International Telecommunication Union

ITU-T Study Group 5

EMF Environmental Characterization

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Workshop on:

"EMC, safety and EMF effects in telecommunications"

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EMF Environmental Characterization

- Introduction
- Approach of Study Group 5
- Recommendation K.52
- Basic principles
- Application examples
- Current and future efforts
- Additional slides

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Introduction

- Exposure of human being to Electromagnetic Fields (EMF) raises concerns of possible health effects
- Radio transmitters used for telecommunication are proliferating
- ITU-T SG5 began to study a question on health effects of EMF in 1996

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SG5 Approach

- SG5 will provide guidance for compliance with EMF exposure limits
- SG5 will not develop new limits
- Operators should determine appropriate limits based on relevant national or international standards or national regulations

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SG5 Approach

- Study Period 1996-2000
  - Focus on the development of K.52
- Study Period 2000-2004
  - Radio-frequency environmental characterization and health effects related to mobile equipment and radio systems

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EMF Exposure Standards

- International
  - ICNIRP, *Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic field (up to 300 GHz)*
    - Adopted in many countries
    - Fundamental reference for K.52
    - Should be used unless a national standard takes precedence

Exposure Fundamentals

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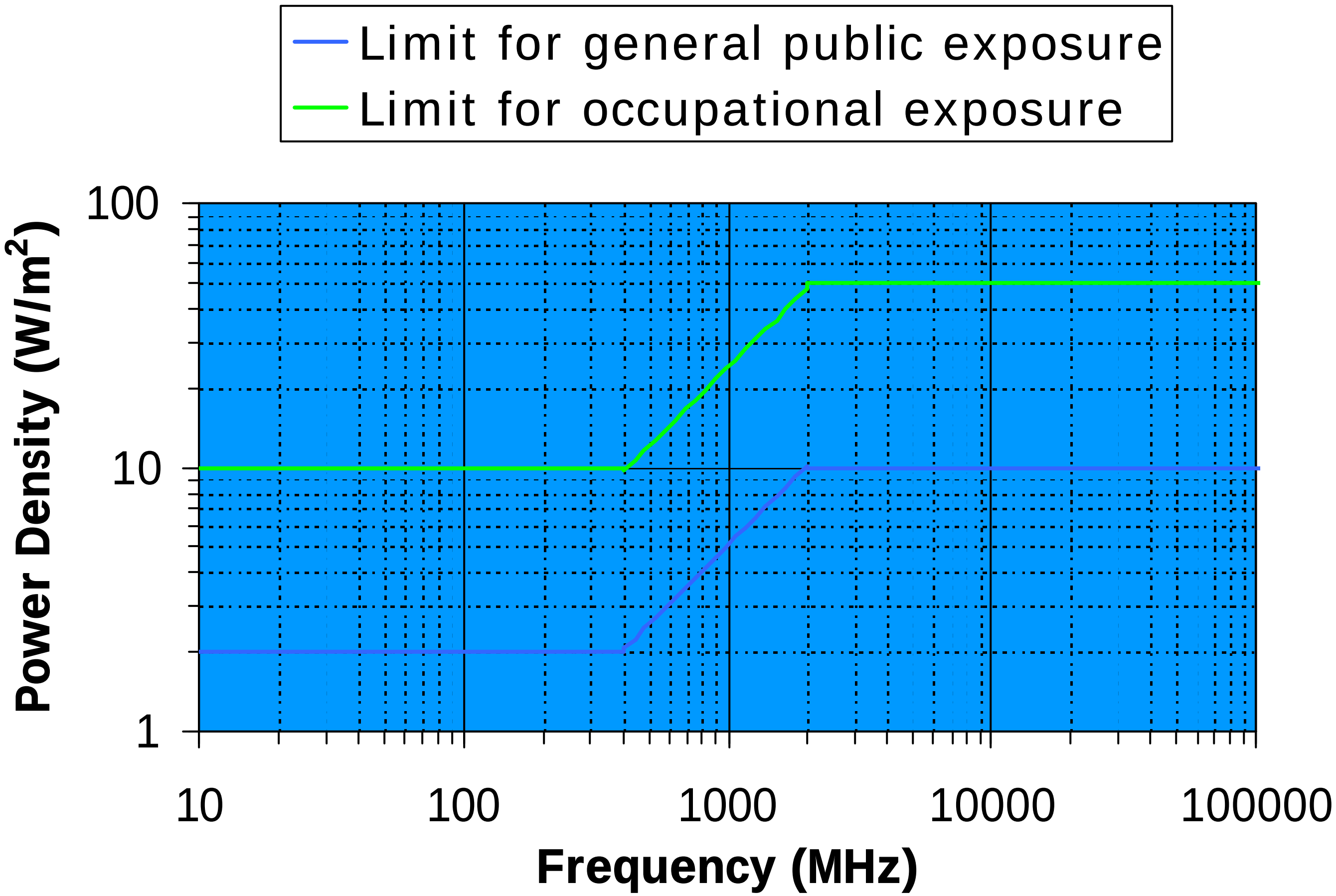
- Two-tier exposure limits
  - **Controlled/occupational exposure**
  - **General population/uncontrolled exposure**
    - Also called General Public exposure
- Formulas for multiple exposures
- Formulas for short-term exposures

ICNIRP Exposure Limits ¾ Power Density



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Achieving Compliance

- Identify appropriate compliance limits
- Perform exposure assessment for intentional transmitters only
- If needed, perform by calculations or measurement

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Achieving Compliance

- If the EMF exposure assessment indicates that pertinent exposure limits may be exceeded in areas where people may be present, mitigation/avoidance measures should be applied

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Achieving Compliance

- Assessment should be performed as part of planning, licensing or commissioning
  - Use basic criteria of K.52 (Annex B) and/or
  - Use software simulation tools
    - Can use database of transmitter and antenna parameters and locations

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K.52 Exposure Classification

- Compliance zone
  - Potential exposure to EMF is below the applicable limits
- Occupational zone
  - Potential exposure to EMF is below the limits for occupational exposure but exceeds the limits for general public exposure
- Exceedance zone
  - Potential exposure to EMF exceeds the limits for both occupational and general public exposure

Mitigation Techniques

- Occupational zone
  - Restrict access to general public
    - Physical barriers, lockout procedures or adequate signs can accomplish the access restriction
  - Workers may be permitted to enter the area
    - Workers entering the occupational zone should be informed

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Mitigation Techniques

- Exceedance zone
  - Restrict access to workers and the general public
    - If workers need to enter the area, take steps to control their exposure
      - Temporarily reduce the power of the emitter,
      - Controlling the duration of the exposure so that time-averaged exposure is within safety limits,
      - Use shielding or protective clothing

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K.52 Analytical Method

- K.52 Provides simple analytical method using far-field expressions
  - Valid in far field region
  - Conservative evaluation
  - Key parameters
    - Power, antenna pattern, antenna height, antenna azimuth and elevation
    - Note — if antenna pattern is not known
      - Use regulatory envelopes, or
      - ITU-R Reference patterns

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Exposure Evaluation Examples

- Frequency = 900 MHz
  - Limit for general public = 4.5 W/m^2
- Power to antenna = 100 W
- Reflection coefficient = 1
- Structures of the exceedance zones

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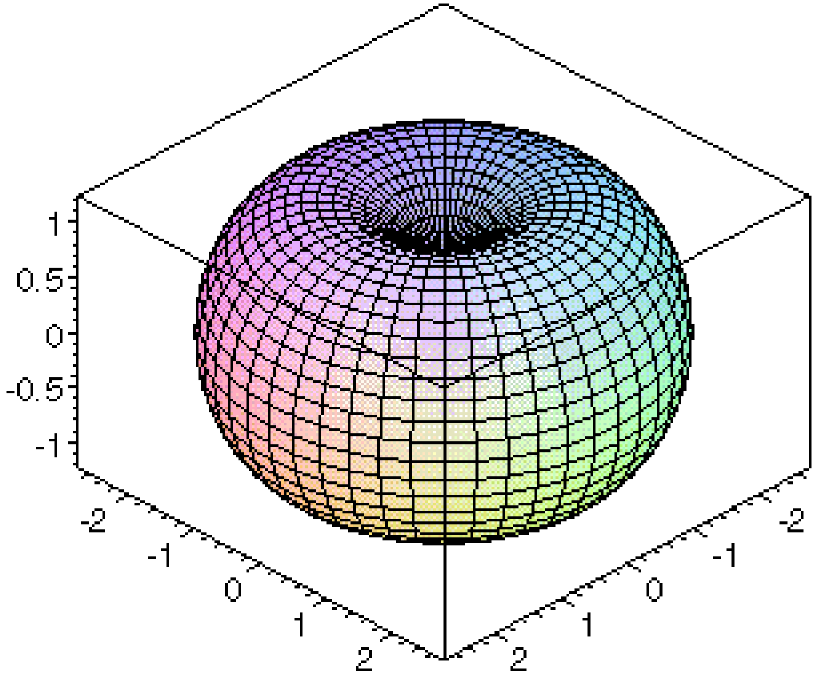
Half-Wave Dipole



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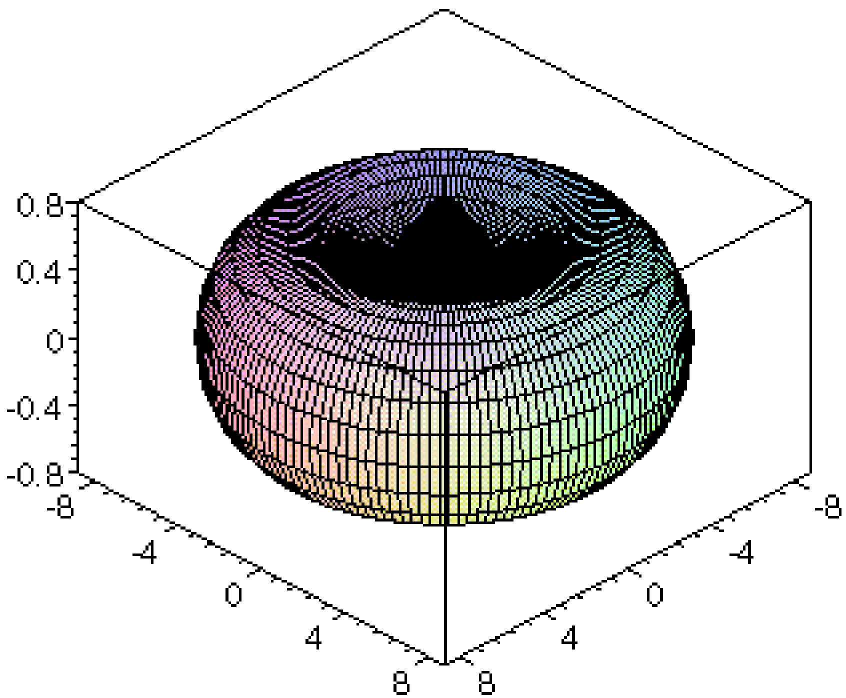
Point-Multipoint Reference Pattern

- Omnidirectional, Maximum gain = 10



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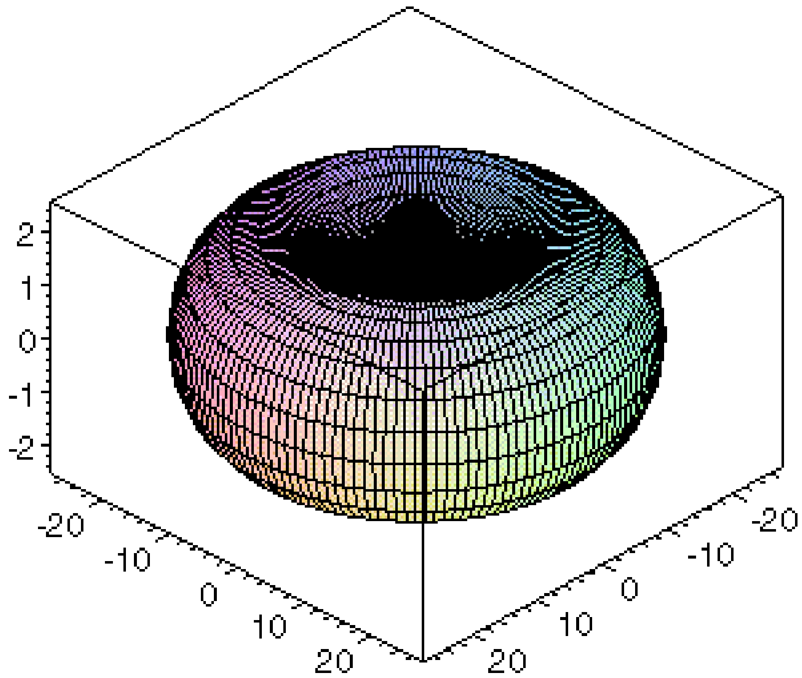
Multipoint Reference Pattern

- Same pattern, output power = 1000 W



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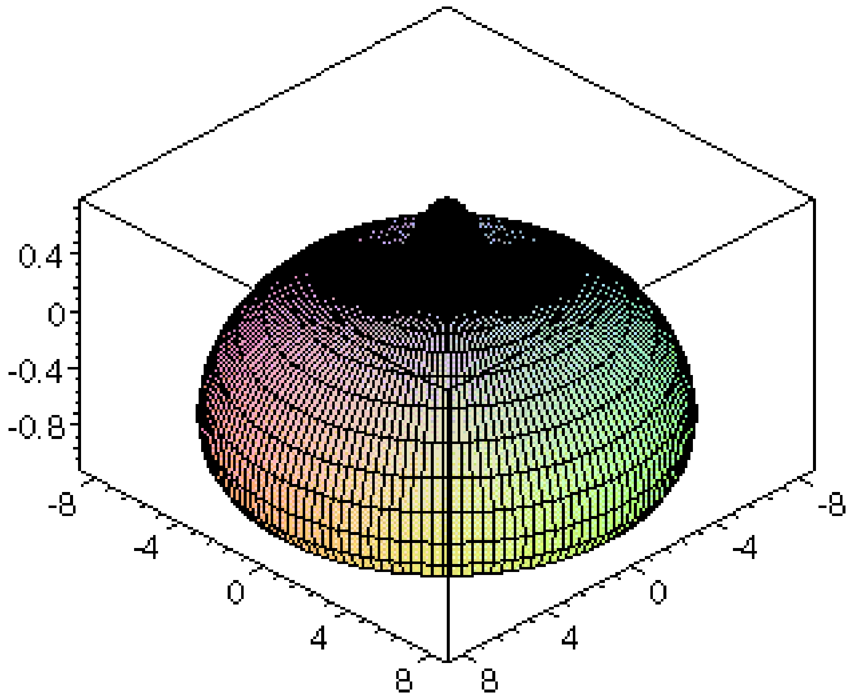
Multipoint Reference Pattern

- Same pattern, output power = 100 W
- Elevation tilt = -5 deg



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Multipoint Reference Pattern

- Same pattern, output power = 1000 W
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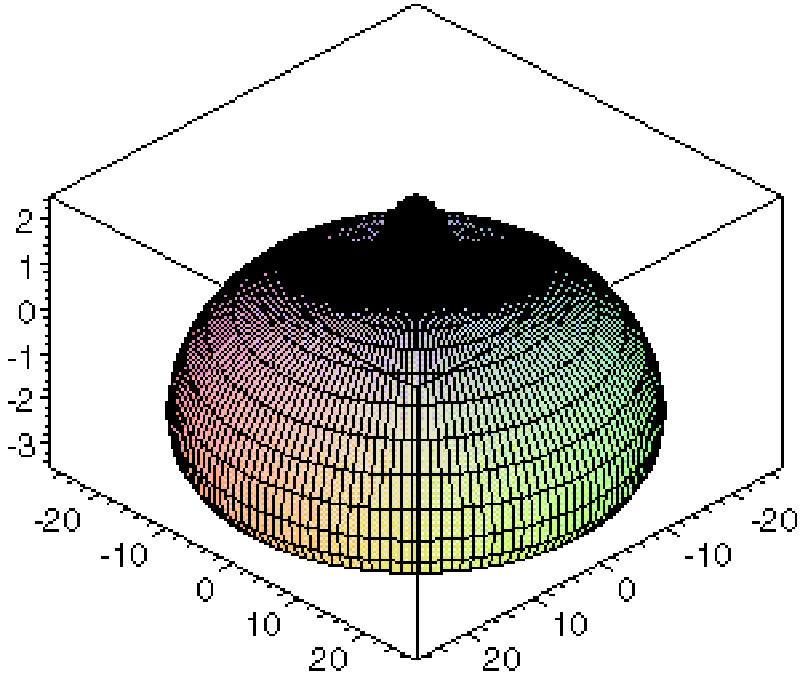

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Example Results

- Exceedance zones near the antennas would require mitigation if accessible
- For general public the area of concern is often at ground level

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Exposure Evaluation Examples

- Frequency = 2 GHz
  - Limit for general public = 10 W/m^2
- Power to antenna = 0 dBW
- Reflection coefficient = 1
- Structures of the exceedance zones

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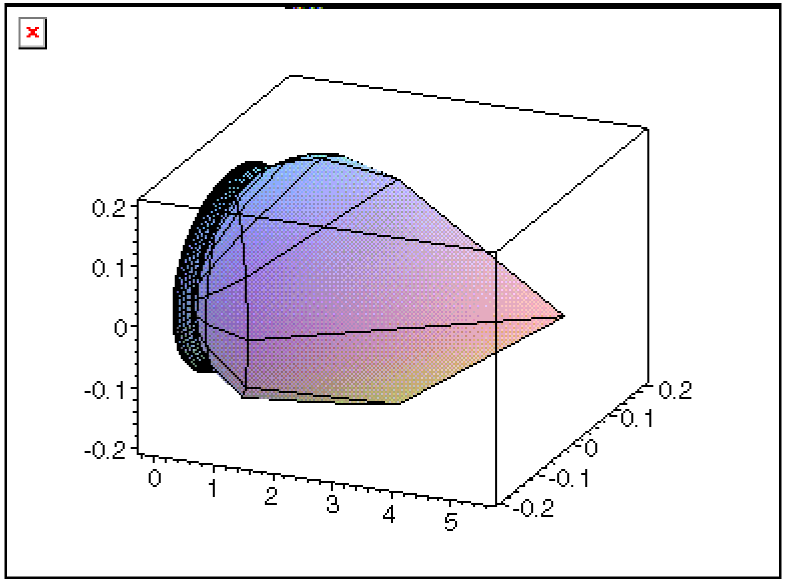
30-dB Reference Pattern for Fixed Service



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Study Period 2001-2004 Question 3: Work Program

Two new Recommendations

1. K.mes for tlc installations compliance to reference level: procedure, tools and instrumentation requirement
2. K.rt for radio terminals: compliance to basic limits, i.e. SAR

K.mes:

Measurement and numerical prediction of EMF for tlc installations compliance with human exposure limits

- K.52: indications to perform an exposure assessment based on the evaluation of the electromagnetic field and on accessibility considerations
- K.mes defines tools, methods and procedures that can be used to achieve a reliable compliance assessment.

It is intended to provide:

- Basic requirement for e.m. field measurement: methods, instruments, procedures
- Indications on numerical methods for exposure prediction

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K.rt: Mobile Phone and SAR Limits

- The goal: a Recommendation which provides harmonized indications on
  - Definition of a conformance test
  - SAR limits
  - Procedure
  - Calibration of E-field probe
  - Setup

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Q. 3: The Work Until Now

- K.mes: measurement 75%
- K.mes: calculation <10%

- K.rt: nothing

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Questions

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Additional Material

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National EMF Exposure Standards

- USA
  - FCC, 96-326, *Guidelines for Evaluating the Environmental Effects of Radiofrequency Radiation*
  - ANSI/IEEE C95.1, *Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz*

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Exposure Fundamentals

- The key quantity is the **Specific Absorption Rate (*SAR*)**
  - The time derivative of the incremental energy (*dW*) absorbed by (dissipated in) an incremental mass (*dm*) contained in a volume element (*dV*) of a given mass density (r_m)

$$SAR = \frac{d}{dt}\frac{dW}{dm} = \frac{d}{dt}\left(\frac{1}{r_m}\frac{dW}{dV}\right)$$

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Exposure Fundamentals

- SAR is difficult to measure or predict
  - Used for non-inform exposure or where the EMF is influenced by the presence of a body
    - Used for handset exposure
- Use levels for electric and magnetic field or power density derived from SAR limits
- K.52 and this presentation use power-density limits

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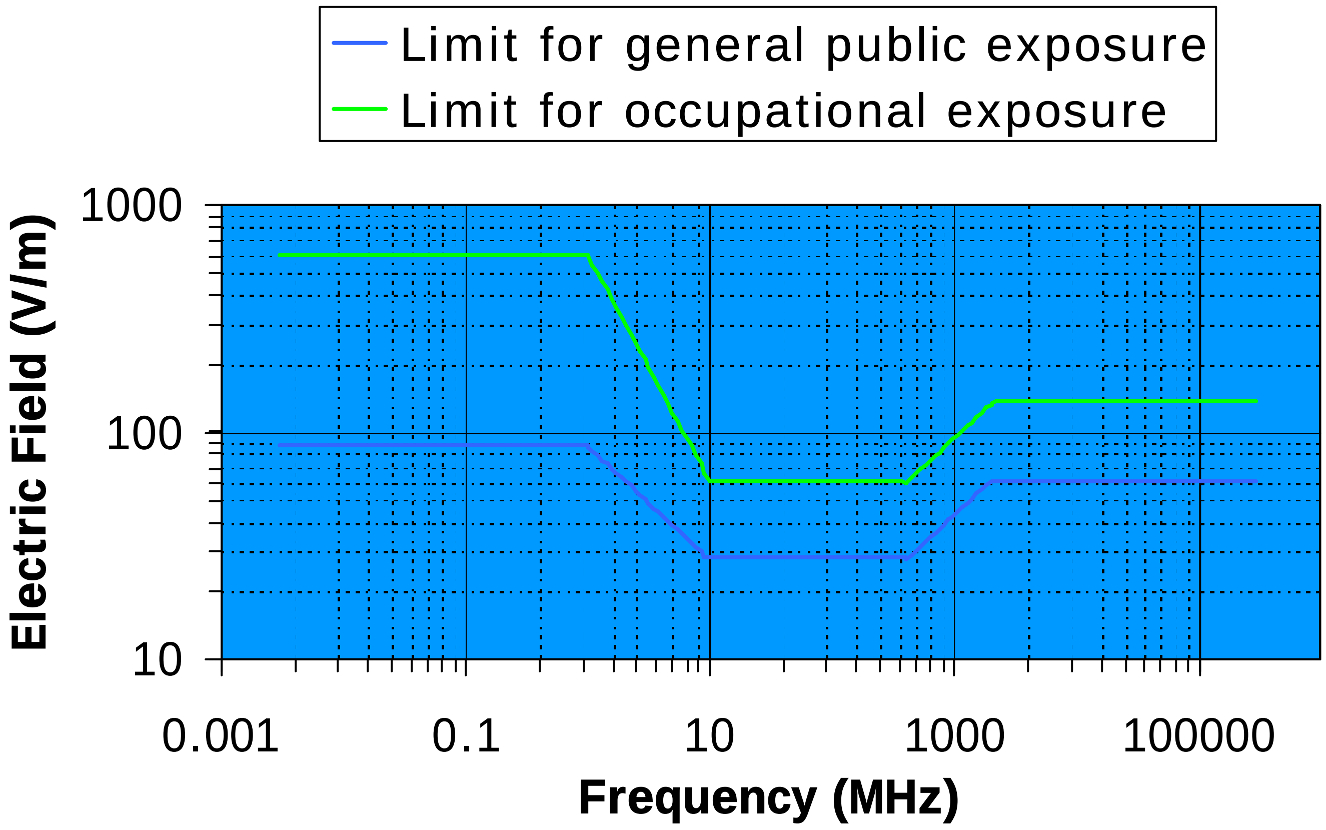
ICNIRP Exposure Limits
¾ Electric Field



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Simultaneous Exposure to Multiple Sources

- Multiple sources at different frequencies above 1 MHz
  - E_i is the electric field strength at frequency *i*
  - $E_{l,i}$ is the reference limit at frequency *i*
  - S_i is the power density at frequency *i*
  - $S_{l,i}$ is the reference limit at frequency *i*

$$\sum_i \left(\frac{E_i}{E_{l,i}} \right)^2 \leq 1 \quad \text{OR}$$

$$\sum_i \frac{S_i}{S_{l,i}} \leq 1$$

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Analytical Methods

- K.52 Provides simple analytical method using far-field expressions
  - *S(R,q, f)* is the power density in W/m^2
  - *f(q, f)* is the relative field pattern of the antenna
  - *EIRP* is the EIRP of the antenna in W
  - *r* is the absolute value of the reflection coefficient
  - *R* is the distance to the putative exposed person

$$S(R,q,f) = (1+r)^2 \frac{EIRP}{4pR^2} f(q,f)$$

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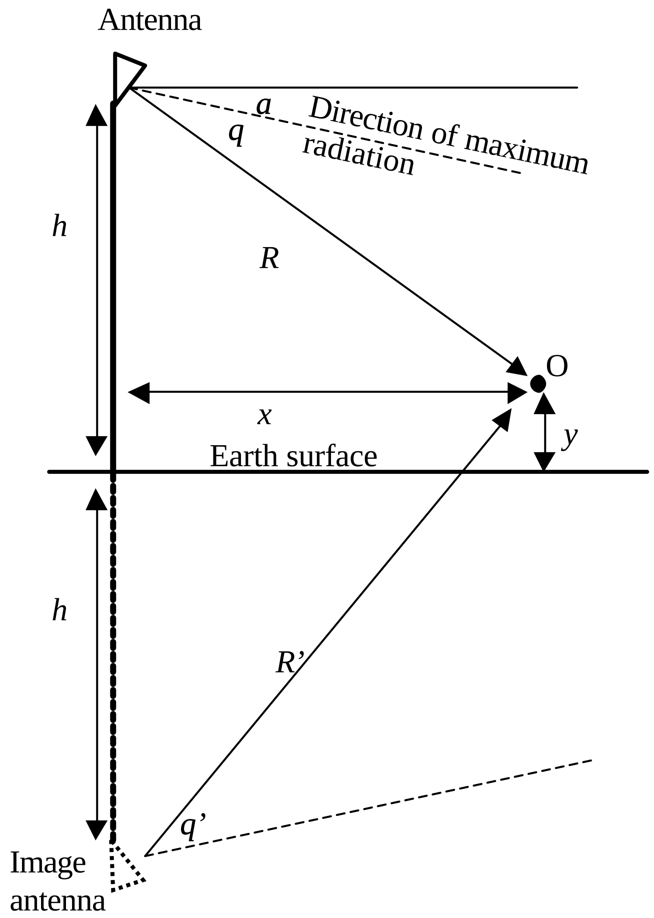
K.52 Analytical Method

- Valid in far field region
- Conservative evaluation
- Key parameters
  - Power, antenna pattern, antenna height, antenna azimuth and elevation



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Antenna Patterns

- Important for determination of exposure
- Use manufacturers data
- If unknown,
  - Use regulatory envelopes, or
  - ITU-R Reference patterns

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Antenna Patterns

- Basically two type
  - Cylindrically symmetrical
    - Dish-type antennas
  - Separable in spherical coordinates
    - Azimuthal pattern
    - Elevation pattern
    - Mobile or broadcast systems

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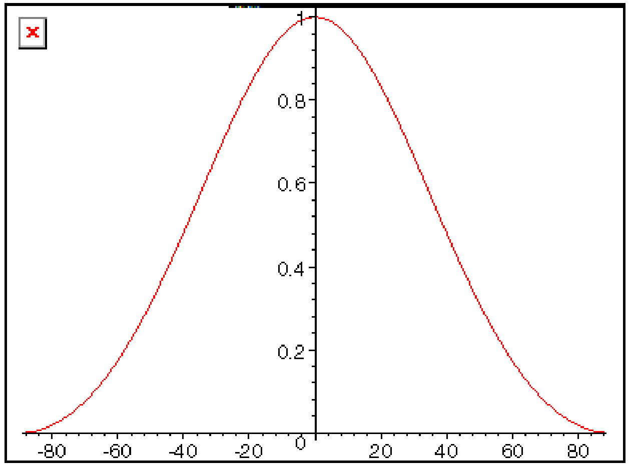
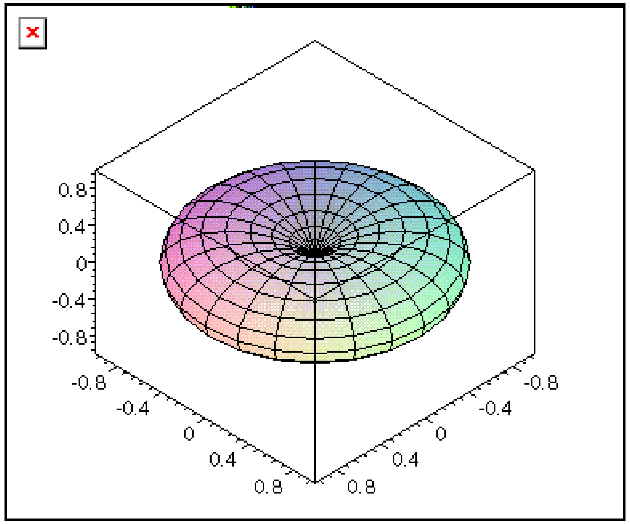
Half-wave Dipole





- Simple analytical example
- Omnidirectional azimuthal pattern

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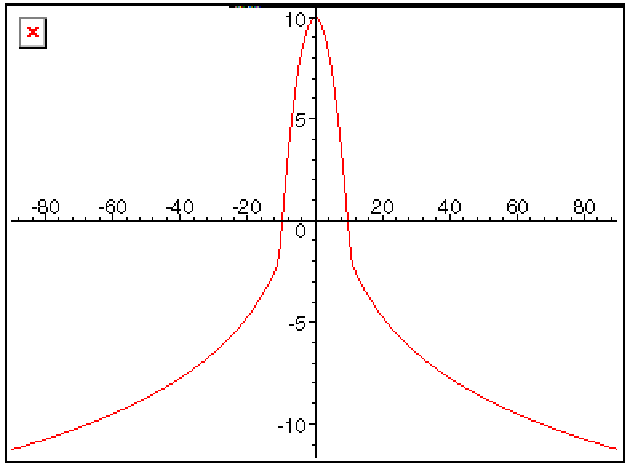
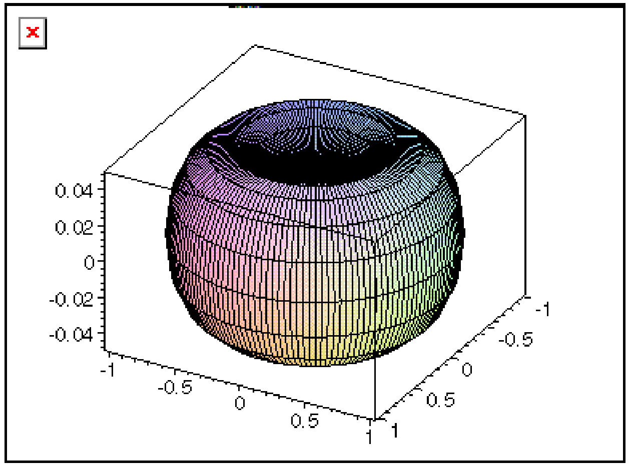
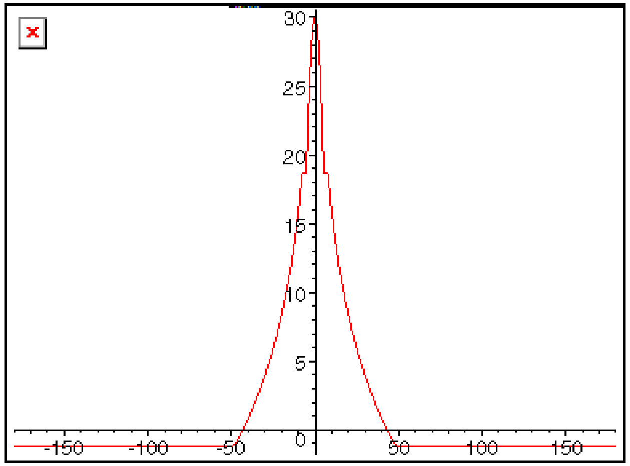
Example Point to Multipoint

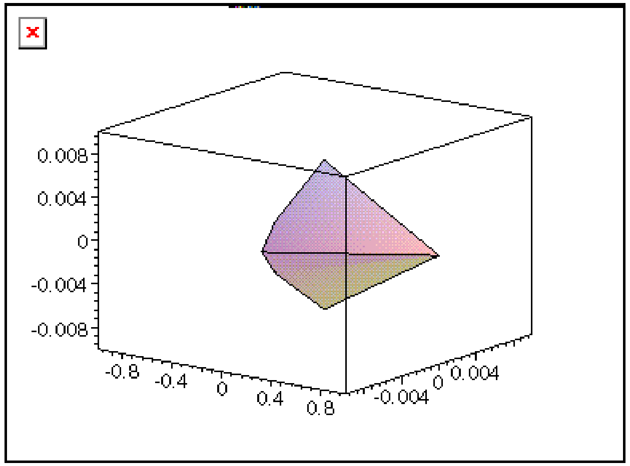




- Omnidirectional azimuthal pattern
- Reference pattern from the ITU Radio Regulations
  - Maximum gain = 10

Example Cylindrically-Symmetrical Pattern





- Reference pattern from the from ITU-R Recommendation F.699
  - Maximum gain = 30

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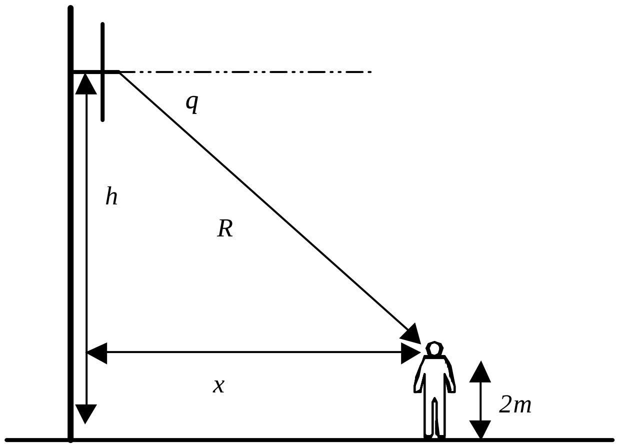
Ground-Level Calculation



$$S = \frac{(1+r)^2}{4p} f(q) \frac{EIRP}{x^2 + (h-2)^2}$$

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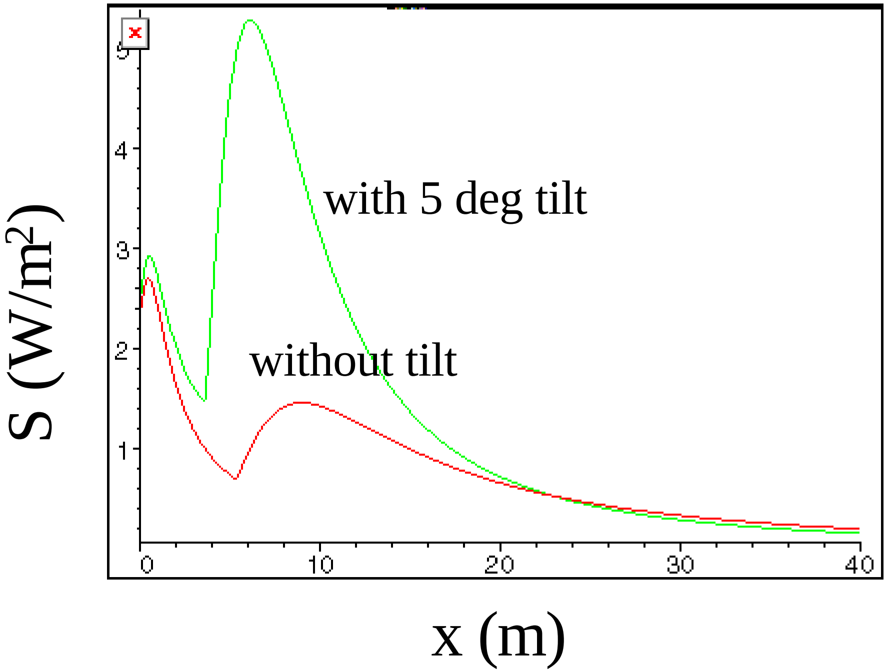
Power Density at Ground Level

10-dB Multipoint Reference Pattern, h = 3 m



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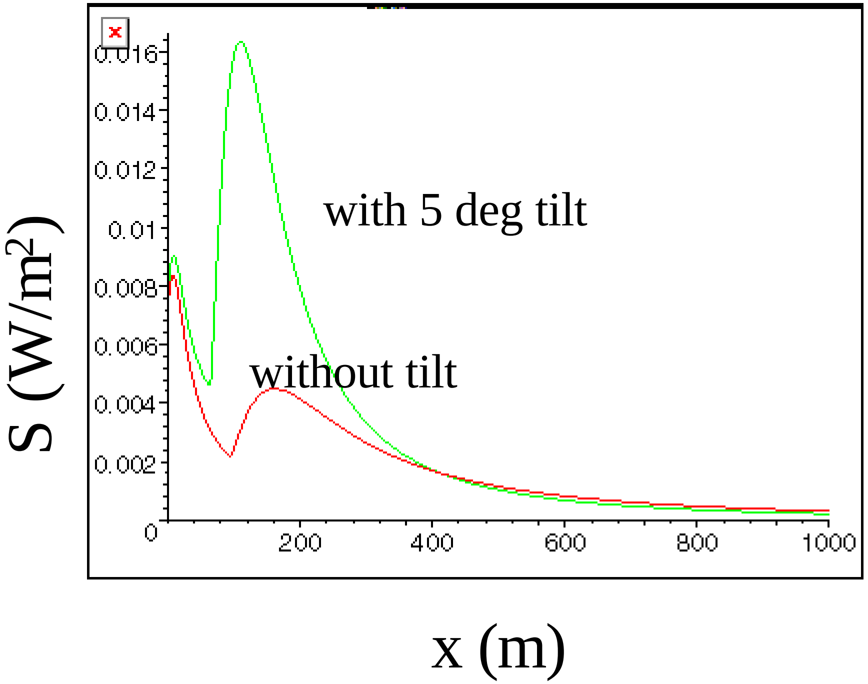
Power Density at Ground Level

10-dB Multipoint Reference Pattern, h = 20 m



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K.mes: Contents

Measurement

1. Instruments basic requirement (e.g. calibration factors, isotropy, linearity…)
2. Uncertainties
3. Procedures
4. Compliance and results analysis

Numerical predictions

1. Exceedance volume (see K.52) and punctual calculation
2. Propagation models (far field, near field…)
3. Ray-tracing techniques

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K.mes — Measurement Instrument Requirement (1)

Characterization of:

- Antenna factor (for frequency selective meas)

$$k_a\left[\frac{1}{m}\right]=\frac{E_{incident}\left[\frac{V}{m}\right]}{V_{measured}[m]}$$

- Calibration Factor

$$CF=\frac{E_{incident}\left[\frac{V}{m}\right]}{E_{measured}\left[\frac{V}{m}\right]}$$

As functions of frequency, amplitude…

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K.mes — Measurement Instrument Requirement (2)

- Amplitude linearity
- Isotropic respond
- Multiple sources integration:

$$E_{tot} = \sqrt{\sum_f E_f^2}$$

- Respond to Pulsed modulated signals (insted of simple continous wave)
- ...

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K.mes-Numerical Predictions

- Applicability of numerical models
  - Free space far field
  - Free space near field
  - Ray tracing: line of sight, reflected and diffracted contributes
  - Full wave methods (FDTD, MOM, FEM...)
- Topographic data base
- Realistic analysis for the maximum radiated power