ITU Workshop on
“Practical measurement of EMF exposure”

(Gaborone, Botswana, 25-26 July 2011)

Evaluating RF field strength and SAR from radio base station sources

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1. **Global standards**
2. IEC 62232 concepts
3. IEC 62232 base station standard
4. Conclusion

Global Standards

Overview

- IEC, IEEE and ITU working on EMF globally
- CENELEC standards for European countries
- Close liaison IEC, IEEE and CENELEC with agreements in place to support work on a topic only in one organisation wherever possible

Global Standards

International Electrotechnical Commission

- International Electrotechnical Commission is recognised by the World Trade Organisation
- Promotes international cooperation on electrotechnical standardization & related matters,
  - such as the assessment of conformity to standards, in the fields of electricity, electronics and related technologies
  - relationship with other standards bodies – CENELEC, IEEE...
- Objectives for IEC standards include
  - contribute to the improvement of human health and safety
  - meet the requirements of the global market efficiently
  - increase the efficiency of industrial processes
- Many Technical Committees on wide range of issues
  - TC 106 scope relates to human exposure to RF fields

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Global Standards

IEC TC106 - Scope

- To prepare international standards on measurement and calculation methods to assess human exposure to electric, magnetic and electromagnetic fields.
  - characterization of the electromagnetic environments with regard to human exposure
  - measurement methods, instrumentation & procedures
  - calculation methods
  - assessment methods for the exposure produced by specific sources basic standards for other sources
  - assessment of uncertainties.
  - Frequency range 0 Hz to 300 GHz.
  - Basic restrictions and reference levels.
- Excludes the establishment of exposure limits & mitigation methods

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Global Standards

IEC TC106 - Scope

- The next few slides record the published standards from IEC TC106
- There are in addition other published documents e.g. technical reports
- I will not present each document but the slide pack is intended as a useful reference

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Global Standards

IEC TC106 - Communications devices

- IEC 62209-1:2005 Exposure to radio frequency fields from hand-held and body-mounted wireless communication devices - Human models, instrumentation, and procedures - Part 1: Procedure to determine the specific absorption rate (SAR) for hand-held devices used in close proximity to the ear (frequency range of 300 MHz to 3 GHz)
- IEC 62209-2:2010 Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices - Human models, instrumentation, and procedures Part 2: Procedure to determine the Specific Absorption Rate (SAR) in the head and body for 30 MHz to 6 GHz Handheld and Body-Mounted Devices used in close proximity to the Body

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Global Standards

IEC TC106 - Communications infrastructure

- IEC 62232:2011 Determination of RF field strength and SAR in the vicinity of radiocommunication base stations for the purpose of evaluating human exposure
- IEC 62577:2009 Evaluation of human exposure to electromagnetic fields from a stand-alone broadcast transmitter (30 MHz - 40 GHz)

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Global Standards

IEC TC106 - Generic

- IEC 62311:2007 Assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields (0 Hz - 300 GHz)
- IEC 62479:2010 Generic standard to demonstrate the compliance of low power electronic and electrical apparatus with the basic restrictions related to human exposure to electromagnetic fields (10 MHz - 300 GHz)

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Global Standards

IEC TC106 - Specific standards

- IEC 62233:2005 Measurement methods for electromagnetic fields of household appliances and similar apparatus with regard to human exposure
- IEC 62110:2009 Measurement procedures of electric and magnetic fields generated by AC power systems with regard to human exposure
- IEC 62369-1:2008 Evaluation of human exposure to electromagnetic fields from Short Range Devices (SRDs) in various applications over the frequency range 0-300 GHz. Part 1: Fields produced by devices used for Electronic Article Surveillance, Radio Frequency Identification and similar systems.

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Global Standards

IEC TC106 - Calculation standards

- IEC 62226-1:2004 Exposure to electric or magnetic fields in the low and intermediate frequency range - Methods for calculating the current density and internal electric field induced in the human body - Part 1: General
- IEC 62226-2-1:2004 Exposure to electric or magnetic fields in the low and intermediate frequency range - Methods for calculating the current density and internal electric field induced in the human body - Part 2-1: Exposure to magnetic fields - 2D models
- IEC 62226-3-1:2007 Exposure to electric or magnetic fields in the low and intermediate frequency range - Methods for calculating the current density and internal electric field induced in the human body - Part 3-1: Exposure to electric fields - Analytical and 2D numerical models

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Global Standards

CENELEC TC106x

- Specifies product standards for compliance limit requirements and basic standards for assessment methods
- Works under mandates of the European Commission
  - **Mandate M/305:** Standardization mandate in the field of electro technology, information technology and telecommunications
    - **instructs to use the limits of COUNCIL RECOMMENDATION (**1999/519/EC) on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz) [~~ICNIRP General Public]
  - **Mandate M/351:** Standardisation mandate to develop harmonised standards for the assessment, measurement and calculation of workers' exposure to static magnetic and varying electric, magnetic and electromagnetic fields with frequencies from 0Hz to 300 GHz.
    - **2004/40/EC Directive** of the European Parliament and of the Council on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) (18th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC) - Implementation of 2004/40/EC delayed (**>>** 2012)

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Global Standards

CENELEC TC106x

- WG 1: Mobile phones and base stations
- WG 2: EAS & RFID
- WG 3: Basic Standards
- WG 4: Generic Standards
- WG 7: Broadcast transmitters
- WG 9: Inductive and dielectric heaters
- JWG 10/TC26/TC106x: Welding
- JEG13/TC61/TC106x: Domestic appliances
- WG 15 Active Implants
- WG 16 Electrolysis
- WG 17 Electricity supply industry
- JWG18 Radar

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Global Standards

IEC TC106 - Scope

- The next few slides record the published standards from TC106x WG1
- I will not present each document but the slide pack is intended as a useful reference

Global Standards

TC106x WG 1: Mobile Phones

- **EN 50360:2006** Product standard for mobile phones *
  - **AM1:201x**
- **EN 62209-1:2006** replaced **EN 50361:2001** Basic Standard for mobile phones
  - **AM1**: IEC 62209-1 CDV circulated
- **EN 62209-2:2010,** Basic standard for Mobile phones and devices close to the body
- **prEN 50566:201x** Product standard for 62209-2: under enq. + voteLink to the European limit values**

*listed in the OJEC (R&TTE) **to become listed in the OJEC

Global Standards

TC106x WG 1: Base stations

- **EN 50383:2002** Basic standard for base stations
  - **EN 50383:2010** new edition published
- **EN 50384:2002** Product standard for base stations (workers)
- **EN 50385:2002** Product standard for base stations (general public)*
- **EN 50400:2006** Basic standard for Base stations when put into service
- **EN 50401:2006** Product standard for Base stations when put into service*

  EN 50400 prAm1 & **EN 50401 prAm1** to eliminate A-deviations
- **EN 50492:2008** Basic standard for the in-situ measurement of electromagnetic field strength related to human exposure in the vicinity of base stations

*listed in the OJEC (R&TTE)

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Global Standards

Concluding remarks

- Need to promote consistency between international standards
- IEC, IEEE and CENELEC prepare detailed technical standards based on latest science and engineering
- Many standards have been developed but task is on-going to address new technologies and apply latest techniques

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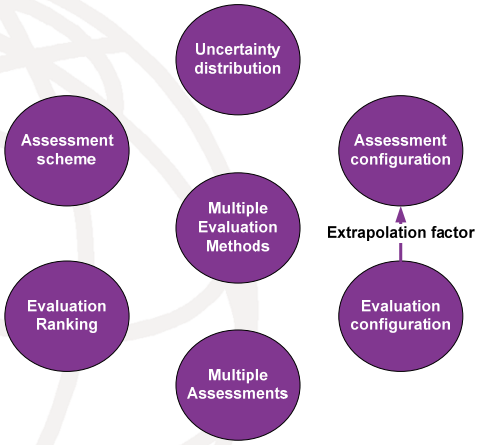
2. **IEC 62232 concepts**
3. IEC 62232 base station standard
4. Conclusion

IEC 62232 Concepts

Overview

- Evaluation challenge for RF fields from base stations
  - Evaluation = Measurement and or Calculation/Computation
- Some new concepts defined and applied
- Considers what regulators define and what is under control of surveyor
- Guides a professional test house on developing their in-house test procedures for their specific evaluation needs



IEC 62232 Concepts

Evaluation challenge - Source

- RF field characteristics change with distance from RF source
- Familiar thinking for standards

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IEC 62232 Concepts

Evaluation challenge - Environment

BUT…..

Environment also affects field characteristics

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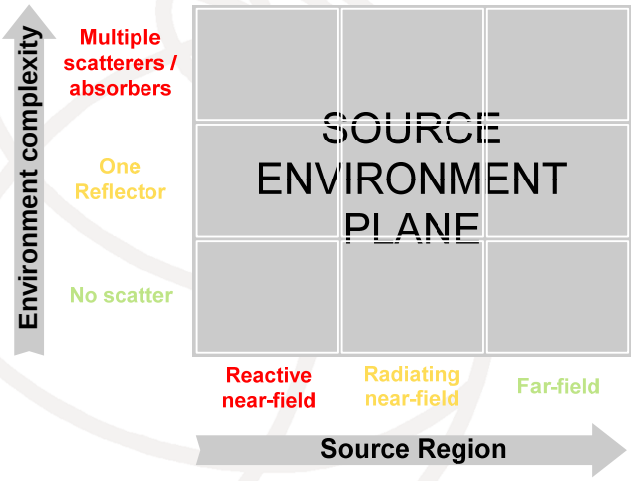
IEC 62232 Concepts

Evaluation challenge – Source–Environment Plane



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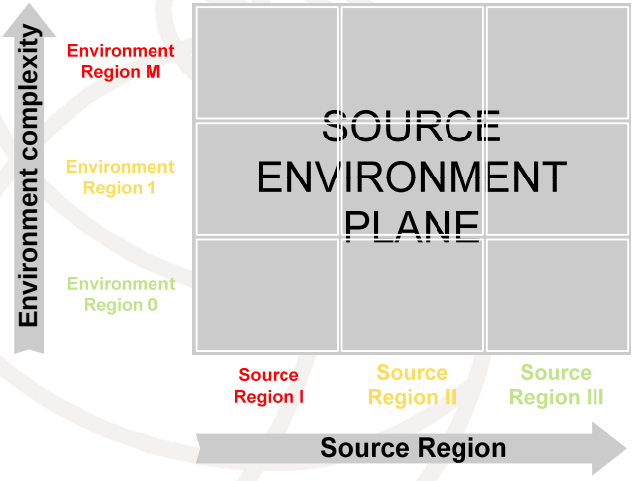
IEC 62232 Concepts

Evaluation challenge – Source–Environment Plane



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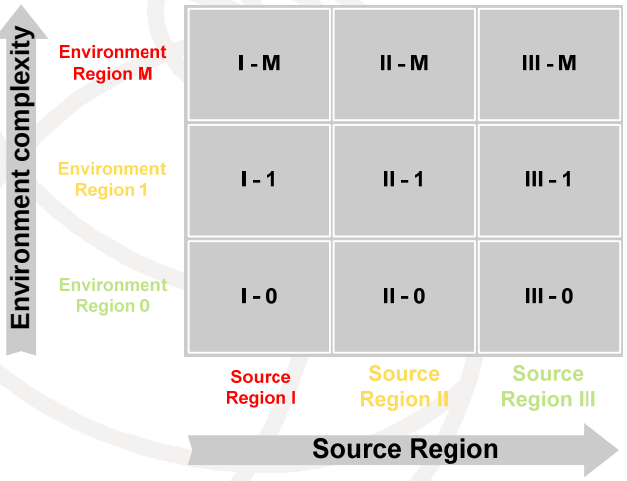
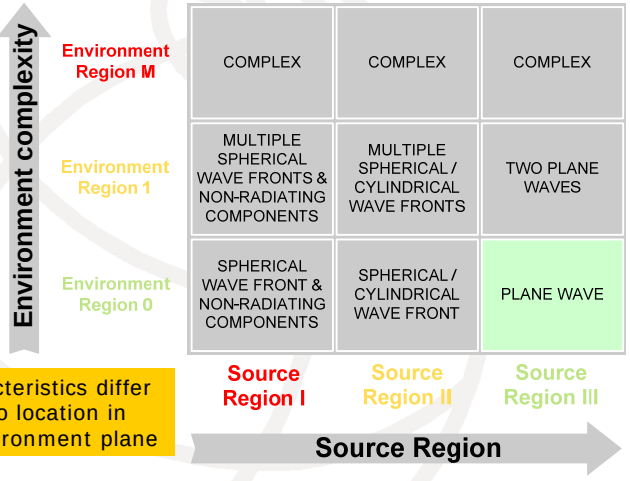
IEC 62232 Concepts

Evaluation challenge – Source–Environment Plane



IEC 62232 Concepts

Evaluation challenge – Field characteristics

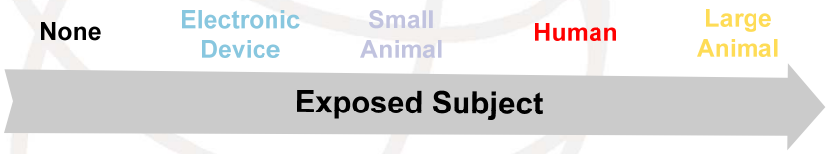


Field characteristics differ according to location in source-environment plane

IEC 62232 Concepts

Evaluation challenge – Exposed subject?

- Need to consider the context of the evaluation
  - Undisturbed field
  - Electromagnetic compatibility
  - Living creature or human



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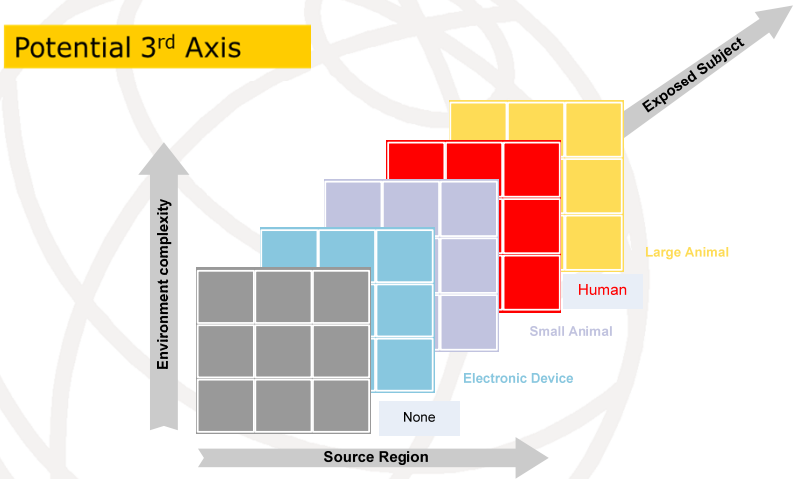
IEC 62232 Concepts

Evaluation challenge – a VOLUME?



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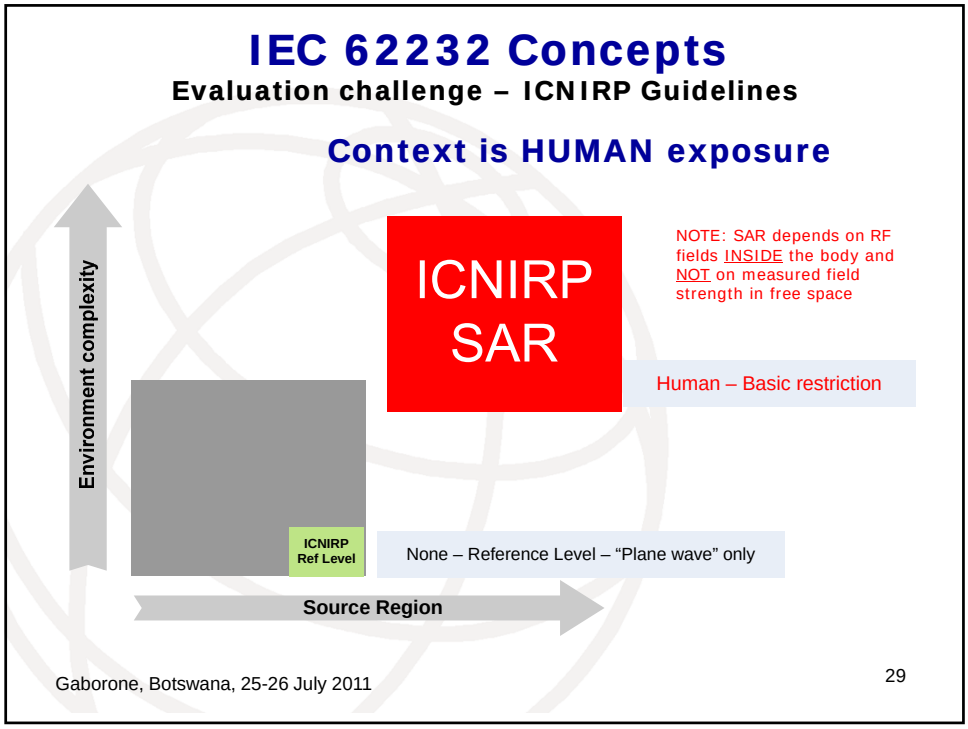
IEC 62232 Concepts
Evaluation challenge – ICNIRP Guidelines
Context is HUMAN exposure
Environment complexity
ICNIRP SAR
NOTE: SAR depends on RF fields INSIDE the body and NOT on measured field strength in free space
Human – Basic restriction
ICNIRP Ref Level
None – Reference Level – "Plane wave" only
Source Region
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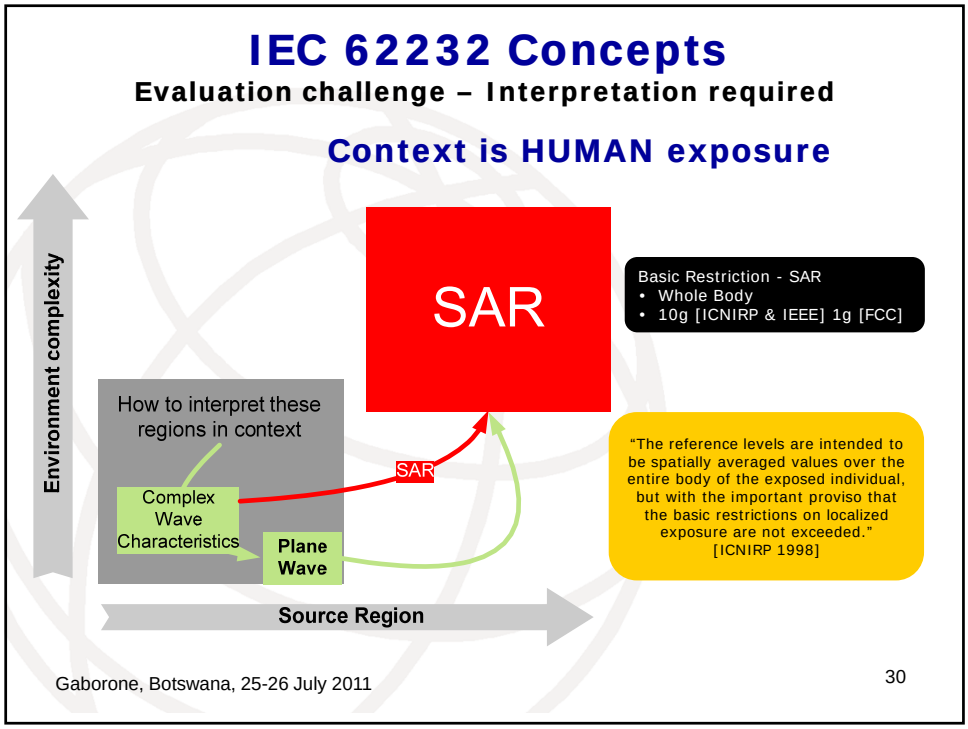
IEC 62232 Concepts
Evaluation challenge – Interpretation required
Context is HUMAN exposure
Environment complexity
SAR
Basic Restriction - SAR
• Whole Body
• 10g [ICNIRP & IEEE] 1g [FCC]
How to interpret these regions in context
Complex Wave Characteristics
SAR
Plane Wave
"The reference levels are intended to be spatially averaged values over the entire body of the exposed individual, but with the important proviso that the basic restrictions on localized exposure are not exceeded." [ICNIRP 1998]
Source Region
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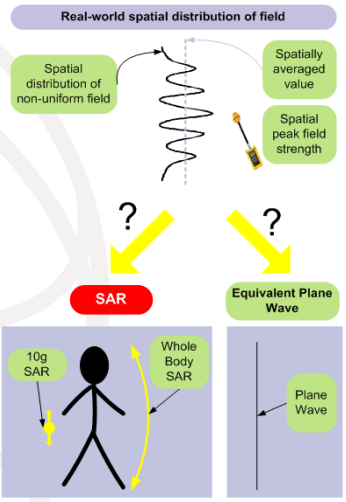
IEC 62232 Concepts

Evaluation challenge – Interpretation required

- RF exposure guideline limits based on SAR and plane waves BUT non-uniform fields normal
  - Spatial peak-to-average characteristic
  - Spatial averaging reduces non-uniform field to single value
- Different field characteristics close to antenna to general public areas
- Results from GSMA/MMF dosimetry II programme SAR / field strength modelling informed the IEC 62232 guidance on spatial-peak & spatial-average field



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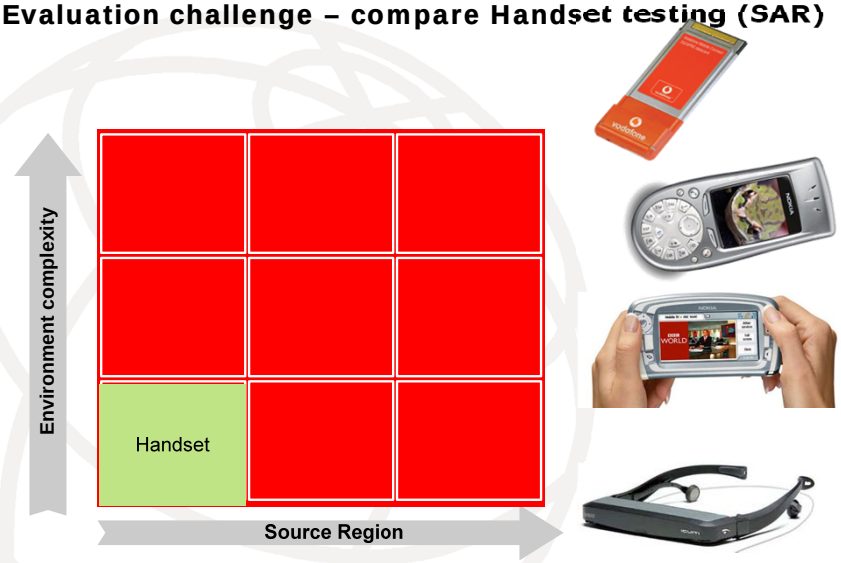
IEC 62232 Concepts

Evaluation challenge – compare Handset testing (SAR)



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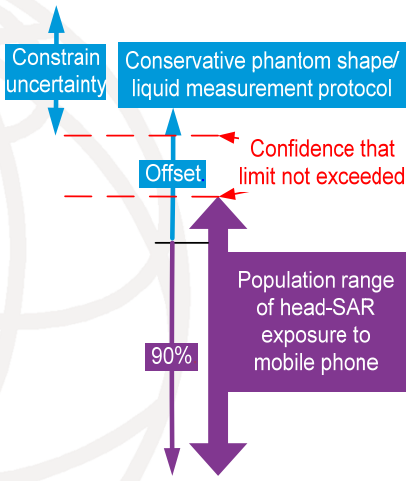
IEC 62232 Concepts

Evaluation challenge – compare Handset testing (SAR)

IEC 62209-1 approach

- Handset characteristics
  - Small product INTENDED to be used close to head
  - Exposure CONSEQUENTIAL to intended use
  - Can operate at maximum power
- Measurement purpose
  - Lab-based SAR compliance
- Protocol derivation
  - Establish exposure data from population
  - Determine a reference
  - Establish evaluation conditions to give offset
  - Constrain uncertainty by having very precise measurement protocol
- Ensures that within the stated uncertainty, a measured result at the compliance limit will correspond to an actual exposure below the limit
- Actual measured value/uncertainty no real relevance beyond giving confidence in product's compliance for population exposure



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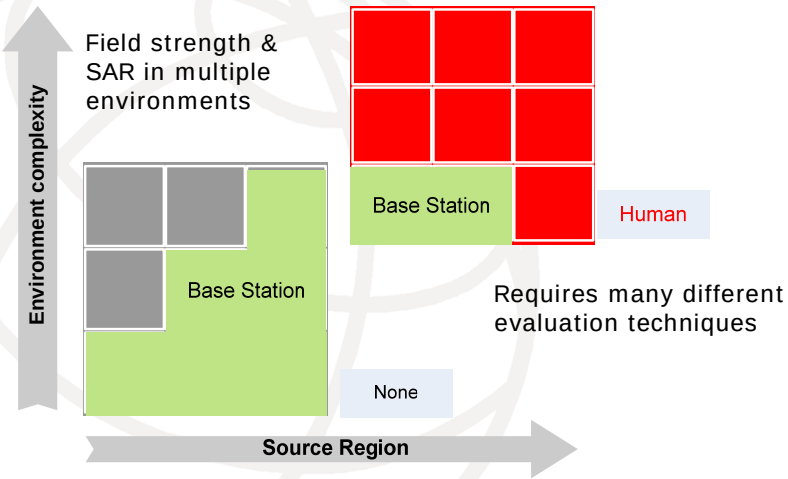
IEC 62232 Concepts

Evaluation challenge – to Base Station



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IEC 62232 Concepts

Evaluation challenge – summary

- Radio Base Stations
  - Are NOT INTENDED for use near people – exposure INCIDENTAL to correct operation
  - Operate over a range of output powers dependent on traffic and propagation
  - Range in size/power - sold to public to network infrastructure
- Varied field conditions dependent on what and where you are evaluating
  - Exposure guidelines not explicit for all practical exposure situations (non-plane wave)
  - Need to select methods and interpret results in human exposure context
- May not be able to make measurement at all
  - Access restrictions prevent survey of some (e.g. private) locations
  - RF source may not be operational
- Need to address different evaluation purposes
  - Compliance perimeter design or confirmation; Product compliance
  - Investigation of alleged over-exposure e.g. within control boundary
  - Public area confidence
- Consider field strength / SAR evaluation
  - Measurement & Computation

Multiple Evaluation Methods

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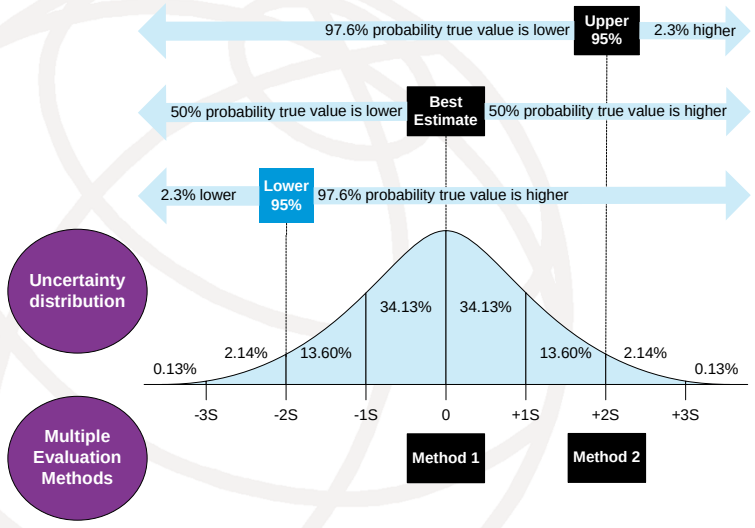
IEC 62232 Concepts

Uncertainty - Comparing results from different methods



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IEC 62232 Concepts

Uncertainty - Comparing results from different methods

CAR SPEED EXAMPLE – CASE 1

- The speed limit is 50 km/h
  - Your car speedo indicates 49 km/h
  - Police speed trap indicates 55 km/h
  - Inconsistent?
- You challenge
  - Your speedo is checked to be within +/- 1%
  - The police speed trap is checked to be within +/- 20%
- Independent assessment
  - Speed trap: 95% confident 44 km/h < speed <66 km/h
  - Your car: 95% confident 48.5 km/h < speed <49.5 km/h
  - Measurements ARE consistent
- Verdict - Insufficient evidence to convict

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IEC 62232 Concepts

Uncertainty - Comparing results from different methods

CAR SPEED EXAMPLE – CASE 2

- The speed limit is 50 km/h
  - Your car speedo indicates 49 km/h
  - Police speed trap indicates 55 km/h
  - Inconsistent?
- You challenge
  - Your speedo is checked to be within +/- 20%
  - The police speed trap is checked to be within +/- 1%
- Independent assessment
  - Speed trap: 95% confident 54.4 km/h < speed <55.6 km/h
  - Your car: 95% confident 39 km/h < speed <59 km/h
  - Measurements ARE consistent
- Verdict - Sufficient evidence to convict

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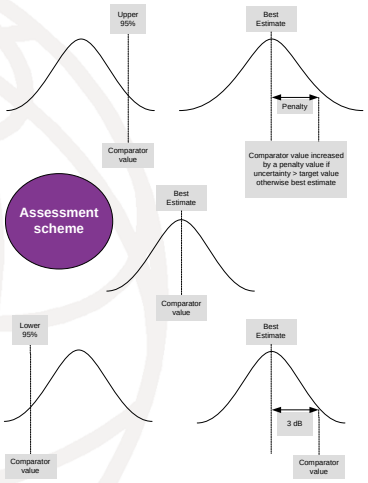
IEC 62232 Concepts

Assessment scheme - Comparing results to a limit

- Define what should be compared to the limit based on
  - Either the requirement to have % confidence that the measurand value is above / below "true" value
  - Or the requirement to follow specific algorithm referenced to e.g. "best estimate" or "Upper 95%" confidence value
- Defined/inferred from regulation or stated as part of assessment report



IEC 62232 Concepts

Assessment scheme - Audience participation

- This is for people who work for
  - Regulators/Government
  - RF testing organisations
  - Telecommunications operators
  - Broadcast service providers
  - Radio site providers

IEC 62232 Concepts

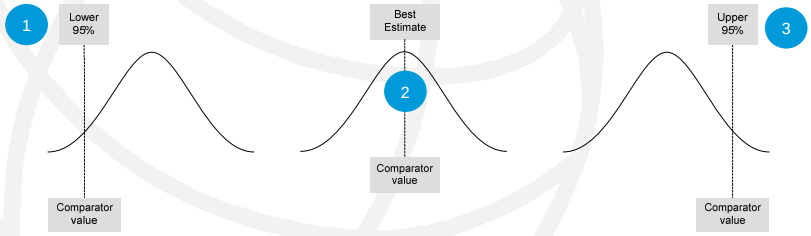
Assessment scheme - Audience participation

- Scenario 1: An operator is to define the control boundary around a base station antenna for maximum transmitted RF power.
- How would your National REGULATOR expect the operator to address the inevitable evaluation uncertainty according to the following three broad categories of assessment scheme?

Subtract uncertainty and set boundary accordingly.

Use the best estimate value to set the boundary.

Add uncertainty and set boundary accordingly.



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IEC 62232 Concepts

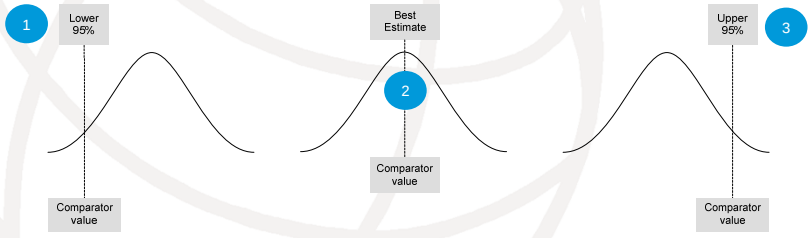
Assessment scheme - Audience participation

- Scenario 2: An operator has implemented a RBS site and has completed their assessment and defined the control boundary. The regulator has asked for a confirmation assessment.
- How would your National REGULATOR address the evaluation uncertainty according to the following three broad categories of assessment scheme?

I want to be confident that the limit has been exceeded before taking action.

I will simply take the best estimate value and if limit is exceeded will take action.

I will add my uncertainty and if limit is exceeded will take action.



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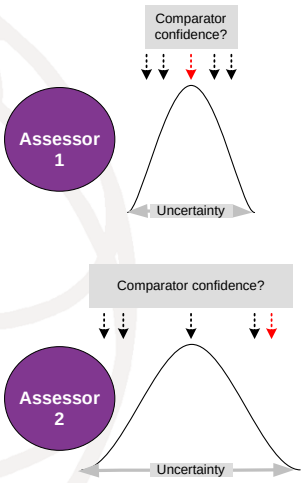
IEC 62232 Concepts

Considering multiple assessments

- The combination of uncertainties and assessment schemes in both surveyor 1 (e.g. operator) and surveyor 2 (e.g. regulator) RF evaluations leads to the possibility of the following important compliance verification events:
  - Non-compliance determination: surveyor 2 finds that RF exposure at surveyor 1's compliance boundary is non-compliant with the exposure limit
  - Compliance error: Surveyor 2 decides that surveyor 1's compliance boundary is compliant with the exposure limit when it really isn't
  - Non-compliance error: Surveyor 2 decides that surveyor 1's compliance boundary is non-compliant with the exposure limit when it really is compliant



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IEC 62232 Concepts

Multiple evaluation methods & Evaluation ranking

- Surveyor develops evaluation plan(s) for their specific task(s)
  - Guidance on selection from multiple evaluation methods
    - Purpose specific
    - Pre-validated methods
  - Guidance on how to validate own method
  - Guidance on application of methods to tasks
- Clear evaluation ranking considering
  - Measurand
  - Evaluation method
- Enables simple (economic) evaluations or more precise reference methods if needed.

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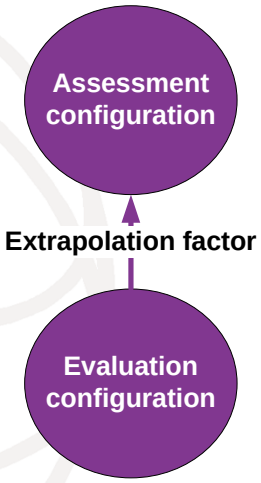
IEC 62232 Concepts

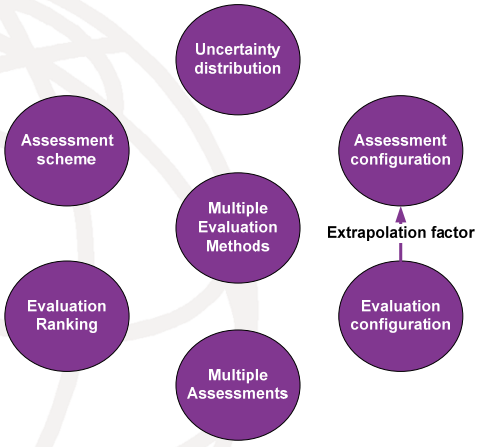
Addressing "extrapolation"

- Generic approach is
  - Know the configuration of the RBS that you have evaluated
  - Specify the configuration which needs to be assessed against a "limit"
  - Establish the "extrapolation factor" to adjust the evaluated measurand to the assessment measurand
- Adaptable
  - Purpose dependent
  - May/may not be specified by regulator
  - Generic approach enables "worst case" or defined alternative
  - Provides rationale for handling new technology e.g. LTE, adaptive array antennas



IEC 62232 Concepts

Summary



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IEC 62232 & IEC/TR 62669

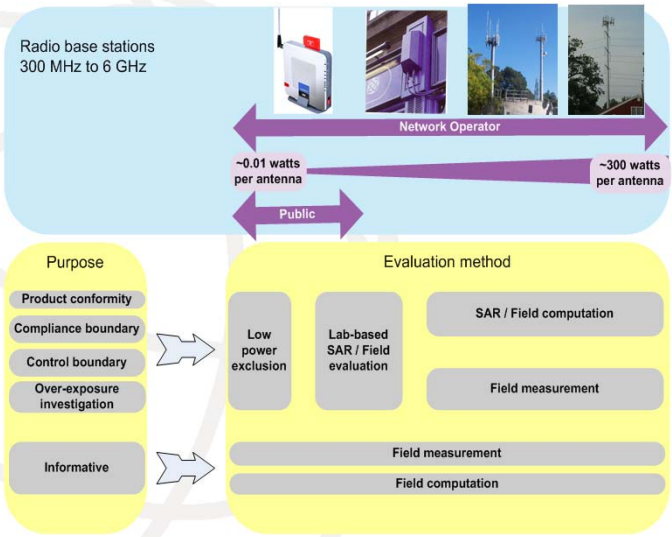

IEC 62232
Edition 1.0 2011-05
INTERNATIONAL STANDARD
NORME INTERNATIONALE
colour inside
Determination of RF field strength and SAR in the vicinity of radiocommunication base stations for the purpose of evaluating human exposure
Détermination des champs de radiofréquences et du DAS aux environs des stations de base utilisées pour les communications radio dans le but d'évaluer l'exposition humaine
INTERNATIONAL ELECTROTECHNICAL COMMISSION
COMMISSION ELECTROTECHNIQUE INTERNATIONALE
PRICE CODE CODE PRIX XJ
ICS 13.280; 17.240
ISBN 978-2-88912-493-0


IEC/TR 62669
Edition 1.0 2011-05
TECHNICAL REPORT
colour inside
Case studies supporting IEC 62232 – Determination of RF field strength and SAR in the vicinity of radiocommunication base stations for the purpose of evaluating human exposure
INTERNATIONAL ELECTROTECHNICAL COMMISSION
PRICE CODE XK
ICS 13.280; 17.240
ISBN 978-2-88912-528-9

IEC 62232 base station standard

Scope

Determination of RF field strength and SAR in the vicinity of radio communication base stations for the purpose of evaluating human exposure



Over 50 National Committee and invited experts
- Africa
- America
- Asia
- Australasia
- Europe

IEC 62232 base station standard

Scope

- Aims
  - Targeted at RBS
  - Clear, practical "How to"
  - Explanatory Annexes
- Approach
  - New standard
  - Considers existing standards and new research
- Does NOT define limits
  - Evaluation methodologies only
- Uncertainty evaluation
  - Common basis for interpreting ANY included method
- Multiple purposes
  - Compliance
    - Boundary determination
    - Location confirmation
  - Over-exposure investigation
  - Public information
- Multiple methodologies
  - Measurement / computation
  - RF field strength / SAR
- Any valid method may be used
  - "Reference" method specific to source-environment plane location and purpose
- Also covers situations where it is not possible for a surveyor to measure

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Scope

- Key things:
  - Deciding on the evaluation approach
  - Performing the evaluation
  - Understanding what results mean
  - Accurate and complete reporting

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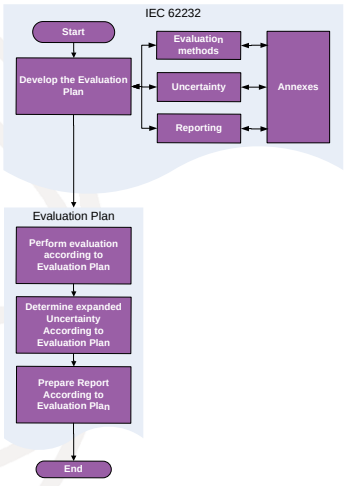
Overview

- Flow chart based - Linked to clauses
- "Kit of Parts" approach – flexible way for test houses to develop specific evaluation plans according to their work
- Evaluation plan defines methods based on - Purpose, RBS category, Available data, Extent of control over RBS, Source-Environment Plane location.....
- "How to" described in main text with annexed additional information
- Embedded files in electronic format for validation & for assessment schemes
- IEC/TR 62669 Case study examples



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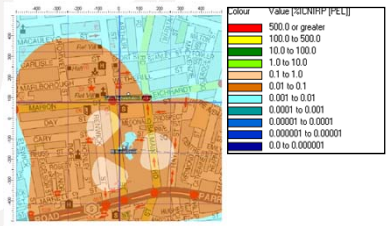
Measurement or computation?

… a matter of perception

EVERYONE believes a measurement EXCEPT the person who made it

NO ONE believes a computation EXCEPT the person who did it



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Measurement or computation?

Computation

- Client request
- No access
- Comprehensive visualisation
- Base station not transmitting

Measurement

- Client request
- Insufficient information for computation
- Specific limited routes/nominated locations
- Physical demonstration

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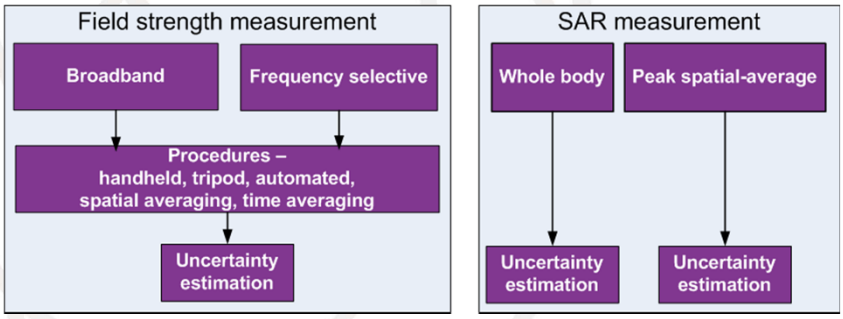
Evaluation methods – Measurement, SAR / Field strength?

- SAR in source region I or where smallest boundary required
- Frequency selective field strength preferred
- Broadband field strength simple but limited



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Evaluation methods - Measurement

- RF field strength sub-clauses cover
  - Applicability of broadband / frequency-selective methods
  - Procedures
    - To measure fixed points of interest
    - To sweep a volume
    - To use tripod-supported probe
    - To use automated spatial positioning equipment
    - To use spatial averaging
    - To use time averaging
  - Uncertainty estimation
- SAR measurement sub-clauses cover
  - Whole body SAR measurement
  - Peak spatial-average SAR measurement
  - Refers extensively to IEC 62209-2 for detail

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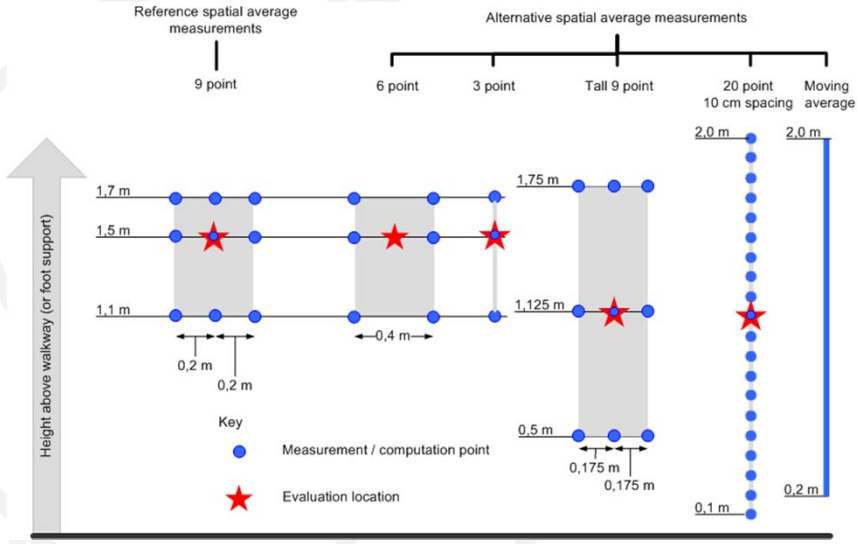
Evaluation methods – Spatial averaging



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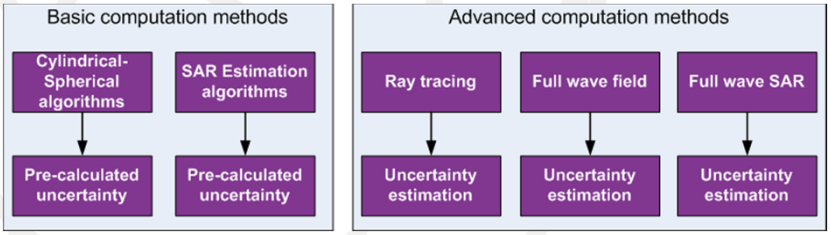
Evaluation methods - Computation

- Range of techniques from simple-to-apply to more precise evaluation
- ACCURATE INPUT DATA CRITICAL
- Basic methods describe algorithms rather than just formulae
  - Enables clear application and use of pre-calculated uncertainties
- Provides guidance on how to validate methods



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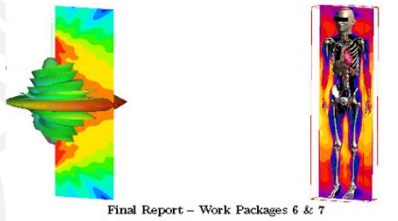
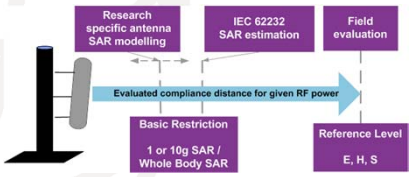
Evaluation methods – SAR Estimation

- Ericsson initiative
  - SAR-estimation formula concept from Nordstrom 2004 MSc thesis
  - Literature review & additional modelling ~700 random data points
  - Extended to define SAR off-main-beam 700 – 2700 MHz
- GSMA/MMF dosimetry II prog SAR/Field modelling[1]
  - Extended freq range 300 – 5000 MHz with ~1200 optimised data points
- More than just "formulae"
- Uncertainty addressed
  - Conservative >95% confidence



Final Report – Work Packages 6 & 7

MMF/GSMA Phase 2: Scientific Basis for Base Station Exposure Compliance Standards



1. KÜHN, S. et al. *MMF/GSMA Phase 2: Scientific Basis for Base Station Exposure Compliance Standards*, [cited 2011-02-17] Available on Internet: http://www.itis.ethz.ch/news-events/news/it-is-papers/2009/mmf-gsma-commissioned-study-scientific-basis-for-base-station-exposure-compliance-standards/

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Evaluation Methods - Spherical / Cylinder models

- Modern computers make it easy to get a number and present convincing visualisation. The uncertainty & applicability work supporting IEC 62232 gives meaning to the numbers with uncertainty estimation.
- Algorithm for field strength from omni/sector type arrays at any point around antenna from near to far-field with clear applicability criteria for each formula.
  - Establishes clear boundaries on applicability and guidance on interpreting results
  - Based on standard free space formula & cylinder formulae[1,2]
- EMSS numerical modelling[3] of a range of antennas gives confidence level for application of these in the near field considering a range of uncertainty contributors

1. CICCHETTI, R., FARAONE, A., and BALZANO, Q. A Uniform Asymptotic Evaluation of the Field Radiated from Collinear Array Antennas. *IEEE Transactions on Antennas and Propagation*, Jan. 2003, Vol. 51, No. 1, pp. 89-102
2. CICCHETTI, R., and FARAONE, A. Estimation of the Peak Power Density in the Vicinity of Cellular and Radio Base Station Antennas. *IEEE Transactions on Electromagnetic Compatibility*, May 2004, Vol. 46, No. 2, pp. 275-290
3. DU PLESSIS, F. *Near-field Computation and Uncertainty Estimation using Basic Cylindrical-Spherical Formulae* http://www.emssixus.com/download/Near_Field_Computation_using_Basic_Cylindrical_and_Spherical_Formulae_EMSS.pdf

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Evaluation Methods - Spherical / Cylinder models

2.3 Boundaries for computation

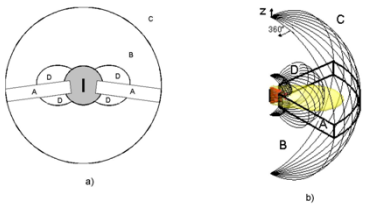

Figure 2-3 a) Antenna 2-D side view, and b) equivalent 3-D view, illustrating the three valid zones for calculation. The 3-D view shows pie-slice sections of the same three zones, which are symmetrically equivalent around the z-axis.

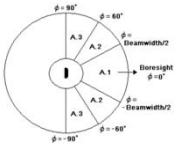

Figure 4-1 Definition of sub-zones in the horizontal plane. Omni-directional antennas fall under zone A.1, while panel arrays can fall under zones A.1, A.2 or A.3 according to Φ.

EMSS — Basic Near-Field Computation

4.2 Adjustment tables

Table 4 Power density (dB) adjustment table for cyl-sph formulae, no external uncertainty parameters.

	Average Cylindrical formulae	Peak Cylindrical formulae	Adjusted spherical formulae	Simple spherical formulae
		CI-95%		
A.1	+0.3	+0.6	-	-
A.2	+1.1	+1.4	-	-
A.3	+7.2	+7.5	-	-
B	-	-	+0.0	-
C	-	-	-	+3.5
D			+5.8	
		CI-80%		
A.1	+0.2	+0.5	-	-
A.2	+0.9	+1.2	-	-
A.3	+6.9	+7.2	-	-
B	-	-	-1.0	-
C	-	-	-	+1.5
D			+4.6	
		CI-50%		
A.1	+0.0	+0.3	-	-
A.2	+0.2	+0.5	-	-
A.3	+4.7	+5.1	-	-
B	-	-	-1.6	-
C	-	-	-	+0.3
D			-1.7	
		CI-20%		
A.1	-0.1	+0.1	-	-
A.2	+0.1	+0.3	-	-
A.3	+0.1	+0.4	-	-
B	-	-	-2.0	-
C	-	-	-	+0.0
D			-4.8	
		CI-5%		
A.1	-0.2	-0.1	-	-
A.2	-0.1	+0.0	-	-
A.3	-0.1	+0.1	-	-
B	-	-	-2.6	-
C	-	-	-	+0.0
D			-7.3	

DU PLESSIS, F. *Near-field Computation and Uncertainty Estimation using Basic Cylindrical-Spherical Formulae* http://www.emssixus.com/download/Near_Field_Computation_using_Basic_Cylindrical_and_Spherical_Formulae_EMSS.pdf

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Evaluation Methods - Advanced computation

- Powerful computer techniques
- Several years experience in modelling EM fields and SAR on case by case basis by universities and design organisations
- Standardised approach for at least the common cellular antennas to enable use for compliance evaluation
- GSM Association / MMF dosimetry II programme developed approach to establish applicability boundaries, enable uncertainty analysis to be applied and provide validation basis
- First standard to apply "virtual human family" set of models
- Validation data included in Annex H to aid implementation

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Evaluation Methods - Extrapolation

- Process to use the evaluated data in order to determine the corresponding value for the defined assessment configuration (e.g. Max Power)
  1. Define the configuration as evaluated
  2. Define the configuration to be used as basis for assessment
  3. Determine case-specific extrapolation factor considering steps 1. and 2.
  4. Apply the extrapolation factor to the measurand to get the assessment value
- E.g. Measure component of total signal (GSM – BCCH) which does not vary in power output over time and known relationship to maximum power (GSM – no of installed transmitters) to estimate measurand value at max power.

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Evaluation Methods - Summation

- Process to combine evaluations of a number of evaluated field strengths / SAR values from multiple frequencies or multiple sources at a given location
- Refers to IEC/TR 62630:2010 for more detail
- Enables the evaluation methods to be applied to radio sites with many base stations and other radio sources

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Uncertainty estimation

When estimating uncertainty

Consider the whole picture!

e.g. Next slide shows Table 6, used in estimating ray tracing uncertainty

Source of uncertainty	Unit	Prob. distrib. type	Uncertainty or semi span *a*	Divisor *d*	Sens. coeff. *c*	Standard uncertainty *u = a/d*	Corr. fact *t*	c^2u^2
System								
Variation in the power of the RF transmitter from its nominal level	dB	rect.		√3	1			
Cable/connector losses	dB	normal		1,96	1			
Mismatch between antenna and its feed	dB	U		√2	1			
Antenna radiation pattern data (see NOTE 2)	dB	normal		1,96	1			
Antenna positioning, mounting & support structure	dB	rect.		√3	1			
Technique Uncertainties								
Inherent uncertainties associated with the approximate numerical model used to represent the antenna.	dB	rect.		√3	1			
Null-filling of antenna patterns (if applied)	dB	Depends on algorithm			1			
Environmental Uncertainties								
Scattering from nearby objects and the ground	dB	rect.		√3	1			
Uncertainty in using electric field strength evaluations to estimate magnetic field strength, or vice versa	dB	rect.		√3	1			
Combined correction factor, $u_c = \sqrt{\sum_{i=1}^{N}(c_i^2\ u_i^2)}$								N/A
Combined standard uncertainty, $U = k \times u_c$								
Coverage factor for required (e.g. 95 %) confidence interval,								
Expanded uncertainty,								
NOTE 1 The value of divisor *d* for normal probability distribution is for 95 % confidence, see Annex O.2.								
NOTE 2 The normalized radiation pattern uncertainty can be different inside the HPBW (very small); outside the main beam (larger); and in the side lobes.								

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Reporting

- The two main goals of the reporting are:
  - that another skilled person has all the information necessary to repeat the assessment
  - to present the results of the assessment
- The reporting typically consists of:
  - Evaluation data sheets - used to record equipment set up and measured or calculated results.
  - Final report – a detailed technical report and executive summary. The executive summary is usually provided to the customer or client and may vary considerably depending on the requirements of the client.

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Annexes

- Annex A Developing the evaluation plan
  - Describes how to select the (set of) method(s) for the specific task
- Annex B Defining the source-environment plane
- Annex C Guidance on the application of the standard to specific evaluation purposes
  - Compliance boundaries
  - Confirming control boundary
  - Overexposure evaluation
- Annex D Evaluation parameters
  - Defines the coordinate systems and the main evaluation parameters used within the standard
- Annex E RF field strength measurement equipment requirements

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Annexes

- Annex F Basic computation implementation
  - Provides detailed formulae and their applicability
- Annex G Advanced computation implementation
  - Guidance on advanced computation implementation/data requirements
- Annex H Validation of computation methods
  - Example computation results for validation of implementation
- Annex I Guidance on spatial averaging schemes
- Annex J Guidance on addressing time variation of signals in measurement
- Annex K Guidance on determining ambient field levels
  - How to evaluate the RF field strengths from sources other than from the target RBS, in locations where people may also be exposed to RF fields from the target RBS

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Annexes

- Annex L Guidance on comparing evaluated parameters with a limit value
  - Describes the information required to make a valid comparison according to the relevant assessment scheme and evaluation uncertainty
- Annex M Guidance on assessment schemes
  - Describes a number of assessment schemes and introduces a model (excel workbook embedded in electronic version of standard) to simulate compliance error probabilities when an auditor reassesses an earlier evaluation
- Annex N Guidance on specific technologies
  - Technical information specific to the air interface under evaluation
  - Introduces probabilistic considerations for smart antennas
- Annex O Guidance on uncertainty

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Annexes – TR 62669

- Annex P Case studies
  - Guidance example evaluations introduced in "case study" annex to support
    - Understanding
    - Traceability
  - Full case studies are found in IEC /TR 62669

Approach supports accreditation process for competent testing bodies

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Contents

1. Global standards
2. IEC 62232 concepts
3. IEC 62232 base station standard
4. **Conclusion**

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CONCLUSION

Observations about IEC 62232 / TR 62669 approach

- Aimed at trained engineers to support their development of protocols specific to their tasks
  - Implements findings of major targeted research work
- Provides flexibility without having a special "recipe" for each conceived case
  - With 5 purposes, ~3 categories of RBS, Laboratory / in situ, SAR / Field strength – potential need for 60 recipes to give equivalent coverage (consider alternative of ~10 pages per "recipe", only 40 described recipes and some overhead = 450 pages)
- Clear guidance on deciding what method to apply
- Emphasis on uncertainty estimation
- Enables meaningful comparison of different methods' results
- Clarifies understanding on how to compare with limit

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CONCLUSION

Observations - What should a computation tool include?

- Verification data
  - How has package been proven?
  - Are the limitations/applicability clearly defined?
- Uncertainty addressed
  - Uncertainty budget provided?
  - Criticality of accurate data addressed?
  - Defines where on the uncertainty probability distribution the computed value lies – "best estimate", "upper 95%"?
- Ideally
  - Linkage to common data management structure included to minimise transcription errors

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CONCLUSION

Acknowledgements

IEC PT 62232 colleagues for technical content of standard

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Questions ?

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