ITU Workshop on "Practical measurement of EMF exposure"

(Gaborone, Botswana, 25-26 July 2011)

Application of the IEC 62232 standard to EMF measurements around cellular base stations

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EMSS CONSULTING, SOUTH AFRICA

International Telecommunication Union

Content

- Why EMF Measurements?
- EMSS Overview
- RF fields in our environment
- Guidelines for safe exposure
- Typical exposure vs guidelines
- Cellular Networks

Content

- Measurement Equipment
- Measurement Methodology
- Demo
- Reporting
- Uncertainty analysis
- Exclusions

Content

- Base station Compliance
- Conclusion

Content

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- EMSS Overview
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- Typical exposure vs guidelines
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Why EMF Measurements?

- Cellular exclusion zone accessibility
  - Measurements normally not required or used to determine compliance boundary
- Measure at publicly accessible areas around cellular base stations
  - Public concern

RONDEBOSCH DEBATE

School heads mixed over cellphone mast plan

DOMINIQUE HERMAN

THE principal of Rondebosch Boys' Preparatory School is objecting to a proposed 30m-high MTN cellular base station at nearby St Thomas's Church until there is "clear scientific proof" that the masts are safe.

Tony Ryan said yesterday that he was responsible for the children of 700 families and until he had more information that the mast was not a health risk, he was not going to support it.

Grant Nupen, principal of Bishops, which lies adjacent to the church, said he had asked the head of their biology department to study the issue and provide an assessment by the end of the month.

He said five years ago there had been a request to erect a base station on school premises and there was a similar request at his son's school in Somerset West about three years ago – both of which were rejected.

"It's far more dangerous to cross the street. We've got to be practical as a society. Wherever you put them it's going to be damaging to someone," he said.

Elizabeth Pollard, the principal of Rosebourg Girls' High School, also on Campground Road, said that she had not yet formed an opinion on the mast since she had not studied the facts.

However, it appeared one would have to stand right next to it for it be a health risk.

"The kids hardly have the cellphones away from their ears. They are probably doing themselves far more damage than any pole could do," she said.

Malcolm Brown, shop assistant at Dean's toy and stationery shop in the Sidwood Shopping Centre, said they had posted the proposal notice in their shop and had received mostly negative comments.

"Everyone seems to be dead against it," he said.

The proposal came about when Tony Hoare, a lay minister at St Thomas, contacted MTN regarding the "appalling" cellphone reception in the area.

MTN told him they had no masts there as nobody would let them put one up. He said he had used radios all his life as an electrical engineer and there was greater exposure – the same as was emitted by cellphone masts – from television, police radios and cellphones themselves. He added that radio frequencies were "total toy low" on the frequency band.

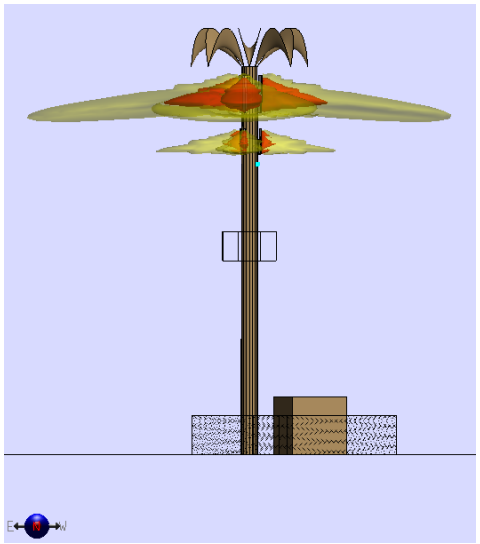
Revenue from the 30m-high mast, which would be disguised as a stone pine, would probably be R2 000 to R3 000 a month.

Don't chance it with cellpho

Row grows over cell mast forest

City council is losing track of applications for equipment close to homes, says critic

By RYAN WILLIAMS



Why EMF Measurements?

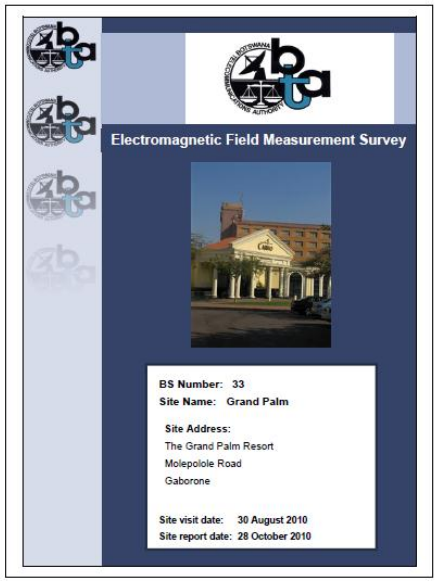
- Example site: Photographs

Why EMF Measurements?

- Example site: Map

Why EMF Measurements?

- Example site: Report


Electromagnetic Field Measurement Survey

BS Number: 33
Site Name: Grand Palm

Site Address:
The Grand Palm Resort
Molepolole Road
Gaborone

Site visit date: 30 August 2010
Site report date: 28 October 2010

Introduction

As part of an electromagnetic measurement survey program of base station installations performed by the Botswana Telecommunications Authority (BTA), measurements were performed at Grand Palm. The aim of the survey was to measure the electromagnetic exposure levels at various positions around the base station.

Measured results are compared to the guidelines of limiting exposure proposed by the International Commission on Non-Ionizing Radiation Protection (ICNIRP).

Measured Results

Table 1 and Figure 1 presents the measured positions and exposure levels in terms of a percentage of the ICNIRP guidelines, where a 100% value would indicate that the safe exposure limit for the General Public has been reached. The total exposure is given in the first column of the table. Since the aim of the survey was to measure the typical exposure values, the reported results are un-extrapolated peak field instantaneous exposure results, at the specific date and time of the measurement survey.

Summary of Results & Conclusion

For the measured results presented in this report a 100% value would indicate that the ICNIRP exposure limit for the General Public has been reached. The highest value measured is 1.0578% of the ICNIRP General Public guidelines and was obtained at position 3. This is more than 90 times below the General Public limit.

Table 1: RF Exposure Levels at Measurement Positions

Measured On	No.	Position	Total Exposure	GSM900 DL	GSM1800 DL	UMTS DL	Others
2010/08/30 16:30	1	At the entrance of the Grand Palm Resort.	0.0354%	0.0235%	0.0004%	0.0005%	0.0110%
2010/08/30 16:48	2	On the 6th floor in the guest lift room.	0.0238%	0.0026%	0.0001%	0.0001%	0.0210%
2010/08/30 16:57	3	On the 6th floor in the service lift room.	1.0578%	1.0396%	0.0020%	0.0039%	0.0123%
2010/08/30 16:10	4	In line with antenna, along the second drive way from entrance.	0.2212%	0.2089%	0.0008%	0.0004%	0.0111%
2010/08/30 16:17	5	In line with antenna, next to swimming pool at the back of the hotel.	0.0597%	0.0483%	0.0000%	0.0001%	0.0113%
2010/08/30 16:24	6	In line with antenna, on the rocky outcrop close to the pond, behind the hotel.	0.0191%	0.0078%	0.0001%	0.0001%	0.0112%
2010/08/30 16:32	7	In line with antenna, in the maintenance yard east of building.	0.0388%	0.0258%	0.0001%	0.0002%	0.0127%
2010/08/30 16:44	8	In line with antenna, at the maintenance offices.	0.0391%	0.0271%	0.0000%	0.0004%	0.0115%

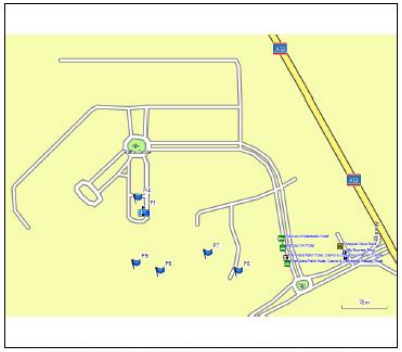


Figure 1: Map of Area around Base Station Site and Measurement Positions

Measurement Equipment and Methodology

Both survey meter and probe must be calibrated on a regular basis. The calibration status is presented in the following table.

Survey Meter:	Narda SRM 3000 Selective Radiation Meter, S/N: G-0113	Calibration Status:	Valid calibration: 17 September 2008
Probe:	Narda BN 3501 Three-Axis E-Field Probe, S/N: J-0019	Calibration Status:	Valid calibration: 26 February 2009

Assessment Process and Software

The assessment process, software and training were developed by EMSS Consulting (EMSS). EMSS has expertise in the field of human exposure assessment to radio-frequency fields.
BTA engineers were trained by EMSS to perform measurements in accordance with the measurement protocol of the CENELEC 50492 (November 2008) standard for the in-situ measurement of electromagnetic field strength related to human exposure in the vicinity of base stations. The CENELEC 50492 standard requires an uncertainty assessment to be performed when extrapolation is not used to address maximum traffic. A full uncertainty analysis for the measurement methodology developed by EMSS has been performed and resulted in an expanded uncertainty of 3.8 decibel (dB).
Additional survey information, typically shown in a CENELEC 50492 report, is available from BTA on request.

For more information, contact the BTA at:
Tel: +267 395 7755
Fax: +267 395 7976
Email: engineering@bta.org.bw

Why EMF Measurements?

- Example site: Report

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Why EMF Measurements?

- Determine compliance boundary
  - Radar, TV, etc installations
- Not covered in this talk

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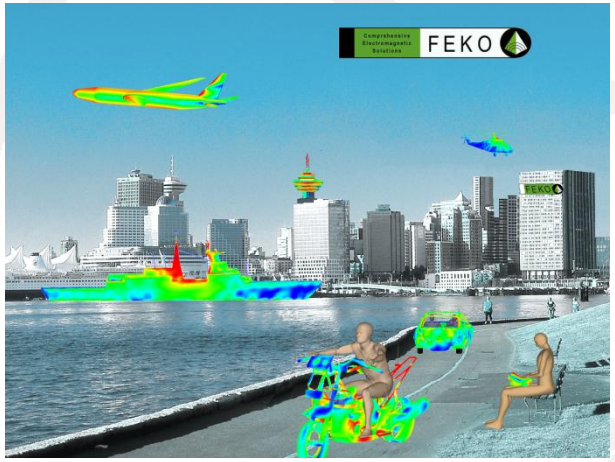
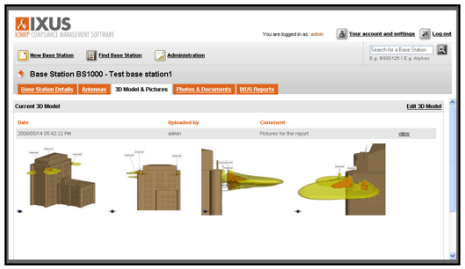
EMSS Overview

- Based in Stellenbosch, South Africa
- Focus on electromagnetics
- Non EMF safety activities
  - FEKO
  - Radio Astronomy Karoo Array Telescope



EMSS Overview

- Products and services in the field of EMF Safety
  - Ixus – Compliance Software
  - fieldSENSE
  - Site assessment and certification
  - RF awareness training
  - EMF Measurements



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Radio Frequency Fields in Our Environment

- RF Sources?

TV

Microwave Ovens

Base Stations

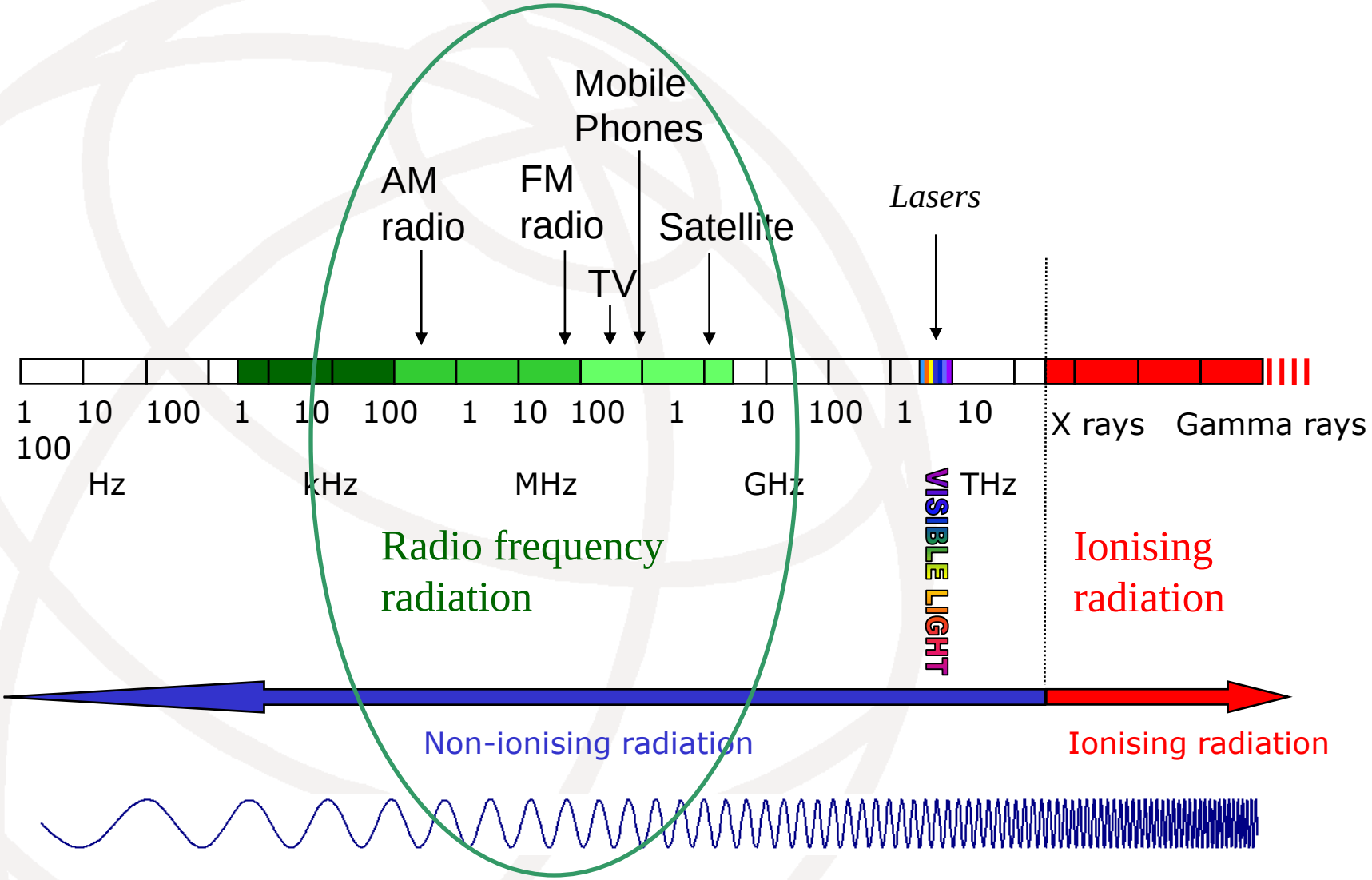
Radio

Comms in Vehicles

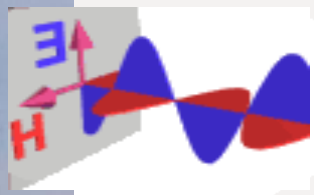
WiFi

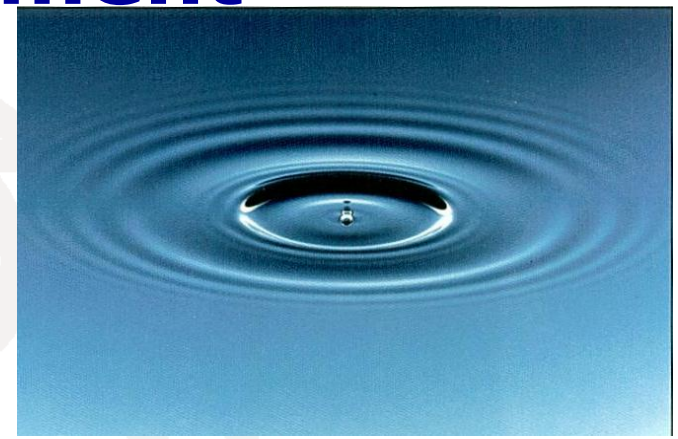
Cellphones

Radio Frequency Fields in Our Environment

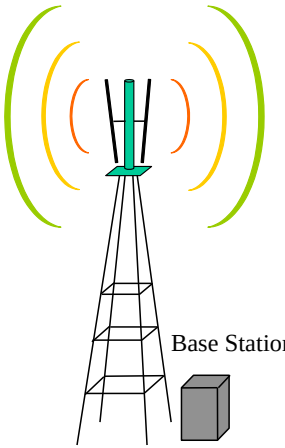


Radio Frequency Fields in Our Environment



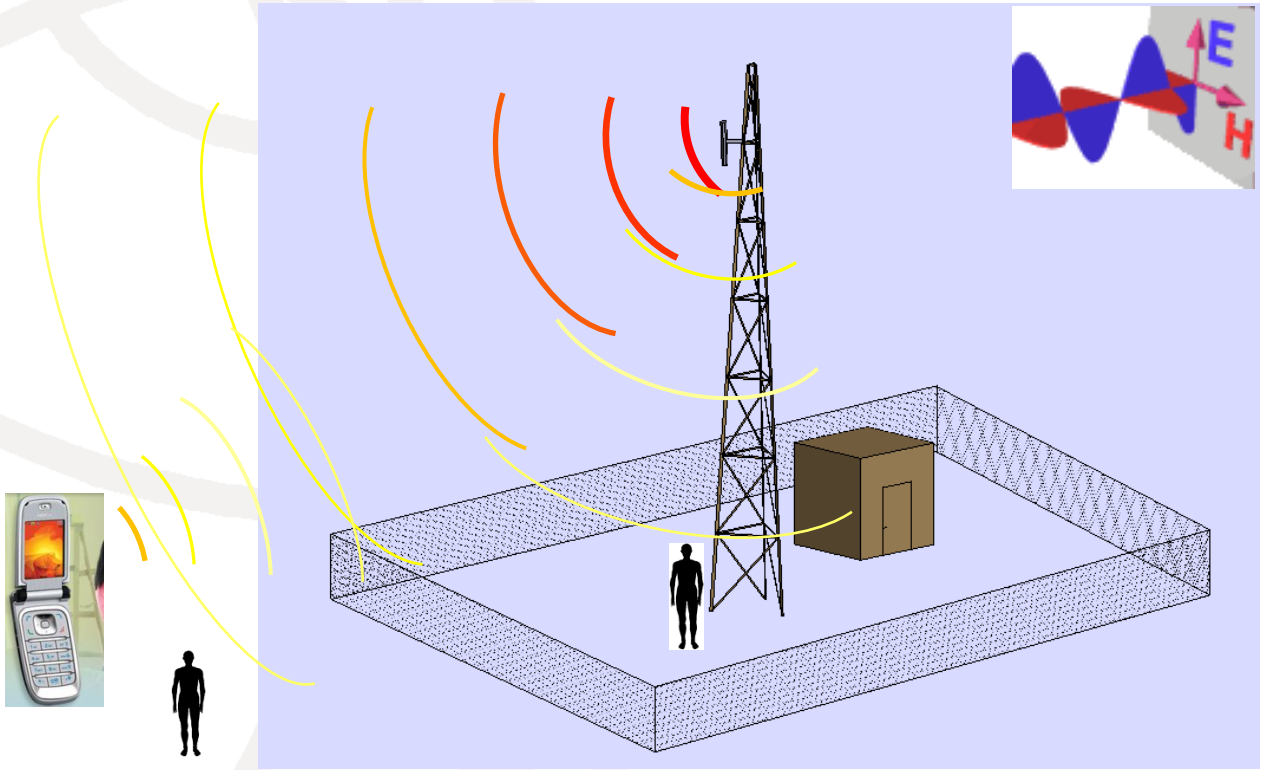


RF
Exposure



Radio Frequency Fields in Our Environment

- Cellular communications



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Guidelines for Safe Exposure

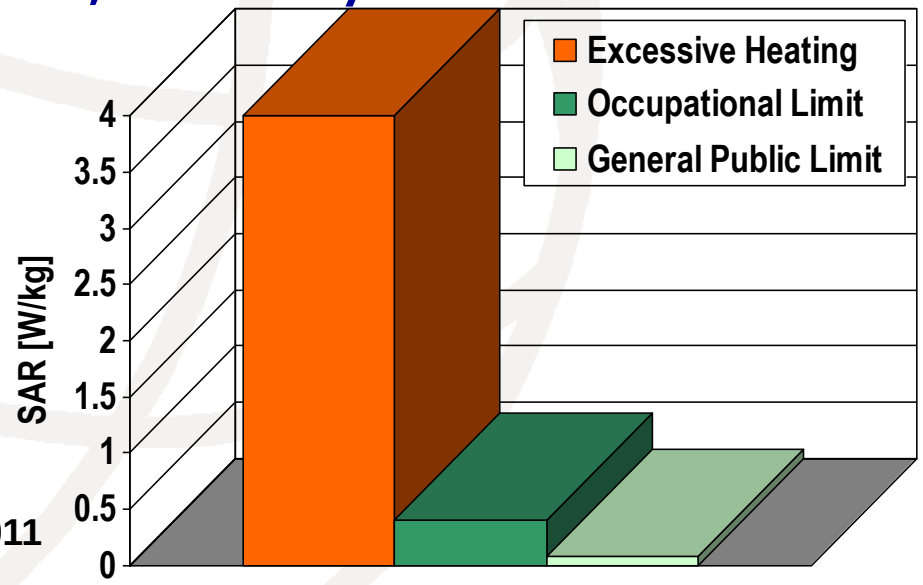
ICNIRP

International Commission on Non-Ionizing Radiation Protection

- De facto standard for RF safety
- Endorsed by World Health Organization (WHO) and numerous other international health bodies
- Thousands of Research Studies (since 1950s)
- Intense periods of research: 1970s (Microwave Oven), 1990s (Mobiles)

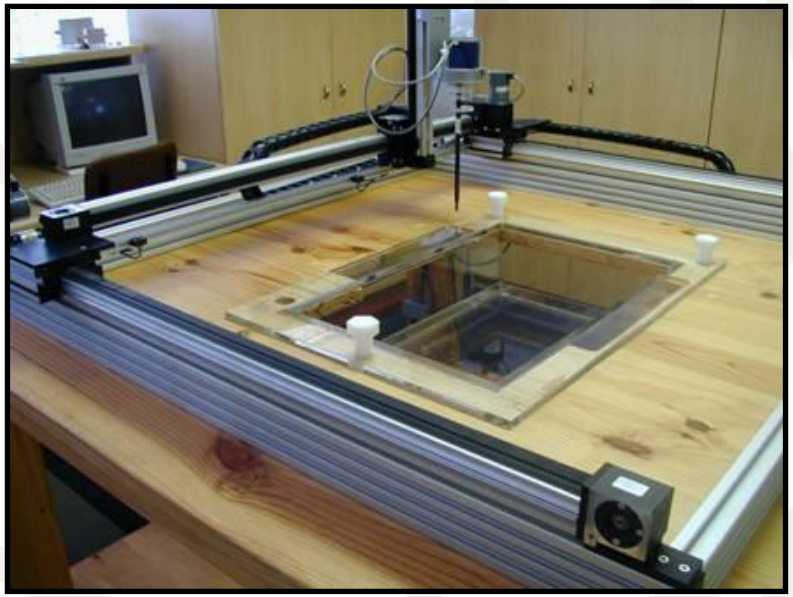
Guidelines for Safe Exposure

- Basic restrictions – Protect against heating (Known health effect)
- Two Tiers
  - Occupational, Safety factor of 10, RF trained, medically screened
  - General public, Safety factor of 50



Guidelines for Safe Exposure

- At mobile frequencies:
  - Basic restrictions (W/kg) not easily measured in field



Guidelines for Safe Exposure

- At mobile frequencies:
  - Thus "reference levels" (V/m or W/m^2) derived from basic restrictions
  - Measurements in terms of the "reference levels"

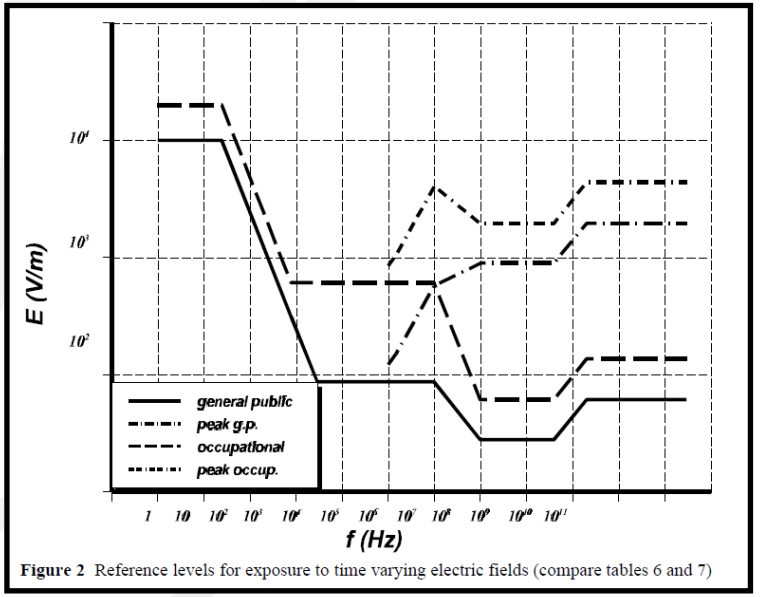


Figure 2 Reference levels for exposure to time varying electric fields (compare tables 6 and 7)

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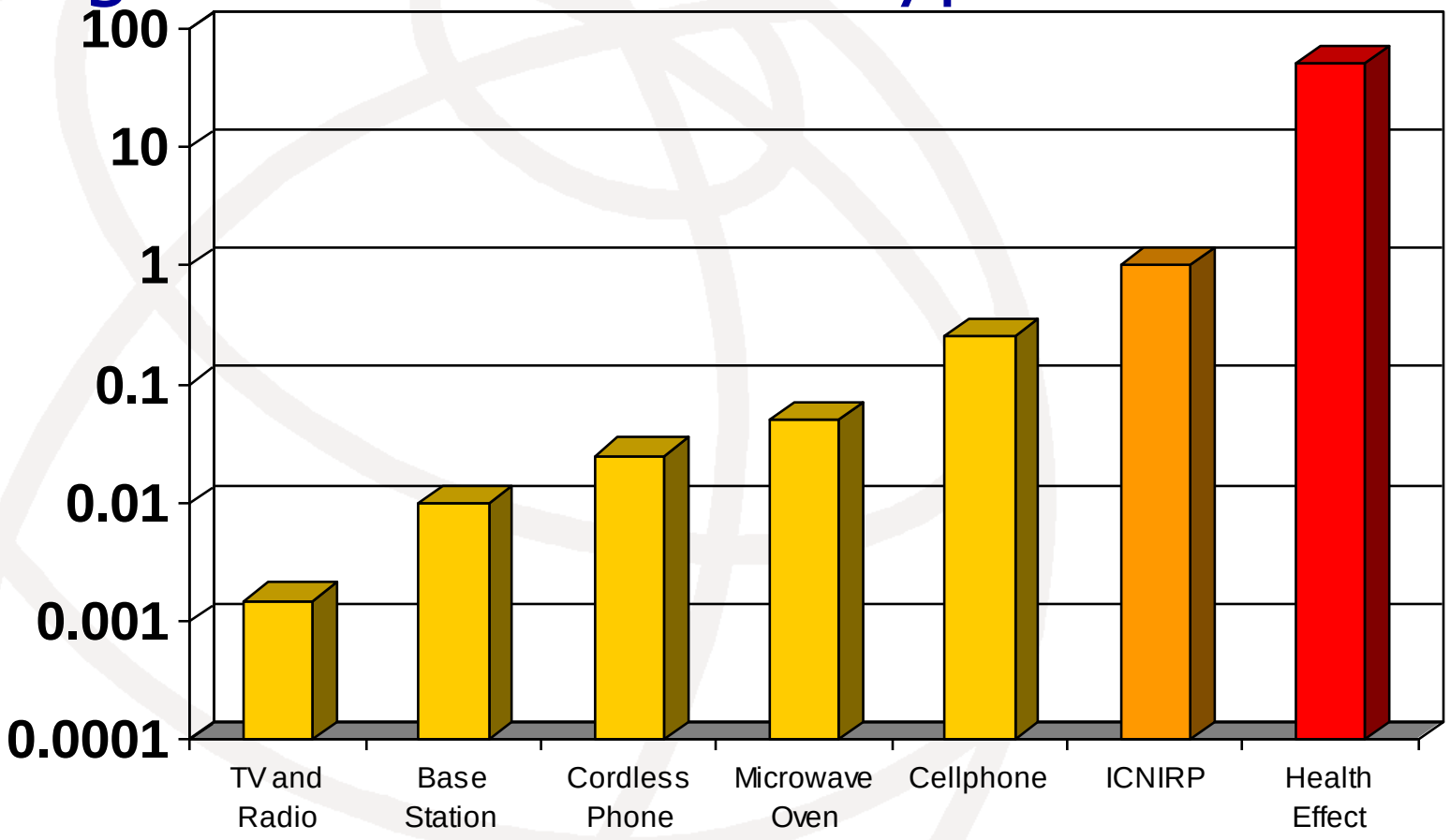
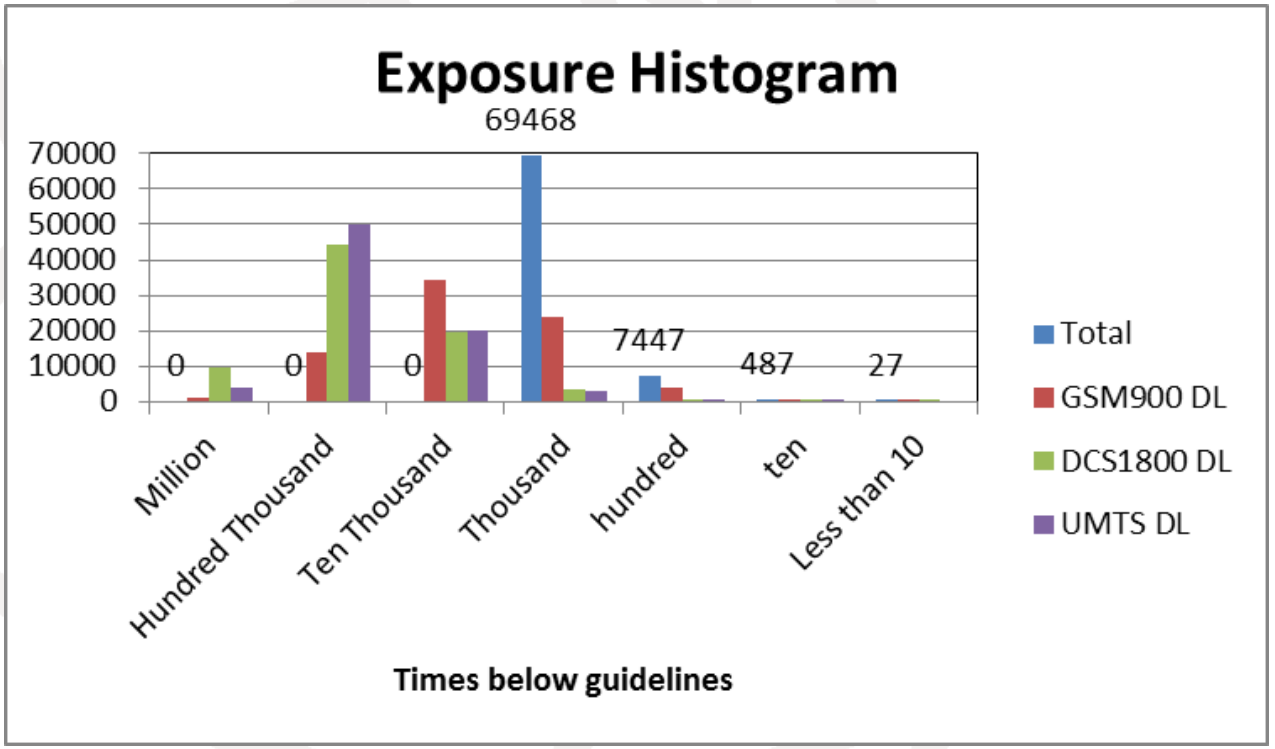
Typical Exposure vs Guidelines

- Logarithmic scale of "typical" values



Typical Exposure vs Guidelines

- More than 77 000 measurements



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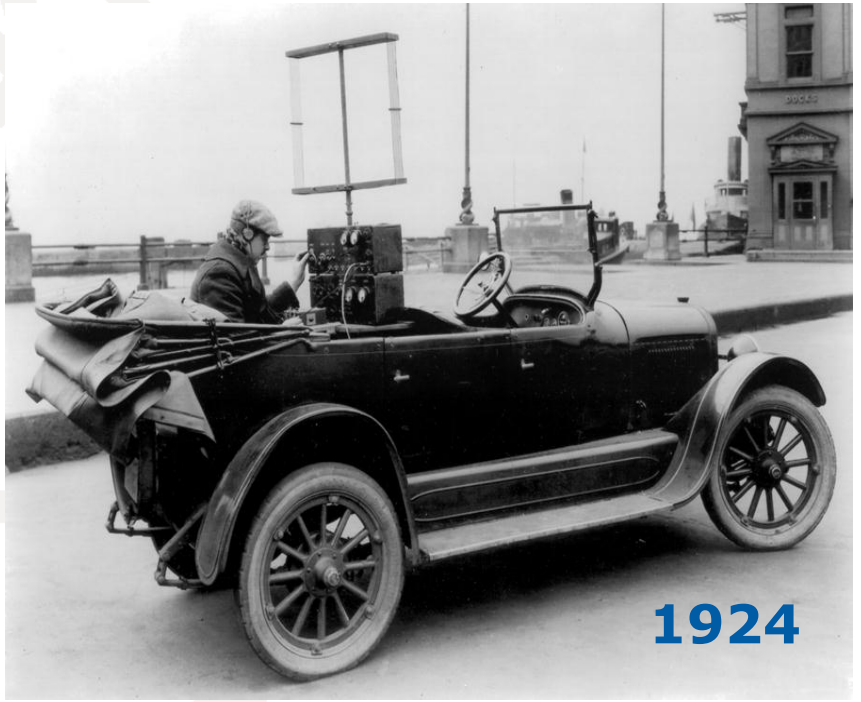
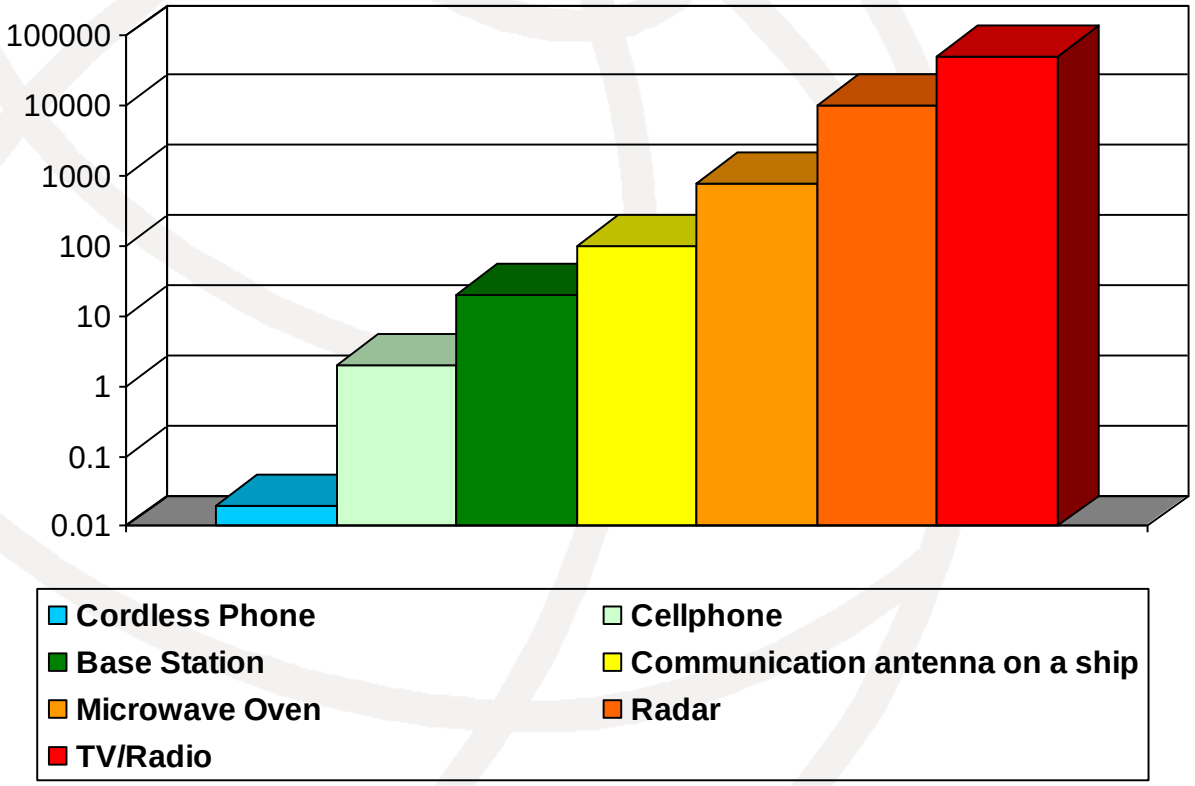
Cellular networks

- First mobile?
- Analog wireless phone took of in 70s
- GSM early 90s



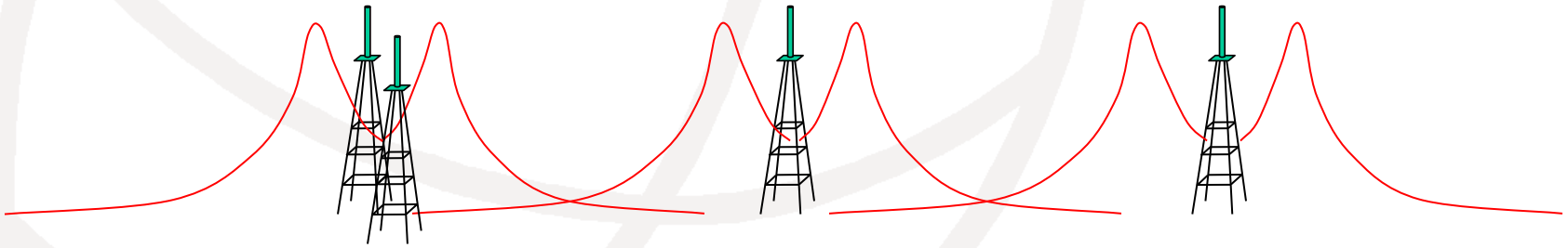
Cellular networks

- Maximum of 60W per polarization on GSM900 on each antenna
- Typical transmit power levels



Cellular networks

- "Low" power transmitters (60W)
- Short distances between base station sites
  - 2 way communication with 2W cellphones
- Avoid interference
  - Use relatively low power

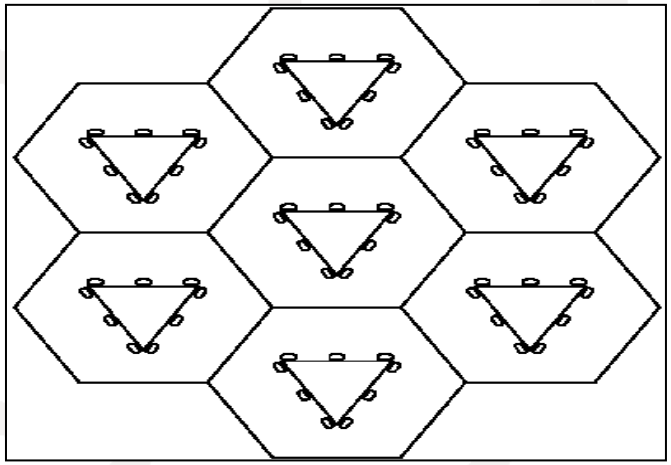


Cellular networks

- Compared to TV / Radio high power transmitters (50kW)
- One site, one way communication

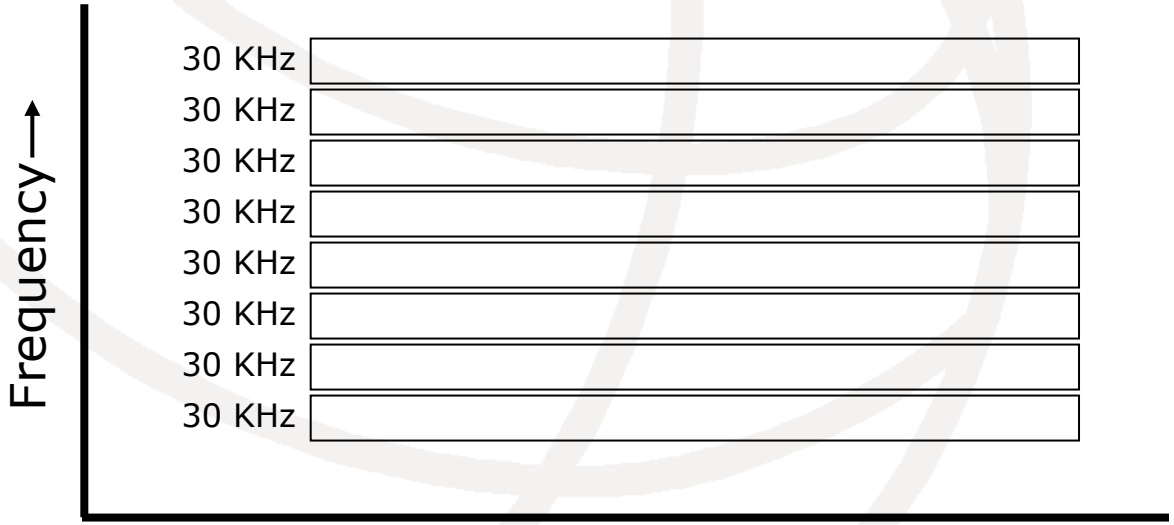
Cellular networks

- Evolution
  - First generation (1G) – Analog
  - Second generation (2G) – Digital
  - Third generation (3G) – Digital & additional data services eg video calling
  - LTE…



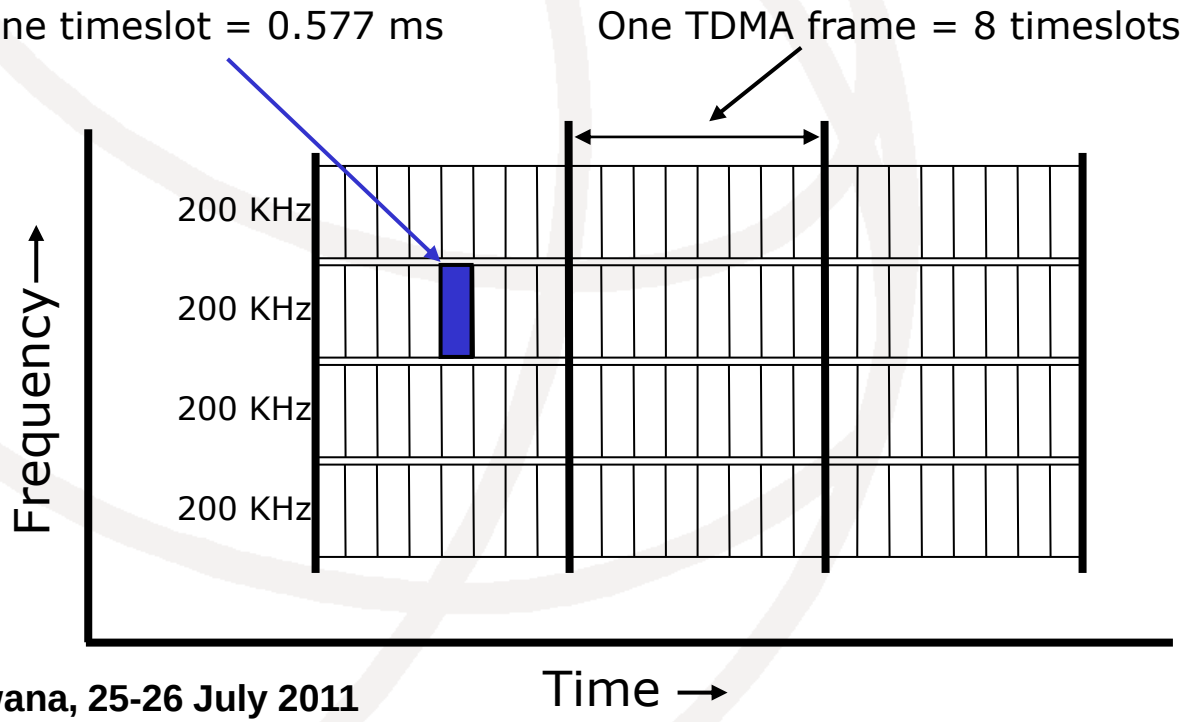
Cellular networks

- First generation (1G)
  - Analog
  - Separate Frequencies
  - FDMA — Frequency Division Multiple Access



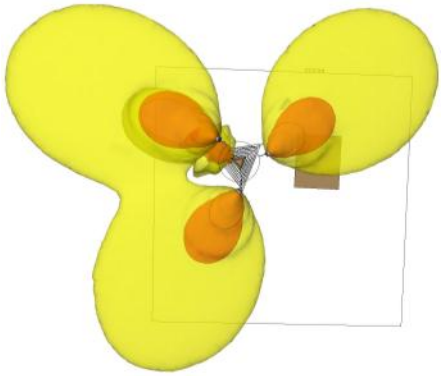
Cellular networks

- Second generation (2G)
  - Digital
  - Time Division Multiple Access
  - BCCH channel (Broadcast & Control)



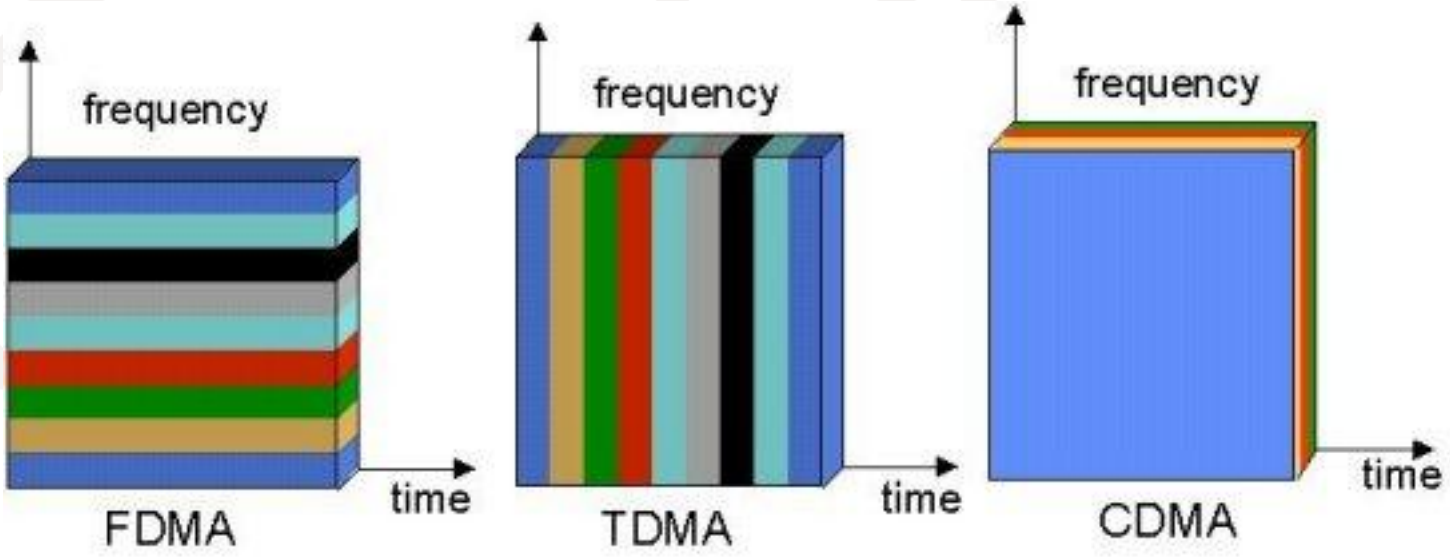
Cellular networks

- Adaptive Power Control
- 2G site call capacity
  - Each Transceiver 8 timeslots
  - Assume each sector 4 transceivers
  - 8*4 timeslots; at least 1 for BCCH
  - =>32-1 calls
  - Site has 3 sectors
  - =>31 * 3 calls



Cellular networks

- Third generation (3G)
  - Digital & additional data services eg video calling
  - Code Division Multiple Access



Cellular networks

- Sources
  - www.nmscommunications.com
  - www.attws.com
  - www.wikipedia.org

Content

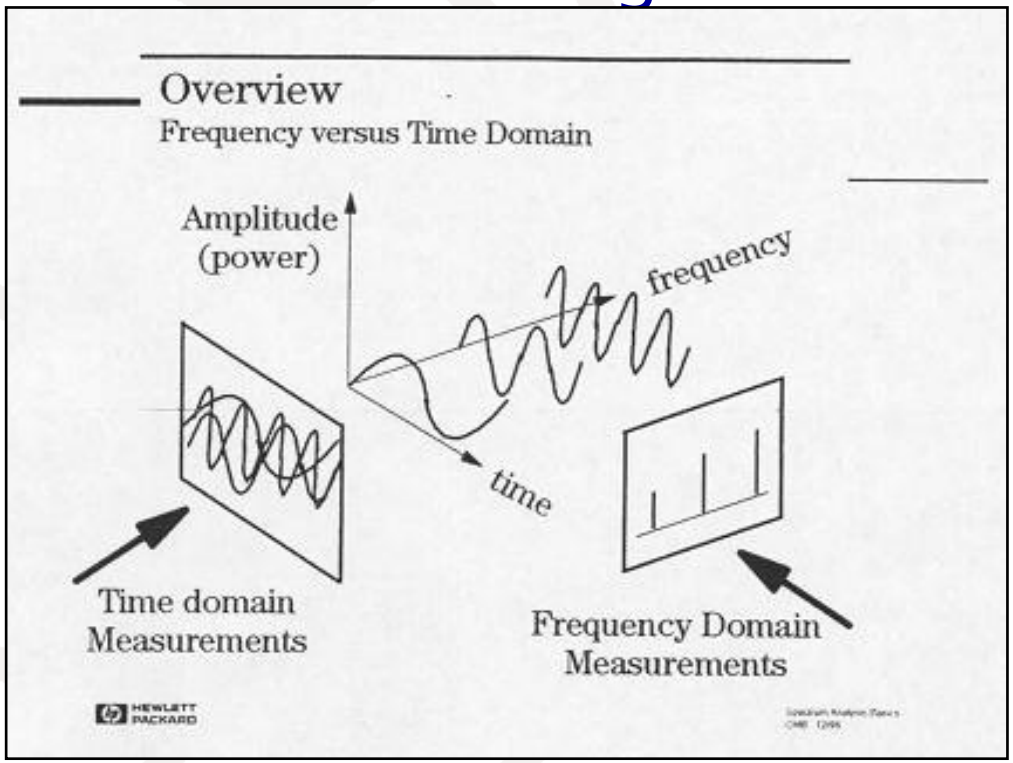
- Measurement Equipment
- Measurement Methodology
- Demo
- Reporting
- Uncertainty analysis
- Exclusions

Measurement Equipment

- Two types of measurement devices
  - Broadband meters
    - Cannot differentiate between different sources
  - Frequency selective
    - Spectrum analyser
    - Differentiate different sources
- Choose spectrum analyser

Measurement Equipment

- Spectrum analyser
  - Differentiate different sources
  - Generally better for low signal levels

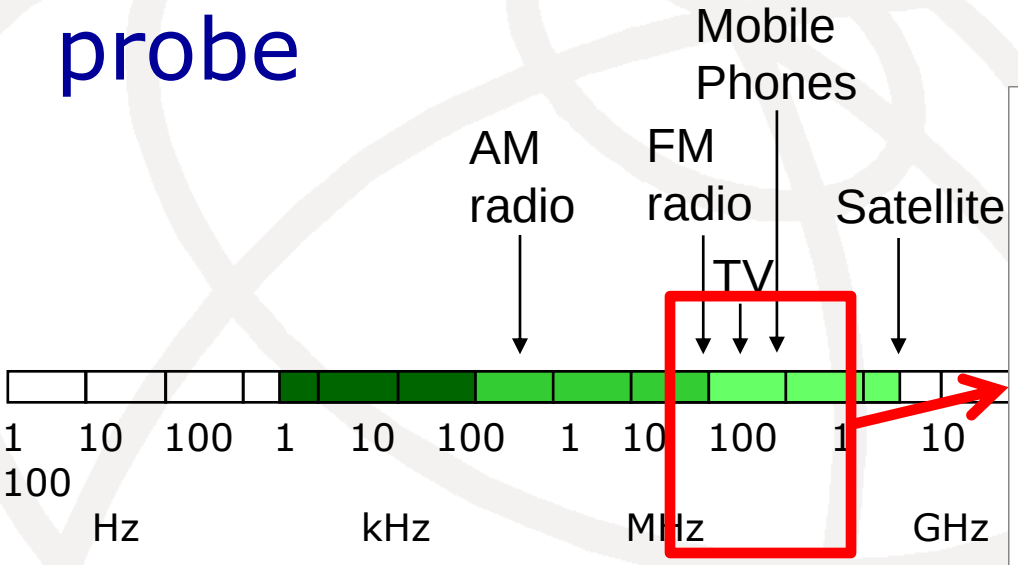


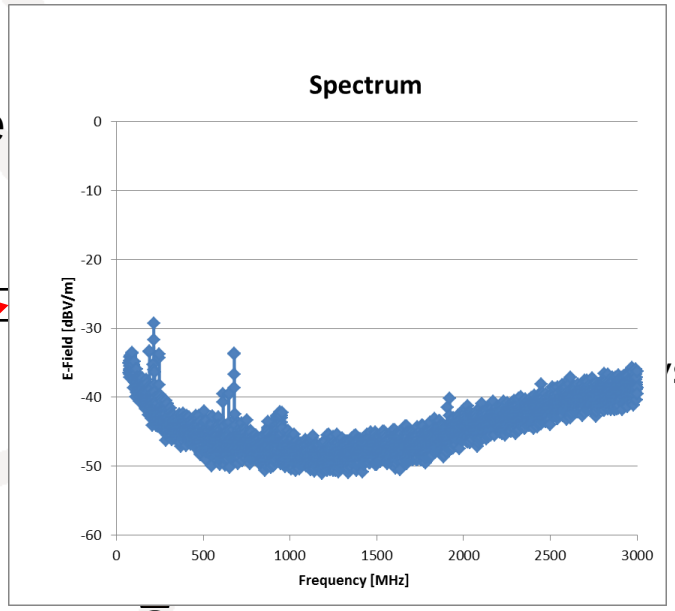
Measurement Equipment

- Isotropic probe (antenna) – Not directional

Measurement Equipment

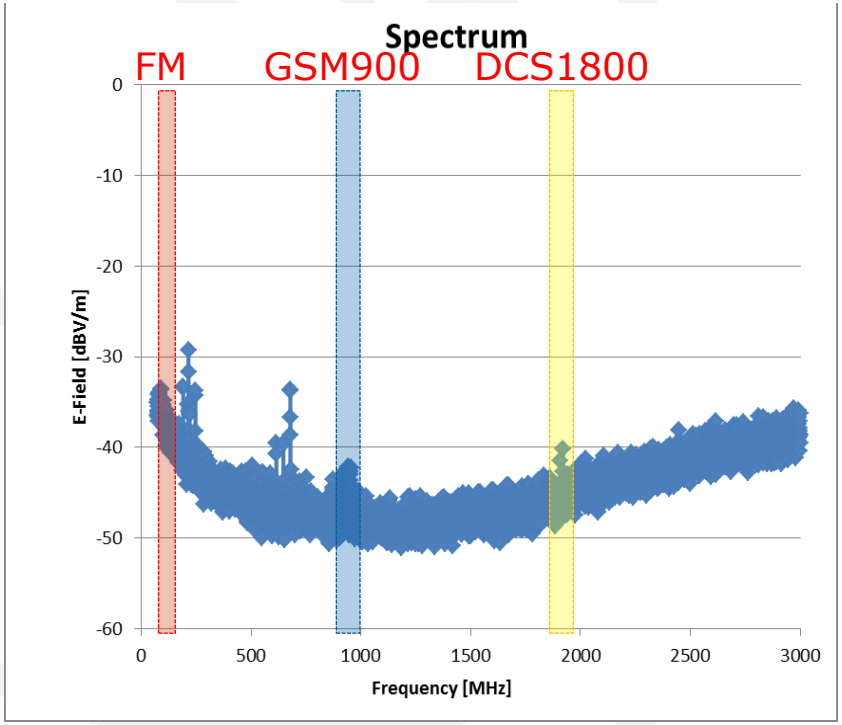
- Mostly use 27 (75) MHz to 3GHz probe





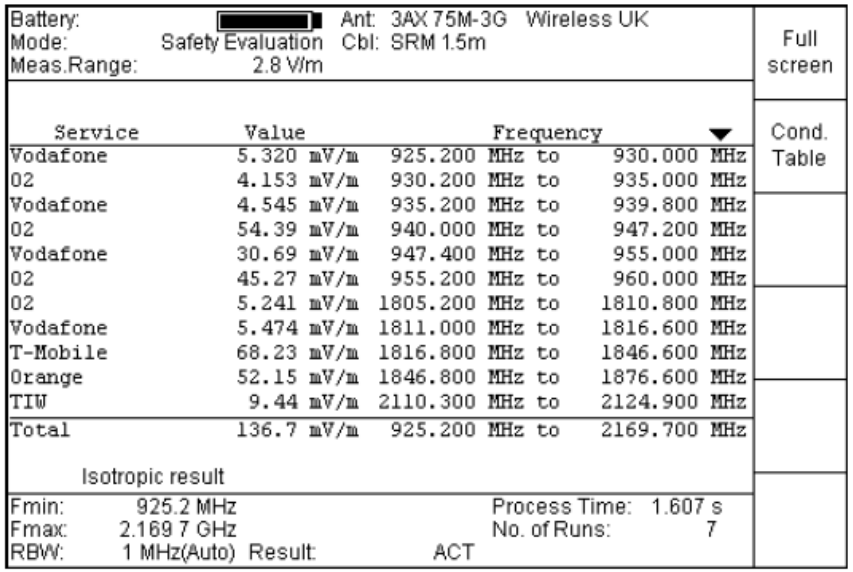
Measurement Equipment

- Want to allocate service or operators to spectrum parts



Measurement Equipment

- Straight forward, since spectrum analyser differentiates between different sources
- Integrate spectrum results to give exposure per service/operator



Battery: [redacted] Ant: 3AX 75M-3G Wireless UK
Mode: Safety Evaluation Cbl: SRM 1.5m
Meas.Range: 2.8 V/m

Full screen | Cond. Table

Service	Value	Frequency
Vodafone	5.320 mV/m	925.200 MHz to 930.000 MHz
O2	4.153 mV/m	930.200 MHz to 935.000 MHz
Vodafone	4.545 mV/m	935.200 MHz to 939.800 MHz
O2	54.39 mV/m	940.000 MHz to 947.200 MHz
Vodafone	30.69 mV/m	947.400 MHz to 955.000 MHz
O2	45.27 mV/m	955.200 MHz to 960.000 MHz
O2	5.241 mV/m	1805.200 MHz to 1810.800 MHz
Vodafone	5.474 mV/m	1811.000 MHz to 1816.600 MHz
T-Mobile	68.23 mV/m	1816.800 MHz to 1846.600 MHz
Orange	52.15 mV/m	1846.800 MHz to 1876.600 MHz
TIW	9.44 mV/m	2110.300 MHz to 2124.900 MHz
Total	136.7 mV/m	925.200 MHz to 2169.700 MHz

Isotropic result

Fmin: 925.2 MHz
Fmax: 2.169 7 GHz
RBW: 1 MHz(Auto) Result: ACT
Process Time: 1.607 s
No. of Runs: 7

Measurement Equipment

- BTA Spectrum allocation used

Lower Frequency	Upper Frequency	Name
27 MHz	88MHz	Below FM
88 MHz	108 MHz	FM Radio
108 MHz	117.975 MHz	Aeronautical Radionavagation
117.975 MHz	136.00 MHz	Aeronautical Mobile (R)
138.00 MHz	143.7 MHz	Alarms
146.00 MHz	174.00 MHz	Land Mobile
380.00 MHz	395.00 MHz	TETRA
410.4 MHz	424.9 MHz	Public Trucking
880 MHz	915 MHz	GSM900UL
935.2 MHz	943.2 MHz	GSM900DL Mascom
943.2 MHz	951.4 MHz	GSM900DL Orange
951.4 MHz	955.6 MHz	GSM900DL BTC
1.71 GHz	1.785 GHz	DCS1800 UL
1.8052 GHz	1.8154 GHz	DCS1800DLMascom
1.8154 GHz	1.8258 GHz	DCS1800DLOrange
1.8258 GHz	1.8298 GHz	DCS1800 DL BTC
1.92 GHz	1.98 GHz	UMTS UL
2.125 GHz	2.14 GHz	UMTSDL Orange
2.14 GHz	2.155 GHz	UMTSDL BTC
2.155 GHz	2.17 GHz	UMTSDL Mascom
2 995MHz	3 000MHz	3GHz Band

Measurement Equipment

- Various devices available

Measurement Equipment

- Narda SRM3000 – old model
- Narda SRM3006 – built in GPS
- Calibration frequency: 2 years
- Expanded measurement uncertainty: 3.7dB

Measurement Equipment

- Equipment demo
  - Spectrum measurement
  - GSM power control
  - W-CDMA demodulation 2157.4MHz
  - Tabled results - Safety table

Content

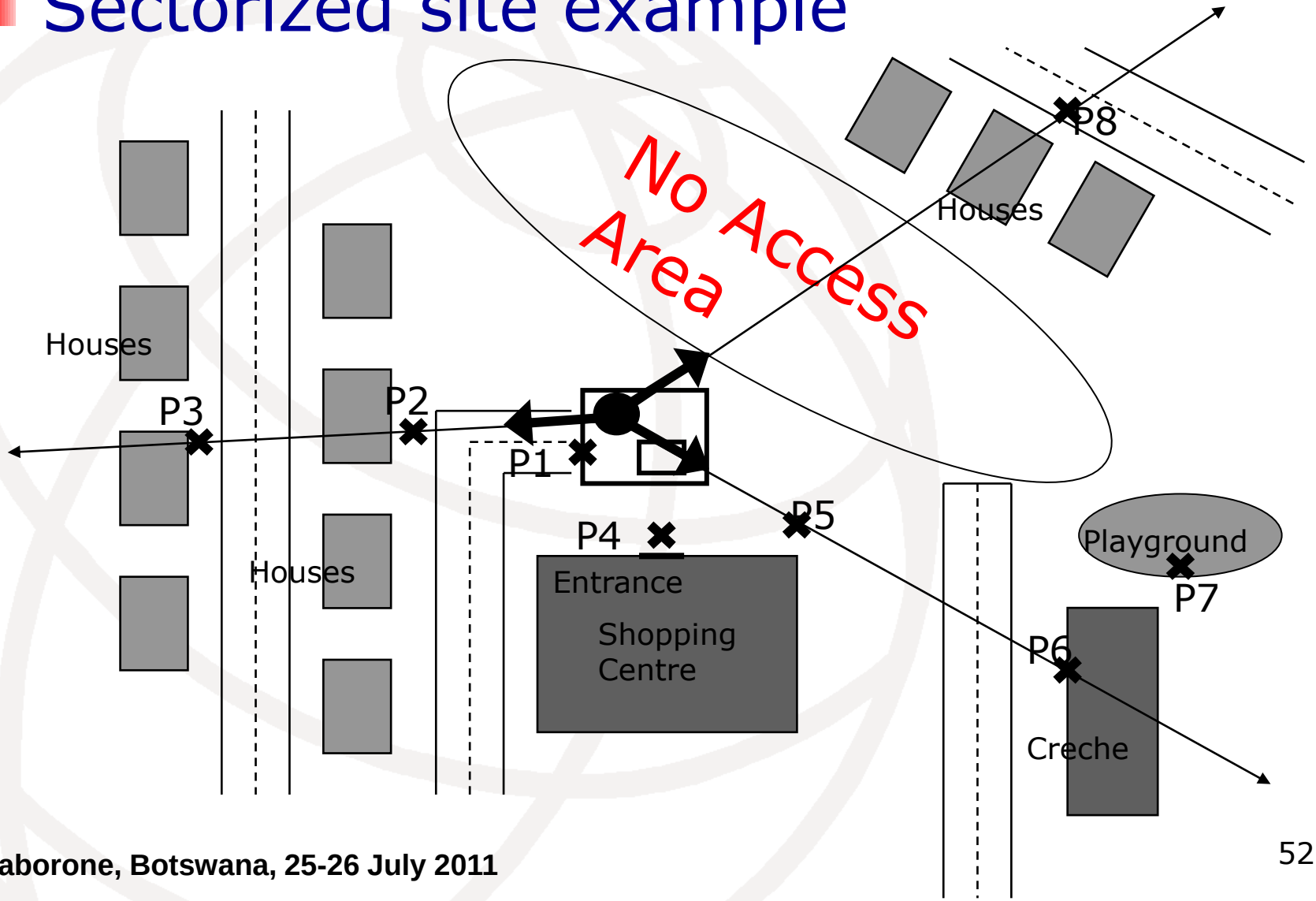
- Measurement Equipment
- Measurement Methodology
- Demo
- Reporting
- Uncertainty analysis
- Exclusions

Measurement Methodology

- Choosing measurement positions
  - Publicly accessible positions
  - Points of local maximum exposure
  - Points of specific interest
  - Typically 6-10 points per site

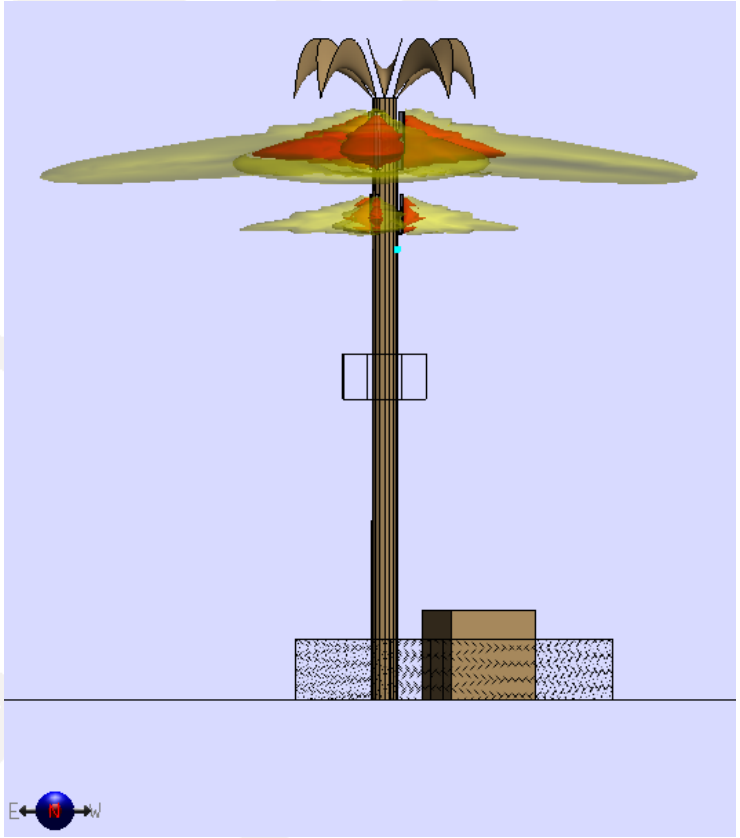
Measurement Methodology

- Sectorized site example



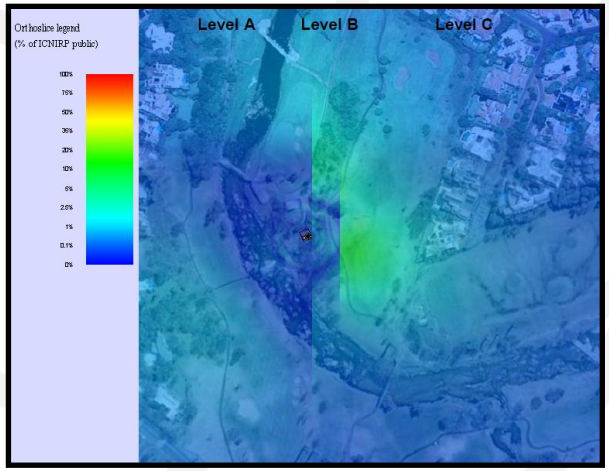
Measurement Methodology

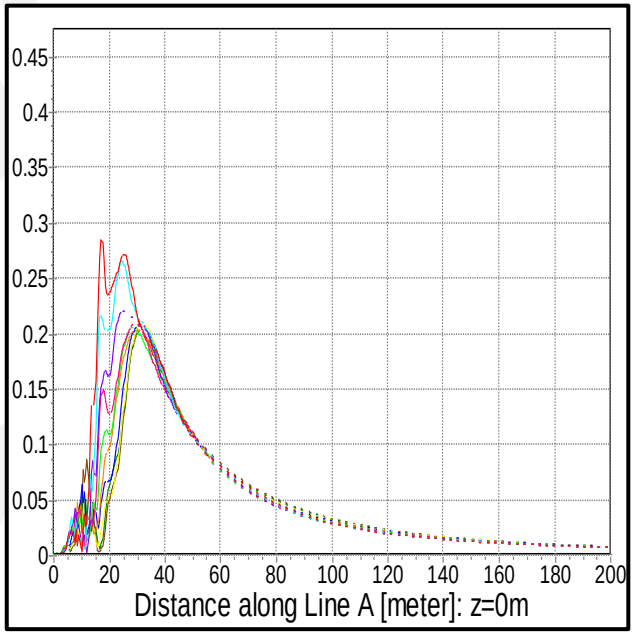
- Choosing measurement positions
  - Publicly accessible positions
  - Normally well outside exclusion zones



Measurement Methodology

- Choosing measurement positions
  - Points of local maximum exposure
  - In sector lines, where mainlobe hits the ground



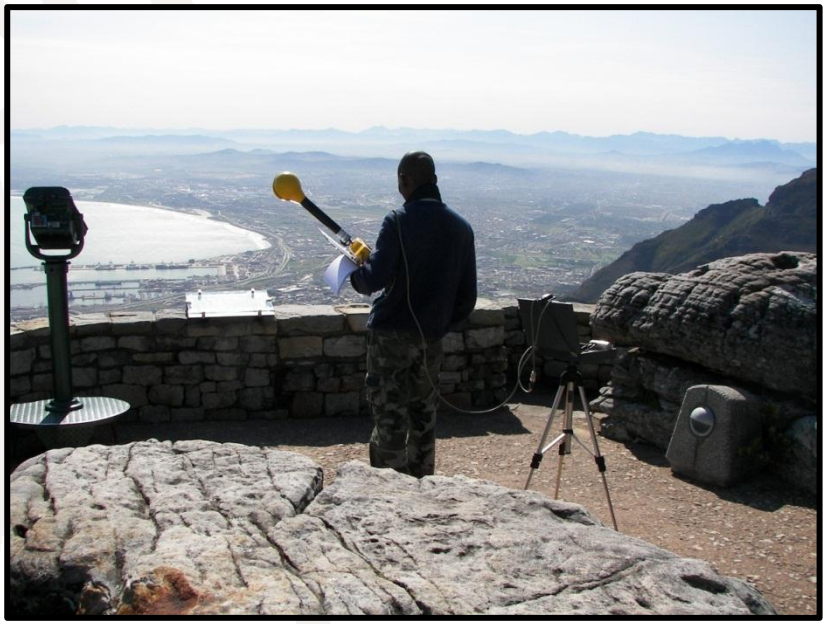


Measurement Methodology

- Choosing measurement positions
  - Typically 6-10 points per site
  - 1 Position at site location
  - Sector line positions
  - Positions of specific interest

Measurement Methodology

- Example positions



Measurement Methodology

- Example positions

Measurement Methodology

- Example positions

Measurement Methodology

- Example positions

Measurement Methodology

- Example positions

Measurement Methodology

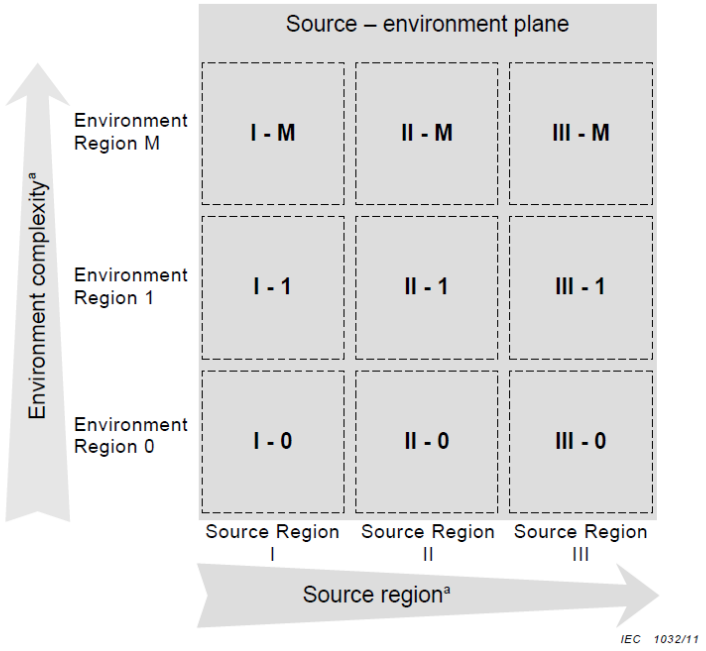
- IEC 62232
- Evaluation purpose
  - RF field strength for interested parties at arbitrary locations outside control boundary
- RBS category
  - Simple or complex (multiple antenna & operator) RBS

Measurement Methodology

- Information availability
  - Spectrum licensing info available, etc
- Parameter control
  - RBS not controlled (BCCH and traffic)
- Ambient sources
  - Visual inspection
  - Spectrum measurement

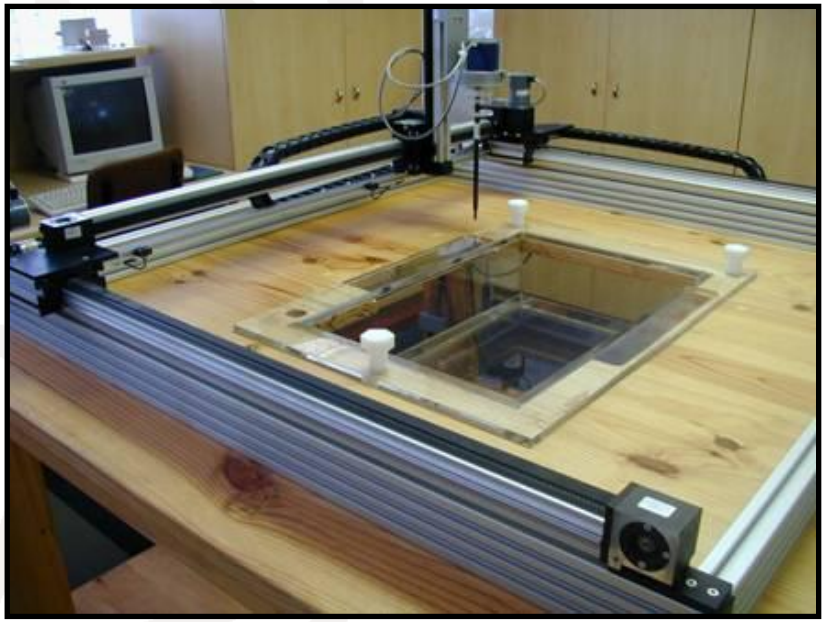
Measurement Methodology

- Source-Environment plane
  - Source region III (Far field)
  - Environment region 0,1,M due to possible reflections



Measurement Methodology

- Evaluation method
  - E-Field (V/m) or Power Density (W/m^2)



Measurement Methodology

- In situ measurements used
  - Client requirements / physical demonstration for interested persons
  - Publicly accessible areas chosen for evaluation locations
  - Use handheld instrument at 1.5m
  - Sweep area, searching maximum
  - Spatial averaging not used
  - Frequency selective measurement (not broadband flat or shaped)

Measurement Methodology

- Evaluate in terms of limit
  - Extrapolation might be required
  - Extrapolate from BCCH / CPICH for maximum transmission possible
- Reporting
- Uncertainty assessment

Content

- Measurement Equipment
- Measurement Methodology
- Demo
- Reporting
- Uncertainty analysis
- Exclusions

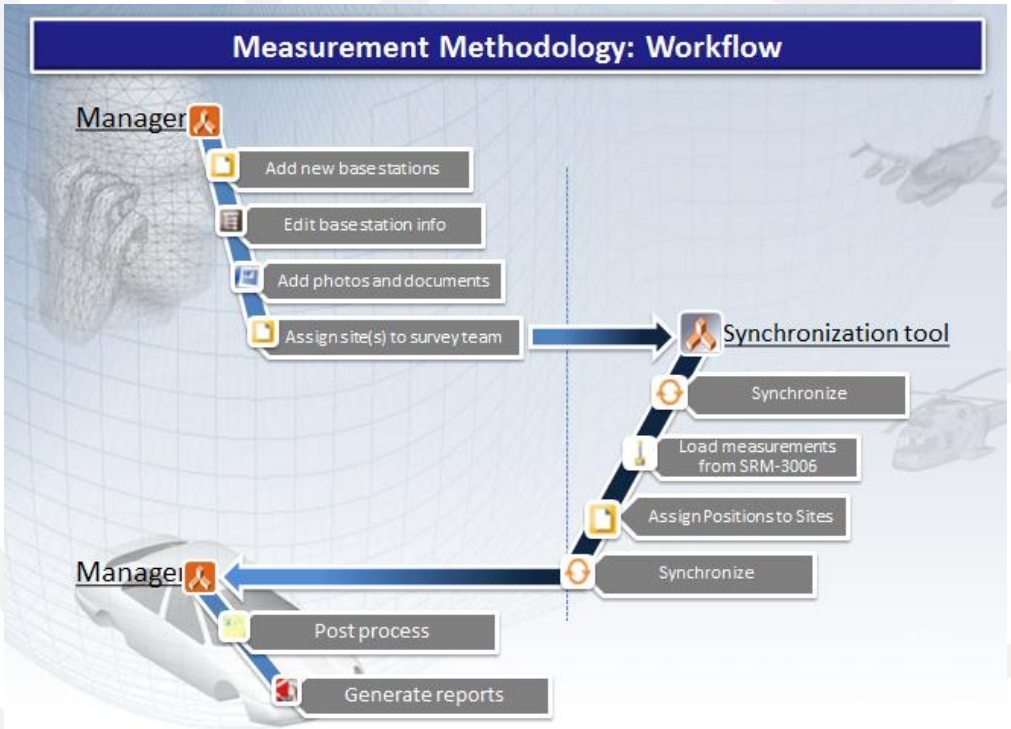
Demo

Content

- Measurement Equipment
- Measurement Methodology
- Demo
- Reporting
- Uncertainty analysis
- Exclusions

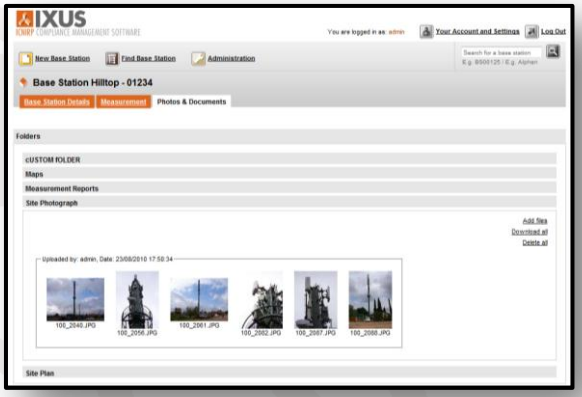
Reporting

- Procedure automated in Ixus
  - Improve accuracy & efficiency
  - Data stored on central database

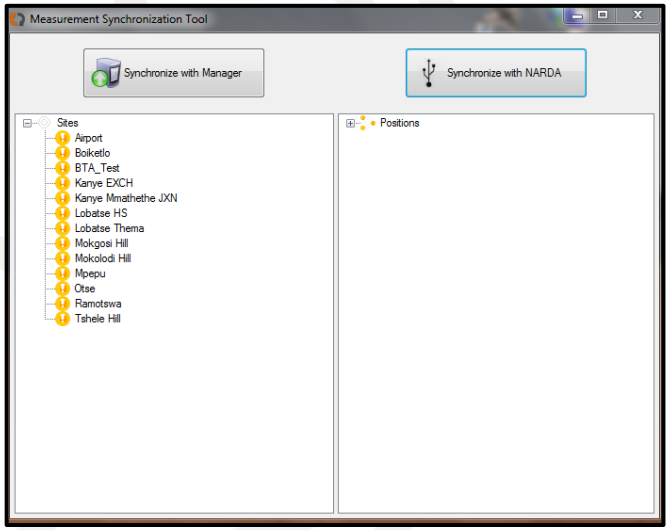


Reporting

- Procedure
  - Pre-processing

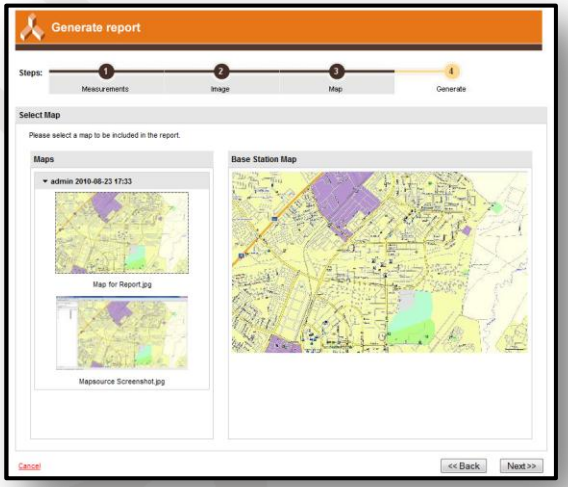


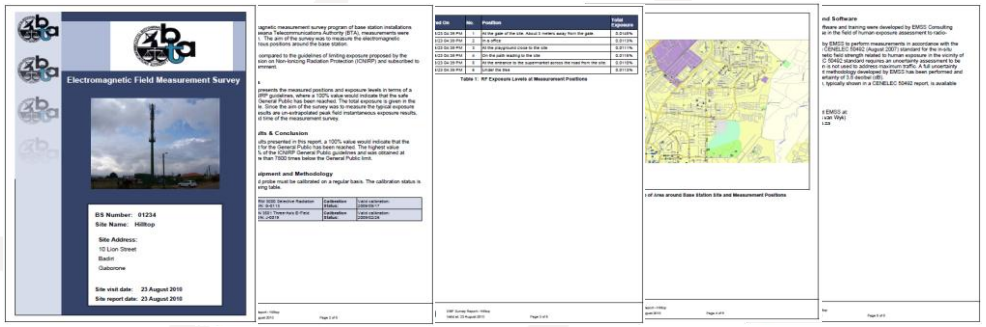
  - Measurement



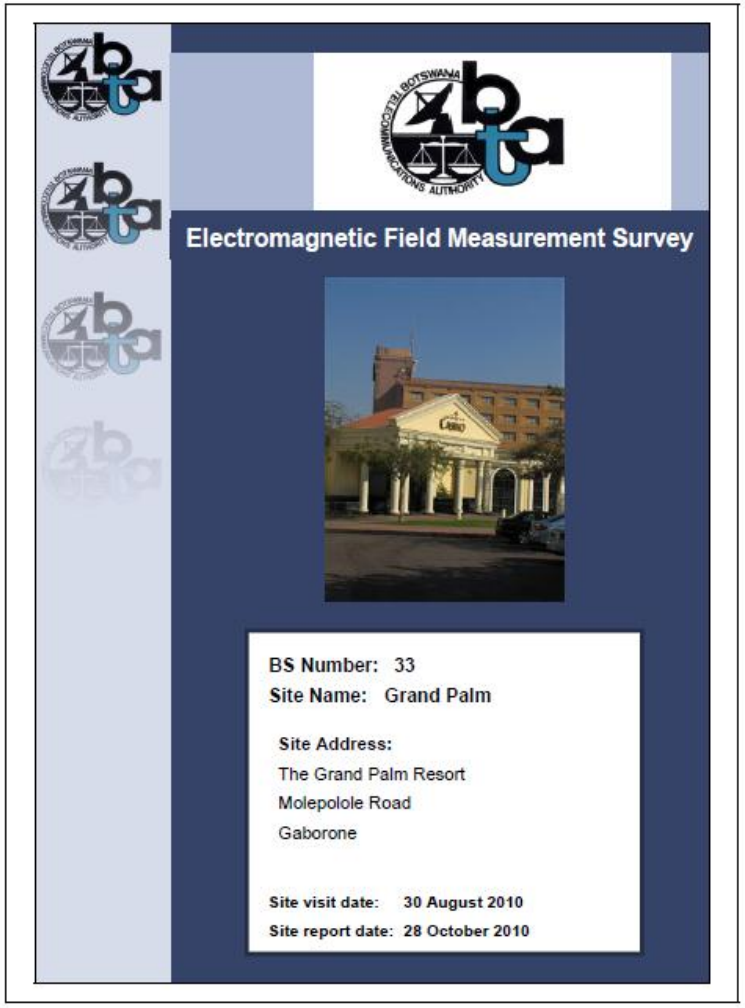
Reporting

- Procedure
  - Post-processing
    - Front page photo
    - Map
    - Position comments
    - PDF report





Reporting



Electromagnetic Field Measurement Survey

BS Number: 33
Site Name: Grand Palm

Site Address:
The Grand Palm Resort
Molepolole Road
Gaborone

Site visit date: 30 August 2010
Site report date: 28 October 2010

Reporting

Introduction

As part of an electromagnetic measurement survey program of base station installations performed by the Botswana Telecommunications Authority (BTA), measurements were performed at Grand Palm. The aim of the survey was to measure the electromagnetic exposure levels at various positions around the base station.

Measured results are compared to the guidelines of limiting exposure proposed by the International Commission on Non-Ionizing Radiation Protection (ICNIRP).

Measured Results

Table 1 and Figure 1 presents the measured positions and exposure levels in terms of a percentage of the ICNIRP guidelines, where a 100% value would indicate that the safe exposure limit for the General Public has been reached. The total exposure is given in the first column of the table. Since the aim of the survey was to measure the typical exposure values, the reported results are un-extrapolated peak field instantaneous exposure results, at the specific date and time of the measurement survey.

Summary of Results & Conclusion

For the measured results presented in this report a 100% value would indicate that the ICNIRP exposure limit for the General Public has been reached. The highest value measured is 1.0578% of the ICNIRP General Public guidelines and was obtained at position 3. This is more than 90 times below the General Public limit.

Reporting

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2010/08/30 16:44	8	In line with antenna, at the maintenance offices.	0.0391%	0.0271%	0.0000%	0.0004%	0.0115%

Reporting

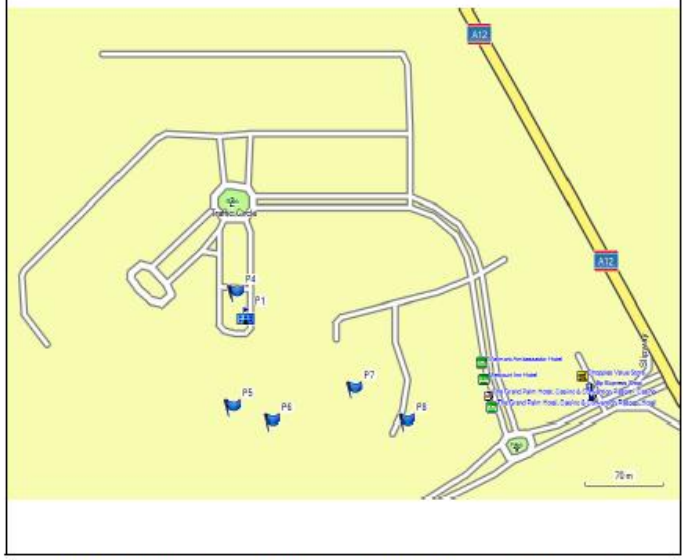

Figure 1: Map of Area around Base Station Site and Measurement Positions

Reporting

Measurement Equipment and Methodology

Both survey meter and probe must be calibrated on a regular basis. The calibration status is presented in the following table.

Survey Meter:	Narda SRM 3000 Selective Radiation Meter, S/N: G-0113	**Calibration Status:**	Valid calibration: 17 September 2008
Probe:	Narda BN 3501 Three-Axis E-Field Probe, S/N: J-0019	**Calibration Status:**	Valid calibration: 26 February 2009

Assessment Process and Software

The assessment process, software and training were developed by EMSS Consulting (EMSS). EMSS has expertise in the field of human exposure assessment to radio-frequency fields.
BTA engineers were trained by EMSS to perform measurements in accordance with the measurement protocol of the CENELEC 50492 (November 2008) standard for the in-situ measurement of electromagnetic field strength related to human exposure in the vicinity of base stations. The CENELEC 50492 standard requires an uncertainty assessment to be performed when extrapolation is not used to address maximum traffic. A full uncertainty analysis for the measurement methodology developed by EMSS has been performed and resulted in an expanded uncertainty of 3.8 decibel (dB).
Additional survey information, typically shown in a CENELEC 50492 report, is available from BTA on request.

For more information, contact the BTA at:
Tel: +267 395 7755
Fax: +267 395 7976
Email: engineering@bta.org.bw

Content

- Measurement Equipment
- Measurement Methodology
- Demo
- Reporting
- Uncertainty analysis
- Exclusions

Uncertainty analysis

- Important to assess the uncertainty, when interpreting results

Uncertainty Source	Description	Uncertainty value (%)	Probability distribution	Divisor	c_i	Standard Uncertainty (%)
Measurement Equipment						
Calibration	Manufacturer calibration certificate values used, Verified at accredited calibration lab within 1dB Measurement Uncertainty	41.25 % (1.5 dB)	Normal	K=2	1	20.625 %
Isotropy	Ellipse Ratio according to Manufacturer's data sheet	34 % (1.27 dB)	Rectangular	√3	1	19.63 %
Linearity	Manufacturer's data sheet: 25 Frequency points through complete f range, measurement range settings -27 -> 23 dBm	4 % (0.17 dB)	Rectangular	√3	1	2.31 %

Uncertainty analysis

Physical parameters						
Drifts in output power of probe (Temperature and Humidity)	Not measured before, assume within temperature range of Manufacturer's data sheet to be corrected	0 %	Rectangular	√3	1	0 %
Pertubation by the Environment	Influence of Probe ~0.5m in front of surveyor. Use CENELEC Annex G results from simulation (worst case) in cellular band	58.5 % (2 dB)	Rectangular	√3	1	33.77 %
Influence quantities for environmental field characteristics						
Spatial Averaging	Statistical uncertainty with a 95 % confidence interval for a 1-point grid as per CENELEC	90.55 % (2.8 dB)	Rectangular	√3	1	52.28 %

Uncertainty analysis

Post Processing						
Extrapolation for maximum traffic	BCCH and UMTS Pilot channels are used to obtain maximum output power. Technical information obtained from operators	0 %	Rectangular	√3	1	0 %

Combined Standard uncertainties	$\sqrt{\sum_{i=1}^{m} c_i^2 \cdot u_i^2}$	68.48 % (2.27 dB)				
Expanded uncertainty (confidence interval of 95%)	$u_e = 1.96\, u_c$	134.22 % (3.70 dB)	Normal			

Content

- Measurement Equipment
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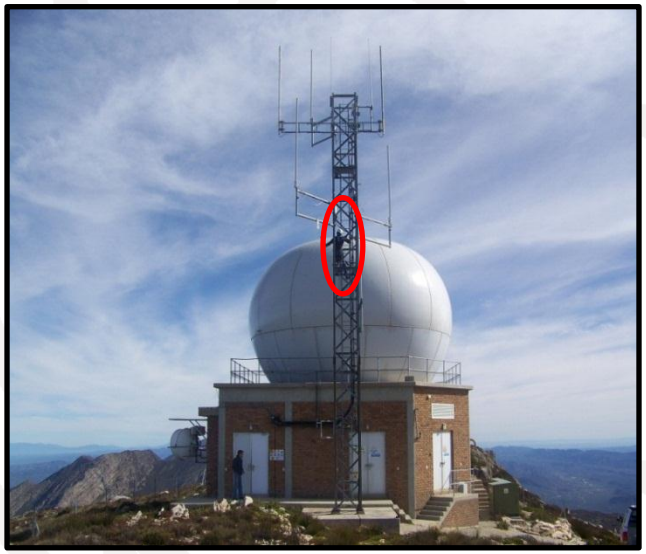
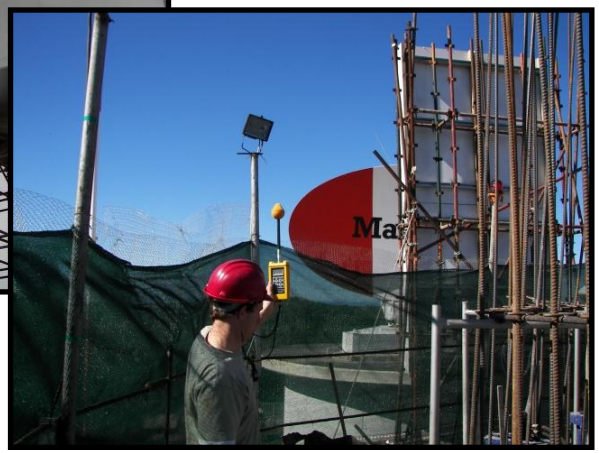
Exclusions

- Determine compliance boundary
  - Extrapolation for maximum
  - Region I (Reactive near-field)

Exclusions

- Radar installations
  - Time on Target -> Peak or RMS relevant
  - Probe displayed value needs correction, based on radar PRF, Duty cycle





Content

- Base station Compliance
- Conclusion

Base station Compliance

- Assess accessibility of EMF Exclusion zones
  - Generic rules

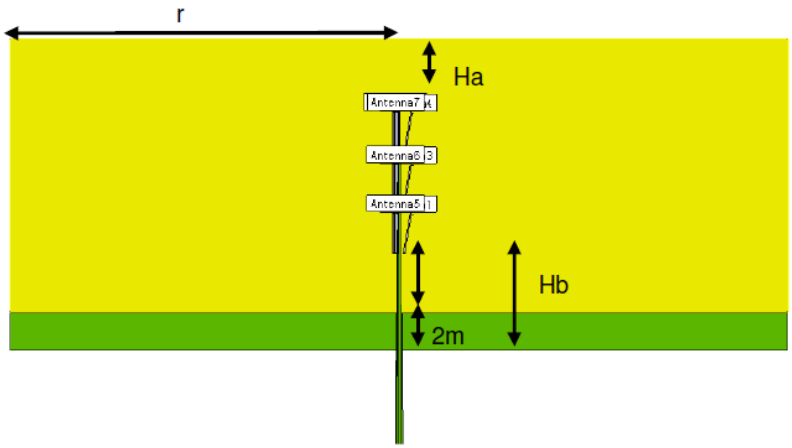
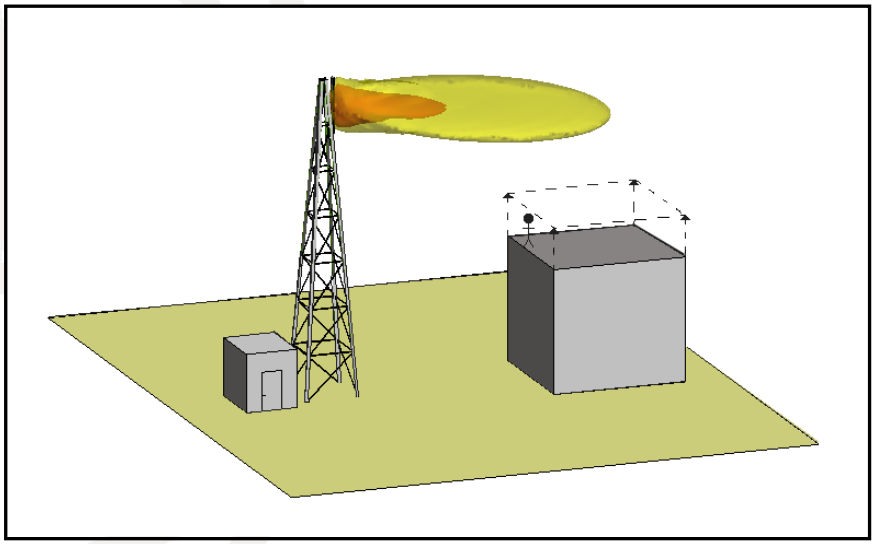
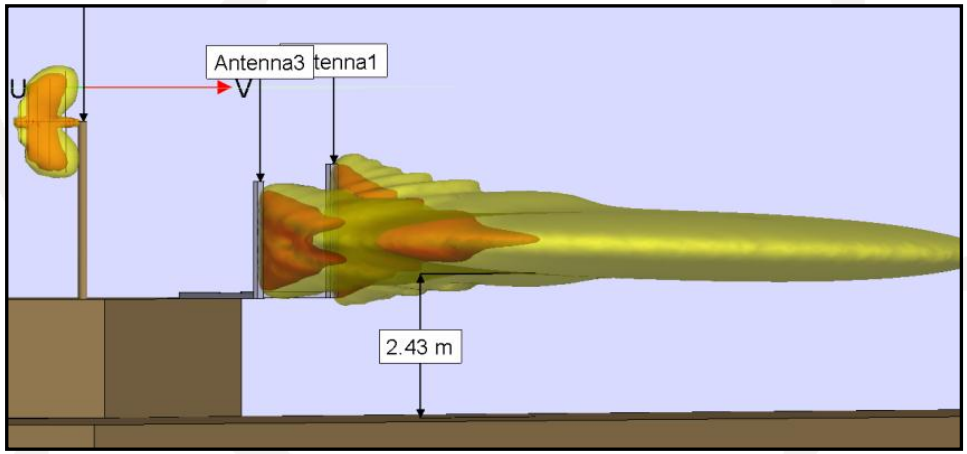


Figure 1. Generic Public exclusion zone



Base station Compliance

- Assess accessibility of EMF Exclusion zones
  - Numerical simulation

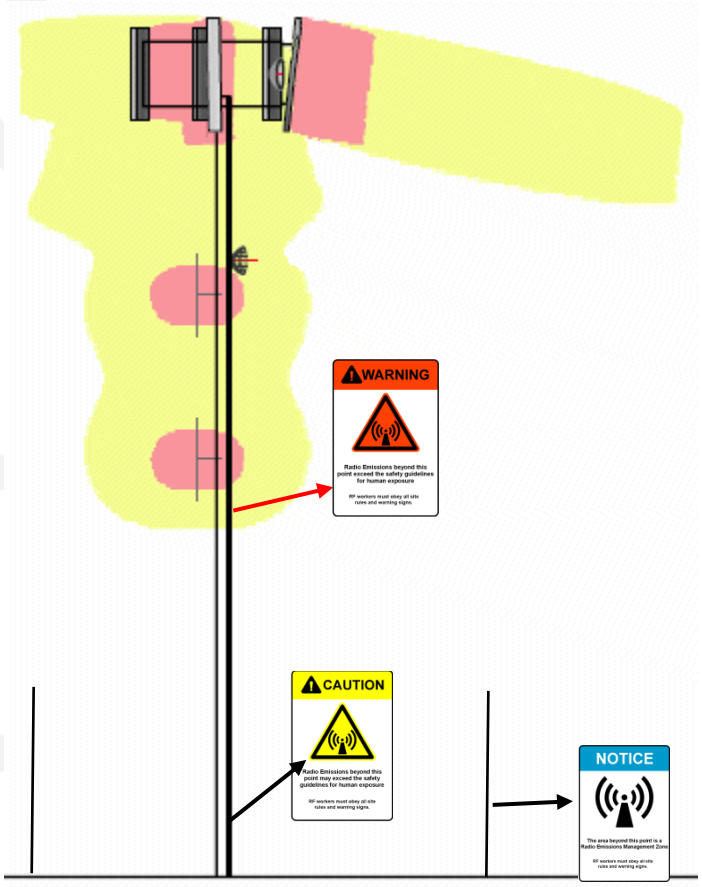


Base station Compliance

- Assess accessibility of EMF Exclusion zones
  - Measurements

Base station Compliance

- Administrative controls
  - Access control
  - RF warning signage



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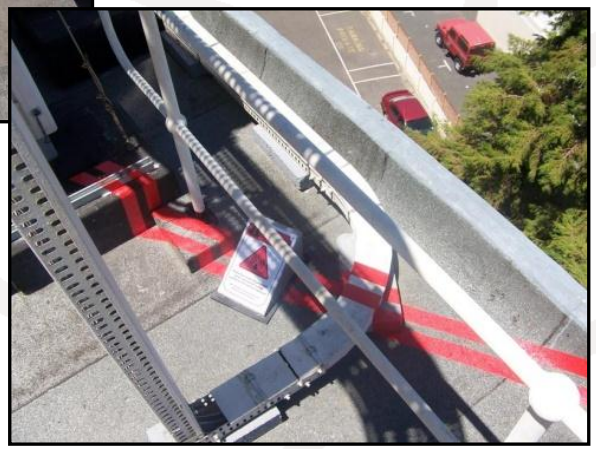
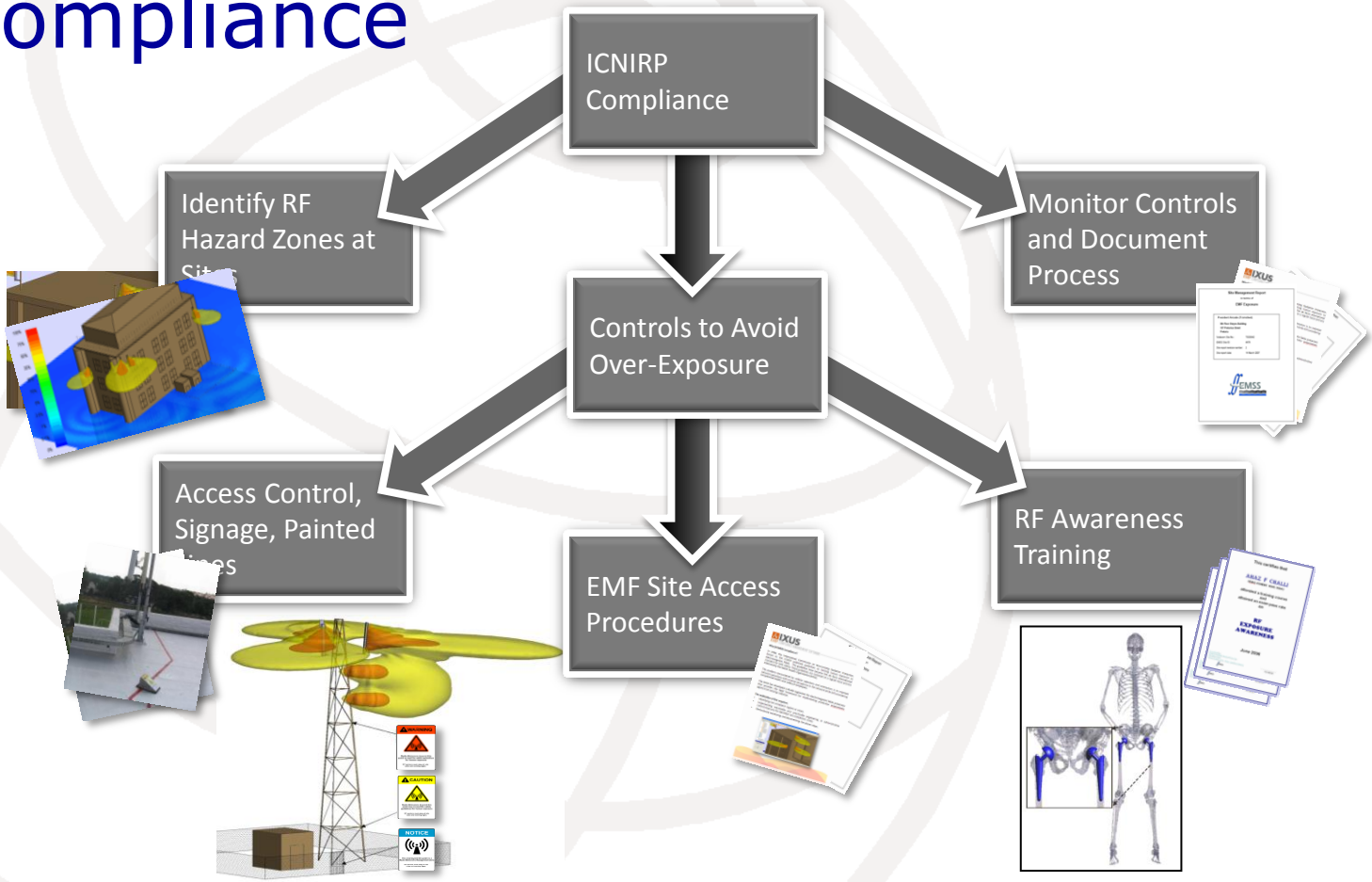


Base station Compliance

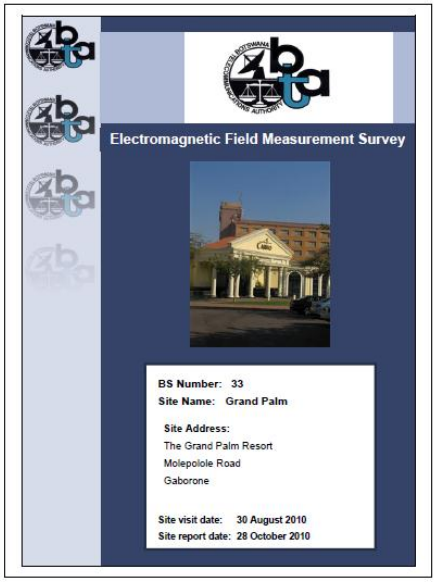
- Use Ixus to manage network compliance



Content

- Base station Compliance
- Conclusion

Conclusion



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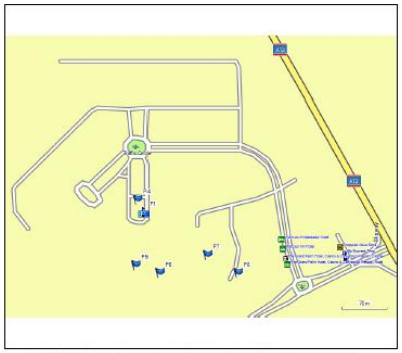

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- Thank you
- Questions?

mvanwyk@emss.co.za