SPECIFIC ABSORPTION RATE (SAR)

NEW COMPLIANCE REQUIREMENTS for MOBILE TELECOMMUNICATIONS EQUIPMENT

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New Compliance Requirements for Mobile and portable RF Telecommunications Equipment

The use of hand-held and body worn mobile telecommunications equipment (MTE) has experienced exponential growth. There is now a proliferation of consumer MTE that is used in close proximity to the human body in constant use for extended periods. It is known that exposure of the human body to high levels of Electromagnetic Radiation (EMR) leads to adverse health effects. To ensure the protection of the public from exposure to EMR from MTE, governments around the world have mandated or will soon mandate regulations and standards to limit the maximum permissible levels of exposure to the public. Regulations now exist in many countries including Australia, USA, Canada, Japan, Europe and many other countries.

Most country's regulatory and standards bodies (FCC, ACA, ICNIRP, ARIB, CENELEC) now require or recommend the testing of low power MTE for compliance with RF radiation safety standards. All handheld or body mounted MTE must be evaluated against human exposure standards which set basic restrictions for the Specific Absorption Rate (SAR) of RF energy by any part of the human body. SAR is a dosimetric quantity and is defined as the rate at which RF energy is absorbed per unit mass of biological tissue. RF dosimetry is the quantification of the magnitude and distribution of absorbed electromagnetic energy within human and biological objects that are exposed to EMR.

The scope of the SAR evaluation includes virtually all RF transmitting devices that are used in close proximity to the human body and transmit more than 20 mW of RF power. This includes mobile phones such as AMPS, GSM, CDMA, DECT, CT2/CT3, PHS, spread spectrum devices, Laptop WLAN and EFTPOS terminals. Two way radios and wireless devices are also required to comply.

Standards

The recent publication of SAR measurement standards EN50361and IEEE 1528 have virtually harmonised SAR measurement methodologies but the SAR limits may vary between countries. Harmonising standards for SAR limits has not been possible due to widespread public concern and the differences of opinion between the experts from within the industry itself. The intensity of the public debate and the political responses vary from country to country.

The International Committee for Non-Ionising Radiation Protection (ICNIRP) sets guidelines for limiting exposure to EMR. These guidelines are generally accepted around the world however some countries such as the USA and Canada have more conservative SAR limits. Refer to Tables 1, 2 and 3.

ICNIRP Guidelines – SAR Limits

SAR Limits	Occupational Workers	Non-occupational workers
Whole Body	0.4 W/kg	0.08 W/kg
Localised Exposure: ***Head and Trunk**	10 W/kg	2 W/kg
***Hands and Feet**	20 W/kg	4 W/kg

***SAR measured in a 10g cube of tissue**

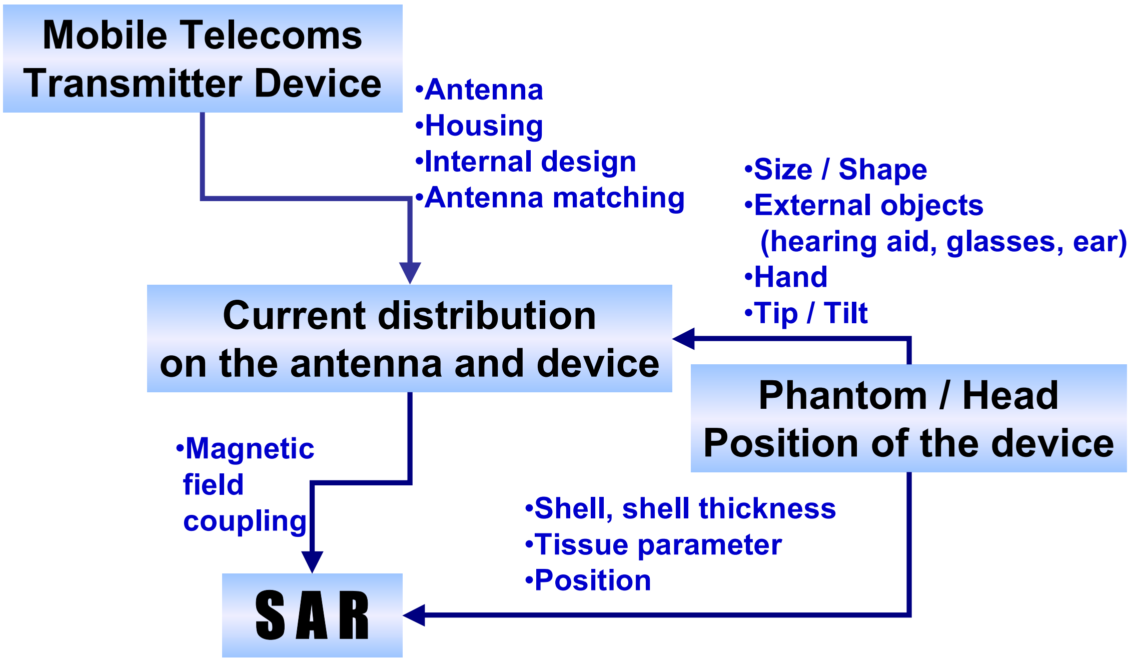
SAR Limits - Occupational

	Australia	USA	Europe	Japan	New Zealand
	ACA	**ANSIC95.1**	**ENV50166**	**TTC/MPT**	**NZS2772**
Whole Body	0.4 W/kg	0.4 W/kg	0.4 W/kg	0.4 W/kg	0.4 W/kg
Spatial Peak	10 W/kg	8 W/kg	10 W/kg	8 W/kg	10 W/kg
Averaging Time	6 min	6 min	6 min	6 min	6 min
Averaging Time	10g	1g	10g	10g	10g
Shape	Cube	Cube	Cube	Cube	Cube

SAR Limits – Non Occupational

	Australia	USA	Europe	Japan	New Zealand
	ACA	**ANSIC95.1**	**ENV50166**	**TTC/MPT**	**NZS2772**
Whole Body	0.08 W/kg	0.08 W/kg	0.08 W/kg	0.04 W/kg	0.08 W/kg
Spatial Peak	2W/kg	1.6 W/kg	2 W/kg	2 W/kg	2 W/kg
Averaging Time	6 min	30 min	6 min	6 min	6 min
Averaging Time	10g	1g	10g	10g	10g
Shape	Cube	Cube	Cube	Cube	Cube

Factors effecting SAR



In Europe and Australia, the SAR limit for MTE is 2 mW/g (2 W/kg) and measured as an average over a 10 gram cube of tissue. In the USA and Canada, MTE must comply with the 1.6 mW/g (1.6 W/kg) SAR limit measured as an average in a 1 gram cube of tissue.

As can be seen from the table of SAR limits, it will not be possible to determine worldwide compliance by testing to one limit or one standard until international harmonisation occurs. In the meantime, manufacturers must ensure that MTE meets the SAR limits of each target market, and testing must be performed to the appropriate standard.

Measurement of SAR

SAR is the most reliable predictor of thermally related health effects. SAR evaluations present very restrictive specifications since very tight margins are set with respect to the maximum permitted exposure, based on spatially averaged peak absorption. Temperature rise measurements in a tissue simulating liquid are extremely difficult to perform due to the very small temperature increments to be measured (< 0.01^0C rise). The effects of heat diffusion compound the measurement difficulties.

$$SAR = \frac{\sigma E^2}{\rho}$$

E = internal electric field

σ = electrical conductivity of tissue

ρ = mass density of tissue

Dielectric Parameters Equivalent to Human Brain Tissue

Brain Tissue	900 MHz		1800 MHz	
	ε_r	σ	ε_r	σ
Grey brain matter	51.4	1.06	49.5	1.44
White brain matter	34.0	0.59	32.6	0.84
Homogeneous medium	42.5	0.85	41.0	0.85

ε_r = relative permittivity

σ = conductivity

Typical Recipe for Brain Tissue

Ingredients	900 MHz	1800 MHz
Water	10.3 ℓ	11.44 ℓ
Cellulose	64.0 g	63.8 g
Salt	177.4 g	-
Sugar	14.88 kg	13.72 kg
Preventol	26.8 g	24.7 g
	20.0 ℓ	20.0 ℓ
Dielectric Parameters At 20^0 C	ε_r **= 42.5** σ = **0.85 S/m**	ε_r **= 41.0** σ = **0.85 S/m**

RF Field Measurement in Tissue Simulating Liquid.
The measurement of Electric field is the most convenient method as E-field probes have fast time response and adequate sensitivity for SAR measurements. The measurement of Electric field strength in the extreme near field of the radiating antenna is however very difficult, and the difficulties are further compounded by the interaction of the radiating source(s) with the human body. SAR results depend on various parameters, such as position of the RF source near the human body, posture, size, anatomy and many other factors. The absorption and distribution of electromagnetic energy in the body are very complex phenomena that depend on the mass, shape and size of the body, the orientation of the body with respect to the field vectors and the electrical properties of both the body and environmental factors. Accurate repeatable measurement of the electromagnetic field within human tissue and in the extreme near field of transmitters is therefore a difficult task. The complexity of the field distributions places great demands on measurement probes with respect to spherical isotropy, linear response, spatial resolution, minimal field disturbances and boundary effects.

SAR Probe Positioning System and Body Simulating Phantom
The SAR measurement system must perform precise measurements in the extreme near field within simulated human tissue. Ideally, it should have sufficient flexibility in the measurement data evaluations and visualisation capabilities to allow testing of a variety of MTE and similar devices. It generally consists of a computer controlled high precision robotics system to position the SAR probe, robot controller, extreme near-field measurement probes, probe alignment sensor, and the phantom (mannequin) containing the biological tissue equivalent liquid. A precision 6 axis robot is generally required to precisely position the probe at the points of maximum electromagnetic field. The SAR measurements are made in shell models (phantoms) filled with tissue-simulating liquids of similar dielectric properties to that of human tissue.

Locating SAR peaks
One of the major difficulties encountered in SAR compliance measurements, is the location of the site of maximum SAR for a given MTE. When the site is located, more detailed measurements are then made, using a finer, cube-like lattice. This cube-like lattice must be located so as to overlap the SAR maxima obtained from

the previous measurement. The entire MTE must be scanned since the location of the peak SAR is not known nor is it intuitively obvious. In modern phones, the location of the SAR maximum is often not at the antenna, but on the surface of the phone in the vicinity of the keypad, display or earpiece. It is often located at the point of closest contact with the body.

The SAR measurement probe is equipped with an integrated, non-metallic optical sensor so that its position relative to any surface of the phantom is automatically determined with a high degree of precision. The robot positioner must have six axis so that it can position the probe tip normal (or very close to normal) to the curved surface of the head phantom. The broadband E-field probes must have excellent isotropy (typically 0.2 dB) and a spatial resolution of less than 1mm. Precise methods are required for traceable probe calibrations in air and in the simulated tissue.

The E-field measurements must be rapidly transmitted by an optical link to a PC for data processing. Extremely low noise and low drift instrumentation amplifiers are necessary in the data acquisition section. The effects and parameters causing distortion of probe performance in the extreme near-field, near the phantom surface must be compensated by the calibration of the probes and by numerical modelling. The SAR values for given tissue masses (eg 10g or 1g) are than calculated by means of three-dimensional polynominal integration.

Typical System Specifications for SAR Measurements:

1. The E-field measurement system should be highly automated, with a typical measurement time of less than 30 minutes.
2. The standard mannequin or phantom should not underestimate the SAR in the human tissue equivalent liquid.
3. The reference head phantom (SAM) must be used for devices used at the ear and both left and right ear should be tested.
4. The SAR measurement is performed at maximum MTE output power for each band and protocol. Multiple frequencies are tested in each band, usually in the centre and at each end of the band.
5. Testing is performed in the Touch Position and the 15 degree Tilt position. The phone positioner should place the phone in an exact pre-defined position, with a very high order of repeatability.
6. Testing should be performed with antennas both retracted and extended
7. Measurement uncertainties should be accurately assessed (better than 30% for devices used at the ear)
8. The system should perform visualisation of the SAR distribution around the surface of the MTE in the 3 planes and inside the phantom. (head or flat phantom).
9. Extremely high positioning accuracy for the E-field probe (<0.1mm). This requires that the probe tip be positioned normal to the surface of the phantom.
10. Scanning for location of spatial peak must be accurate – high order spatial resolution and accuracy is required. This is more critical when testing at higher frequencies, say 5-6 GHz.
11. Very sensitive, RF dosimetric probes calibrated in the same tissue simulating liquid must be used. Accurate measurement of liquid dielectric properties is

essential for each MTE operating frequency band. Dielectric parameters of the brain simulating liquid must be accurately measured prior to each test.

12. Calibration/system validation should be performed routinely prior to testing.
13. The MTE must be operated via air-link at maximum output power. Interconnecting leads or power supple connections may disturb the measurements. A base-station simulator and a shielded test chamber are required.
14. The software must have powerful computational and post measurement data processing capability.

Cost of SAR Measurements

Commercially available systems range from single dimension, 3 axis and 6 axis positioners (robots). The systems necessary to perform the SAR measurements involve sophisticated measurement techniques, complex calculations and modelling software. The cost of commercially available systems vary greatly, as does the quality and performance specifications. When commissioning SAR testing it is strongly recommended that the test house be accredited for testing to the latest SAR standards such as EN50361 and IEEE 1528. In Australia and some other countries, regulations specify that the SAR test house be specifically accredited for SAR testing. Accredited SAR testing provides a high confidence level that the SAR measurements are accurate and that your product complies with government requirements.

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A NATA accredited test house for SAR measurements.