



# RF Exposure Procedures

**TCB Workshop**  
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Laboratory Division  
Office of Engineering and Technology  
Federal Communications Commission



# Overview

- KDB Publications Update
- Product Platform Procedures Update
- Technology Specific Procedures Update
- RF Exposure Numerical Simulation
- SAR Measurement System and Methodology
- Miscellaneous Updates



# KDB Publications Update

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# KDB Publication General Updates

- References to PBA and related text have been updated to PAG
- References to equipment approval filed at FCC have been revised
- References to IEEE Std 1528-2003 have been updated to 1528-2013
  - to align with test lab and TCB accreditation KDB guidance
    - KDB Publication 853844 and KDB Publication 668797
  - the fundamental measurement concepts in IEEE Std 1528-2013 for head SAR are applied in conjunction with published KDB procedures
  - KDB guidance supersedes 1528-2013
    - 1528 supports head SAR measurement only
    - throughout the development of 1528, applicable procedures have already been integrated in KDB guidance
    - technology and product specific test procedures, equipment certification and other general testing policies are only available in KDB guidance



## Updated KDB Publications

- Formatting, PBA/PAG & 1528 updates, editorial changes etc.
  - KDB 615223 D01, 648474 D03 & D04, 865664 D01 & D02, 941225 D01, D05, D05A, D06 & D07, 643646 D01, 248227 D01, 447498 D01 & D02, 616217 D04
- Specific changes in individual KDB publications
  - 248227 D01: removed incorrect 802.11g 40 MHz column from tables in Appendix C, the configuration does not exist
  - 447498 D01 & D02, 616217 D04: deleted 1.2 W/kg PBA requirement; PBA was removed earlier, it is now handled by KDB inquiry
  - 447498 D01: included a few clarifications and some general cleanup
  - 941225 D05: removed outdated LTE info and included general guidance for TDD, NS signaling & test channel requirements for wide frequency bands
  - 941225 D05A: included channel BW & selection details for downlink carrier aggregation power measurement requirements
  - 648474 D04: updated text to match recent generation smartphones
  - 648474 D03: expanded the procedures to cover Qi, PMA & A4WP





## KDB 941225 D05A

- Updated the uplink power measurement procedures for SAR test exclusion due to downlink carrier aggregation (CA)
  - power is measured on uplink channel for highest SAR configuration without CA
  - PCC (DL) channel is determined by uplink channel configuration without CA
  - uplink power is measured for
    - intra-band contiguous CA with adjacent downlink PCC and SCC
    - intra-band non-contiguous CA with maximum allowed PCC-SCC separation
    - inter-band CA with SCC in/near middle of the transmission band
  - all CC (component carriers) must remain fully within the transmission band
  - apply TS 36.521, clause 5.4.1A, to determine nominal channel spacing
    - $[(BW_1 + BW_2) - 0.1 \cdot |BW_1 - BW_2|] \cdot [0.3/0.6]$  MHz
    - $BW_1$  &  $BW_2$  are the CC channel BW for 2-CC CA
  - TS 36.521, 5.4.2A, defines downlink CC combinations according to
    - CA configuration, CC BW, maximum aggregated BW & combination set etc.
- SAR test exclusion requires power test configurations & results in reports
  - test configurations and results generally do not qualify for confidentiality



# **Product Platform and Technology Specific Updates**

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# Mobile Device Exposure Evaluation

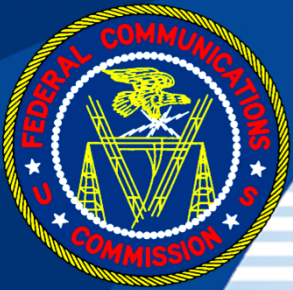
- Routine evaluation for §2.1091 requires MPE measurement or numerical simulation to show compliance; i.e., when ERP is
  - $\geq 1.5$  W at  $\leq 1.5$  GHz or  $\geq 3.0$  W at  $> 1.5$  GHz
- When categorical exclusion applies the required separation distance for MPE compliance may be estimated
  - to verify the distance specified in user and installation instructions
  - the estimated distance must be consistent with the instructions provided to users and installers
- For certain devices that operate in mostly isolated and stationary conditions, when routine evaluation applies, a KDB inquiry may be submitted to determine if the required separation distance can be estimated to determine MPE compliance
  - with respect to exposure conditions and distances supported by the installation and use conditions





# Mobile Exposure Test Distance

- The separation distance required for MPE compliance must be fully supported by device installation and consistent with use conditions
  - unjustified or arbitrarily large separation distances are unacceptable for demonstrating MPE compliance
- Field strength and power density must be estimated or measured at separation distances of at least 20 cm to apply MPE limits
  - distances less than 20 cm are unacceptable to show MPE compliance for equipment authorization; SAR limits apply
- The most conservative distance among the antennas and frequency bands supported by a device for all use conditions in each operating configuration, including simultaneous transmission, must be used to determine compliance
  - cannot apply different separation distances for the same exposure or use condition among different wireless modes in a device
  - users are not expected to know which frequency band or wireless mode is in use to maintain the correct separation distance



# GMRS, FRS and PTT Radios

- GMRS radios generally do not fully support occupational use
  - GMRS rules (§95.179) allow family members and employees to operate under one license
  - when GMRS is combined with FRS both must satisfy general population exposure limit
- Typical SAR testing concerns for PTT radios:
  - SAR measurement requires continuous transmission
    - battery capacity and other design limitations can result in continuous power droop
  - radios are often overdriven and causing overheating issues
    - the SAR results could be invalid when devices operate outside of specs
    - invalid SAR results cannot be scaled to compensate for power droop
    - SAR may be scaled if radio is tested at lower power without overheating
  - a KDB inquiry is required to address the measurement issues
    - PAG is required for non-standard measurement requirements



# A4WP SAR & Field Measurements

- Recent info indicates ES3DV3 SAR probe may be calibrated
  - at 6 & 13 MHz; valid for 4 – 9 MHz and 9 – 13 MHz
  - with  $\epsilon_r = 55.5$  and  $\sigma = 0.75$  S/m
    - tissue-equivalent liquid recipe info unavailable
  - have not received info for other probe models
- 3<sup>rd</sup> party preliminary data shows SAR is not sensitive to  $\epsilon_r$  at 6.78 MHz
  - based on numerical simulation, for  $\epsilon_r = 50 \sim 300$  and  $\sigma = 0.63$  S/m
- Until procedures are established, SAR measurement specifics for A4WP devices may be addressed through KDB inquiry
- Miniature H-field probes are also available for field mapping
  - around 5 ~ 10 MHz to determine field distributions next to the device
  - for example, to validate numerical models or to support certain analysis for SAR test exclusion



# A4WP Wireless Charging Devices

- Coils and antennas are transmitting elements/components
  - equipment approval does not apply to such components
  - these also do not fit the criteria required for module approval
- §2.1091(d)(4) generally applies to mobile devices that may have some potential to operate in portable device exposure conditions, but not next to persons, where SAR may need consideration
- For portable device exposure conditions, §2.1093 and SAR limits apply
- MPE and SAR may both need evaluation for certain combinations of accessory and use configurations specific to each exposure condition
  - for example, accessory applies to portable but not mobile device use conditions
- When making field measurements
  - scan field probe across entire edge or surface of the device for highest value
  - rotate probe around its axis to check for isotropy at each highest field location
  - report highest recorded field value or, if appropriate, average measurements for each position (surface or edge)
    - do not average numbers across different test positions





## Implant SAR Test Exclusion

- Implant devices are typically evaluated by SAR simulation
- KDB 447498 allows for implant SAR test exclusion
  - when worst case total power available to the antenna is less than 1 mW
- Power measurement results and test setup configurations are required in exposure analysis report to qualify for SAR test exclusion
- The antennas are typically hidden within the implant or embedded in header connectors, with no access port for power measurement
  - explanations to demonstrate how measured results are obtained under specific device operating conditions are necessary in analysis reports
- Design specifications and tune-up tolerance info are also necessary to correlate with measured results
- TCBs are required to verify these before making equipment approval





# **RF Exposure**

## **- Numerical Simulation -**



# RF Exposure Simulation

- The general requirements for using numerical simulation techniques to demonstrate SAR compliance are described in section 4.5 of KDB Publication 447498 D01 with respect to IEC draft 62704-1
- The reporting requirements for SAR simulation are described in KDB Publication 865664 D02
- IEC 62704-1 supports FDTD simulation for 30 MHz – 6 GHz
  - includes detailed protocol for SAR evaluation
  - additional considerations are required to adapt protocol for MPE evaluation
- RF exposure simulations are mostly used outside of IEC 62704-1 frequency range for equipment approval when SAR measurement is difficult
  - other numerical methods, when applicable, are handled case-by-case
  - field simulation and measurement results, in conjunction with additional benchmarking, are often required to validate device modeling and computational accuracy
    - for example; WiGig, A4WP chargers and other low frequency wireless power transfer or charging applications



# Code Validation & Benchmarking

- Numerical code validation according to IEC draft 62704-1 is typically performed by software vendors to demonstrate the accuracy of core numerical algorithms and conformance with standard protocols
- IEC 62704-1 canonical benchmarks may be performed by either the software vendor or end user to demonstrate general acceptability of the simulation tools
- When IEC 62704-1 does not fully apply, additional benchmark results with close relevance to the specific conditions and configurations simulated for the individual device are often necessary to confirm
  - modeling resolution, RF source-feed configurations, lump-circuit elements, device model simplification, use of special techniques, return-loss and resonance conditions etc.
  - the results are compared against known analytical, published or equivalent reference results to demonstrate user competence in applying the numerical tools to simulate the problem at hand



## Applying Numerical Simulation

- Code validation and benchmarking for 30 MHz – 6 GHz SAR simulations have been reviewed on a case-by-case basis for equipment authorization
  - according to on-going developments for IEC 62704-1
  - results from code vendors or users are reviewed through KDB/PAG
  - KDB guidance will be considered after IEC 62704-1 is finalized
    - SAR Star code validation issues recently resolved within IEC 62704-1
- Code validation and benchmarking requirements for other frequencies should be addressed through KDB inquiries, before performing the simulation
  - according to the type of numerical code used and device modeled
  - additional user benchmarking relevant to device seeking approval is typically necessary



## Applying Numerical Simulation (continued)

- Computational and modeling uncertainties have been mostly ignored for the interim and addressed by available compliance margins
  - uncertainty procedures in IEC 62704-1 can be substantially involved for the typical users
  - KDB guidance will be considered after code validation & benchmarking procedures are established
- The same approach is applied to all numerical simulations, but on different time schedules
  - for FDTD-based IEC 62704-1 compliant implementations vs. other numerical methods
  - due to frequency, wireless product and technology or exposure limit issues
  - when coordination with standards development is necessary





# **SAR Measurement System and Methodology Updates**

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# Dynamic Antenna Tuner SAR

- Recently expanded the SAR screening considerations for devices with certain dynamic antenna tuner characteristics
- When tuner hardware is not an integral part of the antenna and it does not affect antenna characteristics and SAR distribution
  - may be able to test SAR with auto-tuned antenna states, and
  - if applicable, single point SAR measurements may be considered for SAR screening of other antenna tuner states to determine additional full SAR measurement configurations
- Results for both single point screening and full SAR measurements must be included in SAR reports
  - sufficient test setup information and rationale are required in test reports to support test results and qualify for SAR test exclusion/reduction
  - the SAR report must be a self supporting standalone document
  - test setup information and results do not qualify for confidentiality
  - only information that satisfies FCC regulations for confidentiality may be included in confidential exhibits and cross referenced in test reports
- A KDB inquiry is required to determine the single point SAR screening test requirements for individual circumstances
  - depending on device capability to switch tuner states remotely while positioned at the phantom without moving it



## Diversity Antenna SAR

- When a transmitter uses identical antennas to support transmit diversity, where
  - the diversity antennas are fed by the same set of identical hardware
    - amplifier, tuning and matching etc.
  - the only difference is the antenna locations within the device
  - there is no simultaneous transmission among the diversity antennas
- To reduce testing time for such combinations while maintaining the same number of normally required tests for each frequency band, wireless mode and exposure condition combination
  - either array sensor SAR systems or the area scan estimated 1-g SAR procedures (Motorola fast SAR) in KDB 447498 may be used in conjunction with full SAR
- SAR is measured using one of these methods; do not mix methods



## Diversity Antenna SAR (continued)

- Full SAR is required for the configuration with highest reported fast SAR among the diversity antennas
  - for each frequency band, wireless mode and exposure condition combination
  - if all required SAR measurement protocols are satisfied in using Motorola fast SAR, when appropriate, the area scan does not need to be repeated
- Full SAR is also required for configurations above certain SAR threshold
  - in each frequency band, wireless mode and exposure condition combination
  - for the antenna with highest reported fast SAR, full SAR measurements are required for all configurations with reported fast SAR  $> 0.8$  W/kg
  - for the other diversity antenna, full SAR is required only when the reported fast SAR of a configuration is  $> 1.2$  W/kg
- All results must be included in the SAR report
- Only full SAR results are used to determine compliance with respect to reported SAR procedures
- When full SAR results are unavailable, fast SAR results should be used to determine simultaneous transmission SAR test exclusion and reduction





# SAR Probe Calibration

- DASYS systems are in the process of implementing sensor model based SAR probe calibration procedures (SMC)
  - the calibration details are not included in on-going SAR measurement standards
- SMC is used in cDASY6 systems, in conjunction with the MAIA
  - PMR calibrations are used for below ~700 MHz; UID based
  - MAIA is optional for DASY5 systems, when unavailable, PMR is used
    - therefore, probe calibration and test signal matching is determined by the user
- SMC is also used in cSAR3D, the sensor array system
  - procedures for this will be considered separately
- Details required to establish KDB guidance are under consideration
  - until KDB procedures are available, TCBs must ensure SAR measurements using probes with SMC are coordinated with the FCC through KDB inquiries to ensure the test procedures and results are acceptable before equipment approval





# Sensor Array SAR Systems

- We are still waiting for certain details to address specific concerns for these systems
- We have reviewed some data for one system
  - system manufacturer is currently addressing certain specific questions and concerns relating to measurement variations and compliance margins
  - in order to understand the source of measurement variations to address compliance margins, the system manufacturer plans to coordinate with several test labs to perform additional testing to address these concerns
- We will continue to provide KDB guidance, on a case-by-case basis, for individual circumstances to use sensor array systems for SAR screening
  - for example, dynamic antenna tuners, diversity antennas etc.
  - this will enable us to collect relevant results and to understand these systems
- In order to consider KDB guidance, we will need to address concerns and differences among currently available sensor array systems
  - therefore, additional coordination would be necessary



# Miscellaneous Updates



## IEC TC106/MT62209 Activities

- Wrist watch and head mounted device SAR procedures
  - IEC TC106/MT62209 is in the process of considering a project to establish SAR measurement protocols for these types of products
- IEC MT62209 is in the process of finalizing a document on protocols for Rel. 8 LTE SAR test reduction
  - the procedures are a little different than those implemented in KDB 941225 D05, which have been in use for 3 – 4 years; but the difference is not substantial
  - since LTE technology is already migrating to Rel. 10, there is no plan to update KDB Publication 941225
- IEC TC106 plans to initiate wireless power transfer project
  - there is proposal from Japan to apply the concepts of coupling factor described in IEC 62233 to determine compliance with induced E-field and SAR limits based on external H-field



## LTE-U Considerations

- This is mostly related to basestation equipment approval; however,
  - for client devices, certain implementation information is necessary to ensure existing test requirements are sufficient and applicable
- Recent implementations of LTE-U involve carrier aggregation
  - different combinations of channel BW may be aggregated using U-NII-1 and U-NII-3 channels and in conjunction with LTE bands
- A KDB inquiry is required for client devices supporting LTE-U or other related Wi-Fi off-loading techniques to determine if certain issues may need consideration; for example,
  - LAA (Licensed Assisted Access)
  - LWA (LTE-WLAN Radio Level Integration and Interworking Enhancement)
  - MuLTEfire
- LTE-U and Wi-Fi off-loading require PAG for equipment approval