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Thank You for Attending Today's Webinar:

WAVECONTROL - EMF Health, Applications & Emerging Trends

WAVECONTROL
Safety, Quality, Service

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WAVECONTROL
Safety, Quality, Service

EMF Measurement Techniques

- Introduction to EMF
- Using the SMP3
- Standards compliance, Industry updates and applications.

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ABOUT WAVECONTROL: HIGHLIGHTS

27 years
since 1997

+16000
Delivered instruments

WAVECONTROL
Safety, Quality, Service

+80
countries

+10000
ILAC accredited calibrations

Continuous
R+D

ISO 9001
certified company

ISO 17025
accredited calibration lab

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PRODUCTS

EMF METERS

1 Hz – 10 MHz

100 kHz – 90 GHz

Static
Fields

SMP3

RF PERSONAL MONITORS

LF-400
DC – 400 kHz

RF-8
100 kHz – 8 GHz

RF-60
100 kHz – 60 GHz

WaveMon

AREA MONITORS

Outdoors

Indoors
MonitEM-Lab

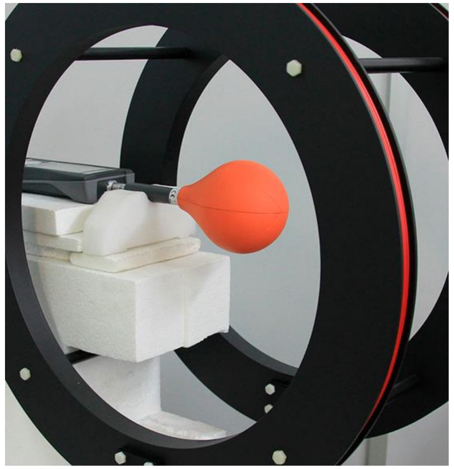
MonitEM

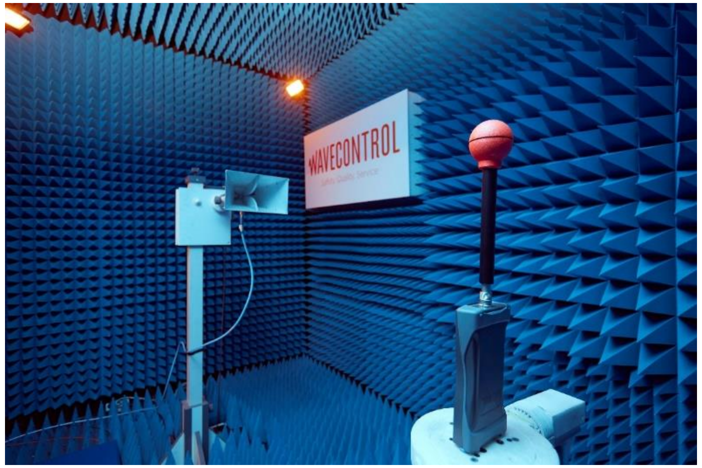
LabCal WAVECONTROL

- **ISO 17025** accredited field probe calibration laboratory
- All our instruments are delivered with **LabCal** accredited calibration
- **ILAC** accredited calibration accepted worldwide

ilac-MRA

ENAC
CALIBRACIÓN
Nº 184/LC10.132





TYPE OF FIELD		FREQUENCY	ACCREDITED
STATIC	DC Magnetic Field	0 Hz	YES
LOW FREQUENCY	AC Magnetic Field	10 Hz – 100 kHz	YES
	AC Magnetic Field	100 kHz -200 kHz	Traceable
	Electric Field	10 Hz – 400 kHz	YES
HIGH FREQUENCY	Electric Field	100 kHz – 40 GHz	YES
	Magnetic Field	300 kHz – 1 GHz	YES

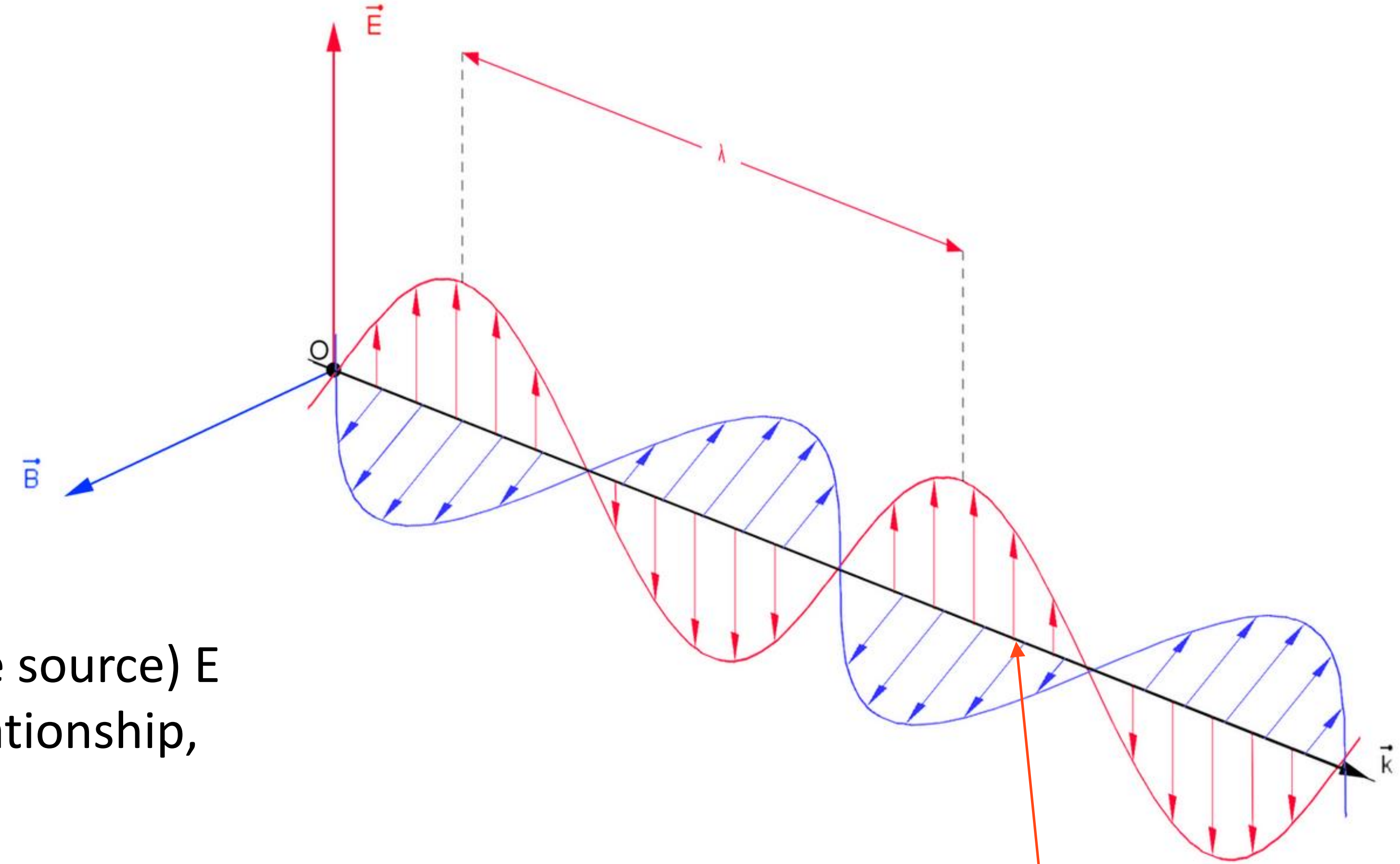
Introduction to EMF

Electromagnetic Wave and its Propagation

An electromagnetic wave consists of two waves that are oscillations of the **electric** and **magnetic** fields.

- Frequency (f)
- Wavelength (λ)
- Photon energy

$$f = \frac{c}{\lambda}$$

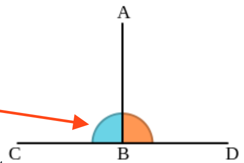


In Far Field conditions (far enough from the source) E and H are orthogonal and have a direct relationship, so only one of them must be measured:

$$\frac{E}{H} = Z$$

Z=377 ohm (impedance of free space)

Two vectors are orthogonal if they are perpendicular, i.e., they form a right angle (90°)



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Introduction – EMF biological Interaction mechanisms

Mechanism 1: Non-thermal effects – **Nerve and muscle stimulation (1 Hz – 10 MHz)**

Non-thermal effects include stimulation of muscles, nerves or sensory organs. These effects might have a direct effect on the mental and physical health of exposed individuals. Moreover, the stimulation of sensory organs may lead to transient symptoms, such as vertigo.

Mechanism 2: Thermal effects – **Heat (100 kHz – 300 GHz)**

Thermal effects include tissue heating through energy absorption from electromagnetic fields in the tissue. This energy is absorbed in different body tissues depending on frequency. From 6 GHz, the absorption is more superficial (on skin surface).

Static fields (0 – 1 Hz) – Biological effects

STATIC FIELDS

DIRECT EFFECTS

- Changes in chemical reactions
- Deflection of ionic currents
- Induction of electrical ‘flow’ potentials across blood vessels.

MOVEMENT-INDUCED EFFECTS

- Vertigo
- Nausea
- Visual sensation
- Metallic taste in mouth
- Acute neurocognitive effects

INDIRECT EFFECTS

- Contact currents
- Coupling with AIMD (e.g. pacemakers)

Low frequencies (1 Hz – 10 MHz) – Biological effects

Neurobehavior

- Stimulation of nerve and muscle tissue
- Induction of retinal phosphene
- Induced electric fields

Neurodegenerative disorder

- Links to Alzheimer and ALS
- No conclusive association between LF and neurodegenerative disorder

Cardiovascular disorder

- No likely hazardous cardiovascular effect associated with LF fields environmentally of occupationally.

IARC (WHO Research Institute)

- 50/60 Hz H-field and childhood Leukemia
- IARC category 2B (possibly carcinogenic)

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High frequencies (100 kHz – 300 GHz) – Biological effects

Biological effects

Exposure to electromagnetic fields at frequencies above about 100 kHz can lead to **significant absorption of energy** and temperature increases.

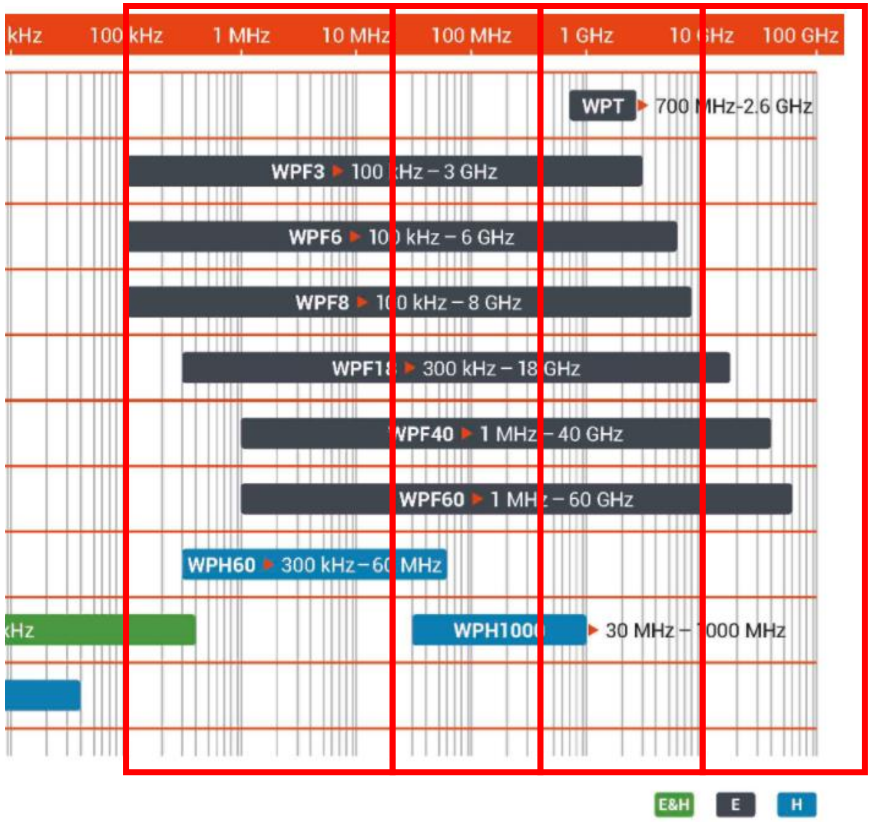
Regarding absorption of energy, EMF can be divided into four ranges:

100 kHz – 20 MHz: Absorption in neck and leg

20 MHz – 300 MHz: relatively high absorption may occur in the whole body.

300 MHz – several GHz: Significant local, nonuniform absorption occurs.

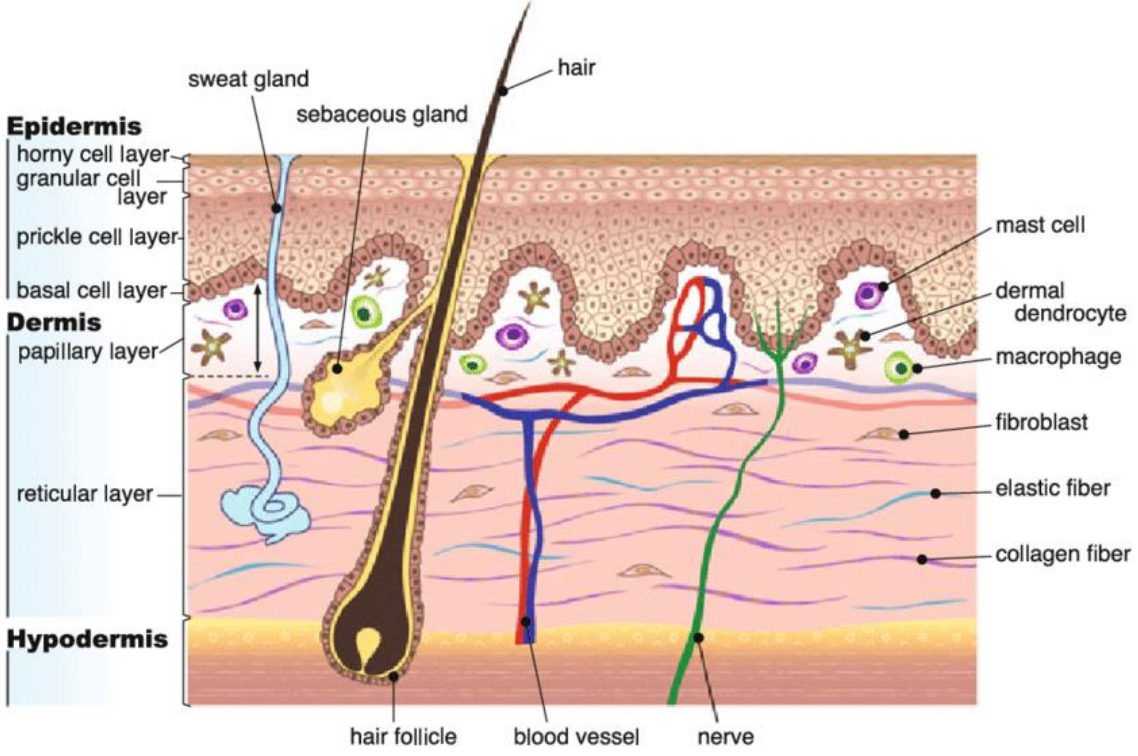
>6 GHz: Energy absorption primarily occur at the body surface.



EMF penetration depth in HF > 6 GHz

As EMF frequency increases, exposure of the body and the resultant heating becomes more superficial, and above about 6 GHz this heating occurs predominantly within the skin.

However, research has shown that high EMF frequencies cause heating within the dermis, and the vascular network can transport this heat deep within the body, which can increase body core temperature beyond the 1°C.



So, it is ICNIRP's opinion that it is still appropriate to also protect against body core temperature rise above 6 GHz.

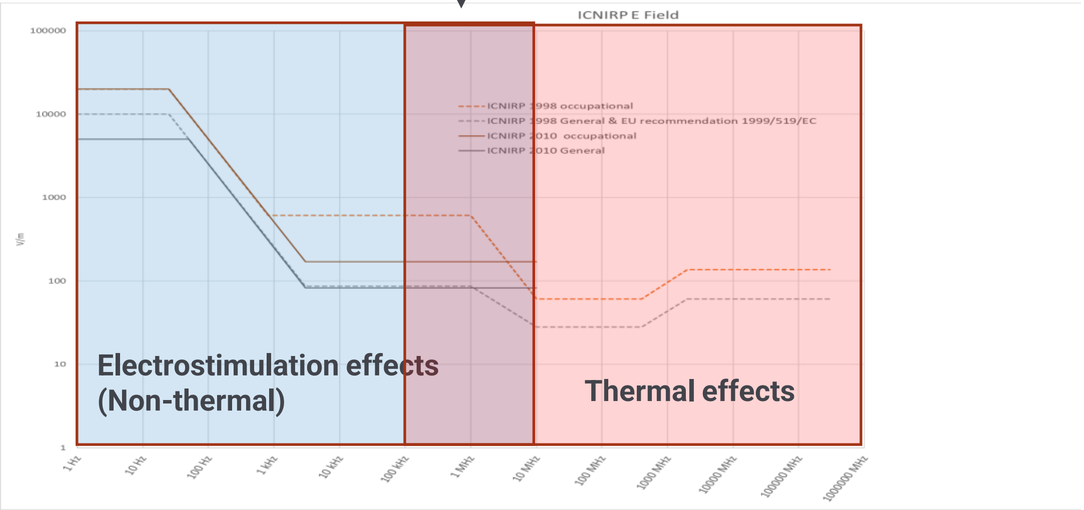
Methods for Performing Assessment

<u>Non-thermal effects</u>: Weighted Peak/RMS Method (Recommended) or FFT Analysis.

The WPM is preferred in complex multifrequency LF environment because it takes into account both the amplitude and the phases of the spectral components that make up the signal.

<u>Thermal effects</u>: Time-averaged measurement (Broadband or Frequency selective measurement devices).

Overlapped region 100 kHz – 10 MHz (where both effects must be assessed)



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Standards and Guidelines

Standards and Guidelines

Emission standards (Product standards)

These standards provide specification that limit EMF emission from devices. For example, they specify measurement procedures, distances and measurement methods.

Exposure standards (Limits)

These standards provide specification that limit EMF exposure to people. These standards provide EMF exposure limits to avoid overexposure of humans to EMF.

Exposure Standards (Limits) – Introduction

Exposure limits
(RL, ERL, MPE)
Set by numerous bodies

GB IEEE
ICNIRP
INTERNATIONAL COMMISSION ON NON-IONIZING RADIATION PROTECTION
FCC Health Canada

Occupational Exposure (Controlled/Restricted Environments)

- Exposed under controlled conditions.
- Trained to be aware of RF EMF risks.
- Trained to employ mitigation measures.
- Have the sensory and behavioral capacity.
- Subject to an appropriate H&S program.

Public Exposure (Uncontrolled/Unrestricted Environments)

- Individuals of all ages.
- Differing health statuses.
- Including vulnerable groups or individuals
- No knowledge of or no control over their exposure to EMFs

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ICNIRP Guidelines – Overview

ICNIRP has published **Guidelines (covering both public and workers)**:

- **1998** Guideline (1 Hz – 300 GHz) – LF/HF
- **2010** Guideline (1 Hz – 10 MHz) – LF
- **2020** Guideline (100 kHz – 300 GHz) – HF

ICNIRP 1998
Guideline

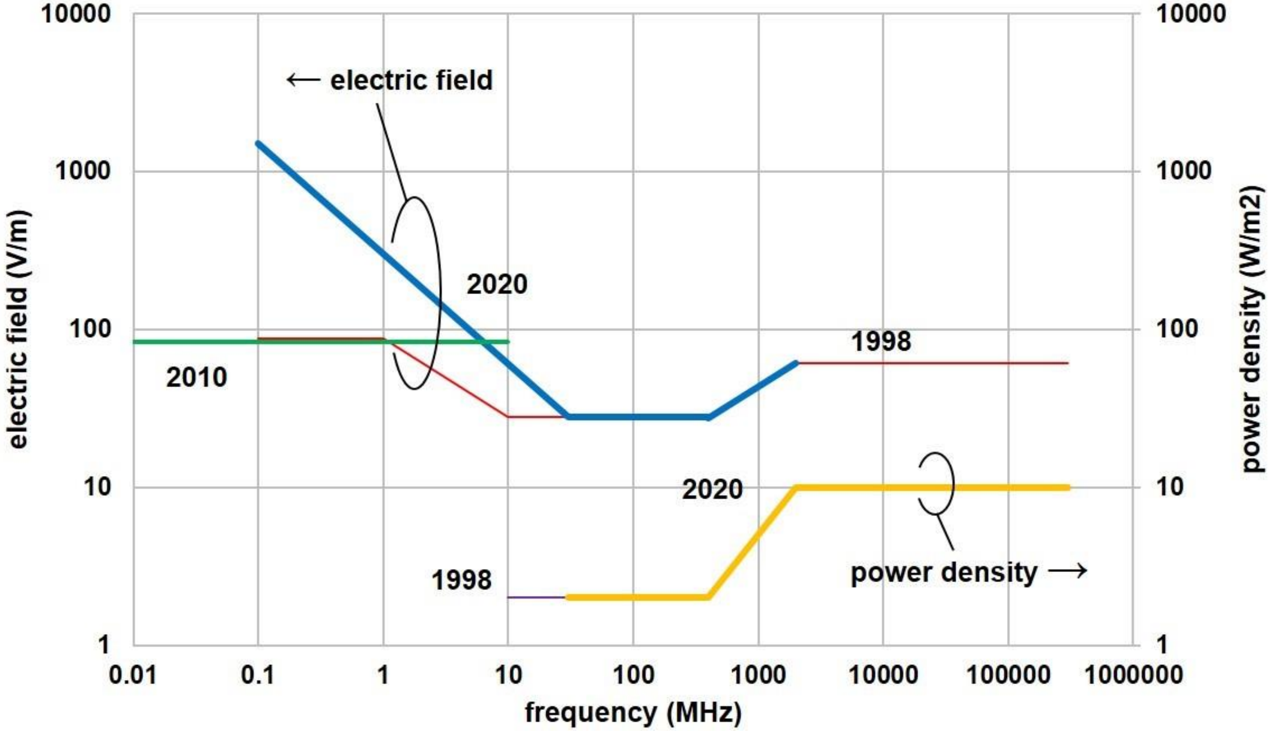
1998 limits are still in use but are to be replaced by 2020 limits in HF

ICNIRP 2010
Guideline

2010 limits cover 1 Hz to 10 MHz and are valid for non-thermal effects.

ICNIRP 2020
Guideline

2020 replaces both 1998 and 2010 limits between 100 kHz and 300 GHz. 2010 limits to be used for LF.



Europe – 1999/519/EC and Directive 2013/35/EU

EU Standards (covering both public and workers):

- **General Public** – Council Recommendation 1999/519/EC
- **Occupational** – EU Directive 2013/35/EU

General public

Council Recommendation
1999/519/EC

General public limits published in 1999 and are same as ICNIRP 98 Public limits.

Occupational safety

EMF Directive
2013/35/EU

CEMFAW UK (2016)

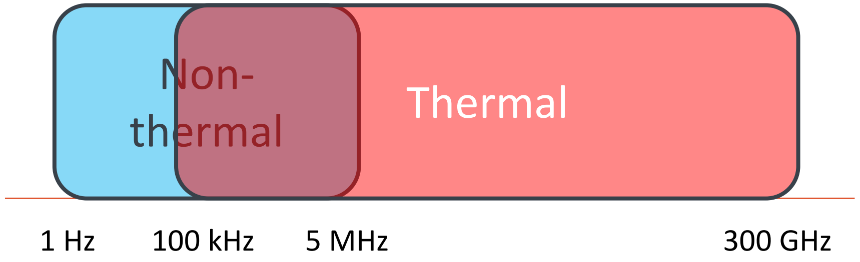
20th directive on EMF for occupational safety and the limits are similar to the 2010 ICNIRP Occupational reference levels

Adapted by EU member states in 2016

North America

IEEE Standards (ERL – Exposure reference levels):

- **Electrostimulation effects** – 0 Hz to 5 MHz
- **Thermal effects** – 100 kHz to 300 GHz (30 min. averaging time)



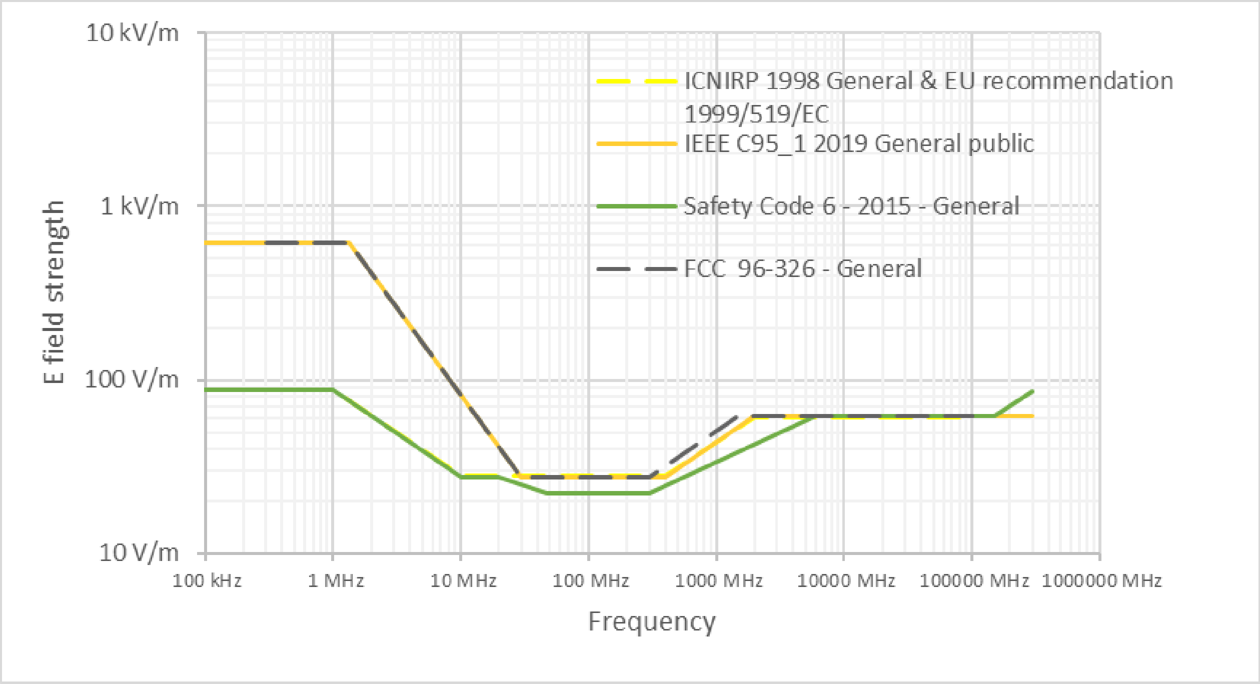
Safety Code 6 Standards (Reference levels):

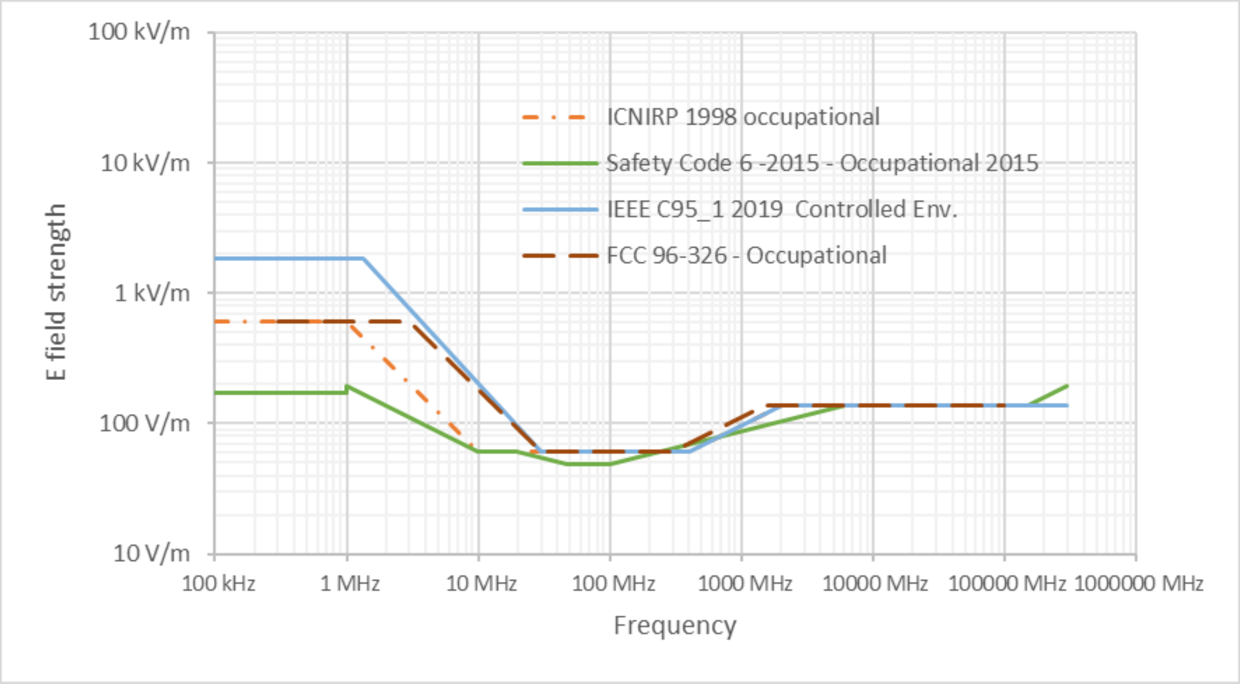
- **Nerve stimulation effects** – 3 kHz to 10 MHz
- **Thermal effects** – 10 MHz to 300 GHz (6 min. averaging up to 15 GHz)

FCC-96 Standards (MPE – Maximum Permissible Exposure):

- Limits for FCC-Regulated transmitters from 300 kHz to 100 GHz.
- The averaging time is 6 mins (controlled environment) and 30 mins (Uncontrolled)
- High frequency standard used in the United States

RF Exposure limits – ICNIRP, IEEE, EU, FCC (Comparison)





General population

Standard	ICN 98	IEEE C95	SC6	FCC
Lowest limit	28 V/m @ 10-400 MHz	27.5 V/m @ 30-400 MHz	22.06 V/m @ 48-300 MHz	27.5 V/m @ 30-300 MHz
Highest limit	87 V/m @ 100 kHz-1 MHz	614 V/m @ 100kHz-1.34 MHz	83 V/m @ 100 kHz-1 MHz	614 V/m @ 300 kHz-1.34 MHz
Averaging	6 minutes (until 10 GHz)	30 minutes	6 minutes (until 15 GHz)	6 minutes

Occupational

Standard	ICN 98	IEEE C95	SC6	FCC
Lowest limit	61 V/m @10-400 MHz	61.4 V/m @30-400 MHz	49.33 V/m @48-100 MHz	61.4 V/m @30-300 MHz
Highest limit	610 V/m @100 kHz-1 MHz	1842 V/m @100 kHz-1 MHz	193 V/m @ 1 MHz	614 V/m @ 300kHz-3 MHz
Averaging	6 minutes (until 10 GHz)	30 minutes	6 minutes (until 15 GHz)	30 minutes

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Emission (Product) Standards

INTERNATIONAL

International Electrotechnical Commission (IEC)
Code: IEC XXXXX
www.iec.ch

International Telecommunications Union (ITU)
Code: ITU-T K XXX, ITU-R, ITU-D
www.itu.int

Institute of Electrical and Electronics Engineers (IEEE)
Code: IEEE C.XX
www.ieee.org

REGIONAL AND NATIONAL

European Committee for Electrotechnical Standardization
Code: EN XXXXX
www.cencenelec.eu

National Standards of the PR of China (Guobiao Standards)
Code: GB or GB/T
www.gbstandards.org

The British Standards Institution
Code: BS (EN/IEC/ISO) XXXXX
www.bsigroup.com

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List of Standards, Sectors and Frequency

Applications	Standard	Frequency
General applications	IEC/EN 62311 IEC 61786-(1,2) EN 50413	Low/High frequency
Automotive	IEC 62764-1 GB/T 37130 Other manufacturer standards	Low frequency
Welding	IEC/EN 62822-(1,2,3) BS EN 50444 and 50445	Low frequency
Detection of articles and people	IEC/EN 62369-1 EN 50357	Low/High frequency
Electricity production and distribution	IEC/EN 62110	Low frequency
Lighting Equipment	IEC/EN 62493	Low/High frequency
Railway	IEC 62597 EN 50500	Low frequency
Transmitters and Telecom Base Stations Radio / TV base stations	IEC 62232 EN 50401, EN 50496 ITU-T K61, 83, 113, 145	Low/High frequency
Worker's safety	EN 50499 EN 50527-1 (AIMD users) EN 50527-2 (Pacemakers)	Low/High frequency
Medical applications	IEC 60601	Low/High frequency
Household appliances	IEC/EN 62233	Low frequency

EMF Measurement Solution

SMP3: Electromagnetic Field Meter

3 INSTRUMENTS IN 1:
Maximize your investment

- DC Field measurement
- Spectrum analysis - FFT (up to 10 MHz)
- Broadband measurement (up to 90 GHz)

One Single Meter for all probes

Integrated GPS (optional)

Weighted Peak Method (WPM)

Check compliance with standard limits
Up to 10 MHz

Probes: Isotropic, Linear, RMS …

High-accuracy field probes.
0 Hz – 90 GHz.
Probe auto-detect capability
Delivered with accredited Calibration.

Easy Steps for ensuring compliance to multiple standards

All limits embedded in a single meter
Adjustable bandwidth for specific applications

USB-C type, Fiber Optic

Download data for automatic reporting.
Remote control. New digital output.

Firmware Upgrade

Easy download and fast install.
Upgrade for future needs at no cost.

FIELD PROBES

Fast version probes for WPF18, WPF40 and WPF60: *For Radar applications, RFID, etc.*

HP Option: *For High Field applications*

Static magnetic field probe

WPH-DC: 0 Hz – 40 kHz (H & FFT)

Low frequency field probes

WP10M: 1 Hz – 10 MHz (E & H & FFT)
WP400/WP400C: 1 Hz – 400 kHz (E & H & FFT)
WP400-3: 1 Hz – 400 kHz (E & H & FFT)
WP50: 10 Hz – 3 kHz (E & H)

High frequency field probes

WPF3: 100 kHz –3 GHz (E Field)
WPF6: 100 kHz – 6 GHz (E Field)
WPF8: 100 kHz – 8 GHz (E Field)
WPF18: 300 kHz –18 GHz (E Field)
WPF40: 1 MHz - 40 GHz (E Field)
WPF60, WPF60S: 1 MHz - 60 GHz (E Field) – Flat/Shaped
WPF90: 30 MHz - 90 GHz (E Field)

Magnetic field probes

WPH60: 300 kHz – 60 MHz (H Field)
WPH1000: 30 MHz – 1000 MHz (H Field)

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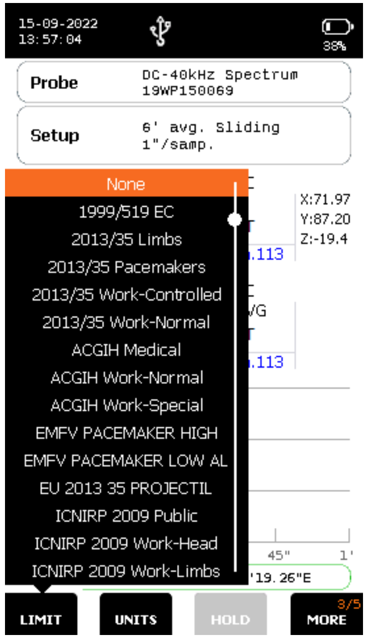
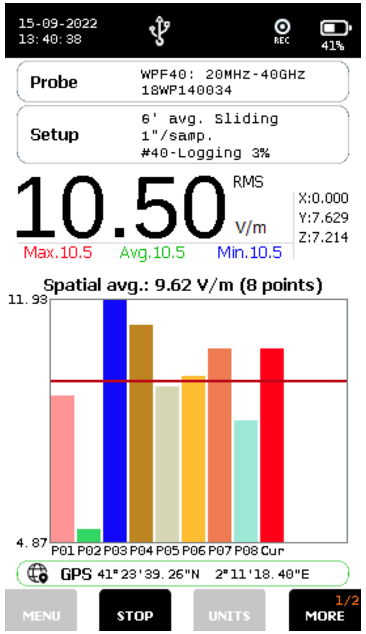
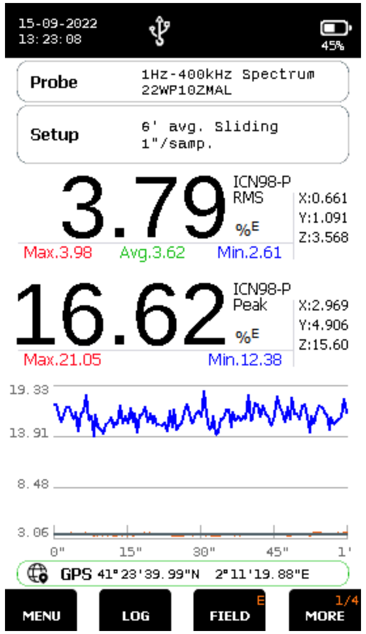
SMP3 – Features I (All probes)

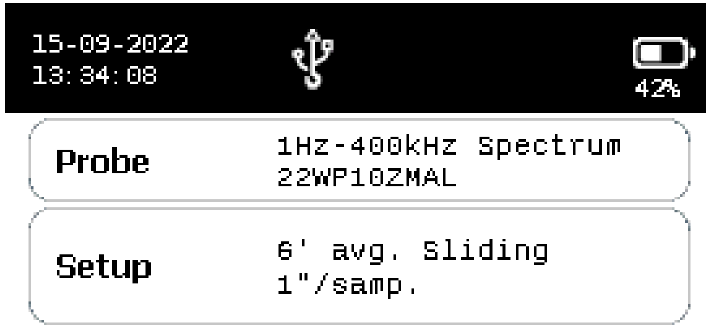
Firmware capabilities I

- **Compatible with all probes (SMP3-DUAL)**
- 3 in 1: all measurements with same meter
- Automatic probe recognition
- Double screen layout
- Limits selection
- Probe calibration warnings
- Spatial average mode
- Measurement Scheduling
- Multiple languages available





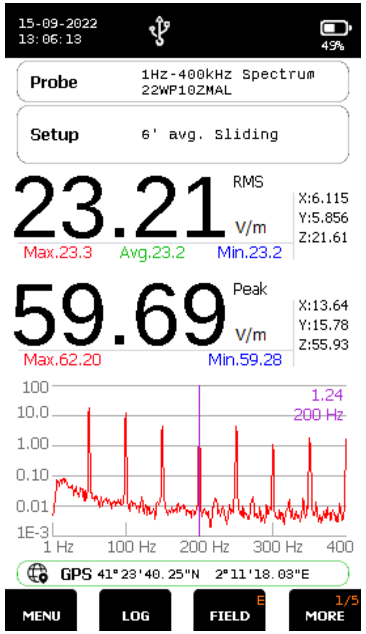


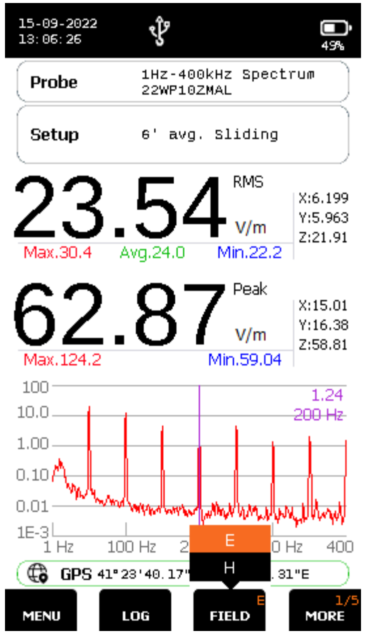


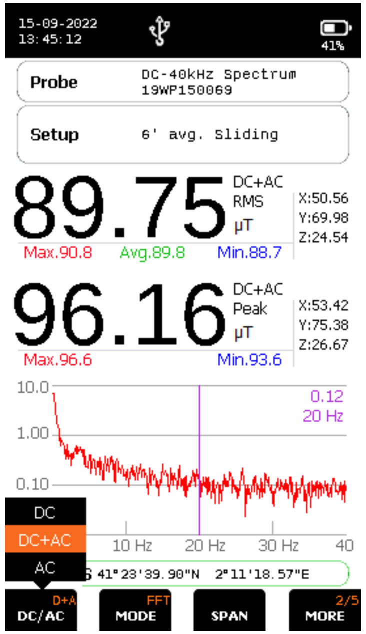
SMP3 – Features II (LF: WPH-DC, WP-Series)

Firmware capabilities II

- Static, Broadband and FFT
- Single frequency log measurements
- Frequency Analysis (FFT) **up to 10 MHz**:
  - Span selection and Max Hold function
- Real time Comparison with limits
  - Weighted Peak Method (**up to 10 MHz**)
- E/H selection with WP-series probes
- Static (0 Hz) H field measurements
- PLOT function (selective probes)
- **Bandwidth (BW) selection:**
  - **20 kHz, 100 kHz, 400 kHz, 5 MHz and 10 MHz.**







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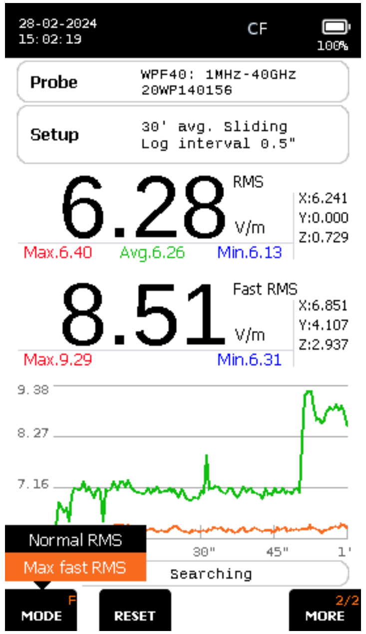
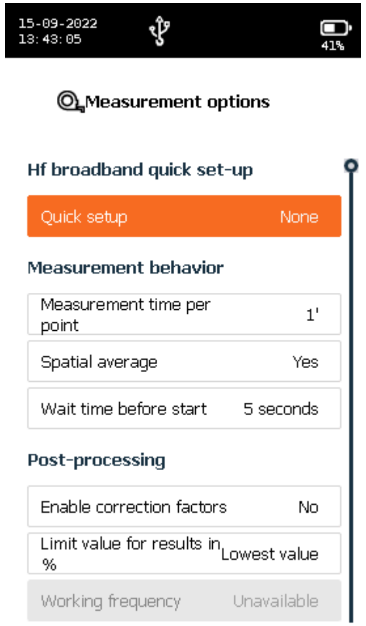
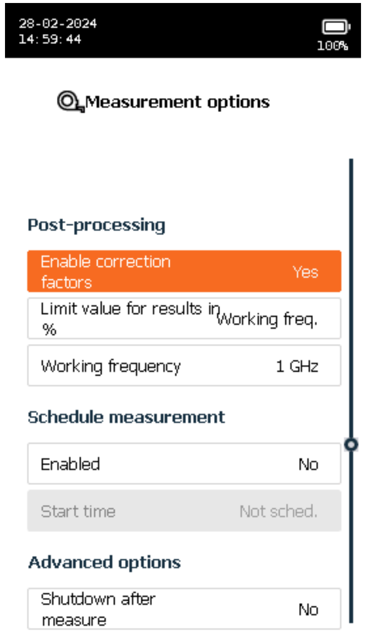
SMP3 – Features III (HF: WPF and WPH)

Firmware capabilities III

- Broadband RMS Measurements
- Measurement using Correction Factor
- Quick Setup (Pre-defined Standards Settings)
- User defined measurement settings
- Max Fast RMS (using Fast probes).







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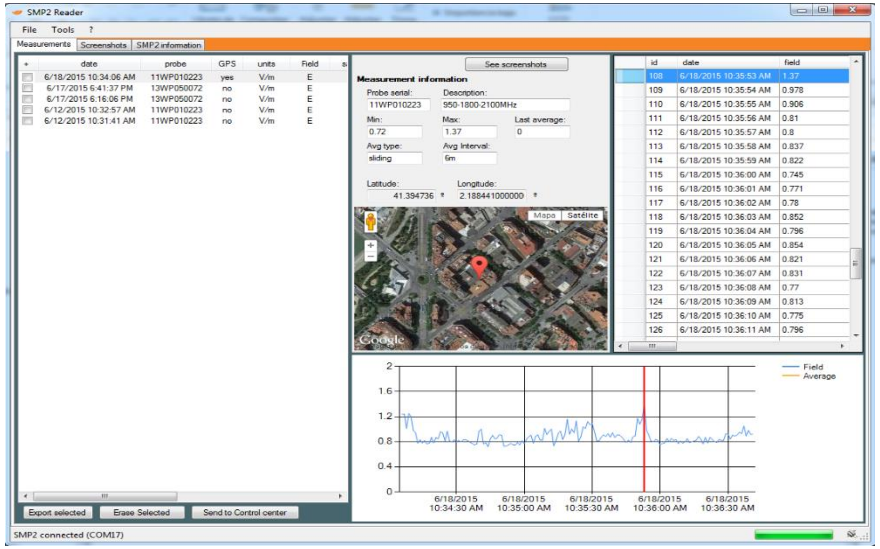
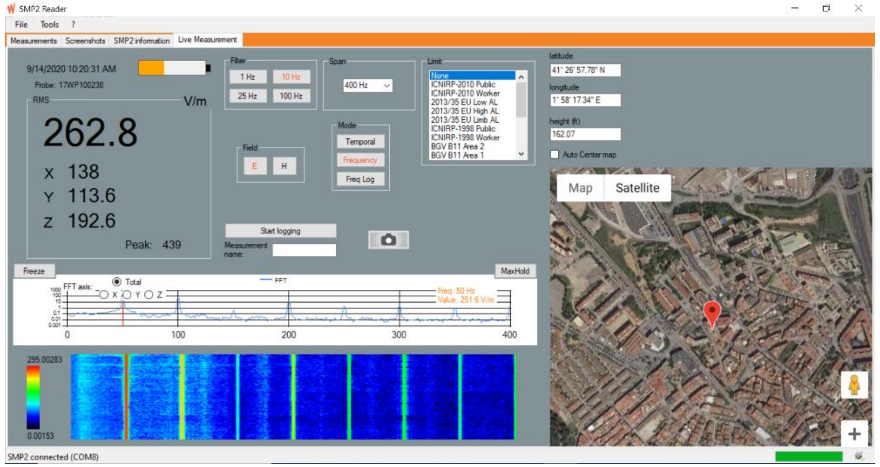
PC Software: SMP Software (SMP2 and SMP3)

- Remote control and Measurement
  - Using F.O. connection
- Display
  - SMP2/SMP3 parameters
  - Real time measurements
  - Google map location (if GPS was ON)
- Measurements visualization
  - Graph format
  - Table format
- Export data from SMP2/3 meters
- Pre-select SMP limits
- Automatic report generator

SMP Reader



Live Measurements – Fiber Optic Option (or USB-C for LF H fields)



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Industry Trends
Applications and Sectors

EMF in the Energy industry (IEC 62110)

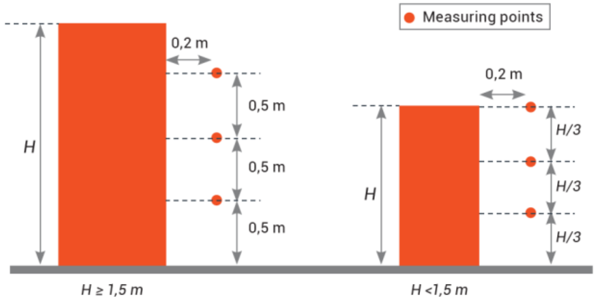
Field type, Frequency and Main EMF Sources

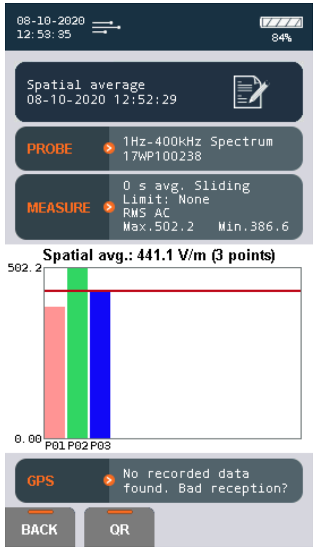
Evaluation of E and H fields from AC power systems (especially around 50/60 Hz). The main sources according to IEC 62110 are overhead power lines, buried cables and substations and power systems.

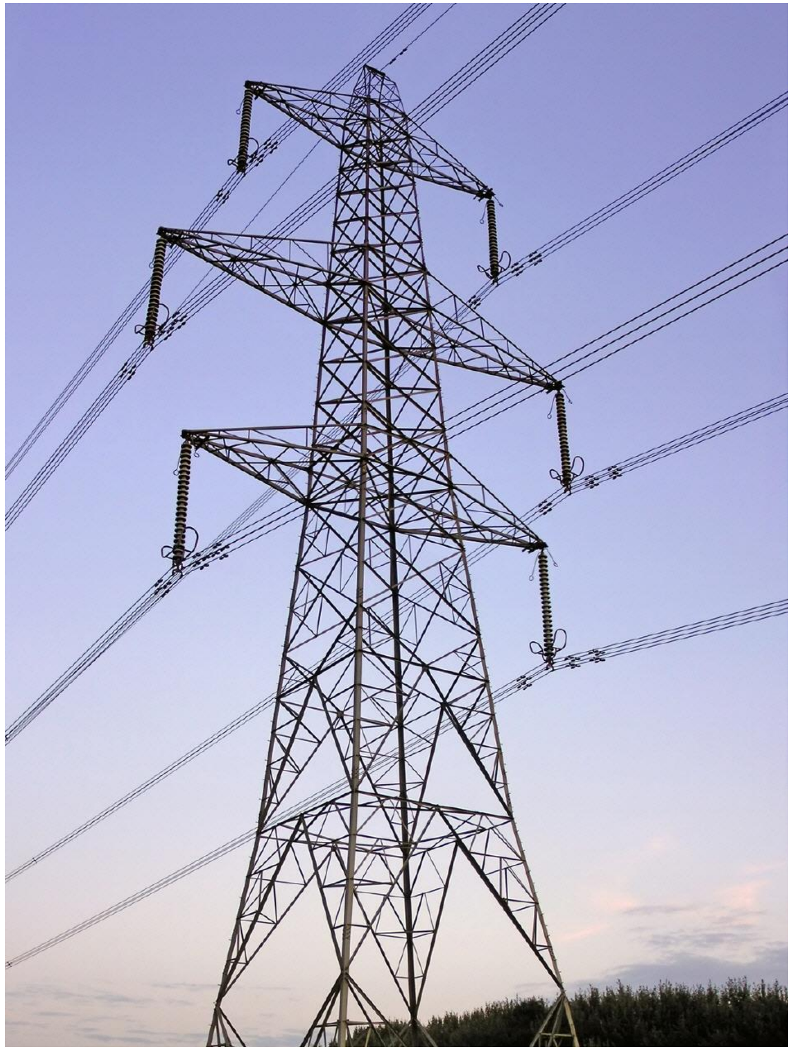
Measurement Procedure

Fundamental procedures:

- Single point measurement
- Three-point measurement.
- Five-point measurement.







Measurement instrument

Compliance with **IEC 61786-1** standard (WP50, WP400 and WP10M).

EMF in the Railway industry (IEC 62597 and EN 50500)

Field Type and Frequency Range

Evaluation of Magnetic field generated in railway environment from DC to 20 kHz for general public and workers safety.

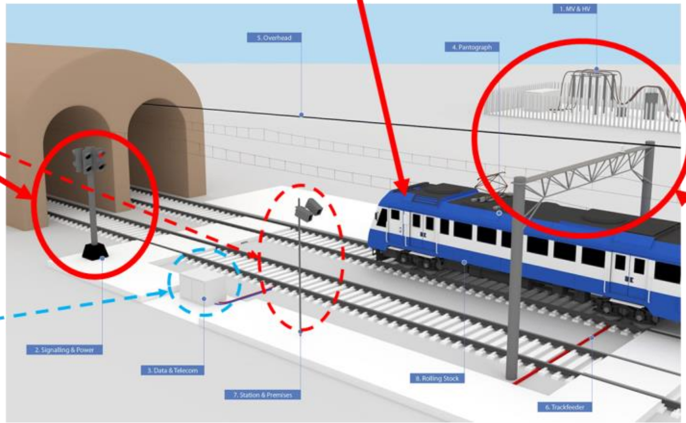
Main EMF Sources

As covered by the standard, the main sources are:

- Rolling stock
- Traction power supply and fixed installation
  - Open railway route
  - Power supply installation
  - Platform
- Signalling equipment (negligible).

Rolling stock

Signaling equipment



Traction Power Supply

Other sources are:
— Data and Telecoms
(not covered in standard)

Measurement instrument and method

Compliance with **IEC 61786-1** standard. AC Magnetic field (using the Weighted Peak Method) up to 20 kHz and DC Magnetic field measurements are both required.

Solution: SMP + WPH-DC + WP400/WP10M

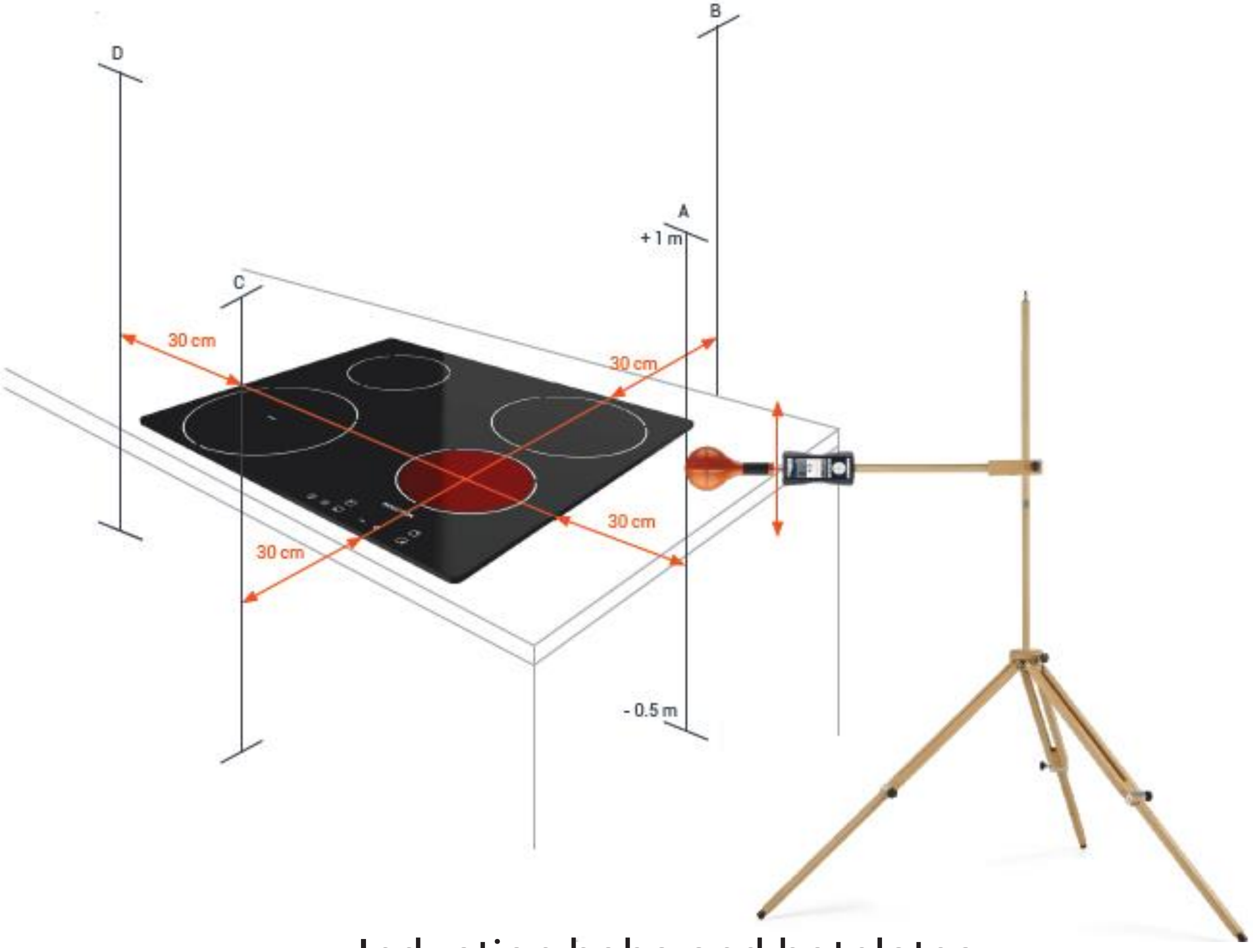
EMF in Household appliances (IEC/EN 62233)

Reference Standard (IEC 62233:2005 -> EN 62233:2008)

"Measurement methods for electromagnetic fields of household appliances and similar apparatus with regard to human exposure".

Field type and frequency range:

— Electric and **Magnetic** fields (10 Hz to 400 kHz)



Induction hobs and hotplates

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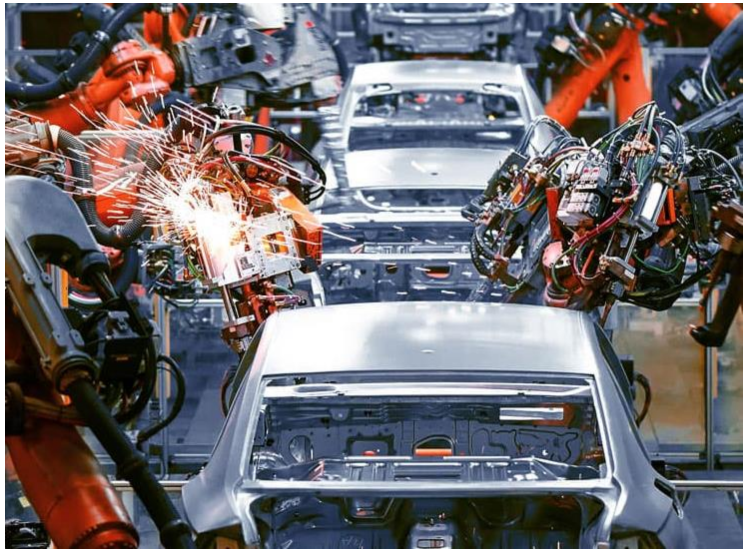
EMF in the Automotive industry (IEC 62764)

Field Type, Frequency and Main EMF Sources

In automotive application, low frequency **H field** assessment (from 1 or 10 Hz to **400 kHz**) is a requirement for human safety. Measurement must be done inside the vehicle (cabin area, engine), multiple spots on the seat, outside the vehicle (like charging ports) and electrical and electronic components.



Measurement conditions

Electric vehicle operational modes (depending on standard):

- Stationary mode
- Driving mode (at recommended speed of 40 ± 8 km/h)
- Dynamic mode
- Plug-in charging mode.

Measurement instrument and method

Compliance with **IEC 61786-1** and **IEC 62311** standards and Weighted Peak Method or FFT analysis up to 400 kHz.

Some standards require special frequency resolution steps for FFT analysis.

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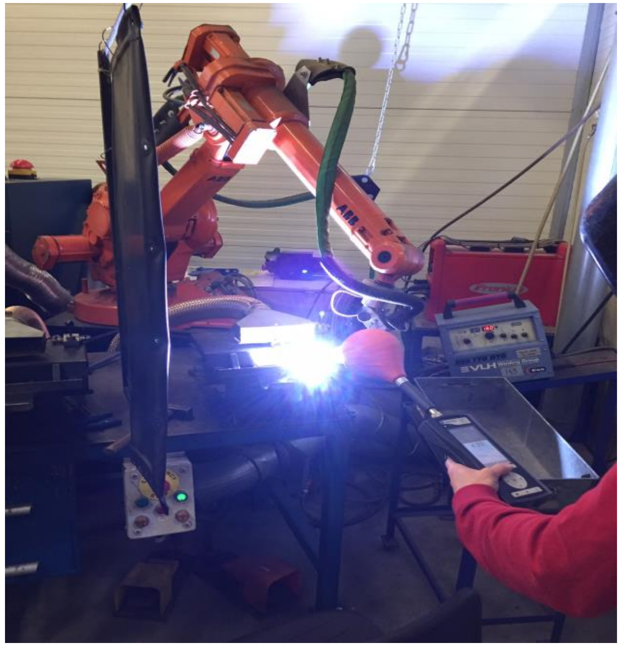
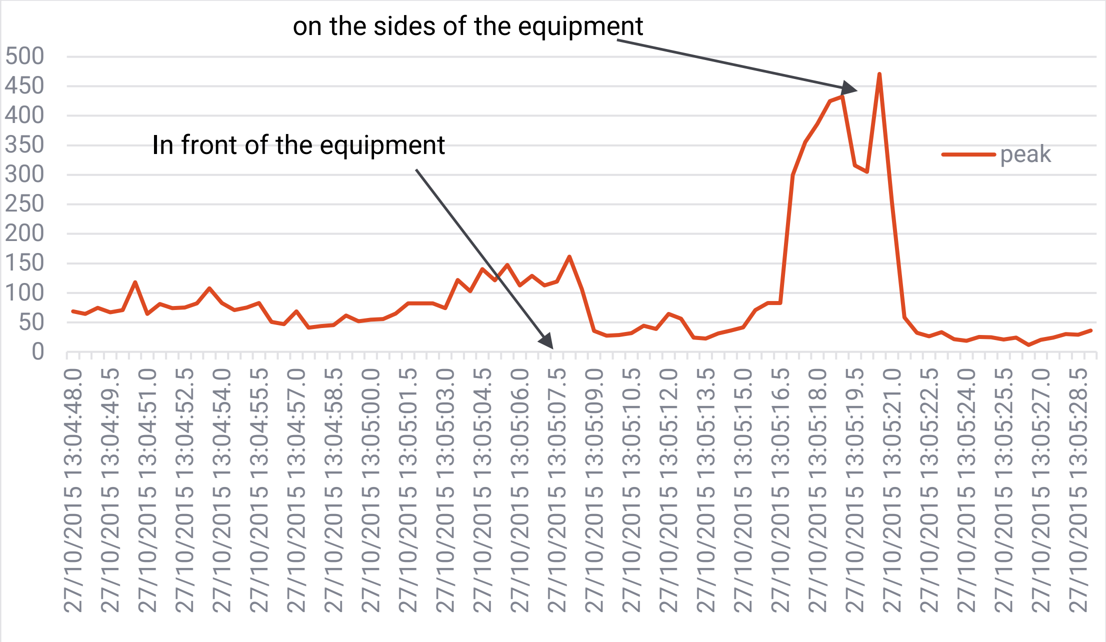
EMF in the Welding industry (IEC 62822)

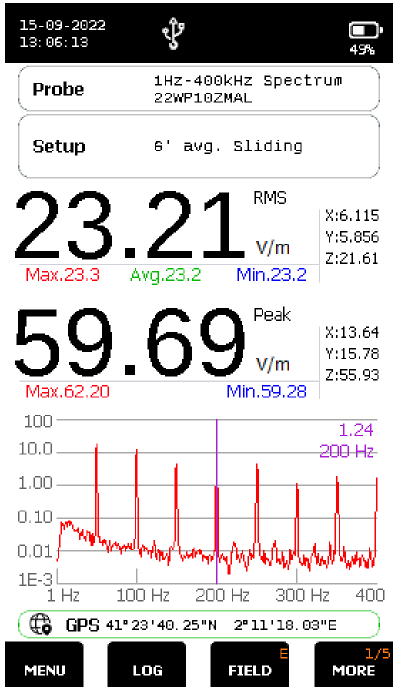
Evaluation of LF Magnetic fields (up to 10 MHz) – Non thermal effects

Reference Standards

IEC 62822 (1-3) “Electric welding equipment – Assessment of restrictions related to human exposure to electromagnetic fields (0 to 300 GHz)”.







In welding, the current is high whereas the voltage is low, hence, only H field measurement is relevant

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EMF in the Medical industry (IEC 60601)

IEC 60601	Medical electrical equipment

Medical application	**Frequency range**
Magnetic Resonance Imaging	0.024 -65 kHz; 10-400 MHz
Diathermy	27 MHz ; 2.45 GHz
Hyperthermia	434 MHz ; 70 MHz
Electrosurgery	300-600 kHz ; 13.5 MHz ; 27 MHz

MRI

Electrosurgery

Deep hyperthermia

Microwave diathermy

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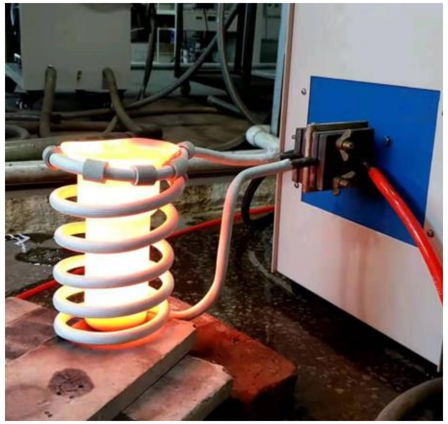
Work safety Assessment (IEEE, SC6, ICNIRP)

Industrial work safety is mandatory for every workplace. An important part of work safety is low frequency EMF assessments. Safety laws (e.g., 2013 EU Directive) and organizations (ACGIH, Health Canada, ARPANSA, IEEE, ICNIRP) mandate assessing LF E and H fields up to 5 MHz or 10 MHz.

The WP10M probe can be used for all types of low frequency applications:

- Standards compliant EMF assessment for work safety.
- All existing applications and sectors with the WP400 and WP50 probes.
- Industries with equipment > 400 kHz such as WPT, welding, semiconductor, induction heating, medicine/biomedicine and RFID system, AM radio broadcasting (non-thermal).

Semiconductor (300 kHz – 10 MHz)

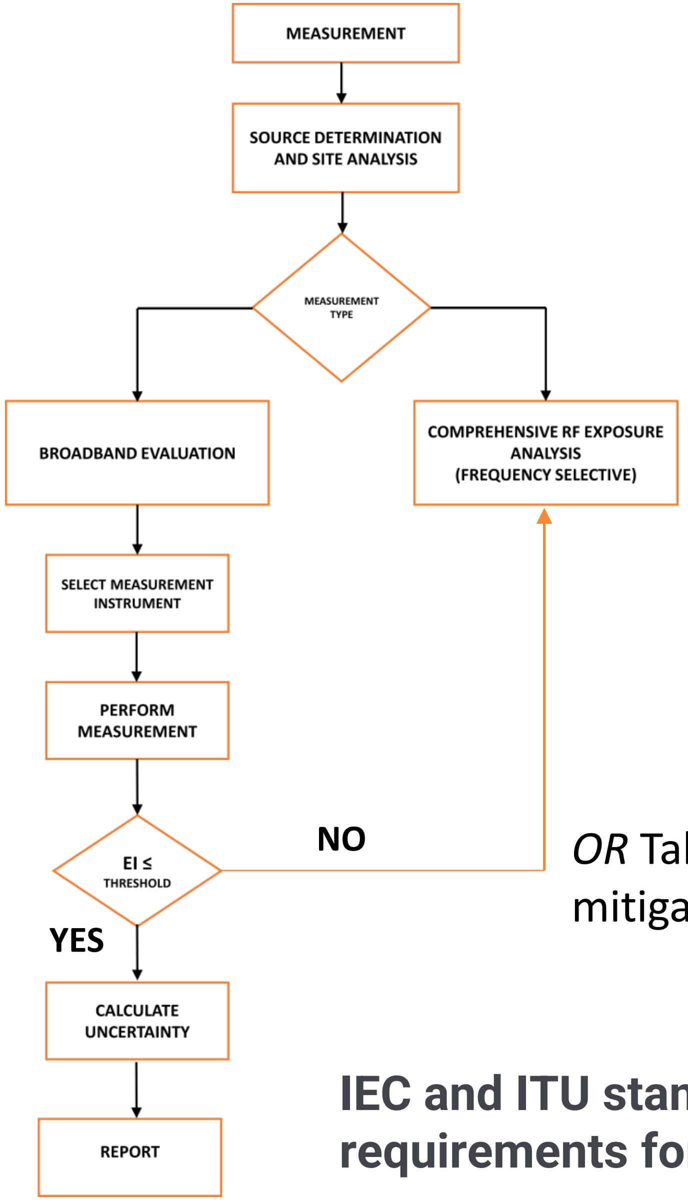


Induction heating (50 Hz – 8 MHz)

LF/MF RFID systems (100 kHz – 5 MHz)

AM Radio (530/540 kHz – 1.7 MHz)

EMF in the Telecommunication (IEC 62232, ITU)



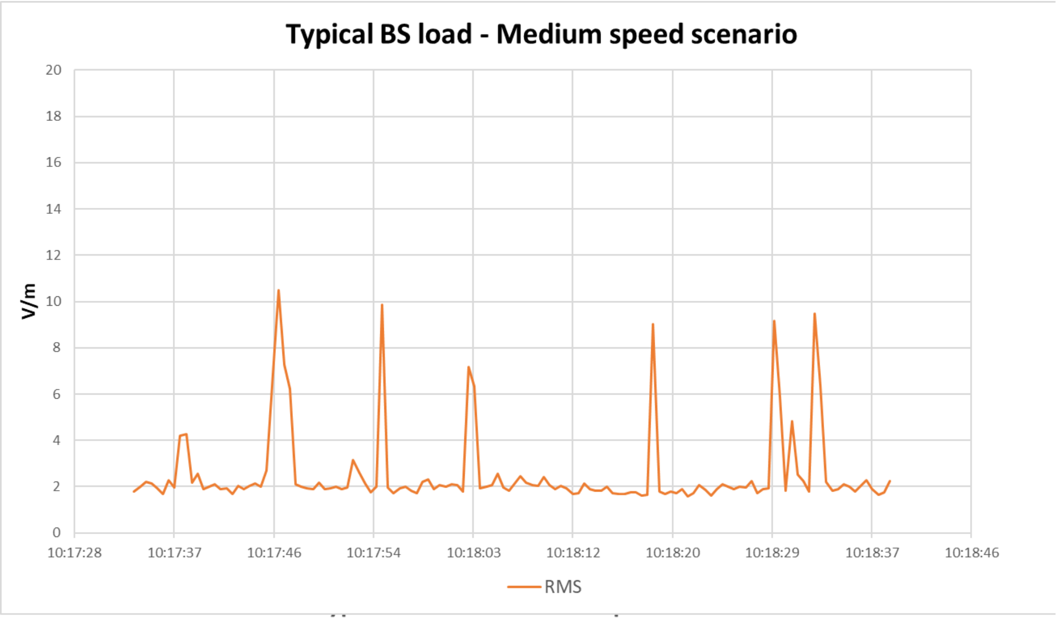
Frequency selective measurements

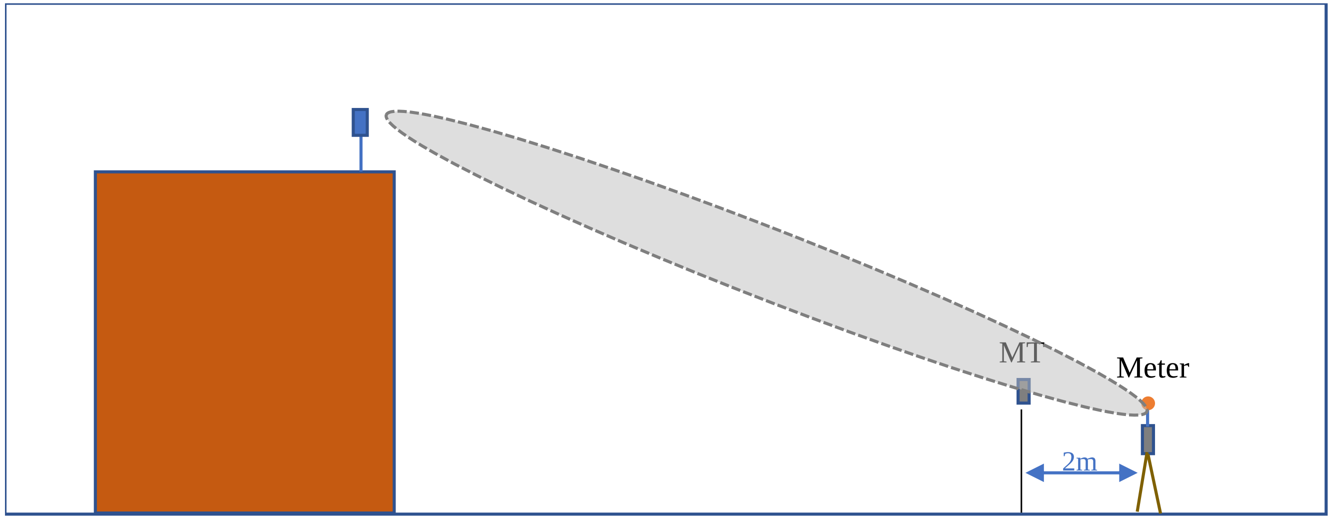
- Time consuming
- Relatively difficult
- Technical skills needed

OR Taking precautionary strategies to mitigate EMF overexposure

IEC and ITU standards define minimum requirements for measurement instrument.

5G NR - EMF total exposure assessment





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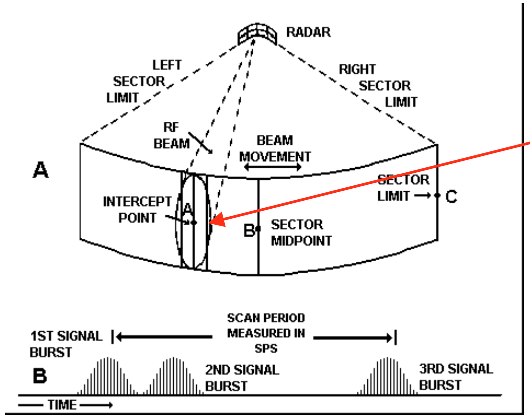
EMF in Defense and Radar application

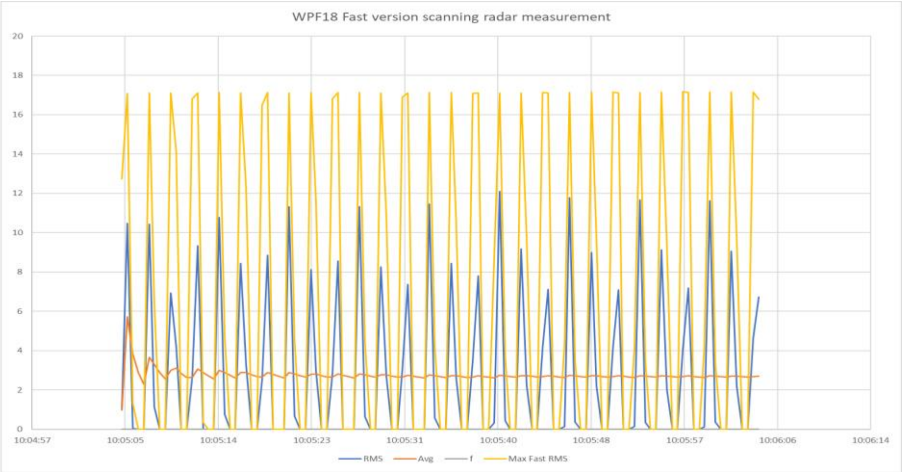
Scanning radars rotate on their axis to scan a full 360°



Only during a fraction of time (few milliseconds), the radar will illuminate the field probe.

The probe's integration time should be smaller or at least similar to the illumination (exposure) time.

Standard field probe integration time:	500 ms	→	RF safety
FAST field probe integration time:	4 ms	→	Measure the radar output power



How to perform measurement

How to perform measurements with SMP2/3

EMF Measurement using the SMP2/3

- In MENU **Measurement Option**, configure measurement settings (duration, samples, etc).
- Depending on probe type, configure the dynamic menu (MODE, LIMITS, UNITS).
- Place SMP3 at correct distance/heights
- Press **LOG** to start and save measurement.

Go to **MENU -> MEASUREMENT LOG** to find your Measurement Data

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Summary

Summary

- ✓ **Multiple applications solution.**
- ✓ **Compliance with Measurement method requirements.**
  - ✓ Weighted Peak Method and FFT analysis up to 10 MHz (LF).
  - ✓ Time-averaged measurements up to 90 GHz (RF).
- ✓ **Adjustable bandwidth for different LF applications and standards.**
- ✓ **Excellent Measurement Capabilities for E and H field.**
- ✓ **Multiple limits selection for static, LF and RF fields.**

THANK YOU

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Q&A Session

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