Near-field Occupational Exposure in FM Transmission Pylons

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Introduction

- Occupational exposure is monitored when workers climb transmission pylons in order to do maintenance work
- ICNIRP recommended limits are made of basic restrictions and reference levels
- Basic restrictions define whole-body and local specific absorption rate (SAR) limits
- Compliance to reference levels guarantees a compliant whole-body SAR, but not applicable to local SAR compliance
- Is there a relationship between maximum local SAR and maximum field strength?

Specific absorption rate (SAR)

- SAR is the absorbed energy by the human body when exposed to a an electromagnetic field. SAR is defined on the entire human body or locally on 10 g of human tissues

$$SAR = \frac{\sigma E^2}{2\rho}$$

E is the electric field in V/m.
ρ is the tissue density in kg/m^3.
σ is the electric conductivity in S/m.

- SAR cannot be measured on-site, must be computed.

Near-field exposure: previous studies

- Most of the studies were conducted using plane waves, but on-site exposure is not uniform
- Plane waves studies do not reflect near-field environments
- Real cases studies are too specific and cannot be generalized
- Previous studies can't provide a rule on electric field value that guarantees a local SAR under the limit
- Those studies must be generalized to all exposure cases that can be encountered.

Method

1. Pylons fields simulation
   Real cases of transmission pylons were modeled with high details and EMF occurring inside pylons can be analyzed to assess exposure

2. Fields generation
   Generate random near fields similar to those encountered inside pylons

3. Fields characterization & discrimination using human volumes
   Assess near-fields in a human-sized volumes and retain volumes with similar characteristics to pylons

4. Local SAR computation using FDTD
5. Find a relationship between local SAR and maximum field strength

Pylons' fields simulation

- 50 real transmission pylons were modeled with high details using CST
- Electromagnetic fields inside pylons were computed
- Human sized volumes slide inside pylons and assess fields by measuring the following physical quantities ➔ Human vector ($Hvect$)

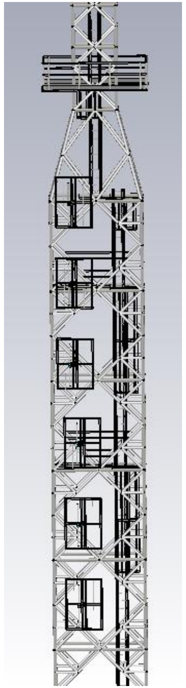
$$HVect = \left[\frac{<|E|>}{\max(|E|)} ; \frac{<|E|>}{<|H|>} ; <angles>; <concentration\ around\ \max(|E|)>\right]$$

$<|E|>$: electric field averaged over a human volume

$<|H|>$: magnetic volume averaged over a human volume

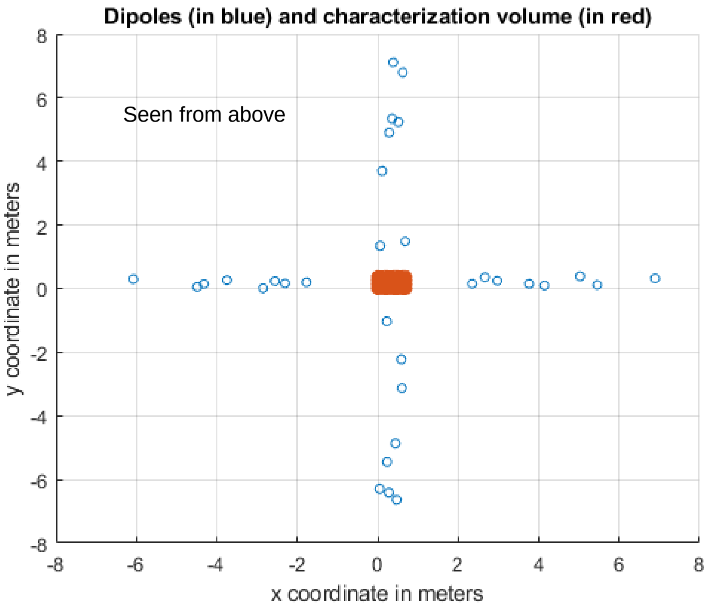
$<Angles>$: angles formed between electric and magnetic fields

$<Concentration>$: averaged distances between maximum field location and fields values 90 % under the maximum

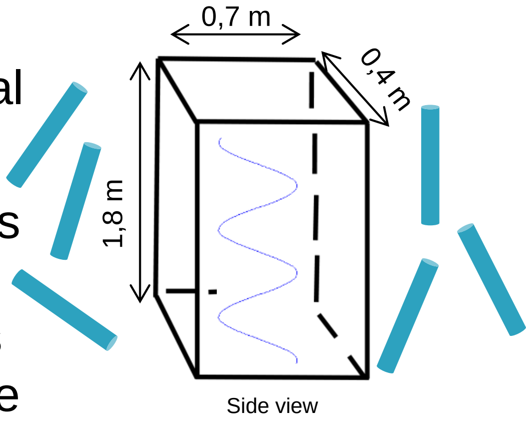


Tower with FM transmitters

Fields' generation

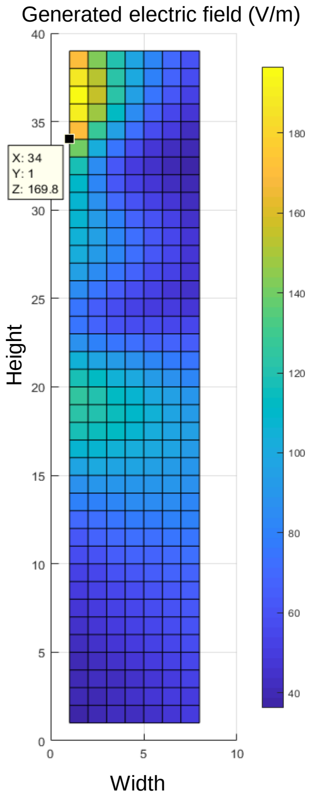


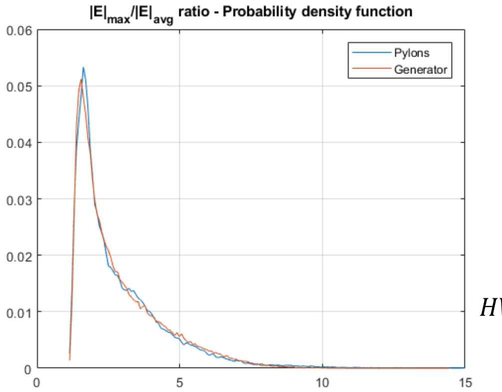
- A near-field generator was developed using infinitesimal dipoles
- Each dipole offers 7 degrees of freedom
  Dipole position (coordinates x, y and z), amplitude, phase shift and 2 orientation angles
- Inputs are set randomly to generate fields

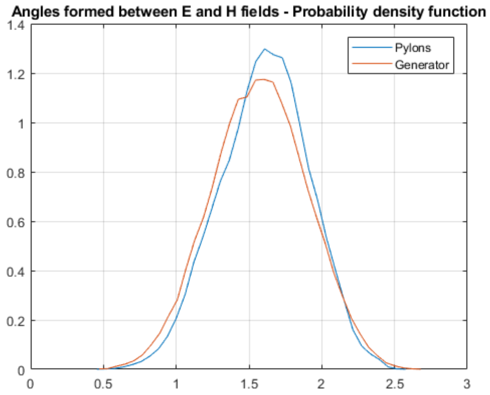


Fields' characterization & discrimination

One division is 5 cm







- Probability density function of $Hvects$ from the near-field generator are computed and compared to $Hvects$ coming from pylons

$$HVect = \left[\frac{<|E|>}{\max(|E|)} ; \frac{<|E|>}{<|H|>} ; < angles >; < concentration\ around\ \max(|E|) > \right]$$

- Statistical tests (Jensen-Shannon divergence & Kolmogorov-Smirnov test) enable us to find the best fitting $Hvects$ distribution, therefore the best generator inputs

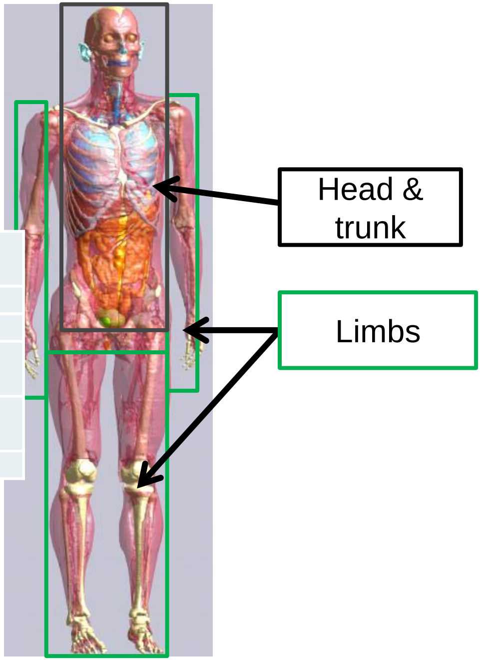
Local SAR calculation

- Human model used: « Duke »

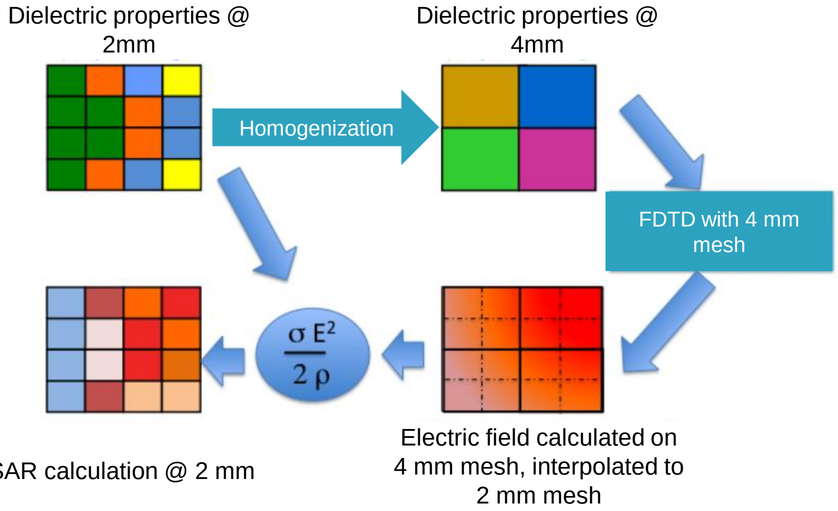
Age: 34 yrs
Height: 1,77 m
Weight: 70,2 kg
No of tissues: 47

Tissue	Conductivity σ	Density ρ
Air (vide)	0	0
Blood	1,23	1060
Veins	0,46	1060
Spinal fluid	0,02	1038
Skin	0,49	1100

$$SAR = \frac{\sigma E^2}{2\rho}$$



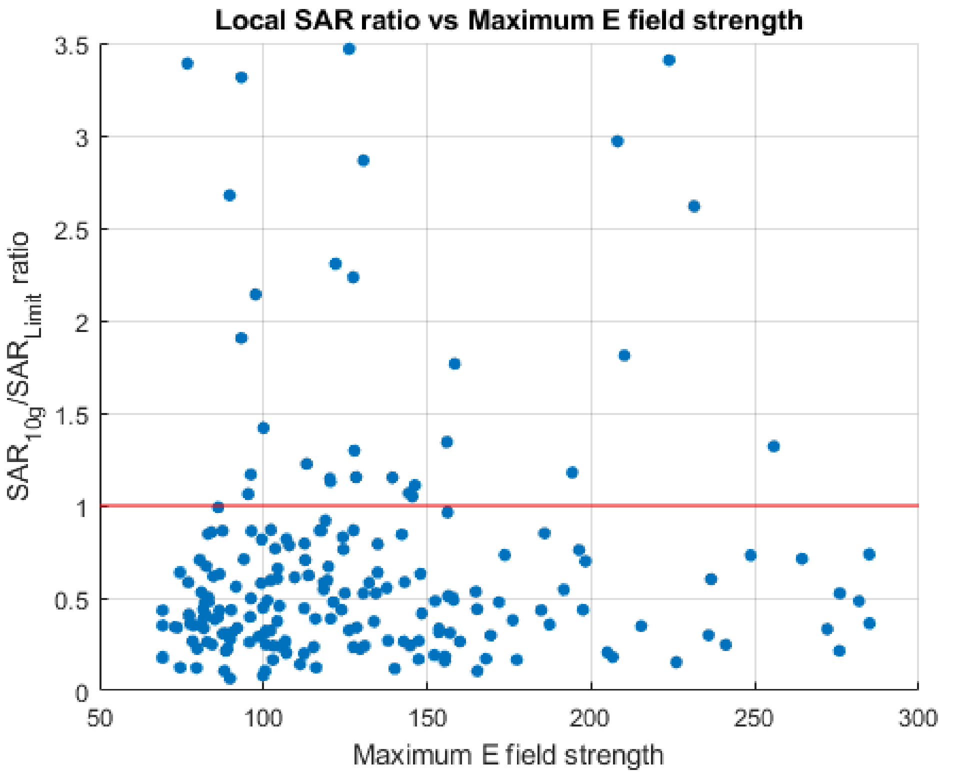
- SAR simulations require 1 mm or 2 mm resolution, 192 hrs per simulation at 100 MHz
- To circumvent this limitation, we use a tissues homogenization technique



- SAR simulations duration go from 192 to 12 hrs
Trade-off: 8% error on electric field strength.

Local SAR calculation results

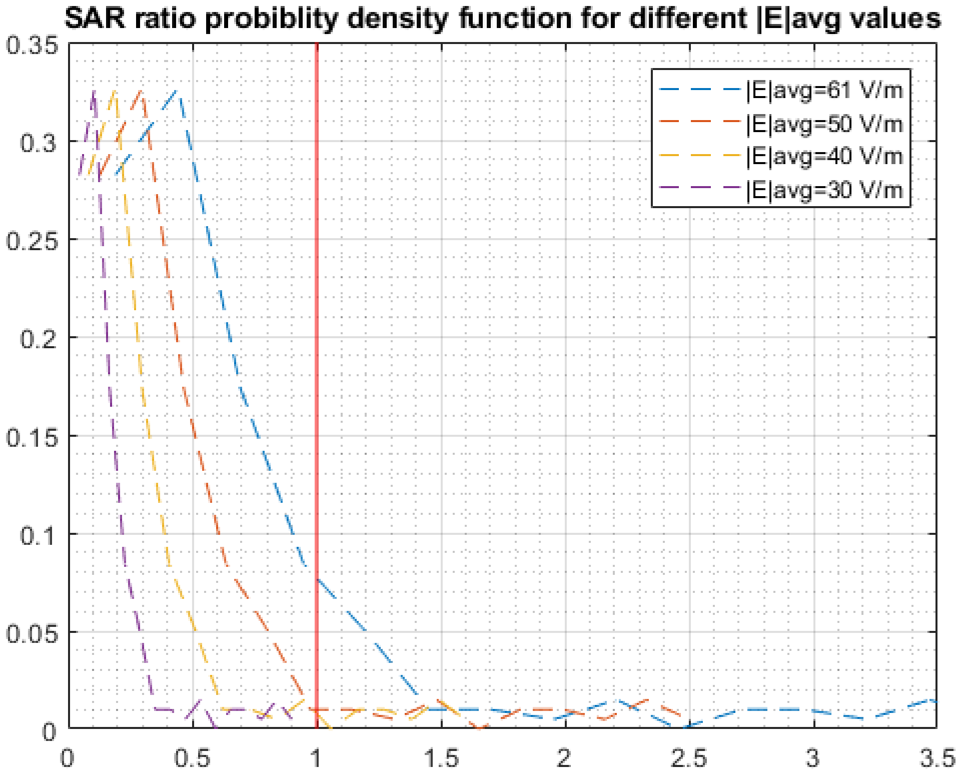
- Near fields are randomly selected after fields' discrimination for local SAR calculation. 500 simulations were performed.
- Local SAR ratio ($\frac{local\ SAR}{local\ SAR\ limit}$) vs maximum E field shows different local SAR values for same E field values. Averaged E field is 61 V/m in all cases.
- Red line represents the $k = 1$ threshold where local SAR is over the limit.
- Correlation between local SAR and max E field is 35 %



Local SAR distribution results

- Graph shows local SAR ratio ($\frac{local\ SAR}{local\ SAR\ limit}$) probability density function for 500 cases.
- Red line represents the $k = 1$ threshold. $k > 1$ means local SAR is over the limit.
- E field averaged over the equivalent volume of the body normalized to different values.

Averaged E field	Percentage of cases with $k < 1$
61 V/m	86 %
50 V/m	93 %
40 V/m	96 %
30 V/m	100 %



Local SAR and maximum E field relationship: conclusion

- A method is implemented to generalize and analyze EMF in near-field
- 500 local SAR simulations were performed & simulations are still ongoing
- The relationship between maximum local SAR and maximum E field in near field is yet to be defined.

Thank you