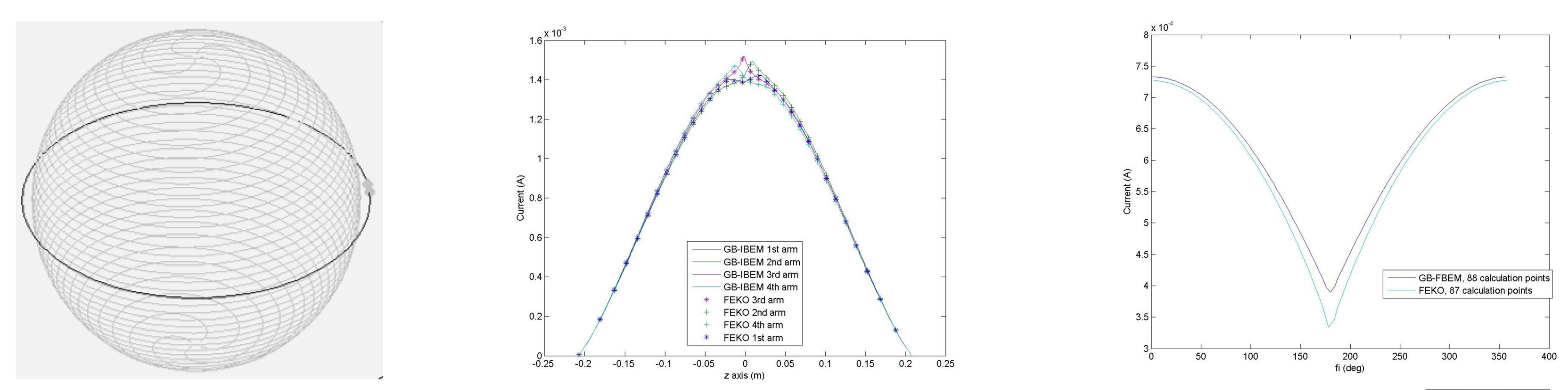
The deterministic approach in my research is based on **Galerkin-Bubnov scheme of Finite Element and Boundary Element Methods.**

The stochastic models are based on **Stochastic Collocation (SC)** method.

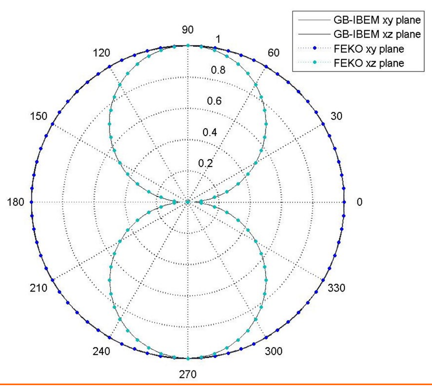
Other stochastic approaches are being explored such as Stochastic Reduced Order Method (SROM), Stochastic Finite Element Method.

Modelling of thin wire antenna structures

Multiple-folded spherical helical antenna (SHA)



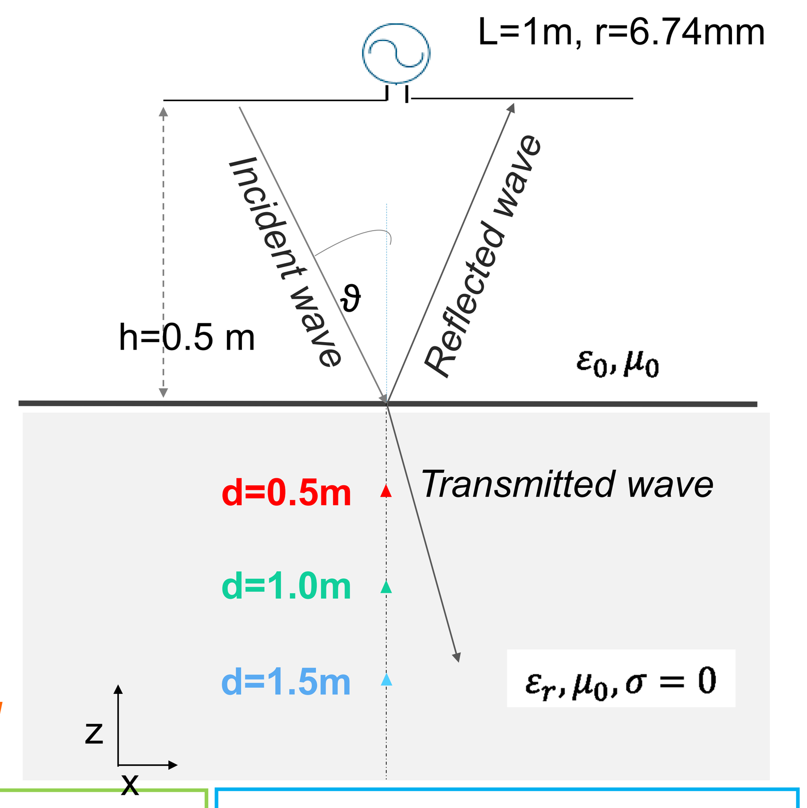
$$E_{w_n}^{inc} = \frac{j}{4\pi\omega\varepsilon_0}\sum_{m=1}^{N_w}\int_0^{L_m} I(w_m')\left[k_1^2\vec{e}_{w_n}\vec{e}_{w_m'} - \frac{\partial^2}{\partial w_n\,\partial w_m'}\right]g_0(w_n,w_m')\,dw' + Z_L' I(w_n)$$



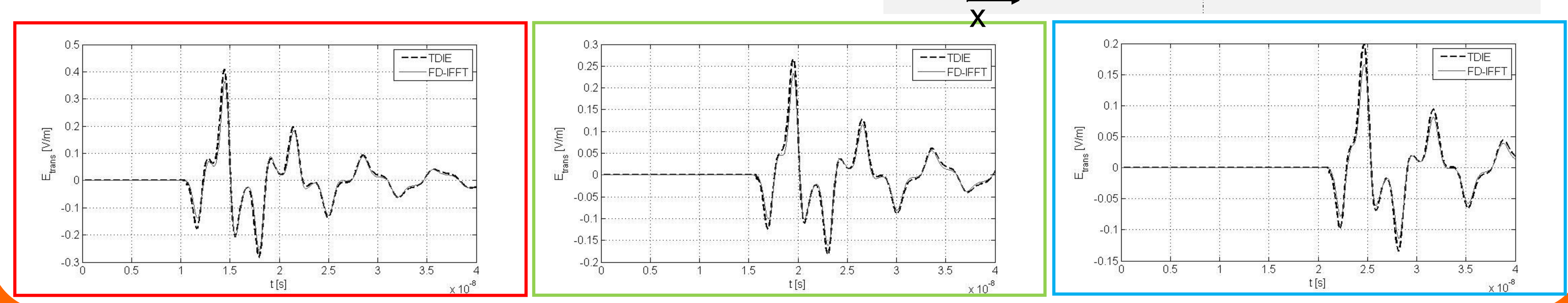
- The current along the axis of **arbitrarly shaped wire** is governed by Pocklington's integro-differential equation in frequency domain. The equation is given for a set of Nw arbitrarly shaped wires.
- The computational example exhibits **four arm folded spherical helical antenna (SHA)** that is used in **wireless power transfer (WPT) applications**.
- The equation is solved by means of **GB-IBEM method** and results are compared with the ones obtained by FEKO. The used method is computationaly less expensive.

GPR dipole antenna above the dielectric halfspace

- The formulation of the problem is based on Pocklington's integro-differential equation in frequency domain **(FD)** and Hallen's space-time integral equation in time domain **(TD).**
- The field transmitted into the ground is calculated for three penetration depths.
- The results obtained by means of **GB-IBEM method** are compared in TD and show good agreement.



** This work was undertaken within framework of EU funded COST Action TU 1208 "Civil Engineering Application of Ground Penetrating Radar".*

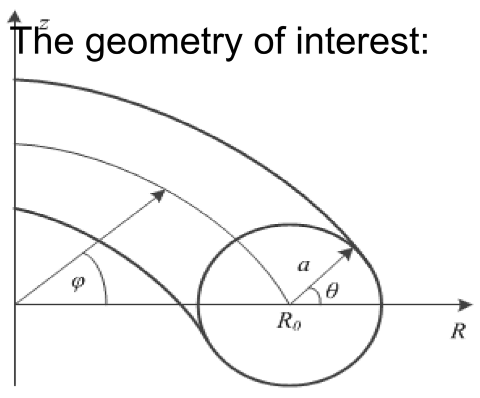


Magnetohydrodynamics and plasma physics

- Group from FESB is part of *EUROfusion Work Package – Code Development (WPCD) project for Integrated Tokamak Modelling (ITM).*
- The main goal of this project is code development for the European Transport Solver (ETS).
- The research group from FESB is working on the implementation of transport solver by using the Galerkin-Bubnov Finite Element Method in Fortran programming language.
- Transport equations for magnetically confined plasmas comprise six differential equations that describe the transport in plasma core. The equations are solved for:
  - poloidal flux (current diffusion equation),
  - electron and ion temperature,
  - electron and ion density,
  - toroidal velocity.

The solutions are functions of toroidal flux coordinate. All the equations take standardised form in order to make implementation generic.

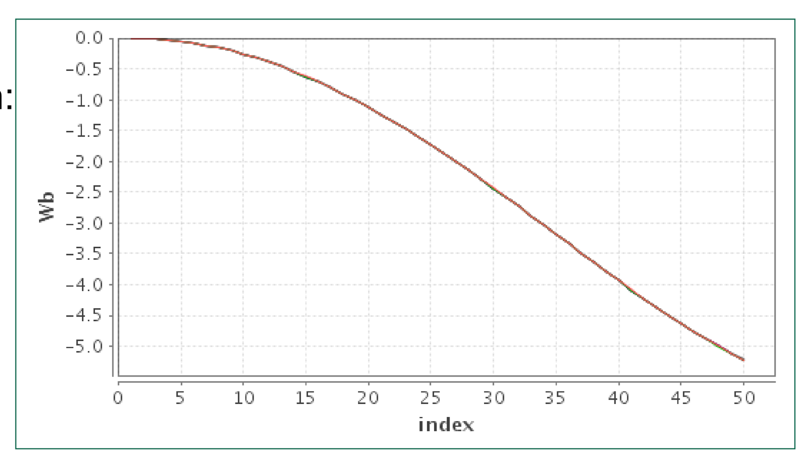
The geometry of interest:



Generalized form of the equations for FEM solver and generic boundary condition:

$$a\cdot c\frac{\partial Y}{\partial t} = -\frac{(a-b)\cdot c}{\Delta t}\cdot Y - (gc+e')\cdot Y + (d'-e)\frac{\partial Y}{\partial x} + d\cdot\frac{\partial^2 Y}{\partial x^2} + fc$$

$$v\cdot\frac{\partial Y}{\partial x}\Big|_{x=1} + u\cdot Y = w$$



Poloidal flux profile

Electron denisty profile