Updates on Guidelines for 5G Equipment Authorization

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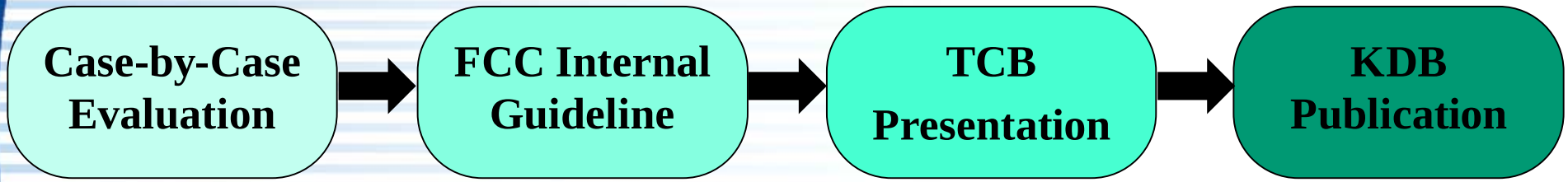
Laboratory Division
Office of Engineering and Technology
Federal Communications Commission

Overview

1. Building Compliance Guidelines
2. Equipment Authorization Filings for 5G: PAG requirements
3. 5G General Compliance Requirements
4. Building Support Tools for Compliance Analysis
5. Building 5G Compliance Guidelines: Phase 1

Building Compliance Guidelines

- In general, new technologies require a multi-phased process for devising compliance guideline
- Overall process: from case-by-case evaluation to official guidance



5G Nomenclature

NSA-EN-DC

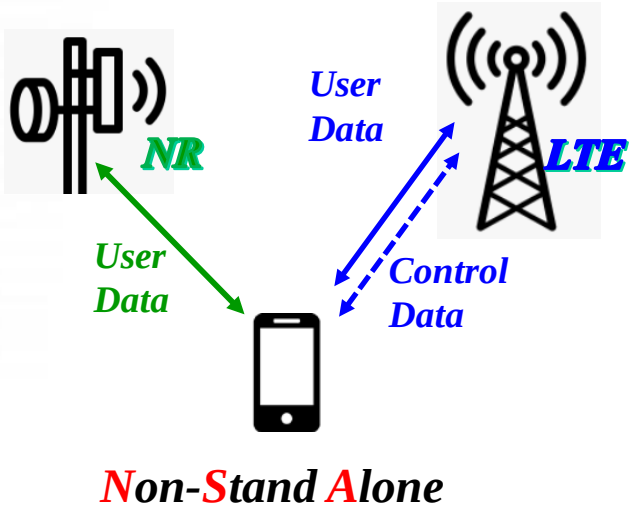
NSA → Non-Stand Alone

EN → **E**-UTRAN

↓

Evolved Universal Terrestrial Radio Access Network

DC → Dual Connectivity



E-UTRAN: *defines functionality of base stations to support over-the-air links in LTE cellular network.*

E-UTRA: *specifies the functionality for the LTE mobile devices [Rel-7 3GPP TR 25.913]*

DC: Dual Connectivity of User Equipment (UE) to two nodes, here coupling LTE and NR

Filing: PAG Requirements

Confirming **Nov. 2019 TCB Workshop** PAG guidelines for both intra-band and inter-band NSA-EN-DC:

1. 5G-NR devices are already subject to standard PAG processing per 388624 D02 v16r07, section II.C.1. clauses e., k., and l.
2. If the single uplink 1-g SAR values for each band are both less than 0.8 W/kg and the algebraic summation of the 1 g SAR values are less than 1.45 W/kg, additional measurements are not needed; **PAG may be waived** via pre-TCB KDB inquiry test plan consultation
3. If one of the single uplink 1-g SAR values is greater than 0.8 W/kg, instead of algebraically summing the 1-g SAR values, sum up the SAR distributions, similar to the enlarged zoom scan (volume scan) procedures KDB Pub. 865664 D01; **PAG is required**.
4. If the algebraic sum of the 1-g SAR values is greater than 1.45 W/kg, additional measurements might be needed; **PAG is required and KDB inquiry** is needed for additional testing guidance

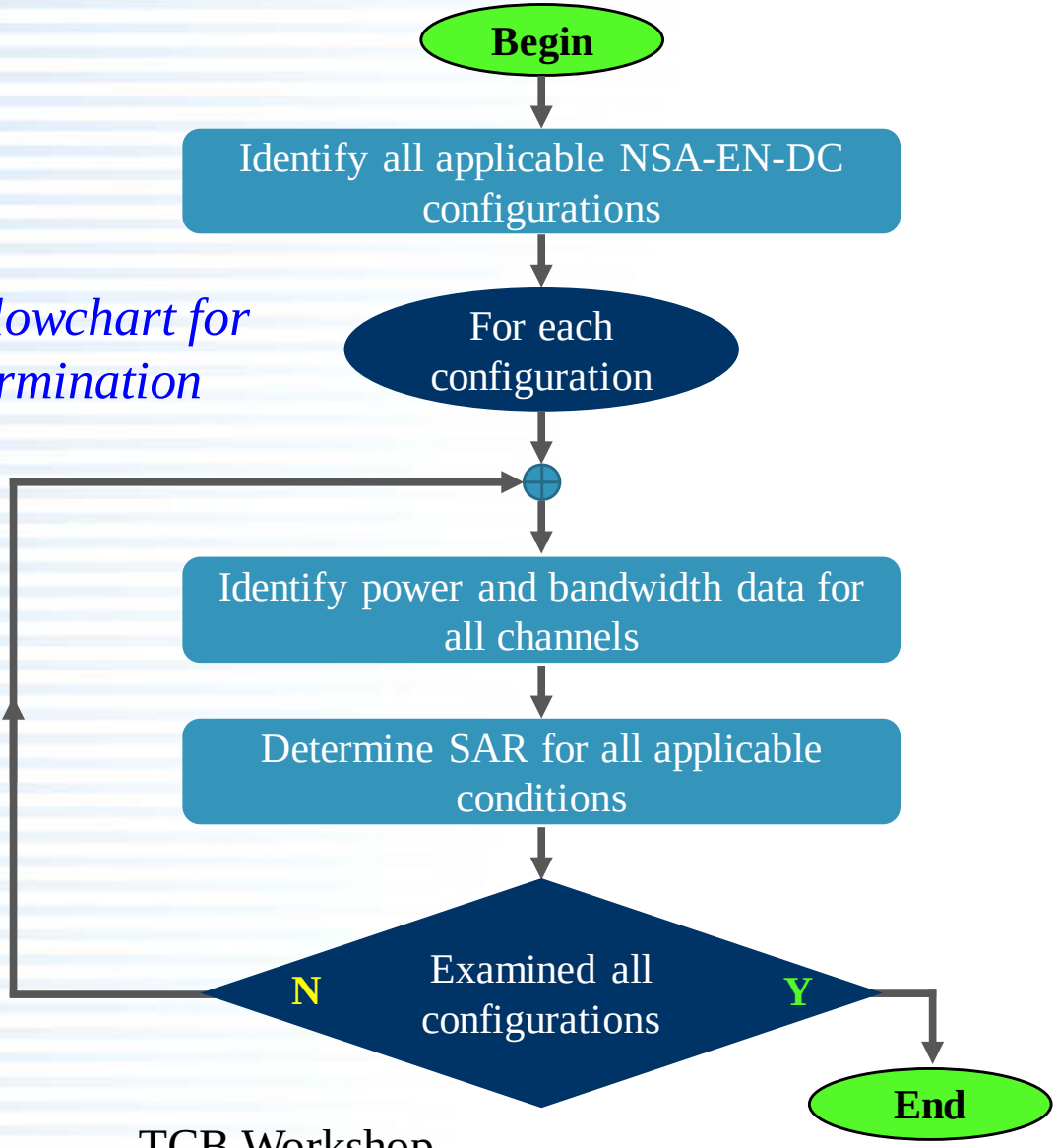
5G General Compliance Requirements

- Compliance needs to be demonstrated for all modes and modulations and band combinations transmitted by a device.
- For 5G-FR1 SAR evaluations are being generally based on adapting the existing LTE SAR procedures (KDB Pub 941225 D05A)
- For non-stand-alone configurations, both LTE and 5G-NR are added to derive a total SAR.
- SAR for EN-DC need to consider each exposure (head, body, etc.), highest standalone (SA) condition, and each frequency band combination.

Building Compliance Analysis Tools

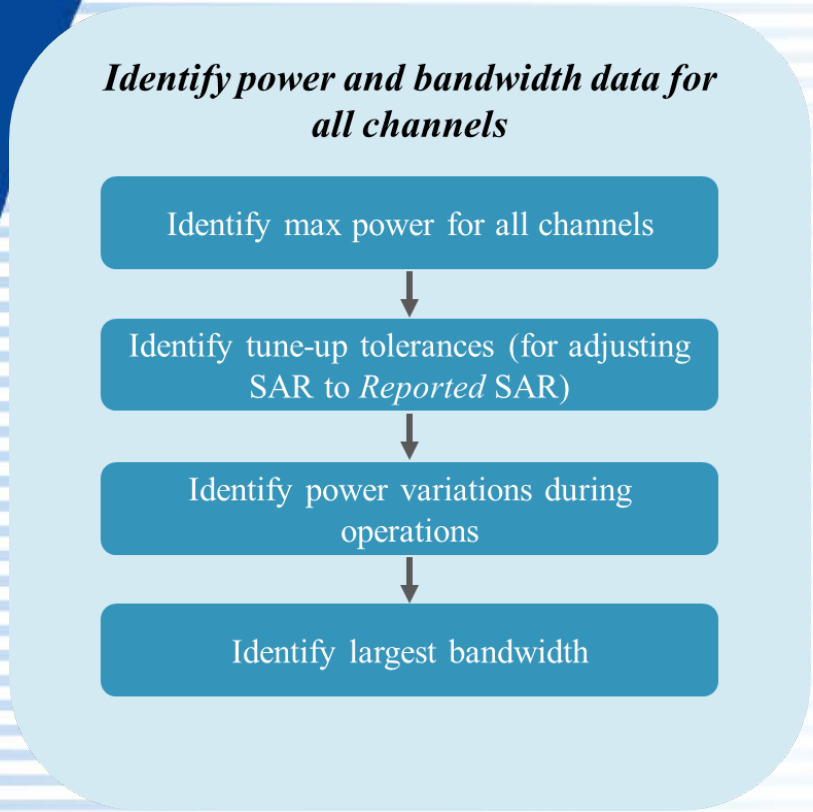
Example

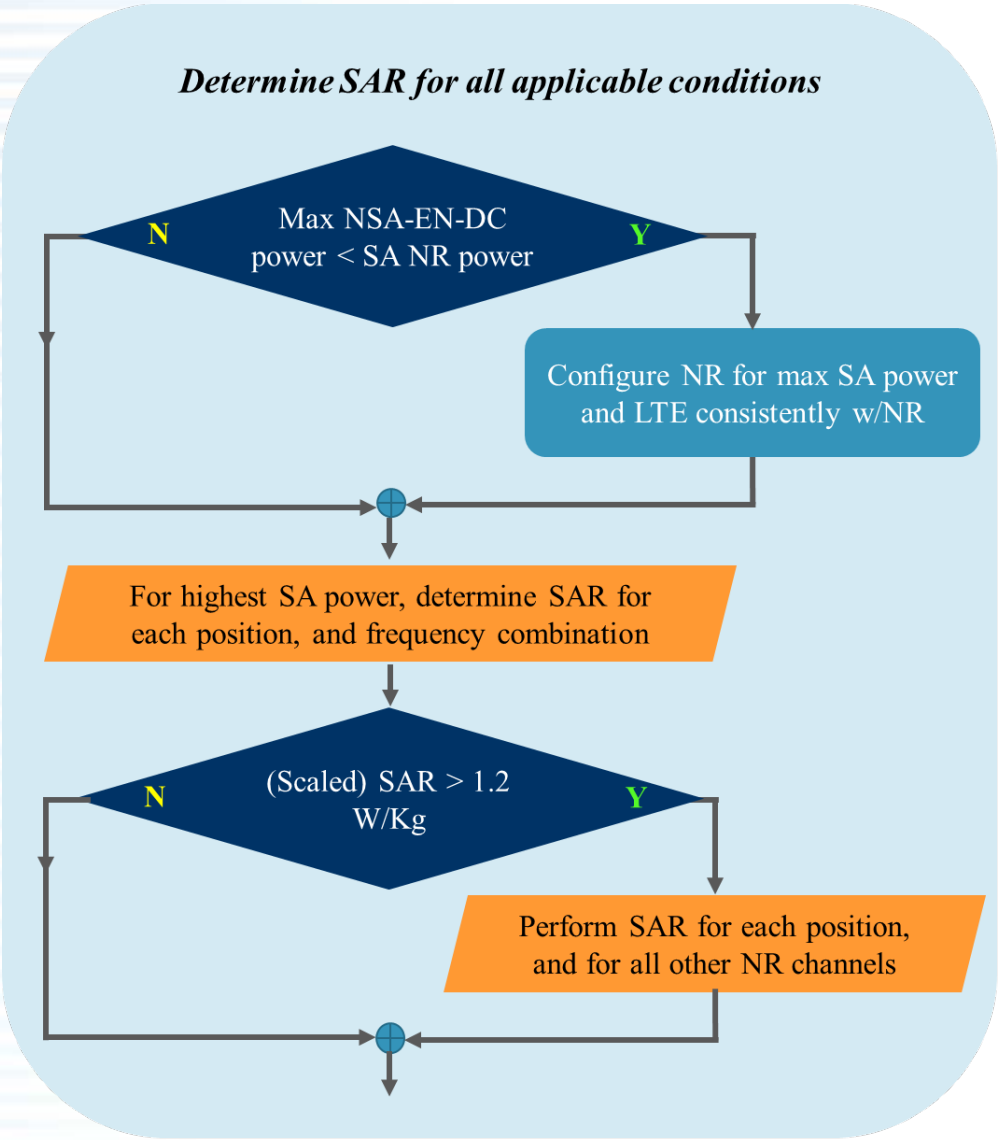
High-level algorithm flowchart for NSA-EN-DC SAR determination



Building Compliance Analysis Tools

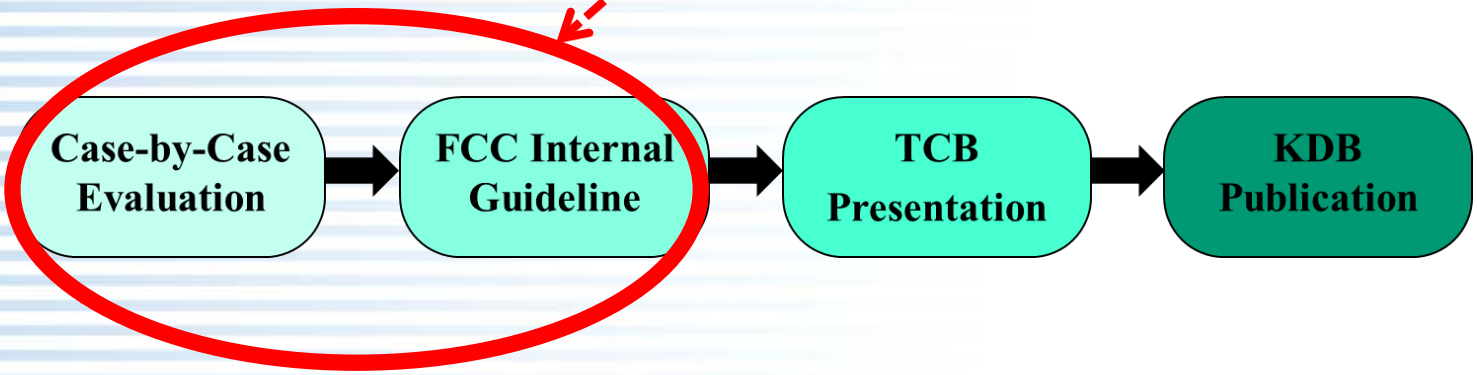
Details on algorithm flowchart for NSA-EN-DC SAR determination





Building 5G Compliance Guideline - Phase 1

- Review device-specific analysis results from KDB Inquiry System
- Synthesis to extract common features to meet general industry requirements
- Ensuring higher level of consistency for compliance review among different products
- Enabling **design-to-compliance** approach for manufacturers, **shortening time to market**



Building 5G Compliance Guideline – Phase 1

- Review device-specific analysis results from KDB Inquiry System
- Synthesis to extract common features to meet general industry requirements

Case-by-Case Evaluation

- Antenna Tuning
- Carrier Aggregation
- Power Configuration Algorithm for SAR
- Simultaneous Transmission SAR Evaluation for EN-DC
- Adding DSS to Base Stations
- Testing for 5G NR CBSD
- Indoor 5G NR FR2 Femtocell
- NR in the Upper Microwave Flexible Use Service

FCC Internal Guideline

Selected Topics for Devising 5G Compliance Evaluation Guideline

Antenna Tuning

- Device uses dynamic antenna tuning for EN-DC
- Factory Test Mode (FTM) mode for NR, w/o antenna tuning test capability for determining transmit power worst-case
- Interim Recommended Procedure:
  - Find the NR tune code by connecting to the call box in LTE mode at the NR frequency with auto-tuning active
  - Position device under the phantom in each test position. Record active tune-state for that frequency
  - For NR testing with FTM mode, set the tune code state recorded for that position and frequency
  - Perform point SAR measurements for NR at the other tune states per April 2019 TCBC WS Guidance

Carrier Aggregation Combinations with LTE Bands

- Latest applicable guidance:
  - KDB 941225 D05A LTE Rel.10 KDB Inquiry Sheet v01r02
  - TCB Workshop April 2018, FCC Talks 5.1 and 5.2
- Salient features to be include in test report data:
  - conducted power for each band and each component carriers for both downlink and uplink
  - accounting for all carrier combinations used in the device
  - conducted power measurement for MIMO scenarios
  - highest standalone SAR values for each band

Power Configuration Algorithm for SAR

IF (the maximum output for EN-DC is less than the standalone NR test configuration without EN-DC)

THEN

- NR shall be configured according to the highest standalone SAR configuration tested
- For Resource Block (RB) NR allocation, for the different channel, power table and SAR shall follow a similar approach to KDB Pub. 941225 D05 SAR for LTE Devices v02r05, Section 4.3
- Determine call box configuration based on maximum defined duty cycle
- Determine Maximum Power Reduction (MPR) allowed for each band
- Determine settings to omit measurement of channels with high MPR (for possible significant overall testing time reduction)
- Confirm that power level is not changed (or account for) in different modulation schemes
- LTE anchor is configured according to procedures used for power measurement and parameters (BW, RB, etc.) similar to that used for NR

END IF

Power Configuration Algorithm for SAR (II)

Stand-Alone (SA) Measurement LTE-SAR Scaling Algorithm

IF (a Stand-Alone LTE SAR was measured **AND** the antenna path is not changed)

THEN

Scale Stand-Alone LTE SAR value to EN-DC LTE SAR to obtain single uplink LTE 1-g SAR

END IF

Power Configuration Algorithm for SAR (III)

Identification of SAR Worst-Case Scenario

- General reference in KDB Publication 941225
- Review all conducted power measurements for the highest bandwidth with all supported modulations and all required Resource Block (RB) configurations
- Exclude conducted power and SAR measurements for overlapping channels within a band to align with LTE procedures in 941225
- Select closest RB Offset to the lower and upper edge to capture the 0 dB MPR configuration for conducted power measurements
- For SAR measurements, the 0 dB Maximum Power Reduction (MPR) conditions (worst case of 1 RB, and 50% RB conducted power) with the highest BW for SAR measurements will be chosen to align with KDB Pub 941225 D01-v0301, Sect.5.2.
- Exclude modulations and RB configurations with MPR > 0 for SAR testing and conducted power measurements due to lower power/SAR

Simultaneous Transmission SAR Evaluation for EN-DC

- SAR testing for LTE and NR is performed separately, and apply FCC KDB 447498 techniques for simultaneous LTE+NR.
- Base station simulator is used for LTE SAR and Factory Test Mode (FTM) for NR SAR (consider Tx FTM power reduction consistent w/design duty cycle)
- For 5G NR Sub-6 GHz, the simultaneous transmission scenarios shall be evaluated independently [Reference: TCB Workshop 2019/04]

Simultaneous Transmission SAR Evaluation for EN-DC (II)

Procedure w/examples [Ref: TCB Workshop 2019/04]

- Identify configuration

  EN-DC configuration is DC_2A_n78A

- Measure SAR separately for LTE and 5G-NR

  Measured SAR for LTE B2 and n78

- Compute total SAR

  Compute SAR_Total = , SAR_LTE_B2 + SAR_n78

- Compare total SAR with 1.6 W/Kg limit

Simultaneous Transmission SAR Evaluation for EN-DC (III)

IF (SAR_Total < 1.6 W/Kg) **THEN**
system is RFX compliant
ELSE
compute SAR to Peak Location Separation Ratio (SPLSR)
IF (SPLSR < 0.04) **THEN**
system is RFX compliant
ELSE
compute SAR via enlarged zoom per KDB 865664-D01
END IF
END IF

Adding DSS to Base Stations

- DSS (Dynamic Spectrum Sharing) functionality can be added to for a certified Base Station operating with LTE B5 and the 5G NR n5 bands.
- DSS addition does not require operational changes in such as of max. output power, modulation, channel bandwidths, subcarrier spacings (SCS).
- With DSS as an added, all modes of operation have to be tested, since in this case there is no well-established procedure determining which is the worst-case scenario.
- Accordingly, for all the modes of operations allowed by design (that is combinations of DSS, LTE and NR) it is necessary to show that the system remains compliant with the FCC requirements, and identify operation worst-case.

5G Citizens Broadband Radio Service Devices (CBSD)

- End user devices operating in 5G NR n48 (3550 - 3700 MHz like LTE band 48) must be tested to Part 96.47 with at least one authorized CBSD Call box or Base Station
- Callbox are available with 5G CBSD, n48 support to test EMC for Base Transceiver Station (BTS) functionality
- Since the 4G and 5G NR protocols are different, testing using E-UTRA (LTE) air interface to represent 5G NR CBSD band are not acceptable
- 5G NR air interface for Spectrum Access System (SAS) handshake N/A yet: full testing/certification cannot be attained at a present time

Indoor 5G NR FR2 Femtocell

- To be included in EMC test data report:
  - discuss if conducted RF power measurement via direct antenna connection is available (to the minimizing impedance mismatch)
  - Total RF power, not just EIRP
  - conducted peak and average power measurement in-band and out of band (average power only during active transmission w/o duty cycle)
  - Accounting for different Resource Block sizes and offsets, modulation/waveform combinations, and bandwidths
  - Minimum measurement distance for final radiated measurements (KDB 842590 D01 v01r01 –Sect. 3.8)

Indoor 5G NR FR2 Femtocell (II)

- Where applicable, items to be included in RFX test data report are:
  - Power density (PD) calculation details: how configuration (beam ID, resource allocations, bandwidths, carrier spacings, modulations) impacts PD
  - effective provisions for ensuring minimum distance conditions
  - availability/instructions for user installation
  - installation location requirements and constraints
  - highest standalone SAR values for each band

NR in the Upper Microwave Flexible Use Service

- Applicable rules are in Part 30 and Part 101
- Details on certification an measurement procedures are in KDB Publication 842590
- Work in progress for RFX Compliance determination above 6 GHz: PD vs. SAR evaluation

- See T. Harrington's talk at this workshop

RF Exposure Policies and Procedures

TCB Workshop

October 2020

Laboratory Division
Office of Engineering and Technology
Federal Communications Commission

Overview

- Considerations and interim RF exposure test procedures for U-NII 6-7 GHz portable devices
- Continuing developments on selected other RF exposure policies and procedures

U-NII 6-7 GHz RF Exposure

- Initial filings expected to be low-power indoor client devices (Sec. 2.1093 portable devices)
  - equipment class 6XD; EMC/radio-parameter technical guidance given in KDB draft-review 987594 DR01-44057
- Sec. 15.407(f) requires U-NII device filings to address RF exposure compliance
  - According to KDB Pub. 447498 and references therein
  - Until specific 6-7 GHz test guidance is established, a KDB inquiry including device design and operating info and RF exposure evaluation plan for review is required before completing testing and submitting for TCB PAG processing
    - Consistent with KDB Pub. 388624 PAG list and procedures
- Portable devices transmitting at frequencies > 6 GHz, including U-NII 6-7 GHz band, are subject to MPE incident power density (PD, or IPD) limits
  - MPE limit is 1 mW/cm^2 plane-wave-equivalent PD, averaged over 4 cm^2, evaluation distance emulating normal use conditions

U-NII 6-7 GHz Measurement Considerations (1)

- For FCC RF exposure compliance evaluation purposes, in recent years near-field localized PD measurements have been used with portable devices transmitting in 28 GHz, 39 GHz, and 60 GHz bands
  - Typical commercially-available test systems use a single-probe scanning system and multiple E-field measurements per test point in multiple planes in air near a test device
  - Field-component and phase reconstruction techniques are applied to the measured data to derive the full vector E-fields, H-fields, Poynting vector, and maximum spatial-averaged incident PD
- This millimeter-wave (mmw-) band PD evaluation method is optimized for and has lowest measurement uncertainties at frequencies above about 24 GHz
  - Similar low-perturbing low-measurement-uncertainty solutions for near-field incident PD testing of 6-7 GHz portable devices are not known to be commercially available at present

U-NII 6-7 GHz Measurement Considerations (2)

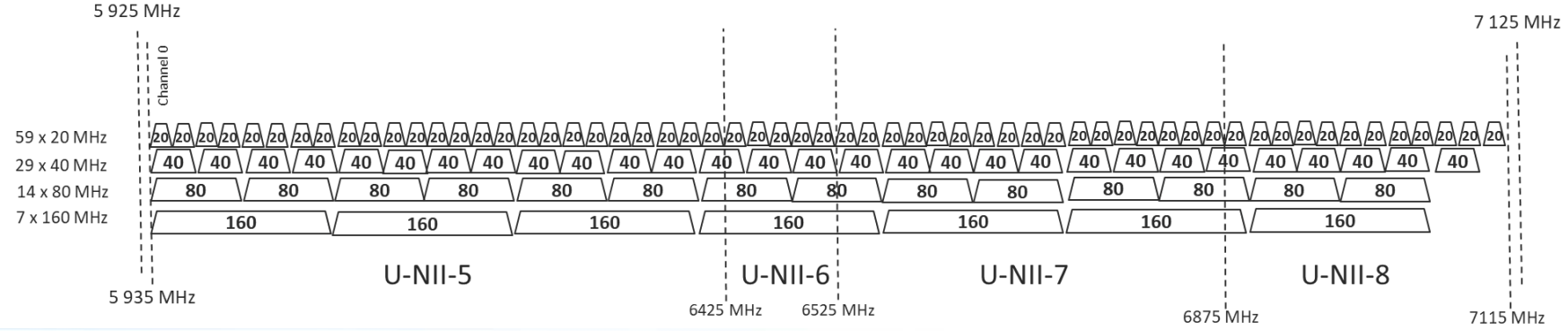
- Whereas commercial solutions presently may not be available for routine measurements of localized near-field incident PD for RF exposure compliance evaluation of portable devices
  - Existing methods used for SAR measurements below 6 GHz in recent years were extended for use in 6-10 GHz
  - Associated test system requirements and parameters for 6-10 GHz were also amended in the soon-to-be-published IEC/IEEE 62209-1528 SAR measurement standard
- The following interim procedures may be considered for FCC RF exposure evaluations of U-NII 6-7 GHz band portable devices

U-NII 6-7 GHz Interim Procedures (1)

- Interim procedures for FCC RF exposure evaluations of U-NII 6-7 GHz band portable devices
  - First, evaluate SAR using 6-7 GHz parameters per IEC/IEEE 62209-1528:2020
    - Per procedures of KDB Pubs. 447498 and 248227, and applicable product-specific procedures among KDB Pubs. 648474 (handsets/phablets), 616217 (tablets/ laptops), 941225 (D06 hotspots, D07 UMPCs)
    - Where supported by the test system, also report estimated absorbed (epithelial) power density (for reference purposes only, not specifically for compliance) and estimated incident PD, derived from measured SAR
  - In addition, for the highest SAR test configurations evaluate incident PD using the mmw near-field probe and total-field/power-density reconstruction method (2 mm closest meas. plane)
    - Adjust measured results per amount that measurement uncertainty exceeds 30 % (see e.g. IEC 62479:2010)
- Data from the preceding tests (measured SAR with estimated PD; measured incident PD) will be considered together during FCC review of pre-TCB KDBs and/or TCB PAG KDBs
  - For determining compliance, or whether other or different test configurations or test conditions or supporting information may need to be requested

U-NII 6-7 GHz Interim Procedures (2)

- Based on a channel plan such under consideration in 802.11 WG, per the formula in 4) g) of KDB Pub. 447498 D01 v06, with 5925-7125 MHz the number-of-required-test-channels is 10
- For the interim procedures specified above, start instead with a minimum of 5 test channels across the full band, then adapt and apply conducted power and SAR test reduction procedures of KDB Pub. 248227 v02r02
  - Also 802.11ax SAR basics in Apr 2019 TCB conference notes



Example draft 802.11ax channel-plan; submitted in docket no. 18-295, 2020-06-29; HWG/Apple et al., RKF E. S. LLC (https://www.fcc.gov/ecfs/filing/1063041931946)

Continuing Developments on Various RF Exposure Policies and Procedures

Interim and Developing Policies

- Development and preparation is continuing for several mobile and portable device RF exposure evaluation procedures, and review and approval uniform policies and procedures
  - RF exposure policies and procedures generally overlap with and are impacted by topics and activities in the exposure rulemaking release, measurement standards projects and working groups, and evolving device technologies in KDB inquiries and PAG reviews
  - Some highlights in following pages
- Along with information of this session, existing evaluation and review and approval policies and procedures guidance continue to apply

Development Topics (1)

- Chipset and modem-based dynamic power control for exposure time averaging in portable devices
  - Non-TCB / pre-TCB KDB inquiry[1] for test plan review is not required before TCB-PAG for devices implementing latest Qualcomm-based WWAN methods
    - PAG remains required for TCB application processing[2]
    - Simultaneous-transmission power density and SAR evaluation
  - Pre-TCB test plan KDB inquiry and TCB PAG generally remain required for other or different and new WWAN and WLAN dynamic power control exposure time-averaging methods

[1] KDB Pub. 388624 **D01** v11r04 II) B) 1) to 3) describes pre-TCB KDB for devices subject to PAG

[2] KDB Pub. 388624 **D02** v16r09 II) A) 6); KDB Pub. 388624 **D01** v11r03 III) (TCB PAG KDB)

Development Topics (2)

- Continued OET staff participation in IEC and IEEE exposure measurement standards working groups
  - IEC 63195-1 (mmw measurements); IEC 63195-2 (mmw simulations); IEC TC 106 JWG 13 AHGs (time-averaging; 5G-NR-FR1)
  - Generally after standards are finalized, selected provisions and procedures will be identified and qualified as acceptable in FCC guidance documents
- Ongoing KDB pub. change considerations for various SAR measurement procedures and measurement systems topics
  - Acceptable provisions and procedures from soon-pub. IEC/IEEE 62209-1528 to be identified and adapted into basic measurement guidance KDB Pub. 865664 as applicable
  - Vector-measurement-based probe-array systems (VMBPAS)
    - Adapt system verification guidance based on IEC 62209-3:2019; as appropriate accounting also for recent IEC TC 106 JWG 13 amendment consideration discussions
    - Evaluate and consider establishing conditions to accept use of IEC/IEEE 62209-1528 Fast SAR Procedure A (pre-scans), possibly in coordination with interested device and test system manufacturers and test labs

Development Topics (3)

- Preparing cohesive guidance for 5G-NR sub-6 GHz SAR evaluations
  - Considering device-setup and test-exemption considerations
  - Considering information from application-specific evaluations in existing FCC IDs
    - Dynamic power sharing in EN DC (E-UTRAN & New Radio dual connectivity)
    - Call-box and signaling test setup; device test modes supporting info
    - Conducted power measurements for establishing test reductions across CP-OFDM, DFT-s-OFDM pi/2-BPSK etc.
    - Non-standalone and standalone modes (NSA, SA)
    - Resource block allocations per 3GPP TS 38.521-1, etc.
    - Associated measurement and test system issues as relevant (signal bandwidths, liquid parameters, etc.)
  - Considering information presently under discussion in IEC TC 106 project for 5G NR SAR draft technical report (candidate amendment to IEC/IEEE 62209-1528:2020)
- See also other presentation this session

Thanks for your attention !

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- Updated slides 19 and 21