Aim

• Is this site safe?
• Is this site safe?
**Aim**

- Is this site safe?

<table>
<thead>
<tr>
<th>Name</th>
<th>Integral equations</th>
<th>Differential equations</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gauss’s law</td>
<td>$\iiint_{\partial \Omega} \mathbf{E} \cdot d\mathbf{S} = \frac{1}{\varepsilon_0} \iiint_{\Omega} \rho , dV$</td>
<td>$\nabla \cdot \mathbf{E} = \frac{\rho}{\varepsilon_0}$</td>
<td>The electric field leaving a volume is proportional to the charge inside.</td>
</tr>
<tr>
<td>Gauss’s law for magnetism</td>
<td>$\iiint_{\partial \Omega} \mathbf{B} \cdot d\mathbf{S} = 0$</td>
<td>$\nabla \cdot \mathbf{B} = 0$</td>
<td>There are no magnetic monopoles; the total magnetic flux through a closed surface is zero.</td>
</tr>
<tr>
<td>Maxwell–Faraday equation (Faraday’s law of induction)</td>
<td>$\oint_{\partial \Sigma} \mathbf{E} \cdot d\mathbf{l} = -\frac{d}{dt} \iiint_{\Sigma} \mathbf{B} \cdot d\mathbf{S}$</td>
<td>$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$</td>
<td>The voltage accumulated around a closed circuit is proportional to the time rate of change of the magnetic flux it encloses.</td>
</tr>
<tr>
<td>Ampère’s circuit law (with Maxwell’s addition)</td>
<td>$\oint_{\partial \Sigma} \mathbf{B} \cdot d\mathbf{l} = \mu_0 \iiint_{\Sigma} \mathbf{J} \cdot d\mathbf{S} + \mu_0 \varepsilon_0 \frac{d}{dt} \iiint_{\Sigma} \mathbf{E} \cdot d\mathbf{S}$</td>
<td>$\nabla \times \mathbf{B} = \mu_0 \left( \mathbf{J} + \varepsilon_0 \frac{\partial \mathbf{E}}{\partial t} \right)$</td>
<td>Electric currents and changes in electric fields are proportional to the magnetic fields circulating about the areas where they accumulate.</td>
</tr>
</tbody>
</table>

**Maxwell’s Equations (from Wikipedia)**
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• Based in Stellenbosch, South Africa
• Focus on electromagnetics since 1994
• Products and services in the field of EMF Safety
  – Ixus – Compliance Software
  – fieldSENSE – personal RF safety meter
  – Site assessment and certification
  – EMF Measurements
  – RF awareness training
Projects: Africa

EMSS Consulting

Communication Network Safety
RF training, measurements, 3D modelling, base station compliance.

Flags of Botswana, Namibia, Lesotho

Logos of Helios Towers, MERICANTOWER, Safaricom, MTN, Vodacom

mongabay.com
• Non EMF safety activities
  – Radio Astronomy Karoo Array Telescope
  – KAT 7
  – Meerkat
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- RF Sources?
  - TV
  - Microwave Ovens
  - Comms in Vehicles
  - Cellphones
  - WiFi
  - Radio
  - Base Stations
Introduction to Electromagnetics

Radio frequency radiation

Non-ionising radiation

Ionising radiation

Can Cause Heating

Can Cause Cancer

AM radio  FM radio  Satellite

Mobile Phones

Radio frequency radiation

Can Cause Heating

Ionising radiation

X rays  Gamma rays

Ionising radiation

Can Cause Cancer
Introduction to Electromagnetics

- Cellular communications
Introduction to Electromagnetics

Typical Cellphone Base stations
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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

- Network limits (124 ICNIRP, 11 FCC)
- Incl Kenya

Note: Information from public sources except where indicated.
Last updated: 19 May 2015
Guidelines for Safe Exposure

- Handset limits (147 ICNIRP, 19 FCC)
- Incl Kenya
**Guidelines for Safe Exposure**

**ICNIRP**

*International Commission on Non-Ionizing Radiation Protection*

- Based on scientific research in the field, considering various outcomes.
- **Protect against known possible negative health effects** – *Overheating* at this frequency range.

<table>
<thead>
<tr>
<th>SAR [W/kg]</th>
<th>Excessive Heating</th>
<th>Occupational Limit</th>
<th>General Public Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Chart:**

- **Excessive Heating**
- **Occupational Limit**
- **General Public Limit**
Guidelines for Safe Exposure

- At mobile frequencies:
  - Basic restrictions
    - SAR (W/kg)
    - Energy absorbed per unit mass
    - Two tiers
    - Details not covered

Table 4: Basic restrictions for time varying electric and magnetic fields for frequencies up to 10 GHz.

<table>
<thead>
<tr>
<th>Exposure characteristics</th>
<th>Frequency range</th>
<th>Current density for head and trunk (mA m⁻²)(rms)</th>
<th>Whole-body average SAR (W kg⁻¹)</th>
<th>Localized SAR (head and trunk) (W kg⁻¹)</th>
<th>Localized SAR (limbs) (W kg⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occupational exposure</td>
<td>up to 1 Hz</td>
<td>40</td>
<td>40</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>1–4 Hz</td>
<td>40f²</td>
<td>40</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>4 Hz–1 kHz</td>
<td>10f²</td>
<td>10</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>1–100 kHz</td>
<td>10f²</td>
<td>10</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>100 kHz–10 MHz</td>
<td>10f²</td>
<td>10</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>10 MHz–10 GHz</td>
<td>10f²</td>
<td>10</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>General public exposure</td>
<td>up to 1 Hz</td>
<td>8</td>
<td>8</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>1–4 Hz</td>
<td>8f²</td>
<td>8</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>4 Hz–1kHz</td>
<td>2f²</td>
<td>2</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>1–100 kHz</td>
<td>2f²</td>
<td>2</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>100 kHz–10 MHz</td>
<td>2f²</td>
<td>2</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>10 MHz–10 GHz</td>
<td>2f²</td>
<td>2</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

Note:
1. f² is the frequency in hertz.
2. Because of electrical inhomoogeneity of the body, current densities should be averaged over a cross-section of 1 cm² perpendicular to the current direction.
3. For frequencies up to 100 kHz, peak current density values can be obtained by multiplying the rms value by √2 (1.414). For pulses of duration t, the equivalent frequency to apply in the basic restrictions should be calculated as f ≈ 1/(2t²).
4. For frequencies up to 100 kHz and for pulsed magnetic fields, the maximum current density associated with the pulses can be calculated from the rise/fall times and the maximum rate of change of magnetic flux density. The induced current density can then be compared with the appropriate basic restriction.
5. All SAR values are to be averaged over any 6-minute period.
6. Localized SAR averaging mass is any 10 g of contiguous tissue; the maximum SAR so obtained should be the value used for the estimation of exposure.
7. For pulses of duration t, the equivalent frequency to apply in the basic restrictions should be calculated as f ≈ 1/(2t²). Additionally, for pulsed exposures, in the frequency range 0.3 to 10 GHz and for localized exposure of the head, in order to limit or avoid auditory effects caused by thermoelectric expansion, an additional basic restriction is recommended. This is that the SAR should not exceed 10 mJ kg⁻¹ for workers and 1 mJ kg⁻¹ for the general public averaged over 10 g tissue.
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A large number of studies have been performed over the last two decades to assess whether mobile phones pose a potential health risk. To date, no adverse health effects have been established as being caused by mobile phone use. This is the general conclusion reached by numerous international medical bodies.
Recent reviews

– SCENIHR 2015
  • Final opinion on potential health effects of exposure to electromagnetic fields (EMF), Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR), adopted on 27 January 2015.

– Swedish Radiation Safety Authority 2015
  • Recent Research on EMF and Health Risk – Tenth report from SSM’s Scientific Council on Electromagnetic Fields, Strålsäkerhetsmyndigheten (Swedish Radiation Safety Authority), March, 2015.

– New Zealand 2015

– ARPANZA 2014

– Austria 2014
  • WBF Expertenforum 2014, Wissenschaftliche Beirat Funk (WBF), 2014 (Austria).

– Belgium 2014
  • Téléphonie mobile et santé avec en point d’attention la 4G, Avis du Conseil supérieur de la Santé (CSS) [Superior Health Council of Belgium], No. 8927, 1 October 2014. Published 16 December 2014.

– Canada 2014
Current / future reviews

• **WHO**
  – Thorough review of latest science
  – WHO currently conducting a formal risk assessment of all studied health outcomes from radiofrequency fields exposure. Results expected soon.

• **ICNIRP**
  – Workshop in Cape Town May 2016.
• **Further research:**

• Long term health monitoring of a large group of people so that we can identify if there are any health issues linked to long term mobile phone use.

• Assess the potential link between the risk of brain tumors and environmental risk factors, including use of communication devices.
Incidence rates

Observed and predicted glioma incidence rates under scenarios of risk, Nordic countries, men 40-59 years, 1979-2008

Under the assumption of risk for heavy users (>1640 hours)

Deltour et al. 2012

From http://www.icnirp.org/cms/upload/presentations/rf/RFWshop_Feychting.pdf
What does all this mean?

- Science based guidelines exist for EMF
- Regular reviews of latest science by international bodies
- General consensus is that the guidelines are sufficient to protect us against known potential health risks.
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Mobile phone networks

• First mobile phone?

• 1924?

• Analog 1970’s
• Digital 1990’s
Mobile phone networks

• Which technologies are used in Kenya?

• Fairly “standardized” world wide

• GSM900 and DCS1800 (2G in 900 and 1800 MHz bands)
• UMTS900 (3G in 900 MHz band)
• LTE800 and LTE1800 (4G in 800 and 1800 MHz bands)
• Microwave links for backhaul
• Wimax

1 Info from Safaricom
Mobile phone networks

Making a call & Handovers
Handovers

- Mobile phone looks for best signal from base station as mobile phone moves from cell to cell
- Complex handover scheme to ensure continuous communication

Adaptive power control

- Transmit minimum power required for connection, based on signal strength
- Advantages?
  - Saves battery power
  - Reduces interference
- Both directions
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ICNIRP refresher

- Basic restrictions – to protect against known negative health effects
Application to mobile phones and networks

- At mobile frequencies:
  - Basic restrictions
    - SAR (W/kg)
    - Energy absorbed per unit mass
  - 2 Tiers
• Show application to phones

• Show application to base stations

• Many technical details not covered
Application to mobile phones

• Is your phone’s SAR below these levels?
• How is this measured?
Application to mobile phones

• How is this measured?

• Reported value is “worst case”
  – Multiple technologies
  – Maximum transmit power (no Adaptive power control)
Application to mobile networks

- **At mobile frequencies:**
  - **Basic restrictions**
    - SAR (W/kg)
    - Energy absorbed per unit mass
    - Not easily measured in field
  - ICNIRP specifies “reference levels”
  - Conservative approximation of Basic restrictions
  - Can do computer simulation or measurement
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Aim

- Is this site compliant?
Antennas at a Base Station

- Various antennas at a BTS site
- They all transmit RF waves
Antennas at a Base Station

- Example “exclusion zones”
- Yellow: ICNIRP General public
- Red: ICNIRP Occupational
- Dimensions affected by?
  - Antenna characteristics
  - Transmit power level
  - etc
Antennas at a Base Station: Panel (Typical)

Side view

Top view

8m

18m

14m
Antennas at a Base Station: Omni (Typical)

Top view

Side view

0.4m

2.2m

2.8m
Antennas at a Base Station

- Exclusion zones for typical site
Aim

- Is this site compliant?
• To answer that question:

• Determine the location of any EMF exclusion zones
  • Computer simulation
  • Measurement

• Consider accessibility of such zones
Exclusion zone and accessibility

- Computer simulation
Exclusion zone and accessibility

• Computer simulation
Exclusion zone and accessibility

• Computer simulation
Administrative Controls

• Examples: Mast site
Aim

• Is this site compliant?
  – Zone?
  – Accessibility?
  – Measures?
Aim

- Is this site compliant?
  - Zone?
  - Accessibility?
    - Building occupants?
    - Measures?
      - Not sure, but not easily accessible
Exclusion zone and accessibility

• Is this site compliant?
  – Zone?
  – Accessibility?
  – Measures?
Aim

• Is this site compliant?
  – Zone?
  – Accessibility?
    • Building occupants?
  – Measures?
    • Not sure, but not easily accessible
Exclusion zone and accessibility

• Is this site compliant?
  – Zone?
  – Accessibility?
  – Measures?
Exclusion zone and accessibility

• Is this site compliant?
  – Zone?
  – Accessibility?
  – Measures?
Exclusion zone and accessibility

• Where is the closest site to our current location?
  • On rooftop
  • In building?
Exclusion zone and accessibility

• Is this site compliant?
  – Zone?
  – Accessibility?
  – Measures?
Exclusion zone and accessibility

- Is this site compliant?
  - Zone?
  - Accessibility?
  - Measures?
Exclusion zone and accessibility

• Is this site compliant?
  – Zone?
  – Accessibility?
  – Measures?
Exclusion zone and accessibility

- Is this site compliant?
  - Zone?
  - Accessibility?
  - Measures?
• Science based guidelines exist for EMF

• Regular reviews of latest science by international bodies

• General consensus is that the guidelines are sufficient to protect us against known potential health risks.
• Applied these guidelines to mobile base stations, considering
  – Where is the Exclusion Zone?
  – How Accessible is the Zone?
  – Administrative Measures?
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Why EMF Measurements?

• Measure at publicly accessible areas around cellular base stations
  – Public concern

• Cellular exclusion zone determination
  – Measurements normally not required or used to determine compliance boundary
  – Not covered here
EMF Measurements

• Use Narda portable spectrum analyzer
• Follow established measurement procedure (IEC 62232, CENELEC, etc)
• Automated
Measurement Methodology

- Example positions
Measurement Methodology

- Example positions
Measurement Methodology

- Example positions
EMF Measurements

• Example positions
Measurement Methodology

• Example positions
Typical Results

• Example site: Report

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.

<table>
<thead>
<tr>
<th>Survey Meter:</th>
<th>Calibration Status:</th>
<th>Calibration valid until:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Probe:</th>
<th>Calibration Status:</th>
<th>Calibration valid until:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naica PN 25001/03 Three-Axis E-Field Probe, S/N: K-0238</td>
<td></td>
<td>14 March 2016</td>
</tr>
</tbody>
</table>

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.

NRPA engineers were trained by EMSS to perform measurements in accordance with the measurement protocol of the IEC 62222 (May 2011) standard for determination of RF field strength and SAR in the vicinity of radiocommunication base stations for the purpose of evaluating human exposure.

A full uncertainty analysis for the measurement methodology used by EMSS, as required by the IEC 62232 standard, has been performed and is available from EMSS on request.

For more information, contact the NRPA at:
Tel: +204 61 260 2417
Typical Results

- “Mobile” Results (>200,000 measurements)
- Comparable to other international surveys

Ken H. Joyner et al. Radiat Prot Dosimetry 2013; rpd.nct222
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Further reading

• [http://www.who.int/peh-emf/](http://www.who.int/peh-emf/)

• [www.emfexplained.info](http://www.emfexplained.info)

• [http://www.mobil mastinfo.com](http://www.mobil mastinfo.com)
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- Applied these guidelines to mobile base stations, considering
  - Where is the Exclusion Zone?
  - How Accessible is the Zone?
  - Administrative Measures?
Summary

- EMF measurements to inform public
- Results similar to rest of the world
Conclusion

• Is this site safe?
  – Covered EMF guidelines
  – Applied to Mobile networks
• Asante sana

• Questions?

mvanwyk@emss.co.za