



KDB 248227

802.11 SAR Procedures

Update Proposal

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



Overview

- Current status of KDB 248227
 - based on 2007 802.11 a/b/g technology
- Update proposal
 - to streamline SAR testing for 802.11 a/b/g/n/ac according to
 - DSSS and OFDM
 - exposure conditions
 - next to the ear, UMPC mini-tablet and hotspot mode equivalent exposure conditions vs. other exposure conditions
 - frequency, power and reported SAR
 - OFDM signal characteristics and frequency band requirements
 - channel BW requirements, modulations and data rates
 - frequency band and channel aggregation conditions
 - to streamline power measurement requirements
 - to resolve and address MIMO SAR measurement configurations
- Identify other issues that may need to be addressed

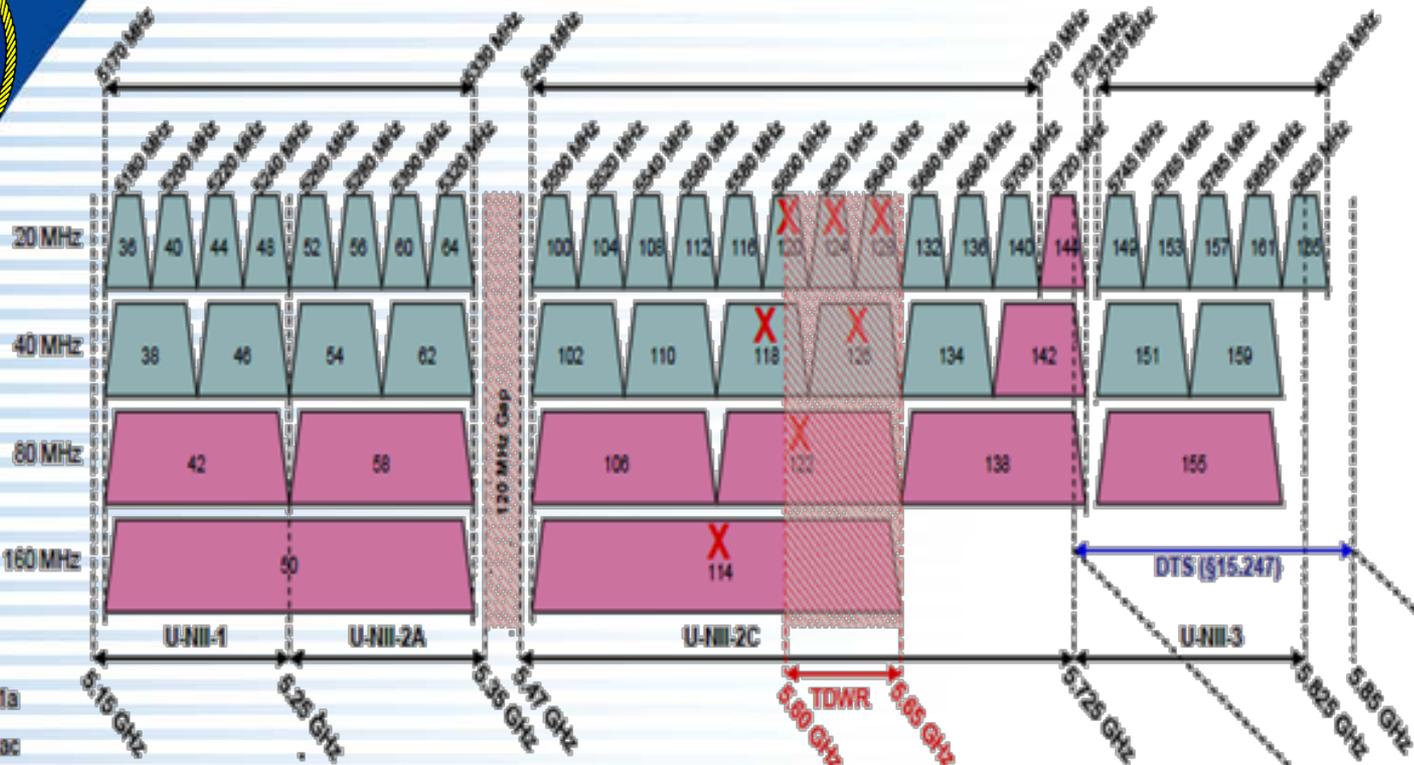


Additional Info

- Slides contain only high level info
- Review draft revision proposal for additional details
- Slides and draft proposal are intended to “identify” possible options to streamline KDB 248227 with respect to
 - recent changes to 802.11 standards, product implementation and anticipated developments
- A subsequent draft KDB document will be considered based on feedback to this draft proposal
- The considerations in this draft proposal must **not** be applied to test 802.11 products
 - items in the proposal are expected to evolve and change in subsequent draft KDB document



5 GHz Channel Configurations



- Existing 802.11a
- New in 802.11ac
- Prohibited Channels

	U-NII Bands, §15.407 (Part 15E)				DTS, §15.247 (Part 15C)
Frequency Range (MHz)	5150-5250	5250-5350	5470-5725		5725-5825
Indoor/Outdoor Operations	Indoor only	Indoor/Outdoor			Indoor/Outdoor
Max conducted TX Power, whichever is lower (B is the 26-dB Emission BW in MHz)	17 dBm (50 mW) or 4 dBm + 10 log B	24 dBm (250 mW) or 11 dBm + 10 log B			30dBm (1 W) or 17 dBm + 10 log B
Max EIRP	23 dBm (200 mW) with 6 dBi antenna	30 dBm (1 W) with 6 dBi antenna			36 dBm (4 W) with 6 dBi antenna; 53 dBm (200 W) for P-t-P with 23 dBi antenna
					36 dBm (4 W) with 6 dBi antenna. No EIRP limit and no antenna gain limit for P-t-P



SAR Considerations for Frequency Band Requirements



§15.247: 2.4 – 2.4835 GHz

- The required test channels are
 - 1, 6 and 11 for 22/20 MHz channel BW (DSSS and OFDM)
 - channels 3 and 9 for 40 MHz channel BW (OFDM)
- Channels 12 & 13 do not require SAR measurements
 - these channels have to operate at reduced power to satisfy adjacent band restrictions (2.4835 – 2.5 GHz)
- When the maximum output power of a required test channel is reduced to satisfy adjacent band or other product implementation requirements
 - the closest adjacent channel with non-reduced maximum power should be considered for SAR testing



§15.407 UNII Band 1 & 2A

- Different maximum allowed output power
 - 5.15 – 5.25 GHz UNII band 1
 - 50 mW / 23 dBm EIRP for 5.15 GHz band
 - 5.25 – 5.35 GHz UNII Band 2A
 - 250 mW / 30 dBm EIRP for 5.25 GHz band
 - UNII emission BW restrictions may require lower maximum power
- Power differences need consideration
 - to streamline SAR test exclusion and reduction
 - according to frequency, power and reported SAR



Standalone UNII 1 & 2A

- When both bands apply to the same transmitter and antenna configurations where maximum output power specifications of production units, including tolerance, are
 - the same; start with the higher frequency band (2A) and if the highest reported SAR is
 - ≤ 1.2 W/kg, SAR is not required for the lower frequency band
 - tissue conductivity difference is about 4.5%
 - > 1.2 W/kg, both bands should be tested independently for SAR
 - different, and the highest reported SAR for the higher maximum output band is
 - ≤ 1.2 W/kg, SAR is not required for the lower maximum output band
 - > 1.2 W/kg and the difference in maximum output is ≤ 1 dB
 - both bands should be tested independent for SAR



UNII 1 & 2A Aggregation

- 160 MHz channel requires band aggregation
 - aggregated band fits only one channel: channel 50
- Maximum output of aggregated band
 - limited by band with lower allowed or specified maximum output
- SAR is not required when
 - all reported standalone SAR for both bands are ≤ 1.2 W/kg and
 - maximum output of aggregated band is lower than individual bands by at least 1 dB
 - when standalone SAR test exclusion applies to a band, SAR is assumed to be ≤ 1.2 W/kg
- Simultaneous transmission of two non-contiguous 80 MHz channels is not equivalent to transmitting in a single 160 MHz channel



5.47 – 5.85 GHz Bands

- Different maximum allowed output power
 - 5.6 GHz UNII 2C: 250 mW / 30 dBm EIRP
 - 5.8 GHz UNII 3 & §15.247: 1 W / 36 dBm EIRP
 - UNII emission BW restrictions may require lower maximum output power
- Frequency range of the bands: 380 MHz
 - SAR probe calibration and tissue dielectric parameter (8%) concerns need consideration to streamline SAR
- 5.60 – 5.65 MHz is restricted due to TDWR until further notice
 - must be considered for SAR when the restriction is removed
- When both 5.6 and 5.8 GHz bands apply to same transmitter and antenna
 - additional 20, 40 or 80 MHz channels span across these bands also need SAR
 - maximum output limited by UNII 2C
 - channels above 5.65 GHz in UNII 2C are grouped with 5.8 GHz UNII 3 or §15.247 channels to facilitate SAR test reduction
- 160 MHz channel is not defined in 802.11 standard between UNII 2C and 3, possibly due to channel number misalignment
 - SAR is required when used by individual products on ad hoc basis



SAR Probe Calibration & Measurement Considerations



SAR Probe Calibration

- Calibrate SAR probes with at least ± 100 MHz coverage at
 - 5.25 GHz for UNII 1 and 2A: 5.15 - 5.35 GHz
 - 5.60 GHz for UNII 2C: 5.475 – 5.725 GHz (250 MHz)
 - calibration is expected to become marginal for band edge channels
 - actual channel frequency span is 5.49 – 5.71 GHz (220 MHz)
 - channel center frequency span is 5.5 – 5.7 GHz (200 MHz)
 - acceptable only when tissue dielectric parameters are within 5% of targets
 - 5.75 GHz for UNII 3 and §15.247, upper UNII 2C and UNII 3 or §15.247: 5.65 – 5.85 GHz
- SAR system validation dipoles must be calibrated
 - within frequency range covered by probe calibration points required for device testing



SAR Measurement Considerations

- Influence of high peak to average power ratio of OFDM signals to SAR probe calibration
 - improved probe calibration techniques are in progress
- Conservativeness of existing tissue-equivalent dielectric parameters
 - possible concerns at 2.4 GHz and 5 GHz for certain test separation distances and exposure conditions, according to on-going investigation
 - further investigation is planned by SAR measurement standards committees



Power Measurement Considerations



Measurement Reduction

- For SAR purposes, power must be measured for each frequency band and aggregated band for the highest output wireless mode specified for production units, including tolerance
 - according to channel band BW, modulation and data rate
 - at the highest and lowest channels in the frequency band
 - at the mid-band channel when there are at least 3 channels
- When power specifications vary across channels, channel BW or wireless configurations, power measurement reduction does not apply; the variations must be verified through power measurements
- Power measurement is required for all configurations requiring SAR measurements to
 - determine reported SAR
 - confirm test conditions satisfy KDB 447498
- When power measurement is not required, the maximum output power specified for production units, including tolerance, must be applied to determine SAR test exclusion and reduction



SAR Test Reduction for Exposure Conditions



Initial Test Position

- Next to the ear, UMPC mini-tablet and hotspot mode equivalent exposure conditions have multiple test positions
- An initial test position may be selected to facilitate test reduction
 - to test highest measured output channel in initial test configuration
 - start on the side (left or right) of SAM phantom and test position (touch or tilt) with smallest Wi-Fi antenna to phantom separation and maximum antenna to phantom coupling
 - when differences in separation distance are indistinguishable, select test position with maximum antenna coupling to the SAM phantom
 - consider antenna coupling first if this dominates the exposure
 - for UMPC or hotspot mode, start with position for smallest antenna (**device**) to flat phantom separation and maximum antenna coupling
 - for example, front or back surface vs. side edge with respect to the antenna surface
- When it is unclear, all equivalent conditions must be tested
- Phablets need further review to consider if initial test position may apply



SAR Test Reduction for Test Position

- When all reported SAR of the initial test position are
 - ≤ 0.4 W/kg, further SAR measurement is not required for the DSSS or OFDM configuration in that frequency band
 - > 0.4 W/kg, repeat SAR for subsequent next smallest antenna to phantom separation and maximum antenna coupling test positions in the initial test position wireless configuration until
 - reported SAR is ≤ 0.8 W/kg or all test positions are considered
 - select position with maximum antenna to phantom coupling when positions have the same antenna to phantom separation
- Initial & subsequent positions with reported SAR > 0.8 W/kg
 - test these on subsequent next highest measured output channels until reported SAR is ≤ 1.2 W/kg or all channels are considered



2.4 GHz DSSS SAR



2.4 GHz DSSS SAR

- 2.4 GHz DSSS and OFDM are considered separately
- When SAR is required
 - measure SAR on DSSS channel with highest output power
- An initial test position may be considered for next to the ear, UMPC mini-tablet and hotspot mode equivalent exposure conditions for test reduction
- For other exposure conditions, when the reported SAR is
 - ≤ 0.8 W/kg, no further SAR is required for 802.11b DSSS
 - > 0.8 W/kg, measure SAR on the next highest measured output channel
 - when any reported SAR is > 1.2 W/kg, SAR is required for all channels



OFDM SAR



2.4 and 5 GHz OFDM

- SAR is measured for 802.11 a/g/n/ac modes according to the requirements for each frequency band and aggregated band
 - for the initial test configuration and
 - if applicable, an initial test position
- Different test conditions apply to contiguous frequency band aggregation vs. aggregating channels across bands
 - the number of transmitters, channel BW, simultaneous transmission conditions and tissue absorption characteristics across channels and bands need consideration
 - two non-contiguous 80 MHz channels (80 + 80) is not equivalent to transmitting in a 160 MHz channel



2.4 GHz OFDM SAR Test Exclusion & Reduction

- SAR is not required for an OFDM mode (802.11 g or n) when the specified maximum output for OFDM is
 - at least 1 dB lower than DSSS and
 - highest reported SAR for DSSS is ≤ 1.2 W/kg
 - or
 - $\leq 1/4$ dB higher than DSSS and
 - highest reported SAR for DSSS is ≤ 0.8 W/kg or SAR test exclusion applies to DSSS



OFDM SAR Measurement

- The OFDM SAR measurement procedures apply to
 - 2.4, (4.9) and all 5 GHz bands, including aggregated bands
- Start with channel BW, modulation and data rate combination
 - with highest maximum output specified for production units, including tolerance, to determine the initial test configuration for each frequency band or aggregated band
 - test SAR on the highest measured output channel
 - when the same maximum output specification applies to multiple configurations, select the largest channel BW, lowest order modulation and lowest data rate combination
 - data rate and modulation are for test setup consistency
- Support for 4.94 – 4.99 GHz with respect to §§90.1213 and 90.1215 (in existing KDB 248227) or other 802.11 related frequencies such as §90.377 (OBU/RSU) etc. remain to be determined



Initial Test Configuration

- SAR is measured for the initial test configuration to determine subsequent SAR test reduction
- An initial test position may be selected for next to the ear, UMPC mini-tablet and hotspot mode equivalent exposure conditions for additional test reduction
- Test reduction for other exposure conditions is determined according to reported SAR of the initial test configuration
 - ≤ 0.8 W/kg; further SAR is not required for the initial test configuration
 - > 0.8 W/kg; repeat the initial test configuration for subsequent next highest measured output channel
 - until reported SAR is ≤ 1.2 W/kg or all channels are considered



Next Highest Output Configuration

- When maximum output specification of production units for the next highest output combination according to channel BW configuration, modulation and data rate is
 - within $\frac{1}{2}$ dB of that specified for highest output combination in the initial test configuration and the highest *reported* SAR with respect to the initial test position or other exposure conditions is
 - > 0.8 and ≤ 1.2 W/kg
 - test the next highest output combination on channels that overlap with the highest output combination or apply the > 1.2 W/kg procedures
 - start with highest measured output channel and continue with subsequent highest output channel until *reported* SAR is ≤ 1.2 W/kg
 - > 1.2 W/kg, apply initial test configuration procedures to the next highest output combination
 - power measurement is necessary to determine *reported* SAR and identify highest output channel



Subsequent Highest Output Configurations

- Apply the procedures for next highest specified output configuration by replacing
 - “next to highest output configuration” with “subsequent highest output configuration”
 - “highest specified output configuration” and “initial test configuration” with “all already tested higher output configurations”



MIMO Configurations



MIMO SAR Test Reduction

- MIMO SAR is considered separately
 - for each channel BW and frequency band and aggregated band
 - in the different exposure conditions
- SAR test exclusion may be considered according to
 - the aggregate maximum output power of all simultaneous transmitting antennas in all MIMO chains
 - according to standalone SAR exclusion provisions of KDB 447498
 - sum or 1-g SAR or SAR to peak location ratio for each MIMO combination when standalone SAR exclusion does not apply



MIMO SAR Measurement

- MIMO configurations are determined according to
 - channel BW, frequency band or aggregated band and exposure conditions
 - all antennas in the MIMO chains must be transmitting simultaneously at maximum output to determine compliance in a single SAR measurement
- An initial test position may be selected for next to the ear, UMPC mini-tablet and hotspot mode equivalent exposure conditions
- SAR is measured on the highest reported standalone SAR channel for each MIMO chain applicable to the exposure configuration and position
- Still need procedures to determine reported SAR for MIMO
- When the reported SAR for MIMO is > 1.2 W/k/kg
 - the channel combinations with subsequent next to highest aggregated standalone SAR for the MIMO chains should be tested in that exposure configuration until MIMO SAR is ≤ 1.2 W/kg



802.11ac VHT Beam Forming

- According to recent information from manufacturers
 - 802.11ac VHT beam-forming is applied to OFDM sub-carriers
 - antennas and algorithms are implemented to optimize far-field conditions according to sub-carrier propagation characteristics
 - significant coherence at the OFDM channel output and energy focusing in the near-field would not be expected
- Non-coherent MIMO procedures should generally apply under such circumstances
- This does not apply to other types of ad hoc beam-forming or similar configurations for 802.11 ac or other 802.11 modes



Coherent Signals

- Signal coherence for 802.11 due to phased array and other beam-forming operations below 6 GHz remain to be identified
- Maximum worst-case SAR possible for coherent signals is a function of N^2 , where N is the number of coherent signals
 - i.e., 4, 9 and 16 times for 2, 3 & 4 coherent signals
- When signal coherence applies
 - sum of SAR and SAR to peak location ratio test exclusion do not apply
 - except when antennas are sufficiently far apart with no noticeable overlapping SAR distributions
 - SAR of one antenna has little or no contribution to the other antennas
- Applying results of scalar field probes to estimate SAR according to IEC TR 62230 for coherent signals need case-by-case consideration
 - according to individual product design and implementation