Effects of the Dielectric Properties Changes in Newborn: the Case of the Exposure to an RFID System for Mother-Newborn Identity Reconfirmation

Serena Fiocchi, **Marta Parazzini, Paolo Ravazzani**

CNR Consiglio Nazionale delle Ricerche
Istituto di Ingegneria Biomedica ISIB
Milan, Italy

RFID newborn exposure

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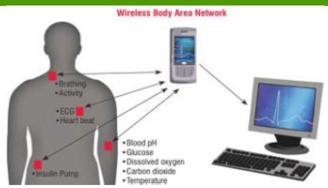

New Technologies in Healthcare

- Radio Frequency Identification (RFID) is a Near Field Communication (NFC) technology to communicate digital information among movable objects, using wireless technology.

- RFID system for Newborn-Mother Identity Reconfirmation, currently used and widespread in the neonatology units based on **reader-tag** communication.

- It's becoming highly diffuse:
  - Automatic newborn-mother match
  - Increase safety and security levels
  - Fast and reliable

RFID: previous findings

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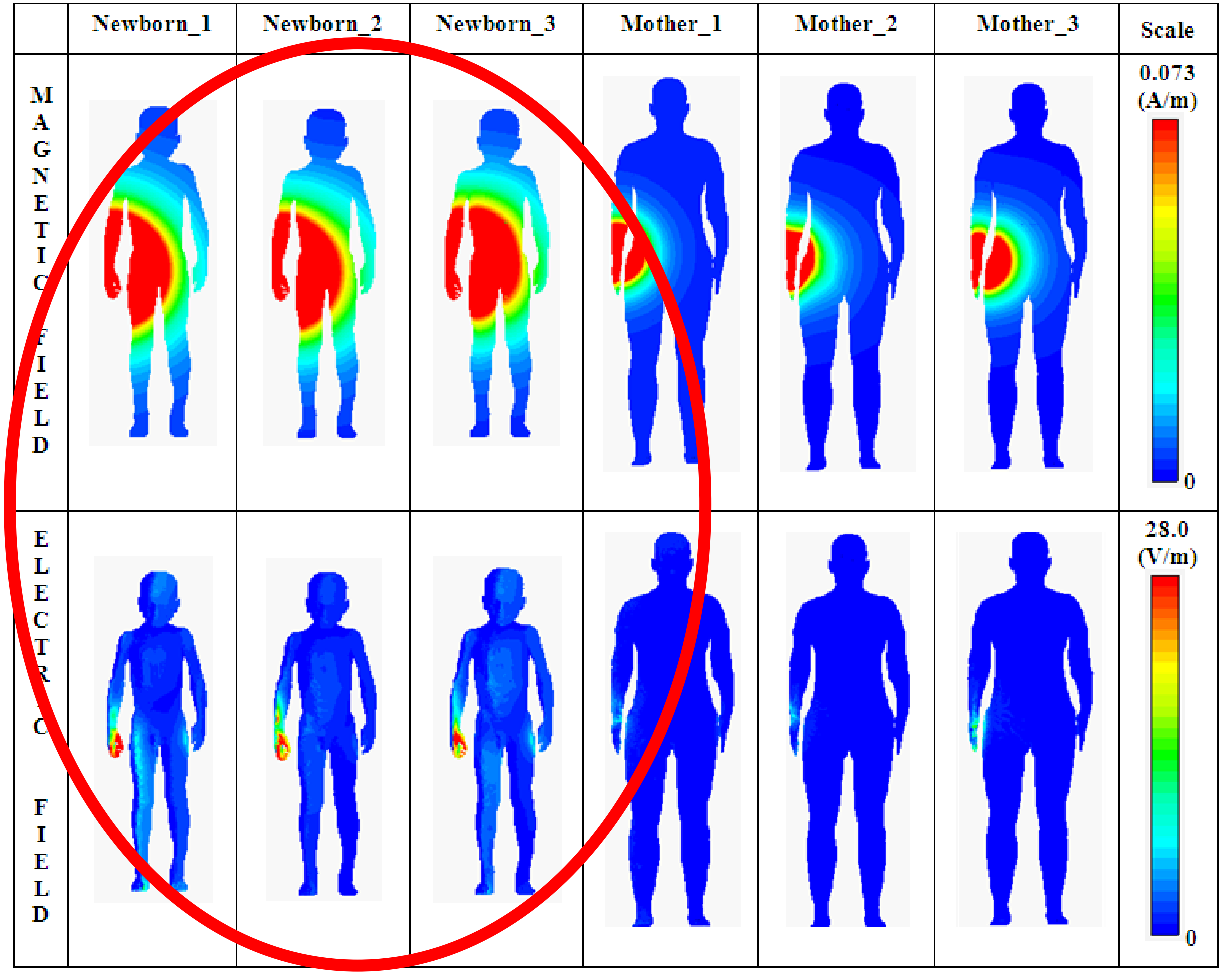


Issues:

1) Newborn model: scaled from a child ("Thelonious")

2) Adult dielectric Properties

Fiocchi S, Parazzini M, Paglialonga A, Ravazzani P. "Computational exposure assessment of electromagnetic fields generated by an RFID system for mother-newborn identity reconfirmation" Bioelectromagnetics. 2011 Feb 15 [Epub ahead of print]

Aims

Exposure assessment of EMFs generated by an RFID system for mother-newborn identity reconfirmation:

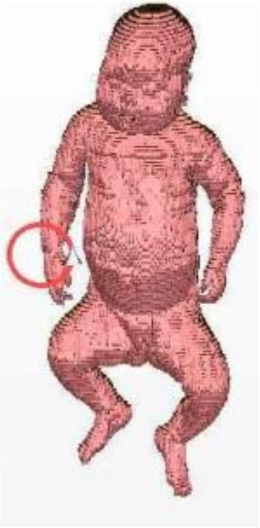
- on a realistic newborn model (1st issue)

- as a function of the variation with age of dielectric properties (2nd issue)

Methods: Exposure scenario

→ RFID reader → modeled as a coil, whose **technical specifications** were derived by commercial devices (DATALOGIC J-Series) used in clinical applications for newborn-mother reconfirmation in Italian hospitals

From datasheet → "average reader"
1 turn circular air coil
R= 3.5 cm
I= 0.308 A
f=13.56 MHz
H_{th}=104 dBμA/m



Tag → passive element, identified according to the reader technical specifications [circular ring of copper Rext=0.15 cm Rint=0.13 cm]

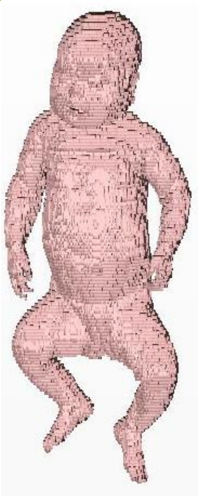
1st issue: Realistic Newborn Model

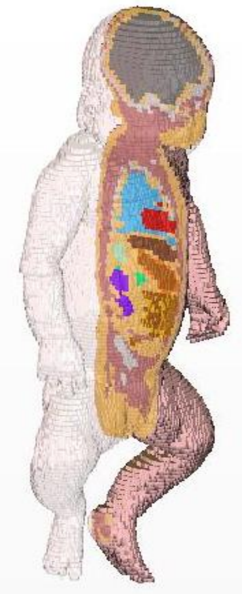
- Newborn model derived from the CST voxel family (CST EM STUDIO by CST GmbH, Darmstadt, Germany)

- “Baby” : 8-week hybrid newborn derived from a female subject (size 57 cm and weight 4.2 kg) based on high resolution magnetic resonance (MR) images segmented in a voxel based format at a resolution of 0.85*0.85*4 mm (made by GSF, Germany)

- 30 tissues (Bone, Brain, Fat, Hearth, Liver, Lung, Muscle, Ovaries, Skin, Testes,….)

- Adult Dielectric Properties (ADP): data set available from Gabriel and colleagues (Gabriel et al., 1996) at 13.56 MHz





Simulations

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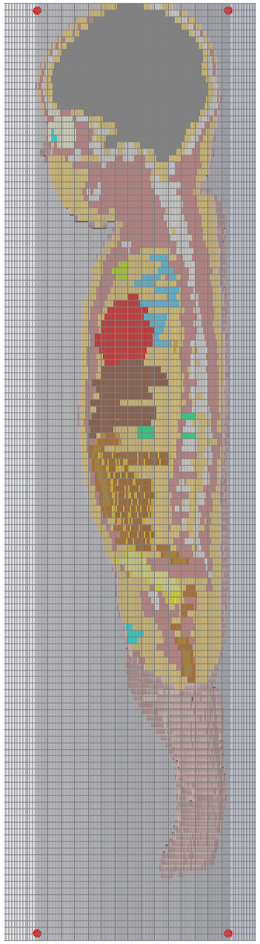
- → Low frequency solver of CST EM STUDIO → finite integration technique (FIT) under magneto-quasi-static approximation



- → Hexahedral mesh = 7.890.372 cells,
- → min resolution = 0.85 mm,
- → max resolution= 4 mm

1st issue: Results_ ICNIRP compliance

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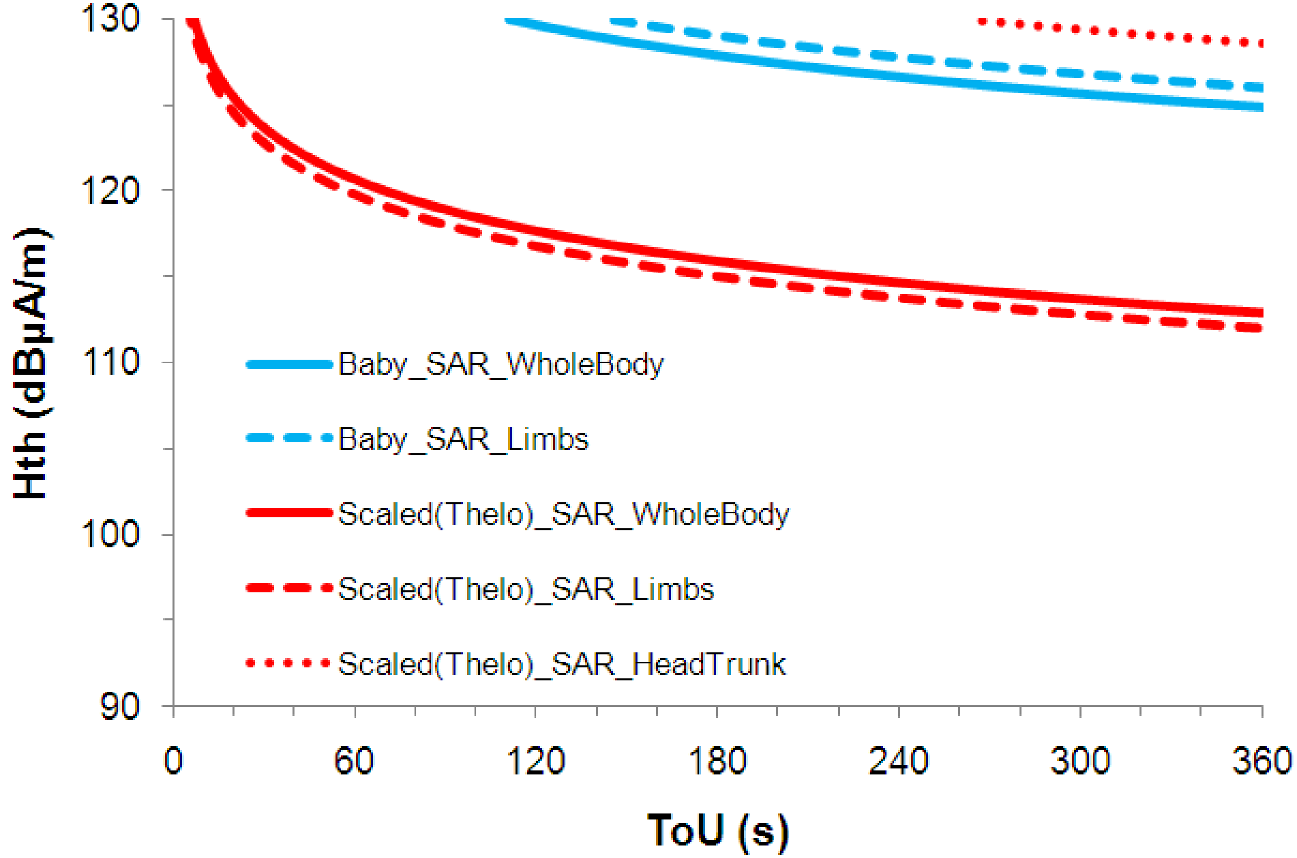

SAR differences between Newborn model (Baby) and scaled model (Thelo):
- -12 db (Whole Body)
- -14 dB (Limbs)

2nd issue: Newborn dielectric properties

Dielectric properties of tissues vary as a function of age

[Dymbylow, 2010; Gabriel, 2005; Keshvari, 2006; Olawale, 2005; Peyman 2001, 2009, 2010; Schmid, 2005; Thurai, 1984, 1985; Wang, 2006;….]

Literature presents a large variety of results about newborn properties in terms of frequency range and child's age

↓

Comparison of a detailed matrix exposure:

- **induced intra-corporal magnetic field**
- **electric field**
- **SAR averaged on different body districts**

between ADP dielectric model and three other newborn dielectric models (WDP, DDP, LDP)

WDP_ Wang Dielectric Properties

- **WDP** (Wang et al., 2006)
- The dielectric properties of body tissues have been recalculated, taking into account the variation with age of the total body water (TBW) content.

$$\dot{\varepsilon_r} = \varepsilon_{rw}^{\frac{\alpha-\alpha_A}{1-\alpha_A}} * \varepsilon_{rA}^{\frac{1-\alpha}{1-\alpha_A}} * \left(1 - j\frac{1}{\omega\tau}\right)$$

$$TBW\left(\frac{ml}{kg}\right) = 784 - 241e^{\left[-\left(\frac{\ln\left(\frac{Age}{55}\right)}{6.9589}\right)^2\right]}$$

ε_r = complex relative permittivity of a biological tissue,
ε_{rw} =relative permittivity of water ,
ε_{rA} = adult relative permittivity of the organic material considered (ADP approach)
α = the hydrated rate related to mass density ρ and TBW by $\alpha = \rho \cdot TBW$
α_A= adult hydrated rate 543 ml/kg for adult)
Age= age in years (in this study 8 weeks=0.15 years)

- Once calculated the complex relative permittivity of each tissue, the product $\varepsilon_{rw}^{\frac{\alpha-\alpha_A}{1-\alpha_A}} * \varepsilon_{rA}^{\frac{1-\alpha}{1-\alpha_A}}$ represent the relative permittivity ε_r and the conductivity σ is derived from τ as $\sigma = \varepsilon_0 \varepsilon_r / \tau$.

DDP_Dymbylow Dielectric Properties

- **DDP** [Dimbylow et al., 2010]
- Calculation of the ratios between the dielectric properties of newborn rat and adult rat (data from Peyman et al., 2001)
- These ratios were then used to multiply the Gabriel adult's properties values (ADP approach) at 13.56 MHz to compute the corresponding newborn's dielectric properties.
- newborn tissues classified in four classes:

Class	σ multiplier	ε multiplier
Bone	3.9	2.2
Skin	2.2	1.9
Soft Tussues	1.5	1.25
Liquid*	1.0	1.0

* whose properties would not change with age (e.g. blood, CSF, gallbladder bile, vitreous humor)

LDP_Literature Dielectric Properties

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- **LDP**
- Estimation of multipliers (similar to DDP approach)

Literature reviewing (Thurai et al., 1984; Thurai et al., 1985; Lu et al., 1996; Peyman 2001; Peyman 2003; Gabriel 2005; Schmid 2005; Peyman 2007; Peyman 2009)

↓

Multipliers for each tissue ($M_{tissue,frequency}$)
Es. $M_{brain,20} = LDP_{brain,20} / ADP_{brain,20}$

→

✓In case of **more than one multiplier** for a single tissue, the M_{tissue} nearest to the frequency used (13.56) were selected

✓ in case of **unavailability of data** for a tissue: $M_{tissue} = 1$.

↓

$$\boldsymbol{Die\_Prop_{tissue,13.56} = M_{tissue} * ADP_{tissue,13.56}}$$
Es. $Die\_Prop_{brain,13.56} = M_{brain} * ADP_{brain,13.56}$

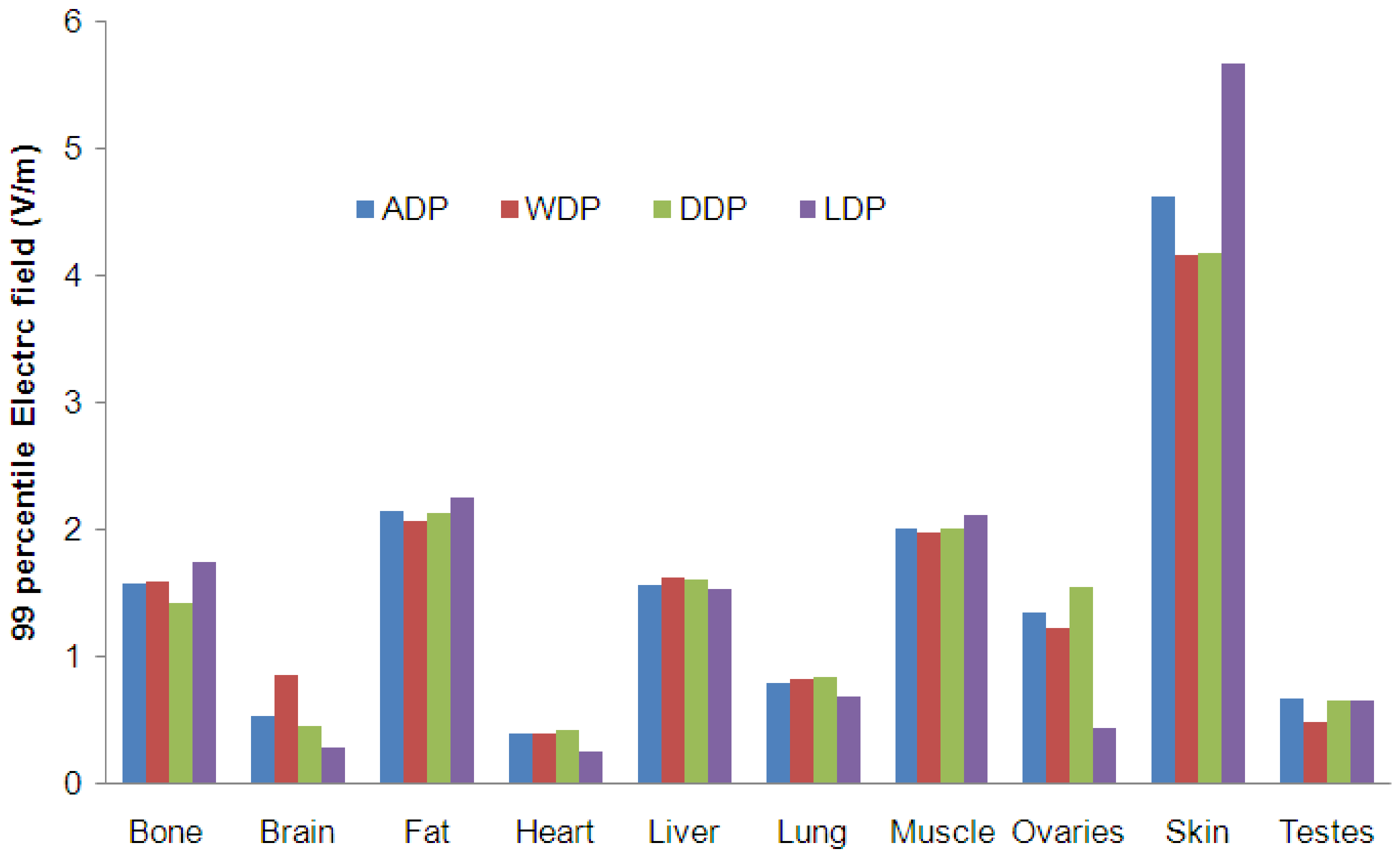
2nd issue: Newborn Dielectric Properties

Conductivity Percentage differences between ADP and the others approaches

	Diff% (WDP-ADP)	Diff% (DDP-ADP)	Diff% (LDP-ADP)
Bone	161.3	290.0	291.3
Brain	-26.3	50.0	23.0
Fat	50.5	50.0	260.0
Heart	-30.3	50.0	-42.2
Liver	-22.3	50.0	-17.9
Lung	-6.9	50.0	99.6
Muscle	-16.9	50.0	0.5
Ovaries	-30.7	50.0	0.0
Skin	-36.6	120.0	21.5
Testes	-34.9	50.0	0.0

2nd issue:Results_Electric Field

Mean difference among mean ADP and mean:
- WDP= +1.8 %
- DDP= -0.8 %
- LDP= -12.4 %



Max difference among mean ADP and mean:
- WDP= +61.7 % (brain)
- DDP=+14.1 % (ovaries)
- LDP= -67.8 % (ovaries)

2nd issue:Results_ICNIRP compliance

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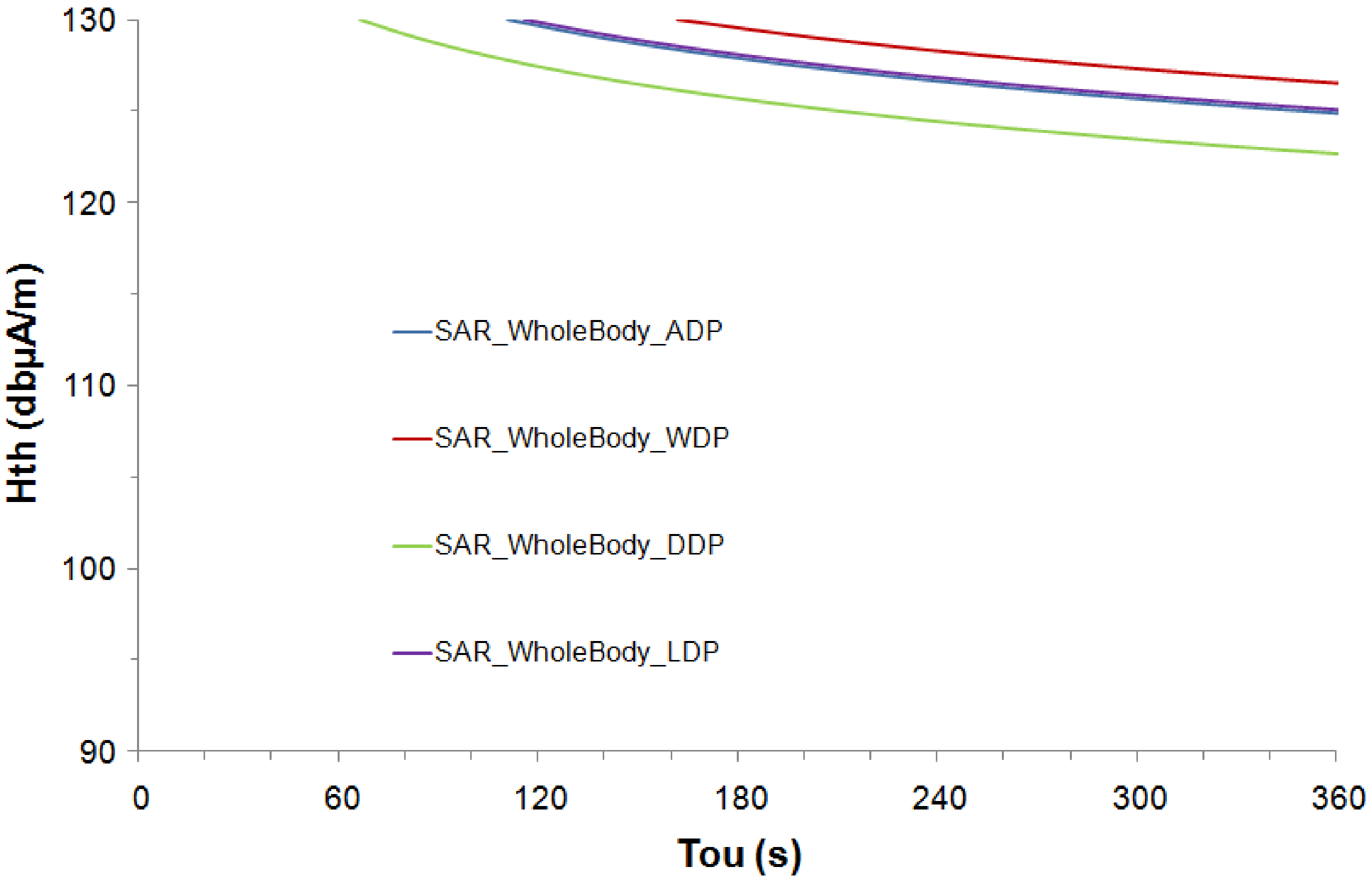
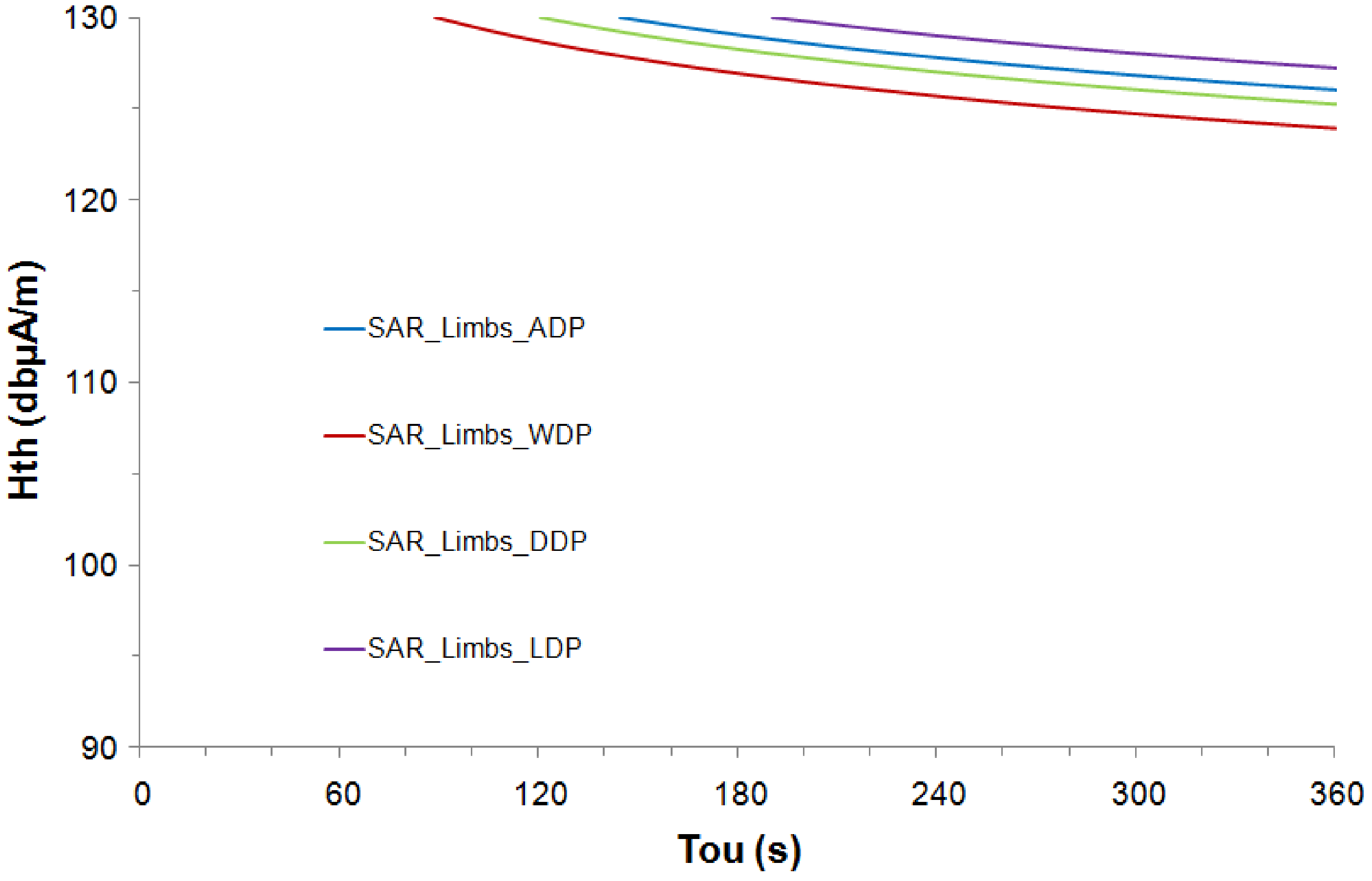


SAR whole body levels difference between ADP and:

- **WDP (-1.65 dB)**
- **DDP (+2.21 dB)**
- **LDP (-0.19 dB)**

2nd issue:Results_ICNIRP compliance



SAR limbs levels difference between ADP and:

- **WDP (+2.11 dB)**
- **DDP (+0.78 dB)**
- **LDP (-1.21dB)**

Conclusions

Exposure Assessment for RFID newborn identification

- 1st issue: Comparison between Scaled Model (Thelonious) and Realistic Newborn Model (Baby)
  - Extremely higher EMFs and SAR levels obtained with the Scaled Model (Thelo)
  - Newborn in compliance at higher Hth and ToU

- 2nd issue: Comparison between dielectric models
  - Large variability in EMFs and SAR levels across models
  - Compliance as a function of the model

A further open issue:

identification of the best dielectric properties for newborn

Thank you for your attention!

Dr. Serena Fiocchi
Istituto di Ingegneria Biomedica
Consiglio Nazionale delle Ricerche,
Milano (Italy)

Phone: +39 (02) 23993344
Mobile: +39 (349) 1622576
Fax: +39 (02) 23993367

Email: serena.fiocchi@polimi.it
Website: http://www.isib.cnr.it