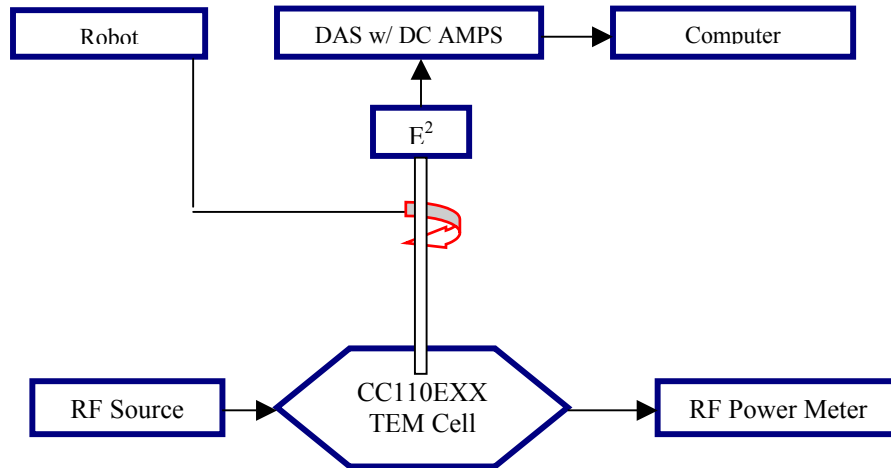


FREE SPACE CALIBRATION

Sensitivities are determined under the waveguide (free space) calibration feature of the software. The free space calibration determines the output from each of the probe channels in the known RF field.

Test Configuration:



Determining the E-field from Amplified Probe Outputs

The power density of the field in the TEM is set to 1 mW/cm².

The probe is rotated 360° in 10° increments.

The voltage output of each channel is recorded at each rotation.

The following are the equations used to find the sensitivity of each channel of the probe:

$$V_{avg} = ((V_{maxn} - OFF_n) + (V_{max2n} - OFF_n)) / 2$$

$$\eta_n = V_{avgn} / \sin^2(DA) / AmpGain_n$$

Where η is the sensitivity for channel n (mV/(mW/cm²)).

DA=Dipole Angle (nominally 54.7°)

V_{maxn} = maximum voltage recorded for channel n during a 360° rotation of the probe about its long axis within a TEM Cell containing an E-field perpendicular to the probe axis.

V_{max2n} = voltage of other peak (180° from max peak)

V_{avgn} = average voltage of both peaks in a single channel

OFF_n = DC voltage offset of channel n (i.e. the voltage output with the probe amplifier on and the RF-power off)

$AmpGain_n$ = Amplifier Gain (nominally 20x)

WAVEGUIDE CALIBRATION

Conversion Factor, γ , is determined by the fundamental SAR equation¹:

$$\begin{aligned} \text{SAR} &= \sigma/\rho |E|^2 = \sigma/\rho * [f_x/(\eta_x*\gamma_x) + f_y/(\eta_y*\gamma_y) + f_z/(\eta_z*\gamma_z)] \\ &= \sigma/(\rho*\gamma) * [f_x/(\eta_x) + f_y/(\eta_y) + f_z/(\eta_z)] \end{aligned}$$

And $f_i = 3770 * \text{avg}(\text{Ch}_i) * \text{Gain}_i$.

The relationship between the SAR at the cross-sectional center of the lossy waveguide and the longitudinal distance, z , from the dielectric separator in the waveguide² is:

$$\text{SAR (mW/cm}^3\text{/W)} = 4(P_f - P_b) / \rho ab \delta * \exp [-2z/\delta]$$

Where

a, b are the dimensions of the conventional waveguide in cm

δ is the penetration depth in cm

z is the distance from the bottom of the waveguide separator and the diodes in the probe in cm

ρ is the density of brain tissue, assumed to be 1.0 g/cm³.

When the system measures SAR, it outputs a z -scan plot which shows a retraction curve at the center of the waveguide. The line is extrapolated from the distance between the diodes in the probe to the bottom of the liquid via a software interpolation method.

With the computer generated interpolation, SAR($z=0$) can be determined from the “Zoom Scan SAR” (peak reading in scan area). This measured value can be compared to the theoretical value of SAR ($z=0$) via term substitution.

Using proprietary PCTEST curve-fitting software, the conversion factor is found. Calculations at three sample retraction depths are detailed below:

Sample Calculation: For 1900 MHz in the waveguide

$$\begin{aligned} \text{SAR}_{\text{theoretical}}(z=0) &= 4(P_f - P_b) / \rho ab \delta * \exp [-2z/\delta] \\ &= 4 (249) / (1.0 * 10.92 * 5.46 * 2.415) * \exp (0) \\ \text{SAR}_{\text{theoretical}}(z=0) &= 6.917 \text{ mW/g} \end{aligned}$$

Also $\text{SAR}_{\text{theoretical}}(z=3) = 4 (249) / (1.0 * 10.92 * 5.46 * 2.415) * \exp (-2*0.3/2.415) = 5.395 \text{ mW/g}$

And $\text{SAR}_{\text{theoretical}}(z=10) = 4 (249) / (1.0 * 10.92 * 5.46 * 2.415) * \exp (-2*1.0/2.415) = 3.022 \text{ mW/g}$

From the measurement taken in the waveguide,

$$\begin{aligned} \text{SAR}_{\text{measured}}(z=0, \gamma=1.0) &= 32.65 \text{ mW/g} \\ \text{SAR}_{\text{measured}}(z=3, \gamma=1.0) &= 25.23 \text{ mW/g} \\ \text{SAR}_{\text{measured}}(z=10, \gamma=1.0) &= 14.26 \text{ mW/g} \end{aligned}$$

¹ IEEE Std P1528-200X, A1

² *Ibid.*, A5

WAVEGUIDE CALIBRATION (CONTINUED)

For z=0,

$$\begin{aligned}\gamma &= \text{SAR}_{\text{measured}} / \text{SAR}_{\text{theoretical}} \\ \gamma &= 32.65 / 6.917 \\ \gamma &= \mathbf{4.720}\end{aligned}$$

And z=3,

$$\begin{aligned}\gamma &= \text{SAR}_{\text{measured}} / \text{SAR}_{\text{theoretical}} \\ \gamma &= 25.23 / 5.395 \\ \gamma &= \mathbf{4.677}\end{aligned}$$

And z=10,

$$\begin{aligned}\gamma &= \text{SAR}_{\text{measured}} / \text{SAR}_{\text{theoretical}} \\ \gamma &= 14.26 / 3.022 \\ \gamma &= \mathbf{4.719}\end{aligned}$$

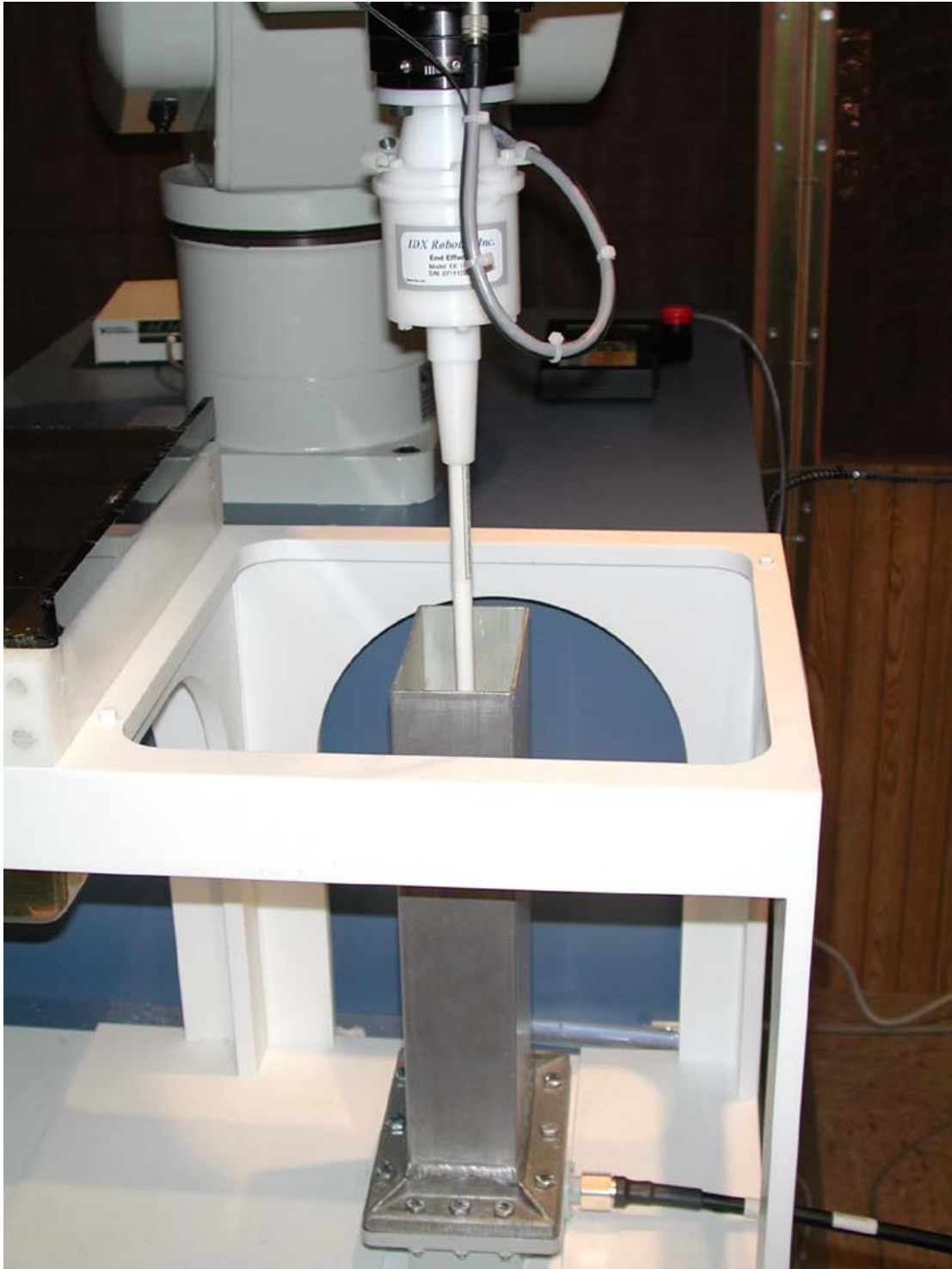
Applying the conversion factor into the software, another measurement is taken in the waveguide for verification. SAR(z=0, $\gamma = 4.7$) = 6.83 (-1.3% error)

Validation with $\gamma = 4.7$ resulted in $\pm 10\%$ of specification

WAVEGUIDE TEST SETUP PHOTOS (1900 MHZ)



WAVEGUIDE TEST SETUP PHOTOS (1900 MHZ)-CONTINUED



WAVEGUIDE TEST SETUP PHOTOS (1900 MHZ)-CONTINUED

