



IEEE ICES Exposure Limits Above 6 GHz

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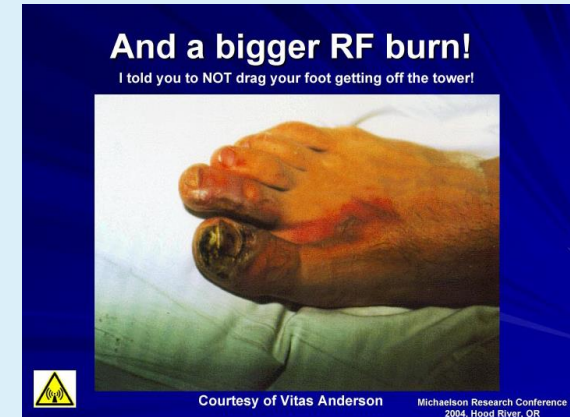
Purpose of C95.1-2005 (also C95.1-2345-2014)

- ❖ The purpose of this standard is to provide exposure limits to protect against **established adverse effects to human health** induced by exposure to RF electric, magnetic and electromagnetic fields over the frequency range of 3 kHz to 300 GHz.



Risk profile for adverse effects (C95.1-2005)

1. RF shocks and burns
 2. Localized RF heating effects
 3. Surface heating effects
 4. Whole body heating effects
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5. Microwave hearing effects
 6. Low-level effects (*previously 'non-thermal effects'*)



Low-level effects ?



- ❖ No adverse effects have been established from low-level exposures despite 50 years of research
- ❖ No known interaction mechanisms
- ❖ No meaningful dose-response relationship
- ❖ Speculative
- ❖ Inappropriate for standard setting

*The committee is unaware of any more recent studies that would change the conclusions reached in the 2005 version of the standard (June 2011).





Basis of C95.1-2005

The development of this standard is based on protection against the following **established adverse health effects**:

- aversive or painful electrostimulation due to excessive RF internal electric fields (3 kHz – 5 MHz)
- RF shocks or burns due to contact with excessively high RF currents (3 kHz – 110 MHz)
- heating pain or tissue burns due to excessive localized RF exposure (> 100 kHz)
- behavioral disruption, heat exhaustion or heat stroke due to excessive whole body RF exposures (> 100 kHz)



Dosimetry Reference Limits (Basic Restrictions)



- ❖ 3 kHz – 5 MHz: In situ electric fields
- ❖ 100 kHz – 3 GHz: SAR [Whole-Body Average; Localized (peak spatial-average)]
- ❖ 3 GHz – 300 GHz: Incident power density [Whole body or localized exposure]
 - 3 GHz – 6 GHz: Transition range (either SAR or incident power density)



MPE ➔ Exposure Reference Level (ERL)

- ❖ The highest level of an electric field, magnetic field, electromagnetic field, induced current or contact current to which the standard permits exposure, and which includes an adequate **margin of safety** against established adverse health effects.
- ❖ The ERL is expressed as a metric appropriate to the frequency and temporal characteristics of the exposure. The ERL is **based on the dosimetric reference limit** (DRL – *in situ* electric field, SAR, or power density) and may be exceeded if it can be demonstrated that the corresponding DRL is not exceeded.
- ❖ ERLs are sometimes called **reference levels**, derived limits, permissible exposure limits, **maximum permissible exposure values**, or investigation levels.

DRLs for frequencies between 3 GHz and 300 GHz



- ❖ DRL in terms of incident power density are intended to **protect against adverse health effects associated with heating** for frequencies between 3 GHz and 300 GHz.

Above 3 GHz, the relevant dosimetric parameter becomes incident power density.

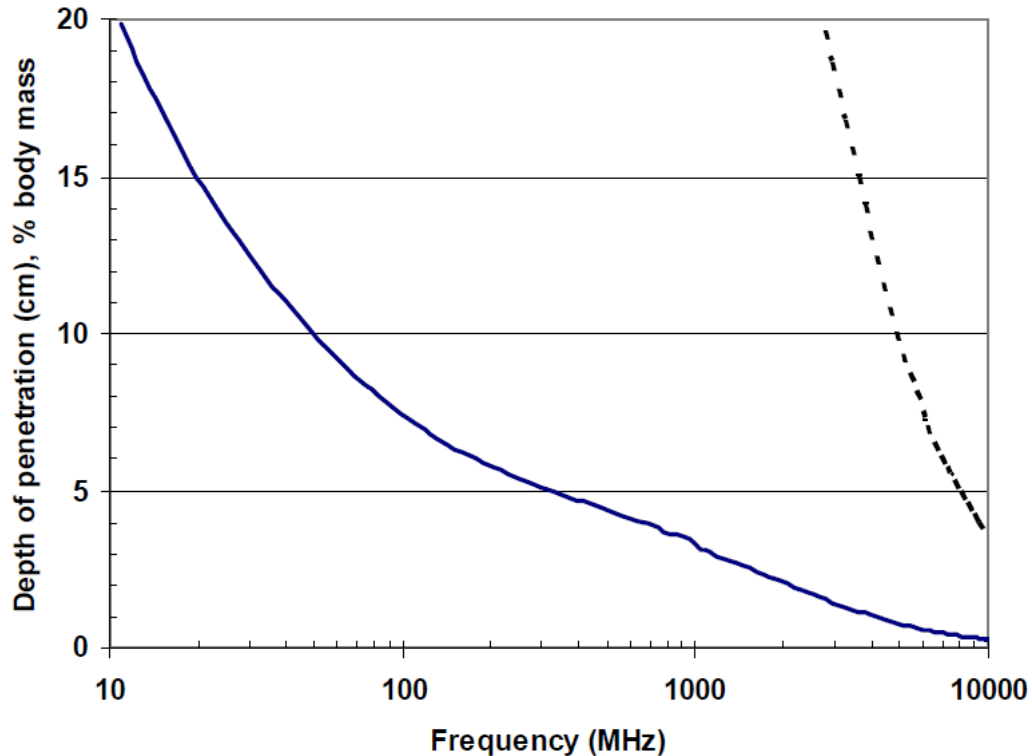


Figure C.1—Calculated depth of penetration (solid line) and percent of body mass (broken line) in which most of the incident RF energy is absorbed as a function of frequency. Calculations are for muscle-equivalent material and are based on a planar slab model.



Whole Body Exposure Limits

Dosimetric Reference Limits and Exposure Reference Levels (C95.1-2345-2014)

Frequency Range (GHz)	Power Density (S) (W/m ²)	Averaging Time (min)
Unrestricted Environment		
5-30	10	150 / f_G
30-100	10	25.24 / $f_G^{0.476}$
100-300	$6.43 \times 10^{-4} f_G^{2.096}$	$3.925 \times 10^5 / f_G^{2.572}$
Restricted Environment		
3-30	100	19.63 / $f_G^{1.079}$
30-300	100	2.524 / $f_G^{0.476}$
Note 1: Tabulated values are rms values		
Note 2: f_G is the frequency in GHz		



Averaging area

- ❖ From 3 GHz to 30 GHz, the power density is spatially averaged over any contiguous area corresponding to $100 \lambda^2$, where λ is the free space wavelength of the RF field.
- ❖ For frequencies between 30 GHz and 300 GHz, the power density is spatially averaged over any contiguous area of 0.01 m^2 (100 cm^2).



Localized exposure

- ❖ The spatial peak values of the power density shall not exceed 20 times the allowed power density in the previous table.



Multiple frequencies

- ❖ For mixed or broadband fields at a number of frequencies for which there are different values of the ERL, the fraction of the ERL incurred within each frequency interval shall be determined and the sum of all such fractions should not exceed unity.



Pulsed RF fields

- ❖ The peak pulse power densities (S_{pk}) are limited by the use of normal time averaging, with one exception: The total incident energy density during any 100 ms period within the averaging time shall not exceed one fifth of the total energy density permitted during the entire averaging time (T_{avg}) for a continuous field, i.e.,

$$\sum_0^{0.1s} (S_{pk} \times \tau) \leq \frac{ERL_{avg} \times T_{avg}}{5}$$

where τ is the pulse width.



Conclusions

- ❖ IEEE ICES standards are developed to protect against established adverse health effects of RF exposures (heating for above 100 kHz).
- ❖ For above 6 GHz, the dosimetric reference limits and exposure reference levels are the same.
- ❖ For localized exposures of portable RF devices, a 20 times higher exposure limits than whole body exposure limits are allowed.
- ❖ Exposure levels should be averaged in both time and space.

A wide-angle photograph of the Golden Gate Bridge in San Francisco, California. The bridge's iconic orange-red towers and suspension cables are prominent against a clear blue sky. The bridge spans across the blue waters of the Golden Gate Strait, with the San Francisco city skyline visible in the background. The foreground shows a grassy hillside.

Thank you

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