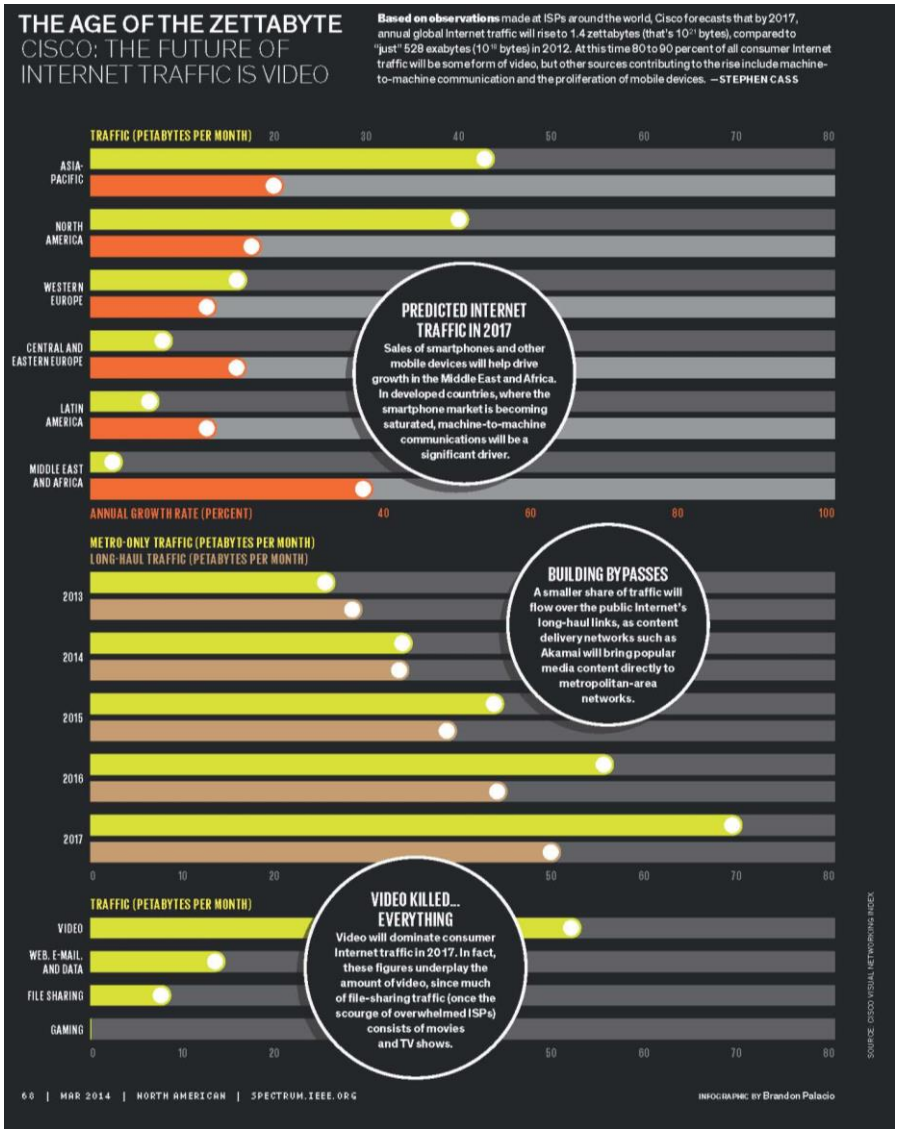
Μέθοδοι εκτίμησης της έκθεσης σε μη-ιοντίζουσα ακτινοβολία

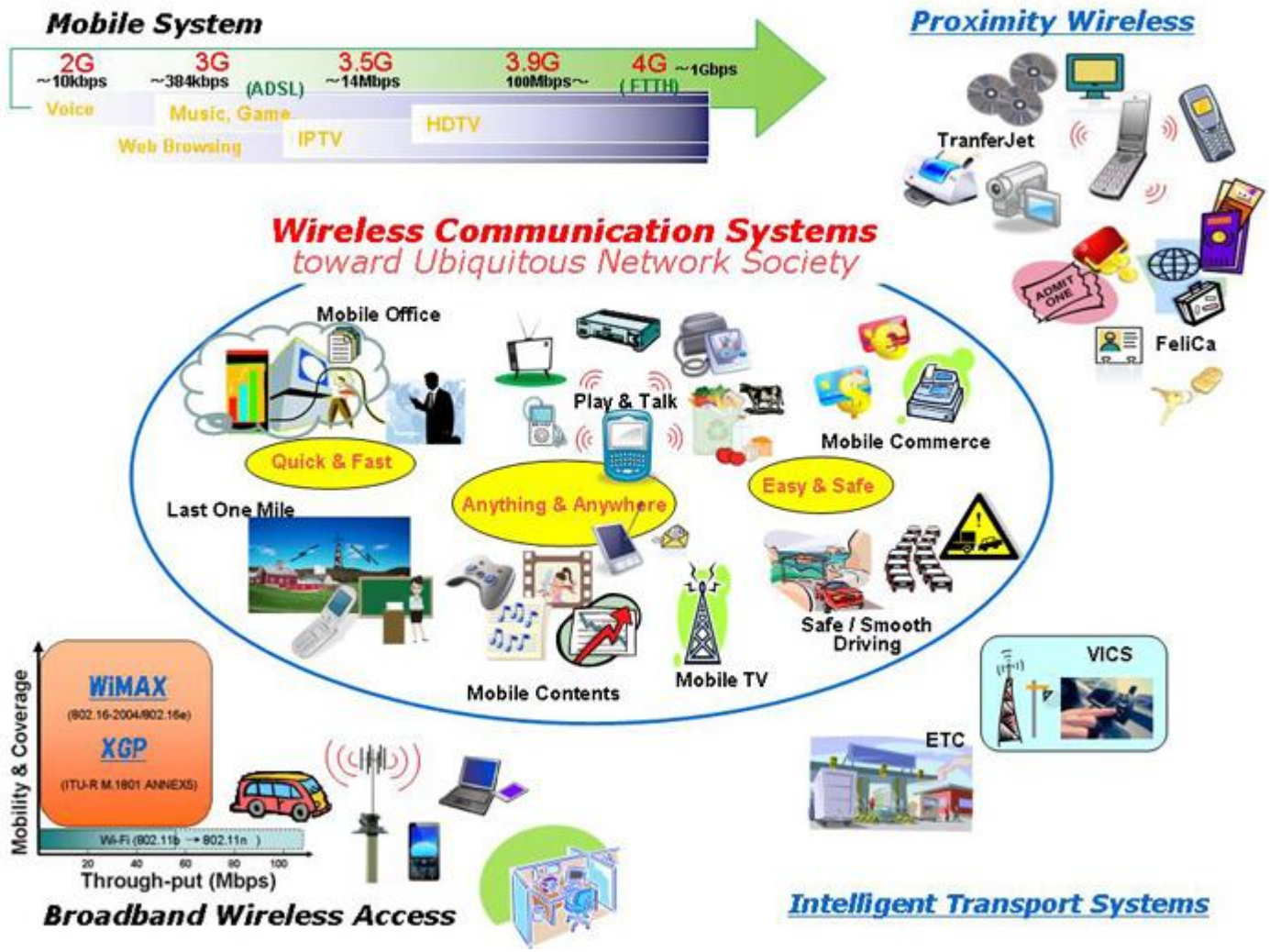
Θεόδωρος Σαμαράς
Τμήμα Φυσικής Α.Π.Θ.



source: IEEE Spectrum (March 2014)

source: IEEE Spectrum (March 2014)

source: www.wirelessgigabitalliance.org



source: Association of Radio Industries and Businesses (www.arib.or.jp)

Assessment of exposure to EM radiation

epidemiology

identification of hazard

why?

compliance

prevention of hazard

Assessment of exposure to EM radiation

measurements

how?

computations

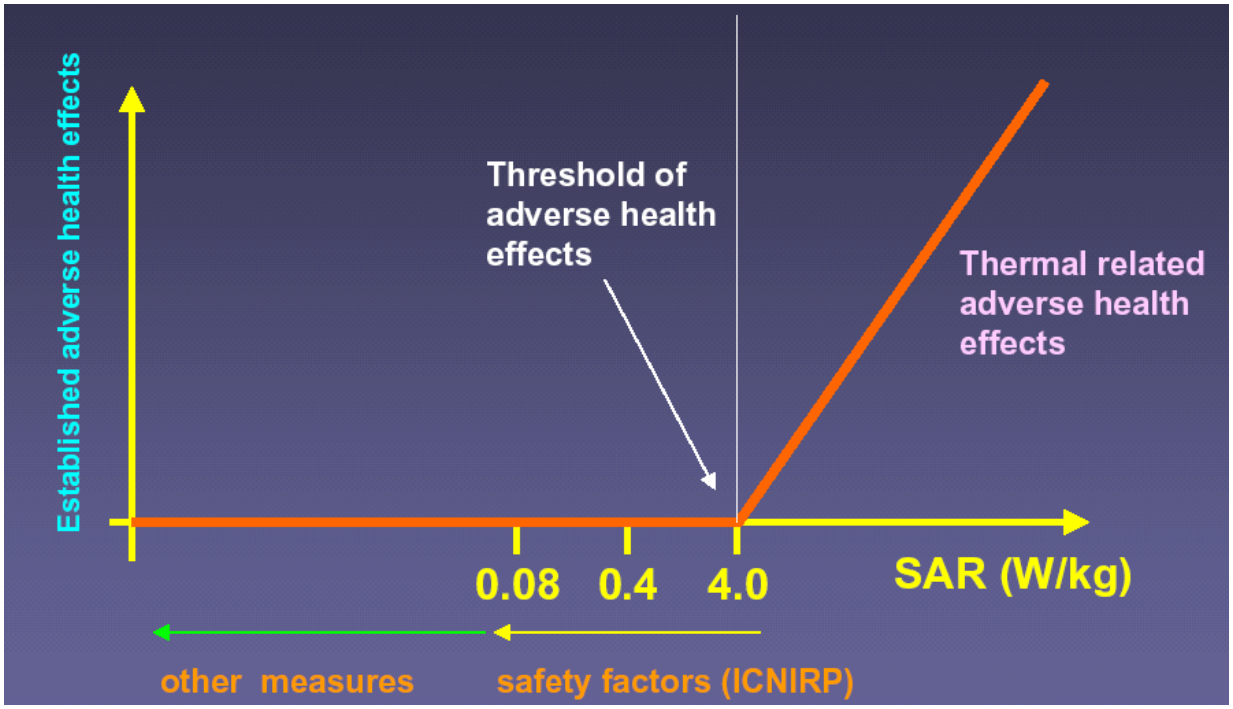
combination

Θεόδωρος Σαμαράς
Τμήμα Φυσικής, Α.Π.Θ.

Guidelines for limiting exposure

Basic limits

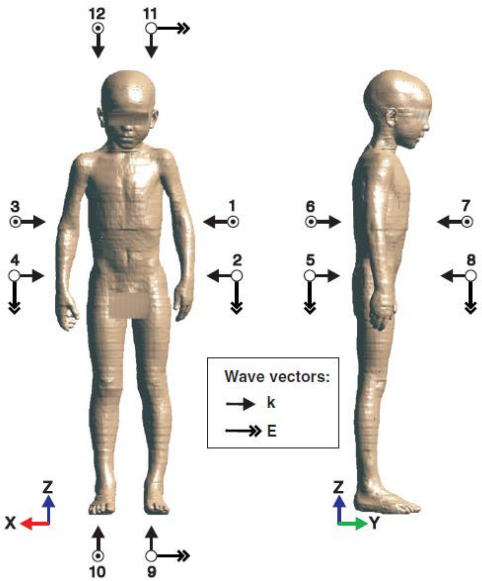
- directly related to biological/health adverse effects
- most quantities cannot be readily measured



Guidelines for limiting exposure

Reference levels

- derived levels from basic limits
- quantities can be readily measured



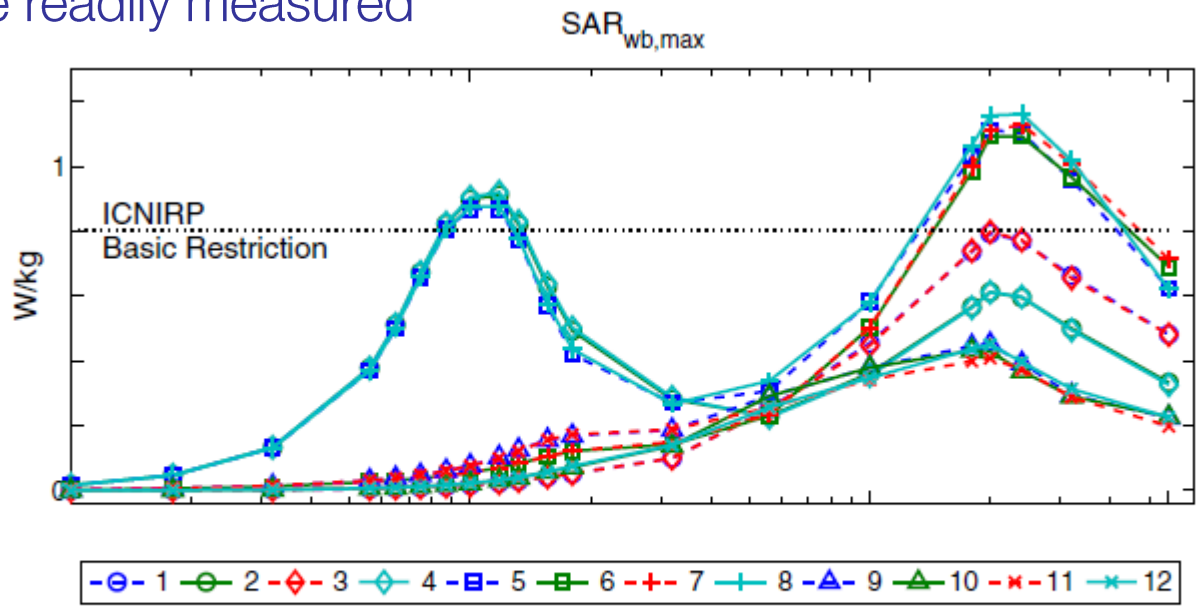


Figure 3. SAR_{wb} (top) and SAR_{10g} (bottom) for exposure at the ICNIRP reference level in the Thelonious model for 12 plane wave configurations.

source: Bakker et al., Phys Med Biol, 55:3115–3130, 2010

Assessment modes

Environmental fields

- continuous (long-term) monitoring
- spot (in situ) measurements

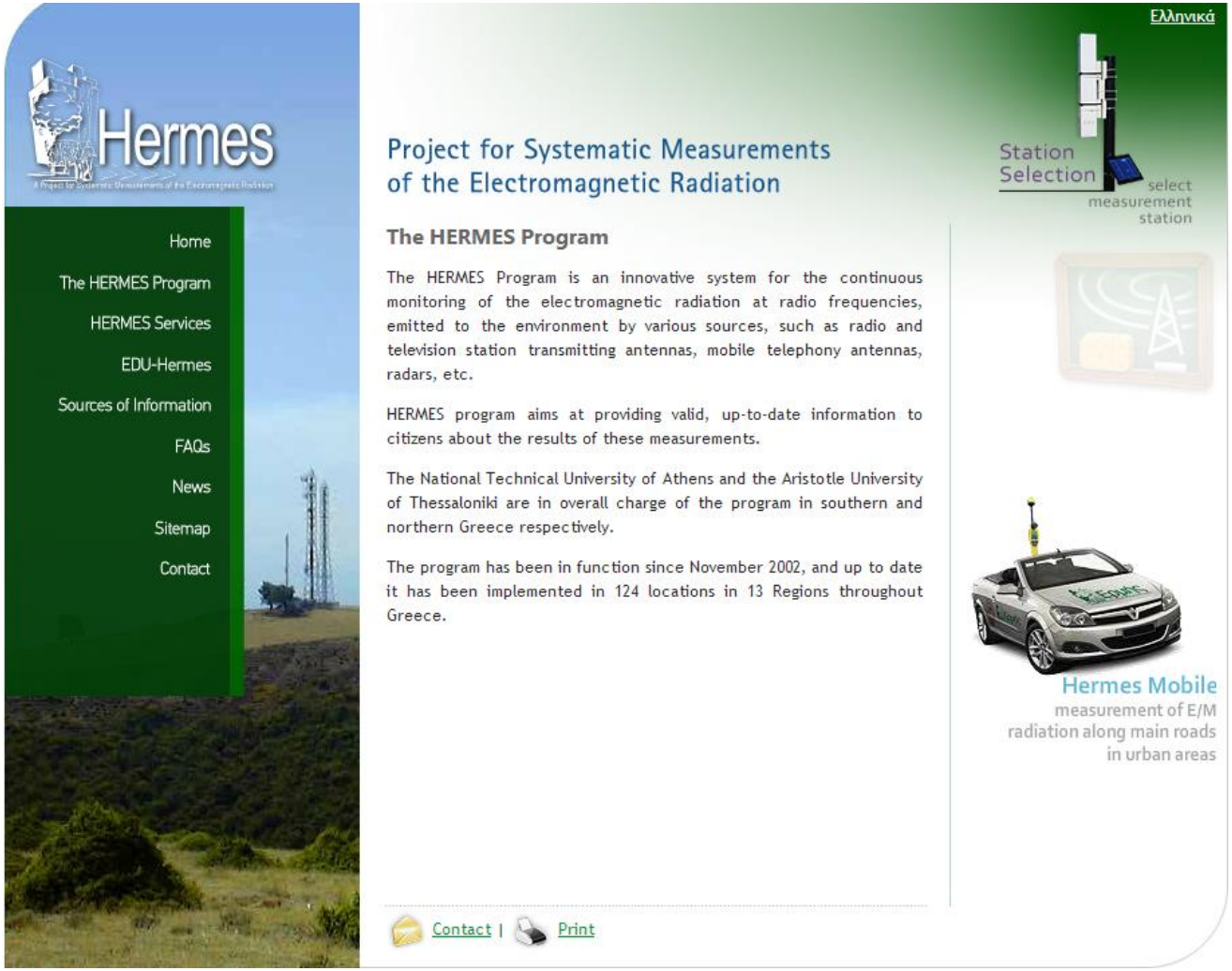
Personal exposure

- living (micro-)environment
- individual exposure

Monitoring networks in Greece (presentation)

Hermes

www.hermes-program.gr/en/



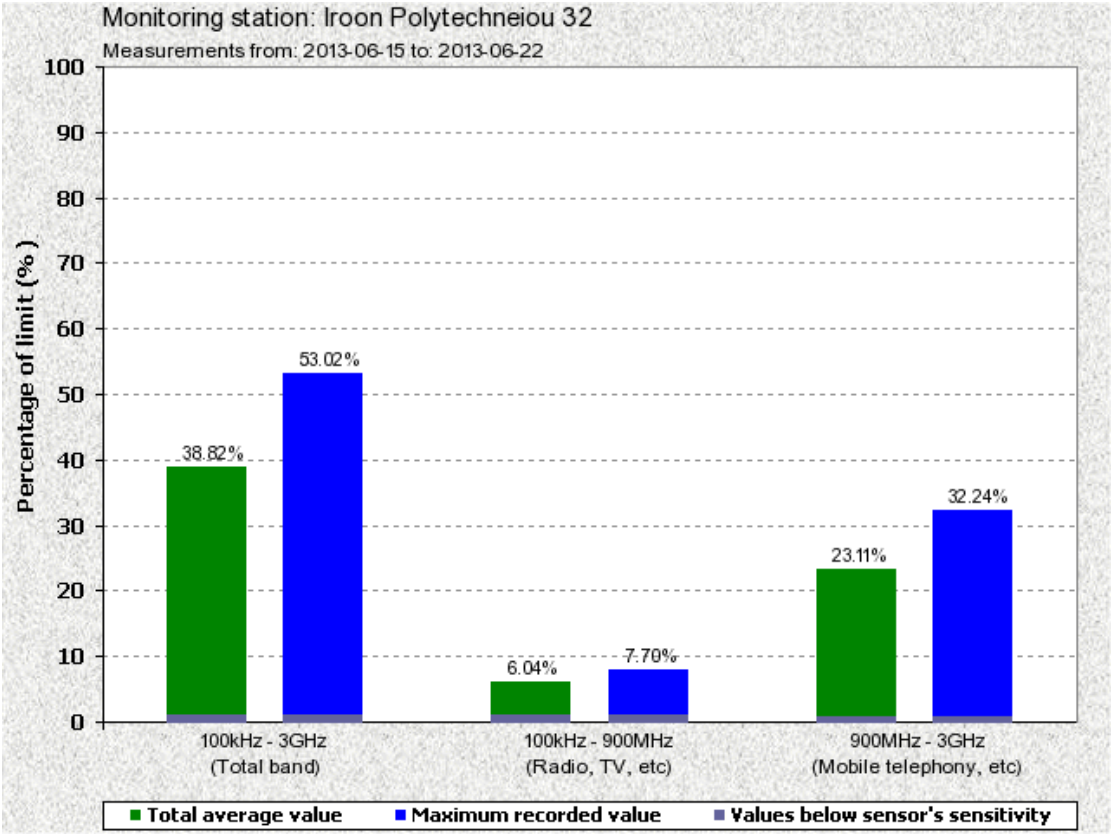
Monitoring networks in Greece (presentation)

Pedion24

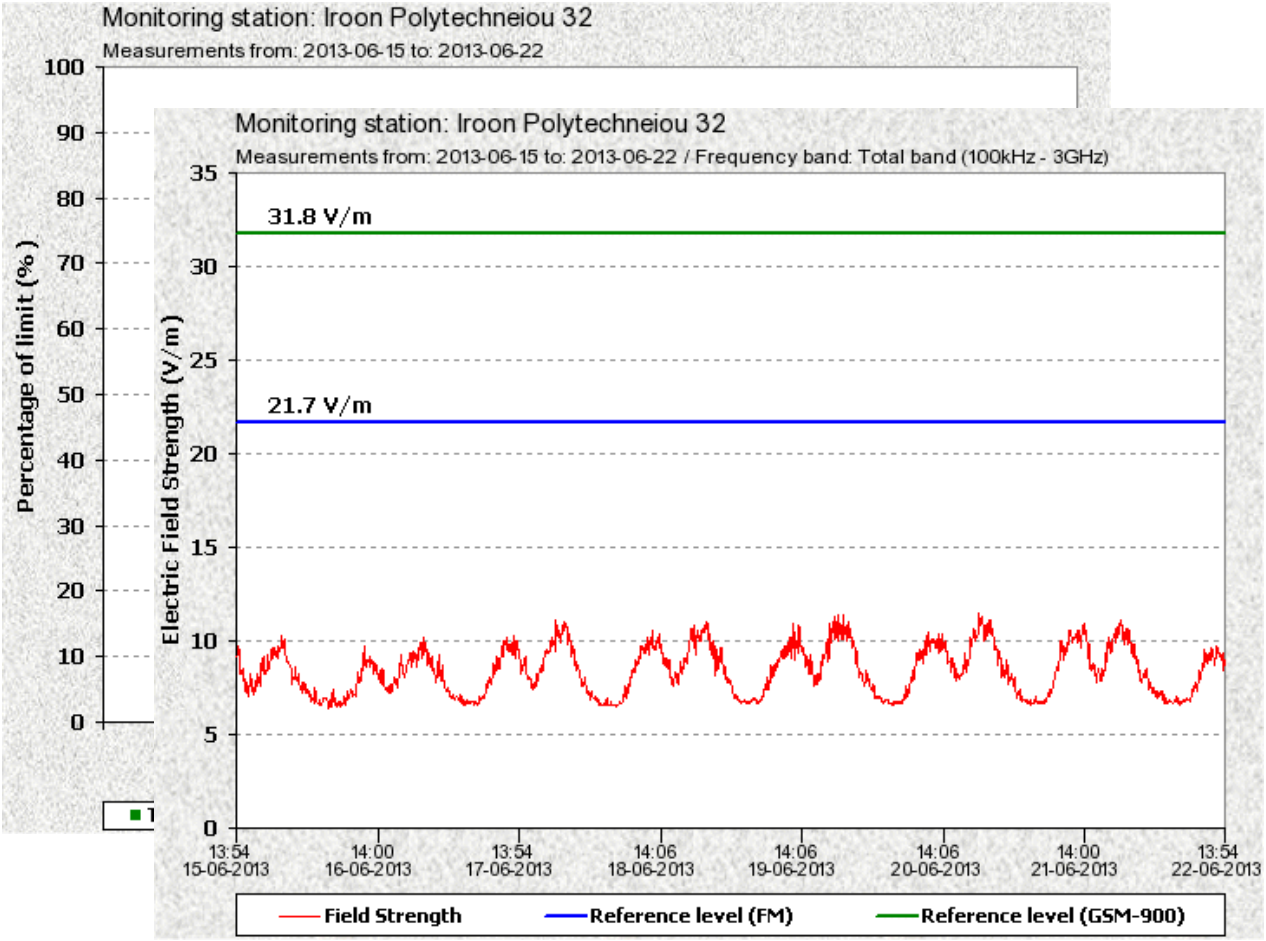
www.pedion24.gr/en/

Θεόδωρος Σαμαράς
Τμήμα Φυσικής, Α.Π.Θ.

Monitoring networks in Greece (presentation)

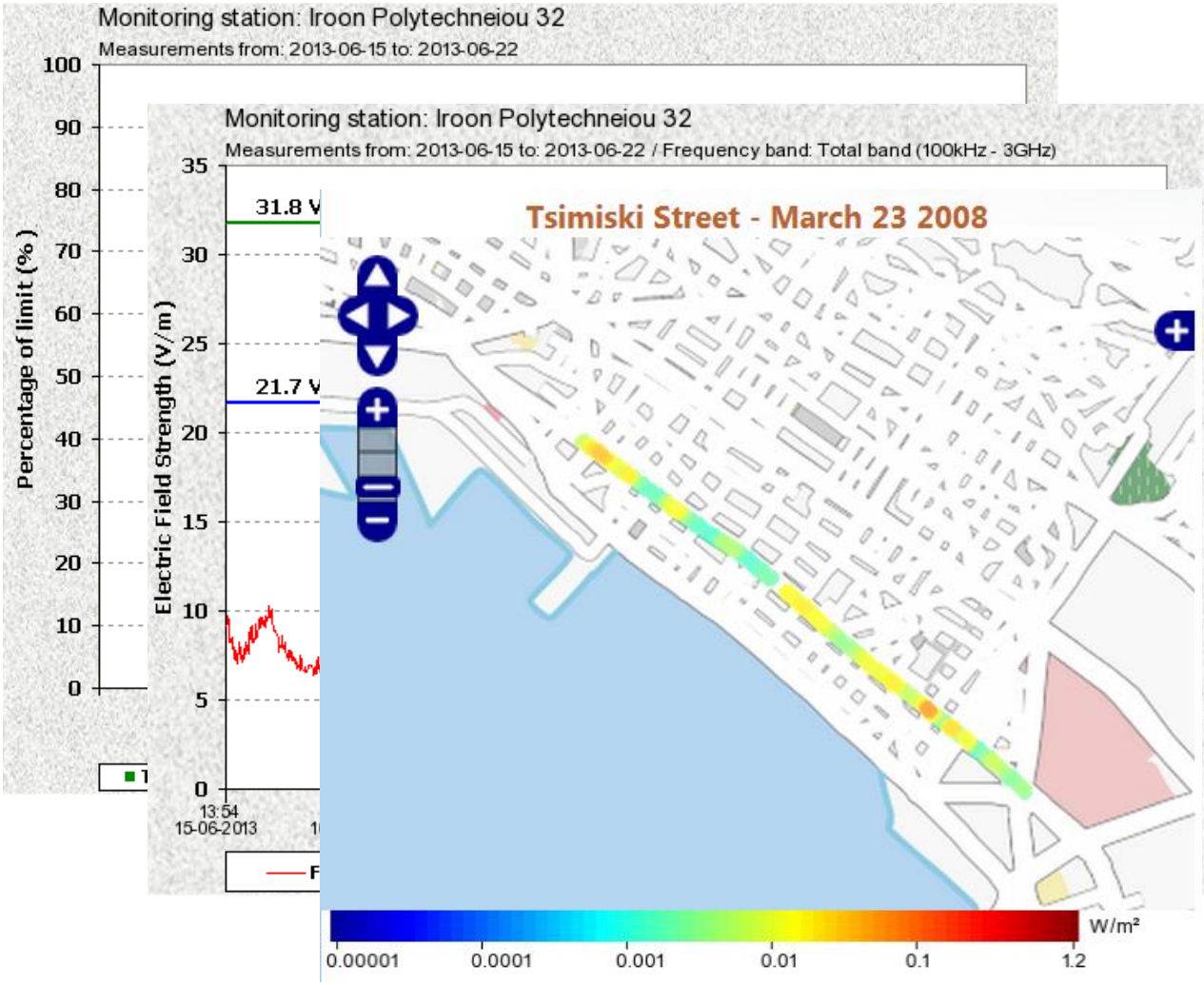


Monitoring networks in Greece (presentation)



Θεόδωρος Σαμαράς
Τμήμα Φυσικής, Α.Π.Θ.

Monitoring networks in Greece (presentation)



Θεόδωρος Σαμαράς
Τμήμα Φυσικής, Α.Π.Θ.

Monitoring networks in Greece (lessons learned)

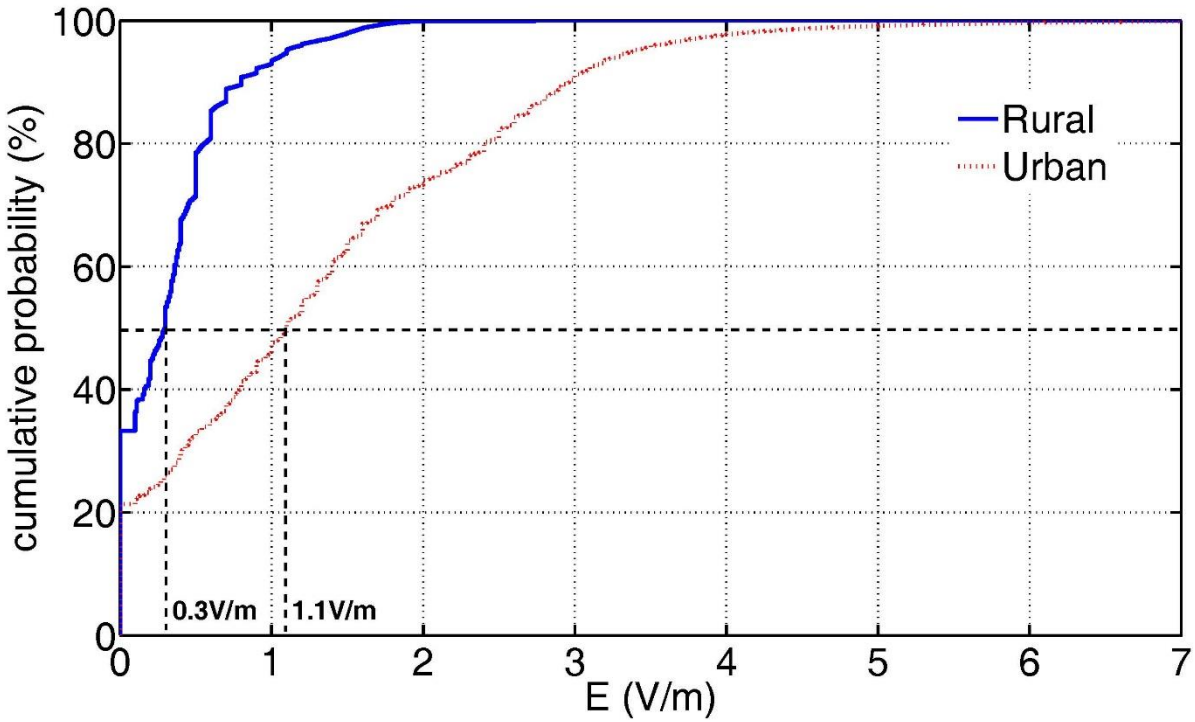


Figure 2. Cumulative distribution function (CDF) plot of all 6-min averaged values in the urban and rural areas.

source: Manassas et al., Radiat Prot Dosimetry, 151: 437-442, 2012

Monitoring networks in Greece (lessons learned)

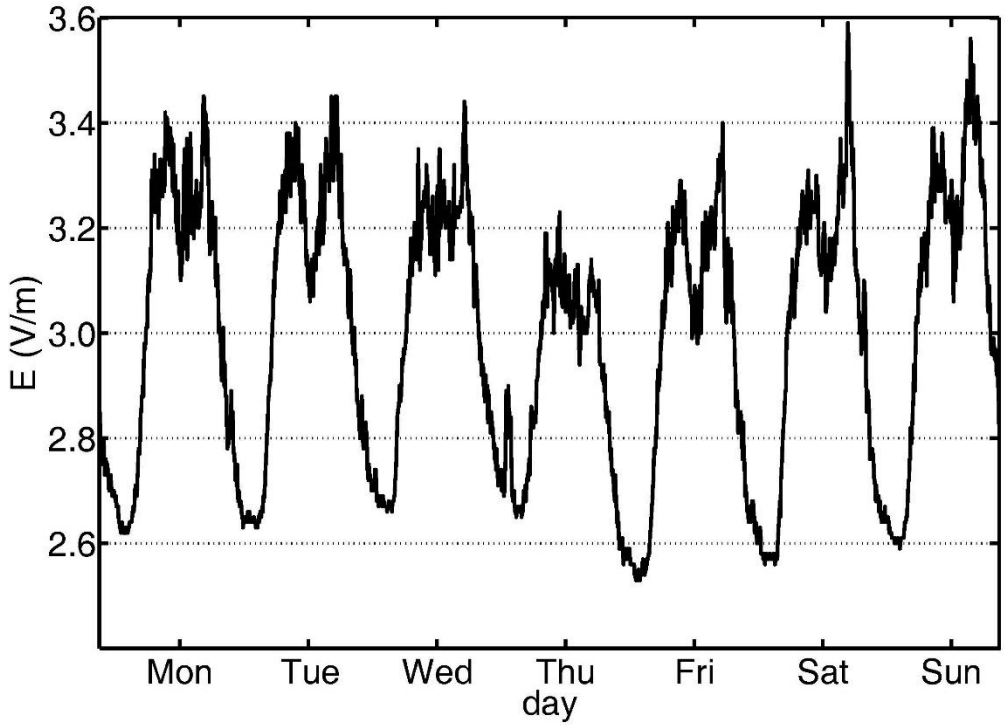


Figure 3. Recording of the 6-min averaged electric field from an installed station during the third week of June

source: Manassas et al., Radiat Prot Dosimetry, 151: 437-442, 2012

Monitoring networks in Greece (lessons learned)

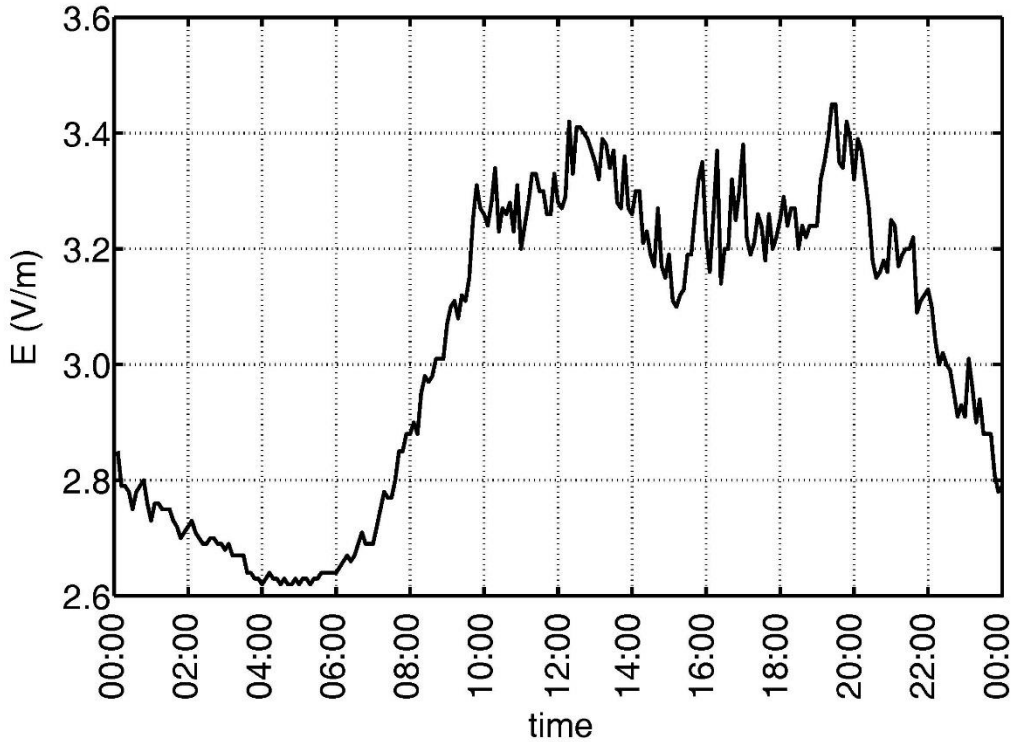


Figure 4. Recorded data for the Monday of the week depicted in Figure 3.

source: Manassas et al., Radiat Prot Dosimetry, 151: 437-442, 2012

Monitoring networks in Greece (lessons learned)

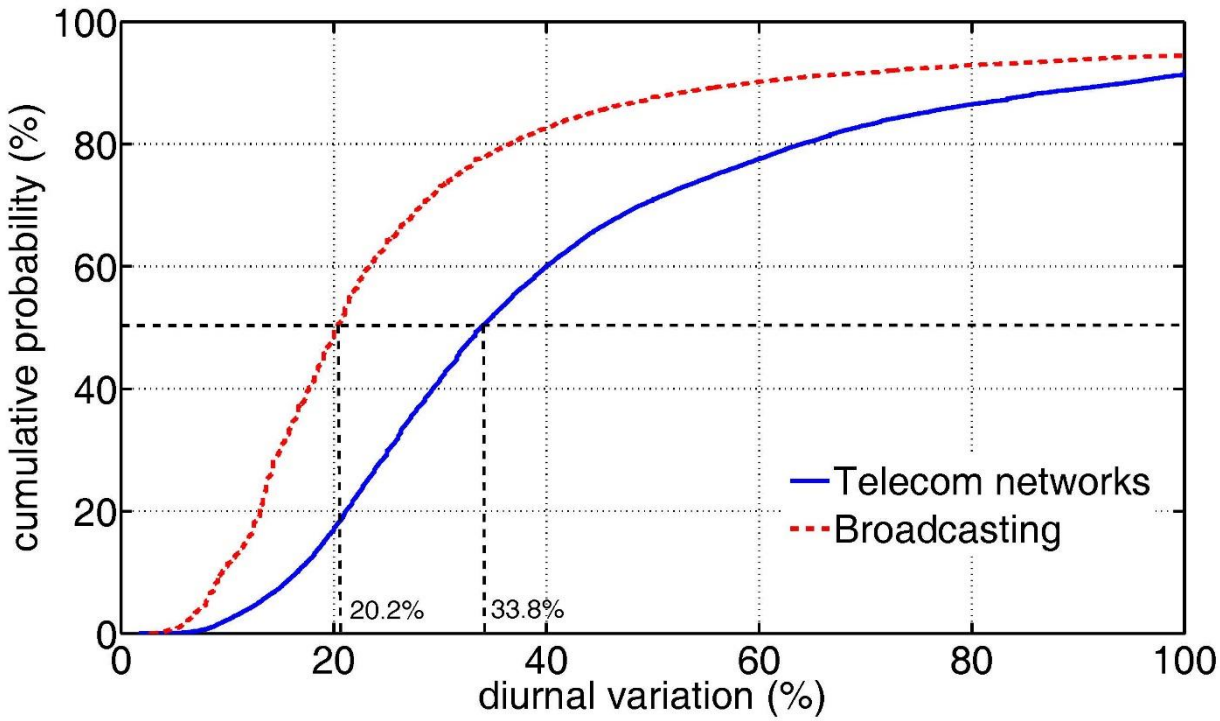
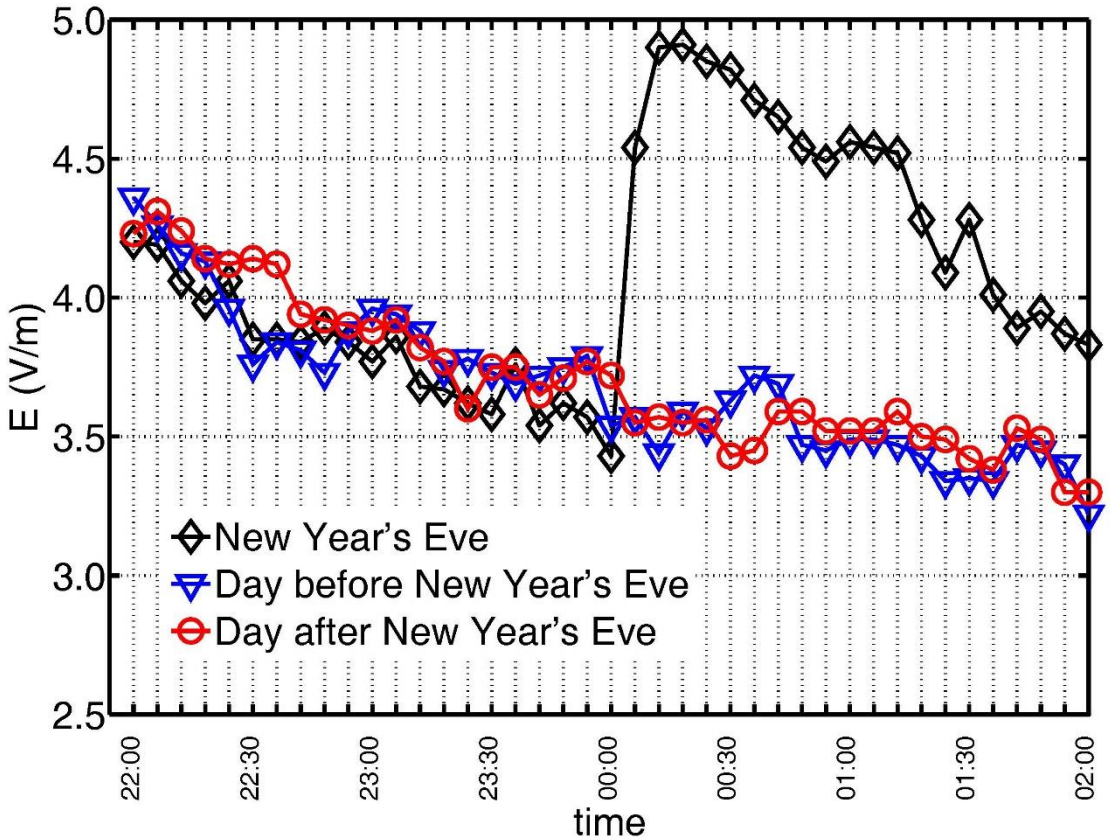


Figure 6. Cumulative distribution function (CDF) plot of diurnal variation of electric field for the two categories of measurement units.

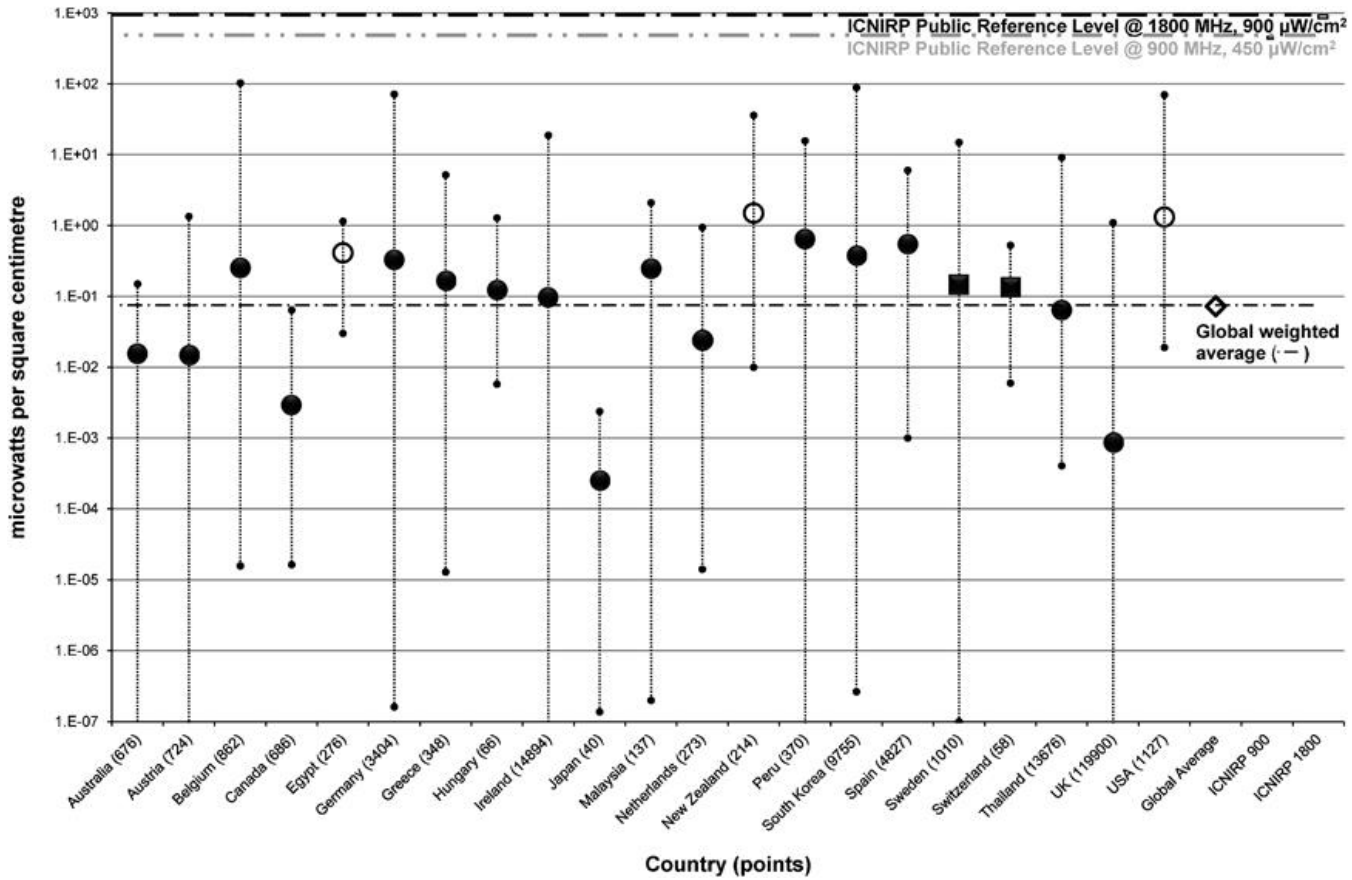
source: Manassas et al., Radiat Prot Dosimetry, 151: 437-442, 2012

Monitoring networks in Greece (lessons learned)



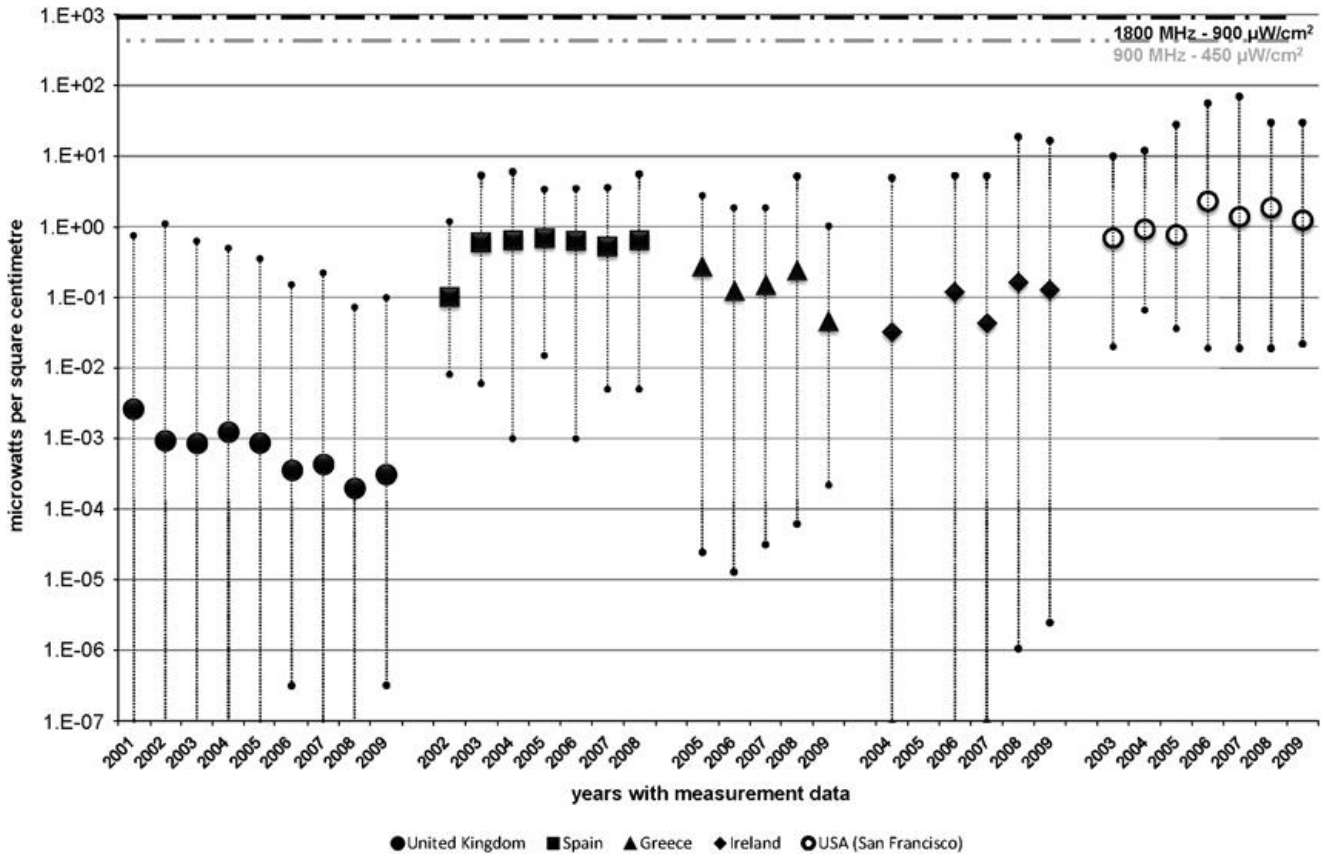
source: Manassas et al., Radiat Prot Dosimetry, 151: 437-442, 2012

Measurement campaigns (average values)



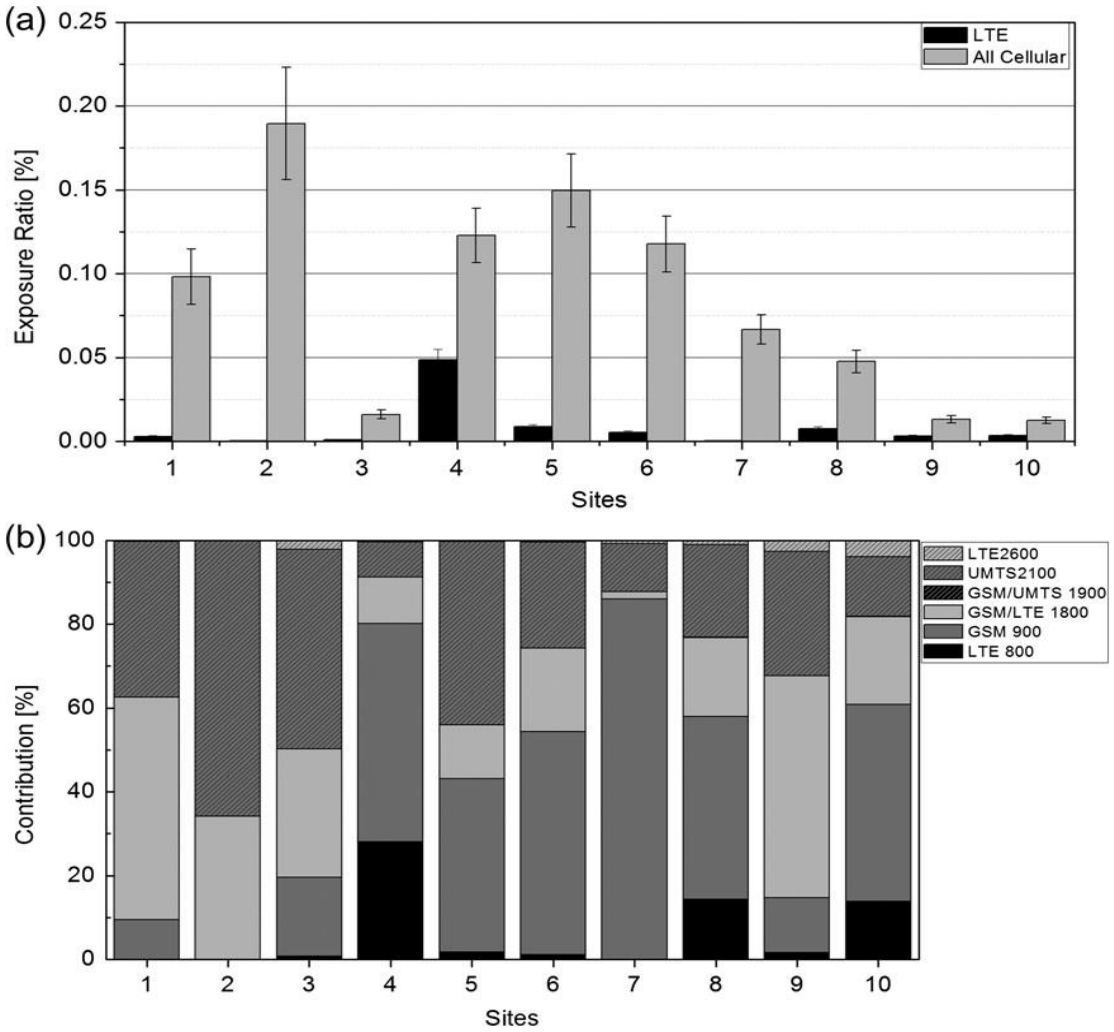
source: Rowley and Joyner, J Expo Sci Environ Epidemiol, 22: 304-315, 2012

Measurement campaigns (evolution with time)



source: Rowley and Joyner, J Expo Sci Environ Epidemiol, 22: 304-315, 2012

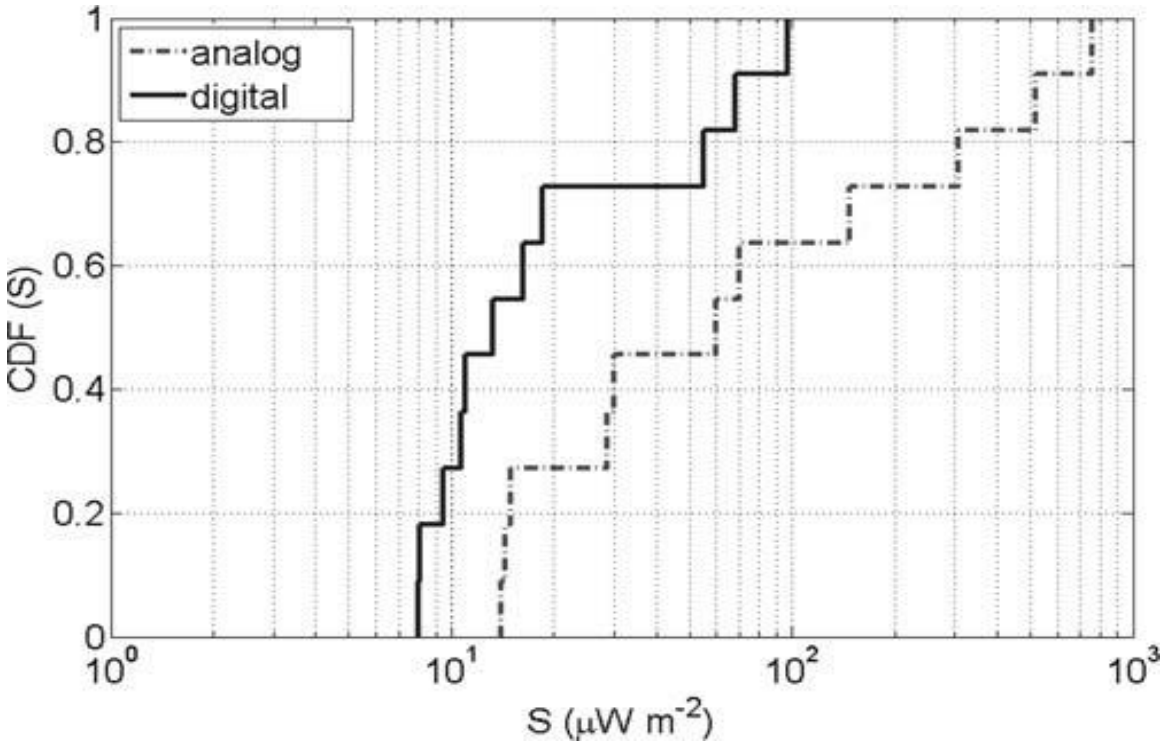
New technologies (LTE)



source: Gkonis et al., Radiat Prot Dosimetry, 175: 388-393, 2017

Θεόδωρος Σαμαράς
Τμήμα Φυσικής, Α.Π.Θ.

New technologies (digital broadcasting)



source: Gkonis et al., Health Physics, 113: 382-386, 2017

Considerations

When

- maximum traffic (otherwise extrapolation)

Where

- criterion the purpose (epidemiology or compliance)

Personal Exposure Meters (PEM)

Advantages

- compact, lightweight
- easy to handle in epidemiological studies

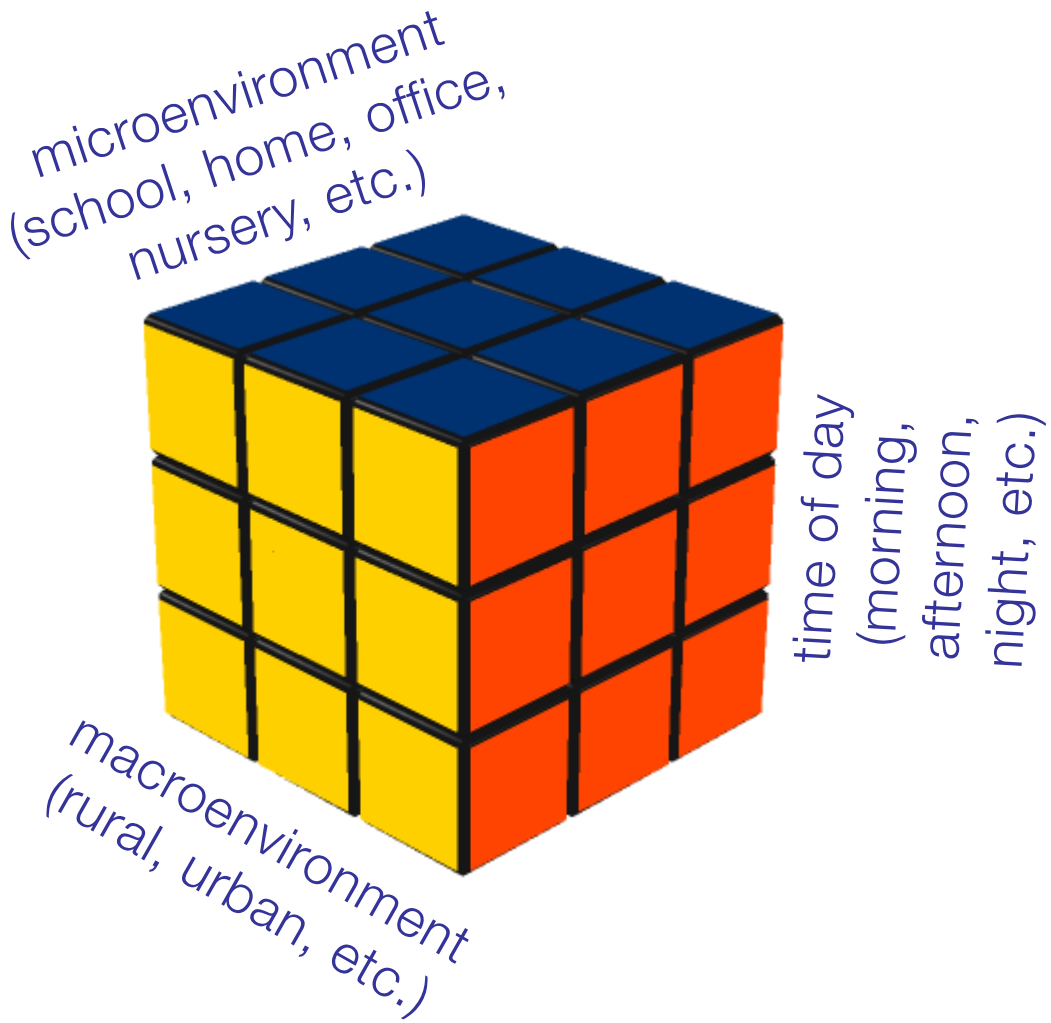
Personal Exposure Meters (PEM)

Limitations

- very poor correlation between the readings of the two devices
- a PEM is prone to manipulation (e.g. a participant can deliberately put it next to a transmitter to record high exposure)
- always some out of band reception of the signals (poor selectivity)
- isotropy is poor for both PEM when worn on the body
- measurements are affected from body presence (e.g., shielding may need the use of two PEM on the body)
- sensitivity of PEM is not low enough compared to the background radiation level (large quantities of non-detects)
- calibration of the PEM should be performed with the appropriate signals and regularly (highly portable equipment)

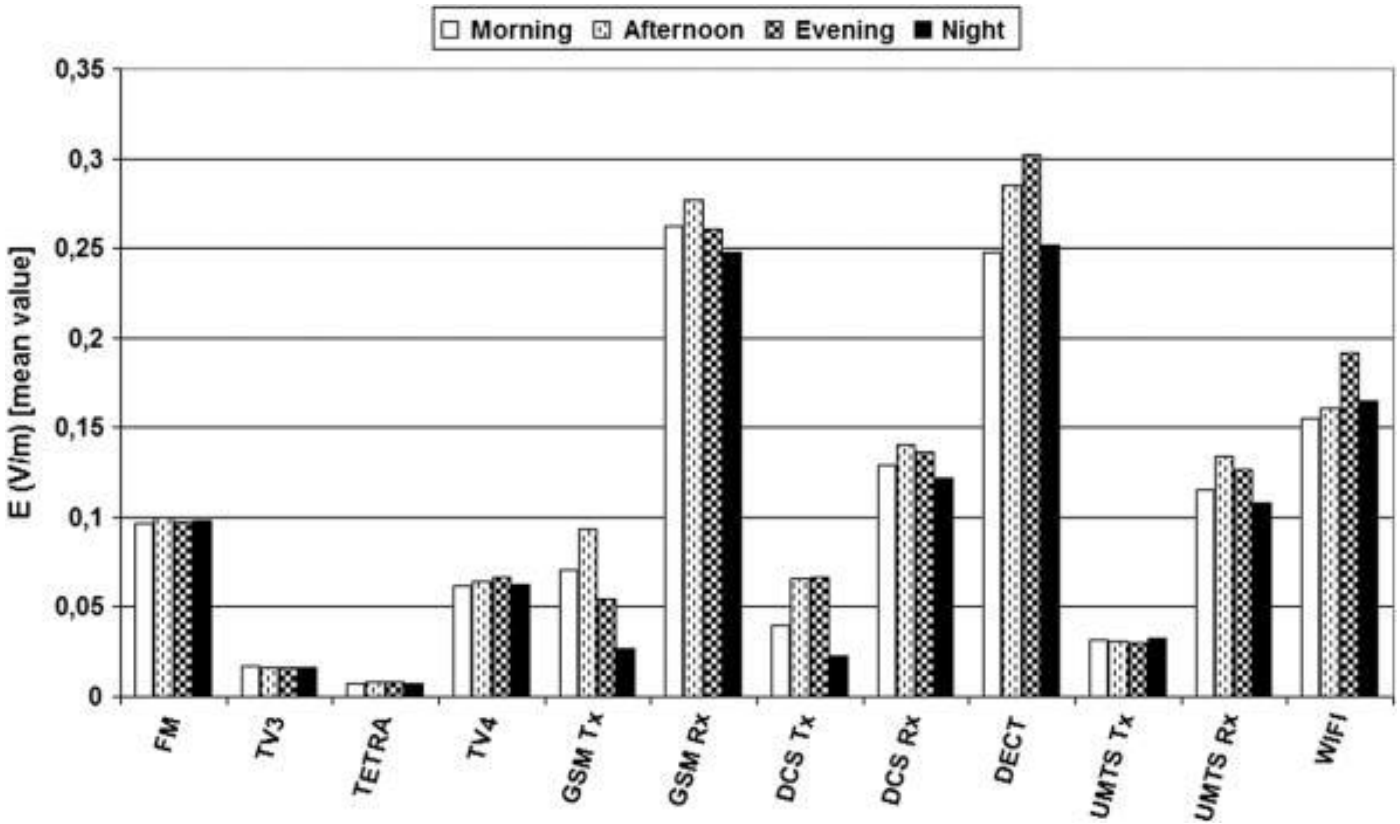
Θεόδωρος Σαμαράς
Τμήμα Φυσικής, Α.Π.Θ.

Situation matrix



Θεόδωρος Σαμαράς
Τμήμα Φυσικής, Α.Π.Θ.

The SEAWIND Project



source: Markakis and Samaras, Health Physics, 104: 293-301, 2013

Θεόδωρος Σαμαράς
Τμήμα Φυσικής, Α.Π.Θ.

Computational approach (plane wave)

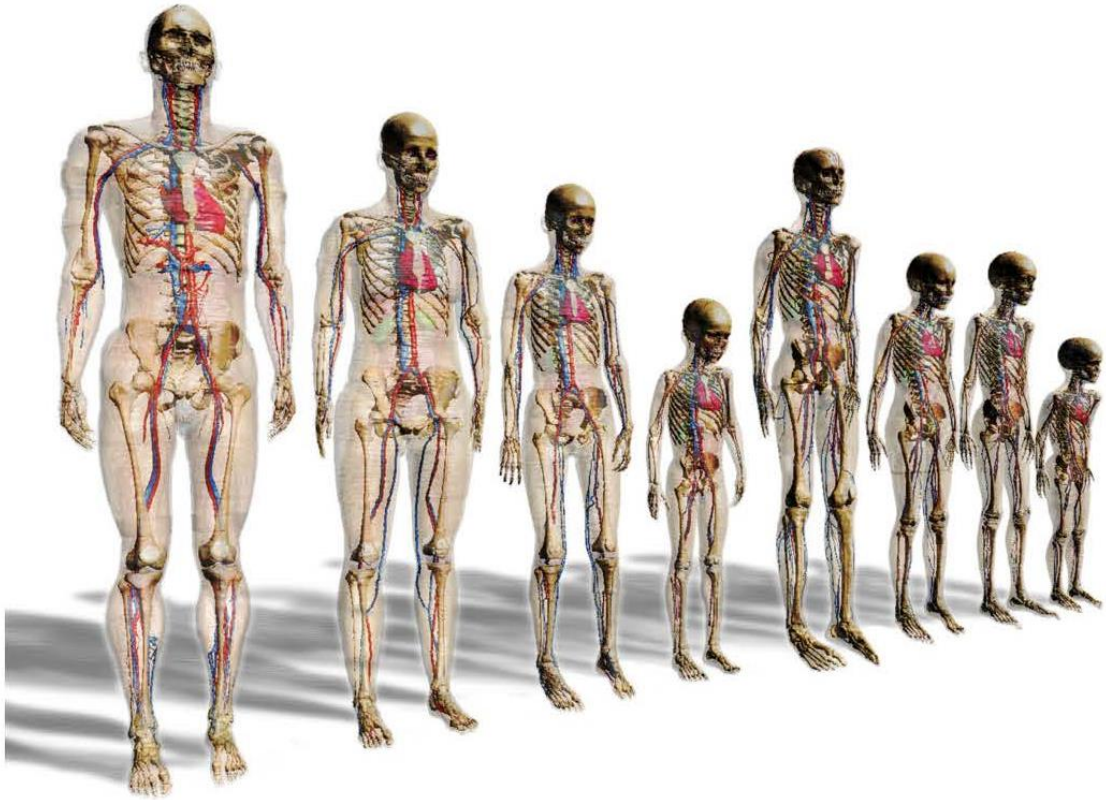
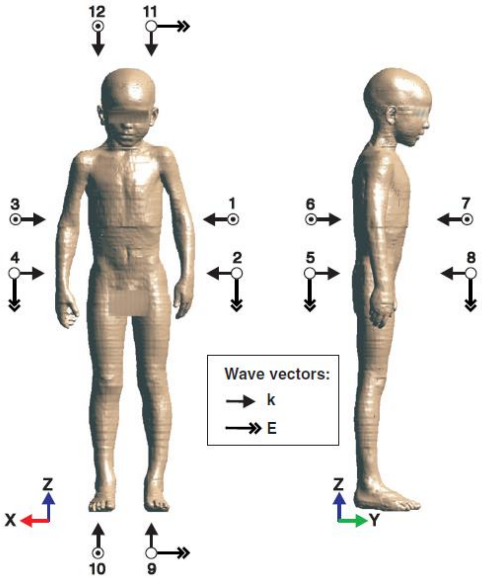


Figure 1. Virtual family models. From left to right: Duke, Ella, Billie, Thelonious, Louis, Eartha, Dizzy and Roberta.



source: Bakker et al., Phys Med Biol, 55:3115–3130, 2010

Computational approach (plane wave)

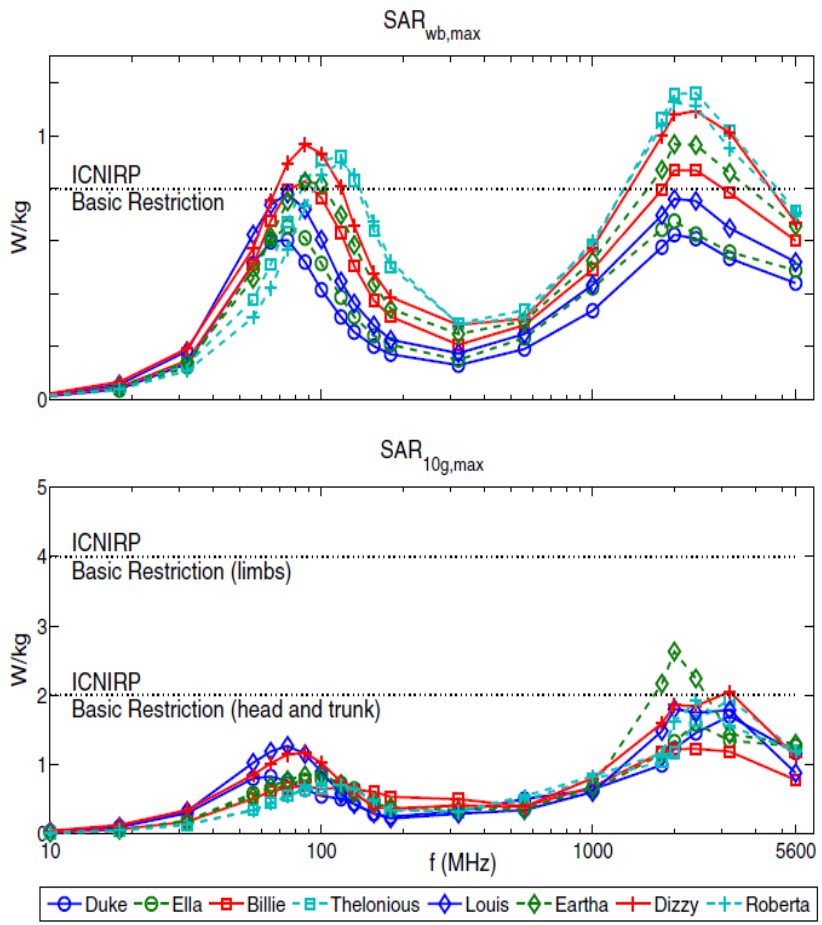


Figure 4. Worst case SAR_{wb} (top) and SAR_{10g} (bottom) in the eight human models for 12 plane wave configurations. Note that the locations where the SAR_{10g} restrictions for head and trunk are exceeded are all located in the limbs.

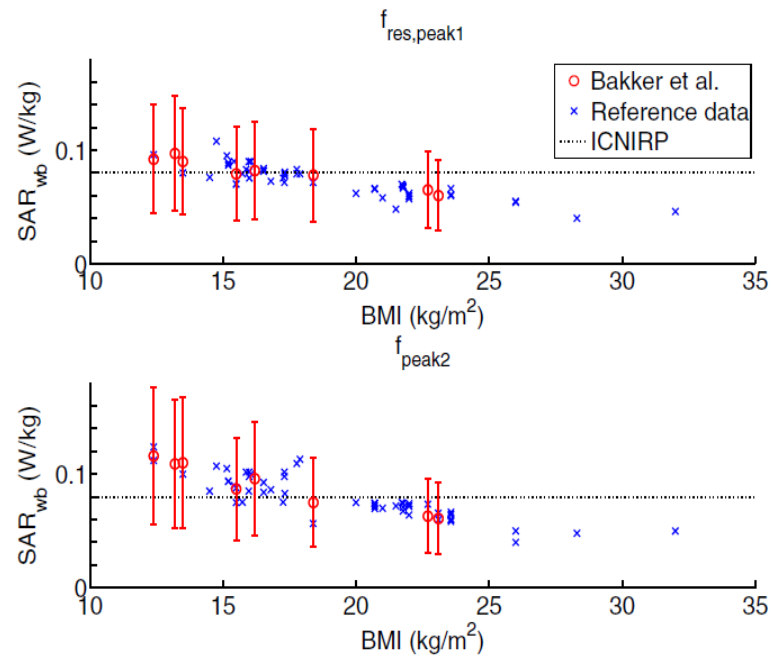


Figure 7. Comparison with reference data of the SAR_{wb} at $f_{res,peak1}$ (top) and f_{peak2} (bottom) for the plane wave configuration 8. The error bars indicate the expanded uncertainty U with a coverage factor $k = 2$.

source: Bakker et al., Phys Med Biol, 55:3115–3130, 2010

Θεόδωρος Σαμαράς
Τμήμα Φυσικής, Α.Π.Θ.

Computational approach (statistical approach)

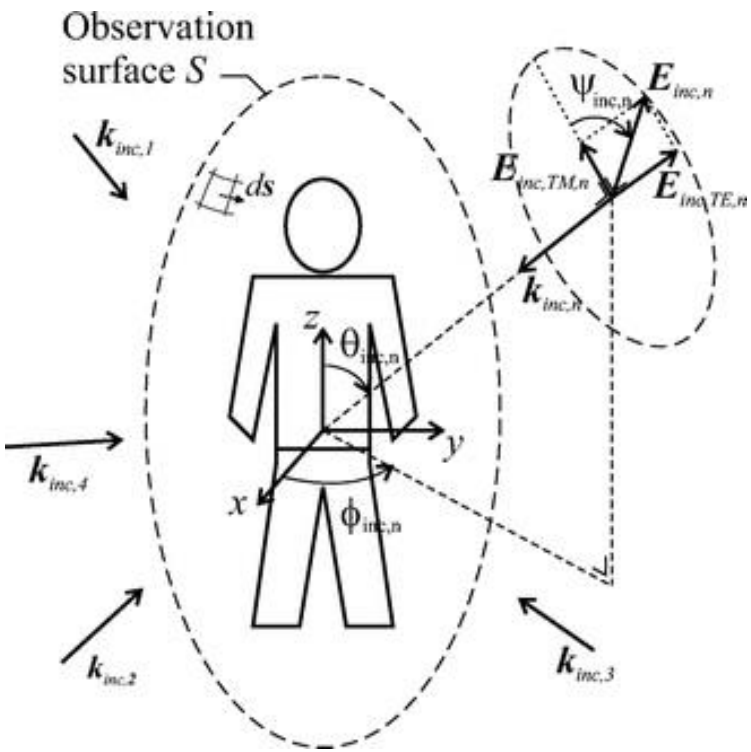
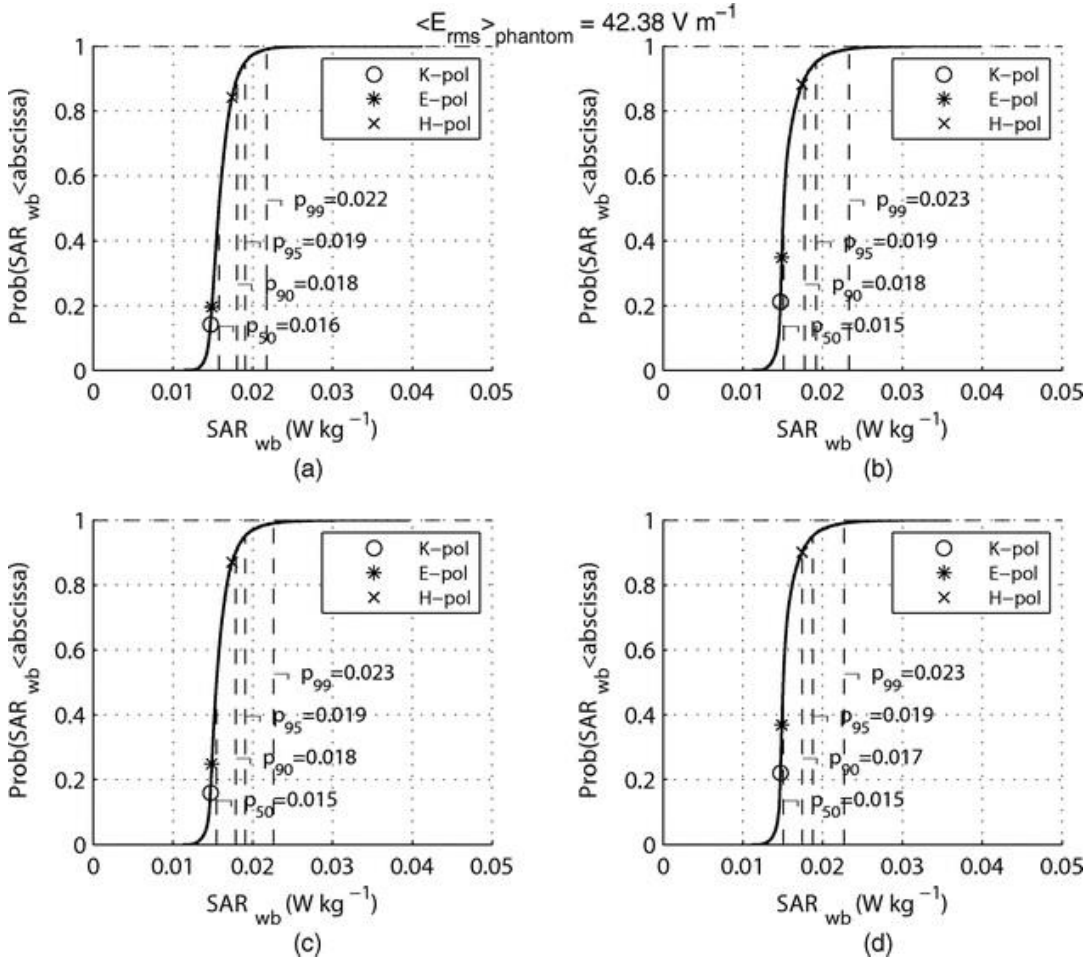


Table 1. Realistic environments.

Environment	Urban macro-cell	Urban micro-cell	Indoor pico-cell	Outdoor-indoor
Elevation (Kalliola et al. 2002)				
θ_0 (deg)	87.8	88.0	88.0	90.2
σ^- (deg)	3.9	4.3	6.9	5.4
σ^+ (deg)	17.8	8.2	9.4	5.5
Polarization (Kalliola et al. 2002)				
XPR (dB)	7.3	11.1	7.0	10.7
Number of paths (Zhao et al. 2002)				
η	2.7	3.5	4.7	4.5
N_T	22	14	16	21
Shadowing				
σ_E (dB)	6	9	6	12

source: Vermeeren et al., Health Phys, 94: 345-354, 2008

Computational approach (statistical approach)



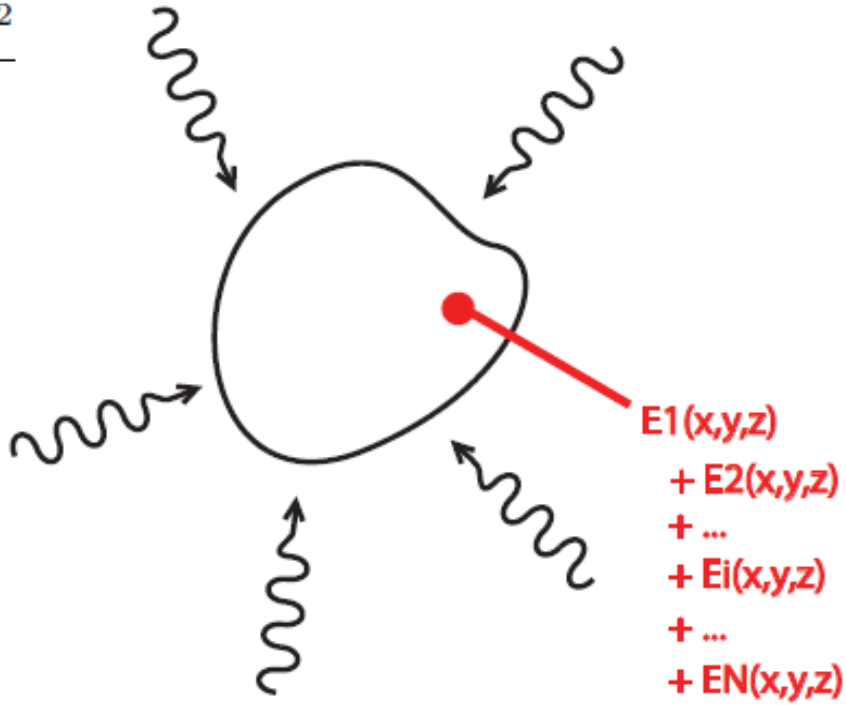
source: Vermeeren et al., Health Phys, 94: 345-354, 2008

Θεόδωρος Σαμαράς
Τμήμα Φυσικής, Α.Π.Θ.

Computational approach (worst-case approach)

- definition of the SAR: $SAR = \frac{\sigma |\vec{E}|^2}{2\rho}$
- if the field is generated by *N* independent sources, each having with a complex amplitude c_i:

$$SAR = \frac{\sigma \left| \sum_i c_i \vec{E}_i \right|^2}{2\rho}$$

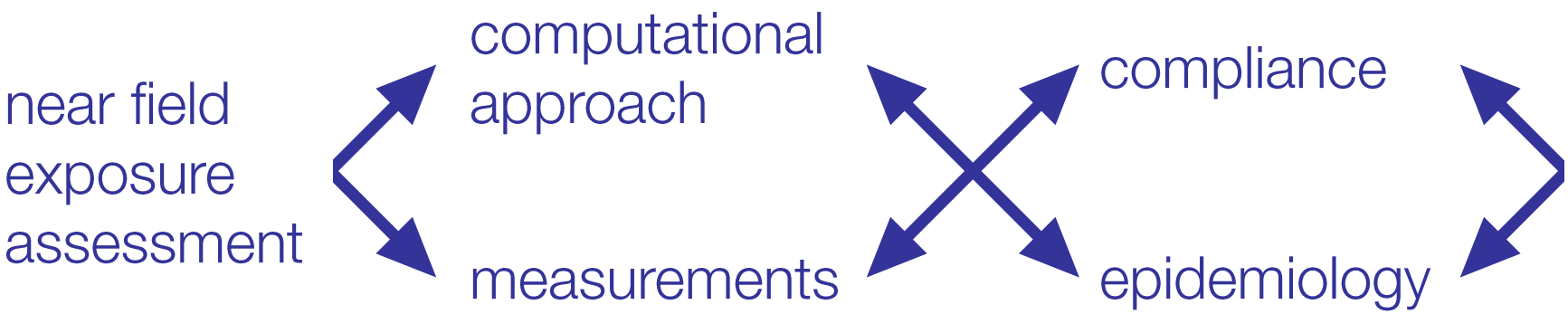


$$(x+y)^2 = xx + xy + yx + yy$$

$$\left| \sum_i c_i \vec{E}_i \right|^2 = \sum_{i,j} c_i c_j^* \vec{E}_i \cdot \vec{E}_j^*$$

$$SAR = \frac{\sigma}{2\rho} \sum_{i,j} c_i c_j^* \vec{E}_i \cdot \vec{E}_j^*$$

Θεόδωρος Σαμαράς
Τμήμα Φυσικής, Α.Π.Θ.



Θεόδωρος Σαμαράς
Τμήμα Φυσικής, Α.Π.Θ.

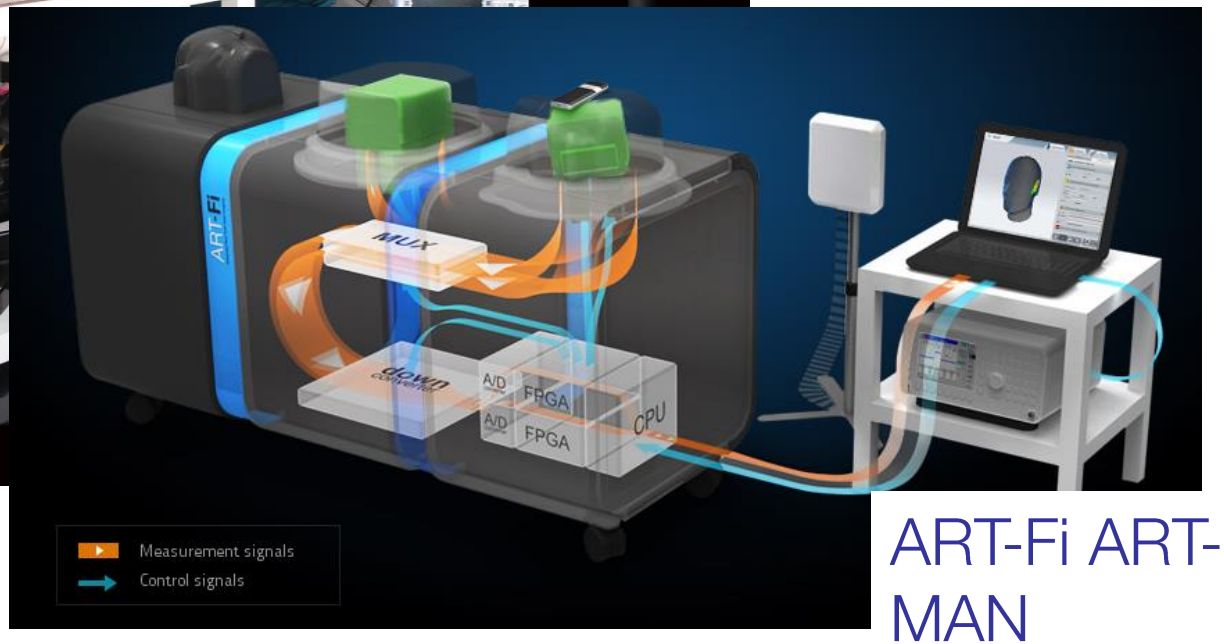
IEC 62209, IEEE 1528-2013

SPEAG
DASY 52

Θεόδωρος Σαμαράς
Τμήμα Φυσικής, Α.Π.Θ.

IEC 62209, IEEE 1528-2013

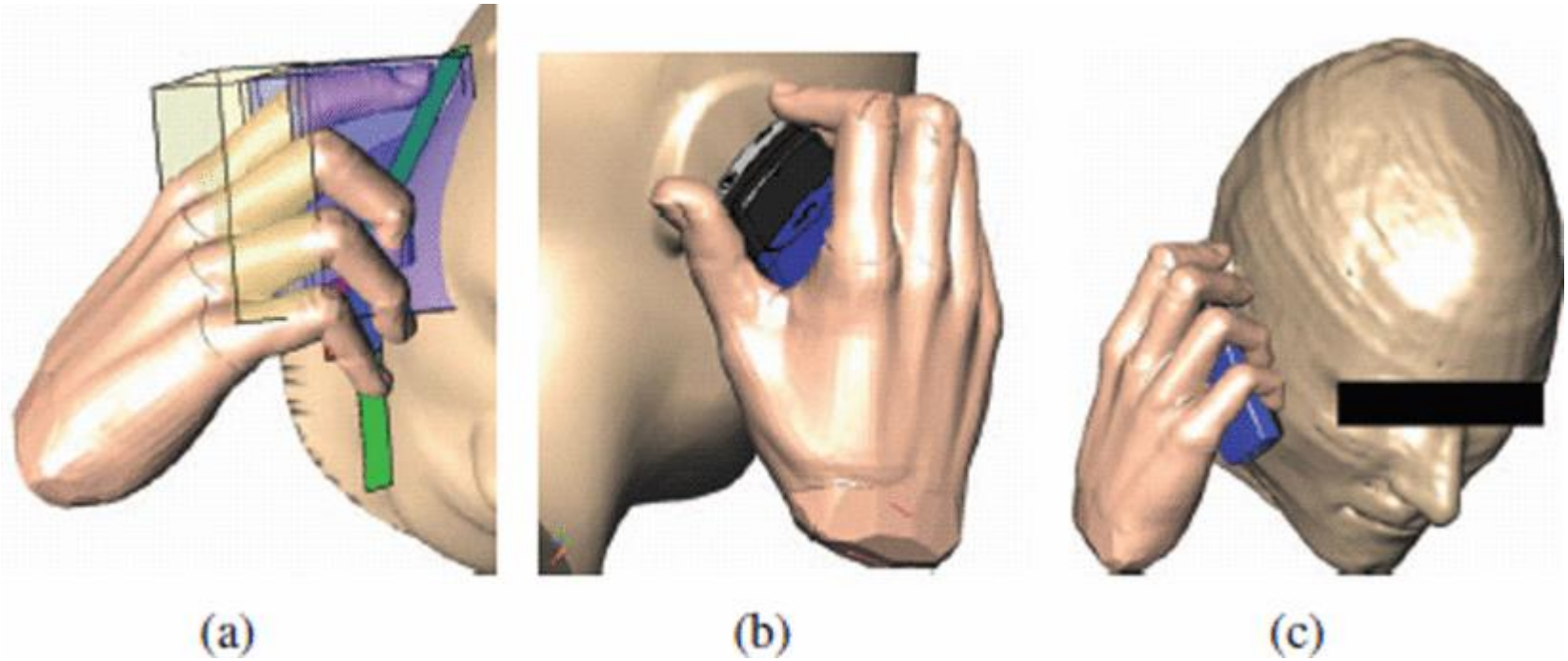
SPEAG
DASY 52



ART-Fi ART-MAN

Θεόδωρος Σαμαράς
Τμήμα Φυσικής, Α.Π.Θ.

Mobile phone



source: Chung-Huan et al., APSURSI , 2011 (10.1109/APS.2011.5996661)

Portable devices (WiFi)

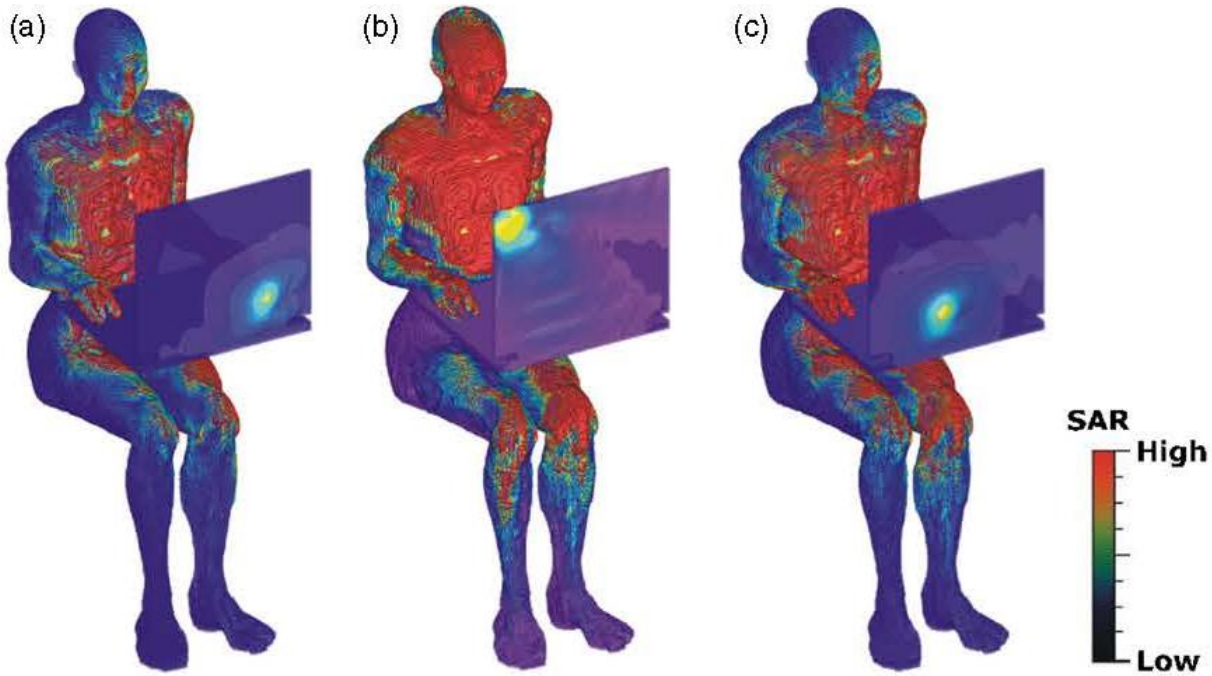


Figure 2. SAR intensity plots for the antenna in the (a) BL, (b) TR and (c) BC positions at 2.4 GHz.

source: Findlay and Dimbylow, Phys Med Biol, 55: N405–N411, 2010

Portable devices (WiFi)

Applying the duty factors found in this study to the earlier laboratory measurements will result in **maximal time-averaged exposure at 0.5 m distance of 220 μW m^{-2} (22 mW m^{-2} with 1% duty factor) from individual laptops and 22 mW m^{-2} (87 mW m^{-2} with 12% duty factor) from access points. The localised SAR value in the torso model of the child will scale to 400 μW kg^{-1}, based on a 100 mW burst power and 80 μW kg^{-1} based on a 20 mW maximum power, as measured with real devices.**

source: Khalid et al., Prog Biophys Mol Bio, 107: 412–420, 2011

The SEAWIND Project

(unpublished data)

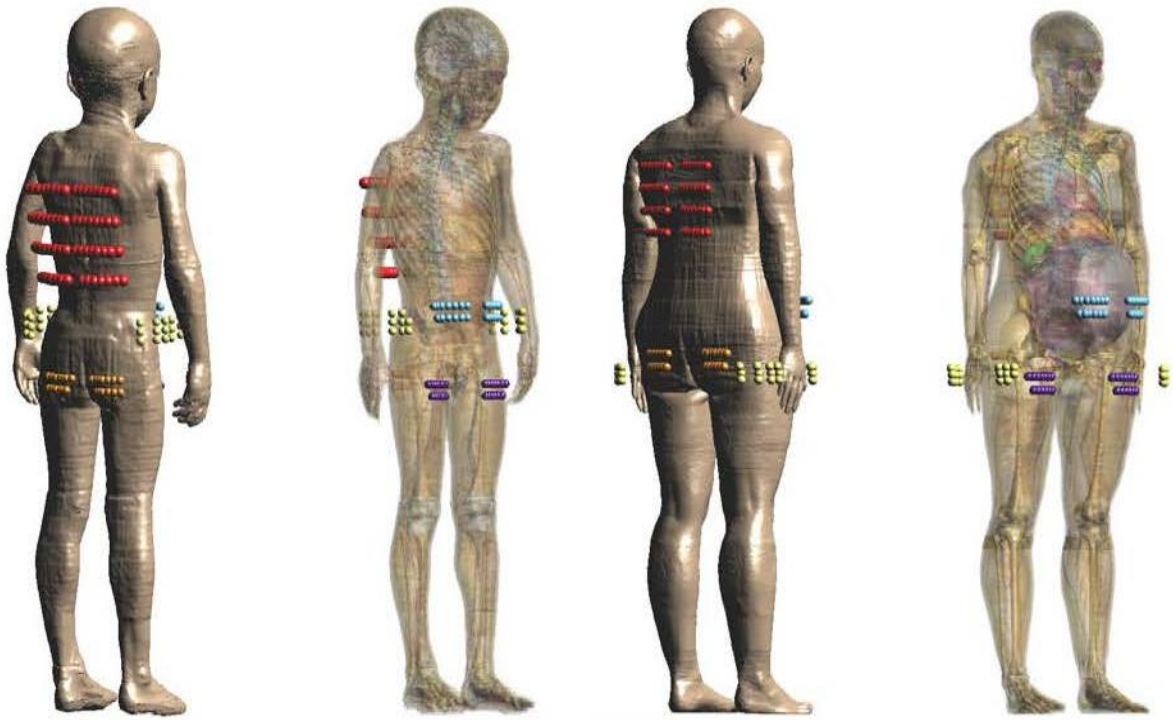


Figure 4: RF sources positions around Thelonious and a 9 months Pregnant Woman (back and front views); front trousers pocket (purple), back trousers pocket (orange), jacket pocket (blue), side-carry bag (yellow), and backpack (red).

Θεόδωρος Σαμαράς
Τμήμα Φυσικής, Α.Π.Θ.

The SEAWIND Project

(unpublished data)

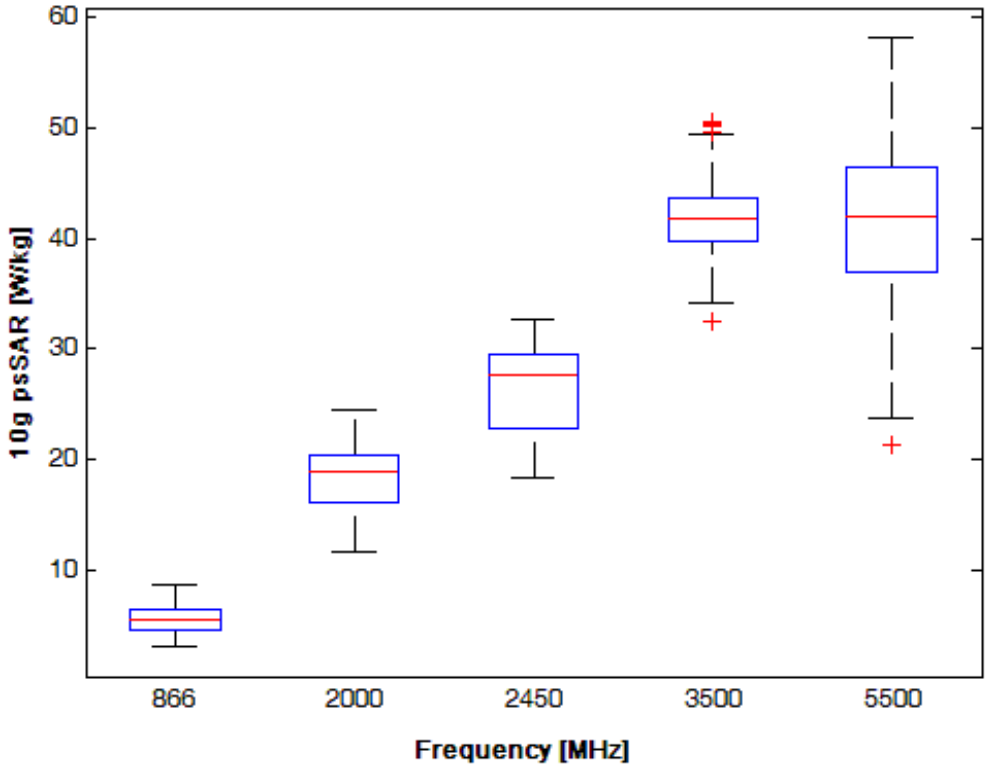
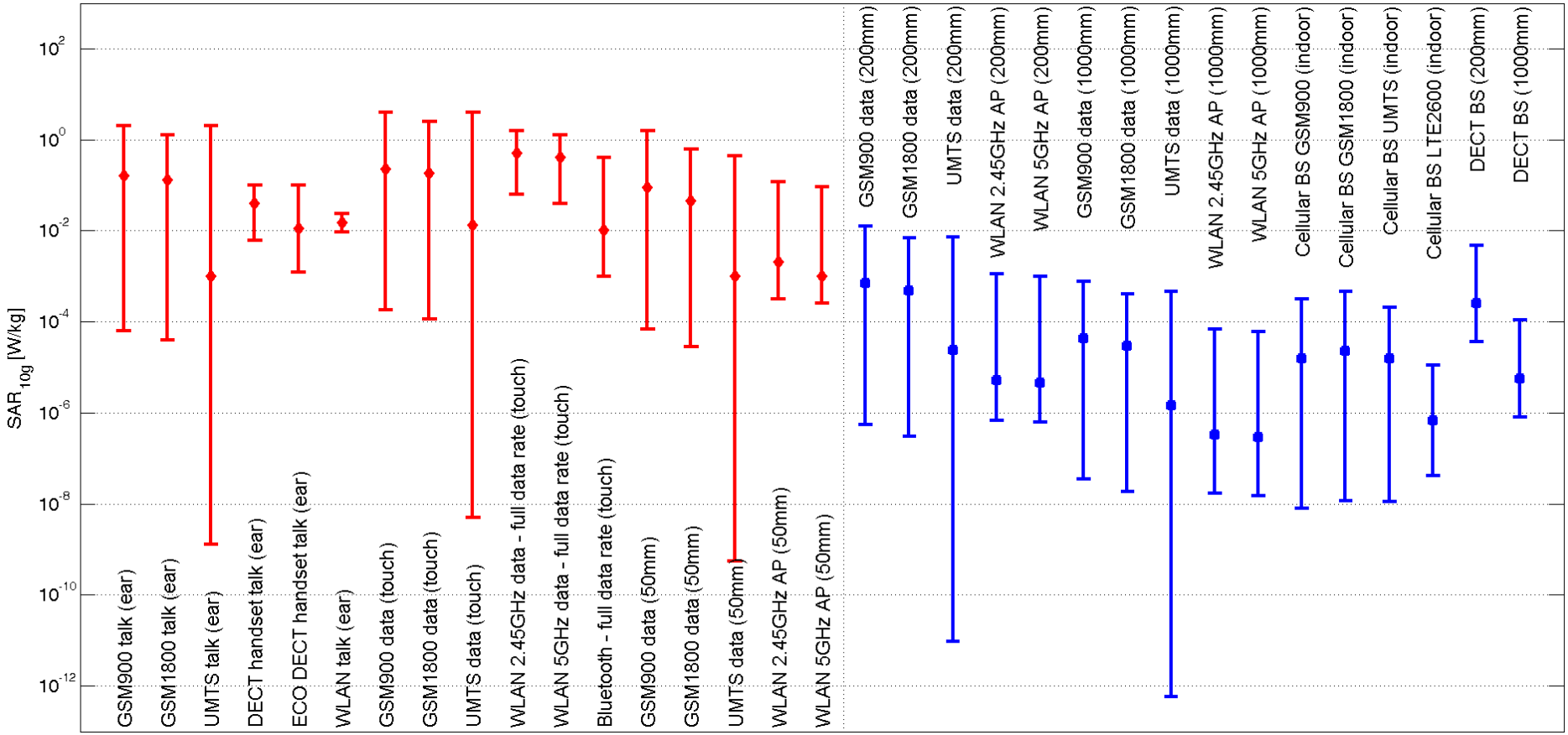


Fig 4a. Statistical representation of psSAR10g from all models in the case of typical use of the generic device (dipole) in the **back trousers pocket**; distance of dipole **5mm**; SAR values normalized to 1 Watt antenna radiated power

Θεόδωρος Σαμαράς
Τμήμα Φυσικής, Α.Π.Θ.

The SEAWIND Project



Θεόδωρος Σαμαράς
Τμήμα Φυσικής, Α.Π.Θ.

Conclusions

- Assessment of human exposure to the electromagnetic radiation of wireless technologies is necessary for their deployment
- There are several techniques for evaluating exposure against guidelines or standards
- Measurement techniques are becoming faster with the use of sensor arrays as devices become multiple in operating modes

Θεόδωρος Σαμαράς
Τμήμα Φυσικής, Α.Π.Θ.

Conclusions

- Computational approaches are gaining room with the advances in computational power (e.g., hardware acceleration)
- The assessment may aim either at the typical or the worst case exposure
- It is easier to determine procedures for compliance testing than to define measurement protocols for assessing the exposure of the general public

Θεόδωρος Σαμαράς
Τμήμα Φυσικής, Α.Π.Θ.

Thank you for your attention!

Θεόδωρος Σαμαράς
Τμήμα Φυσικής, Α.Π.Θ.