Probe Linearity Uncertainty

Uncertainty:

Over range of 0.01 – 100 W/kg: **+/- 2.92 %**

Standard:

IEEE P1528/D1.2, April 21, 2003 ***E.2.4 Probe linearity uncertainty***

E-field probe linearity uncertainty is assessed using the procedures described in Clause 3 (see 3.3.1) and A (see A.2) according to the square of the measured electric field strength magnitude. Since diode sensors can become peak detectors in pulsed fields, pulsed signals at 10% duty factor with a repetition rate of 500 Hz should be used to assess probe linearity. The assessment should be in the range of 0.4 W/kg to 100 W/kg in steps of 3 dB or less. The SAR tolerance is determined as the maximum deviation in the square of the measured and actual field strength for the entire assessment. A rectangular probability distribution has been assumed for probe linearity uncertainty in Table 7.1

Procedure:

To measure the response of the probe and amplifier to modulated signals, the probe is held vertically in a liquid-filled waveguide.

An RF amplifier is allowed to warm up and stabilise before use. A spectrum analyser is used to demonstrate that the peak power of the RF amplifier for the CW signals and the pulsed signals are within 0.1dB of each other when the signal generator is switched from CW to modulated output. Subsequently, the power levels recorded are read from a power meter when a CW signal is being transmitted.

The test sequence involves manually stepping the power up in regular (e.g. 2 dB) steps from the lowest power that gives a measurable reading on the SAR probe up to the maximum that the amplifiers can deliver.

At each power level, the individual channel outputs from the SAR probe are recorded at CW and then recorded again with the modulation setting. The results are entered into a spreadsheet. Using the spreadsheets, the modulated power is calculated by applying a factor to the measured CW power (e.g. for GSM, this factor is 9.03dB). This process is repeated 3 times with the response maximised for each channel sensor in turn.

The probe channel output signals are linearised with the DCPs determined from the linearisation procedure. Calibration factors for the probe are used to determine the E-field values corresponding to the probe readings. SAR is determined from the equation below:

$$\text{SAR (W/kg)} = E_{liq}^2 \text{ (V/m)} * \sigma\text{(S/m)} / 1000$$

Where σ is the conductivity of the simulant liquid employed.

Using the spreadsheet data, the DCP value for linearising each of the individual channels (X, Y and Z) is assessed separately.

Additional tests have shown that the modulation response is similar at 1800MHz and is not affected by the orientation between the source and the probe.

Probe integration-time uncertainty

Uncertainty:
GSM / GPRS: **±0.4%.**
CDMA/FDM: **0.00%**
The uncertainty of GSM/GPRS is used in the Table of Measurement Uncertainties.

Standard:
IEEE P1528/D1.2, April 21, 2003 ***E.2.8 Probe integration-time uncertainty***

Probe integration-time uncertainties may arise when test devices do not emit a continuous signal, such as the digital modulations used in some handsets. When the integration time and discrete sampling intervals used in the probe electronics are not synchronized with the modulation characteristics of the measured signal, the RF energy at each measurement location may not be fully or correctly captured. This uncertainty must be evaluated according to the signal characteristics of the test device prior to the SAR measurement.

For signals with amplitude or pulse modulation components and a periodicity greater than 1% of the probe integration time, additional SAR tolerances must be considered when the probe integration time is not an exact multiple of the longest periodicity. The uncertainty should be assessed according to the maximum uncertainty expected for unsynchronized probe integration time with an assumed rectangular probability distribution. As an example, the tolerance for TDMA system can be estimated as follows:

$$\mathrm{SAR}_{\mathrm{tolerance}}[\%] = 100 \times \sum_{all\ sub-frames} \frac{t_{frame}}{t_{int}} \frac{slot_{idle}}{slot_{total}}. \qquad \text{(E.3)}$$

Here t_{int} is the probe integration time used in the measurement, $slot_{idle}$ is the number of idle slots in a frame with $slot_{total}$ being the total number of slots. The frame duration is t_{frame}, with $t_{frame} < t_{int}$. The total probe integration-time uncertainty is the sum of the errors for all sub-frames in the frame structure that have idle slots. For example, the basic frame for GSM systems has a frame duration t_{frame} = 4.6 ms, with 7 idle slots in an 8-slot frame, and the multi-frame duration is $t_{multi\text{-}frame}$ = 120 ms, 1 idle slot in a 26-slot frame. For a probe integration time of 0.2 s, the tolerance is estimated to be 0.0201 + 0.0231 = 0.0432 or 4.32%. The uncertainty for other modulations should be determined using similar means. For US TDMA (IS-136), t_{frame} = 20 ms, with 2 idle slots in a 3-slot frame, and no multi-frames. GPRS is the same as GSM, except that the number of idle slots can be 6, 5, …, where 7 idle slots is worst case.

Table 7.1 assumes a rectangular probability distribution for probe integration-time uncertainty. FDMA and CDMA devices are tested with continuous or CW-equivalent signals, therefore, a tolerance value of zero should be entered.

Procedure:
Integration Time:
For an integration time of t_{int} = 20 milliseconds (the SAR probes sampling rate), if 1 pulse was missed, this induces the following uncertainty:

$$u = 2.\frac{4{,}6x10^{-3}}{t_{\mathrm{int}}}$$

$$u = \pm 2.3\%$$

Only 1 pulse will be missed as a GSM standard TDMA signal has an idle frame of 1 in 26 over a period of 120 milliseconds. No other integration time figure is required as this is covered by the CW/TDMA investigation and linearity The Indexsar probe amplifiers have the facility for increasing the integration time in multiples of 20mS (50 Hz) or 16.67mS (60Hz). It is recommended that the integration period is set to 6 cycles for GSM phone testing. This reduces the uncertainty above as a good match with the frame rate can be achieved. The uncertainty above is reduced to ±0.4%.