



# **RF Exposure Procedures**

**TCB Workshop**

**April 2012**

Laboratory Division

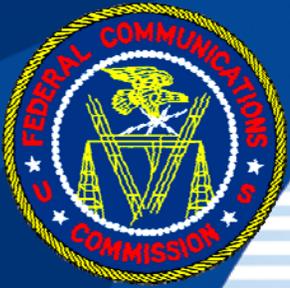
Office of Engineering and Technology

Federal Communications Commission



# Overview

- These KDB publications are undergoing revision
  - drafts are available for review on the KDB website
    - KDB 447498 – mobile & portable RF exposure
    - KDB 865664 – SAR methodology & reporting
    - KDB 616217 – laptop and tablet computers
    - KDB 648474 – wireless handsets
    - KDB 941225 – SAR procedures for LTE
    - KDB 643646 – occupational PTT 2-way radios
  - TCB Exclusion and PBA lists are also updated
    - KDB 628591 and 388624
- Q&A and other miscellaneous updates



**KDB 447498**

**Mobile and Portable Devices  
RF Exposure Procedures  
and  
Equipment Authorization Policies**



## KDB 447498

- The entire collection of RF exposure KDB publications and TCB workshop updates are referred to as the “*published KDB procedures*”
- KDB 447498 is the entry point for the other KDB procedures
  - for testing and equipment approval of transmitters and devices operating in mobile and portable exposure conditions
  - other KDB procedures are applied in conjunction with the procedures in KDB 447498
  - the most recent revision of the *published KDB procedures* must be applied at the time when device testing begins
- KDB 447498 includes procedures required for
  - TCB review and approval
  - equipment and conditions on the TCB Exclusion list



# TCB Approval Requirements

- Equipment approved by a TCB must satisfy all applicable requirements in the *published KDB procedures* to avoid a PBA
- Devices that are categorically excluded from routine RF exposure evaluation must apply the *published KDB procedures* to qualify for TCB approval
- Minor deviations may be accepted with confirmation through KDB inquiry to avoid PBA
- Equipment approval requiring substantial FCC involvement can be subject to FCC approval only
  - for example, new technologies and emerging products
  - applicants wanting to apply alternative procedures or seeking substantial deviation from the guidance documents
  - these are determined during KDB inquiry for test requirements



## General RF Exposure Policies

- When equipment approval is filed at the FCC
  - test results are not required for devices that are categorically excluded from routine RF exposure evaluation
  - except when §1.1307 (c) or (d) is required
- Mobile and portable exposure conditions and host platform approval requirements are determined
  - according to the standalone and simultaneous transmission conditions for host and product configurations
  - with respect to *mobile exposure*, *portable exposure* or *mixed mobile and portable exposure* host platforms



# Host Exposure Platforms

- *Mobile exposure host* platform requires
  - all transmitters in a host to operate in mobile exposure conditions
- *Portable exposure host* platform requires
  - a host to support portable exposure conditions for all transmitters in the host
- *Mixed mobile and portable exposure* host platform allows
  - a host to incorporate transmitters to operate in qualified mobile or portable exposure conditions for standalone and simultaneous transmission operations
- When mobile exposure test exclusion applies to the simultaneous transmission conditions
  - approval for *portable exposure host* platform also qualifies the transmitter or module to operate in *mixed mobile and portable exposure host* platform
  - according to Class I permission change & documentation requirements



## Mixed Mobile & Portable Exposure Conditions

- The *published KDB procedures* should be applied
  - when guidance is unavailable, a KDB inquiry is required
- RF exposure compliance is addressed for the operating configurations and exposure conditions of the transmitters required by the hosts
  - MPE and SAR test exclusion may be applied
  - the *published KDB procedures* or conservative test configurations are required for standalone & simultaneous transmission evaluation
  - the platform configurations and exposure conditions must be supported by the test results or exclusion conditions



# Transmission and Operation Restrictions

- Transmitters and modules approved for use
  - in dedicated host and product configurations are restricted to conditions tested for equipment approval
  - devices approved for standalone operations only cannot be used in any simultaneous transmission operations
    - test exclusion or equipment approval is required
    - grantee must maintain all Class I permissive change records
  - simultaneous transmission operations are restricted
    - to the host platform and product configurations documented in the equipment approval



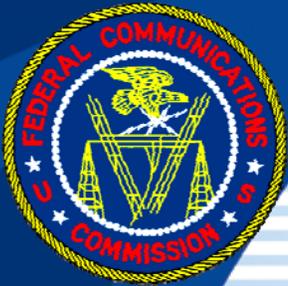
# General Population Exposure

- Consumer products must satisfy general population exposure limits
- The test configurations and exclusion conditions must cover all required operations
- Operating and installation instructions must be supported by test configurations and results
  - instructions cannot be used as a substitute for test requirements
- A device must operate transparently without specific user intervention to maintain compliance
  - when accessories are required, the instructions must support proper use
- Caution statements and labels are generally intended for
  - exposures in unintended use conditions that are not required for normal operation



# Occupational Exposure

- Device use must be “*work-related*”
- Users must be “*fully aware of*” and able to “*exercise control over*” their exposure
- Mandatory RF exposure training is required
  - training instructions provided in user manual, in conjunction with device labeling, may be accepted when
    - users are required to adhere to training instructions, and
    - able to mitigate compliance concerns by applying the instructions
- Equipment approved for general population exposure does not require separate approval for occupational exposure use



# Operating and Installation Instructions

- Instructions for standalone and simultaneous transmission operations are required with respect to §§ 2.1033 (b)(3) and (c)(3)
  - the qualified host platforms & exposure conditions must be identified, including all operating restrictions
- OEM integration, third-party assembly instructions etc. must be consistent with documentation provided for equipment approval
- Instructions must enable the typically unskilled users to install and operate the equipment to ensure compliance



# Operating and Installation Instructions

- The grantee is responsible
  - for ensuring installers and integrators have a clear understanding of the compliance requirements
  - for providing installation support to fulfill grantee responsibility
- 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

- The fundamental SAR test methodologies described in
  - Supplement C 01-01, IEEE Std 1528-2003, should be applied in conjunction with *published KDB procedures*
- Source-based time-averaging should be considered according to
  - maximum conducted output power for SAR
  - ERP for MPE, as required by §2.1091
  - the required *published KDB procedures*
- Far-field antenna gain generally does not apply to SAR
- Devices should be tested at the maximum rated output power
  - within the specified tune-up tolerance range, and
  - also within 2 dB of the maximum tune-up tolerance limit
  - when tune-up info is not required for equipment approval, equivalent criteria must be applied based on maximum output of production units



# General Test Requirements

- A device must remain compliant
  - when measured results are scaled to the maximum tune-up tolerance, according to the output power of the channel tested
- The scaling should be documented in test reports
  - for the highest measured results in each frequency band, and
  - for all measured SAR > 1.5 W/kg; MPE within 5% of the limit
- 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
- The test setup must not perturb device performance and SAR characteristics or inconsistent with required test protocols to avoid
  - test device holder and device performance interactions
  - field scattering from nearby objects



# Head Exposure Conditions

- For handsets operating next to the ear
  - the procedures in IEEE Std 1528-2003, Supplement C 01-01 and the *published KDB procedures* must be applied
  - SAM phantom is required for SAR measurements
- For other head exposure conditions, such as in front of the face
  - handheld PTT two-way radios procedures should be applied
    - KDB 447498 for consumer products
    - KDB 643646 for occupational PTT 2-way radios
  - flat phantom is used for SAR measurements
    - according to the *published KDB procedures*



# Body-Worn Accessory Exposure Conditions

- Body-worn accessory SAR testing is required for
  - all body-worn accessories supplied or available as options from grantee
    - accessories without metallic components are tested selectively for worst case exposure
    - accessories containing metallic components must be each tested separately
- Off the self body-worn accessories for cellphones
  - the test separation distance should be consistent with the device form factor and types of accessory users may acquire, and fully justified in the SAR report
- All wireless and operating modes of a phone must apply the same body-worn accessory test separation distance
- Body-worn accessory SAR for voice and/or data mode is determined by the transmission requirements of a device while operating with a body-worn accessory



# Body Worn Accessory Exposure Conditions

- Manual instructions are required to support body-worn accessory use
  - for users to acquire the correct body-worn accessories to meet minimum separation distance requirements
  - to disclose all unsupported operating configurations
    - for example, pocket and lanyard use while in speaker mode, with wired or Bluetooth headset etc.
  - to identify all body-worn accessories with metallic components
  - to identify the device orientations when inserted in body-worn accessories, in accordance with the test results
- The instructions must enable users to easily understand the operating requirements to maintain compliance
- For devices designed to support next to body use without body-worn accessory, SAR compliance at  $\leq 5$  mm is required



# Extremity Exposure

- Extremity and body exposure may apply to devices
  - operated on extremities or only by the extremities
    - such as hands, wrists, feet and ankles
  - in close proximity to the user's body
- The test exclusion procedures are only applicable to
  - operations at 100 MHz – 6 GHz, and
  - with minimum separation distances  $\geq 5$  mm and  $\leq 50$  mm
- Extremity SAR evaluation is not required when
  - the maximum output and minimum separation distance conditions are  $< 2.5$  times the SAR Exclusion Threshold requirements



## Extremity Exposure

- Body SAR evaluation is not required when
  - the maximum output and minimum separation distance conditions are  $<$  the SAR Exclusion Threshold requirements
- In applying the SAR Exclusion Threshold, tune-up tolerances should be included in the maximum output power of a test channel
- The minimum separation distance is determined
  - by the smallest distance between any part of the extremity or user's body and the antenna and radiating structures or outer surface of a device,
  - according to the host form factor and platform requirements; for example, laptop vs. cellphones



# Implanted Transmitters

- SAR test exclusion may be applied
  - when the maximum total available power at the antenna port or radiating structures of an implanted transmitter is  $\leq 1.0$  mW
  - maximum total available power implies worst case power and exposure conditions under all operating circumstances
  
- The maximum output and exposure conditions
  - must be fully justified in a SAR analysis report
    - in lieu of the SAR evaluation to qualify for the test exclusion
    - according to the design and implementation requirements
    - fully supported by the power measurement results



## Standalone SAR Test Exclusion

- Except when required by the *published KDB procedures*, the SAR Exclusion Threshold for standalone operations is determined by the following
- $[(\text{max. power of channel, including tolerance, mW}) / (\text{min. separation distance, mm})] \cdot [\sqrt{f_{(\text{GHz})}}] \leq 3.0$ , where
  - $f$  is the RF channel transmit frequency in GHz
  - power & distance are rounded to the nearest mW & mm
  - the result is rounded to 1 significant digit for comparison



# SAR Exclusion Threshold

- The exclusion applies for frequencies between 100 MHz and 6 GHz
  - when the minimum separation is  $\geq 5$  mm and  $\leq 50$  mm, and
    - must be fully justified by the operating configuration and exposure conditions of the transmitter/module and host platform configurations
  - minimum separation distance is determined by the separation from
    - antenna and radiating structures to the user for large form factor hosts
    - outer surface of device to the user for small form factor devices
  - when no other testing or reporting is required
    - a statement of justification is required, in lieu of the SAR report, to qualify for the test exclusion



## SAR Exclusion Threshold

- The exclusion threshold is based on
  - $[(\text{max. power of channel, including tolerance, mW}) / (60 / \sqrt{f_{(\text{GHz})}}, \text{mW})] \cdot [20 \text{ mm} / (\text{min. separation distance, mm})] \leq 1.0$
- The threshold is configured to limit the estimated SAR to  $\leq$  approximately 0.4 W/kg, based on substantially conservative exposure conditions



# SAR Exclusion Threshold

- Approximate SAR Test Exclusion power thresholds at selected frequencies and distances are illustrated

MHz	5	10	15	20	25	mm
150	39	77	116	155	194	SAR Test Exclusion Threshold (mW)
300	27	55	82	110	137	
450	22	45	67	89	112	
835	16	33	49	66	82	
900	16	32	47	63	79	
1500	12	24	37	49	61	
1900	11	22	33	44	54	
2450	10	19	29	38	48	
3600	8	16	24	32	40	
5200	7	13	20	26	33	
5400	6	13	19	26	32	
5800	6	12	19	25	31	



# SAR Exclusion Threshold

- Approximate SAR Test Exclusion power thresholds at selected frequencies and distances are illustrated

MHz	30	35	40	45	50	mm
150	232	271	310	349	387	SAR Test Exclusion Threshold (mW)
300	164	192	219	246	274	
450	134	157	179	201	224	
835	98	115	131	148	164	
900	95	111	126	142	158	
1500	73	86	98	110	122	
1900	65	76	87	98	109	
2450	57	67	77	86	96	
3600	47	55	63	71	79	
5200	39	46	53	59	66	
5400	39	45	52	58	65	
5800	37	44	50	56	62	



## Estimating SAR for Simultaneous Transmission Test Exclusion

- When standalone SAR test exclusion is applied, the SAR must be estimated and used to determine simultaneous transmission SAR test exclusion
  - the standalone SAR is estimated by
    - $[(\text{max. power of channel, including tolerance, mW}) / (\text{min. separation distance, mm})] \cdot [\sqrt{f_{(\text{GHz})}} / 7.5] \text{ W/kg}$ , rounded to 2 significant digits
  - the peak SAR location is assumed to be at the feed-point or geometric center of the 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



# Estimated SAR for Simultaneous Transmission SAR Test Exclusion

MHz	10	25	50	100	150	200	mW	Min. Distance
150	0.0	0.1	0.1	0.2	0.3		194	25 (mm)
300	0.0	0.1	0.1	0.3			137	
450	0.0	0.1	0.2	0.4			112	
835	0.0	0.1	0.2				82	
900	0.1	0.1	0.3				79	
1500	0.1	0.2	0.3				61	
1900	0.1	0.2	0.4				54	
2450	0.1	0.2					48	
3600	0.1	0.3					40	
5100	0.1	0.3					33	
5400	0.1	0.3					32	
5800	0.1	0.3					31	
<p>Red number column is approximate maximum output power at the SAR Exclusion Threshold            Top row indicates different maximum output power levels for test device</p>								



## Simultaneous Transmission SAR Test Exclusion

- The measured or estimated standalone SAR are used to determine simultaneous transmission SAR test exclusion, when
  - the sum of 1-g SAR for all simultaneous transmitting antennas in each operating and exposure condition is  $\leq 1.6$  W/kg, or
  - the SAR peak location separation ratio is  $\leq 0.04$ 
    - for each antenna pair in each simultaneous transmission configuration
    - according to  $(SAR_1 + SAR_2)^{1.5} / R_i \leq 0.04$ , that is
      - $R_i$  must be  $> 25 \cdot (SAR_1 + SAR_2)^{1.5}$  to qualify for exclusion
      - $R_i$  is rounded to the nearest mm



## Simultaneous Transmission SAR Test Exclusion

- When power reduction applies, SAR test exclusion may be based on the standalone SAR at non-reduced maximum output
- When simultaneous transmission SAR testing is required, the maximum output in power reduction mode must be used



# SAR Peak Location Separation Ratio

- 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
- When standalone SAR is measured for both antennas in the pair, the peak location separation distance is determined by
  - $[(x_1-x_2)^2 + (y_1-y_2)^2 + (z_1-z_2)^2]$
- When SAR for one antenna is estimated and the other is measured
  - the measured peak location should be projected onto the test device to determine peak location separation distance
  - the projection should be through the point normal to the phantom surface, corresponding to a straight line connecting the measured peak and the device
  - the projection should be illustrated on SAR plots



## SAR Test Channel Reduction

- When the frequency channels required for SAR testing are not specified in the *published KDB procedures*, the following applies

$$N_c = \text{Round} \left\{ \left[ 100(f_{\text{high}} - f_{\text{low}}) / f_c \right]^{0.5} \times (f_c / 100)^{0.2} \right\}$$

- $N_c$  is the number of test channels, rounded to the nearest integer;
- $f_{\text{high}}$  and  $f_{\text{low}}$  are the highest and lowest channel frequencies within the transmission band,
- $f_c$  is the mid-band channel frequency, and
- frequencies are in MHz



## SAR Test Channel Reduction

- When the highest output or middle channel satisfies the following, other channels do not need testing
  - $\leq 0.8$  W/kg and transmission band  $\leq 100$  MHz
  - $\leq 0.6$  W/kg and,  $100$  MHz  $<$  transmission bandwidth  $\leq 200$  MHz
  - $\leq 0.4$  W/kg and transmission band  $> 200$  MHz
- Where
  - the highest maximum output power of all transmission channels in a frequency band must not be higher than the channel tested, or
  - the measured SAR is scaled to the upper tune-up tolerance limit to account for highest maximum output expected for production units



# Numerical SAR Simulation

## ● When FDTD is used

- the most recent draft standard IEEE 1528.1 & draft IEC 62704-1 must be applied
  - including the numerical code validation requirements
  - differences in numerical codes and algorithms used, including gram-averaging requirements, must be insignificant
- the tissue dielectric parameters on the FCC/OET website should be applied to heterogeneous anatomical models
  - <http://transition.fcc.gov/oet/rfsafety/dielectric.html>
- the dielectric parameters required for SAR measurements should be applied to homogeneous models
- a detailed test report is required
  - similar to that required for SAR measurements
  - in accordance with the FDTD reporting procedures in Supplement C 01-01



## Numerical SAR Simulation

- Validation is required for the anatomical and device models
  - due to simplified assumptions required for modeling complex transmitters, devices and anatomical structures
  - due to limitations required by constraints for simulation and modeling
  - by verifying numerical results against field strength and/or SAR measurement results in selected configurations
  - device models may be verified by comparing simulated and measured return loss and field strength results in free-space conditions
- When other numerical computation methods are used in accordance with FCC provision
  - the equivalent considerations required for FDTD must be applied



# Modules and Peripheral Transmitters

- Modules and module-like peripheral transmitters include
  - modules approved according to modular approval requirements
  - module-like peripheral transmitters connected through standard interface connections that are internal or external to the host device
- Peripheral transmitters require a host to operate
  - ExpressCard, USB etc.
- The operating and exposure conditions are dependent on host device implementation, form factor and use conditions
  - for both standalone and simultaneous transmission operations
  - SAR characteristics of a transmitter may vary with different host configurations
- The transmitters and modules must remain compliant in all host configurations



# Modules and Peripheral Transmitters

- Influence of newly added transmitter or module in a host may trigger additional equipment approval requirements for existing transmitters
- Additional equipment approval may include
  - Class II permissive changes from the module transmitter grantee
  - a new FCC ID for the host device
  - a change of FCC ID, followed by subsequent Class II permissive change by the module transmitter manufacturer



# Modules and Peripheral Transmitters

- Modular approach may not be appropriate for some configurations
  - when transmitters and antennas are in close proximity to each other or to users and there are RF energy coupling or high SAR concerns
  - the mixed modular and dedicated host approach allows testing of the higher output transmitters in a host to account for interactions due to low power/SAR devices through normal testing, without the need to test the low power/SAR transmitters



# Acceptable Transmitter Module Approval Configurations

- For standalone operations only, without simultaneous transmission
  - in either mobile or portable exposure conditions
  - without or without host platform restrictions, as supported by the test results, or
  - in dedicated host or product configurations
- For standalone and simultaneous transmission
  - in either mobile only or portable only exposure conditions
  - with or without host platform restrictions, as supported by test results, or
  - in mobile and portable exposure conditions
  - in qualified hosts and product configurations that support mixed mobile and portable exposure conditions, or
  - in dedicated host and product configurations
- New filing may be required to qualify for other operating and exposure conditions to minimize various approval difficulties



## Modules in Portable Standalone Exposure Conditions

- Approval considerations according to measured SAR
- $\leq 0.4$  W/kg, there is no host platform restriction
  - SAR is required when SAR Exclusion Threshold at 5 mm is exceeded
  - need to verify energy coupling enhancement with separation distance
  - cannot be applied when
    - separation distance is  $> 5$  mm
    - energy coupling enhancement requires 1-g SAR and is  $> 0.45$  W/kg
- $> 0.4$  and  $\leq 0.8$  W/kg, may qualify for multiple host platforms
  - each host platform must be tested independently
  - same FCC ID may cover multiple host platforms
    - the same test, installation requirements must be satisfied under the same approval criteria and category



# Modules in Portable Standalone Exposure Conditions

- Approval considerations according to measured SAR
- $> 0.8$  and  $\leq 1.2$  W/kg, module is limited to a single platform
  - separate FCC ID is required for each host platform to manage testing and compliance issues
  - all subsequent Class II permissive changes must be within the scope of defined host configurations and exposure conditions in initial approval
- $> 1.2$  W/kg, transmitter is limited to dedicated host only
  - approval is for host configurations tested for compliance
  - peripheral transmitters cannot be restricted to dedicated host operations; therefore, may require design changes to satisfy SAR compliance for use in multiple hosts



## Modules in Portable Standalone Exposure Conditions

- Unless there are specific provisions in *published KDB procedures*
  - due to SAR influence concerns, all power control and related operating functions must be fully contained within an approved transmitter
  - dedicated host approval is preferred when control of transmitter functions and parameters is shared or provided by the host
- When it is not specified in the *published KDB procedures*, the minimum separation distance used for SAR testing must be conservatively justified according to host platform requirements
- Peripheral transmitters connected through or supplied with cables and adapters should be tested with a separation distance  $\leq 15$  mm
  - separation distance is determined by the antenna & radiating structures or outer housing, according to the operating requirements & exposure conditions



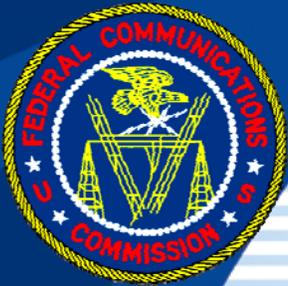
# Modules in Portable Standalone Exposure Conditions

- Detailed OEM integration and installation requirements are required
- Grantee responsibilities and third-party obligations must be clearly identified in instructions, including all restrictions
  - to incorporate or use the transmitter or module in approved host platforms and configurations
- The approved and required antenna configurations for use in qualified host platforms must be specified in the instructions
  - antenna-to-user separation distances
  - antenna-to-antenna separation distances
  - antenna polarization and orientation requirements in different host configurations
- Documentation for requiring acceptable operating instructions to be provided to end users of all final products is required



# Modules in Portable Simultaneous Transmission Exposure Conditions

- Simultaneous transmission SAR test exclusion is determined by
  - the sum of 1-g SAR, or
  - peak SAR location separation ratio
- When test is required, enlarge zoom scan measurements and volume scan post-processing procedures in KDB 865664 must be applied
- A KDB inquiry is required for the following
  - when coherent signals are involved in the simultaneous transmission
  - when different maximum output power levels are applied to the individual antennas of a transmitter or MIMO chain
  - the maximum output power of a transmitter or antenna varies by more than 1 dB cross all channels in a frequency band



## Handheld PTT Two-Way Radios

- In front of the face and body-worn accessory exposure conditions apply to handheld PTT radios
- 50% duty factor applies to PTT mode using a mechanical button
  - when duty factor is  $> 50\%$ , the highest duty factor should be tested
    - such as in PSTN calls, Bluetooth or voice activated transmissions etc.
  - duty factors inherent to TDMA should also be considered
- SAR test Exclusion applies to face and body-worn accessory exposure
  - according to duty factor adjusted maximum output power
  - 25 mm separation for face and 10 mm for body-worn accessory must be used to apply the SAR Exclusion Threshold
- PTT radios supporting next to ear use requires SAR with SAM phantom
  - this generally does not apply to cellphones with PTT mode



# Wrist Watch and Wrist-Worn Transmitters

- Voice communication for wrist watch is typically in speaker mode
  - with device worn on wrist and held next to the mouth
  - 1-g SAR applies to the mouth and 10-g SAR applies to the wrist
- SAR test exclusion applies to body and extremity
- Wrist SAR is tested with back of device in contact with flat phantom
  - wrist bands should be unstrapped and touching the phantom
  - when back of device does not conform to flat phantom, certain curved regions of the SAM phantom may be considered, after confirmation through KDB inquiry
- Head SAR is tested with front of device at 10 mm from flat phantom
  - wrist bands should be strapped to represent normal use conditions
- The procedures may not apply to wrist-worn devices with other use conditions



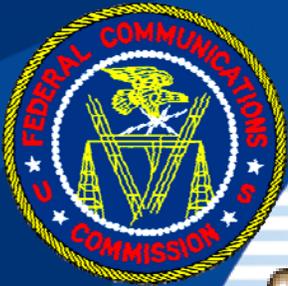
# Low Transmission Duty Factor Devices

- Intermittent transmissions in data mode may not be source-based, but the duty factor can be quite low
  - when an acceptable worst case or most conservative transmission duty factor is determined
  - when the duty factor adjusted maximum output and minimum distance satisfy the SAR Exclusion Threshold
    - SAR analysis report may be accepted in lieu of SAR measurements
  - when SAR measurements are required, SAR may be scaled by the duty factor to determine compliance
- Low duty factor exclusion does not apply to voice mode
  - except transmission duration is very short and seldom required
  - requires case-by-case determination



## After-Market Accessories

- Accessories that do not contain transmitters
  - but have potential to change the exposure characteristics of approved host devices are assessed with the intended hosts to qualify for use with such hosts
- Equipment approval does not apply when there is no transmitter in the accessory
  - however, an accessory is not qualified to operate with intended hosts unless the hosts remain compliant when operating with the accessory



## After-Market Accessories

- Compliance of accessories available from original host manufacturer
  - may be addressed through Class I and Class II permissive change requirements
  - when there is no equivalent test configurations in the original approval that enable SAR distributions and exposure conditions to be compared to determine SAR degradation, Class II permissive change applies
- Third-party accessory suppliers should consult with original host equipment manufacturer to determine approval options
  - adding the accessory through host equipment approval, or
  - apply for a change of FCC ID followed by Class II permissive changes



## After-Market Accessories

- Separate equipment approval is required for accessories that contain transmitters
- Equipment approval is not required for hosts without transmitter
- SAR compliance is determined according to
  - the standalone operating requirements of the transmitter(s) in the accessory, with and without the host
  - simultaneous transmission operating requirements of all transmitter combinations, with and without the host
- This type of accessories may be used with
  - handsets, music players or other small consumer electronic devices; as snap-on sleeves, plug-in components or other carrying accessories
- A KDB inquiry is required to determine test requirements due to significant variations in accessory and host use conditions



## Other Consumer Electronic Devices

- The exposure conditions for transmitters and modules used in consumer electronic devices, such as printers, cameras, camcorders etc. may vary
- The SAR exclusion and test requirements are determined according to
  - the transmitter and antenna configurations
  - antenna-to-user separation distance
  - simultaneous transmission requirements
  - device operating configurations
- When test exclusion applies
  - the details must be fully explained in the equipment approval or Class I permissive change records
- The standalone and simultaneous transmission SAR procedures for modules should be considered



## Standalone Mobile Exposure Conditions

- Transmitters approved only for standalone mobile exposure conditions
  - must not transmit simultaneously
  - all transmitters must meet mobile exposure requirements
  - with  $\geq 20$  cm between users and nearby persons
- The SAR required for §2.1091(d)(4) is determined by KDB inquiry
- Cable losses and attenuations included to determine compliance must be consistent with the actual use configurations



## Standalone Mobile Exposure Conditions

- When categorical exclusion applies, the minimum separation distance should be estimated according to simple calculations
  - to ensure the device operates in manners exceeding the estimated distance
  - the estimate must be based on worst case conditions – power, antenna gain etc.
  - the calculations must be appropriate for the type of antenna used
- When the estimated distance is overly conservative, MPE measurements may be considered to determine the minimum separation distance



# Standalone Mobile Exposure Conditions

- Exclusion thresholds are
  - 1.5 W ERP  $\leq$  1.5 GHz and 3.0 W ERP  $>$  1.5 GHz
- When routine evaluation is required
  - estimated distances based on simple calculations are not acceptable
  - MPE measurement or computational modeling is required to determine compliance and to qualify for TCB approval
  - table below illustrates the issues relating to maximum ERP associated with distance and power density derived from simple calculations

MHz	mW/cm <sup>2</sup>	20	21	22	23	cm
< 300	0.2	0.61	0.68	0.72	0.81	estimated max. ERP (W)
450	0.3	0.92	1.01	1.11	1.22	
835	0.6	1.72	1.89	2.08	2.27	
> 1500	1.0	3.07	3.38	3.71	4.05	



# Standalone Mobile Exposure Conditions

- MPE evaluation is with respect to field strengths and power density
  - compliance is determined by peak or spatially averaged results for
    - E & H field strengths < 300 MHz
    - plane-wave equivalent power density  $\geq$  300 MHz
  - equipment with isotropic sensors is used to measure the orthogonal field components to determine total field
  - unless access is restricted, measurements in all directions surrounding the antenna is required



# Standalone Mobile Exposure Conditions

- For measurements in horizontal planes
  - measured points should be along radials from antenna that are 45° apart
    - $\leq 30^\circ$  when the distance is  $> 60$  cm from the antenna
  - direction of maximum exposure should be aligned to a radial
  - unless the person is aligned in horizontally, spatial averaging should not be applied to results in the horizontal plane



# Standalone Mobile Exposure Conditions

- For measurement in vertical planes, the measurements points
  - should extend at least 10 cm beyond the exposed portions of a person's body or until the results are  $< 10\%$  of MPE limit
  - should be  $\geq 10$  cm from the ground
  - may be spatially averaged to determine compliance
- When antennas transmit in multiple frequency bands
  - users 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



## Standalone Mobile Exposure Conditions

- When specific antennas are not identified in the installation requirements
  - users and installers may choose antennas with different gain requirements
  - the maximum antenna gain allowed for each frequency band must satisfy the most restrictive separation distance required for all frequency bands
- The required antenna type, radiating characteristics, antenna gain and unique separation distance must be fully disclosed in all instructions



# Simultaneous Transmission Mobile Exposure Conditions

- MPE test exclusion may apply to mobile exposure conditions
  - when all antennas in the host comply with mobile exposure requirements for standalone use
  - the minimum separation distance for standalone use is the same or more conservative than that required for simultaneous transmission
  - sum of MPE ratios for all simultaneous transmitting antennas is  $\leq 1.0$
- Test exclusions may apply to mixed mobile and portable exposure conditions when
  - $[\sum \text{ of (the highest measured or estimated SAR for each standalone antenna configuration, adjusted for maximum tune-up tolerance) / 1.6 W/kg}] + [\sum \text{ of MPE ratios}] \leq 1.0$ ; or
  - SAR to peak location separation ratios for all simultaneous transmitting antenna pairs operating in portable exposure conditions are all  $\leq 0.04$  and the  $[\sum \text{ of MPE ratios}] \leq 1.0$



# Simultaneous Transmission Mobile Exposure Conditions

- In mixed mobile and portable exposure conditions, when test exclusion does not apply
  - simultaneous transmission SAR is required for simultaneous transmitting antennas in portable exposure conditions
- The [(highest measured simultaneous transmission SAR, adjusted for maximum tune-up tolerance) / 1.6 W/kg] + [∑ of MPE ratios] must be  $\leq 1.0$ ; 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



# **KDB 865664**

SAR Measurement Requirements  
for  
100 MHz – 6 GHz

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RF Exposure Compliance Reporting  
and  
Documentation Considerations



## KDB 865664

- This revision replaces the earlier version
  - earlier version was for 3 – 6 GHz
  - revision is for 100 MHz to 6 GHz
  - certain SAR measurement parameters in draft standard IEEE 1528-2011 have been considered
  - SAR probe and dipole calibration requirements in KDB 450824 are now integrated with KDB 865664
    - KDB 450824 will be eliminated
- KDB 865664 is limited to above 100 MHz
  - RF exposure limits are not established below
    - 300 kHz for MPE
    - 100 kHz for SAR
  - SAR test requirements are not established below 100 MHz
    - compliance with respect to §1.1307 (c) & (d) may be required



## KDB 865664

- KDB 865664 has an attachment to provide guidance for
  - documenting RF exposure compliance
  - reporting test results
  - test labs to maintain reporting consistency
    - allow a TCB to streamline the review and approval process
- The RF Exposure Compliance Reporting and Documentation attachment identifies the information
  - to be included in all RF exposure reports
  - specific to MPE, SAR and analysis reports, including
    - general device information
    - test setup information
    - test results to support standalone and simultaneous transmission
    - other supporting information, such as plots, illustrations and calibration data



# SAR Probe Requirements

- Probe tip diameter can influence probe boundary effect error
  - without compensation, probe tip needs to maintain  $\frac{1}{2}$  the tip diameter distance from the phantom surface
- Probe sensor offset from the probe tip can affect how close measurements are made from the phantom surface
- Closest measurement point from phantom surface is determined by
  - measurement point defined at the geometric center of the probe sensors
  - aggregate requirements of probe tip diameter and probe sensor offset
- Probe tip diameter must be
  - $\leq 8$  mm for measurements  $\leq 2$  GHz
  - $\leq 1/3$  of a wavelength in the required tissue medium when  $> 2$  GHz
- Closest measurement point must be
  - $\leq 5$  mm for measurements  $\leq 3$  GHz
  - $\leq \frac{1}{2} \cdot \delta \cdot \ln(2)$  in the required tissue medium when  $> 3$  GHz
    - $\delta$  is the penetration depth



# SAR Probe Calibration

- Probes should be calibrated
  - according to IEEE Std 1528-2003 and probe manufacturer requirements
  - by probe manufacturer or its accredited /designated calibration facility
- The effective frequency interval of a probe calibration point
  - should be  $\geq 50$  MHz to cover measurements in most frequency bands
  - must be sufficient to cover the channel bandwidth of measured signal
    - wide frequency bands may require multiple calibration points
  - can be influenced by the tissue dielectric medium recipe and parameters used during calibration vs. routine measurements
- SAR probe requirements are verified during system validation
  - before a system is deployed for routine measurement
  - after hardware upgrades, software updates, component calibrations etc.



# SAR Probe Calibration

- Probes are typically calibrated using sinusoidal CW signals
  - for measurements of CW-equivalent signals
  - periodic pulse-modulated CW-equivalent signals
    - such as GMSK in GSM
  - pulse duty factor is often called “crest factor”
    - but it is not related to the voltage crest factor of a signal
- Additional considerations are required for probes calibrated with CW-equivalent signals to measure signals
  - that are non-periodic
  - with high peak-to-average power ratio
- Signal specific calibrations may be available from probe manufacturers
  - standardized protocols have not been established
- All probes must be calibrated with an expanded uncertainty  $\leq 15\%$ 
  - for a confidence interval of  $k = 2$



# Tissue Dielectric Parameters

- Head and body tissue dielectric parameters are listed in Supplement C 01-01
  - the parameters should be linearly interpolated to the test channel frequency
  - to determine the parameters are within tolerance
  - 5% tolerance is required for  $\epsilon_r$  and  $\sigma$ ; except
  - when SAR error compensation for tissue dielectric parameter deviations is implemented in the SAR system
    - according to the algorithms in draft standard IEEE 1528-2011, and
    - applied correctly to the measurements
    - 10% tolerance may be applied



## Tissue Dielectric Parameters

- The dielectric parameters must be measured before each series of SAR measurements that uses the tissue medium to determine tolerances
  - the measurement should be repeated every 3 – 4 days, or
  - sooner when parameters are marginal before the initial measurements
- The tissue medium temperature between parameter characterization and routine measurement must be
  - within 2°C of each other, and
  - also within 18 – 25°C
- The temperature sensitivity and short term stability of the dielectric parameters also need examined



## Phantom Requirements

- The SAM phantom defined in IEEE Std 1528-2003 is required for next to the ear head SAR measurement
- Flat phantoms are normally used for other SAR measurements
  - in front of the face, body-worn accessories, extremities etc.
- The tissue media depth must be
  - $\geq 15.0 \pm 0.5$  cm for measurements  $\leq 3$  GHz
  - $\geq 10.0 \pm 0.5$  cm for measurements  $> 3$  GHz
  - measured from the ERP of SAM and center of the measurement region for flat phantoms



## Phantom Requirements

- The required phantom shell dielectric parameters are
  - $2 \leq \epsilon_r \leq 5$  at  $\leq 3$  GHz
  - $3 \leq \epsilon_r \leq 4$  at  $> 3$  GHz
  - loss tangent  $\leq 0.05$
  
- Phantom shell thickness must be
  - $2.0 \pm 0.2$  mm in the measurement regions
  - $6.0 \pm 0.2$  mm at ERP location of the SAM phantom



# SAR Measurement Requirements

- Measurements below 300 MHz must be within  $\pm 50$  MHz of probe calibration point frequency
- Measurement above 300 MHz must be within
  - $\pm 100$  MHz of probe calibration point frequency, or
  - valid frequency range of the probe calibration point
  - whichever is less
- When the measured 1-g or 10-g SAR is within 10% of the SAR limit, additional considerations are required for measurements exceeding 50% of the  $\pm 50$  and  $\pm 100$  MHz requirements (above) to qualify for TCB approval
  - (list continues on next slide)



# SAR Measurement Requirements

- when the actual tissue dielectric parameters are recorded for the probe calibration
  - $\epsilon_r$  and  $\sigma$  must be within 5% of those recorded during calibration and also within 5% of the required target values, or
  - within 10% when SAR error compensation for dielectric parameter deviation is correctly applied
- When nominal tissue dielectric parameters and tolerances are recorded for the probe calibration
  - $\epsilon_r$  must be less than and  $\sigma$  must be greater than the required tissue dielectric target values, or
  - within +5% and -10% for  $\epsilon_r$  and within -5% and +10% for  $\sigma$  when SAR error compensation for dielectric parameter deviation is applied
- The applicable conditions must be clearly identified in SAR reports



## Area Scan Parameters

	$\leq 3$ GHz	$> 3$ GHz
Maximum distance from closest measurement point (geometric center of probe sensors) to phantom surface	$5 \pm 1$ mm	$\frac{1}{2} \cdot \delta \cdot \ln(2) \pm 0.5$ mm
Maximum probe angle from probe axis to phantom surface normal at the measurement location	$30^\circ \pm 1^\circ$	$20^\circ \pm 1^\circ$
Maximum area scan spatial resolution: $\Delta x_{Area}$ , $\Delta y_{Area}$	$\leq 2$ GHz: $\leq 15$ mm $2 - 3$ GHz: $\leq 12$ mm	$3 - 4$ GHz: $\leq 12$ mm $4 - 6$ GHz: $\leq 10$ mm
	When either the x or y dimension of the test device in the measurement plane is smaller than the above, the measurement resolution must be $\leq$ the corresponding x and y dimensions of the test device, with at least one measurement point on the test device.	



# Zoom Scan Parameters

		$\leq 3$ GHz	$> 3$ GHz	
Maximum zoom scan spatial resolution: $\Delta x_{Zoom}$ , $\Delta y_{Zoom}$		$\leq 2$ GHz: $\leq 8$ mm 2 – 3 GHz: $\leq 5$ mm	3 – 4 GHz: $\leq 5$ mm 4 – 6 GHz: $\leq 4$ mm	
Maximum zoom scan spatial resolution, normal to phantom surface	uniform grid: $\Delta z_{Zoom}(n)$	$\leq 5$ mm	3 – 4 GHz: $\leq 4$ mm 4 – 5 GHz: $\leq 3$ mm 5 – 6 GHz: $\leq 2$ mm	
	graded grid	$\Delta z_{Zoom}(1)$ : between 1 <sup>st</sup> two points closest to phantom surface	$\leq 4$ mm	3 – 4 GHz: $\leq 3$ mm 4 – 5 GHz: $\leq 2.5$ mm 5 – 6 GHz: $\leq 2$ mm
		$\Delta z_{Zoom}(n>1)$ : between subsequent points	$\leq 1.5 \cdot \Delta z_{Zoom}(n-1)$	
Minimum zoom scan volume	x, y, z	$\geq 30$ mm	3 – 4 GHz: $\geq 28$ mm 4 – 5 GHz: $\geq 25$ mm 5 – 6 GHz: $\geq 22$ mm	



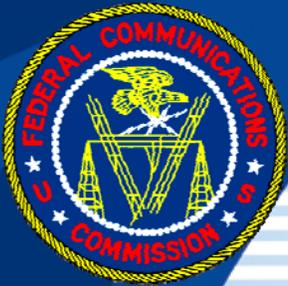
# SAR Scan Requirements

- When probe boundary effect error compensation is applied, it must be clearly indicated in test reports; otherwise
  - $\frac{1}{2}$  probe tip diameter spacing is required between the probe tip phantom surface
  - some probes may not satisfy requirements above 3 GHz without compensation
- The probe and measurement parameters must be clearly identified in SAR reports to support the measurement setup and results
- Post-processing algorithm tolerances are verified during SAR system validation; the results are maintained by the test lab



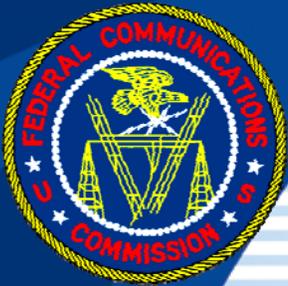
## SAR Scan Requirements

- Area scan should cover the projected areas of a device and its antennas
  - all peak locations must be  $\geq \frac{1}{2}$  the zoom scan volume edge dimensions from the area scan boundary
- When the 1-g or 10-g SAR is within 2 dB of the SAR limit,
  - all peaks within 2 dB of the highest peak also require zoom scan measurement
- 1 or 10-g averaging volume must be fully contained within the zoom scan



# Post-Processing Requirements

- The interpolation and extrapolation algorithms of the SAR system
  - are verified against reference SAR distribution functions in IEEE Std 1528-2003
  - to ensure measurement resolutions used in area and zoom scans are acceptable
- Most SAR systems have built-in provisions for this
  - SAR values are generated by the reference functions for the assumed measurement points and then input to the SAR system for post-processing
  - the interpolated and extrapolated results from the SAR system are compared to values generated by the reference functions
  - verification for different grid offset conditions are also required
- This is normally performed as part of the system validation process
  - for the measurement resolutions required in routine measurements



# 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
  - apply the normal area and zoom scan procedures with all transmitters operating simultaneously
  - a KDB is required to determine test requirements for coherent signals
- For transmissions in multiple frequency bands
  - apply enlarged zoom scan procedures to all transmitters operating within each valid probe calibration point & tissue frequency interval
  - apply volume scan post-processing procedures to determine the 1-g SAR for the aggregate 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 required for a normal zoom scan should be applied
- Area scan is not required; when necessary, may be used to determine the extent of SAR distributions to minimize the enlarged zoom scan measurement volume(s)
- volume scan post-processing algorithms may vary among SAR systems or implementation versions that may impose measurement restrictions; for example
  - measurement resolutions
  - interpolation and extrapolation procedures
  - overlapping scan regions
  - other measurement parameters



## Enlarged Zoom Scan and Volume Scan Post-Processing

- Contour plots for enlarged zoom scans and volume scan distributions are required to support test results
- When the RF performance characteristics of a transmitter is different for standalone and simultaneous transmission operations
  - it could be incorrect to determine the aggregate SAR by summing SAR distributions
  - volume scan procedures may not apply
- When SAR scaling is required, additional considerations are required
  - scaling must be applied to the measured points before any post-processing



## Measurement Repeatability

- When the highest 1-g SAR in a frequency band is  $< 1.5$  W/kg
  - measurement uncertainty analysis is not required in SAR reports
  - measurement repeatability results are required in all reports to qualify for TCB approval
  - the highest SAR measured among all test configurations in each frequency band should be repeated
    - $< 0.4$  W/kg, additional measurement is not required.
    - $\geq 0.4$  W/kg and  $< 1.2$  W/kg, repeat once.
    - $\geq 1.2$  W/kg and  $< 1.5$  W/kg, repeat twice.
    - $\geq 1.5$  W/kg; repeat at least three times.
  - these should be performed after the completion of all measurements in each frequency band



# Measurement Repeatability and Uncertainty

- Measurement Uncertainty analysis is required only when the highest measured SAR in a frequency band is  $\geq 1.5$  W/kg
  - The IEEE Std 1528-2003 procedures should be applied
    - according to the SAR measurement parameters used
  - The expanded uncertainty must be  $\leq 30\%$ , 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
  - to determine measurement repeatability and uncertainty analysis requirements



# SAR System Validation

- SAR system validation is required
  - before a system is deployed
  - after hardware upgrades, software updates
  - after components are repaired or re-calibrated
- Validation is performed according to the combinations of
  - probes and components used by a system
    - probes and certain components can be used interchangeably across similar system models
- 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 test labs
  - these may be requested during equipment approval to address measurement issues or support test results



## Reference Dipoles

- Dipole SAR targets are calibrated for specific test setups
  - dipole to phantom spacing, phantom shell dielectric properties, tissue medium parameters etc.
- Dipoles may qualify for extended 3-year calibration
  - when return loss and impedance measurements are performed at least annually and meeting specific requirements
  - immediate re-calibration is required when results are out of tolerance or after any type of repair



## Reference Dipoles

- Dipole and probe calibration frequencies are usually aligned
  - when new spectrums are introduced
    - dipoles may not be available
    - probe calibration, dipole and device test frequencies can be misaligned
    - verification of SAR system measurement accuracy can be difficult
- When dipoles are unavailable from SAR system manufacturers, if applicable, alternative procedures may be considered



## System Validation Procedures

- SAR systems are validated for all system measurement specifications
- The basic validation applies a CW signal, within the sensitivity range of the SAR probes and system components, at each test frequency
  - the measured 1-g and 10-g SAR is normalized to 1.0 W net power and must be within 10% of the calibrated reference dipole SAR target value
    - different range of SAR levels are tested according to the applicable SAR limits



## System Validation Procedures

- The measured results are also used to determine probe linearity
  - with respect to a straight line through the dipole SAR target and origin (0) vs. net power applied in the dipole
  - the maximum deviation must be  $< 10\%$
- Probe isotropy is assessed by rotating the probe along its axis to make single-point measurements at  $15^\circ$  intervals, with the probe tip positioned at  $\frac{1}{2}$  the probe tip diameter
  - single point measurements are made at a power level near the SAR limit
  - the maximum deviation from the averaged value in each test should be within the required SAR probe specification



## System Validation Procedures

- Signal and modulation specific validations are also required
- For signals with periodic duty factor; such as TDMA
  - apply the CW procedures to the range of duty factors required for routine measurements
  - the results are duty factor compensated and normalized to 1.0 W CW-equivalent net power for comparison to the dipole SAR target



## System Validation Procedures

- For signals with high peak-to-average power ratios ( $> 5$  dB)
  - apply the CW procedures to the modulated signal
  - the SAR is normalized to 1.0 W CW-equivalent net power and compared to the dipole SAR target
  - when probe linearity error is  $> 10\%$ 
    - test device should be operated at reduce maximum power to maintain probe linearity in 5 – 10% range or use signal specific probe calibration
- Similar procedures are used to validate probe with signal specific calibration or combinations of the above conditions
  - high peak-to-average ratio, duty factor, modulation etc.



# 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 using the probe calibration & tissue medium required for device testing
    - this option has further restrictions
  - both options must meet specific dipole return loss, tissue dielectric difference, and other conditions in 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 SAR system manufacturers
- 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 probe calibration frequency point required for device testing, and associated 150 MHz tissue medium
  - 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



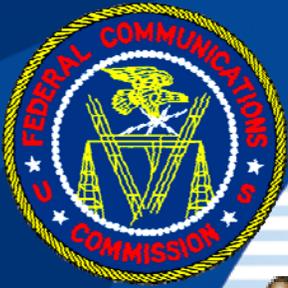
# Reporting RF Exposure Compliance

- General reporting guidance is provided in an attachment document to KDB 865664, to identify
- The necessary documentation for demonstrating RF exposure compliance, including
  - general information required for all RF exposure reports
  - additional information required for MPE, SAR and analysis reports
- Other specific descriptions, such as
  - general device information
  - test setup and other supporting information
  - measurement results
  - equipment calibration
  - plots and illustrations



**KDB 616217**

**SAR Evaluation Considerations  
for  
Laptop, Notebook, Netbook & Tablet  
Computers**



# General Considerations

- This is a new revision for KDB 616217
  - it supersedes 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 KDB procedures*
  - it only applies to transmitters operating in the 700 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 provisions in KDB 447498 are applied
  - for both standalone and simultaneous transmission operations



## Modular Approach

- Modular approach requires testing without a representative host
  - for the antennas or integral assembly
    - in different polarization, physical orientations & rotation and various installation configurations required by the intended hosts
- Testing with representative host is required only when the SAR measured without a host is  $> 0.8$  W/kg
  - testing with hosts may be considered incrementally through subsequent Class II permissive changes
    - when specific host implementations are introduced
    - to widen the approval scope for higher SAR configurations
- When the measured SAR is  $> 1.2$  W/kg, dedicated host approval can be considered



# Laptop Platform Requirements

- The following are required to apply modular approach
  - antenna and user separation  $\leq 25$  mm for use in display screens
  - keyboard and user separation distance  $\leq 5$  mm
    - for keyboard bottom and edge exposure conditions
  - the antenna configurations used in hosts must have been tested for 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
- KDB 447498 is used to determine simultaneous transmission SAR test exclusion



## Tablet Platform Considerations

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



## Tablet Platform Requirements

- Modular approach may not be appropriate for higher power transmitters because tablet use conditions are at close proximity to users
  - dedicated host or mixed modular & dedicated host approach should be considered
- Modular approach can be applied to lower power transmitters for tablet use
  - tablet to user separation  $\leq 5$  mm is required for bottom and edge exposure
  - antenna configurations used must have been tested for equipment approval
  - 5 mm separation is used to determine SAR test exclusion



## Tablet Platform Requirements

- When testing is required, tablet is positioned in direct contact with phantom
  - as antennas are usually embedded with  $\leq 5$  mm separation from outer housing
- The SAR Exclusion Threshold is used to determine if adjacent edge testing is required, with edge containing the antenna rotated  $\pm 90^\circ$ 
  - antenna is perpendicular to phantom
- KDB 447498 is applied to determine SAR test exclusion for simultaneous transmission



# Proximity Sensor Considerations

- Procedures are provided to determine proximity sensor triggering distances in bottom and edge exposure conditions
  - the tablet bottom or edge is moved toward and away from the phantom
    - through specific steps, to determine the triggering conditions, and
    - to ensure the triggering remains active as required
- Procedures for determining antenna and sensor coverage are also provided
  - the tablet bottom or edge is moved laterally into and out of the phantom boundary while maintaining the required triggering separation
    - the tablet is moved in the directions and orientations determined by the spatial offset between the antenna and sensor
  - when the measured peak SAR location is outside the triggering coverage region, a KDB inquiry is required to determine if additional SAR measurement is required



# Transmitter & Tablet Host Manufacturer Responsibility

- When proximity sensors are used in tablets and modular approach is applied
  - the sensor triggering and power reduction control functions are often implemented outside of the transmitter module
  - the module manufacturer may not have full control of the implementation
- A module manufacturer can address the equipment approval concerns through a change of FCC ID and subsequent Class II permissive change
  - to substantiate the joint responsibility required by the tablet host and module manufacturer to ensure all conditions of implementation are compliant



# Transmitter & Tablet Host Manufacturer Responsibility

- The new FCC ID is only applicable to the specific tablet
  - with the specific sensor and antenna configuration
- Any inapplicable grant conditions inherited from the change of ID, which can introduce conflicts, must be omitted
- A separate FCC ID is required for different tablets configurations



**KDB 648474**

**SAR Evaluation Considerations  
for  
Handsets with Multiple Transmitters and  
Antennas**



## General Considerations

- KDB 648474 has been revised
  - to apply the test reduction and exclusion provisions in KDB 447498
- The SAR test methodology related information has been removed and included in KDB 865664
  - additional guidance for reporting compliance is available in an attachment to KDB 865664
- 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



# Standalone and Simultaneous Transmission Requirements

- When applying the SAR Exclusion Threshold in KDB 447498
  - a separation distance of 5 mm should be used for exposure conditions with separation distances less than 5 mm
  - there is enough conservativeness in the test exclusion to account for this, with respect to device housing vs. antenna to user considerations
- The body-worn accessory procedures in KDB 447498 are applied
  - SAR compliance for third-party body-worn accessories is tested with a separation distance of 10 mm or one tenth the diagonal dimension, whichever is larger, to maintain testing consistency and to qualify for TCB approval



## Standalone and Simultaneous Transmission Requirements

- The hotspot mode procedures in KDB 941225 are applied
- Simultaneous transmission SAR exclusion and SAR testing are addressed according to the wireless modes, operating configurations and exposure conditions
  - for the individual test positions, or
  - if appropriate, collectively using the highest measured SAR for equivalent exposure conditions (as explained in the KDB)



## Simultaneous Voice and Data

- Most smart phones have simultaneous voice and data capabilities
  - 3G WCDMA/HSPA allows this in the same physical channel
  - 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 transmitter and antenna path combinations
  - wireless technologies, operating modes, exposure conditions
  - power reduction requirements & restrictions enforced by firmware or hardware
- Test results are unacceptable without clear supporting information to identify the simultaneous transmission configurations
- Additional consideration is required for simultaneous voice & data operations requiring power reduction to maintain compliance



# Transmitter and Antenna Configurations

- Phones typically use one or two antennas for the 3G transmitters
  - to cover domestic and international bands
- Separate antennas are normally used for the 4G transmitters
  - as more LTE bands are introduced, antenna requirements may change
- Additional antennas may be used in different wireless modes for receive diversity
- Different transmitter and antenna configurations have been used for WLAN and Bluetooth, which may require additional considerations to streamline SAR test requirements
- When MIMO becomes available, more complicated antennas configurations are expected
- There are also proposals to apply advanced antenna schemes
  - to allow antennas to be tuned dynamically for wider frequency operations, which could introduce SAR testing difficulties



## Power Reduction Considerations

- Power reduction is often considered when multiple transmitters operate simultaneously at relatively high maximum output power levels
  - for small form factor devices, such as cellphones
    - with tight coupling between transmitters and antennas, and to the user
  - to address internal interference and SAR compliance concerns
- Power reduction enables the phone to maintain voice quality by reducing the maximum output power for data connection



## Power Reduction Considerations

- various power reduction mechanisms have been applied by phone manufacturers
  - there is no industry standard for this
  - case-by-case considerations are necessary to determine SAR test requirements for each varying implementation
  - power reduction could be fixed or dynamic, with respect to various parameters
    - transmitting and receiving conditions
    - frequency bands, selected groups of channels and wireless modes
    - operating modes and exposure conditions
    - specific user or phone activities



# NFC & Wireless Charging Accessories

- SAR procedures are included in KDB 941225 for wireless charging battery covers
  - the SAR procedures can be adapted for testing phones with NFC battery covers
- These types of accessories generally do not require SAR testing; however,
  - the additional hardware can introduce different SAR influences to intended hosts
- When the hardware is built-in as an integral part of a phone
  - the SAR influences and interactions due to the additional accessory hardware can be accounted for transparently by the normal SAR tests required for a phone



## NFC & Wireless Charging Accessories

- When the accessory is supplied separately by the phone manufacturer, compliance can be addressed through Class II permissive changes
  - or Class I permissive change for subsequent modifications to an approved accessory
- When the accessory is provided by a third-party supplier
  - the test and approval considerations in KDB 447498 must be considered to determine if the intended hosts can remain compliant while operating in conjunction with the 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
- When VoIP is built-in as an integral part of the phone and voice call is supported by wireless carriers, normal SAR testing is required
  - for head and body-worn accessory exposure conditions
- Third-party VoIP apps downloaded by users are not supplied as part of the phone
  - it may not be feasible to test these ad hoc features consistently
  - when the feature cannot be blocked
    - manufacturers may choose to test these in representative data modes of the applicable wireless technologies, or
    - provide clear disclosure to inform users that these features cannot be blocked and have not been tested for RF exposure compliance



## SAM Phantom Limitations

- Antennas are often at the bottom or lower edges of recent generation phones
  - when the peak SAR location is near inaccessible regions of the SAM phantom
  - the SAR distribution could be truncated because of phantom setup, SAR probe accessibility or other measurement issues
- While acquiring additional SAM phantoms in rotated configurations may address some of the difficulties, it could be impractical for many test labs



## SAM Phantom Limitations

- 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
    - when this is not feasible, the top edge of the phone should be touching the flat phantom
  - the same separation distance between the peak SAR location, identified in the truncated SAR distribution tested with the SAM phantom, and the phone should be established at the same location for the phone and 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



**KDB 941225**

**SAR Evaluation Considerations  
for  
LTE Devices**



# General Considerations

- This is a new revision of the LTE SAR procedures
  - it takes into consideration the additional testing and implementation concerns identified through using the earlier preliminary procedures
- The same procedures are applied to test voice and data exposure conditions
  - these are applied in conjunction with the SAR test reduction and exclusion provisions in KDB 447498 and other applicable *published KDB procedures*
- When the procedures are followed, LTE devices may be approved by a TCB without a PBA, except
  - when a properly configured basestation simulator is not used for SAR testing
  - when power reduction, other than the MPR defined by 3GPP, is implemented or required



## General Considerations

- When additional guidance is required, all LTE test and approval issues should be 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 must verify that all LTE procedures and related KDB inquiries have been correctly applied; therefore, PBA is not required and there are no other PBA requirements



# Standalone SAR Test Requirements

- The LTE procedures have been simplified to support
  - testing for both voice and data exposure conditions
  - to facilitate TCB approval without a PBA
- The test reduction threshold has been lowered to 1.2 W/kg
  - it should have minimal impact to most LTE devices
- Power measurement results are applied to streamline the SAR test reduction requirements
- The test reduction process begins with 100% RB allocation
  - additional tests may be required with RB offset at the middle of the channel
    - for 1 RB and 50% RB allocations
    - to address new concerns for output power variations
  - additional test reductions can be recognized for higher modulations, besides QPSK, and other channel bandwidths
    - through streamlining and generalization



# 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 maximum output power levels are different or there is noticeable output power variations
- Test results alone without clear documentation to explain the combinations of applicable configurations to support the test configurations are unacceptable
  - the descriptions and explanations must be sufficient for a TCB to perform the review for equipment approval
  - this is required to qualify for TCB approval without a PBA



**KDB 643646**

**RF Exposure Evaluation Considerations  
for  
Occupational Push-to-Talk Two-Way Radios**



## PTT Vehicle-Mounted Antennas

- Additional procedures have been included in KDB 643646 to provide testing and approval guidance for PTT two-way radios operating with vehicle-mounted antennas
- Both occupational and general population exposure limits need consideration for exposure from vehicle-mounted antennas
  - occupational limit applies to the radio operator in work-related conditions only
    - training is required to maintain compliance and mitigate exposure concerns
  - general population limit applies to passengers and bystanders
    - these exposure conditions are managed by the radio operator to ensure compliance



## Standalone Test Requirements

- The separation distances used to test vehicle-mounted antennas must be support compliance for all installations
  - antennas tested on larger vehicles may not qualify for installation on smaller vehicles
  - large vehicles may require testing in different antenna mounting configurations to support the minimum distance required for all installations
    - for passenger and bystander exposure
- The MPE measurement procedures in KDB 447498 should be adapted
  - passenger exposure should be determined at  $\leq 10$  cm from the back seat surface
  - bystander exposure should be determines at distances  $\geq 20$  cm from the edge of the vehicle and must be  $\leq 90$  cm from the antenna



## Standalone Test Requirements

- The test separation distance should be in multiples of 15 cm or 6” to facilitate implementing operating instructions and exposure labels
- The evaluation should be along  $0^\circ$ ,  $\pm 45^\circ$ , if applicable,  $\pm 90^\circ$  radials from the antenna
- When a separation distance  $> 60$  cm from the antenna is required for the installation, a caution label is required to alert radio operators about his or her obligations to maintain bystander RF exposure compliance



# Simultaneous Transmission Test Requirements

- When an antenna transmits in multiple frequency bands
  - the most conservative separation distance among all frequency bands must be applied to determine compliance and used in the installation
- When antennas can transmit simultaneously
  - RF exposure compliance must be addressed to support such operations
    - through Class II permissive changes or in the initial filing
- When simultaneous transmission applies
  - the minimum antenna-to-passenger and minimum antenna-to-bystander distances must be satisfy compliance for all operating conditions
  - the information must be provided to antenna installers and radio operators
    - all prohibited configurations and operations must also be clearly identified



# Numerical SAR Simulation

- When MPE limits are exceeded in some mobile exposure conditions
  - it may be acceptable to demonstrate compliance with respect to SAR limits using FDTD simulations
    - procedures in KDB 447498 & other *published KDB procedures* are applied
    - the requirements of draft standard IEEE 1528.1 and 1528.2 must be fulfilled and clearly explained in the SAR report
- when the source-based time-averaged maximum output power is  $> 25$  W or the calculated 1-g SAR is  $> 0.8$  W/kg
  - free-space simulated E & H field strengths should be compared to measured results to confirm modeling accuracy and validity
    - at the same spatial locations required for MPE evaluation
  - numerical and measured results at each location should be within 25% and the spatially averaged values should be within 20%
  - when the spatially averaged results from the numerical simulation are lower than those measured
    - the 1-g SAR must be scaled up by the  $E^2$  and  $H^2$  difference to determine compliance



**KBD 628591 and KDB 388624**

**TCB Exclusion List  
and  
PBA List**



# TCB Exclusion List

- The TCB Exclusion list is also undergoing update with the following changes to be aligned with the revised KDB procedures
  - these are related to RF Exposure items
    - there are other changes to the PBA lists for EMC or special considerations that are discussed elsewhere
  - When RF exposure requirements have not been fully established and §1.1307 (c) or (d) applies
  - Portable transmitters operating in
    - general population exposure conditions exceeding 12 times the SAR Exclusion Threshold in KDB 447498
    - occupational exposure conditions exceeding 30 times the (general population) SAR Exclusion Threshold in KDB 447498
      - except for the handheld PTT 2-way radios described in KDB 643646
    - these new thresholds also account for separation distances
    - at 25 mm, the new thresholds are the same as earlier ones



## PBA List

- The following do not have established procedures, they are identified separately on the PBA list for clarity :
  - all Time-Division Duplex (TDD) implementations, except
    - when guidance is available in the *published KDB procedures*
  - when SAR test guidance is unavailable for uplink MIMO and other transmit antenna diversity configurations
  - when coherent signals are involved in the transmission
  - when dynamic antenna tuning is applied to optimize transmission efficiency for wide range frequency operations or other operating requirements
  - wrist-worn devices that are not tested with a flat phantom or according to KDB Publication 447498 requirements



## PBA List

- The following have been modified in the PBA list
  - except for conditions in the LTE procedures of KDB 941225 or triggered by other PBA requirements, PBA is not required for LTE
  - when a power reduction feature is used to reduce the transmit power, except when the *published KDB procedures* are applicable for the specific implementation
  - when a proximity sensing feature is used to reduce the transmit power, except when the *published KDB procedures* are applicable for the specific implementation
- This is new to the PBA list
  - implanted transmitters with maximum total available output power  $\leq 1.0$  mW



# Questions and Answers

**Thanks!**