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Specific Absorption Rate (SAR) Testing, From a Test Laboratory Perspective.

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Abstract: **Specific Absorption Rate Testing (SAR) is now the industry standard for measuring the amount of energy absorbed by biological tissue. There are several systems available, each with their own unique characteristics. RFI Ltd have commissioned the Schmid and Partners DASY3 system, which is a fairly simple system to use, however, the industry requirements have shown that the present testing facilities and standards available are limited in some respects.**

Introduction

With increased public concern over the safety and potential hazards associated with human exposure to RF Electromagnetic Fields radiated by mobiles telephone handsets and similar devices, it has become necessary to employ a method of quantifying the amount of energy absorbed by biological tissue. The method most commonly used is the measurement of the specific absorption rate or SAR as it is usually referred to. SAR is traditionally defined as "*The time derivative of the incremental electromagnetic energy absorbed by an incremental mass contained in a volume element of given mass density*"

The Electric field is measured in a medium of a given permittivity and the SAR value is calculated using the following equation:

$$SAR = \sigma \frac{|E_{rms}|^2}{\rho}$$

Where σ is the conductivity of the medium in which the Electric Field measurement is made and ρ is the density of the medium.

The units are Watts per Kilogram (W/Kg), and the measured values are averaged over a prescribed volume mass, namely 1g and 10g masses.

The Present Standards

The International Commission on Non-Ionising Radiation Protection (ICNIRP) and the National Radiological Protection Board (NRPB), have both published guidelines on the limiting of exposure to RF fields. The SAR standards available have limits similar to that of the guidelines.
Many countries throughout the world are beginning to recognise SAR test levels, although most have yet to make testing mandatory. Much research has been conducted over many years towards the manifestation of a recognised industry standard, and at present a number exist. The USA have produced IEEE C95.1:1999 which provides the SAR limits. The compliment document IEEE C95.3:1997 provides methods of testing, although it is believed the FCC will accept other procedures provided

it can be shown that these are competent. The most recent document in the USA is OET Bulletin 65, which gives up to date information on the requirements for SAR testing. The SAR limit given in these documents is 1.6 W/Kg in a 1g averaging mass.
In Europe the recognised standard is ES59005, which gives a 2W/Kg limit in a 10g averaging mass. The next generation of this European standard, prEN50361, is in final draft form awaiting adoption.
In Australia the required standard is based upon AS/NZS 2772.1 and AS/NZS 2772.2. This is similar in method and limits to that of the USA standards. Canada, Korea and Japan have provided guidelines on limits but no strict procedures appear to have been provided. This information is found in ETS TR 134 925 v3.0.0.

The R&TTE Directive 99/5/EC states in section 3.1(a), that *"the protection of the health and the safety of the user and any other person, including the objectives with respect to safety requirements contained in Directive 73/23/EEC"* Since safety requirements have to be considered here, it is suggested that measuring SAR levels and comparing with National Guidelines might be prudent.

The Measurement systems.
There are various systems available for making SAR measurements. These vary from a single position fixed probe to the more advanced fully computer controlled positioning and data processing systems. The system employed by Radio Frequency Investigation Ltd, is the DASY3 automated system from Schmid and Partner, Switzerland. This comprises an accurate robotic arm probe positioning system, which is completely controlled from a remote PC. The measurements are made in a *Generic Phantom head*, which is essentially an open trough with the left and right hand sides of the trough designed to have dimensions similar to that of the left and right hand sides of the human head respectively. The trough is filled with a fluid, which simulates the dielectric properties of human brain tissue. Different fluids are required for measurements at different frequencies, and other fluids are available that simulate various biological tissues, such as muscle.
Before the test commences, a validation procedure is performed, using a dipole with a known SAR rating. If the SAR value measured differs from that calibrated, then checks are made on the system and the biological material. An example of the cause of variations in validation would be water evaporation from the brain simulating fluid.
The device under test is then placed at defined positions beneath the phantom and the probe is immersed into the fluid and the measurements made.
Before the actual SAR measurements are made, the system performs a number of checks to ensure that the probe is in the correct position. This is in the form of a mechanical and an optical proximity check. A course scan is then made to determine the *hotspot,* the area of highest SAR level. Then system then moves in and does a more resolute scan, incorporating the polynomial interpolation as required by the standard. At the end of the test the 1g and 10g averaging SAR results are produced. These results can be shown graphically with a background diagram of the device under test.

Characteristics of the Test system and client requirements – The Perspective of the Test Laboratory.
As previously discussed, there are a number of checks and procedures that have to be performed in order to ensure

that the uncertainties and errors of the measurements are minimised. Since the system is made up of many complex parts, it is important that maintenance is carried out regularly. In particular, the tissue equivalent material, which should have a lifetime of about 6 months, tends to need renewing every 6-8 weeks. This is due to the amount of work being performed with the fluid and the fact that, regularly, the fluid has to be removed and then refilled in the phantom. A small amount of fluid is lost when the probe is cleaned after each bout of testing. This loss accumulates and becomes appreciable when the testing is continuous.

Due to the various types, shapes and operation of the many mobile telephone handsets available, it is quite difficult to follow the exact procedure presented in the standards to the letter. The first problem arises when trying to position the handset in the device-positioning jig. Due to the many various shapes of handset, difficulty arises when trying to determine the plane of the "reference line". The standard only refers to "box" and "banana" phones, therefore a degree of interpretation and judgement has to be applied by the engineer, since not all phones seat comfortably into these categories. To ensure traceability and repeatability of the positioning of the telephone handset, the perpendicular distance from the base of the antenna to the phantom is measured and recorded. High resolution, digital photographs are also taken and filed with the results.

Much of the work performed is R&D on handsets very much in the development stage and this again may cause problems. The RF module may have difficulty in sustaining the call and often the software in the handset may be prone to "glitches". In this event steps are taken by RFI's engineers to optimise the customers time and resources. Advice and technical help is given wherever possible.

Even earlier in the development stages, the customer's requirement may be, that they wish to test a module, so early in development, that it does not have an enclosure or is a module, not intended for implementation within a mobile handset. The standards available do not adequately address these type of modules. Therefore, it may be necessary to utilise engineering judgement and experience to provide a suitable test configuration and procedure that is typical of a real situation. Again, photographs are taken to ensure repeatability. This also applies to accessories such as chargers and hands free kits. These types of accessories are also gaining a lot of attention in the media and there is much discussion at the moment on how these units should be tested. It is believed that much research is needed into the development of test standards, and in particular the procedure, that adequately envelops these accessories. There are many factors that apply which is beyond the scope of this document.

The greater part of the industry is in possession of the standards, if not they are very much aware of their existence. However, it has become apparent that their understanding of the deeper technical aspects, particularly the interpolation and extrapolation methods, is minimal. This is by no means a fault! The standard is hard reading and it is clear that a considerable knowledge of physics, mathematics and statistics is required. And not just at rudimentary level!! Wherever possible, RFI offers advice on the finer aspects of the standard and attempts to explain the working of the standard in a format that is "palatable"

There is concern from the industry, about the 1g averaging mass (generally, the limit is 1.6W/Kg). This is a difficult limit to meet, and it has been suggested that in the future, may be a harmonised level between the 1g and 10g averaging masses may be established. However, that is for the standards machinery to decide, but first indications are that the industry may have a few comments to contribute. Only the future will tell!!

In Conclusion

Greater awareness of the health issues has become the norm and many governments are looking to adopt a form of recognised standard. However, from our perspective, the requirements of the industry are not fully addressed within the standards. It appears, as may often be the case, that technological advancement of the RF industry is surpassing the standards that are developed to service it. This is causing some concern, and as a result, the independent test houses are trying to accommodate the customer as adequately as possible, through experience and engineering initiative. The ever-increasing number of accessories that are becoming available are not adequately serviced by the standards. It is apparent that their contribution to the radiation mechanism is real and this needs to be fully addressed.
Finally, full and thorough documentation and data recording is required to ensure traceability when non-standard customer requirements are exercised.

Further Information:

If you require any further information on any points covered in this document then please feel free to contact Joe Lomako on the following:

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