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Exposure analysis to multiple plane waves

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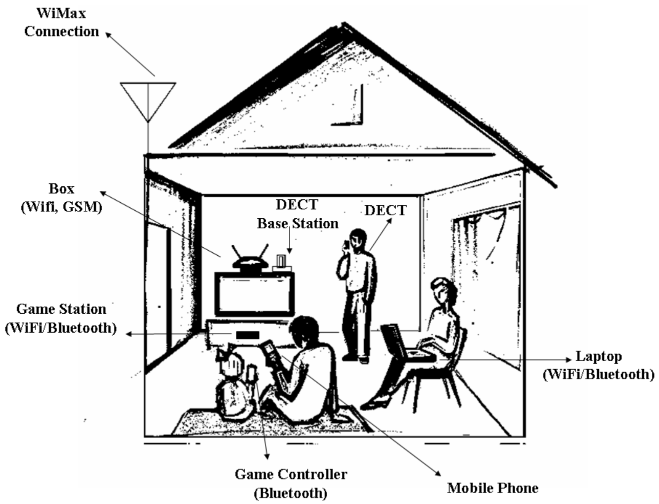
recherche & développement

Summary

- General context
- Problematic
- Multiple plane waves exposure assessment
- Results and discussion
- Conclusion

General context

- With enhancement of wireless telecommunication (WIFI, cells phones etc..) exposure to electromagnetic waves has became a public debate



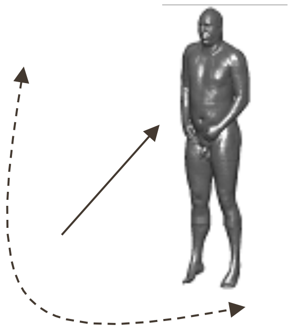
❑ **Exposure assessment is a key question in many countries espicially in France**

❑ **Most of the investigations have been performed to single plane wave exposure but there was a lack of information on multiwaves exposure**

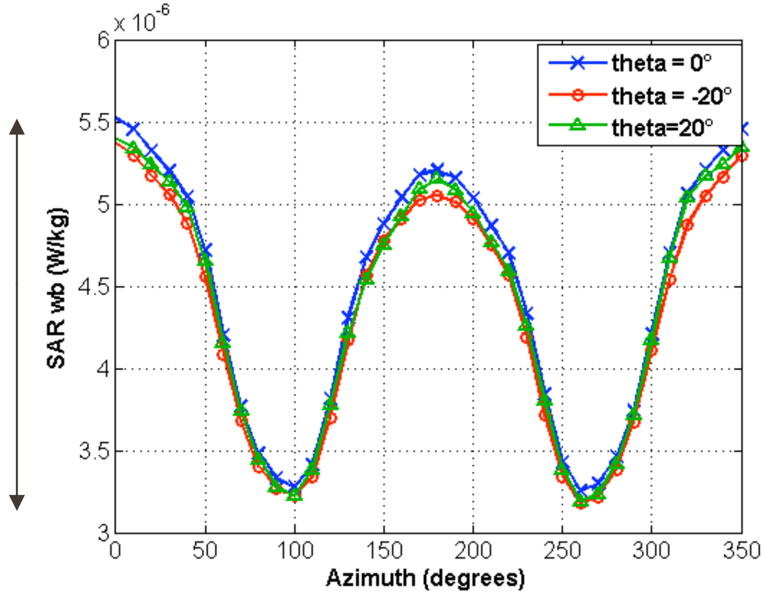
Plane wave exposure assessment

Conil[2007 and 2008] Studied influence of arrival angle(θ,φ) in the case of single plane wave exposure

SAR= $\frac{\sigma E2}{2\rho}$

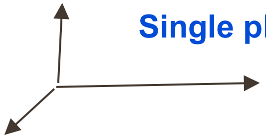


50%

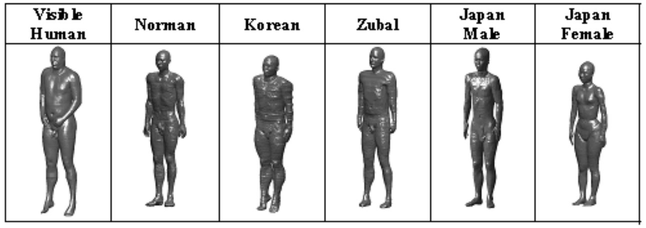


Influence of morphology

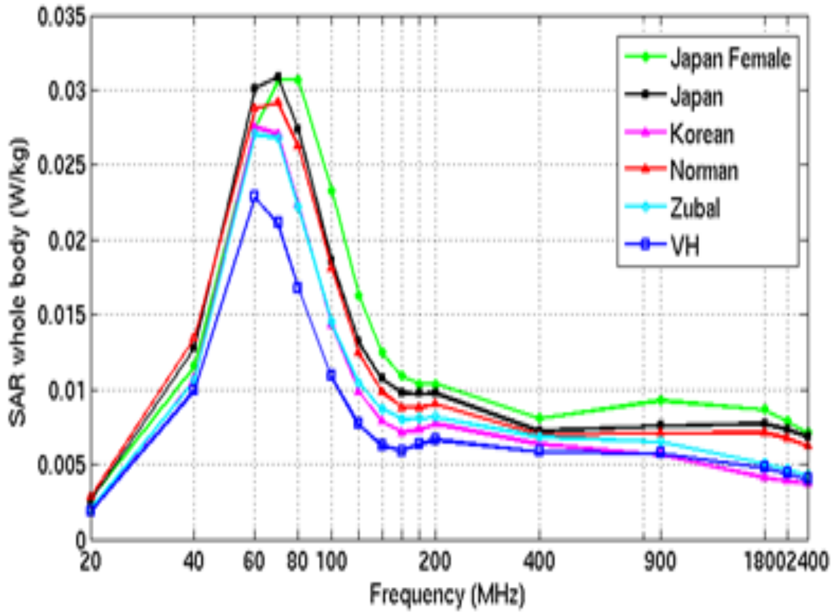
Conil studied influence of the morphology on the Specific absorption rate in the case of single plane wave exposure



Single plane wave exposure



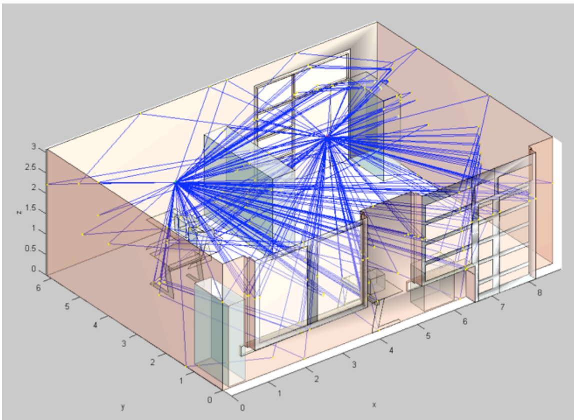
six different phantoms



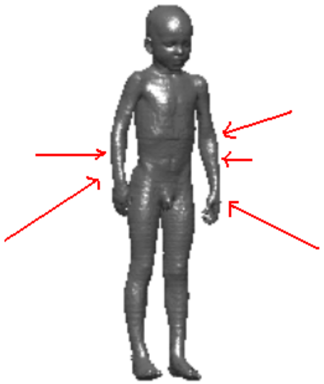
Multi-plane waves problematic

- In reality, the fields are coming from all direction due to reflections and diffractions. This field is affected by fast fading. The fast fading is induced by the recombination in phase of waves coming from everywhere with random phase

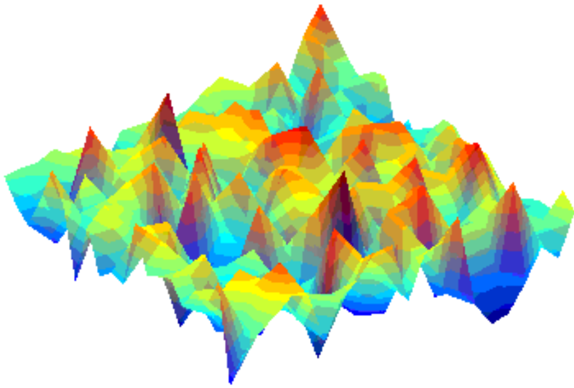
- How assess exposure of a person who moves in a realistic environment



Indoor exposure



Phantom exposure to multiple plane waves



Fading phenomenon

Parameters influencing multi-plane waves exposure

The incident electric field can be modelled by a sum of plane waves coming from different directions with different phases and amplitudes

$$E_{inc}(r)=\sum_{n=1}^{Ninc} E_{inc,n}\exp(i\,\alpha_{inc,n}-ik_{inc,n}.r)\,u_{Einc,n}$$

Number of rays ($Ninc$) — Electric field strength ($E_{inc,n}$) — phase ($\alpha_{inc,n}$) — Wave vector ($k_{inc,n}$)

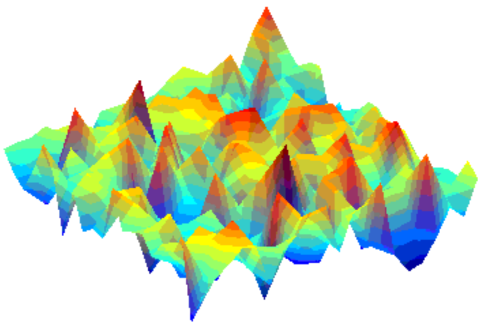
❑ The field parameters must be defined:

- The waves are coming coherent (spatially and temporally) or not
- The numbers of rays (Ninc)
- The amplitude of rays(Einc,n)
- The arrival angles azimuth and elevation(φ and θ)
- The phase of waves(α)

For this study all the rays have vertical polarization and elevation angle of 90°

Compare a plane wave exposure with multi plane waves

In a realistic environment with multi plane waves, we confront to variable electromagnetic field due to fast fading



To ensure to compare exposure of single plane wave to multiple plane waves we normalize the whole body SAR →

$$Normalized\_SAR = \frac{SAR}{(rms\_E)^2}$$

Normalization

If we consider all the space where the field is spread, by a analytic calculation we have the solution

$$E_{inc}(r) = \sum_{n=1}^{Ninc} E_{inc,n} \exp(i\,\alpha_{inc,n} - ik_{inc,n}.r)\,u_{Einc,n}$$

For 2 waves: $I = \left\langle E\ E^{*} \right\rangle = (E_1 + E_2)(E_1 + E_2)^{*} = E_1^2 + E_2^2 + 2\,\mathrm{Re}(\left\langle E_1 E_2^{*} \right\rangle)$

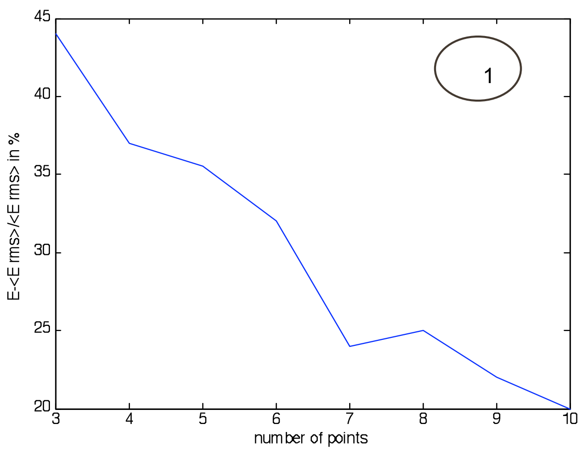
limit is zero

For n waves: $E\_rms = \sqrt{\sum_{i=1}^{n} E_{inc,i}^{2}}$

E (root mean sqare) for two numerical method:

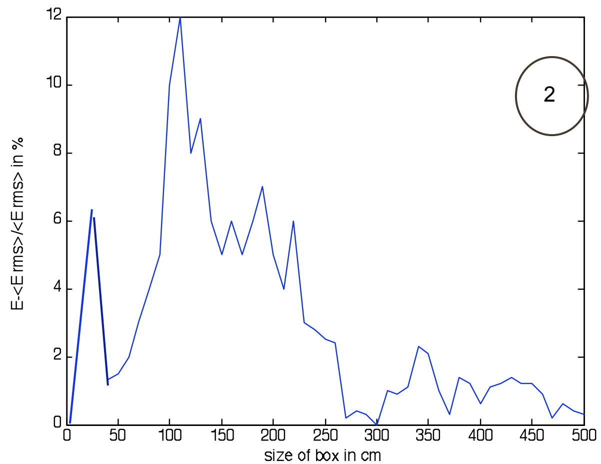
- **Considere many points having a distance of λ/2 in the box assumed not correlate and then have a statistical approach**
- **To calculate a Riemman integral**

(For those two methods we obtained the same numerical results)



We must take more than 20 points to estimate a good value of E rms. For 10 points we have 20% of error on the estimation of E rms

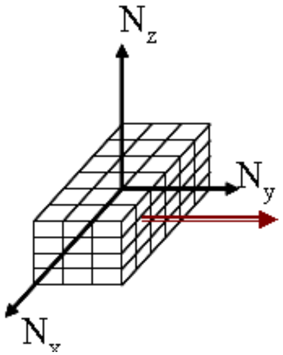
Influence of the box size in the E_rms calculation

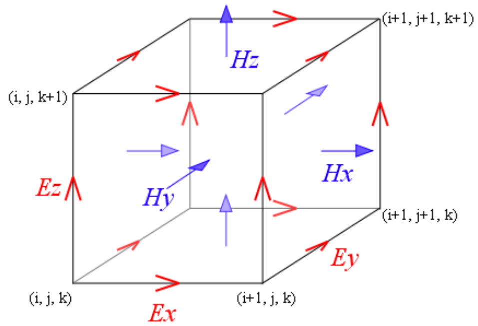


Numerical tools

FDTD (Finite Difference in Time Domain) method:

The FDTD is a numerical method to resolve the maxwell equations by the method of finite difference time domain.

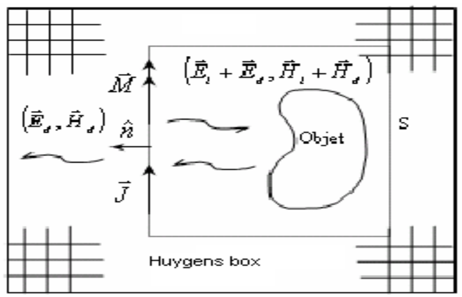




YEE cell

Huygens Box principle:

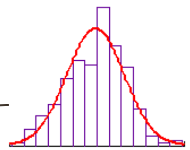
Maxwell equations say that it is possible to reconstruct the field inside a close volume. In the presence of object we have inside the Huygens Box the total field (Et+Es) and outter the Huygens Box the scattered field(Ed); incident E field is null.



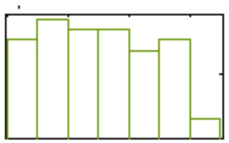
Analysis exposure to multi plane waves

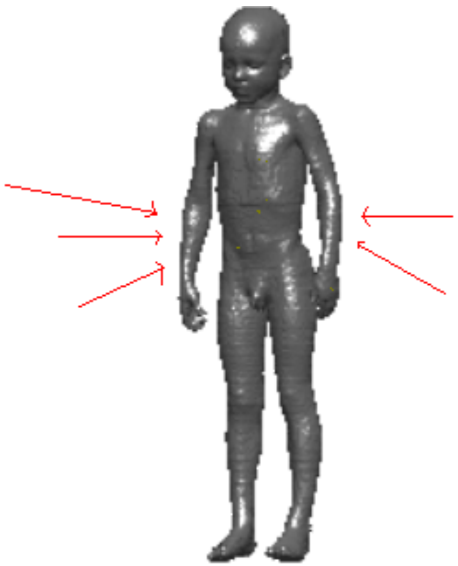
We consider an exposure to 5 rays

Amplitude of rays has a normal distribution



azimutal angle(φ) and phase(α) have a uniform distribution between [0,2pi]





Theloniouss

Weight=19kg

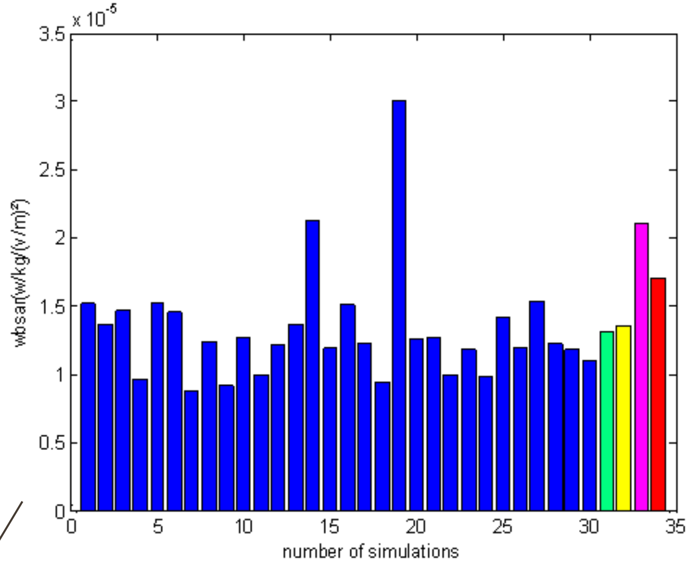
Size=1.19m

6 years

For this study all the rays have vertical polarization and elevation angle of 90°

Discussions

Results of WBSAR →

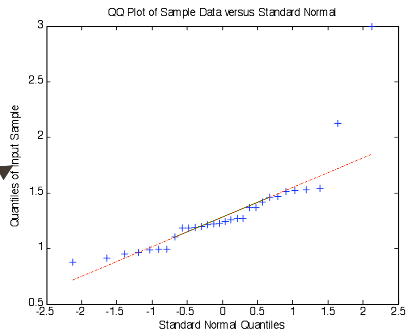


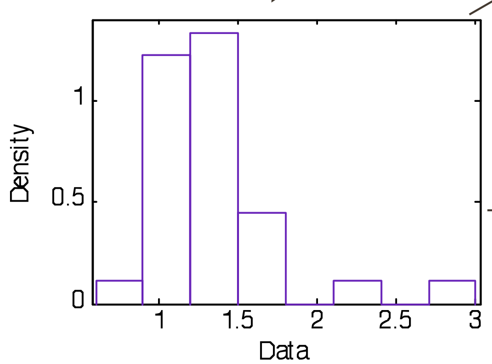
Mean value of wbsar

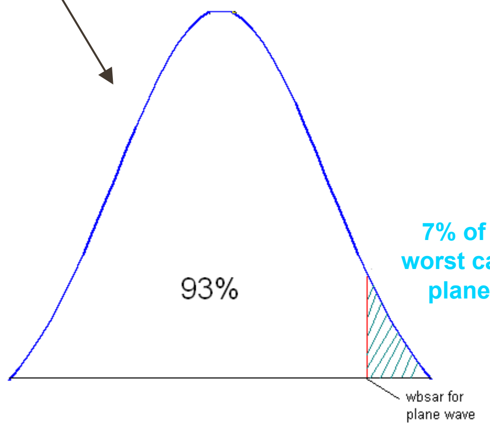
Wbsar Percentile(66%)

Wbsar Percentile(95%)

Wbsar for single plane wave exposure

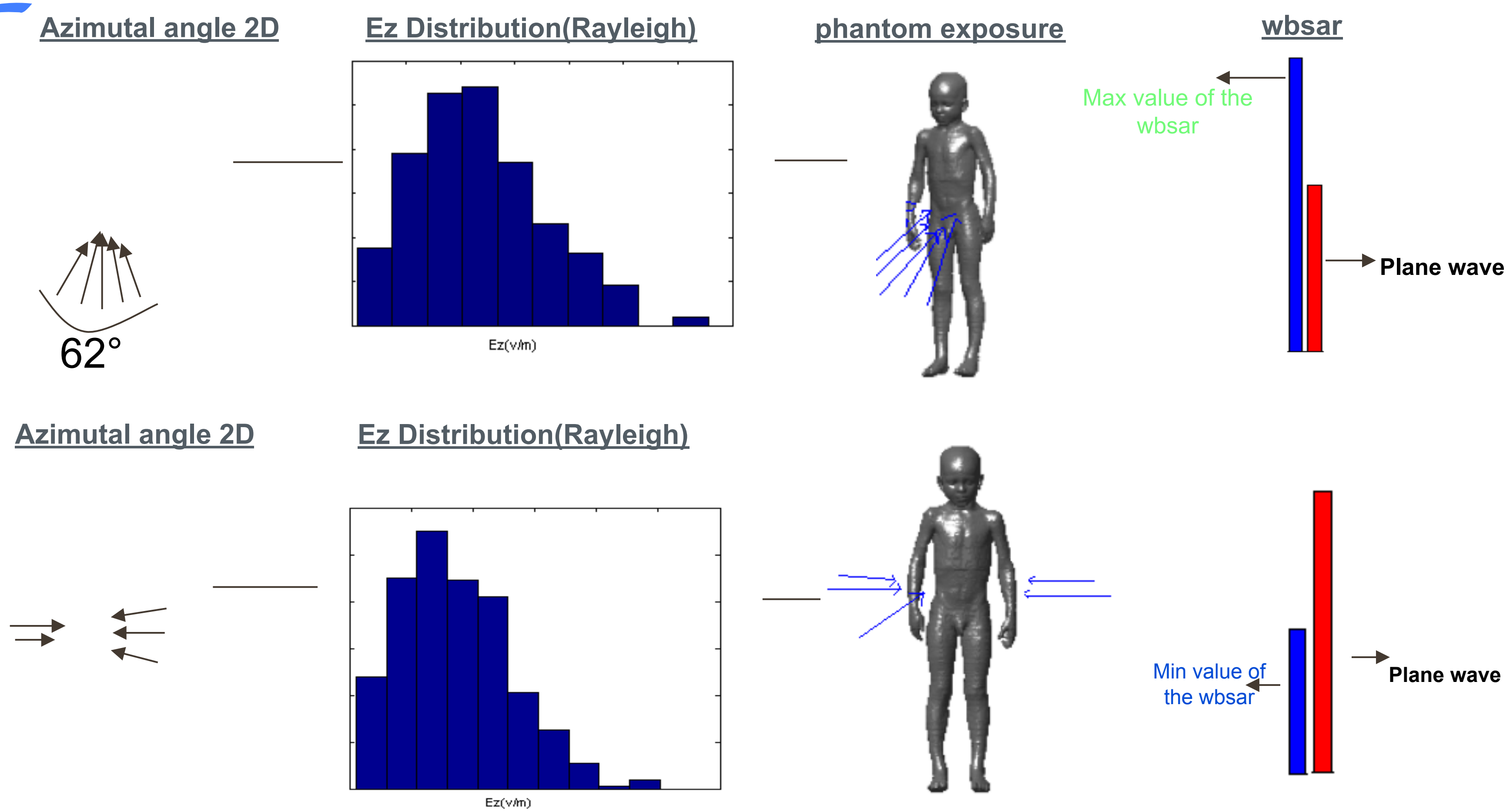






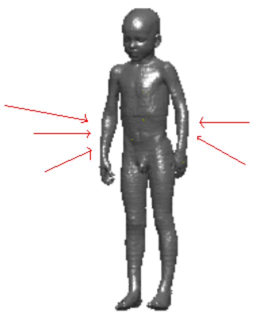
7% of cases represent worst case exposure than plane wave exposure

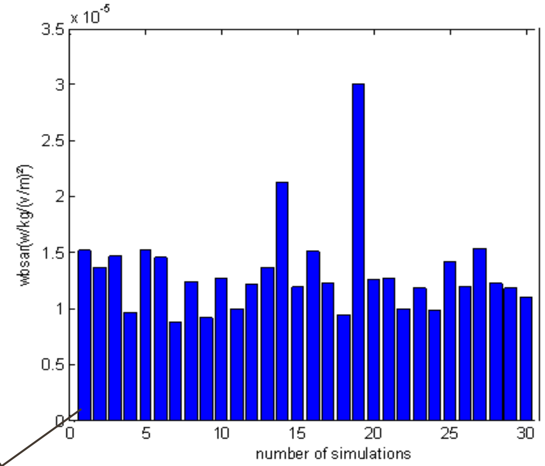
Specific case of exposure

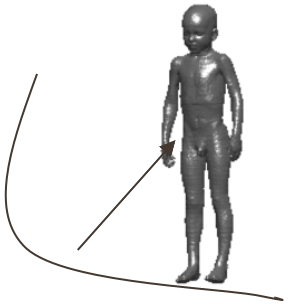


Two different configurations of azimutal angles ,same distribution of E(z) field in the space but results of wbsar very different for each exposure case.

Analyze the wbsar results

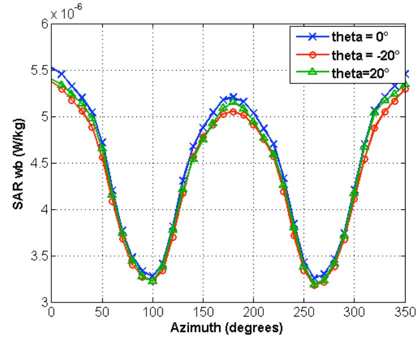






$SAR_{wb} \approx$

Cf emmanuelle Conil[2008]



$(A_i, \varphi_i)_{i=1,..5}$

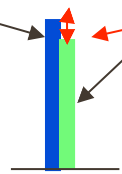
Ai(v/m)	φi
0.6	357°
0.23	207°
1.2	81°
0.7	340°
0.9	292°

One case of exposure

For three simulations we assessed a <α>_mean

$SAR_{wb}(A_i, \varphi_i) \approx \langle\alpha\rangle . \textit{surface\_highlighted}(\varphi_i)$

$$SAR_{wb}\left(\sum_{i=1}^{5}(A_i, \varphi_i)\right)_1 = \sum_{i=1}^{5} SAR_{wb}(A_i, \varphi_i)_1 + \varepsilon_1$$

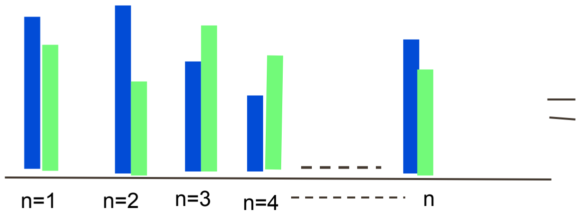


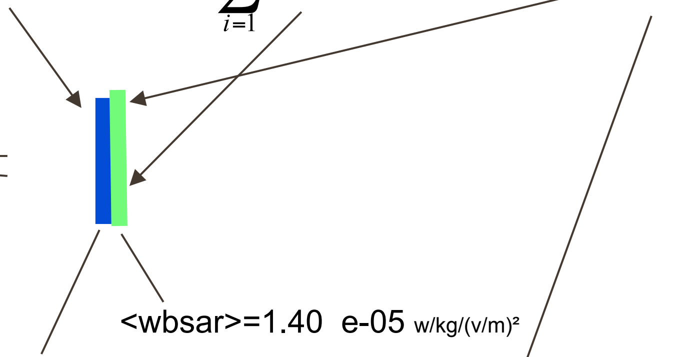
ε_1 represent an deviation of 15%

Discussions

We perform for all cases of exposure

$$< SAR_{wb}\Big(\sum_{i=1}^{5}(A_i,\varphi_i)\Big) >_n = < \sum_{i=1}^{5} SAR_{wb}(A_i,\varphi_i) >_n + < \varepsilon >_n$$





Results for all cases of exposure

<wbsar>=1.31 e-05 w/kg/(v/m)²

Epsilon mean is 0.06

<SAR(∑(A,φ))>

Std wbsar=4 e-006 w/kg(v/m)²

<wbsar>=1.31e-05 w/kg(v/m)²

<∑SAR(A,φ)>

Std wbsar=2.42 e-006 w/kg(v/m)²

<wbsar>=1.40 e-05 w/kg(v/m)²

Conclusion & Perspectives

- Ponctually the impact of fading can be important on WBSAR but it's possible to assess the multiple exposure aproximatively thanks to single plane waves exposure

- Perform other simulations to improve assessment of α

- Investigate other configurations of exposure for different parameters of incident field

- Perform with other phantoms