The Procedures described in this presentation are available in the following KDB publications:

- **KDB 941225:**
  - SAR Measurement Procedures for 3G Devices
    - CDMA 2000 / Ev-Do
    - WCDMA / HSDPA

- **KDB 865664:**
  - SAR Measurement Requirements for 3 – 6 GHz

- **KDB 248227:**
  - SAR Measurement Procedures for 802.11 a/b/g Transmitters
**Agenda**

- SAR Measurement Procedures for 3G Devices
  - CDMA 2000 / Ev-Do
  - WCDMA / HSDPA
- SAR Measurement Requirements for 3 – 6 GHz
- SAR Measurement Procedures for 802.11 a/b/g Transmitters
- SAR Measurement Procedures -

for

3G Devices

CDMA 2000 / EV-DO
WCDMA / HSDPA

(Released June 2006)
Overview

- SAR measurement procedures for 3G devices
  - Part 22 & Part 24 handsets and data modems
  - procedures may not fully apply to other radio services
  - test configurations are mostly derived according to
    - 3GPP2/TIA & 3GPP standards
- devices are tested according to
  - operating capabilities and dominant use conditions
- device test configurations are standardized
  - for head & body SAR measurements
  - to minimize SAR variations
CDMA 2000 procedures for Release 0 & Release A handsets with
- MS Protocol Revision 6 & 7
  - 1x RTT only or
  - 1x RTT and built-in Ev-Do

Head/body SAR is measured in RC3
- with established radio link through call processing
- using the same RC in forward and reverse links

SAR in RC1 is selectively confirmed
- according to output power and exposure conditions
Output Power

- verify maximum output power
  - on high, middle and low channels
  - according to 3GPP2 C.S0011 / TIA-98-E, Sec. 4.4.5
  - to determine SAR test configurations

- power measurement configurations
  - Test Mode 1, SO55, RC1, Traffic Channel @ 9600 bps
  - Test Mode 3, SO55 or SO32, RC3, FCH @ 9600 bps
  - Test Mode 3, SO32, RC3, FCH+SCH @ 9600 bps
  - other configurations supported by the DUT
  - power control
    - Bits Hold for FCH+SCH
    - otherwise All Bits Up
Head SAR

- measure in RC3
  - at full rate with Loopback SO55
  - according to applicable requirements
    - in Supplement C 01-01 & IEEE 1528

- measure in RC1 on the maximum output channel
  - \textbf{only} if maximum average output $\geq \frac{1}{4}$ dB higher than RC3
  - use the exposure configuration that result in the highest SAR for that channel in RC3
    - highest SAR configuration among left & right side, touch & tilt positions with antenna extended and retracted
Body SAR

- measure in RC3 at full rate using TDSO SO32 with
  - FCH only (may use SO55 instead of SO32)
  - FCH + SCH (must use TDSO SO32)
    - only if the maximum average output power ≥ ¼ dB higher than with FCH only
    - use the exposure configuration that result in the highest SAR for that channel with FCH only
    - monitor output fluctuations and SCH dropout

- measure in RC1
  - only if the maximum average output power ≥ ¼ dB higher than RC3 FCH only & FCH + SCH
  - use the body exposure configuration that result in the highest SAR, with antenna extended and retracted, for that channel in RC3
Ev-Do

Procedures for Rev. 0 & Rev. A (IS-856 / TIA-856-A)
– Ev-Do & 1x RTT may roam but not simultaneously active

measure SAR
– with established radio link through call processing
– or use chipset based Factory Test Mode (FTM) with communication test set and no call processing

configure DUT according to
– FTAP/RTAP (C.S0029-0) and Subtype 0/1 PHY configurations
– FETAP/RETAP (C.S0029-A) and Subtype 2 PHY configurations
– maximum output power procedures in C.S0033

SAR in 1x RTT & Ev-Do Rev. A are selectively confirmed
– according to output power and exposure conditions
Output Power

configure measurements according to
– C.S0033-0 / TIA-866 for Rev. 0
  • FTAP: 2 slot version of 307.2 kbps; ACK in all slots
  • RTAP: 153.6 kbps in Subtype 0/1 PHY configuration
– C.S0033-A for Rev. A
  • FETAP: 2 slot version of 307.2 kbps with ACK in all slots
  • RETAP: 4096 bits payload with 16 slot termination target in Subtype 2 PHY configuration

power control
– ‘All Bits Up’ in both FTM & call processing modes
Head & Body SAR

- body SAR
  - is required for Rev. 0 in Subtype 0/1 PHY configuration
  - is **NOT** required for Rev. A when the maximum average output power in Subtype 2 PHY configuration is less than in Subtype 0/1
    - otherwise, measure SAR on the maximum output channel using the exposure configuration that result in the highest SAR for that channel in Rev. 0

- head SAR is **NOT** required unless
  - device supports VOIP for operations next to ear
Ev-Do & 1x RTT

1x RTT SAR is **NOT** required for Ev-Do devices
- when the maximum average output power for 1x RTT < $\frac{1}{4}$ dB higher than Subtype 0/1
  - otherwise, measure body SAR with CDMA 2000 procedures

SAR is **NOT** required for handsets with built-in Ev-Do
- when the maximum average output power for Ev-Do Rev. 0 < $\frac{1}{4}$ dB higher than 1x RTT in RC3
  - otherwise test SAR in Subtype 0/1 PHY configuration on the maximum output channel using the exposure configuration that result in the highest SAR for that channel in RC3
- when the maximum average output power for Ev-Do Rev. A < Rev. 0 or < $\frac{1}{4}$ dB higher than 1x RTT RC3
  - otherwise test SAR in Subtype 2 PHY configuration on the maximum output channel using the exposure configuration that result in the highest SAR for that channel
WCDMA procedures for Release 99 & Release 5 handsets with
- WCDMA only
- WCDMA and built-in HSDPA

Head and body SAR is measured with
- established radio link through call processing
- 12.3 kbps RMC and Test Loop Mode 1

SAR is selectively confirmed for other physical channel configurations (DPCCH & DPDCHn)
- according to output power, exposure conditions and device operating capabilities
Output Power

- verify maximum output power
  - on high, middle and low channels
  - according to 3GPP TS 34.121, Sec. 5.2
  - using appropriate RMC or AMC with TPC set to all “1’s”

- power measurement configurations
  - 12.2 kbps RMC and 12.2 kbps AMC
  - other configurations supported by the DUT
    - 64, 144, 384, 768 kbps RMC
    - DPDCH₂...⁶ when applicable
Head SAR

- measured in 12.2 kbps RMC
  - according to applicable requirements
    - in Supplement C 01-01 & IEEE 1528

SAR is **NOT** required for AMC

- when the maximum average output power for 12.2 kbps AMC < ¼ dB higher than 12.2 kbps RMC
- otherwise, measure SAR on the maximum output channel in 12.2 kbps AMC with a 3.4 kbps SRB
  - use the exposure configuration that result in the highest SAR for that channel in 12.2 kbps RMC
    - highest SAR configuration among left & right side, touch & tilt positions with antenna extended and retracted
Body SAR

- measured in 12.2 kbps RMC

- SAR is **NOT** required for other spreading codes and multiple DPDCH\textsubscript{n} supported by the device
  - when the maximum output for each of these other configurations < $\frac{1}{4}$ dB higher than 12.2 kbps RMC
  - otherwise, measure SAR on the maximum output channel in each of these configurations

  - use the body exposure configuration that result in the highest SAR, with antenna extended and retracted, for that channel in 12.2 kbps RMC
HSDPA

procedures for Release 5

- HSDPA is an integral part of WCDMA
- HSDPA & WCDMA are simultaneously active

measured SAR

- with established radio link through call processing
- or chipset based Factory Test Mode (FTM) with
  communication test set and no call processing
- in WCDMA with 12.2 kbps RMC and Test Loop Mode 1
- in HSDPA with FRC and 12.2 kbps RMC using the
  highest SAR configuration in WCDMA

SAR is selectively confirmed for other physical channel
configurations (DPCCH & DPDCHₙ)

- according to output power, exposure conditions and
device operating capabilities
Output Power

- verify maximum output power
  - on high, middle and low channels
  - according to 3GPP TS 34.121, Release 5, Sec. 5.2
  - using appropriate FRC and RMC with TPC set to all “1’s”

- measurement configurations
  - 12.2 kbps RMC
  - 12.2 kbps FRC with 12.2 kbps RMC

- other configurations supported by the DUT
  - DPCCH, DPDCH<sub>n</sub>, spreading codes, HS-DPCCH etc.
Head & Body SAR

- when voice transmission and head exposure conditions are applicable
  - use WCDMA handset head SAR procedures

- body exposure for HSPDA data devices
  - use WCDMA handset body SAR procedures, and
  - FRC with a 12.2 kbps RMC in Test Loop Mode 1
    - using the highest body SAR configuration in 12.2 kbps RMC without HSDPA
RFC & H-Sets

- H-set is configured in FRC according to UE category
  - HS-DSCH/HS-PDSCHs, HARQ processes, minimum inter-TTI interval, transport block sizes, RV coding sequence are defined by H-set
- use QPSK in H-set
- use CQI feedback cycle of 2 ms in HS-DPCCH
- use $\beta_c=9$ and $\beta_d=15$ for DPCCH and DPDCH gain factors
- use $\Delta_{ACK}=\Delta_{NACK}=5$ and $\Delta_{CQI}=2$
- SAR Measurement Requirements -

for

3 – 6 GHz

(Released October 2006)
Overview

- identify SAR measurement and instrumentation issues
  - smaller penetration depth at higher frequencies
  - higher field gradients closer to the tissue boundary
  - existing SAR procedures for below 3 GHz are insufficient
  - tissue-equivalent media recipes require non-polar liquids

- review of FCC exploratory measurements and standards committees discussions
- provide interim guidance for equipment certification
- enable an acceptable level of measurement confidence while standards are being developed
Phantom

- head and flat phantom
  - according to Supplement C 01-01 & IEEE 1528 criteria
  - phantom shell issues under investigation by IEEE / IEC
    - need to account for underestimated SAR
    - $\pm 10\% \varepsilon_r$ & $\pm 5\% \sigma$ for liquid target value uncertainty
    - dielectric measurement uncertainty remains at $\pm 5\%$
    - 10 cm liquid depth from SAM ERP or flat phantom

- flat phantom size
  - 5 cm surrounding transmitter
  - or 3 penetration depths around measurement region
  - maximum of 2 overlapping area scans to cover entire projections of certain standalone fully integrated DUT
  - regions of host device not contributing to SAR may extending beyond phantom margin
Measurement Constraints

<table>
<thead>
<tr>
<th>Depth/Surface Energy Ratio (%)</th>
<th>3 GHz</th>
<th>4.5 GHz</th>
<th>6 GHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Probe Sensor to Phantom Surface Spacing (mm)</td>
<td></td>
<td></td>
<td></td>
</tr>
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</table>

October 2006 3 - 6 GHz SAR Requirements
# Probe Requirements

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Probe Tip Diameter</th>
<th>Probe Sensor Offset</th>
<th>Probe Calibration Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 4.5 GHz</td>
<td>≤ 4 mm</td>
<td>≤ 2 mm</td>
<td>± 50 MHz &gt; Probe Calibration ≤ ± 100 MHz Calibration Uncertainty</td>
</tr>
<tr>
<td></td>
<td>ε&lt;sub&gt;r&lt;/sub&gt; ≤ ± 10%, σ ≤ ± 5%</td>
<td>ε&lt;sub&gt;r&lt;/sub&gt; ≤ ± 10%, σ ≤ ± 5%</td>
<td>ε&lt;sub&gt;r&lt;/sub&gt; ≤ ± 10%, σ ≤ ± 5%</td>
</tr>
<tr>
<td></td>
<td>&lt; 15%, k=2</td>
<td>&lt; 15%, k=2</td>
<td>&lt; 15%, k=2</td>
</tr>
<tr>
<td>≥ 4.5 GHz</td>
<td>≤ 3 mm</td>
<td>≤ 1.5 mm</td>
<td>ε&lt;sub&gt;r&lt;/sub&gt; ≤ ± 5%, σ ≤ ± 2.5%</td>
</tr>
<tr>
<td></td>
<td>e&lt;sub&gt;r&lt;/sub&gt; ≤ ± 5%, σ ≤ ± 2.5%</td>
<td>e&lt;sub&gt;r&lt;/sub&gt; ≤ ± 5%, σ ≤ ± 2.5%</td>
<td>e&lt;sub&gt;r&lt;/sub&gt; ≤ ± 5%, σ ≤ ± 2.5%</td>
</tr>
<tr>
<td></td>
<td>&lt; 20%</td>
<td>&lt; 20%</td>
<td>&lt; 20%</td>
</tr>
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</table>

(Submit Certification to FCC)
**SAR Scan Requirements**

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Requirement Description</th>
<th>Requirement Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 4.5 GHz</td>
<td>Closest Measurement Point to Phantom</td>
<td>≤ 3.5 ±0.5 mm</td>
</tr>
<tr>
<td></td>
<td>Zoom Scan (x, y) Resolution</td>
<td>≤ 5 mm</td>
</tr>
<tr>
<td></td>
<td>Zoom Scan (z) Resolution</td>
<td>≤ 3 mm</td>
</tr>
<tr>
<td></td>
<td>Minimum Zoom Scan Volume</td>
<td>≥ 30 x 30 x 24</td>
</tr>
<tr>
<td></td>
<td>Minimum Zoom Scan Grid Points</td>
<td>≥ 7 x 7 x 9</td>
</tr>
<tr>
<td>≥ 4.5 GHz</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
SAR Scan Procedures

- probe boundary effect compensation required when
  - probe tip to phantom surface distance < ½ probe tip diameter
  - or probe boundary effects error > 5%

- area scan resolution ≤ 10 mm

- peaks in area scan > 1.0 cm from scan boundary

- zoom scan configurations
  - 1st two measurement points ≤ 5 mm of phantom surface
    - 3 points recommended above 4.5 GHz
  - when graded grids (z) are used
    - 1st point < 3 mm to phantom surface at < 4.5 GHz
    - 1st point < 2.0 mm to phantom surface at ≥ 4.5 GHz
    - subsequent graded grid ratio < 2.0; 1.5 recommended
  - 1-g SAR volume ≥ 5 mm from zoom scan boundary
Post-Processing

- post-processing algorithm accuracy
  - equivalent to 5 mm area scan measurement resolution
  - equivalent to 1 mm zoom scan measurement resolution

- verify with IEC 62209-2 SAR Reference Functions
  - 3 available functions to cover different SAR distributions
  - different area/zoom scan resolutions require independent verification

- verify interpolated/extrapolated peak SAR to identify post-processing errors
  - in highest SAR configuration
  - according to measured and extrapolated (curve-fitted) values
**System Accuracy**

- verify SAR measurement system accuracy
  - according to Supplement C 01-01 & IEEE 1528 criteria
  - using IEC 62209-2 (IEEE 1528a) reference dipoles
  - must measure within a valid probe calibration range

- system accuracy tolerance
  - 1-g SAR within 10% of manufacturer calibrated dipole target value
  - extrapolated peak SAR at phantom surface above dipole feed-point within 15% of calibrated target peak SAR of dipole
higher frequencies are mostly broadband
  – reference dipoles may not be available at desired frequencies
SAR systems may be verified
  – within device transmission band or within $\pm 100$ MHz of device mid-band frequency
  – within $\pm 200$ MHz of device mid-band frequency only if both system verification and DUT are measured
    • using the same tissue-equivalent medium
    • the same probe calibration point, area/zoom scan resolutions, interpolation and extrapolation procedures
Duty Factor vs. Crest Factor

For $t =$ pulse width and $T =$ period of a pulse train

Duty factor of a periodic pulse train is $t/T$

Crest factor (voltage) of a periodic pulse train is $\frac{1}{\sqrt{\frac{t}{T}}}$

Power $\propto$ voltage$^2$; therefore, peak to average power ratio is $T/t$

For TDMA with 2/6 duty factor, $c_f = 3$;

GSM with 1/8 duty factor, $c_f = 8$
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
- \( V_i \propto \text{power} \)
- \( cf \) is \( \propto \text{power} \)
- \( dcp_i \) is the diode compression voltage

\[ E_i = \sqrt{\frac{V_i}{Norm_i \ast ConvF}} \]

- \( E_i \propto \text{E-field} \)
- SAR Measurement Procedures -

for

802.11 a/b/g Transmitters

(Released October 2006)
Overview

- 802.11 a/b/g in §§15.247, 15.407 and Part 90Y
- Dynamic network operating configurations & conditions result in unreliable test environment
- Test mode conditions may not evaluate normal exposure
- Multiple data rates, modulation schemes, operating protocols (a/b/g), antenna diversity and other proprietary configurations require substantial test considerations
- SAR measurement difficulties relating to voltage crest factors and peak to average power ratios of random noise-like signals
SAR Evaluation

- measure SAR according to
  - Supplement C 01-01 and IEEE 1528 criteria
  - October 06 release: “3 – 6 GHz SAR Measurement Requirements”
- configure the DUT in chipset based Factory Test Mode
- test the required channels, proprietary modes and antenna diversity configurations
- report both measured and duty factor adjusted SAR
- verify voltage crest factor and peak to average power ratio issues before SAR measurements and apply modified procedures as necessary
## Modulation & Data Rate

<table>
<thead>
<tr>
<th>Data Rate (Mbps)</th>
<th>Modulation</th>
<th>Data Rate (Mbps)</th>
<th>Modulation</th>
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<tbody>
<tr>
<td>full</td>
<td>half</td>
<td>quarter</td>
<td>802.11 b/g</td>
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<td>6</td>
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<td>BPSK</td>
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<td>2.25</td>
<td>BPSK</td>
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# Part 15 Test Channels

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<tr>
<th>Mode</th>
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<th>Channel</th>
<th>Turbo Channel</th>
<th>“Default Test Channels”</th>
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<td>UNII 5.18 UNII 2.412 b/g</td>
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<td>5.24</td>
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<td>50 (5.25 GHz)</td>
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<table>
<thead>
<tr>
<th>Regulatory class</th>
<th>Channel starting frequency (GHz)</th>
<th>Channel spacing (MHz)</th>
<th>Channel set</th>
<th>Transmit power limit (mW)</th>
<th>Emissions limits set</th>
<th>Behavior limits set</th>
</tr>
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<tbody>
<tr>
<td>1</td>
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<td>20</td>
<td>36, 40, 44, 48</td>
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<td>52, 56, 60, 64</td>
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<td>3</td>
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<td>149, 153, 157, 161</td>
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<td>100, 104, 108, 112, 116, 120, 124, 128, 132, 136, 140</td>
<td>200</td>
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<td>1, 2, 3, 4, 5, 6, 7, 8, 9, 10</td>
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### Part 90Y Test Channels

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<th>Channel BW (MHz)</th>
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</table>
Antenna Diversity

- receive diversity only
  - identify and test dedicated transmit antenna

- legacy switched diversity
  - test and determine highest SAR antenna
    - complete tests using antenna with highest SAR
    - test both antennas if SAR > 1.2 W/kg & > 25% variation
  - apply defined duty factor

- spatial diversity MIMO & cyclic delay diversity
  - simultaneous transmission

- 2-antenna beam-forming
  - simultaneous transmission + maximum EIRP condition

- other diversity configurations: contact FCC
  - STC, phased array, n-antenna beam-forming etc.
devices should be tested according to these procedures to qualify for TCB approval

- SAR Measurement Procedures for 3G Devices
  - CDMA 2000 / Ev-Do
  - WCDMA / HSDPA
- SAR Measurement Requirements for 3 – 6 GHz
- SAR Measurement Procedures for 802.11 a/b/g Transmitters

otherwise, contact the FCC to determine if

- exceptions can be made
- additional procedures and/or requirements may apply
- application should be submitted to the FCC for approval