RF Exposure Procedures

TCB Workshop

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Laboratory Division
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Overview

- LTE Update
- Measurement System and Methodology Update
- Additional Updates

LTE Update

LTE Carrier Aggregation (1)

- The number of LTE bands and configurations in smartphones and similar devices has increased substantially over the last few years
- Recent smartphones may include
  - 4 - 5 component carriers for downlink carrier aggregation, using contiguous/non-contiguous and intra/inter-band configurations
  - 2 - 3 component carriers for uplink carrier aggregation, mostly using intra-band contiguous configurations
  - various channel bandwidth combinations and carrier aggregation configurations have been used for both DL and UL
- The configurations required for UL CA SAR measurement can be implementation dependent and must be clearly specified in KDB inquiries and justified in SAR reports; see 3GPP TS 36.101, 6.2.3A
  - maximum output power and MPR can vary for inter/intra-band, contiguous/non-contiguous configurations and RB allocations
  - output power is typically higher for contiguous RB allocations; however, non-contiguous RB allocations can result in 3.5 to 8 dB MPR
  - the test configurations established by a call box also need verification to ensure the proper LTE modes and configurations are established for testing

LTE Carrier Aggregation (2)

- Recent LTE products have incorporated increasingly complex UL/DL CA configurations
  - the existing SAR procedures for LTE have become ineffective and insufficient as products & technology continue to evolve
  - SAR for carrier aggregation will need to be streamlined into the entire LTE SAR testing process to effectively facilitate test reduction
  - certain power reduction criteria and other RF exposure mitigation mechanisms can introduce substantially complex testing considerations for DL CA SAR test exclusion and UL CA SAR test reduction
- UL CA SAR test configurations must remain conservative
  - by taking into consideration standalone SAR results vs. power requirements, component carrier configurations, varying MPR and RB allocation conditions
  - the applicable UL CA settings described in 3GPP TS 36.101, 6.2.3.A must be considered to establish conservative SAR measurement configurations
  - the details should be fully explained in SAR reports
- If specific guidance is unavailable or when it is unclear
  - a KDB inquiry should be submitted to determine the test requirements

LTE Test Conditions

- The LTE test configurations used for power (SAR exclusion) or SAR measurements should be verified to avoid testing in the wrong configuration, which can lead to incorrect SAR results; e.g.,
  - 64 QAM and 16 QAM should be verified by checking the signal constellation with a call box to avoid incorrect maximum power levels due to MPR and other requirements associated with signal modulation
  - the test setup for UL/DL CA and 4x4 MIMO can be confirmed by throughput results with a call box
- SAR test exclusion for LTE DL 4x4 MIMO should be determined by
  - UL power measurements with and without DL MIMO
  - using the highest UL output power configuration without DL MIMO to confirm that UL output with DL MIMO is < ¼ dB higher
  - for DL MIMO with carrier aggregation, the same SAR test exclusion procedure should be considered

LTE Band 41 Power Class 2

- Rel. 14 has introduced HPUE Power Class 2 for Band 41
- HPUE Power Class 2 allows 26 ± 2 dBm and does not support uplink-downlink configurations 0 and 6 or inter-band CA
  - MPR for non-contiguous RB allocation has not (yet) been specified
- While Rel. 14 is being finalized
  - Band 41 Power Class 2 is already implemented in recent devices
- When Power Class 2 is triggered by network signaling or MCC etc., the conditions should be explained in test reports to support the results
- Power Class 3 is expected to be the dominant use configuration; therefore, SAR should be tested as normally required
- Power Class 2 is tested using the highest SAR test configuration in Power Class 3 for each LTE configuration and exposure condition combination, according to the highest time averaged power for all applicable uplink-downlink configurations in Power Class 2
- Separate SAR testing for Power Class 2 is not required when
  - the reported SAR vs. output power can be linearly scaled with < 10% discrepancy between power classes and all *reported* SAR are < 1.4 W/kg

Measurement System and Methodology Update

Broadband Liquid Above 3 GHz

- Broadband liquid that covers 600 MHz – 6 GHz has been available
  - reported dielectric tolerance for the liquid at above 3 GHz is > 5%
  - uncertainty budgets established for SAR systems at above 3 GHz have been based on 5% dielectric tolerance
  - in some situations, tissue dielectric tolerance correction at above 3 GHz may conflict with probe calibration requirements in KDB 865664 D01
- As an interim consideration, SAR measurements at above 3 GHz may use broadband liquid
  - when high SAR is not expected due to low power or specific use conditions where the *reported* SAR is expected to be ≤ 1.2 W/kg
    - for example, certain U-NII transmitters
  - therefore, applying the 10% tissue dielectric tolerance correction in KDB 865664 D01 will not introduce additional compliance concerns
  - this enables the same liquid to be used for frequencies up to 6 GHz

cDASY6 Considerations

- Certain DASY6 new/special features are not addressed in SAR standards
  - for example; probe calibration, phantom surface detection (mother scan), fast scanning & SAR scaling, time-averaging and certain other time-saving procedures
  - additional consideration and KDB guidance are necessary for these
- cDASY6 can operate in either DASY5 or DASY6 mode
- Recent release of cDASY6.2 has included a comprehensive update
  - addressing concerns from initial deployment
- MAIA is required to use SMC calibrated probes for cDASY6
  - except for CW signals (optional)
  - the specific probe calibration configurations selected by the system for each measurement must be identified in SAR reports
- Other cDASY6 features (different from DASY5) will need further evaluation to provide guidance; therefore, should not be used for now
  - user-related issues and concerns will need to be identified in order to provide more general guidance according to test lab experiences

WiGig Progress and Status

- mm-wave power density measurement procedures are under consideration in a draft Technical Report by IEC TC106 AHG10
  - drafting of a full standard will follow after TR completion
- WiGig testing efforts for RF exposure have been gradually shifting from mostly simulation based schemes to simulations supplemented by preliminary measurements
  - the miniature waveguides and mm-wave field probes described in the IEC draft TR are available and should be considered for compliance testing
- While existing approvals have been mainly for low power and/or exposure conditions, until the measurement procedures in TR are finalized
  - case-by-case consideration is necessary for higher power situations or more complex implementations

mm-wave RF Exposure

- The MPE limits established in standards are based on free-space whole-body exposure conditions
  - without presence of a human body or field coupling in the evaluation
  - power density is defined and evaluated in the direction of wave propagation to determine compliance
  - using only the normal component of a Poynting vector, according to SAR test configurations or user specific exposure conditions is inadequate
    - field polarization is unpredictable at close proximity to complex antenna array/elements
    - recent approvals have shown 2 – 3 dB lower power density using only normal component
  - applying user and exposure specific conditions or coupled conditions for power density evaluation does not satisfy definitions for MPE limits
  - this also erodes the margins built-in for MPE limits to ensure compliance

Additional Update

Sensor Array SAR Systems

- Recent discussions with system manufacturers & others (Nov. 2016)
  - when the final 62209-3 draft is available, a thorough review is necessary to identify specific issues and concerns
  - individual system validation results, when available, will need review
  - additional system check procedures according to individual system implementation and operating status may also need consideration
- Upon completion of the initial review on fundamental concerns
  - besides SAR screening, sensor array SAR can be considered in conjunction with full SAR measurements to streamline 3G testing; GSM, CDMA etc.
- The substantial test reduction allowed by existing Wi-Fi and LTE KDB procedures, typically around 4 – 8% testing, would not be suitable for sensory array SAR; therefore, need further consideration
  - especially due to the more complex configurations in LTE UL carrier aggregation, which may require overall LTE procedures to be streamlined

HSUPA Configuration Update

- β values for HS-DPCCH and E-DCH transmitter characteristics tests have been updated in Table C.11.1.3 of 3GPP TS 34.121-1 V13
- When devices are implemented according to 3GPP requirements, HSUPA generally qualifies for SAR test exclusion
- The configurations corresponding to the 3GPP version implemented for the device must be used for SAR and power measurements
- The same consideration also apply to similar circumstances for future UMTS test configuration updates
- Updated HSUPA sub-test 5:

Sub-test 5	β_c	β_d	β_d (SF)	β_c/β_d	β_{HS} (Note1)	β_{ec}	β_{ed} (Note 5) (Note 6)	β_{ed} (SF)	β_{ed} (Codes)	CM (dB) (Note 2)	MPR (dB) (Note 2)	AG Index (Note 6)	E-TFCI
Rel. 8	15/15	15/15	64	15/15	30/15	24/15	134/15	4	1	1.0	0.0	21	81
Rel. 13	15/15	0	-	-	5/15	5/15	47/15	4	1	1.0	0.0	12	67

Miscellaneous Topics

- Alternative phantoms may require non-standard SAR scanning and post-processing; e.g., limb, wrist or front-face head phantoms
  - a KDB inquiry is required to confirm test methodology and system validation
- Equipment discontinued or no longer supported by the manufacturer are unacceptable for compliance testing
- Demonstration of proper functioning of the detection and triggering mechanisms for control and mitigation of RF exposure (SAR & MPE) is required to support the corresponding SAR results or test exclusion
  - when verification procedures are unavailable, a KDB inquiries should be submitted to determine test setup; for example, multiple proximity sensors
  - also see KDB 388624 for triggering conditions that may require a PAG
- When Bluetooth tethering applies
  - simultaneous transmission SAR needs consideration
  - when tethering is through WWAN, in hotspot mode or equivalent configurations, hotspot mode SAR test exclusion and measurement procedures apply

Proximity Sensors

- Procedures in KDB 616217 are for a single (independent) proximity sensor incorporated in tablets
- A KDB inquiry is required when multiple sensors are used
- We have been unaware of multiple sensor KDB inquiries and there have been indications that such implementations are not uncommon
- When multiple sensors are used, sensor triggering can
  - apply to a single antenna or multiple antennas
  - depend on spatial arrangements of the sensors and antenna(s)
  - vary with threshold parameters established for individual sensors
  - be influenced by individual or multiple sensor detection conditions
- The procedures in KDB 616217 do not account for conditions anticipated in multiple sensor triggering configurations
  - the procedures required to confirm triggering may vary with individual implementation; therefore, need confirmation through KDB inquiry

Simultaneous Dual Band Wi-Fi

- Devices supporting simultaneous transmission in 2.4 and 5 GHz bands are available
- Recent implementations have included
  - 4 transmitters and 4 antennas for supporting different combinations of SISO, MIMO and Bluetooth operations in the 2.4 GHz and U-NII bands
- Some implementations have limited the transmitter and antenna combinations available to specific frequency band and maximum output power combinations
  - to simplify SAR test requirements
  - however, more complex implementations are expected in the near future
- SAR test considerations for standalone & simultaneous transmission
  - can become highly dependent on individual device implementation
  - may vary with differences in maximum output power across different Wi-Fi configurations, transmitter and antenna combinations used for the frequency bands
  - depending on antenna separation, SAR may be measured simultaneously for antennas operating in the same band followed by combining distributions across bands
  - simultaneous transmission SAR measurement and test exclusion may become intermixed in the test considerations due to individual product configurations
- When unclear, a KDB inquiry is recommended to clarify the test requirements

4 – 9 MHz SAR Measurement

- SAR measurement support for 6.78 MHz WPT devices is available
  - probes are calibrated for $\varepsilon_r = 55$ and $\sigma = 0.75$ S/m
  - a current loop antenna (CLA) is also available for SAR system check
    - SAR should be measured at the calibrated frequency and power level to avoid certain SAR scaling concerns due to narrow band nature of the CLA
  - other details are available in previous TCB workshop slides
- SAR measurement is preferred and should be considered to avoid SAR simulation issues due to varying methodologies and non-standardized procedures
- The SAR procedures in KDB 865664 D01 for 150 MHz – 6 GHz should be applied to 6.78 MHz WPT SAR measurements
  - as necessary, the procedures may need some adaptation
  - when unclear, a KDB inquiry should be submitted
- The reporting procedures in KDB 865664 D02 also apply

Low Frequency Body Transmission

- Devices that transmit RF current through the human body by means of capacitive coupling at lower frequencies have become available
- The transmissions may spread across a wide range of frequencies
  - where SAR compliance is required; 100 kHz - 6 GHz
- The RF current levels reported have generally been quite low
  - SAR measurement or simulation is typically unnecessary
  - SAR can be estimated according to worst case current conditions for grounded and ungrounded use conditions according to current density and tissue conductivity ($SAR = J^2/[\sigma \cdot \rho]$) with respect to a 1-g volume
- A KDB inquiry should be submitted
  - to determine the range of tissue dielectric parameters or composite values applicable to the range of frequencies used; for example, 10 kHz – 100 MHz
  - when SAR testing is required, i.e., SAR test exclusion (KDB 447498) does not apply

Human Exposure Limits

- RF exposure limits and guidelines established in the FCC rules are intended to limit human exposure
  - rules do not specifically identified if the limits may or may not apply to non-human exposure; for example, pet animals
  - however, NEPA of 1969 has considered wildlife environmental concerns
- When device use conditions involve pet animals
  - the evaluations required for human exposure generally also take into consideration, either directly or indirectly, exposures to pet animals
- For special circumstances or when it is unclear, a KDB inquiry should be submitted to determine acceptable RF exposure test configurations

MPE Compliance Distances

- Test distances used for MPE compliance must be determined conservatively according to actual installation and use conditions
- The test results must correspond to actual use configurations
- Installation and user instructions must also be consistent with the MPE compliance distances established by test results
- It is unacceptable to select test distances for meeting MPE limits while disregarding the actual installation and use conditions
- Distances that rely on users to maintain a minimum separation are generally unacceptable for satisfying general population exposure requirements; especially when such distances are inconsistent with actual use conditions

Vehicle Mounted Antenna MPE

- Over the years, there have been noticeable changes in the types of vehicles used in occupational exposure environment (law enforcement) that require vehicle mounted antenna exposure evaluation
- While larger vehicles have been used previously and accepted for MPE evaluation, it has become increasingly impractical using such results to support compliance for smaller vehicles
- IEC 62704-2 includes correction factors to compensate for SAR simulation results obtained using a standardized (large) vehicle
- To permit sufficient flexibility to use different vehicles for MPE measurements, the variability of test results with respect to individual vehicles used for testing needs consideration
- While this is under review, an estimate for the range of variability on MPE results due to individual test vehicles is necessary to ensure MPE compliance and to identify SAR simulation configurations
- Testing for vehicle mounted antenna on a simple ground plane is generally not representative and unacceptable; especially at high power

Exposure Standards Activities

- Conservativeness of tissue-equivalent parameters has been under investigation by IEC 62209 Project Team since ~2009 and is on-going
  - the goal is to use one set of conservative parameters for both head and body SAR
  - extension of SAR frequencies to 4 MHz & 10 GHz; however, may require additional consideration/investigation to demonstrate conservativeness
- 62209-2: amendment on SAR scan requirements is expected soon
  - to address higher SAR due to reactive and capacitive field coupling conditions
- 62209-3: decision for PAS vs. CD/CDV
- 62704 numerical simulation draft status
  - FDTD: basics technique, vehicle-mounted antenna and wireless handsets
    - CDVs balloted
  - FEM basics technique (CD expected)
- 62209-Unified draft: 4 MHz and 10 GHz extensions need decision
- AHG 10 mm-wave: PAS under preparation
- IEEE 1528.5: draft a full standard based on AHG 10 PAS
- IEEE 1528.6: 6 – 100 GHz exposure simulation under consideration