RF Exposure Evaluation - Maximum Permissible Exposure (MPE)

1. Introduction

This document attempts to prove the safety of radiation generated by RF devices to the human body. The limit for Maximum Permissible Exposure (MPE), specified in FCC 1.1210, is listed below. The power generated by this product is measured by a power meter. Through use of the Friis transmission formula and the maximum gain of the antenna, the distance from the product at which compliance with the MPE limit is achieved may be calculated. Alternatively, near field measurements may be performed to demonstrate compliance at a specific measurement distance.

Near field probe: Wandel & Goltermann EMR-200.

2. RF Exposure Limit

According to FCC 1.1310: the criteria listed in the following table shall be used to evaluate the environmental impact of human exposure to radio-frequency (RF) radiation as specified in 1.1307(b).

LIMITS FOR MAXIMUM PERMISSIBLE EXPOSURE (MPE)

Frequency Range (MHz)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)	Power Density (mW/cm^2)	Average Time (Minutes)
(A) Limits For Occupational / Control Exposures				
30-300	61.4	.163	1.0	6
300-1500	…	…	F/300	6
1500-100,000	…	…	5	6
(B) Limits For General Population / Uncontrolled Exposure				
30-300	27.5	.073	.2	30
300-1500	…	…	F/1500	30
1500-100,000	…	…	1.0	30

F = Frequency in MHz

3. Friis Formula

Friis transmission formula: $Pd = (P_{out}*G) / (4pr^2)$

Where:

Pd = power density in mW/cm^2 (MPE limit)
P_{out} = output power to antenna in mW
G = gain of antenna in linear scale
p = 3.1416
r = distance between observation point and center of the radiator in cm

Ref.: David K. Cheng, Field and Wave Electromagnetics, Second Edition, Page 640, Eq. (11.133)

4. EUT Operating Condition

Software provided by the client enabled the EUT to transmit and receive data at lowest, middle, and highest channels individually.

5. Climate Condition

The temperature and relative humidity: 22°C and 78% RH

6. Measurement Results

Frequency (MHz)	Level (dBm)	Measurement Distance	Front MPE reading mW/cm^2	Rear MPE reading mW/cm^2	Right MPE reading mW/cm^2	Left MPE reading mW/cm^2	Limit mW/cm^2
4950	25.54	20 cm	.082	.073	.036	.087	1.0
2412	24.0	20 cm					
2402	-1.73	20 cm					

Frequency (MHz)	Level (dBm)	Measurement Distance	Front MPE reading mW/cm^2	Rear MPE reading mW/cm^2	Right MPE reading mW/cm^2	Left MPE reading mW/cm^2	Limit mW/cm^2
4960	26.0	20cm	.079	.077	.033	.086	1.0
2437	23.8	20 cm					
2441	-1.43	20 cm					

Frequency (MHz)	Level (dBm)	Measurement Distance	Front MPE reading mW/cm^2	Rear MPE reading mW/cm^2	Right MPE reading mW/cm^2	Left MPE reading mW/cm^2	Limit mW/cm^2
4965	26.0	20cm	.082	.076	.031	.087	1.0
2462	23.90	20 cm					
2480	-1.73	20 cm					

1. Data taken with all transmitters operating simultaneously

7. Conclusion

The device meets the mobile 20cm separation distance as specified in Section 2.1091 of the FCC Rules. An appropriate RF exposure compliance statement will be placed in the user's manual.

Ref.: David K. Cheng, Field and Wave Electromagnetics, Second Edition, Page 640, Eq. (11.133)

Frequency (MHz)	Level (dBm)	Measurement Distance	Front MPE reading mW/cm^2	Rear MPE reading mW/cm^2	Right MPE reading mW/cm^2	Left MPE reading mW/cm^2	Limit mW/cm^2
4950	25.54	20cm	.083	.072	.035	.079	1.0
5745	22.9	20 cm					
2402	-1.73	20 cm					

Frequency (MHz)	Level (dBm)	Measurement Distance	Front MPE reading mW/cm^2	Rear MPE reading mW/cm^2	Right MPE reading mW/cm^2	Left MPE reading mW/cm^2	Limit mW/cm^2
4960	26.0	20cm	.081	.70	.035	.077	1.0
5785	23.1	20 cm					
2441	-1.43	20 cm					

Frequency (MHz)	Level (dBm)	Measurement Distance	Front MPE reading mW/cm^2	Rear MPE reading mW/cm^2	Right MPE reading mW/cm^2	Left MPE reading mW/cm^2	Limit mW/cm^2
4965	26.0	20cm	.082	.077	.035	.081	1.0
5825	23.2	20 cm					
2480	-1.73	20 cm					

1. Data taken with all transmitters operating simultaneously

8. Conclusion

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EMR-200, EMR-300

For isotropic measurements of electromagnetic fields

- **Versatile system for measuring electromagnetic fields**
- **Mainframe instrument with wide range of accessories**
- **Interchangeable probes allow optimum matching to application and frequency range**
- **Non-directional (isotropic) measurement with three-channel measurement probe**
- **High dynamic range due to three-channel digital results processing**
- **Optical interface for calibration and result data transfer**
- **Excellent measurement accuracy with automatic zeroing even during field exposure**
- **Easy to use**
- **Shock, dust and water-resistant**
- **Calibrated**

In addition to the Mainframe unit, EMR-200 and EMR-300 also include a carrying bag, PC Transfer Set, table-top tripod and rechargeable batteries, together with an appropriate charger unit. To ensure that the instrument is always ready for use, we recommend the rapid charger which provides trickle-charging facilities as well as rapid charging and discharge functions.

At least one probe must be ordered for use with the radiation measuring set. Data specific to the probes ordered is stored in the mainframe before delivery. If further probes are ordered at a later date, the data is supplied on floppy disk and can be permanently loaded into the mainframe using the Transfer Set from a PC operating under Microsoft® Windows™. If you prefer, this can be done by your local Wandel & Goltermann Service Center.

Applications

Precision measurement of electric field strength for personal safety at work where high radiation levels are present, and for applications involving electromagnetic compatibility (EMC), such as:

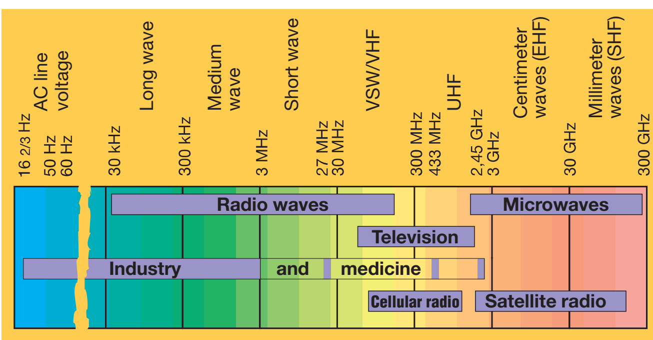
- Service work on transmitting and radar equipment
- Working with plastic welding machines
- Operating diathermy equipment and other medical instruments producing short-wave radiation
- Drying equipment in the tanning and timber industries
- Field strength measurements in TEM cells and absorber chambers

Fields of application

The diagram shows some typical applications where electromagnetic radiation occurs or is utilized. The frequency spectrum is normally divided into two areas:

1: Low frequencies up to about 30 kHz.
This region includes some railway system overhead power supplies running at 16⅔ Hz, domestic a.c. power at 50/60 Hz and extends up to VDU workstations at 30 kHz (see EFA data sheets).

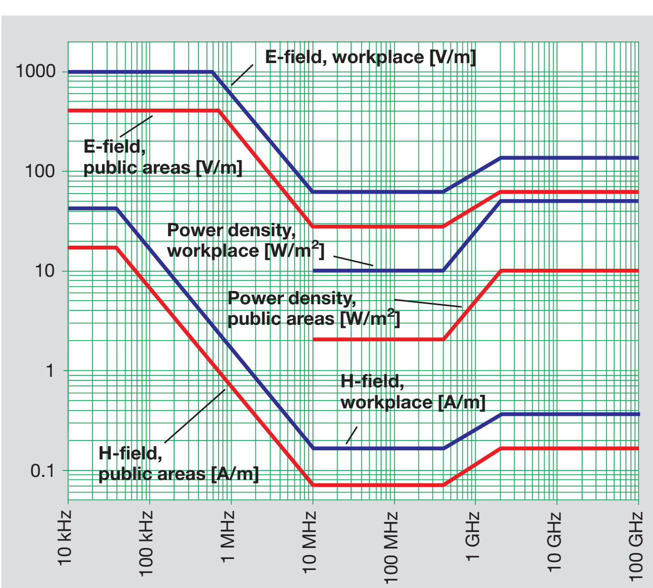
2: High frequencies above 30 kHz.
Typical frequencies encountered here are FM radio (88 to 108 MHz), television signals (40 to 900 MHz), mobile radio (400 to 1800 MHz) and satellite communications (up to 18 GHz). Other frequencies which are often used in industry and medicine are 27, 433 and 2450 MHz. Knowledge of the frequency is important when monitoring limit values for electromagnetic fields because these limit values depend on the frequency.



Frequency ranges of electromagnetic radiation encountered in everyday life.

Limit values

Work on defining legally binding limit values for electromagnetic radiation is currently being done at national and international levels. The limit values specified in the draft CENELEC European standard are quoted here as an example.



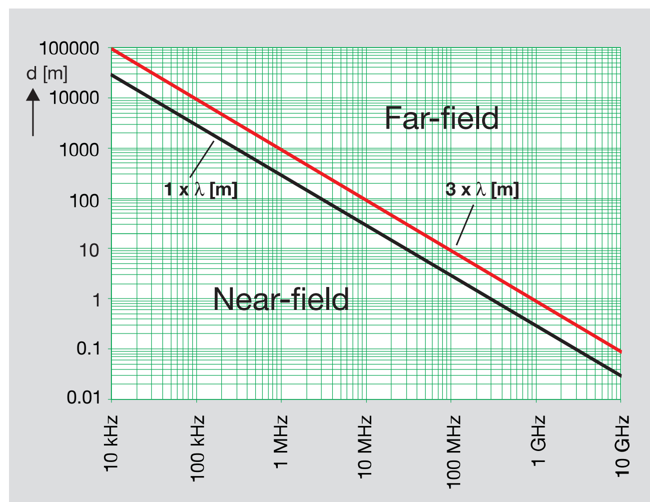
Limit values for electromagnetic radiation. Further details are found in the draft European standard CENELEC 50166-2.

Limit values for common industrial and medical frequencies, derived from the above-mentioned draft standard:

	27 MHz	433 MHz	2.45 GHz
Workplace	61.4 V/m 0.16 A/m 10 W/m^2	63 V/m 0.17 A/m 11 W/m^2	137 V/m 0.36 A/m 50 W/m^2
Public areas	27.5 V/m 0.07 A/m 2 W/m^2	28 V/m 0.08 A/m 2.2 W/m^2	61.4 V/m 0.16 A/m 10 W/m^2

Near-field and far-field

Electromagnetic fields can be split into two components: the electric field E [measured in V/m] and the magnetic field H [measured in A/m]. The E-field and H-field are strongly interdependent for the far-field, i.e. anywhere more than a certain distance from the source (see diagram). If, say, the H-field is measured in this region, the magnitude of the E-field and the power density S [W/m] can be calculated from it. In contrast, the H-field and E-field must be measured separately in the near-field region.



Near-field and far-field definition. Measurements at a distance d of 1 x wavelength λ (better: 3 x λ) from the source are made under far-field conditions.

Applications and tips

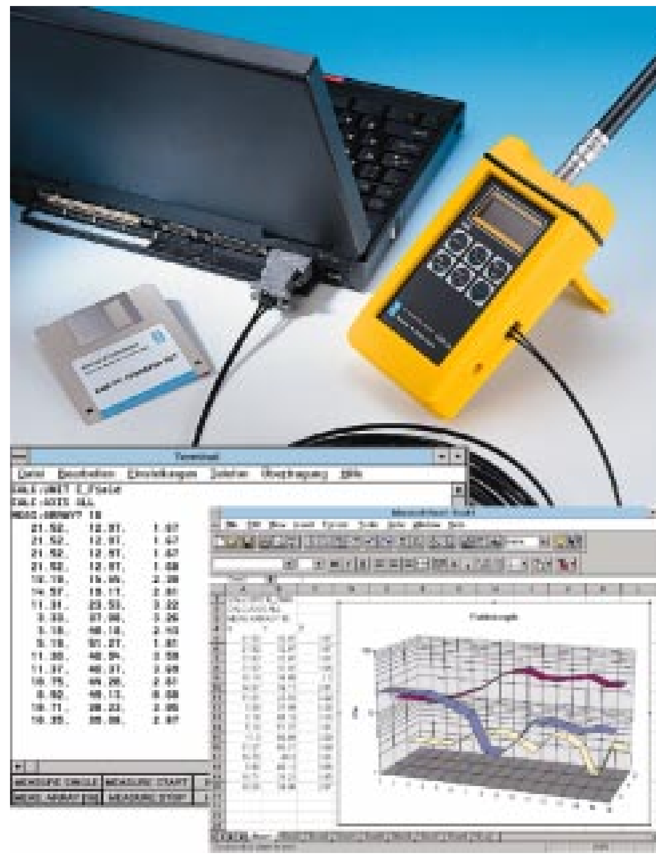
- Induction heaters, RF welding equipment and erosion machines: Electric fields are less important here, the magnetic fields need to be monitored.
- Radio and TV transmitters/antennas: As long as the location is in the far-field region, an E-field probe is preferable due to the large bandwidth. When working close to antennas (near-field) separate checking of the E-field and the H-field is unavoidable.
- Diathermy equipment (RF equipment for medical therapy): Very high field strengths are present at the electrodes and on the connecting leads to the electrodes. The main component is normally the electric field.
- Microwave ovens: The very short wavelength means that exposure is normally in the far-field. E-field measurements are therefore sufficient.

Spatial averaging
The spatial distribution of a field is seldom homogeneous, even within the confines of a low-reflection absorber chamber. Measurements at several points within the area are thus needed. By measuring at different positions, it is also possible to estimate complete body exposure levels. The root mean square of these values is required. The EMR-300 makes light work of this. When set to Spatial Averaging mode, a new measurement is made simply by pressing a key. The squares of these values are summed automatically, providing a display of the average field strength for the area. If the “Spatial” key is held down, the EMR-300 will calculate the average for the time that the key was pressed.
All instruments in the EMR range are also equipped with an averaging function for the 6-minute average specified by the relevant standards.

Spatial averaging

Non-directional measurement
Free-space electromagnetic fields are seldom due to a single source, but are generally the result of several transmitters from different directions. To be able to correctly determine the radiation exposure, any measurement must be non-directional, i.e. isotropic. The value measured by an isotropic instrument is also not affected by the position in which the instrument is used. For these reasons, the probes of the EMR-200/EMR-300 are fitted with three sensors which measure the field strength of the X, Y and Z directions separately. The field strength is calculated by the instrument’s processor by summing the squares of the three measured values. This method has the advantage over conventional analog summing within the probe that all three sensors can be independently calibrated to achieve very high linearity. It also eliminates dependence on the square-law sensor characteristic which leads to large measurement errors as it no longer holds true at high field strengths. Use of this novel, innovative method means that the EMR-200 and EMR-300 can measure the entire field strength range for the first time using just a single probe. This simplifies measurement and makes the purchase of additional probes unnecessary.

PC Transfer Set
If high field strengths are to be measured or long-term monitoring is required, the measured values can be transferred to a PC or printer using an optical interface and the Transfer Set. All products in the EMR range can also be fully remote-controlled via this interface. The software supplied with the Transfer Set when used with, say, the Windows Terminal program, makes it easy to record the results and then process them using programs such as Excel. The EMR-300 can, in fact, store up to 1500 measured values, complete with timestamp and all parameters, so it is capable of monitoring for a whole day without needing to be connected to a PC or printer. The results can be displayed later or read out together with all major parameters by using the Transfer Set mentioned above.
The Transfer Set allows independent output of the measured values, i.e. spatial field strength and the three measurement axes X, Y and Z.



Zeroing
Normally, an instrument for measuring electromagnetic radiation requires zeroing every time it is switched on or the temperature changes, if accurate measurements are to be obtained. Up till now, the instrument had to be placed in a room where no field was present in order to zero it. More often than not, such a room is not available, and the whole procedure is inconvenient. A new zeroing method is used in the EMR range of products that is fully automatic and which is also valid even in the presence of high field strengths. The measurement errors due to inaccurate zeroing are now a thing of the past as far as the EMR range of instruments is concerned.

Rugged casing
The casing is specially constructed to withstand shocks and impacts, to allow use under difficult conditions, e.g. outdoors or at industrial sites. The basic unit includes anti-slip, impact-resistant shock protection. All mechanical connections such as the test probe are designed to withstand rough handling. Practical details like the tripod bush and built-in stand make the instrument equally suitable for laboratory applications.

Calibration

Every instrument in the EMR range is calibrated for absolute level and linearity vs. level. Typical frequency response values for the probes are provided (CAL factor) together with a calibration certificate. The frequency response of every specially-calibrated probe is measured individually, and a calibration report containing all the measured values is included. The calibration can also be carried out automatically via the bi-directional optical interface. This allows easy calibration by the user or by recognized national calibration laboratories, resulting in a significant reduction in the cost of regular re-calibration, which is recommended for all field measuring instruments.

Specifications of the Radiation Meters

EMR-200, EMR-300

Display and warning circuits

Display type	LCD, instrument specific
Display refresh rate	typically 400 ms
Visible warning	bright red LEDs in the foil keypad
Audible warning	built-in piezoelectric device, tone sequence depending on measured value
Display resolution	0.01 V/m, 0.0001 A/m
Settling time	typically 1 s (0 to 90 % of meas. value)

Measurement functions

Units	V/m, A/m, mW/cm^2, W/m^2, % of limit value
Result display	current result or maximum value since switch-on
Averaging	current result or 6-minute average
Alarm functions	variable threshold and on/off
Calibration data	one CAL factor settable per probe

Self tests

Automatic switch-on self test of
- A/D converter, battery, supply voltages, memory and zero adjustment.
- Periodical zero adjustment and battery check during operation.

All tests can be performed during exposure to the field.

Calibration

Calibrated base unit

Recommended confirmation interval	24 months

Interfaces

Serial interface for results transfer, remote operation and calibration	V.24 (RS232) optical/bidirectional

Additional functions EMR-300

Result storage	1500 values

Real-time clock

Spatial averaging within a time period or over measurement points.

General specifications

Power supply

Rechargeable batteries	2 × Mignon (AA) 1.2 V
Dry batteries	2 × Mignon (AA) 1.5 V
Operating time rechargeable / dry batteries	typ. 8 h / > 15 h
Recharging	using NT-20 Charger Unit supplied

Ambient temperature

Operating range	0 to +50 °C

Dimensions (w × h × d) in mm (incl. sensor and impact protection)	approx. 96 × 64 × 465
Weight (incl. batteries)	approx. 450 g

Ordering information

EMR-200 Radiation Meter	**BN 2244/21**
Basic instrument without probe	
EMR-300 Radiation Meter	**BN 2244/31**
Basic instrument without probe	
Nato Stock No.	NSN 6625-66-142-8284

Supplied with:

Support, non-metallic	
PC Transfer Set (O/E converter, fiber cable, floppy disk)	
Storage case, aluminium-lined (Picture see front page)	BN 2244/62
“Electromagnetic Radiation” warning labels, small, 10 pieces	
NiCd cells, Mignon (AA) size	
NT-20 Charger Unit (please specify type)	
Euro version	BN 2238/90.02
UK version	BN 2238/90.03
US version	BN 2238/90.04
Australian version	BN 2238/90.05

Probes (see separate data sheets)	**BN 2244/90.2x**
At least one necessary for operation	

Accessories:

Tripod, non-metallic	BN 2244/90.31
NiCd/NiMH Rapid Charger Unit (European version)	BN 2237/90.03
27 MHz Test Generator	BN 2244/90.38
Sensor extension, 1.2 m, flexible	BN 2244/90.35
Nato Stock No.	NSN 5985-66-142-8286
“Electromagnetic Radiation” warning labels	
Large, 2 pieces	BN 2244/90.36
Small, 10 pieces	BN 2244/90.34

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