SAR Update

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The concept of Specific Absorption Rate (SAR) has been around for many years and radio frequency (RF) safety concerns are not a new development. Most people are aware that a microwave oven can heat tissue (food) by using RF power, and it is this heating affect from other RF devices that causes the most concern from an RF safety point of view.

The human body counters local heating by thermo-regulation by blood flow through the affected organs. The eyes and male testes are particularly susceptible to RF heating as they have no direct blood supply and hence no way of dissipating the heat. Heating effects in biological tissue increase with increase in radio frequency although the penetration depth decreases. Microwave ovens operate at 2.4GHz, which gives a balance between heating efficiency and penetration depth.

The majority of RF safety concerns have focused on RF absorption by the head, particularly from mobile handsets. The dose of RF exposure is linked with exposure time; Maximum SAR is normally averaged over a six-minute period during the 24-hour day. More recent concerns have focused on effects other than the heating effects, since the majority of communications systems are pulse-like in their nature, concerns have been raised about their effects on brain function, for example the GSM frame rate at 8.33Hz is close to the characteristics of the alpha waves in the brain.

Although there is no conclusive proof of these effects a considerable amount of research is currently being conducted into RF and its effects, the majority of which was sparked off by the report of the Independent Expert Group on Mobile Phones, chaired Sir William Stewart, which was released in April 2000.

Further more funds of around £7.4m have been allocated from government and industry to a research programme (LINK Mobile Telecommunications and Health Research, MTHR Programme) over a three-year period. The first call for research projects has been completed and these projects will soon start, with a second call for projects happening at the moment. Much of this research is involved with the actual biological effects of RF on the human body. Currently there are no widely reproducible studies on the RF effects on biological cells.

What is SAR?

SAR is an index quantifying the rate of absorption of energy in biological tissue. SAR is expressed in watts per kilogram of biological tissue (Wkg-1). SAR is generally quoted as a figure averaged over a volume corresponding to 1g or 10g of body tissue. The SAR of a wireless product is either measured directly using body phantoms, robot arms and associated test equipment, or mathematically modelled. Mathematical modelling of a product for SAR can be very costly and time-consuming, possibly taking several months. A dual-band GSM 900 and GSM 1800 handset takes approximately one day to SAR test to the new standards using conventional methods.

The origin of current SAR limits

The following organizations have set exposure limits for acceptable RF safety via SAR levels:

- the American National Standards Institute (ANSI), the RF safety sections of which now operate as part of the American Institute of Electrical and Electronic Engineers (IEEE), which recently wrote one of the most important publications for SAR test methods
- the International Commission on Non-Ionizing Radiation Protection (ICNIRP), which was launched as an independent commission in May 1992
- in the UK, the National Radiological Protection Board (NRPB).

SAR limits are expressed for two different classes of people: workers (occupational/controlled exposure), and the general population (uncontrolled exposure). The general population limit is considered to be 'uncontrolled exposure' and is five times more stringent than the workers limit.

The limits are defined for exposure of the whole body, partial body (for example, head and trunk), and hands, feet, wrists and ankles. SAR limits are based on whole body exposure levels of 0.4Wkg-1 for workers and 0.08Wkg-1 for the general population. There is less concern about hands, wrists, feet, and ankles exposure, so the limit is less stringent. There are also considerable problems with the practicalities of measuring SAR in such body areas.

The majority of SAR testing is concerned with the head, where the current limits are 2Wkg-1 for 10g Volume Averaged SAR for Europe and 1.6Wkg-1 for 1g Volume Averaged SAR for the US and a number of other countries. The US limit is more stringent because it is lower and is volume averaged over a smaller amount of Australia, Canada and New Zealand have adopted the more stringent US limits of 1.6Wkg-1 for 1g Volume Averaged SAR, while Japan and Korea have adopted 2Wkg-1 for 10g Volume Averaged SAR as in Europe.

SAR test methods

SAR testing was originally performed by measuring minute changes in temperature at specific locations in a tissue-simulant material. The tissue simulant for this testing had to be extremely viscous to stop convectional currents producing erroneous results. SAR probes can still be calibrated by this method.

Most SAR probes now measure E-field in volts per meter (Vm-1), allowing SAR to be calculated. SAR is dependent on the conductivity and permittivity of the tissue simulant as well as the E-field present. The equation used to calculate temperature-change SAR relates directly to the one used in current measurements. SAR probes have to be physically small and have good spherical isotropy (that is, they measure equal amounts of E-field regardless of the angle/direction at which they are pointing towards the source of the radiation). SAR probes, and the associated test set up, must also be designed to have an insignificant effect on the RF field.

The probe is positioned at various points within a phantom head or body phantom filled with brain/tissue simulant. Phantom heads and body phantoms in general can only represent the human body; they do not, for example, mimic bone structure. Phantom heads have been produced that mimic the tissue structure of a human head with skin, bone, muscle and brain tissue, but these tissue phantoms are not practical for SAR testing. Also, body phantoms do not take into account natural body thermo-regulation by blood flow, although this is advantageous because it provides an additional safety margin.

Because there are no known 'recipes' for fluids that are representative of body tissue at all frequencies, different tissue simulant fluids are required for different frequencies (for example, 900MHz and 1800MHz for GSM 900 and GSM 1800 products). The brain simulant has to be calibrated to ensure that the permittivity and conductivity are correct for the frequency being used. Fluids are often made from a distilled water, sugar and salt mix, although some frequencies require other chemicals to obtain the required properties. These include glycol, which unfortunately damages plastics used in SAR probes and phantom heads.

SAR testing is performed on handset devices by placing them at various positions on both sides of the phantom head, with the tip of the SAR probe being moved to exact points in a three dimensional grid within the tissue simulant. A complex mathematical formula then calculates the Volume Averaged SAR using extrapolation and interpolation processes.

One key factor is that all current specifications require testing to be performed at the maximum power of the device under test, which represents a worst case scenario. However, mobile phones in the field do not always transmit at maximum power, depending on their location in relation to base stations. SAR probes average out duty cycles of radio devices that are not transmitting continuously. For example, a GSM mobile only transmits for approximately 1/8th of the time, so that a SAR probe measures 1/8th of the peak power from such devices.

New standards

The standards in the table are primarily for mobile phones and similar devices; SAR standards for other transmitters are in preparation.

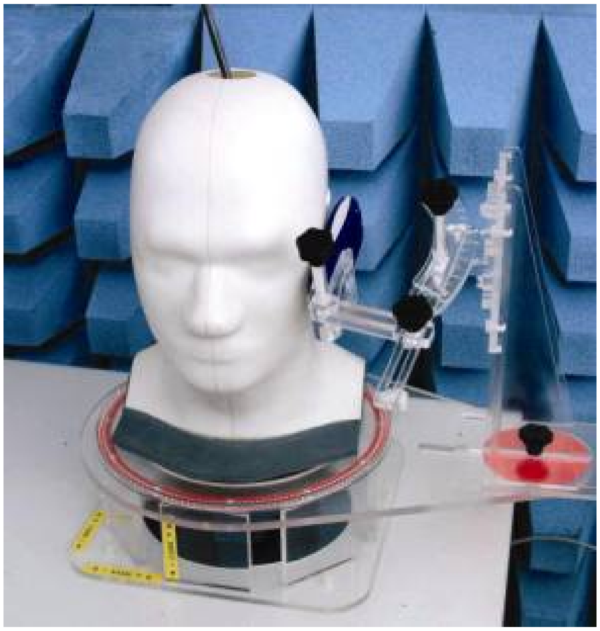
SAR standards around the world

	Australia	New Zealand	USA	Europe	Japan	Taiwan	International
Measurement Method	ACA (old) EN 50361 (new)		ANSI C95.3 (old) IEEE 1528 (new)	EN 50361			IEC 62209 (draft)
Limits	AS 2772.1 (old) ARPANSA (new)	NZS 2772.1	ANSI C95.1	EN 50360 (Council Recommendation 1999/519/EC)	TTC/MPT	DGT	ICNIRP (Health Physics April 1998, Volume 74, Number 4 494-522)
Whole Body	0.08 W/kg	0.08 W/kg	0.08 W/kg	0.08 W/kg	0.04 W/kg	0.08 W/kg	0.08 W/kg
Spatial Peak	2 W/kg	2 W/kg	1.6 W/kg	2 W/kg	2 W/kg	1.6 W/kg	2 W/kg
Averaging Time	6 min	6 min	30 min	6 min	6 min	30min	6 min
Averaging Mass	10g	10g	1g	10g	10g	1g	10g

Developments in test methods

The key developments in test methods are:

- manufacturers are required to use a new head phantom, the Specific Anthropomorphic Mannequin (SAM) phantom, which is based on the 90th percentile of a large survey of American male service personnel, representing a large male head. The SAM phantom has features (ears, nose, etc) and replaces the featureless Generic Twin Phantom.manufacturers are required to use a new head phantom, the Specific Anthropomorphic Mannequin (SAM) phantom, which is based on the 90th percentile of a large survey of American male service personnel, representing a large male head. The SAM phantom has features (ears, nose, etc) and replaces the featureless Generic Twin Phantom.



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- fluid properties are now well defined, as are the methods to make fluids and measure them for the most common frequencies used in testing. The IEEE 1528 specification contains excellent references for this.fluid properties are now well defined, as are the methods to make fluids and measure them for the most common frequencies used in testing. The IEEE 1528 specification contains excellent references for this.
- overall measurement uncertainties have to be below 30% for a 95% confidence level and are defined in the specifications. An uncertainty in measurements of 30% may sound a bit high, but anybody involved in uncertainty calculation for RF radiated emissions will recognise that this is small in decibel terms. There are twenty-one individual uncertainty contributions listed in the EN 50361 specifications, which may require additions depending on the set-up.
- a more pragmatic approach to handset testing is recommended, reducing the number of positions required. Testing is performed at the top, middle and bottom channels of the device under test, but only at the position of highest SAR at the mid-frequency.
- there is a well-defined system check requirement that must be performed regularly. This indicates any drift in all the properties (such as the fluids) and devices (such as the SAR robot positional accuracy) used in the SAR testing.
- the SAR robot positional accuracy must be better than ±0.2mm.

Applicability of the standards

In Europe, a key problem with the CENELEC standard is the fact that it is only concerned with devices held next to the human ear, that is handset testing next to a phantom head. EN 50360 is applicable to all RF devices that are ‘to be used in close proximity to the human ear’. It is applicable to devices transmitting with an average power greater than 20mW and in the frequency range 300MHz to 3GHz. Devices that transmit less than or equal to 20mW are ‘deemed to comply with the basic restrictions without testing’. This leads to the fact that there are no harmonised standards other than for devices such as mobile phones and cordless phones. Manufacturers must still comply with the EU SAR limits for devices such as PDAs with an integral RF module for GSM. Such devices are tested against flat phantoms, which are used to simulate ‘body parts’. EN 50360 does not contain the actual limits – these are found either in the ICNIRP Guidelines (April 1998) or Council Recommendation 1999/519/EC Annex II.

In the US the references required for applicability and the limits are contained in the Federal Communications Commission (FCC) Code of Federal Regulation Title 47 (CFR 47) Part 2.1093, which is for portable devices with their transmitters within 20cms of the user’s body. A full explanation of the relevant parts, SAR limits and SAR test methods is contained in FCC OET Bulletin 65 Supplement C. CFR 47 Part 2.1093 has an applicability list which is virtually all encompassing for radio products, depending on their output power.

A recent development has come from the Radiocommunications Standards Australian Communications Authority, which was proposing to extend the scope of SAR testing to include all radio products except emergency beacons. Once again, there are problems with the lack of test methods in implementing some of the required testing.

Publication of SAR figures

The Stewart Report recommends that information on SAR values for mobile phones must be readily accessible to consumers at the point of sale with information on the box, on leaflets available in stores giving explanatory and comparative information, as a menu option on the screen of the phone and on a label on the phone, and on a national Web site.

In the US, the Cellular Telecommunication Industry Association (CTIA) has announced that any mobile phone it certifies must be sold with explanatory information confirming that it has passed FCC safety standards, and it must include applicable specific absorption rate data for that phone as well as an explanation of how SAR testing is done.

Meanwhile, members of the Mobile Manufacturers Forum (including Alcatel, Ericsson, Mitsubishi Electric, Motorola, Nokia, Panasonic, Philips, Siemens and Sony) have undertaken to report SAR values on a global basis. This involves providing SAR information on all new models of mobile phone as well as on existing models still in production, using a user guide or leaflet in the box and company Web sites.

SAR protection devices and handsfree equipment

A number of devices are being marketed as RF/SAR protection devices, but until formal test procedures are established and results published for these products, it is difficult to comment on their benefits. There was a very public report on the fact that handsfree kits may actually increase SAR levels within the human brain, but the test methods used for this report have fallen into question and these effects have never been repeated. There are many publicly- available SAR test reports from various test houses showing that handsfree kits considerably reduce SAR levels.

The future for SAR testing

SAR testing can be expected to undergo many developments as knowledge of radiation effects and the legislation both mature. For example, in Europe, further standards to be adopted by CENELEC will cover products such as GSM base stations, anti-theft ports and low power radio devices. And in the US, the FCC has cautioned that further revisions to Supplement C can be anticipated before the draft standard is adopted by the IEEE.

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