



# **Overview of RF Exposure Concepts and Requirements**

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## RF Exposure Requirements

- Exposure Standards
  - ANSI/IEEE C95.1-1992
  - NCRP Report No. 86
- FCC Proceedings
  - ET Docket 93-62
    - FCC 96-326: Report & Order
    - FCC 96-489: 1<sup>st</sup> MO&O
    - FCC 97-303: 2<sup>nd</sup> MO&O
  - ET Docket 03-137
    - FCC 03-132: NPRM

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FCC Dockets - <http://www.fcc.gov/oet/>

NCRP Report No. 86 - <http://www.ncrponline.org/rpt86.html>

IEEE Standard 1528 -

[http://grouper.ieee.org/groups/scc34/sc2/wg1/appr\\_memo.html](http://grouper.ieee.org/groups/scc34/sc2/wg1/appr_memo.html)

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## Rules & Procedures

### ● FCC Rules: 47 CFR

- Licensed & Unlicensed transmitters
  - §1.1307: fixed facilities
  - §2.1091: mobile installations
  - §2.1093: portable operations

### ● FCC documents

- OET Bulletin 65: overall requirements
  - Supplement A: fixed transmitters
  - Supplement B: amateur radio
  - Supplement C: mobile & portable devices
- OET Bulletin 56: consumer FAQ

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The appropriate exposure limits are generally applicable to all facilities, operations and transmitters regulated by the FCC; however, some require routine evaluation to demonstrate compliance and others may be categorically excluded from routine evaluation.

CFR Link - [http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?&c=ecfr&tpl=/ecfrbrowse/Title47/47tab\\_02.tpl](http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?&c=ecfr&tpl=/ecfrbrowse/Title47/47tab_02.tpl)

OET Bulletins - <http://www.fcc.gov/oet/rfsafety/>



## Operating Conditions

- Fixed facilities: §1.1307 (MPE)
  - antennas on outdoor permanent structures
    - whole body exposure in far-field conditions
    - broadcast towers, basestations etc.
- Mobile installations: §2.1091 (MPE @  $\geq 20$  cm)
  - antennas on non-permanent objects & structures
    - partial body exposure between near to far field conditions
    - vehicle-mounted antennas, desktop configurations etc.
- Portable operations: §2.1093 (SAR @  $< 20$  cm)
  - devices at close proximity to persons
    - localized exposure in near-field conditions
    - wireless handsets, Wi-Fi products etc.

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•Maximum permissible Exposure (MPE) according to field strength and power density limits based on whole-body SAR averaging concepts are used for evaluating the exposure conditions of fixed and mobile exposure conditions.

•SAR compliance is with respect to both whole-body and partial body SAR limits.

•Certain equipment and operating configurations may need different equipment classes for fixed, mobile & portable configurations that could require a new grant of equipment certification. Therefore, Class II permissive change may not be applicable in certain situations when devices are reconfigured or repackaged that result in changes in fixed, mobile or portable exposure conditions.



## Exposure Conditions

### ● Occupational / Controlled Exposure

- must be work related or transient in nature
  - person must be fully aware of exposure
  - person must have knowledge to control & limit exposure
  - require RF exposure training
  - higher exposure limits apply

### ● General Population / Uncontrolled Exposure

- all other situations
  - apply to all consumer devices
  - no knowledge of exposure required
  - more restrictive exposure limits apply

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•**OCCUPATIONAL / CONTROLLED EXPOSURE:** In general, occupational/controlled exposure limits are applicable to situations in which persons are exposed as a consequence of their employment, who have been made fully aware of the potential for exposure and can exercise control over their exposure. This exposure category is also applicable when the exposure is of a transient nature due to incidental passage through a location where the exposure levels may be higher than the general population/uncontrolled limits, but the exposed person is fully aware of the potential for exposure and can exercise control over his or her exposure by leaving the area or by some other appropriate means. Awareness of the potential for RF exposure in a workplace or similar environment can be provided through specific training as part of a RF safety program. If appropriate, warning signs and labels can also be used to establish such awareness by providing prominent information on the risk of potential exposure and instructions on methods to minimize such exposure risks.

•**GENERAL POPULATION / UNCONTROLLED EXPOSURE:** The general population/uncontrolled exposure limits are applicable to situations in which the general public may be exposed or in which persons who are exposed as a consequence of their employment may not be made fully aware of the potential for exposure or cannot exercise control over their exposure. Members of the general public would come under this category when exposure is not employment-related; for example, in the case of a wireless transmitter that exposes persons in its vicinity. Warning labels placed on low-power consumer devices such as cellular telephones are not considered sufficient to allow the device to be considered under the occupational/controlled category, and the general population/uncontrolled exposure limits apply to these devices.

•In certain situations both occupational/controlled and general population/uncontrolled exposure conditions may exist; therefore, compliance with both limits are necessary. For example, exposure to workers on a broadcast tower and other persons transiting near such facilities.



## Time Averaged Exposure

### ● Occupational / Controlled exposure conditions

- any 6-minute duration for both MPE (and SAR)
- operational based duty factor is acceptable

### ● General Population / Uncontrolled exposure conditions

- fixed installations
  - any 30-minute duration with respect to MPE limits
- mobile and portable operating conditions
  - operational duty factors do not apply
  - source-based time-averaging is acceptable
    - inherent to hardware design or transmission protocol
    - may include certain hardware or firmware restrictions

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Note: do not confuse RF exposure duty factor with dwell time used in frequency hopping configurations; RF power generally remains on as a device hops among different frequency channels



# MPE

## Occupational/Controlled Exposure Limits

Frequency Range (MHz)	Electric Field Strength (E) (V/m)	Magnetic Field Strength (H) (A/m)	Power Density (S) (mW/cm <sup>2</sup> )	Averaging Time  E  <sup>2</sup> ,  H  <sup>2</sup> or S (minutes)
0.3-3.0	614	1.63	(100)*	6
3.0-30	1842/f	4.89/f	(900/f <sup>2</sup> )*	6
30-300	61.4	0.163	1.0	6
300-1500	--	--	f/300	6
1500-100,000	--	--	5	6

## General Population/Uncontrolled Exposure Limits

Frequency Range (MHz)	Electric Field Strength (E) (V/m)	Magnetic Field Strength (H) (A/m)	Power Density (S) (mW/cm <sup>2</sup> )	Averaging Time  E  <sup>2</sup> ,  H  <sup>2</sup> or S (minutes)
0.3-1.34	614	1.63	(100)*	30
1.34-30	824/f	2.19/f	(180/f <sup>2</sup> )*	30
30-300	27.5	0.073	0.2	30
300-1500	--	--	f/1500	30
1500-100,000	--	--	1.0	30

f = frequency in MHz  
 \*Plane-wave equivalent power density

MPE limits apply to both fixed and mobile exposure conditions.

Limits at 30-300 MHz are more restrictive due to possibility of whole-body resonance issues; that is, wavelength is compatible with the dimensions of persons. The limits are increased gradually through 300-1500 MHz with respect to frequency.



# SAR

## Occupational/Controlled Exposure Limits (W/kg)

Whole-Body	Partial-Body	Hands, Wrists, Feet and Ankles
0.4	8.0	20.0

## General Population/Uncontrolled Exposure Limits (W/kg)

Whole-Body	Partial-Body	Hands, Wrists, Feet and Ankles
0.08	1.6	4.0

*Whole-Body SAR* is averaged over the entire body.

*Partial-body SAR* is averaged over any 1 g of tissue in the shape of a cube.

*SAR for hands, wrists, feet and ankles* is averaged over any 10 g of tissue in the shape of a cube.

SAR limits are not applicable above 6.0 GHz; MPE limits for field strength and power density should be applied. Categorical exclusion of routine MPE evaluation for mobile transmitters does not apply to portable devices operating above 6.0 GHz.

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SAR is the basic (fundamental reference) exposure limit. Field strength and power density limits (MPE) are derived from SAR. SAR is defined in tissue media only and must be evaluated in tissue medium. MPE is defined according to free-space fields. MPE limits have included additional margins to ensure compliance with respect to SAR requirements while using simpler free-space field evaluation procedures.



## Routine Evaluation

- Potentials for exposure usually vary with operating configurations & exposure conditions
- Potential for exceeding limits may
  - require routine evaluation to demonstrate compliance
  - allow certain operations to be categorically excluded from routine evaluation
- Routine evaluation is required according to
  - Table 1 of §1.1307 for fixed facilities
  - §2.1091(c) for mobile operations
  - §2.1093(c) for portable devices
- Evaluation may be triggered by §1.1307(c) or (d)

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- Exposure limits apply to all FCC regulated devices & facilities, see §1.1307(b)(1)
- Devices and services not identified in §§ 1.1307, 2.1091 and 2.1093 are considered categorically excluded from routine RF exposure evaluation to demonstrate compliance
- Mobile devices are categorically excluded from routine evaluation according to §2.1091 when operating at  $\leq 1.5$  GHz and  $< 1.5$  W ERP or  $> 1.5$  GHz and  $< 3.0$  W ERP
- Routine evaluation for portable devices includes SAR measurement or computational modeling to show compliance for the applicable operating configurations and exposure conditions of a device, including certain accessories
- Devices using computational modeling to demonstrate SAR compliance are not qualified for TCB approval, including Part 95 subpart H, MICS devices
- Also see TCB Exclusion List for evaluation requirements of equipment seeking TCB approval



## RF Exposure Labels

- Labels must be legible and clearly visible for the exposed persons to meet exposure requirements
- Labels may be used to identify RF exposure training material for satisfying occupational use conditions
- For general population exposure conditions
  - labels generally do not substitute for routine evaluation
  - device should demonstrate compliance for normal operations without use of labels
  - labels may apply to certain unintended and mostly intermittent conditions of increased potential for exposure
  - operating instructions and caution statements should be included in manuals to alert users about proper operation

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- Labeling requirements for fixed transmitter sites and facilities can be quite different for occupational and general population exposure conditions. Workers are likely to be in areas with much higher field conditions that are not accessible by the general public.
- RF exposure labeling is required for certain subscriber transceivers, see Table 1 of §1.1307



## Fixed Transmitter Sites

- Fixed transmitters operate at different frequencies may be collocated on towers and buildings etc.
  - exposure depends on the antenna configuration at a site
  - compliance is usually determined at the time of licensing according to §1.1307(b)(3)
- RF exposure labels are required for subscriber transceivers - BRS, EBS, LMDS AND DEMS
- Compliance for both general population and occupational limits are required
- Unlicensed PCS and NII devices must use general population limits; occupational limits do not apply

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•Basestation and similar transmitter antennas are typically mounted on tower, roof-top, side of commercial buildings and similar outdoor permanent structures. Other than service personnel (authorized workers), unauthorized persons (general public) are not expected to be near the antennas of these transmitters

•Transmitter licensees are (jointly) responsible for RF exposure evaluation and compliance at a particular site. License approval (to transmit) is independent of equipment certification (authorization). The applicable antennas and installation configurations are generally not detailed in the application for equipment authorization. Therefore, exposure compliance is generally not handled during equipment certification

•See OET 65 (page 35) and other relevant sections for procedures on how to apply frequency dependent exposure limits

•Subscriber transceivers:

•Part 27 Subpart M - Broadband Radio Service (BRS) & Educational Broadband Service (EBS):  
<http://wireless.fcc.gov/services/brsebs/>

•BRS formerly known as the Multipoint Distribution Service (MDS)/Multichannel Multipoint Distribution Service (MMDS), is a commercial service. In the past, it was generally used for the transmission of data and video programming to subscribers using high-powered systems, also known as wireless cable. However, over the years, the uses have evolved to include digital two-way systems capable of providing high-speed, high-capacity broadband service, including two-way Internet service via cellularized communication systems. Such services provide consumers integrated access to voice, high-speed data, video-on-demand, and interactive delivery services from a wireless device.

•EBS formerly known as the Instructional Television Fixed Service (ITFS), is an educational service that has generally been used for the transmission of instructional material to accredited educational institutions and non-educational institutions such as hospitals, nursing homes, training centers, and rehabilitation centers using high-powered systems. Our recent revamping of the EBS spectrum will now make it possible for EBS users to continue their instructional services utilizing low-power broadband systems while also providing students with high-speed internet access.

•Part 101 Subpart L - Local Multipoint Distribution Service (LMDS)

•Part 101 Subpart G - Digital Electronic Message Service (DEMS)

•The antenna of subscriber transceivers are typically built-in as an integral part of the transmitter; however, some can be detached

•The RF exposure label for subscriber transceivers should

•provide adequate notice regarding potential radiofrequency safety hazards, e.g., information regarding the safe minimum separation distance required between users and transceiver antennas

•references the applicable FCC-adopted limits for radiofrequency exposure specified in §1.1310

•The RF exposure label of subscriber transceivers must be on the side of the antenna where the highest exposure is expected; if necessary, multiple labels may necessary

•A label at the back of an antenna is generally not acceptable, except when it is the only direction a person can approach the antenna

•See section 2 of OET Bulletin 65 on aperture antennas to estimate minimum separation distance

•Certain micro-basestations, repeaters, boosters etc. may operate indoors. These low power devices are typically categorically excluded. A minimum separation distance may be estimated according to procedures in OET Bulletin 65 (see above) for proper installation



## Mobile Operations

- Mobile configurations require antennas & radiating structures to operate at  $\geq 20$  cm from persons during normal use
- Routine evaluation is required according to §2.1091
  - $> 1.5$  W ERP @  $< 1.5$  GHz and  $> 3.0$  W ERP @  $\geq 1.5$  GHz
- Evaluation may include
  - field strength and/or power density measurements
  - computational modeling
  - estimations based on certain simple & generic exposure conditions
- Different time averaging requirements apply for general population and occupational exposure conditions
- Additional considerations are required for collocated transmitters that may transmit simultaneously

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- Field strength and power density limits based on whole-body SAR averaging concepts are used for evaluating mobile exposure conditions
- In mobile exposure conditions, the whole body may not be exposed. Mostly partial-body exposures are expected. At high power levels, depending on the separation distance, due to non-uniform field conditions inside the body some peak exposure locations could potentially exceed SAR limits. A conservative approach would be to average field strength and power density over the exposed portions or cross-sections of a person's body to evaluate the exposure conditions.
- Compliance is with respect to field strength or power density limits in Table 1 of §1.1310
- See §2.1091(d)(1) on time averaging requirements for occupational exposure
- See §2.1091(d)(2) on source-based time-averaging requirements for general population exposure
- Based on a 20 cm separation distance and applicable power density limits, the following power densities are estimated for 1-5 W EIRP
  - $0.2$  mW/cm<sup>2</sup> @ 1 W EIRP;  $0.4$  mW/cm<sup>2</sup> @ 2 W EIRP;  $0.6$  mW/cm<sup>2</sup> @ 3 W EIRP;  $0.8$  mW/cm<sup>2</sup> @ 4 W EIRP;  $1.0$  mW/cm<sup>2</sup> @ 5 W EIRP
- Routine evaluation is not required for transmitters not specifically identified in §2.1091; i.e., categorically excluded.
- Estimated minimum separation distances could be larger than desired. The distance must agree with the installation and operating requirements of a mobile transmitter; otherwise, MPE measurements may be used to obtain more accurate separation distances (generally smaller) according to the actual exposure conditions
- Specifying a separation distance larger (other than rounding off numbers) than the required minimum separation distance could sometimes cause conflicts with the intended device/equipment installation requirements and operating configurations. It could also lead to misinterpretations on actual exposure hazards and operating requirements. Therefore, use of distances larger than the minimum separation distance required to satisfy compliance should be discouraged and avoided
- Although generic equations can provide estimated separation distances at  $< 20$  cm; however, estimates based on far-field equations are generally not applicable to near-field conditions. §2.1091(b) requires the minimum separation distance of 20 cm for mobile devices; therefore, distances less than 20 cm would disqualify the device as a mobile transmitter.
- It is important to understand the applicability and limitations of RF hazard probes for MPE measurements, errors of 25-100% are typical; expect rather large measurement uncertainties. In addition, poor measurement techniques and confusions in the applicability of safety guidelines can introduce even larger errors.
- RF hazard probes generally use diode detector. Output sensitivity is linear to power in square law region but linear to field strength otherwise. Compensation using squaring circuits can sometimes greatly overestimate field strength in multiple-signal environments. However, diode detectors can also underestimate field levels in high peak pulsed-signal fields. The diode detector may saturate and overestimating the actual field when transitioning from an RMS to a peak-detecting device. There are some probes that use compensation circuitry to account for the change in video resistance (impedance of the rectified probe output signal) for operating outside the square-law region.
- When a probe is calibrated in uniform CW signal/field conditions, the calibration may not reflect the probe's ability to accurately assess multiple signals or pulsed signals. Diode detectors are temperature sensitive, typically about 0.05 dB per degree C; a probe calibrated at room temperature could be off by up to 1 dB when used outdoors at elevated temperatures. See section 2 of OET Bulletin 65 on how to estimate minimum separation distances. See relevant sections of OET Bulletin 65 and page 35 on how to apply frequency dependent exposure limits.
- Installation instructions and user information on applicable minimum separation distance ( $\geq 20$  cm) is generally required for most mobile configurations; except for very low power devices with substantially low (practically no) potential for exposure



## Typical Mobile Configurations

- Vehicle-mounted antennas
  - occupational vs. general population exposure conditions
  - work-related operator vs. passengers & nearby persons
- Independent and embedded consumer devices
  - typical desktop and similar devices
  - desktop and laptop (display only) computer configurations
  - compliance requires proper installation
- Marine radios operating on various size vessels
  - small boats vs. large ocean liners
  - mobile vs. fixed configurations

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- Vehicle operators in work-related situations may qualify for occupational exposure limits through proper RF exposure training; however, general population limits apply to passengers and bystanders. The exposure limits for passengers and bystanders are more restrictive; in some situations they could also be subject to higher exposure due to proximity from antennas.
- A worker in an occupational exposure environment, with the necessary training, may control the transmission of a vehicle-mounted antenna and its separation distance from bystanders (by not transmitting) to ensure passenger and bystander compliance
- When antennas and radiating structures are fixed-mounted on large vessels where persons are exposed in the far-field and a minimum separation distance, as estimated according to far-field conditions (see OET 65), is guaranteed by the antenna/transmitter installation and operating requirements, such configurations may be considered according to fixed-mounted procedures



## Collocated Mobile Devices

- Independent without simultaneous transmission
- Simultaneous or overlapping transmissions
  - at single or multiple frequencies
  - from single or multiple antennas at close proximity
- Determine compliance according to §1.1307(b)(3)
  - apply frequency dependent MPE limits and compute the sum of MPE ratios (MPE/MPE limit at each frequency)
  - include applicable source-based time-averaging
  - determine minimum separation boundary ( $\geq 20$  cm) according to output power and spatial separations among antennas



Example Multiple Tx  
MPE Spreadsheet

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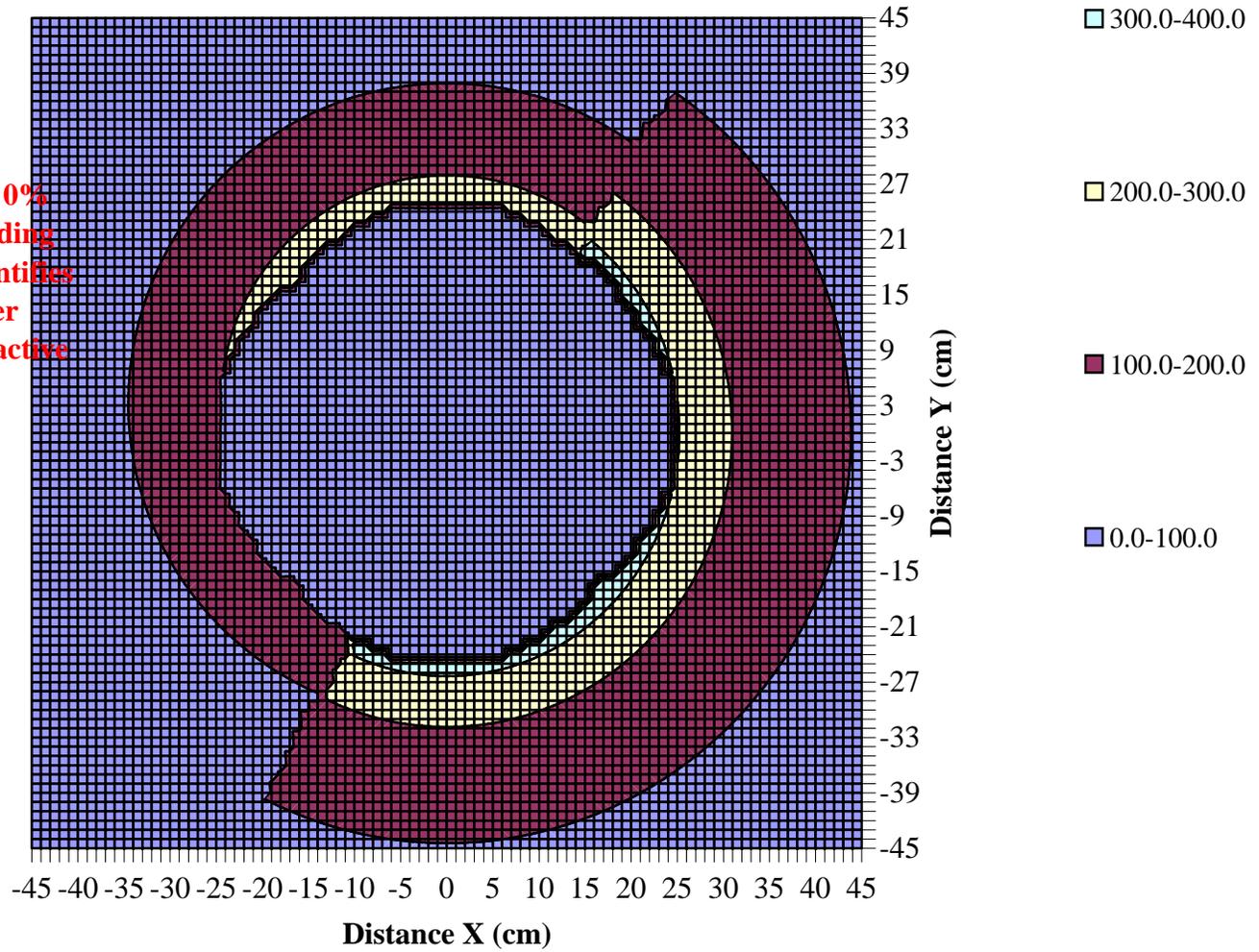
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Spreadsheet is for illustration only

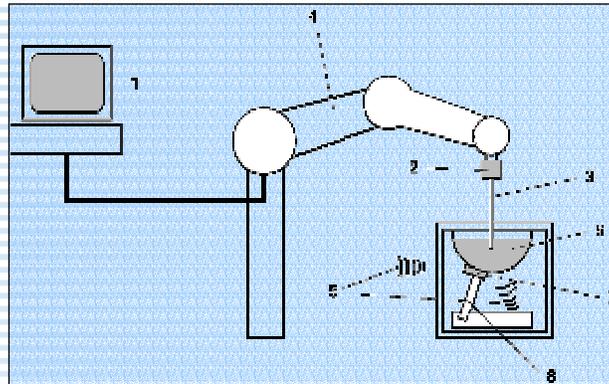
### % MPE Contour

Note: The inside 0% contour surrounding the antennas identifies a 20 cm perimeter surrounding all active





## SAR Measurement Overview



- 1) computer for data recording
- 2) data acquisition unit
- 3) dosimetric E-field probe
- 4) probe positioner
- 5) ambient field
- 6) phantom shell with tissue simulating liquid
- 7) device under test
- 8) device positioner

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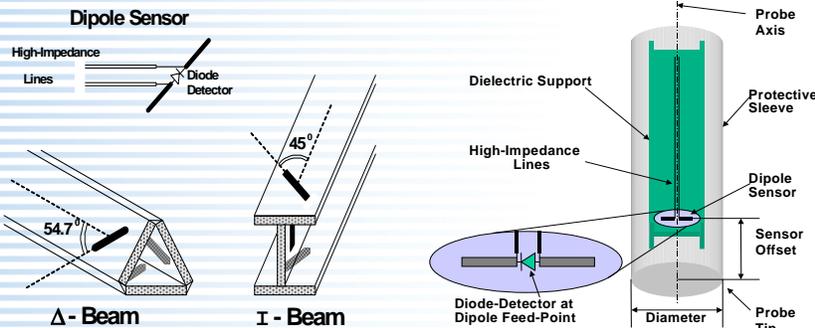
A typical SAR measurement system may include: E-field probe, phantoms (head, body and planar models), field probe holder and positioner, test device holder and positioner, tissue dielectric property measurement equipment (dielectric probe/sensor, network analyzer etc.), SAR system performance verification equipment (RF signal generator, dipoles & phantom etc.), test device signal control equipment (basestation simulator).



## Field Probe Construction

- Miniature E-field probes with 3 orthogonal dipole sensors operating with diode detectors for evaluating the SAR of low power devices

$$|E| = (|E_1|^2 + |E_2|^2 + |E_3|^2)^{1/2} = (v_1/\gamma_1 + v_2/\gamma_2 + v_3/\gamma_3)^{1/2}$$



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- Probe output depends on:
  - field polarization and direction of incidence
  - local field gradients at the vicinity of a measurement point where the probe tip is located
  - media dielectric properties and boundaries between probe, tissue-medium and phantom in the vicinity of the probe
  - frequency, modulation and power level of the source (test device)
  - interfering field sources, e.g., noise, static fields, ELF-fields, etc. from the ambient and nearby equipment
  - other physical influences, e.g., temperature, humidity etc. could change probe performance
- Probes may be calibrated with or without the probe readout electronics and instrumentation (data acquisition unit)
- Error sources may include:
  - isotropy - axial and hemispherical
  - spatial resolution (due to probe dimensions)
  - boundary effects
  - detection limit and response time
  - readout electronics & instrumentation errors
  - linearity
  - offset
- Probe calibration procedures are described in IEEE Standard 1528:
  - dynamic range - 0.01 - 100 W/kg
  - probe tip diameter -  $\leq 8.0$  mm for 0.3-3.0 GHz
- Probes for 3-6 GHz are available from a few manufacturers but established SAR procedures are not available



## Field Probe Calibration

- $SAR = \sigma|E|^2/\rho = c\Delta T/\Delta t$
- Frequency and tissue dielectric property dependent
- Calibration point is at geometric center of sensors
  - sensors are not at probe tip and are offset from probe axis
- Probe calibration procedures for 0.3-3 GHz are described in IEEE Standard 1528
- Probes should be calibrated in gradient fields using
  - temperature rise technique - < 800 MHz
  - waveguide technique -  $\geq$  800 MHz

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(Calibration and characterization of the probe together with the readout electronics and the post-processing system: This is preferred if the probe is uniquely used in a specific system. If the probe is calibrated with different readout electronic devices, manufacturing variations that result in differences in input characteristics from unit to unit must be considered in the uncertainty evaluation. Even though, an E-field probe is calibrated with its associated instrumentation and readout electronics, it is suggested that the probe output performance be evaluated with and without the processing and compensation system, so that the probe characteristics are known specifically.

(Calibration and characterization of the probe without the readout and post processing system, i.e., at the probe connector: The acceptable input characteristics of the readout electronics must be specified, as well as the E-field strength used during calibration and characterization. The probe can then be used in any system that matches these characteristics. Deviations in the input characteristics as well as all errors introduced by the instrumentation must be considered in the uncertainty analysis.



## Phantom Requirements

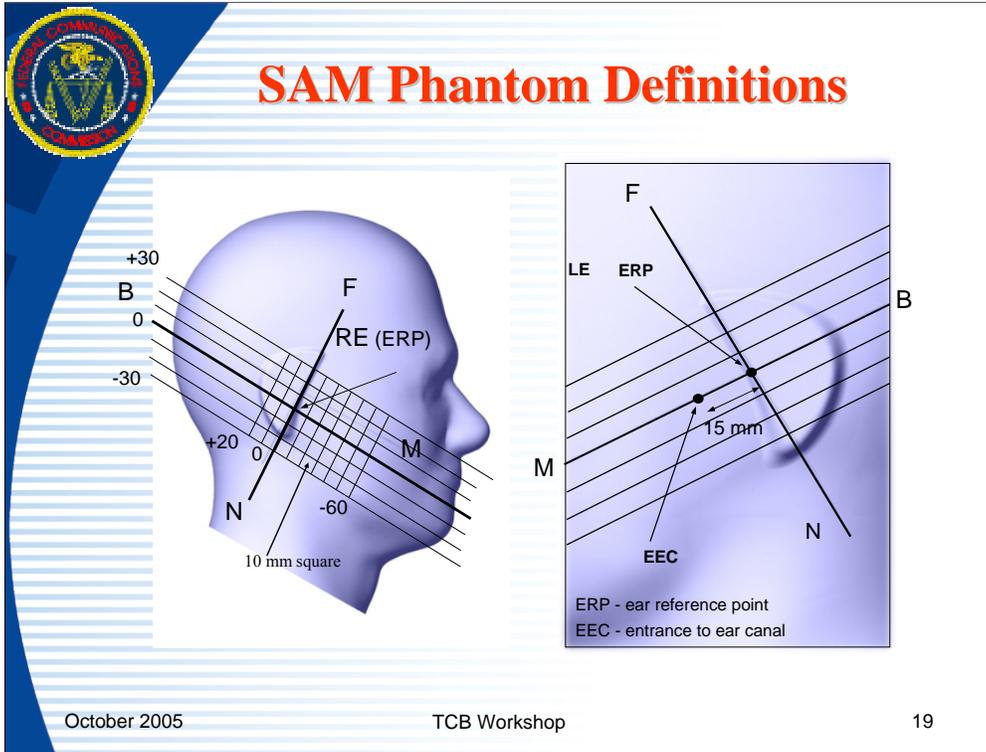
- IEEE Standard 1528 SAM head phantom for testing handsets next to the ear
- Flat phantom for system validation and testing other operating configurations
- Phantom shell dielectric properties, shape and dimensions are fully defined in Standard 1528
- Homogeneous tissue-equivalent liquids are used
- Tissue dielectric parameters are defined
- Currently no hand phantom available

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- SAR is measured in tissue-equivalent models coupled to the test devices (portable transmitters)
- Energy coupling due to phantom shape, device positioning and tissue dielectric parameters can cause substantial SAR variations
- Phantoms are filled with homogeneous tissue-equivalent liquid to simulate the composite dielectric properties of head or body
- The dielectric parameters chosen for the tissue-equivalent liquid, dielectric constant and conductivity, determine the conservativeness of the SAR evaluation
- Hand SAR for low-power handheld devices generally do not have compliance concerns because SAR limits for extremities are 2.5 times higher (4.0 W/kg, 10-g SAR) than the rest of the body (1.6 W/kg, 1-g SAR)

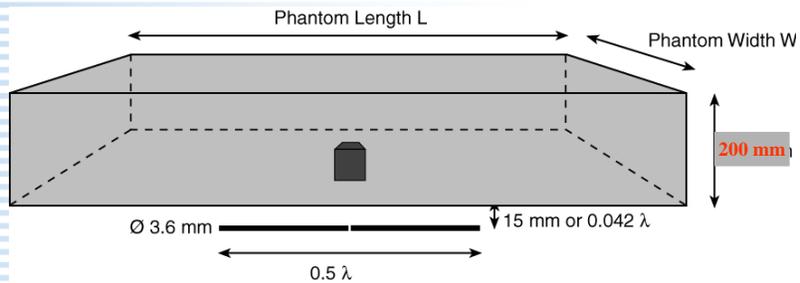


- Reference lines:
  - M-B in reference plane
  - N-F  $\perp$  to M-B **on ear spacer**
  - N-F and M-B bisect at ERP
- ERP is 1.5 cm above EEC
- Ear spacer:
  - 6.0 mm thick along N-F
  - $6.0 \pm 0.2$  mm thick at ERP
  - tapered and truncated below N-F
- Phantom shell thickness is  $2.0 \pm 0.2$  mm for measurement regions



## Flat Phantom Definitions

- shell thickness
  - bottom:
    - > 800 MHz -  $2.0 \pm 0.2$  mm with < 1% sagging (of  $\lambda_{\text{air}}$ )
    - $\leq 800$  MHz -  $6.5 \pm 0.2$  mm with < 0.5% sagging (of  $\lambda_{\text{air}}$ )
  - other regions: unspecified
- length and width:  $\geq 0.6 \lambda$
- liquid depth:  $15.0 \pm 0.5$  cm
- shell material:  $\epsilon_r < 5.0$  and loss tangent < 0.05



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Sagging is 1.0 cm @ 300 MHz

Dimensions established according to numerical simulations done at 835 MHz for 10-g SAR



## Tissue Dielectric Properties

Target Frequency (MHz)	Head		Body	
	$\epsilon_r$	$\sigma$ (S/m)	$\epsilon_r$	$\sigma$ (S/m)
150	52.3	0.76	61.9	0.80
300	45.3	0.87	58.2	0.92
450	43.5	0.87	56.7	0.94
835	41.5	0.90	55.2	0.97
900	41.5	0.97	55.0	1.05
915	41.5	0.98	55.0	1.06
1450	40.5	1.20	54.0	1.30
1610	40.3	1.29	53.8	1.40
1800 – 2000	40.0	1.40	53.3	1.52
2450	39.2	1.80	52.7	1.95
3000	38.5	2.40	52.0	2.73
5800	35.3	5.27	48.2	6.00

( $\epsilon_r$  = relative permittivity,  $\sigma$  = conductivity and  $\rho = 1000 \text{ kg/m}^3$ )

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- IEEE Standard 1528 defines head tissue parameters for 300 MHz – 3000 MHz only. The parameters are derived based on numerical simulations using the various 4-Cole-Cole head tissue parameters
- Head parameters at 150 MHz and 5800 MHz are extrapolated with respect to the slope of the 4-Cole-Cole parameters for average white and gray matters (brain). The choice of tissue parameters in a homogeneous phantom determines the amount of SAR overestimation
- Tissue dielectric parameters used for SAR measurement should be within  $\pm 5\%$  (10% when  $> 2.0 \text{ GHz}$ )
- The temperature of the liquid during SAR measurement should be maintained within  $\pm 2^\circ\text{C}$  of that recorded when the tissue parameters are measured
- Parameters at other frequencies can be computed by linear interpolation
- Body parameters are specified in Supplement C to OET Bulletin 65; adjusted according to the ratios of head & muscle tissues using the 4-Cole-Cole tissue parameters



## Tissue Property Measurements

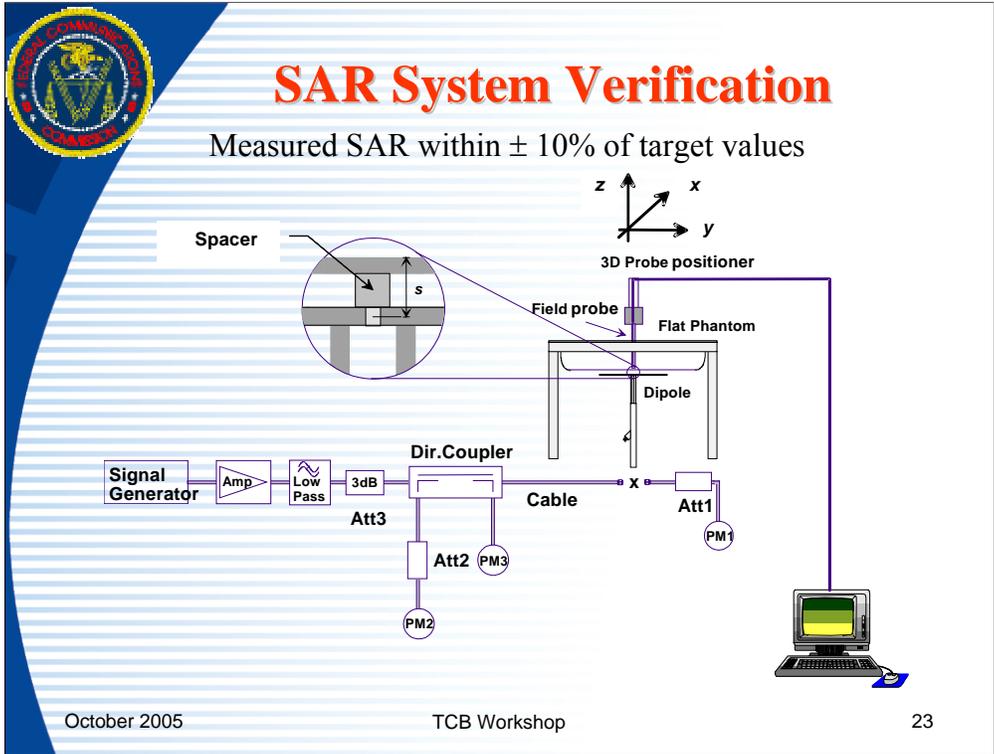
- IEEE 1528 recommended procedures
  - liquid filled Coaxial slotted line
  - Coaxial probe in liquid
  - liquid filled TEM-Line
- Sensors are connected to network analyzer
- dielectric constant and conductivity are calculated from reflection coefficients
- measuring standard liquids to verify accuracy
- 5% measurement uncertainty required

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Details of tissue dielectric property measurement procedures are described in IEEE Standard 1528. 10% measurement uncertainty for dielectric constant is acceptable above 2 GHz when standardized tissue recipes are not available.

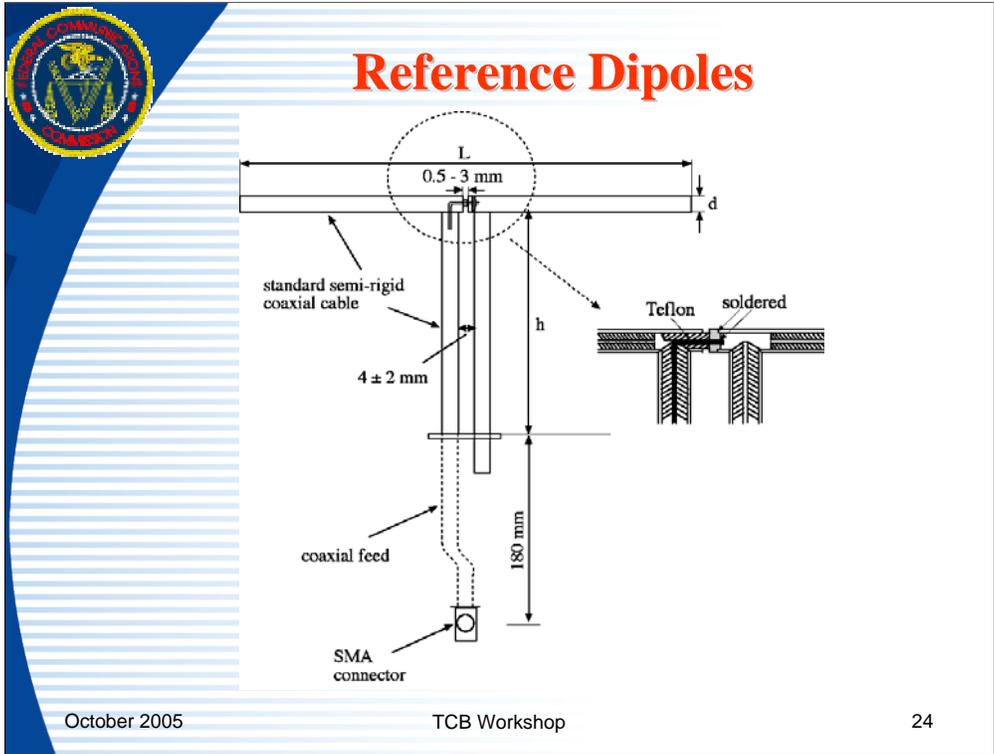


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Distance  $s$ : dipole axis to tissue/liquid surface, after filled with liquid (already sagged)  
 Procedures are specified in IEEE Standard 1528



Dipole dimensions are specified in IEEE Standard 1528.



## Dipole Reference SAR Values

Frequency (MHz)	1 g SAR	10 g SAR	local SAR at surface (above feedpoint)	local SAR at surface (y=2cm offset from feedpoint)
300	3.0	2.0	4.4	2.1
450	4.9	3.3	7.2	3.2
835	9.5	6.2	14.1	4.9
900	10.8	6.9	16.4	5.4
1450	29.0	16.0	50.2	6.5
1800	38.1	19.8	69.5	6.8
1900	39.7	20.5	72.1	6.6
2000	41.1	21.1	74.6	6.5
2450	52.4	24.0	104.2	7.7
3000	63.8	25.7	140.2	9.5

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- Numbers are obtained by numerical simulation and experimental measurements
- Phantom sagging has not been simulated in the numerical computations
- Numbers in the last 2 column are for checking the extrapolation and interpolation procedures used in SAR systems



## Typical Test Configurations

- SAR is typically tested on high, middle & low channels
- Handsets are usually tested
  - on the left and right side of the SAM phantom
  - in cheek touching and 15° tilt positions
  - with antenna extended and retracted, as appropriate
  - tests are repeated for all operating modes and frequency bands with certain exceptions
- Other configurations are generally tested on high, middle & low channels with the device positioned at a appropriate distance from a flat phantom

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•When the measured SAR at the middle channel of each test configuration (left, right, Cheek/Touch, Tile/Ear, extended and retracted) is at least 3.0 dB lower than the SAR limit, testing at the high and low channels is optional (IEEE 1528)

•If the test device has a transmission band less than 10 MHz, testing at the high and low frequency channels is optional (Supplement C)

•Procedures for testing multiple modes in the same frequency band for handsets are described in IEEE 1528; also see PN DA 02-1438



## SAR Scan Procedures

- Area scan to determine peak SAR locations
  - peak SAR mostly near surface of homogeneous phantoms
  - probe boundary effects error requires probe tip location
    - $> \frac{1}{2}$  probe diameter distance from phantom surface
  - typical scan resolution
    - 1-2 cm at  $< 3$  GHz and  $\leq 1$  cm at  $> 3$  GHz
    - measured values are interpolated to identify peak locations
- zoom scan to determine volume averaged SAR
  - typical scan configurations
    - 5 x 5 x 7 points in 3 x 3 x 3 cm<sup>3</sup> volume at  $< 3$  GHz
    - 7 x 7 x 7 or more points at 3-6 GHz
  - 1-g SAR is computed by
    - extrapolating measured values to the phantom surface
    - interpolating and then integrating with respect to a 1 cm<sup>3</sup>

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- Area scan at  $< 8.0 \text{ mm} \pm 1.0 \text{ mm}$  (constant distance) from the phantom surface to reduce probe boundary effect
- Probe diameter  $< 8.0 \text{ mm}$  to minimize spatial resolution error (IEEE 1528)
- Scan area should be larger than region projected by the device on the phantom to capture all peaks
- Area scan resolution (spatial) should provide peak location accuracy within  $\pm 5 \text{ mm}$  according to interpolated values
- Measured values are typically interpolated using 2-dimensional splines
- Scans are repeated if peaks are closer than  $\frac{1}{2}$  the linear dimension of a 1 or 10 gram cube from scan boundary
- All peaks within 2 dB of the highest peak are evaluated with zoom scan to compute the highest 1-g SAR
  
- Zoom scan should be centered at the peak SAR locations determined from the area scan to determine 1-g averaged SAR
- Zoom scan volume should extend 1.5 times or larger the linear dimension of a 1- or 10-g cube in each direction
- Due to probe sensor offset, points at the phantom surface cannot be measured, therefore, must be extrapolated:
  - typically using 4<sup>th</sup>-order polynomial functions
  - 1<sup>st</sup> & 2<sup>nd</sup> point  $< 10 \text{ mm}$  from phantom surface
  - value of last point  $< 25\%$  of 1<sup>st</sup> point
- Trapezoidal integration is usually used to compute 1 or 10 g averaged SAR
- If probe axis is aligned  $> 30^\circ$  from normal to phantom surface, increased probe boundary effect and isotropy errors may require phantom or probe to be tilted to minimize measurement error



## SAR Measurement Uncertainty

- Identifies the probability of a measured value from its true value
- Standard uncertainty of an uncertainty component
  - type A - statistical analysis of a series of observations
    - estimating the standard deviation
  - type B - other than statistical analysis
    - based on scientific judgement - reference data and specifications
- Combined standard uncertainty
  - estimate the standard deviation by combining standard uncertainties using the “root-sum-squares” method
- Expanded uncertainty
  - multiplied the combined uncertainty by a coverage factor
  - defines the probability of the measured result in an interval where the true value is believed to be

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See NIST Technical Note TN 1297 (<http://physics.nist.gov/Document/tn1297.pdf>)



# Reporting Uncertainty



IEEE 1528 Uc



Uc Spreadsheet  
Template

**For Information only**

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Determine compliance according to measured SAR, if uncertainty is too large determine cause and take appropriate actions.  
During equipment certification, compliance is determined according to the measured values provided the expanded measurement uncertainty is less than 30% (IEEE 1528)  
During pre- and post-grant sample compliance tests, compliance is determined according to FCC's measurement uncertainty.  
Device fails if measured value > SAR limit + FCC's uncertainty

**Table E.4—Example of measurement uncertainty evaluation for handset SAR test**

<i>a</i>	<i>b</i>	<i>c</i>	<i>d</i>	$e = f(d, k)$	<i>f</i>	<i>g</i>	$h = c \times f / e$	$i = c \times g / e$	<i>k</i>
Uncertainty component	Clause	Tol. (± %)	Prob. Dist.	Div.	$c_i$ (1 g)	$c_i$ (10 g)	1 g $u_i$ (± %)	10 g $u_i$ (± %)	$v_i$
<b>Measurement system</b>									
Probe calibration (k = 1)	E.2.1	4.8	N	1	1	1	4.8	4.8	∞
Axial isotropy	E.2.2	4.7	R	$\sqrt{3}$	$(1-c_p)^{1/2}$	$(1-c_p)^{1/2}$	1.9	1.9	∞
Hemispherical isotropy	E.2.2	9.6	R	$\sqrt{3}$	$\sqrt{c_p}$	$\sqrt{c_p}$	3.9	3.9	∞
Boundary effect	E.2.3	8.3	R	$\sqrt{3}$	1	1	4.8	4.8	∞
Linearity	E.2.4	4.7	R	$\sqrt{3}$	1	1	2.7	2.7	∞
System detection limits	E.2.5	1.0	R	$\sqrt{3}$	1	1	0.6	0.6	∞
Readout electronics	E.2.6	1.0	N	1	1	1	1.0	1.0	∞
Response time	E.2.7	0.8	R	$\sqrt{3}$	1	1	0.5	0.5	∞
Integration time	E.2.8	1.4	R	$\sqrt{3}$	1	1	0.8	0.8	∞
RF ambient conditions—noise	E.6.1	3.0	R	$\sqrt{3}$	1	1	1.7	1.7	∞
RF ambient conditions—reflections	E.6.1	3.0	R	$\sqrt{3}$	1	1	1.7	1.7	∞
Probe positioner mechanical tolerance	E.6.2	0.4	R	$\sqrt{3}$	1	1	0.2	0.2	∞
Probe positioning with respect to phantom shell	E.6.3	2.9	R	$\sqrt{3}$	1	1	1.7	1.7	∞
Extrapolation, interpolation, and integration algorithms for max. SAR evaluation	E.5	3.9	R	$\sqrt{3}$	1	1	2.3	2.3	∞
<b>Test sample related</b>									
Test sample positioning	E.4.2	6.0	N	1	1	1	6.0	6.0	11
Device holder uncertainty	E.4.1	5.0	N	1	1	1	5.0	5.0	7
Output power variation—SAR drift measurement	6.6.2	5.0	R	$\sqrt{3}$	1	1	2.9	2.9	∞
<b>Phantom and tissue parameters</b>									

**Table E.4—Example of measurement uncertainty evaluation for handset SAR test  
(continued)**

<i>a</i>	<i>b</i>	<i>c</i>	<i>d</i>	$e = f(d, k)$	<i>f</i>	<i>g</i>	$h = c x f / e$	$i = c x g / e$	<i>k</i>
<b>Uncertainty component</b>	<b>Clause</b>	<b>Tol. (± %)</b>	<b>Prob. Dist.</b>	<b>Div.</b>	$c_i$ (1 g)	$c_i$ (10 g)	1 g $u_i$ (± %)	10 g $u_i$ (± %)	$v_i$
Phantom uncertainty (shape and thickness tolerances)	E.3.1	4.0	R	$\sqrt{3}$	1	1	2.3	2.3	$\infty$
Liquid conductivity—deviation from target values	E.3.2	5.0	R	$\sqrt{3}$	0.64	0.43	1.8	1.2	$\infty$
Liquid conductivity—measurement uncertainty	E.3.3	5.5	N	1	0.64	0.43	3.5	2.4	5
Liquid permittivity—deviation from target values	E.3.2	5.0	R	$\sqrt{3}$	0.6	0.49	1.7	1.4	$\infty$
Liquid permittivity—measurement uncertainty	E.3.3	2.9	N	1	0.6	0.49	1.7	1.4	5
<b>Combined standard uncertainty</b>			RSS				13.6	13.2	158
<b>Expanded uncertainty (95% CONFIDENCE INTERVAL)</b>			k = 2				± 27.2	± 26.4	
NOTE—The component values in Table E.4 are for example only and are not intended to represent the measurement uncertainty of any specific SAR test system. The measurement uncertainty for a specific handset tested with a specific SAR test system must be individually evaluated.									

**Table E.5—Example of the measurement uncertainty assessment for system validation**

<i>a</i>	<i>b</i>	<i>c</i>	<i>d</i>	$e = f(d, k)$	<i>f</i>	<i>g</i>	$h = c x f / e$	$i = c x g / e$	<i>k</i>
Uncertainty component	Clause	Tol. (± %)	Prob · Dist.	Div ·	$c_i$ (1 g)	$c_i$ (10 g)	1 g $u_i$ (± %)	10 g $u_i$ (± %)	$v_i$
<b>Measurement system</b>									
Probe calibration	E.2.1	4.8	N	1	1	1	4.8	4.8	∞
Axial isotropy	E.2.2	4.7	R	$\sqrt{3}$	$(1-c_p)^{1/2}$	$(1-c_p)^{1/2}$	2.7	2.7	∞
Hemispherical isotropy	E.2.2	0.0	R	$\sqrt{3}$	$\sqrt{c_p}$	$\sqrt{c_p}$	0.0	0.0	∞
Boundary effect	E.2.3	8.3	R	$\sqrt{3}$	1	1	4.8	4.8	∞
Linearity	E.2.4	4.7	R	$\sqrt{3}$	1	1	2.7	2.7	∞
System detection limits	E.2.5	1.0	R	$\sqrt{3}$	1	1	0.6	0.6	∞
Readout electronics	E.2.6	1.0	N	1	1	1	1.0	1.0	∞
Response time	E.2.7	0.0	R	$\sqrt{3}$	1	1	0.0	0.0	∞
Integration time	E.2.8	0.0	R	$\sqrt{3}$	1	1	0.0	0.0	∞
RF ambient conditions—noise	E.6.1	3.0	R	$\sqrt{3}$	1	1	1.7	1.7	∞
RF ambient conditions—reflections	E.6.1	3.0	R	$\sqrt{3}$	1	1	1.7	1.7	∞
Probe positioner mechanical tolerance	E.6.2	0.4	R	$\sqrt{3}$	1	1	0.2	0.2	∞
Probe positioning with respect to phantom shell	E.6.3	2.9	R	$\sqrt{3}$	1	1	1.7	1.7	∞
Extrapolation, interpolation, and integration algorithms for max. SAR evaluation	E.5.2	3.9	R	$\sqrt{3}$	1	1	2.3	2.3	∞
<b>Dipole</b>									
Dipole axis to liquid distance	8, E.4.2	1.0	R	$\sqrt{3}$	1	1	0.6	0.6	∞
Input power and SAR drift measurement	8, 6.6.2	4.7	R	$\sqrt{3}$	1	1	2.7	2.7	∞
<b>Phantom and tissue parameters</b>									

**Table E.5—Example of the measurement uncertainty assessment for system validation  
(continued)**

<i>a</i>	<i>b</i>	<i>c</i>	<i>d</i>	$e = f(d, k)$	<i>f</i>	<i>g</i>	$h = c \times f / e$	$i = c \times g / e$	<i>k</i>
<b>Uncertainty component</b>	<b>Clause</b>	<b>Tol. (± %)</b>	<b>Prob · Dist.</b>	<b>Div ·</b>	$c_i$ (1 g)	$c_i$ (10 g)	1 g $u_i$ (± %)	10 g $u_i$ (± %)	$\nu_i$
Phantom uncertainty—shell thickness tolerances)	E.3.1	4.0	R	$\sqrt{3}$	1	1	2.3	2.3	$\infty$
Liquid conductivity—deviation from target values	E.3.2	5.0	R	$\sqrt{3}$	0.64	0.43	1.8	1.2	$\infty$
Liquid conductivity—measurement uncertainty	E.3.3	5.5	N	1	0.64	0.43	3.5	2.4	5
Liquid permittivity—deviation from target values	E.3.2	5.0	R	$\sqrt{3}$	0.6	0.49	1.7	1.4	$\infty$
Liquid permittivity—measurement uncertainty	E.3.3	2.9	N	1	0.6	0.49	1.7	1.4	5
<b>Combined standard uncertainty</b>			RSS				10.4	9.8	$\infty$
<b>Expanded uncertainty (95% CONFIDENCE INTERVAL)</b>			$k = 2$				± 20.7	± 19.6	
NOTE—The component values in Table E.5 are for example only and are not intended to represent the measurement uncertainty of any specific SAR test system. The measurement uncertainty for a specific handset tested with a specific SAR test system must be individually evaluated.									

NOTES FOR TABLE E.4 AND TABLE E.5:

- 1—Column headings *a*–*k* are given for reference.
- 2—Column heading abbreviations:
  - a) Tol.—tolerance in influence quantity. If  $c_i = 1$ , this is a SAR tolerance.
  - b) N, R, U—normal, rectangular, U-shaped probability distributions.
  - c) Div.—divisor used to obtain standard uncertainty.
- 3—The uncertainty components indicated in these tables are based on the test procedures and protocols developed for this standard. When test protocols and procedures vary, different uncertainty components may apply, e.g., parameters defined for testing other phantom configurations and device positions.
- 4— $c_i$  is the sensitivity coefficient that should be applied to convert the variability of the uncertainty component into a variability of SAR. For probe isotropy,  $c_p = 0.5$ .
- 5—See F.2.3 for discussions on degrees of freedom ( $\nu_i$ ) for standard uncertainty and effective degrees of freedom ( $\nu_{eff}$ ) for the expanded uncertainty.
- 6—Interim tolerance of 10% may be used for the relative permittivity of glycol-based liquids at frequencies above 2 GHz.
- 7—The measurement system and phantom and tissue parameters uncertainties of Table E.4 should be equal to the corresponding uncertainties of Table E.5.

SAR Measurement Uncertainty Analysis

FCC ID	ZYX0298A	Tolerance (%)	Distribution	Sensitivity	u <sub>i</sub>	v <sub>i</sub>	Comment	IEEE 1528		
Test Date	7/23/2004						mm/dd/yyyy			
Test Frequency (MHz)	835						one Uc analysis per frequency			
g <sub>p</sub>	0.50						isotropy weighting factor	E.2.2		
1-g or 10-g SAR	1.0						enter 1 or 10			
Pulse Width (ms)	0						integration time: "USER" modulation pulse width			
Pulse Period (ms)	0						invalid "USER" pulse width or period	E.2.8		
Target ε <sub>r</sub>	41.50						target dielectric constant (450 - 3000 MHz)	5.3.1		
Target σ (S/m)	0.90						target conductivity (450 - 3000 MHz)	5.3.1		
δ (mm)	13.95						skin depth at 3.0 GHz	E.2.3		
Ambient Reference SAR (W/kg)	0.400						reference SAR for ambient condition tolerance	E.6.1		
SAR Reference: f <sub>1</sub> (W/kg)	0.881						reference SAR (f <sub>1</sub> ) for algorithm tolerance			
SAR Reference: f <sub>2</sub> (W/kg)	1.796						reference SAR (f <sub>2</sub> ) for algorithm tolerance	E.5.1		
SAR Reference: f <sub>3</sub> (W/kg)	3.049						reference SAR (f <sub>3</sub> ) for algorithm tolerance			
Probe Calibration	(±%) 4.85	4.85	N	1.00	4.85	∞	from data on probe calibration certificate	A.10		
Axial Isotropy	(± dB) 0.20	4.71	R	0.71	1.92	∞	from data on probe calibration certificate - ± 0.25 dB	E.2.2		
Hemispherical Isotropy	(± dB) 0.44	10.66	R	0.71	4.35	∞	from data on probe calibration certificate - ± 0.5 dB			
Boundary Effect	SAR <sub>Reference</sub>	1.00	1.03	R	1.00	0.59	∞	SAR <sub>Reference</sub> from probe calibration plot	E.2.3	
	SAR <sub>Measured</sub>	1.02						SAR <sub>Measured</sub> from probe calibration plot		
	SAR <sub>bc</sub> (%)	1.50						d <sub>bc</sub> + d <sub>dep</sub> < 10 mm		
	d <sub>bc</sub> (mm)	3.70						d <sub>bc</sub> = 1 <sup>st</sup> measured point from surface		
	d <sub>dep</sub> (mm)	2.00						d <sub>dep</sub> = distance between 1st & 2nd points		
Linearity	(± dB) 0.20	4.71	R	1.00	2.72	∞	from probe calibration certificate - ± 0.25 dB	E.2.4		
System Detection Limit	0.1 W/kg	CW	0.10	1.00	R	1.00	0.58	∞	maximum SAR difference for CW & pulse, either user or manufacturer measured	E.2.5
		Pulse	0.10							
	2.0 W/kg	CW	2.10							
		Pulse	2.12							
10.0 W/kg	CW	10.50								
	Pulse	10.40								
Readout Electronics	(±%) 1.00	1.00	N	1.00	1.00	∞	from probe & amplifier specifications	E.2.6		
Signal Response Time	t <sub>rise</sub> (ms)	5.00	0.00	R	1.00	0.00	∞	probe rise time from system specs	E.2.7	
	t <sub>hold</sub> (ms)	500.00						probe hold time; Column D ignored		
Integration Time (Sec)	GSM	0.5	1.73	R	1.00	1.00	∞	enter CW, AMPS, CDMA, TDMA, GSM, GPRS or USER in column B	E.2.8	
RF Ambient Conditions	Measured (W/kg)	0.012	3.00	R	1.00	1.73	∞	measured under test conditions with no RF signal, maximum allowed is 3%	E.6.1	
Probe Positioner: Mechanical	d <sub>in</sub> (mm)	0.12	0.43	R	1.00	0.25	∞	in directions parallel to phantom surface	E.6.2	
Probe Positioning: Surface	d <sub>ph</sub> (mm)	0.80	2.87	R	1.00	1.66	∞	in directions normal to phantom surface	E.6.3	
Post-Processing Algorithms	SAR <sub>evaluated</sub> (f <sub>1</sub> )	0.88	1.12	R	1.00	0.64	∞	SAR values evaluated with the interpolation and extrapolation algorithms used to test the DUT	E.5.2.2	
	SAR <sub>evaluated</sub> (f <sub>2</sub> )	1.8								
	SAR <sub>evaluated</sub> (f <sub>3</sub> )	3.015								
Device Positioning Tolerance	Single or Multiple	S	2.92	N	1.00	2.92	4	S=single device, M=multiple devices single=N-1, multiple=(N*M)-1	E.4.2	
	No. of Tests	5.00								
	Tolerance or SAR	1.1								
	Tolerance or SAR	1.17								
	Tolerance or SAR	1.15								
	Tolerance or SAR	1.11								
Device Holder Perturbation	Type A or B	B	9.09	R	1.00	5.25	∞	Type B = single test, Type A = multiple devices	E.4.1	
SAR w/holder	1.2	single test using a flat phantom with and without the DUT holder								
SAR w/o holder	1.1									
SAR Drift	(+ dB / -dB) 0.24 / -0.20	5.68	R	1.00	3.28	∞	enter largest "+" & "-" drifts among all tests for DUT	6.6.3		
Phantom Tolerance	d (mm)	0.2	4.04	R	1.00	2.33	∞	d=maximum deviation of inner & outer phantom shell	E.3.1	
Target σ Tolerance	Measured σ (S/m)	0.92	2.22	R	0.64	0.82	∞	± 5% allowed	E.3.3	
Measured σ Tolerance	No. of Measurements	5	1.92	N	0.64	1.23	4	no. of measurements made on liquid	E.3.3	
	σ <sub>1</sub>	0.92								measured conductivity of reference liquid (preferred) or liquid used to test DUT
	σ <sub>2</sub>	0.91								
	σ <sub>3</sub>	0.93								
	σ <sub>4</sub>	0.95								
	σ <sub>5</sub>	0.9								
Target ε <sub>r</sub> Tolerance	Measured ε <sub>r</sub>	41.55	0.12	R	0.60	0.04	∞	± 5% allowed	E.3.3	
Measured ε <sub>r</sub> Tolerance	No. of Measurements	5	4.00	N	0.60	2.40	4	no. of measurements made on liquid	E.3.3	
	ε <sub>r1</sub>	41.5								measured dielectric constant of reference liquid (preferred) or liquid used to test DUT
	ε <sub>r2</sub>	41.42								
	ε <sub>r3</sub>	41.4								
	ε <sub>r4</sub>	41.46								
	ε <sub>r5</sub>	41.47								
Combined Uncertainty	u <sub>c</sub>				11.08	782.4	v <sub>i</sub> column = v <sub>eff</sub>	F.2.3		
Expanded Uncertainty	(k=2)		PASS		22.15		94.55% confidence interval			

Version 02-2003-1: This spreadsheet will be updated as necessary, please always use most recent Version.



## Simultaneous Transmission

- SAR measurements are frequency dependent due to
  - probe calibration requirements
  - tissue dielectric parameters
- Simultaneous transmission at multiple frequencies requires SAR to be evaluated independently for each frequency using appropriate probe calibration and tissue dielectric parameters in identical device positioning conditions; i.e. measurement registration
- The results can be summed grid by grid according to the same measurement scan setup, followed by interpolation and extrapolation to compute 1-g SAR

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- Standardized SAR measurement procedures for simultaneous transmission at multiple frequencies are currently being developed by the IEC 62209-2
- The draft procedures have been implemented by some SAR system manufacturers



# TCB Exclusion List



## TCB Exclusion List

**For Information only,  
details are discussed separately**

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- The thresholds are for purpose of TCB approval only
- TCB approval of portable devices under occupational SAR requirements is limited to PTTs only

Transmitters included in a TCB Scope and identified in the following **do not** qualify for TCB approval.<sup>1</sup> Review & Approval procedures are described in a separate document that will be revised as evaluation and approval procedures are updated.

Transmitter Category	Exclusions List
I) All Transmitters	a) devices not evaluated according to most recent versions of FCC OET 65 Supplement C or other applicable FCC policies, procedures, and TCB training notes b) applications for equipment approval or permissive change requiring any change in equipment class (e.g., TNB to TNE, etc.) or change in RF exposure limits or exposure category c) devices employing numerical simulation or computational modeling techniques to show RF exposure compliance d) transmitters operating in non-US protocols or radio services (e.g., PHS, etc.)
II) Portable Transmitters	a) devices with operating frequencies above 6 GHz b) devices in standalone configurations with <u>output power</u> <sup>2</sup> greater than the <u>high threshold</u> <sup>3</sup> c) transmitters that are implanted or operated within a person’s body d) devices operating according to occupational exposure requirements, except for push-to-talk radios e) devices containing multiple transmitters that transmit simultaneously, when <i>routine SAR evaluation</i> <sup>4</sup> is required for the highest output (dominant) transmitter, and any of the other (non-dominant) transmitters is operating at higher than 5 mW f) devices containing multiple transmitters with simultaneous transmission, when <i>routine SAR evaluation</i> is not required, and the sum of the individual ratios of the <u>output power</u> divided by the <u>high threshold</u> is greater than one (1) g) modules for operation in licensed services that are not configured in a dedicated host device h) unlicensed modules used alone or with another transmitter <ol style="list-style-type: none"> <li>1) without simultaneous transmission, and the <u>output power</u> of any transmitter is greater than 100 mW with operating frequency less than or equal to 3 GHz, or 50 mW with frequency greater than 3 GHz but less than or equal to 6 GHz</li> <li>2) with simultaneous transmission, and the sum of the individual ratios of the <u>output power</u> divided by the <u>low threshold</u><sup>3</sup> is greater than one (1)</li> </ol>

<sup>1</sup> Each TCB location must have a least one person on staff who has completed the Part 22 Subpart H and Part 24 Subpart E handset SAR training, and the fixed, mobile, and portable transmitters RF exposure procedures training. Additional training will be provided in the future on requirements for new procedures and technology. Training workshops will be repeated as necessary to accommodate new TCBs.

<sup>2</sup> Output power for portable transmitters is the higher of the conducted or radiated (EIRP) source-based time-averaged output.

<sup>3</sup> In the following table,  $f_{\text{GHz}}$  is mid-band frequency in GHz, and  $d$  is the distance to a person’s body, excluding hands, wrists, feet, and ankles.

Exposure category	<u>low threshold</u>	<u>high threshold</u>
general population	$(60/f_{\text{GHz}})$ mW, $d < 2.5$ cm $(120/f_{\text{GHz}})$ mW, $d \geq 2.5$ cm	$(900/f_{\text{GHz}})$ mW, $d < 20$ cm
occupational	$(375/f_{\text{GHz}})$ mW, $d < 2.5$ cm $(900/f_{\text{GHz}})$ mW, $d \geq 2.5$ cm	$(2250/f_{\text{GHz}})$ mW, $d < 20$ cm

<sup>4</sup> *Routine SAR evaluation* refers to that specifically required by § 2.1093, using measurements or computer simulation. When *routine SAR evaluation* is not required, portable transmitters with output power greater than the applicable low threshold require SAR evaluation to qualify for TCB approval.



## TCB RF Exposure Qualification

- TCB training on SAR and general RF exposure procedures required to qualify for RF exposure scope
- Training material may include:
  - information and videos available for previous trainings
  - Supplement C, IEEE Standard 1528 and other related standards
  - summary and updates provided in current workshop
  - all other necessary updates on FCC rules, administrative policies and equipment certification procedures available from the FCC (knowledge database) and through the TCB council
- Attend additional trainings in future workshops on updates and new procedures to maintain qualification

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- TCB training on SAR measurement for Part 22 & Part 24 handsets
- TCB training on general exposure requirements for fixed, mobile and portable transmitters



## Other Considerations

- Modular approval of unlicensed transmitters
  - see Public Notice DA 00-1407
- 3-6 GHz SAR requirements - pending
- Digital technology – Wi-Fi, Wi-Max, 3-G protocols
- Permissive Change requirements: Class I, II, III
- Applying meaningful and acceptable grant comments and conditions
- Pending proceedings – ET Docket 03-137
  - fixed transmitters
  - mobile and portable modules (§§ 15.247 and 15.407)

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- Modules may not have clearly defined operating configurations and exposure conditions; usually dependent on host configurations
- 3-6 GHz SAR measurement standard is not available (only working drafts), measurement difficulties are introduced by the much smaller penetration depth in tissue media
- New digital technologies have complex transmission and communication protocols involving multiple modulations, data rates and dynamic conditions that introduce additional difficulties in configuring a test device to operate in stable conditions for testing
- Permissive change requirements may involve various administrative, EMC and SAR considerations