RF Exposure Procedures

TCB Workshop
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Laboratory Division
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Overview

- Further updates on the RF exposure KDB drafts released for comments in April and September
  - Draft KDB 447498 – mobile & portable RF exposure
  - Draft KDB 865664 – SAR methodology & reporting
  - Draft KDB 616217 – laptop and tablet computers
  - Draft KDB 648474 – wireless handsets
  - Draft KDB 941225 – SAR procedures for LTE
  - Draft KDB 643646 – occupational PTT 2-way radios
    - delayed due to request to extend the commenting period
  - TCB Exclusion and PBA lists
    - KDB 628591 and 388624 will be realigned when draft KDBs are finalized
  - major comments to the KDB drafts and changes considered will be identified during the slide presentation
- Other misc updates to provide
  - interim guidance until KDB drafts and procedures are finalized

Note: "draft" means the on-going KDB drafts and "(draft)" refers to both the on-going drafts and subsequent final-release documents.

Draft KDB 447498

Mobile and Portable Devices
RF Exposure Procedures
and
Equipment Authorization Policies

Draft KDB 447498

- The entire collection of RF exposure KDB publications and TCB workshop RF exposure updates are referred to as the *"published RF exposure KDB procedures"*
- KDB 447498 also serves as an entry point for other KDB procedures
  - applied in conjunction with the *published RF exposure KDB procedures*
- The procedures also include the general TCB review and equipment approval policies
  - RF exposure testing must apply the latest revision of the *published RF exposure KDB procedures* to qualify for TCB approval

Draft KDB 447498

- A few new items and changes in the September draft include
  - area scan based 1-g SAR estimation
    - one very specific implementation of *fast SAR* algorithms and methods
  - 1-g & 10-g SAR test exclusion at other frequencies and distances
  - test exclusions are applied according to *reported* SAR
    - with respect to the maximum output power allowed for production units
  - clarifications for the 1.2 W/kg PBA & dedicated host requirements for modular and peripheral transmitters
- Influence of recent GAO report on RF exposure testing
  - some of the concerns require consideration through the normal administrative process and public proceedings
  - consideration for rule-making is already in the process
  - test and compliance requirements will be determined by the final rules

Equipment Approval Requirements

- Equipment approved by a TCB must satisfy TCB approval policies
  - categorically excluded devices must apply the *published RF exposure KDB procedures*
  - minor deviations from the required policies and test requirements need KDB inquiry to avoid PBA
  - all issues must be resolved during TCB review, between a TCB and the grantee or its test lab, before submitting a PBA
  - approvals requiring substantial FCC involvement can be subject to FCC approval only
    - when unclear, a KDB inquiry should be submitted before the PBA process
- For equipment approvals filed at the FCC
  - except when §1.1307 (c) or (d) applies, RF exposure test results are generally not required when categorically exclusion applies

General RF Exposure Policies

- RF exposure compliance is addressed according to
  - mobile and portable exposure conditions
  - standalone and simultaneous transmission requirements
  - host platform and transmitter operating configurations
- Transmitter modules should be approved according to one of these *exposure host platform* configurations
  - *mobile* only
  - *portable* only
  - *mixed mobile and portable*

Exposure Limits

- Consumer devices must comply with general population exposure limits
  - test and exclusion conditions must cover all required device operations
    - a device should operate without specific user intervention to maintain compliance
  - cautions and labels are for avoiding unintended use conditions only
- Occupational limits apply to "*work-related*" exposure only
  - users must be "*fully aware of*" and able to "*exercise control over*" their exposures
  - mandatory exposure training is required
  - training instructions provided in manuals are acceptable only when
    - users are required and can adhere to the training instructions
    - able to mitigate compliance concerns by applying the instructions
- Equipment approved for general population exposure conditions does not require separate approval for occupational exposure use

Operating and Installation Instructions

- Product instructions must enable the typical unskilled users to install and operate the equipment in manners that can ensure compliance
  - according to qualified host product and platform configurations & exposure conditions
  - as appropriate, for standalone and simultaneous transmission operations
- OEM integration & third-party assembly instructions must agree with those accepted for equipment approval; grantee is responsible
  - for ensuring installers and integrators have a clear understanding of the compliance requirements
  - for providing installation support to fulfill grantee responsibility
- For transmitter modules
  - integrators must be fully informed of their obligations
  - disclosure requirements for the supply chain and end users must be fully documented in the equipment approval

General Test Requirements

- Source-based time-averaging applies to RF exposure compliance
  - maximum conducted output power for SAR
  - maximum ERP for MPE
  - otherwise, as required by the *published RF exposure KDB procedures*
- §2.1091(d)(2) and §2.1093(d)(5) require RF exposure compliance with the maximum (source-based time-averaged) output power
  - devices should be tested at the maximum rated output power within 2 dB of the specified maximum tune-up tolerance
    - maximum output of production units when tune-up info is not required
  - test results are scaled to maximum tune-up/production tolerance by the test channel output power and must remain compliant
    - the highest scaled results in each frequency band and all scaled results > 1.5 W/kg, or within 5% of the MPE limit, must be documented in test reports to support compliance

General SAR Requirements

- For SAR measurements
  - the fundamental concepts in Supplement C 01-01 & IEEE Std 1528-2003 are applied in conjunction with the *published RF exposure KDB procedures*
- Test samples must have the equivalent
  - physical, mechanical and thermal characteristics and operational tolerances expected for production units to enable these interactions to be addressed collectively and transparently through normal testing
- Far-field antenna gain generally does not apply to SAR
- The test setup must not
  - perturb device performance, change SAR characteristics or be inconsistent with the required test protocols

Body Worn Accessory Testing

- Body-worn accessory SAR testing is required
  - when supplied or available as options from the host manufacturer
    - if non-metallic, test selectively for worst case exposure conditions
    - accessories with metallic components are each tested separately
  - a single test separation distance must be applied to all wireless modes
- Off the self body-worn accessories for cellphones
  - apply Supplement C 01-01, according to typical accessories users may acquire at the time of equipment approval
- Body-worn accessory SAR is intended for voice call operations
  - data mode testing is determined by the transmission requirements for the device and body-worn accessory combination; e.g., DTM in GSM/GPRS

Body Worn Accessory Instructions

- User instructions are required for body-worn accessories
  - when applicable, for users to acquire acceptable body-worn accessories to meet minimum separation distance requirements; such as cellphones
  - the disclosure must enable users to clearly understand the operating configurations; for example,
    - if pocket and lanyard use have been tested for compliance
    - whether multiple device orientations are tested with an accessory
    - accessories with metallic components have been clearly identified
- The instructions must enable users to easily understand the operating requirements to maintain compliance
- For devices intended to support next to body use without accessories
  - SAR compliance at an appropriate separation distance according to the operation configuration and exposure conditions is required

Other Exposure Conditions

- Extremity and body SAR may apply to devices that
  - operate on extremities or mainly in extremity use only exposure conditions; such as hands, wrists, feet and ankles
  - 1-g and 10-g SAR test exclusion may apply
- SAR evaluation is not required for implanted transmitters
  - when the maximum total available power at the antenna port and radiating structures of an implanted device is ≤ 1.0 mW
    - i.e., worst case power and exposure conditions under all operating circumstances
  - an analysis report is required in lieu of the SAR evaluation
    - to qualify for SAR test exclusion by measurement or numerical modeling
    - according to the design and implementation requirements of the implant
    - the analysis must be fully supported by power measurement results

Standalone SAR Test Exclusion

- For standalone transmissions, 1-g and 10-g SAR test exclusions may be applied in conjunction with the *published RF exposure KDB procedures*
  - 100 MHz – 6 GHz and test separation distance ≤ 50 mm
    - [(max. power of channel, including tolerance, mW)/(min. test separation distance, mm)] · [$\sqrt{f_{(GHz)}}$] ≤ 3.0 for 1-g and ≤ 7.5 for 10-g SAR
  - 100 MHz – 6 GHz and > 50 mm
    - ≤ 1.5 GHz: [Threshold at 50 mm + (test separation distance-50 mm)•($f_{(MHz)}$/150)] mW
    - > 1.5 GHz: [Threshold at 50 mm + (test separation distance-50 mm)•10] mW
  - < 100 MHz
    - > 50 mm and < 200 mm: [Threshold for test separation distance at 100 MHz]•[1 + log(100/$f_{(MHz)}$)]
    - ≤ 50 mm: ½•[Threshold at 50 mm and 100 MHz]
- Minimum test separation distance is typically determined according to
  - antenna and radiating structures to the user for large form factor hosts
  - outer surface of device to the user for small form factor devices

Estimated Standalone SAR

- When standalone test exclusion applies, standalone SAR is estimated to determine simultaneous transmission SAR test exclusion
  - ≤ 50 mm: [(max. power of channel, including tolerance, mW)/(min. test separation distance, mm)] · [$\sqrt{f_{(GHz)}}/x$] W/kg
    - x = 7.5 for 1-g and 18.75 for 10-g SAR
  - > 50 mm: 0.4 W/kg for 1-g and 1.0 W/kg for 10-g SAR
  - peak SAR location is assumed to be at the feed-point or geometric center of an antenna, whichever is more conservative
  - when the estimated SAR becomes overly conservative, test labs may choose to perform SAR measurements to qualify for simultaneous transmission SAR test exclusion
- When test exclusion applies and no other testing or reporting is required
  - a statement of justification is required, in lieu of the SAR report

Estimated, Measured and Reported SAR

- *Estimated SAR* is for purpose of determine simultaneous transmission SAR test exclusion
  - maximum tune-up tolerance has already been taken into account in the equation
- *Measured SAR* corresponds to the SAR determined by the SAR system for the output power level applied to test a device
  - the device must be tested at a maximum power level within the required tune-up tolerance range and within 2 dB of the maximum tune-up and product tolerance limits
- *Reported* SAR corresponds to the SAR at the maximum tune-up and production tolerance limits
  - the measured SAR is scaled linearly to the maximum tune-up and production tolerance limit for maximum output power

Simultaneous Transmission SAR Test Exclusion

- *Reported* and estimated standalone SAR are used to determine simultaneous transmission SAR test exclusion, according to
  - sum of 1-g or 10-g SAR ≤ limit, in each operating & exposure condition
    - for all simultaneous transmitting antennas

      or
  - SAR peak location separation ratio
    - for each antenna pair in each simultaneous transmission configuration
    - $(SAR_1 + SAR_2)^{1.5} / R_i \leq 0.04$ for 1-g or ≤ 0.10 for 10-g
      - where R_i is the antenna separation distance in mm
- When simultaneous transmission requires power reduction
  - the standalone *reported* SAR at the non-reduced, higher maximum output power may be used to determine simultaneous transmission SAR test exclusion
  - additional standalone SAR at the reduced maximum output power may be performed to qualify for simultaneous transmission SAR exclusion
  - when simultaneous transmission SAR testing is required, maximum output in the power reduction mode must be used for testing

Determining SAR Peak Location

- When standalone SAR is measured
  - peak location is determined by the interpolated and extrapolated x, y and z coordinates in the 1-g SAR reported by the zoom scan measurement or, when applicable, area scan based 1-g SAR estimation
- When both peaks in an antenna pair are from measurements, the peak location separation distance is determined by
  - $[(x_1-x_2)^2 + (y_1-y_2)^2 + (z_1-z_2)^2]$
- For the SAM phantom, when SAR is estimated for one of the antennas in a pair
  - the measured peak location is translated onto the test device to determine peak location separation for the antenna pair
    - with respect to the ear reference point (ERP) location on the SAM phantom
    - because handset and phantom are aligned at ERP
  - the 6 mm offset in z direction due to ear spacer should be ignored

SAR Test Reduction

- SAR is typically tested first on the middle or highest output power channel
  - as required by the *published RF exposure KDB procedures*
- Test reduction for the other channels may be determined according to the width of transmission band and *reported* 1-g or10-g SAR
  - ≤ 100 MHz: ≤ 0.8 or 2.0 W/kg
  - > 100 MHz and ≤ 200 MHz: ≤ 0.6 or 1.5 W/kg
  - > 200 MHz: ≤ 0.4 or 1.0 W/kg

SAR Test Reduction

- Area scan based 1-g SAR estimation
  - a very specific implementation of fast SAR methods
    - reported in the 29th BEMS meeting in 2009
    - using the specific polynomial fit algorithm
  - other implementations are not considered
- When estimated 1-g SAR is ≤ 1.2 W/kg, zoom scan is not required according to the following
  - zoom scan is not required for any other purposes
  - peaks are distinctively identified in the area scan
  - no sharp gradients: SAR at 1 cm from peak ≥ 40% of peak value
  - no measurement warnings or alerts for other measurement issues
  - 1-g SAR for estimated & zoom scan in the system verification (dipole) must be within 3% of each other
  - SAR ≤ 6.0 W/kg when occupational limit applies and permitted by the *published RF exposure KDB procedures*
- Regardless of the SAR value, a zoom scan is required for the highest SAR configuration in each frequency band and wireless mode

Modules and Peripheral Transmitters

- These transmitters must remain compliant in all host configurations
  - for standalone and, when applicable, simultaneous transmission operations
- Adding a transmitter or module to a host may trigger additional equipment approval requirements for existing transmitters in host devices
- Modular approach is typically not appropriate
  - for small hosts or when transmitters & antennas are close to each other
  - the final host must be tested with all transmitters installed to account for interactions among transmitters; for example, cellphones
  - interaction of low power modules that do not require separate SAR testing can be accounted for in SAR tests required for the other transmitters
- Different equipment approval approaches may be considered to incorporate modules in host devices through
  - Class II permissive change to include unqualified configurations
  - a new FCC ID to cover all transmitters in the host device
  - a change of FCC ID followed by Class II permissive changes to enable host manufacturers to address unqualified configurations

Transmitter Module Approval Policies

- Transmitter modules may be approved for mobile only or portable only exposure conditions according to combinations of the following conditions
  - for either standalone operations only or for standalone and simultaneous transmission operations
  - in either mobile or portable exposure conditions
  - according to host platform restrictions, dedicated host and product configurations
  - all operations must be supported by the test results
- Transmitter modules may be approved for mixed mobile and portable exposure conditions according to combinations of the following conditions
  - according to qualified hosts and product configurations
  - all operations must be supported by the test results
- Seeking equipment approval in incorrect categories can require a new filing to qualify for other operating and exposure conditions due to testing and approval difficulties

Module-Like Peripheral Transmitters

- Modules-like peripheral transmitters require a host to operate
  - through standard interface connections that are either internal or external to the host
  - for example, ExpressCard, USB etc
- Operating and exposure conditions depend on host device implementation, form factor and use conditions
  - SAR and exposure characteristics may vary with host configurations
  - for both standalone and simultaneous transmission operations
  - compliance for varying host conditions requires additional SAR margin
  - high SAR configurations may require warnings, cautions and/or additional instructions to ensure compliance or limit approval to dedicated host only

Modules in Standalone Portable Exposure Conditions

- Host platform and operating restrictions are mostly determined by the highest *reported* SAR
- No restriction when the *reported* 1-g SAR is ≤ 0.4 W/kg and the energy coupling enhancement 1-g SAR, when required, is ≤ 0.45 W/kg
  - minimum test separation distance for measurement or SAR test exclusion must be ≤ 5 mm
- When the highest *reported* SAR is > 0.4 and ≤ 0.8 W/kg, a module may qualify for multiple host platforms
  - each host platform must be tested independently
  - multiple host platforms may be considered under the same FCC ID
  - Class II permissive changes must be within the scope of defined host platform configurations and exposure conditions in the initial approval
- Dedicated host approval is required when the *reported* SAR is > 1.2 W/kg
  - except when only a few SAR results are > 1.2 W/kg and ≤ 1.4 W/kg, a PBA may be considered to obviate dedicated host test and approval requirements
  - dedicated host approval does not apply to peripheral devices

After-Market Accessories

- After-market accessories may or may not contain transmitters
  - therefore, may or may not require separate equipment approval
  - if an accessory has potential to change the exposure characteristics of an approved host device, determination of compliance for the accessory and host combination is necessary
- Class I permissive change does not apply when there is no equivalent test configurations in original host approval to compare SAR distributions of equivalent exposure conditions for accessory to determine SAR degradation
- Third-party accessory suppliers should consult with original host equipment manufacturer to determine compliance through
  - host equipment Class II permissive change approval
  - change of FCC ID followed by Class II permissive changes
- Equipment approval is not required for accessories without transmitter
  - the hosts must remain compliant when operated with such accessories
  - determination of compliance necessitates some form of assessment
- Further testing and approval issues are under review
  - when unclear, a KDB inquiry should be submitted to avoid problems

Standalone Mobile Exposure Conditions

- Compliance of mobile exposure conditions must be addressed accordingly for standalone and, when applicable, simultaneous transmission operations
- When §2.1091(d)(4) applies, SAR test requirement is determined through KDB inquiries
- Cable losses and attenuations must be accounted for to determine compliance according to actual installation requirements and use conditions
- When categorical exclusion applies, the minimum separation distance may be estimated by acceptable simple calculations
  - according to worst case power and antenna gain conditions
  - device must be installed to operate in manners exceeding the estimated distance
  - type of calculation must be appropriate for the specific antenna(s) used
- When the estimated distance is overly conservative, MPE measurements may be considered to determine the minimum separation distance

Standalone Mobile Exposure Conditions

- MPE compliance is determined according to peak or spatially averaged
  - E & H field strengths when < 300 MHz
  - plane-wave equivalent power density when ≥ 300 MHz
  - compliance is determined for all accessible locations surrounding the antenna
  - equipment with isotropic sensors that measure the orthogonal field components to determine the total exposure field is required
- When routine MPE evaluation is required
  - unless specified differently by the *published RF exposure KDB procedures*, exposures are evaluated in both horizontal and vertical planes
  - along radials from the antenna that are 45° apart; ≤ 30° if > 60 cm from antenna
  - spatial averaging in horizontal plane is not required unless the exposed person is aligned horizontally
  - measurements in vertical plane should extend to ≥ 10 cm beyond the exposed portions of a person's body or until results are < 10% of MPE limit, and ≥ 10 cm from the ground or ground plane, in the applicable exposure positions

Standalone Mobile Exposure Conditions

- When antennas transmit in multiple frequency bands
  - users generally would not know which frequency band is transmitting at any specific time
  - the most restrictive separation distance among all frequencies must be applied for the antenna installation to ensure compliance
- When specific antennas are not identified in installation requirements
  - users and installers may choose to install an antenna with different gain
  - for antennas that covers multiple frequency bands, the maximum antenna gain in each frequency band must satisfy the most restrictive separation distance required for all frequency bands
- The required antenna type, radiating characteristics, antenna gain, and the requirement of a unique minimum separation distance for meeting compliance must be fully disclosed in all instructions

Simultaneous Transmission Mobile Exposure Conditions

- When applying simultaneous transmission test exclusion to mobile only exposure conditions
  - all antennas in the host must each comply with mobile exposure requirements for standalone use
  - the minimum separation distance required for simultaneous transmission must be ≥ that required for standalone use
  - sum of MPE ratios for all simultaneous transmitting antennas must be ≤ 1.0
- When applying test exclusion to mixed mobile and portable exposure conditions
  - [∑ of (the highest measured or estimated SAR for each standalone antenna configuration, adjusted for maximum tune-up tolerance) / 1.6 W/kg] + [∑ of MPE ratios] is ≤ 1.0; or
  - SAR to peak location separation ratios for all simultaneous transmitting antenna pairs operating in portable exposure conditions are all ≤ 0.04 (0.1 for 10-g) and the [∑ of MPE ratios] is ≤ 1.0

Simultaneous Transmission Mobile Exposure Conditions

- When test exclusion does not apply to mixed mobile and portable exposure conditions
  - enlarged zoom scan measurements and volume scan post-processing must be applied to all antennas operating in portable exposure conditions
- The [(highest measured simultaneous transmission SAR, adjusted for maximum tune-up tolerance) / 1.6 W/kg] + [$\sum$ of MPE ratios] must be ≤ 1.0
  - otherwise, compliance must be determined by the FCC on a case-by-case basis
    - with respect to antenna-to-antenna and antenna-to-user separation distances
    - device form factor, operating requirements and exposure conditions

Draft KDB 865664

SAR Measurement Requirements
for
100 MHz – 6 GHz
&
RF Exposure Compliance Reporting
and
Documentation Considerations

Draft KDB 865664

- This revision covers 100 MHz to 6 GHz
  - some SAR measurement parameters in draft IEEE Std P1528-2011 are included
  - incorporated SAR probe and dipole calibration requirements from KDB 450824
    - KDB 450824 will be retired
- When limits or procedures are not established, compliance according to §1.1307 (c) & (d) may be required
  - limits not established for MPE below 300 kHz and SAR below100 kHz
  - procedures not established for SAR testing below 100 MHz
- Included RF exposure compliance reporting and documentation guidance in attachment to (draft) KDB 865664
  - for maintaining reporting consistency and to streamline the TCB review and approval process

SAR Probe Calibration

- Probe calibrations are verified during SAR system validation
- All probes must be calibrated with an expanded uncertainty ≤ 15%, for a confidence interval of k = 2
- For wide band operations
  - the SAR probe calibration point must be valid for the entire channel bandwidth of the signal tested for the device
  - multiple probe calibration points may be required to cover very wide frequency bands
- Additional system validation and measurement considerations are required for probes calibrated with CW-equivalent signals to measure
  - non-periodic signals
  - high peak-to-average power ratio signals
    - typically > 5 dB; see SAR system validation
- Signal specific probe calibrations have been introduced; however, clear protocols have not been established
  - submit KDB inquiry to determine details and PBA requirements

Tissue Dielectric Parameters

- Draft IEEE Std P1528-2011 have introduced specific algorithms for SAR error compensation due to tissue dielectric parameter deviations for relaxing tissue dielectric parameter tolerances from 5% to 10%
  - some SAR systems may have implemented these specific algorithms
  - it must be verified that SAR is only adjusted upward and not down
  - otherwise, 5% tolerance is required for ε_r and σ
- Tissue dielectric parameters must be
  - measured before each series of SAR measurements
  - repeated every 3 – 4 days or sooner when parameters are marginal
  - parameters must be valid within 2°C between dielectric and SAR measurements and also within 18 – 25°C
- Temperature sensitivity and short term stability of the tissue dielectric parameters should also be examined and reported

SAR Measurement Requirements

- Measurements below 300 MHz must be within ± 50 MHz of probe calibration point frequency
- Measurement above 300 MHz must be within
  - ± 100 MHz of probe calibration point frequency or valid frequency range of the probe calibration, whichever is less
- When the measured 1-g or 10-g SAR is within 10% of the SAR limit
  - further restrictions are required for the tissue dielectric parameters when measurement frequencies exceeding 50% of the ± 50 and ± 100 MHz probe calibration point frequency (above)

Simultaneous Transmission SAR Measurements

- For transmissions in the same frequency band
  - within the valid frequency range of a probe calibration point and tissue dielectric medium
    - when supported by the SAR measurement system, normal area and zoom scan procedures can be used to test all transmitters simultaneously
  - when signals are coherent, a KDB inquiry is required
- For transmissions in multiple frequency bands
  - enlarged zoom scans are required for transmitters operating within each valid probe calibration frequency & tissue dielectric interval
  - volume scan post-processing procedures are applied to determine the aggregate 1-g SAR for the combined SAR distribution

Enlarged Zoom Scan and Volume Scan Post-Processing

- Other than a larger measurement volume to enclose all antennas and radiating structures of a test device, the measurement parameters of a normal zoom scan should be applied
- Area scan is not required; but may be used to determine the extent of SAR distributions to minimize the enlarged zoom scan volumes
- Volume scan post-processing algorithms may vary among SAR systems and system versions
  - the measurement resolution requirements can be different
  - interpolation and extrapolation procedures may vary
  - use of overlapping scan regions and other restrictions may also apply
  - details are required in the SAR report to support test results

Enlarged Zoom Scan and Volume Scan Post-Processing

- Contour plots for enlarged zoom scans and volume scan distributions are required to support the test results
- If the performance of a transmitter is different in standalone and simultaneous transmission modes, the volume scan procedures may not be applicable
  - it could be incorrect to sum the SAR distributions to determine the aggregate SAR
- When SAR scaling must be applied to the raw results, additional considerations are required; for example, WiMax
  - scaling must be applied to the measured points before any post-processing
  - a KDB inquiry should be submitted to determine details

Measurement Variability and Uncertainty

- SAR measurement variability is verified for each frequency band according to the following to qualify for TCB approval
  - repeated measurements are required only when the measured SAR is ≥ 0.80 W/kg
  - when the original (normally required) highest SAR value is ≥ 0.8 W/kg, only one repeated measurement is required to reaffirm results are not expected to have substantial variations that can introduce significant compliance concerns
  - an addition repeated measurement is required only if the measured results are within 10% of the SAR limit or vary by more than 20%, which are often related to device and measurement setup difficulties
- The repeated measurement for a frequency band applies to the tissue medium with highest SAR
  - alternatively, if highest head & body SAR are ≤ 1.45 W/kg and within 10% of each other, either head or body medium may be used

Measurement Variability and Uncertainty

- Measurement Uncertainty analysis is required only when the highest SAR in a frequency band is ≥ 1.5 W/kg
  - the IEEE Std 1528-2003 procedures should be applied
  - according to the SAR measurement parameters used
  - the expanded uncertainty must be ≤ 30%, for k = 2
- Similar approaches should be applied to measurements with respect to extremity and occupation SAR limits
  - by applying the corresponding scale factors; 2.5 and 5.0

SAR System Validation

- SAR system validation is required
  - before a system is deployed
  - after hardware upgrade, software update
  - after components are repaired or re-calibrated
- Validation is with respect to the combinations of
  - probes and components used by a system
    - probes and certain components may be interchangeable across systems
  - parameters used in routine measurements
    - such as measurement resolutions and post-processing algorithms etc.
- Reference dipoles are used for system validation
  - dipoles should meet the design and tolerance requirements of IEEE Std 1528-2003
- The validation results are kept by the test lab
  - these may be requested during equipment approval to address specific measurement issues for supporting the test results

System Validation Procedures

- SAR systems are validated with CW signals for each frequency band
  - within the sensitivity range of SAR probes & system components
  - the measured 1-g and 10-g SAR at different power levels, normalized to 1.0 W net power, must be within 10% of the calibrated reference dipole SAR target value
  - the same results are also applied to determine probe linearity with respect to the power applied to a dipole
    - the maximum deviation must be < 10%
  - probe isotropy is determined by rotating the probe around its axis, to make single-point measurements at 15° intervals, at an SAR level near the SAR limit
    - the maximum deviation from the average value in each test should be within the required SAR probe specification and < ± 0.25 dB

System Validation Procedures

- Signal and modulation specific system validation
  - for signals with periodic duty factor; such as in TDMA operations
    - apply the CW procedures to the lowest duty factor required for routine measurement and compare the duty factor compensated SAR to the 1.0 W normalized results for the CW-equivalent dipole SAR target
  - for signals with high peak-to-average power ratios (> 5 dB)
    - apply the CW procedures to the modulated signal and compare the SAR to the 1.0 W normalized results for the CW-equivalent dipole SAR target
    - when probe linearity error is > 10%
      - test device should be operated at reduce maximum power to maintain probe linearity in the 5 – 10% range or consider signal specific probe calibration
    - the same procedures also apply to signal specific probe calibration
  - depending on the signal characteristics, combinations of the above may be required for system validation

SAR System Verification

- SAR system verification is required for each probe calibration point and tissue dielectric medium combination required for routine measurements
- When the dipole and probe calibration frequencies are misaligned, if applicable, the following alternative may be considered
  - establish a new SAR target at an offset frequency within the test device, probe calibration and tissue medium operating range, or
  - establish a new SAR target at the tuned dipole frequency for the probe calibration and tissue medium required at the device test frequency
    - this option has further restrictions
  - both options must meet specific dipole return loss, tissue dielectric differences, and other stability conditions in (draft) KDB 865664
  - all results and analyses must be included in the test report to justify using these alternatives

System Validation and Verification at 100 - 300 MHz

- This applies only when reference dipoles are unavailable from system manufacturers
  - one SAR system manufacturer has announced the availability of shielded loops for 30 – 300 MHz system validation and verification
  - test labs should acquire the appropriate loops as soon as possible
- When the required validation source is unavailable, the SAR probe must be calibrated at 300 MHz and also at 150 MHz or within the device test frequency range
  - normal system validation and verification is required at 300 MHz
  - a new SAR target is established for the 300 MHz dipole
    - using the 150 MHz or device test frequency probe calibration point and the 150 MHz tissue medium used for device testing
    - with the dipole transmitting at 300 MHz, apply the procedures and requirements established for alternative system verification at offset frequency with dipole operating at its tuned frequency

Draft KDB 616217

SAR Evaluation Considerations

for

Laptop, Notebook, Netbook & Tablet Computers

General Considerations

- This draft is a new revision of KDB 616217
  - it replaces all earlier versions of KDB 616217
  - it applies to laptops and tablets with diagonal dimensions > 20 cm
  - the procedures are applied in conjunction with the other *published RF exposure KDB procedures*
  - it only applies to transmitters operating in the 698 MHz - 6 GHz bands
- Two host platforms are defined
  - the laptop platform includes laptops, notebooks and netbooks
  - the tablet platform includes tablets and laptops with tablet mode
    - tablet platform is more conservative and should also qualify for laptop use
- 3 equipment approval approaches are identified
  - modular, dedicated host, and mixed modular and dedicated host
- The test exclusion considerations in (draft) KDB 447498 are applied
  - for both standalone and simultaneous transmission operations

Modular Approach

- Modular approach requires testing without a representative host
- Testing with representative host is required only when the SAR measured without a host is > 0.8 W/kg
  - testing with representative hosts may be added incrementally through subsequent Class II permissive changes
    - as specific host implementations are introduced
    - to widen the approval scope for higher SAR configurations
- When only a few of the measured SAR are > 1.2 W/kg and ≤ 1.4 W/kg; modular approach may be accepted through PBA
- When SAR is > 1.4 W/kg
  - dedicated host testing is required for transmitters incorporated internally within the host
  - dedicated host testing does not apply to user accessible external peripheral transmitters
    - equipment approval may be submitted directly to the FCC for case-by-case consideration; a KDB inquiry is recommended to determine acceptability
- Note: representative host testing ≠ dedicated host approval

Laptop Platform Requirements

- (Draft) KDB 447498 is used to determine simultaneous transmission SAR test exclusion
- When applying the modular approach, the following are required
  - antenna and user separation distance must be ≤ 25 mm for incorporation in the display screen
  - keyboard and user separation distance must be ≤ 5 mm
    - for keyboard bottom and edge exposure conditions
  - the antenna configuration must have been tested for equipment approval
  - 25 mm and 5 mm must be used, respectively, to determine SAR test exclusion for the display screen and keyboard compartment
  - equipment approval is based on the antenna polarization, orientation, rotation and installation configurations tested for SAR compliance or considered for test exclusion

Tablet Platform Considerations

- Bottom and edge exposure conditions are applicable to tablets
- Exposure from the display screen surface is typically not of concern
  - unless continuous exposure to the hand is expected
- When a display orientation is disabled
  - transmitter/antenna in the corresponding edges should also be disabled or set to operate at reduced power to satisfy SAR compliance
  - due to increasing flexibility required to support interactive use
    - transmission may continue when tablet is transitioning through various vertical and horizontal orientations at different tilt angles while tablet is at close proximity to users and nearby persons
    - disabling the display orientation is no longer sufficient to ensure compliance while supporting these interactive use features of recent generation tablets

Tablet Platform Requirements

- Modular approach may not apply to the higher power transmitters because tablet use conditions are at close proximity to users
  - dedicated host or mixed modular & dedicated host approach should be considered
- When modular approach is applied
  - tablet and user separation distance must be ≤ 5 mm for bottom and edge exposure conditions
  - antenna configurations must have been tested for equipment approval
  - a minimum separation distance of 5 mm is required to apply SAR test exclusion
- (Draft) KDB 447498 is applied to determine simultaneous transmission SAR test exclusion
- When testing is required, the tablet must be in direct contact with the phantom
  - antennas are generally embedded with ≤ 5 mm separation from the outer housing
- SAR test exclusion is applied to determine if adjacent edge testing is required
  - with edge containing antenna rotated ±90°, positioned perpendicular to phantom

Proximity Sensor Considerations

- Sensor triggering distances for bottom surface and side edge exposure conditions are determined
  - by moving the tablet bottom or edge to and from the phantom
    - through specific steps to verify the triggering conditions
    - to ensure triggering and reduced power condition remain active as required
- Antenna and sensor coverage is determined
  - by moving the tablet bottom or edge laterally into and out of the phantom boundary while positioned at the triggering distance
    - from opposite directions along maximum antenna and sensor offset
    - if the measured peak SAR location is outside the triggering location limits, a KDB inquiry is required to determine if additional SAR measurement is required
- Edge tilt angle is varied to verify triggering distance remains valid
- The smallest distance among all triggering conditions is used for SAR testing

Transmitter & Host Manufacturer Responsibility

- When applying the modular approach for tablet hosts with proximity sensors
  - the grantee may not have full control of the power reduction and sensor triggering implemented in the host
  - a change of FCC ID from the module manufacturer is required to manage equipment approval concerns
  - joint responsibility between the tablet host and transmitter manufacturer is addressed in a subsequent Class II permissive change after the change of ID
- The change of FCC ID is only applicable
  - to the specific tablet implementation
  - for the specific type of sensor and antenna configuration
  - any inapplicable grant conditions inherited from the change of ID must be omitted in the subsequent Class II approval to avoid conflicts
- A separate FCC ID is required for tablets with different proximity sensor implementation or configurations

Draft KDB 648474

SAR Evaluation Considerations

for

Handsets with Multiple Transmitters and Antennas

General Considerations

- Test reduction and exclusion provisions in (draft) KDB 447498 are applied
  - a test separation distance of 5 mm is required
- Body-worn accessory procedures are in (draft) KDB 447498
- Hotspot procedures are in KDB 941225
- Discussions of on-going testing concerns for recent generation smart phones are included
  - simultaneous voice & data
  - power reduction
  - NFC & wireless charging accessories
  - VoIP support
  - SAM phantom limitations

Simultaneous Voice and Data

- Most smart phones have simultaneous voice and data capabilities - SVD
  - 3G WCDMA/HSPA allows this in the same physical channel through different code channels
  - 3G with 4G/LTE can support this with separate transmitters
    - voice in 3G and data traffic in 4G – SVLTE
    - voice in 3G and EVDO or LTE with the 4G transmitter – SVDO
- For SAR compliance purposes, the simultaneous transmission capabilities must be clearly identified, according to
  - the combinations of transmitter and antenna paths
  - wireless technologies, operating modes, exposure conditions
  - power reduction requirements & restrictions enforced by firmware and hardware
  - test results are unacceptable without clear supporting information to identify the simultaneous transmission configurations
- In addition, simultaneous voice & data operations often require power reduction to maintain compliance

Power Reduction Considerations

- Power reduction is applied when multiple transmitters operate simultaneously at relatively high maximum output power levels
  - to address internal interference and SAR compliance concerns
- Various power reduction mechanisms have been used by phone manufacturers
  - the power reduction could be fixed or dynamic, with respect to various parameters, and there is no established industry standard
- A KDB is recommended and PBA is required, except
  - when the power reduction is for a fixed level triggered by a specific frequency band or dedicated operation to enable a simultaneous transmission configuration, such as hotspot mode or certain SVLTE/SVDO operations

NFC & Wireless Charging Accessories

- Accessories with NFC or wireless charging functions do not require standalone SAR testing, but they can influence the SAR distribution of phones
  - influences and interactions from accessory hardware are accounted for in the normal SAR tests required for phones
- Class II permissive changes are required when supplied as after-market accessories by the phone manufacturer
  - Class I permissive change may apply to subsequent modifications to the accessory
- Third-party accessory supplier should apply the test and approval considerations in (draft) KDB 447498 to determine compliance requirements for phones to operate in conjunction with an accessory

VoIP Support

- Wireless carriers are in the process of migrating from 3G to 4G to introduce VoIP support as a standard built-in feature for smart phones
- Normal SAR test considerations for head and body-worn accessory exposure conditions are required when VoIP is
  - built-in as an integral part of the phone to support voice calls through wireless carriers
  - supported by apps provided or specifically supported by the phone manufacturer or wireless carriers
- For third-party VoIP apps downloaded by users that are not supplied or specifically supported by the manufacturer or carrier
  - it is not always feasible to test the SAR consistently for these ad hoc features
  - when these features cannot be blocked
    - manufacturers may choose to test these in representative data modes for the applicable wireless technologies, or
    - provide clear user disclosure to identify that these features are not or cannot be blocked and have not been tested for RF exposure compliance; therefore, should be avoided

SAM Phantom Limitations

- Antennas are often at the bottom or lower edges of recent generation phones
  - peak SAR location can be near inaccessible regions of the SAM phantom
  - the SAR distribution can be truncated due to phantom setup, SAR probe accessibility and other measurement issues
- Acquiring additional SAM phantoms in rotated configurations may address some of the measurement difficulties, but it could be impractical for test labs
- These interim procedures should be used until better solutions are available
  - when the SAR distribution is truncated, re-testing with a flat phantom is required
  - a separation distance of 4 mm is required between the phone and the flat phantom, at the point coupled to the ERP location on the SAM phantom
  - the same separation distance at the peak SAR location identified in the truncated SAR distribution tested with the SAM phantom should be established between phone and the flat phantom
    - when this is not feasible, the top edge of the phone should be touching the flat phantom
  - the SAR results for both the truncated distribution using the SAM phantom and the addition test using the flat phantom should both be included in test reports

Draft KDB 941225

SAR Evaluation Considerations

for

LTE Devices

General Considerations

- This is a new revision of the LTE SAR procedures
- The same procedures are used to test voice and data exposure conditions
- A PBA is not required when
  - a properly configured basestation simulator is used for all SAR tests, without the need for other test software support
  - all LTE test and approval issues are fully addressed by the manufacturer and its test lab through prior KDB inquiries with copies provided to the TCB to support review and approval
  - the TCB has verify that all LTE procedures and related KDB inquires have been correctly applied and PBA is not required
  - there are no other PBA requirement, such as
    - power reduction, simultaneous transmission SAR measurements etc.

Standalone SAR Requirements

- The procedures have been streamlined to support testing of both voice and data exposure conditions for TCB approval without a PBA
- Power measurement results are applied to streamline the SAR test reduction requirements
- The test reduction process begins with 1 RB allocation for QPSK
- SAR thresholds are applied to facilitate test reduction
  - 0.8 W/kg for RB offset configurations
  - 1.45 W/kg for test channels
- The 1 RB procedures are also applied to the 50% RB allocation
- 100% RB allocation test reduction is based on the power and SAR levels of 50% and 1 RB allocations
- QAM configuration test reduction is based on power and QPSK SAR levels
- Test reduction for smaller channel bandwidths is based on the power and SAR levels of the highest channel bandwidth

Simultaneous Transmission SAR Requirements

- Simultaneous transmission SAR test exclusion or measurement must be considered separately for the different exposure conditions
  - head, body-worn accessories and other use conditions etc., and
  - with respect to the various LTE test configurations
    - channel bandwidth, RB allocations, modulations etc.
    - especially when the maximum output power levels are different or there is noticeable output power variations
- Without clear documentation that explains the combinations of applicable configurations supported by the test configurations, test results alone are unacceptable
  - the descriptions and explanations must be sufficient for the typical TCB to perform the review for equipment approval
  - this is required to qualify for TCB approval without a PBA

Draft KDB 628591

TCB Exclusion List

Expected Changes

TCB Exclusion List

- Unless it is on the PBA list, devices are excluded for TCB approval when
  - exposure limits are not fully established, or
  - when §1.1307 (c) or (d) applies
- Devices are excluded for TCB approval
  - when *published RF exposure KDB procedures* and PBA requirements are not established for SAR testing and TCB approval

    and
  - SAR data is not provided to support compliance when the source-based time-averaged maximum output power and test separation distance exceed those required in (draft) KDB 447498 for SAR test exclusion by
    - ≥ 8 times for general population exposure
    - ≥ 20 times for occupational exposure

Draft KDB 388624

PBA List

Expected Changes

PBA List

- PBA is required for Release 8 LTE when not tested according to (draft) KDB 941225
  - basestation simulator is not used, requiring power reduction or not using fixed single level power reduction triggered by a single event
- PBA is required when §2.1091(d)(4) applies and SAR evaluation is required
- Modules and peripheral transmitters subject to (draft) KDB 447498 with SAR > 1.2 W/kg that are not tested in dedicated host configurations
  - dedicated host ≠ representative host testing
- When simultaneously transmitted signals are coherent and SAR testing is required
- When test guidance is unavailable for uplink MIMO or other transmit diversity; except for 802.11 2x2 MIMO

PBA List

- Dynamic antenna tuning; except for fixed table look-up implementations that result in static tuning conditions
- Power reduction; except for single fixed level table look-up implementations triggered by single operating mode and event or power reduction is not for SAR compliance and SAR is tested at maximum full power
- Proximity sensor; except when *published RF exposure KDB procedures* can be applied to the specific implementation
- Channel and carrier aggregation and wide band transmissions exceeding SAR probe calibration or tissue dielectric requirements
- Wireless charging applications; except when *published RF exposure KDB procedures* are available for the specific implementation; for example, certain WPC implementations on cellphone battery covers

Transition Considerations

Transition Considerations

- A transition period is planned till January 01, 2013
- During the transition period
  - do not mix the old and the new KDB procedures
  - mixing can cause various problems
  - the new procedures are linked across different (draft) KDB publications; therefore, mixing old and new procedures across wireless technologies can be problematic and unacceptable
    - apply either the old or the new procedures to the entire product
  - when listing SAR numbers on grants
    - apply KDB 690783 when using the old KDB procedures
    - adapt KDB 690783 to use *reported* SAR values when using new procedures
- Inquire when unclear
  - please do not assume or self interpret, which could disqualify device for TCB approval

Interim Updates

Evolving Procedures and Test Guidance

1x Advanced

- Apply existing 1x procedures to measure maximum output power for 1x Advanced using SO75 with RC8 on uplink and RC11 on downlink
  - smart blanking must be disabled
  - use Forward Power Control Mode 000 and 400 bps for Reverse Power Control; i.e., 400 kHz for both uplink and downlink power control
- Based on the maximum output power measured for 1x Advanced, apply the 1x procedures to determine SAR test exclusion
  - i.e., SAR is not required if the maximum output for 1x Advanced is ≤ ¼ dB higher than the maximum output measured for 1x
- If the measured SAR in any 1x mode exposure conditions (head, body etc.) is > 1.2 W/kg, repeat the highest SAR configuration for each exposure condition in 1x Advanced mode
  - Left, right, touch and tilt are considered as one exposure condition
- All measured SAR in 1x mode > 1.5 W/kg must be repeated in 1x Advanced mode
- All power and SAR measurement configurations must be clearly documented in the SAR report

HSPA+ and DC-HSDPA

- Identify the 3GPP release and version number of the HSPA+ and DC-HSDPA implementation used by the device, including the UE categories
  - apply the subtest in Table C.11.1.4 of TS 34.121-1 of the applicable release version to measure 16QAM uplink maximum output power for HSPA+
  - apply FRC H-Set 12 (QPSK) in Table C.8.1.12 of TS 34.121-1 of the applicable release version to measure DC-HSDPA uplink maximum output power using the four Rel. 5 HSDPA subtests in Table C.10.1.4 of TS 234.121-1
    - a basestation simulator or equivalent equipment that supports DC-HSDPA, transmitting two cells simultaneously on adjacent carrier frequencies is required
- Apply KDB 941225 Rel 6. HSPA procedures to determine SAR exclusion for HSPA+ and DC-HSDPA according to the measured power
  - if measured maximum output power for HSPA+ or DC-HSDPA is ≤ ¼ dB higher than the WCDMA 12.2 kbps RMC maximum output, SAR is not required
- UE categories supported by the device, test setup parameters and other details must be clearly described in the test report
- Upcoming modes – DB-DC-HSDPA, DC-HSUPA, DC-HSDPA w/ MIMO

EVDO Rev. B

- Recent generation EVDO Rev. B implementation allows up to 3 (contiguous?) carriers to transmit simultaneously in the same frequency band
- The power measurement requirements are in 3GPP2 C.S0033-C
  - Subtype 3 physical layer with RMCTAP for the Reverse Data Channel and FMCTAP for the Forward Traffic Channel are used
    - RMCTAP: 4096 bits with Termination Target of 4 sub-packets
    - FMCTAP: 2-slot version of 307.2 kbps with ACK Channel transmitted at all the slots
- Multi-carrier mode requires multiple concurrent connections with basestation simulators to verify power backoff, maximum output and making SAR measurements
  - 3GPP2: maximum output with all carriers active is 3.3 dB lower than the maximum allowed for single carrier mode
  - SAR measurement requirements can depend on maximum output power of the multiple carriers in individual product implementations
- Submit KDB inquiry with power measurement results to determine SAR test requirements

Hotspot with Multiple EVDO Revisions

- When multiple EVDO revisions; Rev. 0 and Rev. A are used with hotspot mode, apply the 3G procedures in KDB 941225
  - SAR for Rev. 0 is measured on the maximum output channel, at 153.6 kbps using the body exposure configuration that results in the highest SAR for that channel in RC3
  - SAR for Rev. A is not required when the maximum average output of each channel is less than that measured in Rev. 0 or less than ¼ dB higher than that measured in RC3
  - Otherwise, SAR is measured on the maximum output channel for Rev. A using the same Subtype configurations described in KDB 941225
- Submit KDB inquiry for hotspot mode with EVDO Rev. B SAR test configurations

802.11 Test Reduction

- SAR test reduction for higher data rates and modulations in 802.11g, 802.11n and 802.11ac modes should be determined for each frequency band by comparing the maximum output power of each higher order modulation mode to the lowest order modulation mode
- When the maximum output power varies by more than ½ dB among the required test channels and the highest *reported* SAR for the lowest order modulation is > 1.2 W/kg, instead of comparing the highest maximum output between the lowest and higher order modulations, the individual channels or channels within the same frequency range should be compared to determine test exclusion on a channel-by-channel basis instead of by the frequency band
- The channel selection procedures in KDB 248227 must be applied to determine the channels require testing to qualify for TCB approval
- Until KDB 248227 is revised, the channel selection criteria applied to 802.11g, 802.11n and 802.11ac must be clearly explained in SAR reports

Estimating SAR for Coherent Signals

- Recent generation SAR probes are based on diode sensors
  - intended for measuring uncorrelated narrow band signals
  - impractical for correlated signals that require all phase combinations of the coherent sources to be measured at every measurement point
- Conservative estimates based on scalar field sensors using the complex field envelopes or the field component envelopes may be considered according to derivations in IEC TR 62630
  - with the assumption that all signals are spatially and temporally in-phase, summation of field magnitudes of the sources at each measurement point would lead to SAR overestimation
    - $SAR_{true} \leq [\Sigma_i \sqrt{SAR_i(\mathbf{r})}]^2$
  - with the assumption that all signals are only temporally in-phase, summation of field component magnitudes of the sources at each measurement point would lead to somewhat less overestimation
    - $SAR_{true} \leq [\sigma(\mathbf{r})/2\rho(\mathbf{r})] \cdot \Sigma_{x,y,z} [\Sigma_i |E_i(r)|]^2$
- These require field values to be exported from the SAR system for manual processing to determine the aggregate SAR distribution and 1-g SAR