

RF EXPOSURE LIMITS AND TESTING REQUIREMENTS

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OVERVIEW

- Specific Absorption Rate (SAR) and Maximum Permissible Exposure (MPE) Standards and Limits
- Evaluation Methods
- SAR Measurement Methods
- KDBs and Impact on Compliance
- Common Design and Construction for SAR Compliance

SPECIFIC ABSORPTION RATE (SAR) AND MAXIMUM PERMISSIBLE (MPE) STANDARDS AND LIMITS

– US Standards

- NCRP Report Number 86 – Guidelines For Limiting Exposure To Time-Varying Electric, Magnetic, And Electromagnetic Fields (UP TO 300 GHz)
- ANSI C95.1 – IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz
- FCC 47 CFR 1.1307(b) – Environmental Assessment Requirement
- FCC 47 CFR 1.1310 – MPE Limits
- FCC OET Bulletin 65 - Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields

SPECIFIC ABSORPTION RATE (SAR) AND MAXIMUM PERMISSIBLE (MPE) STANDARDS AND LIMITS

ICNIRP

Frequency Range	E-Field Strength (V/m)	H-Field Strength (A/m)	B-Field (μ T)	Equivalent plane wave power density Seq (W/m ²)
0-1 Hz	—	1.63×10^5	4×10^4	—
1-8 Hz	20,000	$1.63 \times 10^5 / f^2$	$4 \times 10^4 / f^2$	—
8-25 Hz	20,000	$2 \times 10^4 / f$	$5,000 / f$	—
0.025-0.82 kHz	$500 / f$	$20 / f$	$5 / f$	—
0.82-65 kHz	610	24.4	6.25	—
0.065-1 MHz	610	$1.6 / f$	6.25	—
1-10 MHz	$610 / f$	$1.6 / f$	$0.92 / f$	—
10-400 MHz	61	0.16	0.092	10
400-2,000 MHz	$3f^{1/2}$	$0.01f^{1/2}$	$0.0046f^{1/2}$	$f / 40$
2-300 GHz	137	0.45	0.2	50

SPECIFIC ABSORPTION RATE (SAR) AND MAXIMUM PERMISSIBLE (MPE) STANDARDS AND LIMITS

- SAR
- Head and Trunk (Body)
 - US and Canada – 8.0 W/kg averaged over 1 gram of tissue
 - EU and rest of world – 10.0 W/kg averaged over 10 grams of tissue
- Hands, Wrist, Feet and Ankles (Extremities)
 - US and Canada – 20.0 W/kg averaged over 10 gram of tissue
 - EU and rest of world – 20.0 W/kg averaged over 10 grams of tissue

SPECIFIC ABSORPTION RATE (SAR) AND MAXIMUM PERMISSIBLE (MPE) STANDARDS AND LIMITS

- Uncontrolled (General Population)
 - MPE
 - FCC

Frequency Range (MHz)	E-Field Strength (E) (V/m)	Magnetic Field Strength (H) (A/m)	Power Density (S) (mW/cm ²)	Averaging Time E ² , H ² or S (minutes)
0.3 – 1.34	614	1.63	(100)*	30
1.34 – 30	842/f	2.19/f	(180/f ²)*	30
30 – 300	27.5	0.073	0.2	30
300 – 1500	–	–	f/1500	30
1500 – 100,000	–	–	1	30
f = frequency in MHz		*Plane-wave equivalent power density		

SPECIFIC ABSORPTION RATE (SAR) AND MAXIMUM PERMISSIBLE (MPE) STANDARDS AND LIMITS

• ICNIRP

Frequency Range	E-Field Strength (V/m)	H-Field Strength (A/m)	B-Field (μ T)	Equivalent plane wave power density Seq (W/m ²)
0-1 Hz	—	3.2×10^4	4×10^4	—
1-8 Hz	10,000	$3.2 \times 10^4/f^2$	$4 \times 10^4/f^2$	—
8-25 Hz	10,000	$4,000/f$	$5,000/f$	—
0.025-0.8 kHz	$250/f$	$4/f$	$5/f$	—
0.8-3 kHz	$250/f$	5	6.25	—
3-150 kHz	87	5	6.25	—
0.15-1 MHz	87	$0.73/f$	$0.92/f$	—
1-10 MHz	$87/f^{1/2}$	$0.73/f$	$0.92/f$	—
10-400 MHz	28	0.073	0.092	2
400-2,000 MHz	$1.375f^{1/2}$	$0.0037f^{1/2}$	$0.0046f^{1/2}$	$f/200$
2-300 GHz	61	0.16	0.2	10

SPECIFIC ABSORPTION RATE (SAR) AND MAXIMUM PERMISSIBLE (MPE) STANDARDS AND LIMITS

– SAR

- Head and Trunk (Body)

- US and Canada – 1.6 W/kg averaged over 1 gram of tissue

- EU and rest of world – 2.0 W/kg averaged over 10 grams of tissue

- Hands, Wrist, Feet and Ankles (Extremities)

- US and Canada – 4.0 W/kg averaged over 10 gram of tissue

- EU and rest of world – 4.0 W/kg averaged over 10 grams of tissue

EVALUATION METHODS

- Routine Evaluation
 - General requirement that each transmitter must be evaluated for RF exposure
- Fixed Installation
 - Per 47 CFR 2.1091, “the term “fixed location” means that the device is physically secured at one location and is not able to be easily moved to another location.”
 - For example, base station tower, P-P, P-MP
- Mobile Devices
 - Per 47 CFR 2.1091, “For purposes of this section, a mobile device is defined as a transmitting device designed to be used in other than fixed locations and to generally be used in such a way that a separation distance of at least 20 centimeters is normally maintained between the transmitter's radiating structure(s) and the body of the user or nearby persons.”
 - For example, wireless router, laptop with antennas in the top of screen

EVALUATION METHODS

– Portable Devices

- Per 47 CFR 2.1093, “For purposes of this section, a portable device is defined as a transmitting device designed to be used so that the radiating structure(s) of the device is/are within 20 centimeters of the body of the user.”
 - For example, cell phones, tablets, hotspots

– Multiple Transmitter Systems

- Look at each transmitter individually and sum the values
- Distance between hotspots
- Volume scan

KDB'S AND IMPACT ON COMPLIANCE

- KDB 447498 – Mobile and Portable RF Exposure
 - General SAR test methodology for FCC
 - Transmitter Modular Approval
 - Mobile Only
 - Portable Only
 - Mixed Mobile and Portable
 - No restriction when reported 1 g SAR is ≤ 0.4 W/kg and the energy coupling 1 g SAR is ≤ 0.45 W/kg
 - Minimum test separation must be ≤ 5 mm
 - When highest reported 1 g SAR is >0.4 and ≤ 0.8 W/kg, a module may qualify for multiple host platforms
 - Dedicated host approval is required when the report 1 g SAR is > 1.2 W/kg

KDB'S AND IMPACT ON COMPLIANCE

- KDB 447498 – Mobile and Portable RF Exposure (cont.)
 - Cautions and labels are for avoiding unintended use conditions only
 - Occupational Limit
 - Users must be fully aware of their exposures
 - Requires exposure training
 - Source-based time-averaging
 - Maximum conducted output power for SAR
 - Within 2 dB of upper limit in tune-up procedure
 - Scale SAR to the upper limit in tune-up procedure
 - Each frequency band/configuration and all values > 1.5 W/kg
 - Implant Devices
 - No SAR required for devices with ≤ 1.0 mW total power at the antenna port and radiating structure

KDB'S AND IMPACT ON COMPLIANCE

- KDB 447498 – Mobile and Portable RF Exposure (cont.)
 - Standalone SAR Test Exclusion
 - 100 MHz – 6GHz with a test separation distance of ≤ 50 mm
 - $[(\text{max. power of channel, including tolerance, mW}) / (\text{min. test separation distance, mm})] * [\sqrt{f_{(\text{GHz})}}] \leq 3.0$ for 1g and ≤ 7.5 for 10g SAR
 - Use 5 mm for equation if distance is < 5 mm
 - 100 MHz – 6GHz with a test separation distance of > 50 mm
 - ≤ 1.5 GHz: $[\text{Threshold(mW) at 50 mm} + (\text{test separation distance} - 50 \text{ mm}) * (f_{(\text{MHz})} / 150)]$ mW
 - > 1.5 GHz: $[\text{Threshold(mW) at 50 mm} + (\text{test separation distance} - 50 \text{ mm}) * 1]$ mW
 - < 100 MHz
 - > 50 mm and < 200 mm: $[\text{Threshold for test separation distance at 100 MHz}] * [1 + \log(100 / f_{(\text{MHz})})]$
 - ≤ 50 mm: $1/2 * [\text{Threshold at 50 mm and 100 MHz}]$

KDB'S AND IMPACT ON COMPLIANCE

- KDB 447498 – Mobile and Portable RF Exposure (cont.)
 - Estimating Standalone SAR
 - ≤ 50 mm: $[(\text{max. power of channel, including tolerance, mW}) / (\text{min. test separation distance, mm})] * [\sqrt{f_{\text{(GHz)}}} / x]$ W/kg
 - $x = 7.5$ for 1 g and 18.75 for 10 g
 - > 50 mm: 0.4 W/kg for 1 g and 1.0 W/kg for 10 g
 - Peak SAR location is at feed-point or center of antenna, whichever is more conservative
 - You can test if you choose
 - Simultaneous Transmission SAR Exclusion
 - Sum of the 1 g or 10 g SAR \leq the limit
 - SAR peak location separation ratio
 - For each pair
 - $(\text{SAR}_1 + \text{SAR}_2)^{1.5} / R_i \leq 0.04$ for 1 g or ≤ 0.10 for 10 g

KDB'S AND IMPACT ON COMPLIANCE

- KDB 447498 – Mobile and Portable RF Exposure (cont.)
 - After market accessories
 - Mobile Exposure Conditions
 - E & H Field strengths when < 300 MHz
 - Plane-wave equivalent power density when ≥ 300 MHz
 - When MPE testing is required
 - Test in both vertical and horizontal planes
 - Test along radials from antenna 45° apart; $\leq 30^\circ$ if > 60 cm
 - Test in vertical plane to ≥ 10 cm beyond body or until results are $< 10\%$ of MPE Limit and ≥ 10 cm from ground

KDB'S AND IMPACT ON COMPLIANCE

- GAO Report – Cellular Phones
 - Key points
 - Limit
 - Test Methodology - Body

COMMON DESIGN AND CONSTRUCTION FOR SAR COMPLIANCE

- Antenna Placement
 - Largest gap possible
 - Radiating pattern
- Matching, VSWR
 - Better the match the better your SAR
 - Power comes into play
- Component Radiation
 - Shield cans
 - Power ports
- Shielding
 - Metalized paint
- Absorber

Q&A

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