RF Exposure Procedures

TCB Workshop

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Overview

- Product and Technology Related Procedures Update
- WiGig RF Exposure Testing Considerations
- Progress in Measurement Systems and Methodology
- General Issues and Miscellaneous Concerns

Product and Technology Related Procedures Update

LTE & Carrier Aggregation

- KDB 941225 D05A DL CA SAR test exclusion does not apply to UL
- UL CA SAR test requirements can vary with implementation
  - inter-band vs. intra-band
  - contiguous vs. non-contiguous
- SAR can be measured separately for inter-band configurations
  - according to existing simultaneous transmission SAR procedures
- SAR should be measured with all component carriers (CC) active for intra-band configurations
  - contiguous and non-contiguous
- A KDB inquiry with specific info on implementation details is required to receive correct guidance
  - UL CA SAR test reduction consideration is case-by-case, according to the standalone SAR of individual bands and implementation complexity
- As new bands and configurations become available, test channels and parameters may need consideration; e.g., AWS-3/4 bands, 64 QAM

LTE Uplink Carrier Aggregation

- UL CA SAR test configurations may vary according to individual device implementation
  - maximum power, channel BW, RB allocation, MPR, power reduction for individual CCs or specific antenna(s) and exposure conditions (head, body, hotspot mode etc.)
  - aggregate BW and RB configurations
  - channel assignment requirements for CCs in the frequency bands
  - other device specific implementation and test equipment considerations
  - SAR of standalone wireless configurations and exposure conditions
- Implementation details are necessary to identify optimal test approaches
  - the information identified in KDB 941225 D05A
  - power reduction and other exposure mitigation considerations
  - when appropriate, include a test proposal in the KDB inquiry

Wireless Power Transfer

- Small consumer wireless chargers may support multiple protocols
  - independent testing is required due to differences in implementation
    - frequency, power, coil design etc.
    - may need to address SAR in conjunction with portable client devices
- Wireless charging for large vehicles, buses and trucks etc.
  - charging coils embedded at stops, depots or publicly accessible areas
  - exposure is dependent on vehicle and station implementations
    - feed-line and sub-station RF leakage may also need RF exposure evaluation
- Concern for exposure due to field enhancements by medical implants
- Exposure limits are not specified in the rules at lower frequencies
  - below 300 kHz for MPE and below100 kHz for SAR
  - compliance is assessed with respect to potential for exposure according to §1.1307 (c) and (d)
  - results of individual cases may show conservativeness against applicable thresholds; however, these are not considered compliance limits

Bluetooth Duty Factor

- Bluetooth devices typically operate at low power
  - mostly around 10 mW or less
- SAR measurement is usually performed with test software
  - at 100% duty factor
- The measured standalone SAR is typically low and mostly applied to determine simultaneous transmission SAR test exclusion
  - applying Bluetooth duty factor may in some cases alleviate further SPLSR analysis or simultaneous transmission SAR measurement
- Duty factors of 70 – 80% have been reported by some labs using a call box with Bluetooth protocols for the SAR measurement
- SAR measurement systems require periodic duty factors
  - when call box and Bluetooth protocol are used, time-domain plots are required to identify duty factor for supporting the test setup and results
- Test mode configuration and SAR scaling need further consideration
  - to determine worst case duty factor and establish generic KDB guidance

Laptops &Tablets with Dual Displays

- Recently advertisements have revealed a new category of 360º convertible laptop/tablet device
  - also received general KDB inquiry on similar concerns
- A dual-display system may be used to support a virtual keyboard
  - depending on product implementation, different combinations of display orientations and keyboard configurations are possible
- Additional test positions may be required for SAR evaluation
  - according to antenna locations and the respective exposure conditions
- Until more can be learned and formal guidance is available, a KDB inquiry is highly recommended to addressed SAR test requirements and to avoid issues

WiGig RF Exposure

Testing Considerations

Recent Progress and Status

- Recent WiGig products are mostly limited to laptops and tablets
- Exposure standards require power density to be determined
  - in the direction of wave propagation
  - normal component of Poynting vector is insufficient
  - a rectilinear exposure plane may not be consistent with certain device geometry and use conditions for small mm-wave devices
- Antenna implementations continue to evolve
  - arrays may contain multiple element types and configurations
  - beam-steering adds complexity to RF exposure evaluation
- Measurements in conjunction with simulations have been explored by manufacturers to streamline exposure testing
- A mm-wave Technical Report working group has been initiated by IEC TC106 to address mm-wave power density measurement difficulties

Simulation Difficulties

- Applying numerical simulation to evaluate RF exposure of mm-wave WiGig devices has been difficult and time consuming
  - simulations have been limited to regions surrounding the antenna array, in the host device, where impact of adjacent objects can be unclear
  - a large number of simulations is required to determine worst case conditions for antennas with substantial beam-steering flexibilities
  - dielectric parameters of certain critical components at mm-wave frequencies are not always known or easily confirmed for simulation
  - simplifications in antenna and device modeling can introduce errors
- Validating the antenna and device models is also difficult
  - fields may not be easily measured at locations of interest to enable comparison of simulated and measured results
  - uncertainty of measured and simulated results can complicate issues
- Maximum power at antenna/elements is required to scale results and could be difficult to quantify or confirmed due to design constraints

Measurement Considerations

- Recently proposed measurement techniques
  - measure in the far-field with miniature waveguide and apply field transformation to derive near-field results
  - measure directly in the near-field, at a few mm from radiating structures, using applicable probe(s) and field reconstruction procedures
- The field transformation and reconstruction algorithms generally require the phase of fields to be accurately measured or derived
- Reconstruction algorithms require a sufficiently large measurement region, with acceptable spatial and spectral resolution, to capture energy contributions and for results to maintain accuracy
- Field characteristics can be very complex in the reactive near-field
  - probe sensors must correctly capture steep field gradients and unpredictable field polarizations to enable accurate field reconstruction
- Techniques based on mm-wave probes and miniature waveguides are currently under evaluation by different groups
  - in commercial and research settings

Progress in Measurement Systems and Methodology

Progress and Status

- SAR measurement standards and proposals
  - expanding SAR measurement frequency to 4 MHz – 10 GHz
  - alternative phantoms for limb and head worn devices are on-going
  - head and body SAR procedures in 62209-1 and 62209-2 will be unified, most likely, along with 62209-3 vector measurement-based systems
  - investigative results on conservativeness of tissue dielectric parameters need consideration to unify head and body tissue-equivalent parameters
- The inter-laboratory measurement project organized by ISED (IC) is expected to complete by end of 2016, preliminary results show
  - certain unexpected discrepancies in traditional full SAR baseline results
  - different highest SAR test configurations can be identified by the different measurement systems or methods
- Availability of broadband tissue-equivalent liquids with wider frequency range
  - may consider extending dielectric tolerance with correction for > 3 GHz
- Should consider upgrade or decommission outdated SAR equipment

Correlated Signal Considerations

- Questions to be answered:
  - is signal correlated at locations where RF exposure evaluation is needed
  - implementation and design of individual devices may dictate how signal correlation is maintained along propagation path
  - when signal is correlated at the points of measurement, the transmission configurations, applicable techniques and instrumentation required for SAR or MPE evaluation need further consideration
- 802.11 protocols include requirements to minimize signal correlation
  - by adding cyclic delays
  - correlation of OFDM sub-carriers is in baseband
  - RF channels generally lack correlation due to FFT in OFDM
  - test mode configurations are determined according to KDB 248227
- Correlated signals are typically associated with phased array and other beam-steering implementations
  - additional investigation is necessary to determine how signals are correlated at the locations of RF evaluation

Correlated Signal Exposure Testing

- Fundamental concerns and difficulties for RF exposure evaluation involving correlated signals are described in IEC TR 62630
- The exposure evaluation requires all combinations of amplitude and phase conditions to be identified for individual antennas/elements
- Existing scalar probes do not provide phase information
  - SAR or MPE results from existing scalar probes may provide upper bound estimates
- IEC 62630 identifies two methods for estimating exposure of correlated signals using scalar probes
  - summation of total E-field magnitude from all antennas
  - summation of individual E-field components contributed by all antennas
  - both methods result in overestimation
  - total field summation has higher overestimation

Correlated Signal RF Evaluation

- IEEE 1528-2003 and IEC draft 62209-1 SAR procedures have identified two types of correlated signal conditions
  - those that remain stable over the symbol duration; e.g., phased array systems
    - amplitude and phase not expected to change over symbol duration
    - IEC 62630 TR procedures may be applied to estimate SAR
  - those that change rapidly over the symbol duration
    - normal scalar probe SAR measurement can be used by correctly extending the sampling time to capture the mean signal conditions
- These are under consideration by SAR system manufacturer(s) for implementation in specific systems
- For the interim, a KDB inquiry is required to address the related measurement difficulties and to determine how test methodologies can be applied

DUT Holder Perturbations

- SAR perturbation due to test device holders
  - depending on antenna locations, buttons locations on phones or device, form factor (e.g. dongles etc.), the measured SAR could be influenced by the relative positions of the test device and its holder
- SAR measurement standards have included protocols to evaluate this with a flat phantom, with and without the device holder
  - the procedure has generally been ignored in majority (if not all) of recently reviewed SAR reports
- When the highest reported SAR of an antenna is > 1.2 W/kg, holder perturbation verification is required for each antenna, using the highest SAR configuration among all applicable frequency bands
  - in the same exact device and holder positions used for head and body SAR measurements; i.e. same device/button locations in the holder
  - a KDB inquiry is required if the highest reported SAR for each antenna, adjusted for increases in holder perturbation, would introduce non-compliance conditions or noticeably high differences due to perturbation

cDASY6 Considerations

- cDASY6 can operate in either DASY5 or DASY6 mode
- Certain new features introduced in DASY6 mode are not included in current SAR standards; for example,
  - use of SMC calibrated probes in conjunction with the MAIA
  - ultra fast scans, SAR scaling
  - advanced surface detection and other time-saving procedures
- A comprehensive software release for cDASY6 6.2 is expected soon
  - including improvements to address concerns in the initial deployment
  - SPEAG has interacted with the FCC on SMC
  - details of other new features are under review
  - to facilitate providing SAR test guidance, SPEAG has on-going inquiry and FCC has requested further updates when comprehensive software release is ready
- Until it can be confirmed whether additional KDB guidance is necessary for certain new cDASY6 features, a KDB inquiry is highly recommended to avoid issues and unexpected delays in equipment certification

Sensor Array SAR Systems

- No significant info has been received/reviewed on sensor array systems since last TCB workshop
  - there was some minor updates on cSAR3D
  - received minor update and still waiting for additional test results for Art-Man
- We have been informed that there could be up to 3 dB differences between sensor array and full SAR results, but have reviewed only limited details
  - additional considerations are needed to determine how to establish test guidance and address such concerns
- ISED/IC has an on-going measurement project to evaluate fast SAR protocol and approaches, interim results include
  - baseline data from full SAR measurements
  - Motorola fast SAR results
  - sensor array system results
  - preliminary raw results seem to identify certain test device setup concerns
  - highest SAR configuration can be identified differently by the test systems
- KDB guidance will be considered when details are sorted out

General Issues

and

Miscellaneous Concerns

Applying KDB Procedures & Exclusion

- Devices that are designed to satisfy mobile exposure conditions, but with potential to operate in portable exposure conditions, may need to comply with SAR limit
  - with respect to §2.1091(d)(4) of the rules
  - for example, transmitters incorporated in certain utility meters, game controllers, various desktop products or on-board diagnostic (OBD) wireless tracking/recording devices etc.
- These types of consumer products are not designed to be worn or used on the user's body
  - there is typically at least several cm or more of separation
  - such use conditions can easily qualify for SAR test exclusion to support potential portable exposure conditions
- If a transmitter is approved as a module and subsequently incorporated in portable exposure host configurations
  - SAR compliance for all transmitters must be addressed for the host, including simultaneous transmission; e.g. smartphones PTT radios etc.
- Applying KDB procedures for various device types and exposure conditions
  - phones, phablets, tablets, watches vs, head, body, body-worn, extremity, hotspot

Multiple-Module MPE

- When multiple modules are incorporated into various host configurations to operate in mobile exposure conditions, MPE requires additional consideration
- Each module may include multiple antennas; e.g. MIMO in Wi-Fi access points
- The antenna configurations in each module and arrangement of the modules in host devices may vary and require special consideration for MPE evaluation
  - certain simultaneous multiple frequency operations may require the modules and/or antennas in specific spatial arrangements; e.g., sectored and staggered configurations
  - MPE probe calibration factors generally vary with frequency; e.g. 2.4 vs. 5 GHz
  - maximum power may vary among wireless modes, frequency bands, antennas
  - there could be other limitations for individual implementations to use test modes
  - measurement results may need to be scaled according to multiple factors
- A KDB inquiry is required to determine measurement requirements for individual circumstances
  - applying generic KDB procedures in KDB publications to complex situations can often lead to problems and delays due to inappropriate test setups or results

Coordinating KDB Inquiries

- KDB inquiries should include sufficient background information and clearly identify the specific requests that need responses
  - information on operating configurations and exposure conditions are essential
    - wireless modes, power, antenna info and location(s), use conditions, distances and dimensions etc. for determining applicable or device specific test configurations
    - explanations for supporting info in proposals and requests are also necessary
  - referencing previously submitted KDB inquiries with insufficient explanation is generally problematic
    - previous KDB guidance could be outdated, containing other unrelated/inapplicable guidance or insufficient for situation in the new KDB inquiry
- Test guidance obtained through KDB inquiries should be described in test reports to support the test setup and results
  - test reports should be standalone documents for demonstrating compliance
  - KDB inquiry tracking numbers are considered confidential and should not be identified in non-confidential documents
  - test reports may need to reference confidential exhibits; high level descriptions of reference information are necessary for test reports to be meaningful
- Test exclusion does not imply compliance exemption, 1.1307(c) & (d) apply

Status of Rules and Limits

- FNPRM and NOI are on-going (ET Docket 01-137 and 13-84)
  - limits and requirements in existing rules apply until new rules are adopted
  - ICNIRP may consider updating certain RF exposure requirements, which could influence certain considerations in the NOI
- EU is introducing new requirements on SAR test distances for phones
  - existing KDB procedures require body-worn SAR test distance to be supported conservatively by accessories available at the time of equipment certification
  - when applicable, 1-g and 10-g SAR may be derived from the same measurement
- Devices with multiple transmitters that need to satisfy separate SAR limits
  - for example, general population for UNII and occupational for Part 90
  - compliance is determined by sum of the ratios of SAR to respective limits
- As wireless technology continues to advance, different interpretations for source-based time averaging may arise, which can introduce
  - SAR measurement difficulties when test signals are not periodic
  - concerns due to noticeably high peak power over short exposure durations
  - certain limited & restrictive SAR proposals are under consideration in IEC 62209
  - certain issues may not be easily addressed through interpretation or KDB process

IEC TC106/PT62209 Activities

- Conservativeness of tissue-equivalent parameters has been under investigation by IEC 62209 project team since ~2009
  - results from earlier electromagnetic simulation studies show existing dielectric parameters may not be sufficiently conservative
  - additional thermal simulation were performed to demonstrate conservativeness according to temperature rise criteria
  - an incorrect dielectric parameter was used at one of the simulation frequencies in the thermal simulation, which will require further consideration
  - further extension of SAR frequency range may require additional consideration
  - the goal is to use one set of conservative parameters for both head and body SAR
- 62209-2 amendment on SAR scan requirements is on-going
  - to address higher SAR due to reactive and capacitive field coupling conditions
  - when parameters are finalized, update to KDB 865664 is expected
- 62704 numerical simulation drafts have been balloted by IEEE and IEC
  - FDTD: basics technique, vehicle-mounted antenna and wireless handsets (CD)
  - FEM basics technique (CDV)