



SAR Measurement Considerations at 3-6 GHz

Proposed TCB Review Procedures

- May 2005 -



Overview

- current status
- goal
- SAR measurement difficulties
- recommended procedures
- proposed TCB review considerations
- questions & discussions



Current Status



SAR Measurement Standards

● 0.3 – 3.0 GHz

– SAR procedures for handsets only

- Supplement C-0101 (2001)
- IEEE Standard 1528 (2003)
- IEC 62209-1 (2005)

● 30 MHz – 6 GHz

– SAR procedures for body-worn and generic configurations

- IEC 62209-2 preliminary working draft (2005)



Typical 3 – 6 GHz Frequencies

- 5 GHz: 802.11a
 - §15.247: 5.725 – 5.850 GHz (125 MHz)
 - §15.407 UNII
 - 5.15 – 5.25 GHz (100 MHz)
 - 5.25 – 5.35 GHz (100 MHz)
 - 5.725 – 5.825 GHz (100 MHz)
 - 5.470 – 5.725 GHz (255 MHz)
- 2.4 GHz: 802.11 b/g with 802.11a built-in
 - §15.247: 2400 – 2483.5 MHz (83.5 MHz)



Other 3 – 6 GHz Frequencies

- 4.9 GHz public safety
 - Part 90, subpart Y
 - 4940 – 4990 MHz
- 5.9 GHz DSRCs (5.850 – 5.925 GHz)
 - OBUs - Part 95, subpart L (1.0 mW portable)
 - RSUs – Part 90, subpart M (hand carry option)
- 802.16 Wi-Max
 - licensed (3650 – 3700 MHz)
 - unlicensed (most likely 5 GHz)



SAR above 3 GHz

- no standard measurement procedures
 - 62209-2 preliminary working draft
- measurement requirements
 - 6 GHz field probe: available
 - tissue dielectric parameters: achievable
 - field scanning and analyses procedures: under investigation
 - system validation procedures: being confirmed by IEC TC106
 - test device configuration requirements: FCC initiated exploratory measurements



Goal

- establish acceptable test procedures to
 - minimize measurement variations
 - for SAR measurements above 3 GHz
 - in 802.11a/b/g device test configurations
 - provide necessary guidance for
 - manufacturers & test laboratories
 - TCB review & approval
 - to expand TCB scope on RF Safety
 - 3 – 6 GHz SAR review
 - certain multiple-antenna system SAR review



SAR Measurement Difficulties and Recommendations



3 – 6 GHz SAR Measurement

- field probes
- signal conversion
- system validation & verification
- Phantom & tissue dielectric properties
- SAR Scan procedures
- post-processing analysis



Penetration Depth

- penetration depth reduced at 3 – 6 GHz
 - about 6 mm at 6 GHz
 - 55% attenuation at 0.375 penetration depth
 - need measurements at 2-3 mm from phantom surface





Field Probe Requirements

- need measurements at 2-3 mm from phantom surface
- need to reduce probe tip diameter
 - to minimize probe boundary effect errors
 - from 6-7 mm for typical probes
 - to $\leq 3-4$ mm for 6 GHz probes
- need smaller sensor to probe tip offset
 - to reduce measurement point to phantom distance
 - from 2-3 mm sensor offset in typical probes
 - to 1-2 mm in 6 GHz probes
- available probes
 - 2.5 mm tip diameter
 - 1.0 mm sensor offset



Field Probe Proposals

	62209-2	FCC/TCB
frequency	> 2 GHz	3-6 GHz
probe tip	$\leq 16/f_{(\text{GHz})}$ mm (2.67 mm @ 6 GHz)	≤ 3 mm
sensor offset	$\leq 8/f_{(\text{GHz})}$ mm (1.35 mm @ 6 GHz)	≤ 1.5 mm
calibration	waveguide	
closest measurement	$\leq 8.0 \pm 1.0$ mm	< 5 GHz: $\leq 3.5 \pm 0.5$ mm ≥ 5 GHz: $\leq 2.5 \pm 0.5$ mm



Field Probe Calibration

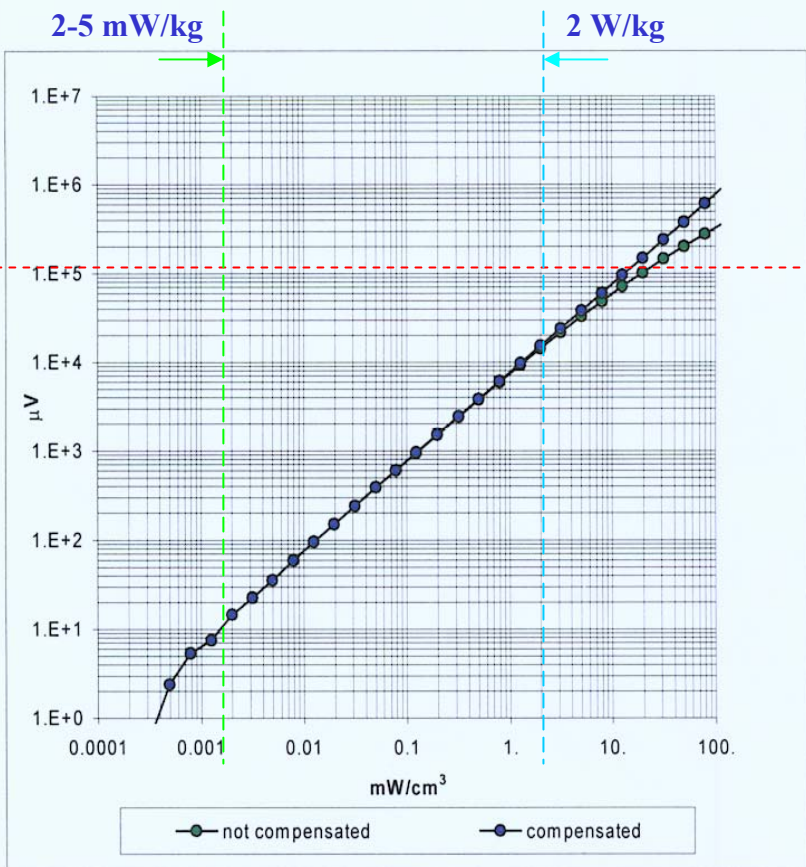
- specifications somewhat unclear in 62209-2
- proposed interim guidance for 3 – 6 GHz
 - validity of each calibration point
 - Supplement C-0101 dielectric parameters
 - $\geq \pm 50$ MHz, $U_c (k=2) \leq 15\%$
 - $\epsilon_r < 10\%$ and $\sigma < 5\%$ for calibration & measurements
 - $\geq \pm 100$ MHz, $U_c (k=2) < 20\%$
 - $\epsilon_r < 5\%$ and $\sigma < 2.5\%$ for calibration
 - $\epsilon_r < 5\%$ and $\sigma < 2.5\%$ between calibration & measurement
 - equipment certification by FCC only



Signal Compression

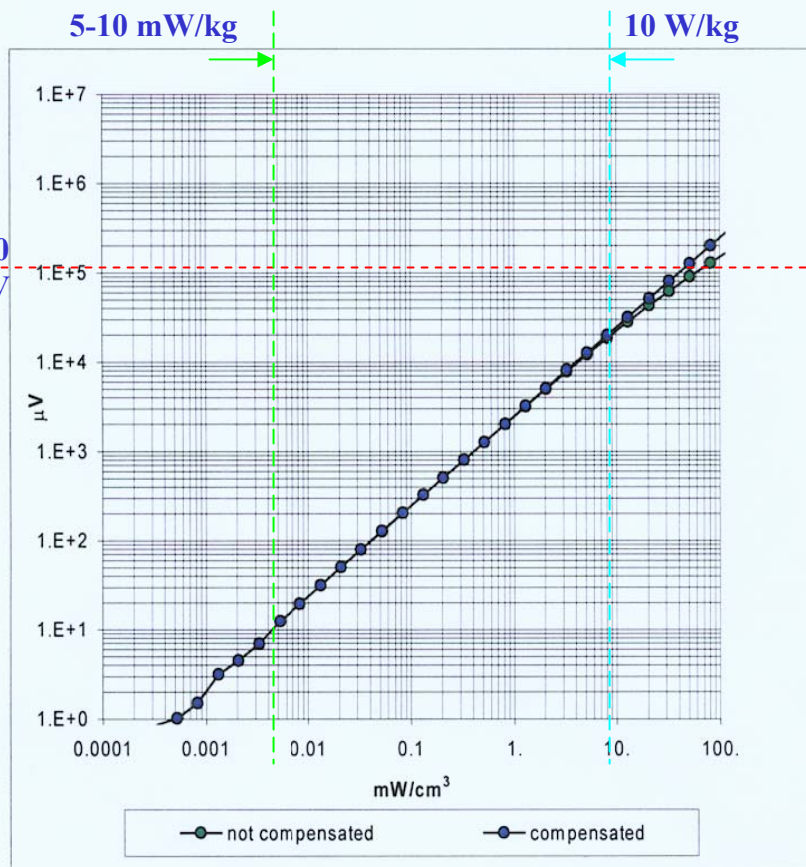
**6.8 mm
Probe**

Dynamic Range $f(\text{SAR}_{\text{head}})$
(Waveguide R22)



**2.5 mm
Probe**

Dynamic Range $f(\text{SAR}_{\text{head}})$
(Waveguide R22)

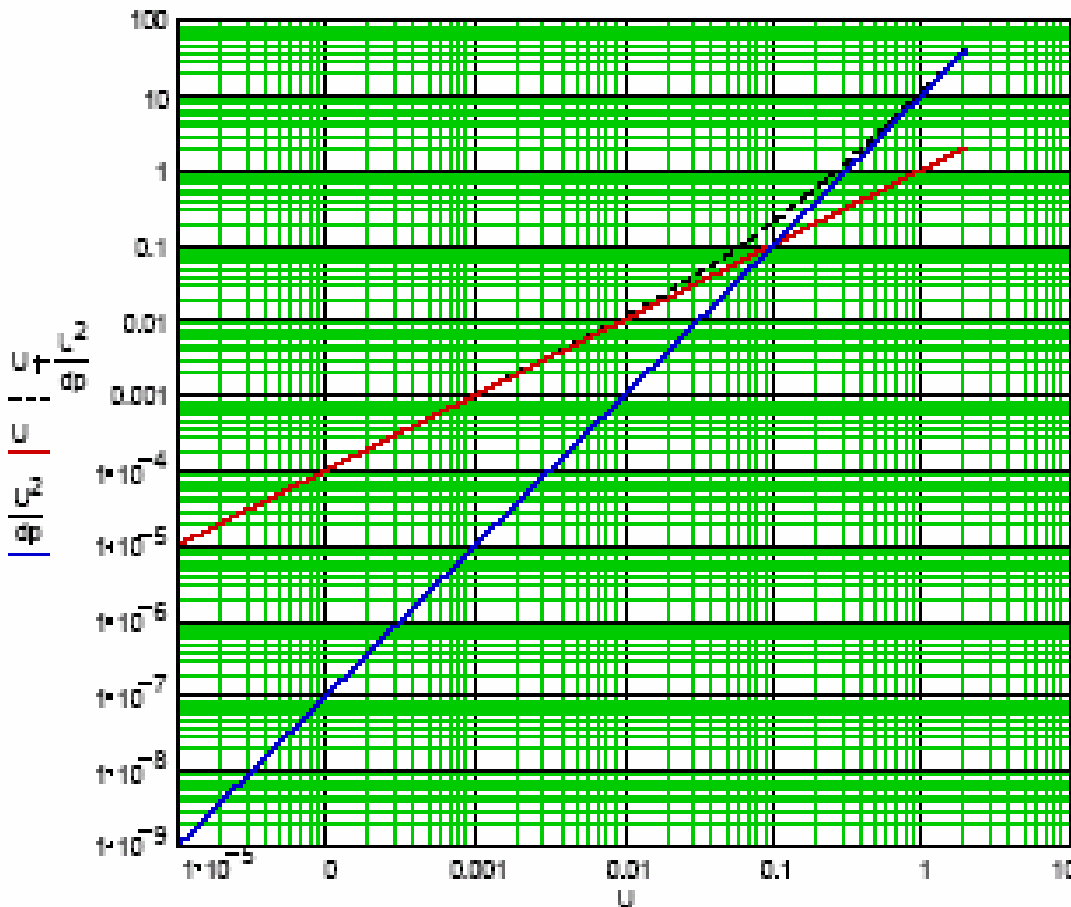




Signal Conversion

- SAR field-probe signal conversion equation in typical systems :

$$V_i = U_i + U_i^2 \frac{cf}{dcp_i}$$



- U_i is the measured voltage
- $V_i \propto$ power
- cf is \propto power
- dcp_i is the diode compression voltage

$$E_i = \sqrt{\frac{V_i}{Norm_i * ConvF}}$$

- $E_i \propto$ E-field



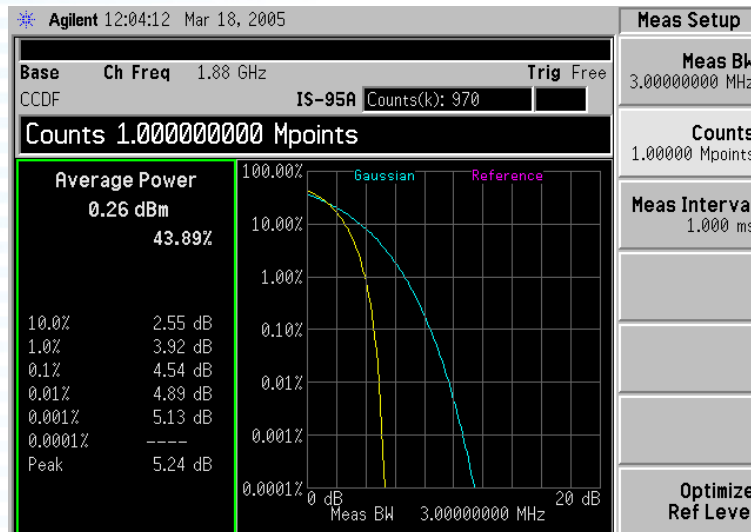
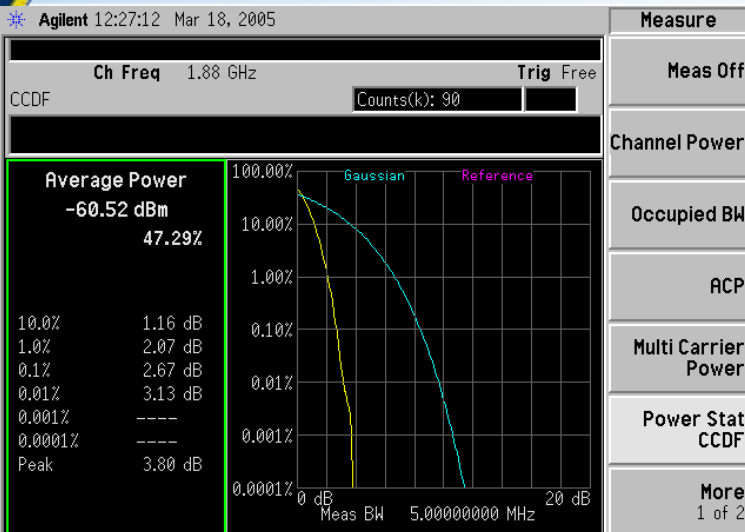
Duty Factor Compensation

- duty factor correction in existing systems are mostly intended for periodic signals, such as GSM or IS-136
- duty factor correction may be limited to certain
 - pulse repetition rate
 - pulse duration
- duty factor correction could be dependent on
 - probe design
 - probe calibration requirements
 - signal characteristics
 - crest factor variations within bursts
- duty factor correction for non-periodic signals may require additional considerations; for example, multiple carrier signals with different sub-carrier modulation & bandwidth

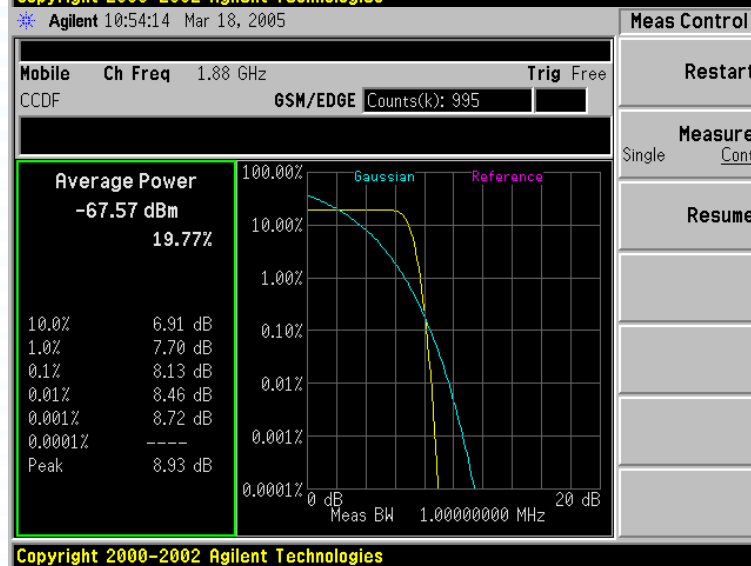
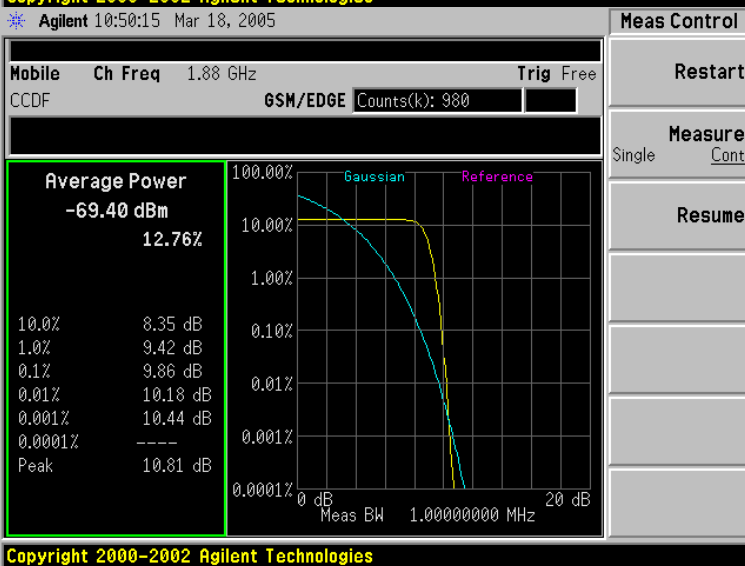


Duty Factor & Crest Factor

CW
IS-95



GSM 1 slot
GSM 2 slots





System Validation & Verification

- proposed procedures at 3 – 6 GHz
- using 62209-2 dipole configuration
 - within transmission band or ± 100 MHz of mid-band
 - $\epsilon_r < 10\%$ and $\sigma < 5\%$ for calibration & measurements
 - within 10% of 1-g SAR targets
 - within 15% of extrapolated peak SAR at phantom surface above dipole feed-point



Optional Verification Procedures

- SAR system verification procedures for wideband requirements at 3 – 6 GHz
- apply same tolerances as dipole target values
- within ± 200 MHz of mid-band, $\epsilon_r < 5\%$ and $\sigma < 2.5\%$
 - both verification and routine measurement should be based on
 - **same probe calibration point – single points**
 - **same tissue simulating liquid**
 - **same area and zoom scan resolutions**
 - **same interpolation and extrapolation resolutions**
- equipment certification by FCC only
 - measurements with extended probe calibration range $> \pm 100$ MHz based on a single probe calibration point
 - use of other RF sources for system verification



Phantom Requirements

- IEEE Standard 1528 & IEC 62209-1
 - SAM & flat phantom
- tissue dielectric parameters
 - $\epsilon_r < 10\%$ & $\sigma < 5\%$ of Supplement C-0101 head & body targets
 - water and non-polar liquid mixture/suspension

flat phantom	62209-2	FCC/TCB
shell (ϵ_r)	4 ± 1	≤ 5 (IEEE 1528)
size	20% > DUT $\geq 24 \times 16 \text{ cm}^2$	5 cm around measurement region
liquid depth	measured SAR variation < 1%	10 cm



Area Scan Requirements

	62209-2	FCC/TCB
peak location accuracy	± 5 mm	± 5 mm
scan resolution	≤ 20 mm	≤ 10 mm
distance to phantom surface	proposed: 4 ± 0.5 mm considered: 8 ± 1.0 mm	< 5 GHz: $\leq 3.5 \pm 0.5$ mm ≥ 5 GHz: $\leq 2.5 \pm 0.5$ mm
peak to scan boundary dist.	$\frac{1}{2}$ zoom scan dimension (IEEE 1528 / IEC 62290-1)	≤ 10 mm



Zoom Scan Requirements

	62209-2	FCC/TCB
scan volume	$\geq 30 \times 30 \times 30 \text{ mm}^3$ ≥ 1.3 times gram-cube linear dimension	$\geq 25 \times 25 \times 25 \text{ mm}^3$ recommend $30 \times 30 \times 25 \text{ mm}^3$
scan resolution	$x/y: 24/f_{(\text{GHz})} \text{ mm}$ $z: 12/f_{(\text{GHz})} \text{ mm}$ (4 / 2 mm @ 6 GHz)	$x/y: < 4.5 \text{ mm}$, recommend $\leq 3.0 \text{ mm} \geq 5 \text{ GHz}$ $z: < 2.5 \text{ mm}$, recommend $\leq 2.0 \text{ mm} \geq 5 \text{ GHz}$
distance to phantom surface	proposed: $\leq 4 \pm 0.5 \text{ mm}$ non considered	$< 5 \text{ GHz}: \leq 3.5 \pm 0.5 \text{ mm}$ $\geq 5 \text{ GHz}: \leq 2.5 \pm 0.5 \text{ mm}$
closest 2 two measurement points	proposed: $< 5 \text{ mm}$ none considered	$< 5 \text{ mm}$
graded grids	proposed earlier none considered	$1^{\text{st}} \text{ point} \leq 2.0 - 2.5 \text{ mm}$ initial grid $\leq 2.0 \text{ mm}$ grid ratio < 2.0 , recommend 1.5



Post-Processing Analyses

- large peak to 1-g averaged SAR ratio
 - 6 mm penetration depth (δ) at 6 GHz
 - 55% of energy attenuated at 0.375δ
 - extent of 1-g cube is about 2δ
 - only points closest to phantom are useful
 - very low values in rest of scan volume
 - 1-g SAR very insensitive to measurement & extrapolation errors
 - extrapolated SAR at phantom surface highly dependent on measured values
 - **highest SAR and noise in the low SAR values**
 - **attenuation characteristics assumed by extrapolation algorithms of measurement system**



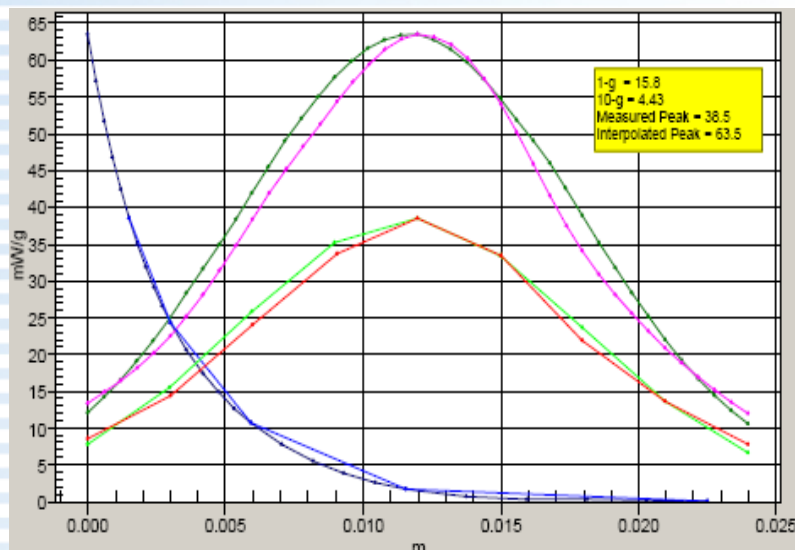
Post-Processing Requirements

- extrapolated/interpolated data should be at least equivalent to those typically measured with
 - 5 mm area scan resolution
 - 1 mm zoom scan resolution
- verify post-processing algorithms
 - according to 62209-2 reference functions
 - with the post-processing procedures in the SAR system according to the same area and zoom scan resolutions used during measurement
- verify potential extrapolation errors in zoom scan with 2-D profile plots through peak SAR location in x, y & z direction



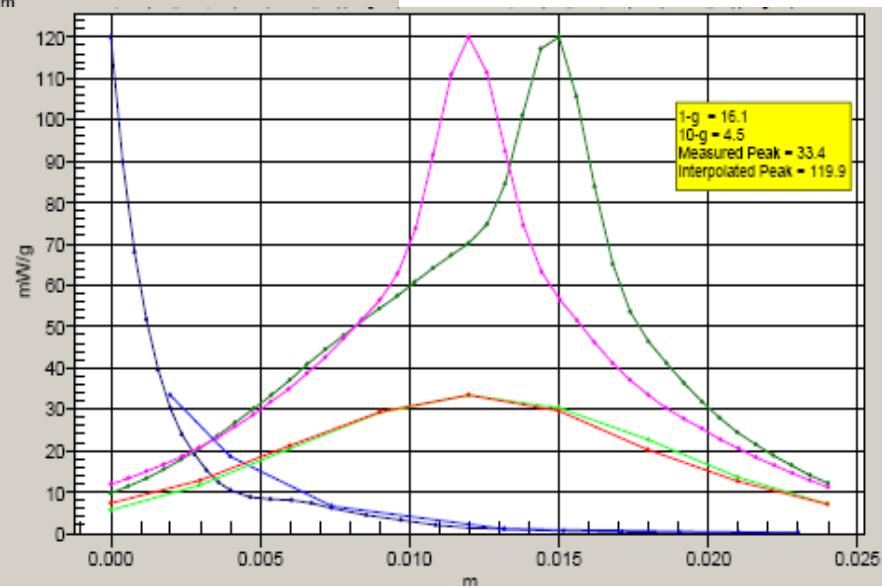
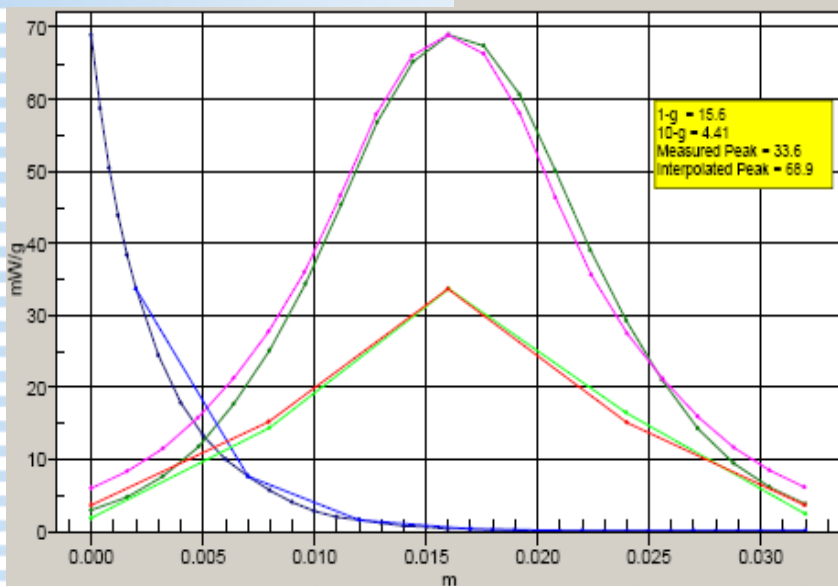
Extrapolation Errors

typically expected



acceptable

unacceptable





TCB Review Considerations

- TCB review proposal (time frame TBD)
 - requires previous SAR training qualifications
 - device tested according to
 - applicable 3-6 GHz procedures
 - applicable LAN device configurations or other DUT operating configuration requirements
- FCC review required if device
 - not tested as specified in various recommended procedures
 - signal characteristics
 - < 10% pulse duty factor
 - periodic repetition rate < 10 Hz
 - non-periodic signals