RF Exposure: SAR Standards and Test Methods

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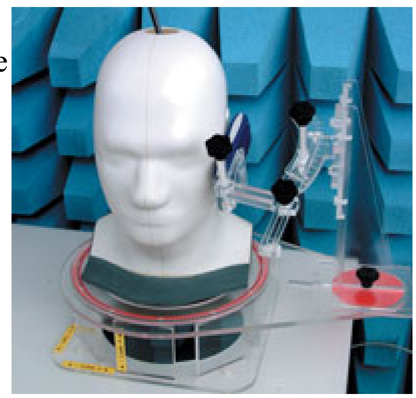
New developments in SAR test methods are bringing stricter limits and requirements, but more-accurate results.

Concern about human exposure to radio frequencies (RF) is not new. Ensuring the safety of RF devices is the primary motivation for new standards and test methods. The concept of specific absorption rate (SAR) has been around for many years, but recent developments have improved test methods. This article provides an overview of the current limits and test methods for SAR. Standards, specifications, and requirements are also discussed.



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Health Effects

The heating effect from RF devices causes the most concern from an RF safety point of view. The human body counters local heating by thermoregulation (blood flow through the affected organs). The eyes and male testes are particularly susceptible to RF heating because these organs have no direct blood supply and, hence, no way of dissipating heat. The heating effects in biological tissue escalate with the increase in frequency, although the heat's penetration depth decreases.

With the proliferation of cellular phones, most RF safety concerns have focused on RF absorption by the head, particularly from mobile handsets. The dose of RF exposure is linked to exposure time: maximum SAR is normally averaged over a 6-minute period during the 24-hour day.

Some concerns have focused on other effects of RF exposure. Most communications systems are pulse-like in nature, and their effects on brain function have been discussed recently. For example, the global system for mobile communications (GSM) frame rate, at 8.33 Hz, is close to that characteristic of alpha waves in the brain. Although there is

April 2000, is also known as the Stewart Report.

In the UK, nearly £7.4 million ($11.7 million) has been allocated from both government and industry sources to research the effects of RF. The LINK Mobile Telecommunications and Health Research (MTHR) Programme will be funded over a three-year period. The Programme Management Committee (PMC) was set up to advise on this research program. To date, PMC has published two calls for research proposals, and the first group of the projects is now under way. PMC has decided to issue a third call for research proposals. Much of this program's research addresses the biological effects of RF on the human body. Currently, widely reproducible studies of RF effects on biological cells are not available.

The SAR Index

SAR is an index that quantifies the rate of energy absorption in biological tissue. SAR is expressed in watts per kilogram (W/kg^1) of biological tissue. SAR is generally quoted as a figure averaged over a volume corresponding to either 1 g or 10 g of body tissue. The SAR of a wireless product can be measured in two ways. It can be measured directly using body phantoms, robot arms, and associated test equipment, or it can be mathematically modeled. Mathematical modeling of a product for SAR can be costly, and it can take as long as several months. Using conventional SAR test methods, a dual-band GSM 900 and GSM 1800 handset takes about one day to test to current standards.

SAR Limits

Several organizations have set exposure limits for acceptable RF safety via SAR levels. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) was launched as an independent commission in May 1992. This group publishes guidelines and recommendations related to human RF exposure.

For the American National Standards Institute (ANSI), the RF safety sections now operate as part of the Institute of Electrical and Electronic Engineers (IEEE). IEEE recently wrote one of the most important publications for SAR test methods.[1]

In the UK, the National Radiological Protection Board (NRPB) sets SAR limits. SAR limits are expressed for two different classes of people: workers (occupational/controlled exposure) and the general population (uncontrolled exposure). Because the general-population exposure is considered to be uncontrolled, the limit for this group is five times more stringent than the limit for the workers, whose environment and exposure can be monitored and controlled.

W/kg[1] for the general population. Limits are less stringent for exposure to hands, wrists, feet, and ankles. There are also considerable problems with the practicalities of measuring SAR in such body areas, because they are not normally modeled. In practice, measurements are made against a flat phantom, providing a conservative result.

Most SAR testing concerns exposure to the head. For Europe, the current limit is 2 W/kg[1] for 10-g volume-averaged SAR. For the United States and a number of other countries, the limit is 1.6 W/kg[1] for 1-g volume-averaged SAR. The lower U.S. limit is more stringent because it is volume-averaged over a smaller amount of tissue. Australia, Canada, and New Zealand have adopted the more-stringent U.S. limits of 1.6 W/kg[1] for 1-g volume-averaged SAR. Japan and Korea have adopted 2 W/kg[1] for 10-g volume-averaged SAR, as used in Europe.

Test Methods

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

Several key developments have been made in SAR test methods. Manufacturers are required to use a new head phantom called the specific anthropomorphic mannequin (SAM) phantom. SAM is based on the 90th percentile of a survey of American male military service personnel and represents a large male head. The SAM phantom, which has human features (ears, nose, etc.), replaces the featureless generic twin phantom. SAM has extremely well-defined dimensions, particularly for parameters such as phantom shell thickness.

Fluid properties for SAR testing are now well defined. The methods are also well defined for making and measuring fluids for the most common frequencies used in testing. The IEEE P1528 specification contains excellent references for fluid properties and methods. It is essential to verify that fluid properties are within the tolerances of the specifications.

Measurement uncertainties are defined in the specifications. Overall measurement uncertainties must be below 30% for a 95% confidence level. An uncertainty in measurements of 30% may seem a bit high, but this percentage is small in decibel terms. EN 50361 lists 21 individual uncertainty contributions.[2] Depending on the setup, additional contributions may be required.

The new methods present a more pragmatic approach to handset testing, reducing the number of positions required. Testing is performed at the top, middle, and bottom channels of the DUT, but only at the position of highest SAR at midfrequency. New methods have a well-defined testing. SAR robot positional accuracy must be better than ±0.2 mm.

SAR Probes

Most SAR probes now measure E-field in volts per meter (V/m^1), which allows SAR to be calculated. In addition to the E-field present, SAR is also dependent on the conductivity and permittivity of the tissue simulant. The equation used to calculate temperature-change SAR relates directly to the one used in current measurements.

SAR probes must be physically small. They must also have good spherical isotropy (i.e., measure equal amounts of E-field regardless of the angle or direction that the probe points toward the radiation source). In addition, SAR probes and their associated test setups must be designed so that they have an insignificant effect on the RF field.

For newer test methods, the probe is positioned at various points within either a phantom head or body filled with an appropriate tissue-simulant liquid. Head and body phantoms, in general, can only represent the shape of 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. However, these tissue phantoms are not practical for SAR testing. The probe cannot be moved within them, hence, the use of homogeneous phantom shells filled with tissue-simulant liquids. The phantoms do not take into account natural body thermoregulation by bloodflow; therefore, the rates of temperature rise within the body deduced from SAR measurements include a safety margin.

Because no known recipes for fluids are representative of body tissue at all frequencies, different tissue simulant fluids are required for different frequencies (e.g., 900 MHz for GSM 900 and 1800 MHz for 1800 products). The brain simulant must be calibrated to ensure that the permittivity and conductivity are correct for the frequency being tested. Fluids are often made from a mixture of distilled water, sugar, and salt. Some frequencies, however, require other chemicals to obtain the required properties.

SAR testing is performed on handset devices by placing them at various positions on both sides of the phantom head. The tip of the SAR probe is 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.

All current specifications require testing to be performed at the maximum power of the device under test (DUT). The use of maximum power is intended to represent the DUT's worst-case scenario. However, depending on their location in relation to base stations, mobile phones do not always transmit at maximum power. SAR probes average the duty cycles for radio devices that do not transmit continuously. For example, a GSM mobile phone transmits for only about one-eighth of

Standards

Several groups have pushed recently to standardize test methods for SAR testing, including uncertainty calculations. Although new standards for measurement have been issued, the overall SAR limits have not changed. CENELEC and IEEE have produced similar specifications because the majority of people involved in writing them were on both boards. The CENELEC standard, EN 50360, has recently been published in the Official Journal of the European Communities as a harmonized standard. EN 50360 references EN 50361, which contains the test methods. SAR test method specification IEEE P1528 is already in draft format and should be due for release shortly.

In Europe, a key problem with the CENELEC standard is 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."[3] The standard does not contain the actual limits. Actual limits can be found in either the ICNIRP Guidelines (April 1998) or Council Recommendation 1999/519/EC Annex II.[4,5] EN 50360 applies to devices transmitting with an average power greater than 20 mW and in the frequency range of 300 MHz to 3 GHz.

Devices that transmit ¾20 mW are "deemed to comply with the basic restrictions without testing." No standards have been harmonized for devices other than those such as mobile phones and cordless phones. However, manufacturers must still comply with the EU SAR limits for devices such as PDAs that have an integral RF module for GSM. Such devices are tested against flat phantoms that simulate body parts.

In the United States, the limits and applicable products are contained in Title 47 of the *Code of Federal Regulations* 47 CFR Part 2.1093, which covers portable devices with transmitters within 20 cm of a user's body.[6] It also includes an applicability list that encompasses virtually all radio products, depending on their output power. A full explanation of the relevant parts, SAR limits, and SAR test methods is contained in FCC OET Bulletin 65 Supplement C.[7]

A recent development in Australia has delayed plans for more-aggressive SAR requirements. The Australian Communications Authority postponed a proposal to extend the scope of SAR testing. That scope would have included all radio products except emergency beacons. Test methods have not yet been developed for implementing some of the required testing.

SAR Data

For the UK, the Stewart Report recommends that information on SAR values for mobile phones should be readily accessible to consumers at the phone's label, and making it available via the phone's display. The report also recommends publishing such data on a national Web site.

New well-defined testing methods incorporate recent key developments.

In the United States, the Cellular Telecommunication Industry Association (CTIA) requires that any mobile phone it certifies be sold with explanatory information. This information must confirm that the phone has passed FCC safety standards. Manufacturers must also include applicable SAR data for that phone and an explanation of how the SAR testing was done.

The Mobile Manufacturers Forum (including Alcatel, Ericsson, Mitsubishi Electric, Motorola, Nokia, Panasonic, Philips, Siemens, and Sony) reports SAR values on its Web site (http://www.mmfai.org). The site provides SAR information on all new models of mobile phones. Information is also posted for existing models still in production.

Protection Devices

Some devices are being marketed to protect users from RF or SAR, but until formal test procedures are established and results are published for these products, it is difficult to comment on their effectiveness. One report found that hands-free kits may actually increase SAR levels within the human brain, but the test methods used for the report have fallen into question. These effects have never been repeated.[8] To the contrary, SAR test reports from various test houses show that hands-free kits considerably reduce SAR levels.

Conclusion

New developments in SAR testing can be expected as knowledge of radiation effects increases. Improved standards and legislation should follow. In Europe, standards are set to be adopted by CENELEC that will cover products such as GSM base stations, antitheft ports, and low-power radio devices. In the United States, FCC has cautioned that further revisions to Supplement C can be anticipated before it adopts draft standard IEEE P1528.

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