Federal Communications Commission
Office of Engineering and Technology
Laboratory Division Public Draft Review

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Laboratory Division Draft Presentation

Title: SAR measurement for IEEE 802.11 transmitters

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Presented: TCB Workshop, October 2013, Baltimore, MD

Purpose of Draft Presentation:

A presentation on guidance for the evaluation of SAR requirements for devices that incorporate IEEE 802.11 transmitters was given at the October 2013 TCB Workshop. Following the workshop an outline of issues to be covered in the guidance document was drafted. We invite comments on these documents as a part of our review of the guidance provided in KDB Publication 248227, as follows:

- The general guidance listed in the presentation
- Areas that need to be further addressed
- Additional questions or concerns
- Other comments related to this subject

Following our review of any comments we plan to issue a draft publication that will also be open for comment, prior to publication of a final guidance document.

Subject of the Draft Presentation:

This presentation was made to start the discussion on needed changes to the KDB Publication 248227, SAR measurement for IEEE 802.11 transmitters.

- Proposal to streamline SAR testing for IEEE 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

KDB 248227
802.11 SAR Procedures Update Proposal

TCB Workshop

October 2013

Laboratory Division
Office of Engineering and Technology
Federal Communications Commission

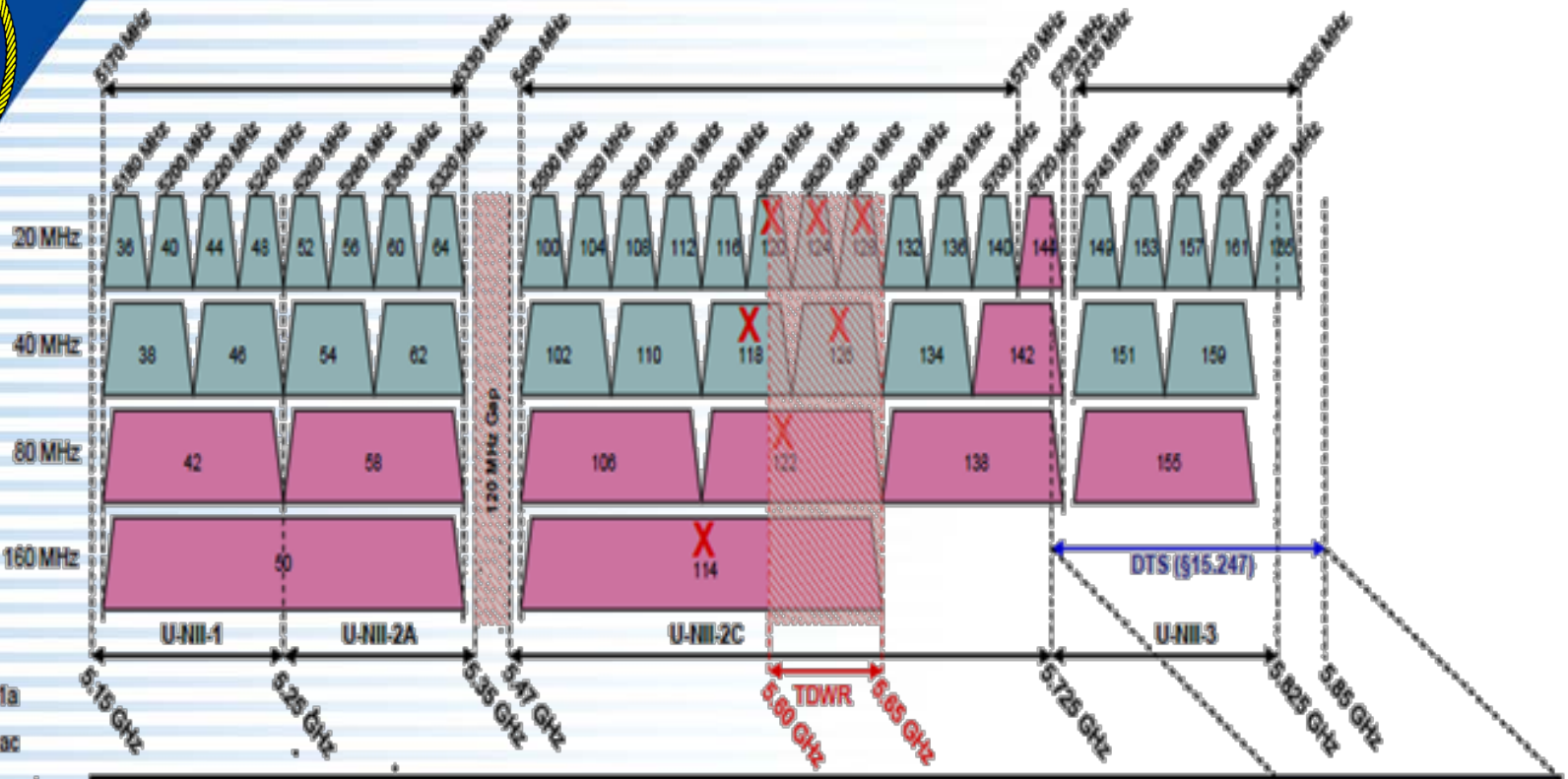
Overview

- 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



	U-NII Bands, §15.407 (Part 15E)				DTS, §15.247 (Part 15C)
Frequency Range (MHz)	5150-5250	5250-5350	5470-5725	5725-5825	5725-5850
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	30 dBm (1 W)
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
  - ≤ ¼ 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 ½ 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

Draft Revision Proposal for KDB 248227

This preliminary draft proposal identifies the possible options for bringing KDB 248227 up-to-date with respect to recent changes to 802.11 wireless technologies operating below 6 GHz, such as 802.11a/b/g/n/ac. There are numerous 802.11 wireless configurations that need consideration to determine SAR compliance. Although the protocols and configurations are defined by the 802.11 standards, some configurations have not been fully considered or implemented in existing small client devices that require SAR evaluation; for example, 4x4 or higher MIMO, MU-MIMO or 160 MHz channel BW configurations etc. The provisions of 802.11 standards to maintain compatibility with earlier implementations and the inherent flexibility of 802.11n and 802.11ac have also introduced additional complexity to SAR evaluation. The intent of this draft proposal is to identify the options that would enable 802.11 SAR test procedures to be streamlined according to latest product implementations, wireless mode configurations and anticipated developments.

To facilitate SAR test reduction, the test configurations for each frequency band and aggregated band are identified as DSSS or OFDM and grouped according to channel BW and exposure conditions (i.e., wireless configurations and exposure test positions). An initial test position may be applied for specific exposure conditions. An initial test configuration is selected according to the maximum output power configuration. Further SAR test reduction may be applied based on *reported* SAR of the measured configurations. SAR probe calibration and power measurement concerns are also reviewed to streamline the test considerations.

General SAR test considerations according to frequency band requirements

1) 2.4 – 2.4835 GHz §15.247
   a) Maximum allowed output power: 1 W / 36 dBm EIRP
   b) Required test channels
      i) 1, 6 and 11 for 22/20 MHz channel BW (DSSS/OFDM)
      ii) 3 and 9 for 40 MHz channel BW (OFDM)
   c) When the maximum output power of a required test channel is reduced to satisfy adjacent band or other product implementation requirements, the closest channel adjacent to a required test channel that operates at non-reduced maximum power must be considered for SAR measurement
   d) Reduced maximum output power is necessary for channels 12 & 13 to satisfy adjacent band restrictions at 2.4835 – 2.5 GHz; when used, SAR measurement is generally not required for these channels

(See Appendix A for 5 GHz 802.11 channel configurations and test setup conditions)

2) 5.15 and 5.25 GHz UNII 1 & 2A
   a) Different maximum allowed output power
      i) 50 mW / 23 dBm EIRP for UNII 1
      ii) 250 mW / 30 dBm EIRP for UNII 2A
      iii) Lower maximum output power may apply due to emission bandwidth restrictions
   b) Additional considerations are necessary to streamline SAR
      i) Combinations of frequency, power and *reported* SAR are applied to consider test reduction across these bands
   c) When the same transmitter and antenna configuration(s) are used for both bands and SAR measurement is required in an applicable exposure condition for at least one of the bands (i.e., SAR test exclusion does not apply), where the maximum output power specification of production units, including tolerance, is
      i) the same for both bands, start with the higher frequency band (UNII 2A) and if the highest *reported* SAR is
         (1) ≤ 1.2 W/kg, SAR is not required for the lower frequency band (UNII 1)
            (a) difference in tissue-equivalent media conductivity is about 4.5%
         (2) > 1.2 W/kg, both bands should be tested independently for SAR
      ii) different for the two bands and the highest *reported* SAR for the higher maximum output band is
         (1) ≤ 1.2 W/kg, SAR is not required for the lower maximum output band
         (2) > 1.2 W/kg and the difference in maximum output power is ≤ 1 dB
            (a) both bands should be tested independently for SAR
   d) 160 MHz channel BW support requires aggregation of both bands

i) Only one channel fits in the aggregated band: channel 50
ii) Maximum output power is limited by the band with lower allowed or specified maximum output
(1) When all *reported* standalone SAR for both bands are ≤ 1.2 W/kg and the maximum output power of the aggregated band is at least 1 dB lower than the individual bands
(a) SAR is not required for the aggregated band
(i) when SAR test exclusion applies to a band, the *reported* SAR is assumed to be ≤ 1.2 W/kg
(b) otherwise, SAR is required for 160 MHz channel in the aggregated band

3) 5.47 – 5.725 GHz and 5.725 – 5.85 GHz UNII 2C, UNII 3 and §15.247 (referred to as 5.6 and 5.8 GHz bands)
a) Different maximum allowed output power
i) 5.6 GHz UNII 2C: 250 mW / 30 dBm EIRP
ii) 5.8 GHz UNII 3 & §15.247: 1 W / 36 dBm EIRP
iii) Lower maximum output power may apply due to emission bandwidth restriction
iv) Frequency range for the three bands is too wide to easily facilitate SAR test reduction, 380 MHz
(1) requires multiple SAR probe calibration points
(2) difference in tissue-equivalent media conductivity is about 8%
b) 5.60 – 5.65 GHz in UNII 2C is restricted for master devices until further notice due to TDWR
i) A client device must be considered for SAR; except when it is specifically disabled to operate in this frequency range through acceptable mechanisms[1]
c) When the same transmitter and antenna configuration(s) are used for both 5.6 and 5.8 GHz bands
i) The additional 20, 40 and 80 MHz channels that span across these bands, unless permanently disabled, must also be considered for SAR testing
ii) The maximum output for these channels is limited by UNII 2C requirement (250 mW)
iii) Channels above 5.65 GHz in UNII band 2C are grouped with 5.8 GHz band channels in UNII 3 and §15.247 for SAR measurement, with respect to the maximum output power levels allowed for each band and specified for the transmitter, to facilitate test reduction
d) Band aggregation for 160 MHz channel BW across UNII 2C and 3 bands is not defined in the 802.11ac standard, most likely due to channel number misalignment. Client devices that do not disable operation in 5.60 – 5.65 GHz may fit a single 160 MHz channel in UNII 2C
i) SAR testing must be considered for products that implement 160 MHz channel(s) in UNII 2C or across the 5.6 and 5.8 GHz bands on an ad hoc basis

4) Simultaneously transmitting in two channels is not equivalent to transmitting in a single channel with twice the BW; i.e., two non-contiguous 80 MHz channels (80 + 80) is not equivalent to a 160 MHz channel. These are considered separately for SAR compliance
a) Issues relating to channel and band aggregation with respect to product implementations need investigation

SAR probes calibration and measurement considerations

1) SAR probes should be calibrated with at least +/- 100 MHz coverage at the following frequencies and according to the tissue dielectric parameter requirements of KDB 865664 to cover the 5 GHz frequency bands
a) 5.25 GHz for UNII 1 and 2A: 5.15 - 5.35 GHz
b) 5.60 GHz for UNII 2C: 5.475 – 5.725 GHz (250 MHz)
i) Probe calibration is expected to become marginal for the band edge channels
(1) Span of actual channel frequencies is 220 MHz (5.49 – 5.71 GHz)
(2) Span of channel center frequencies is 200 MHz (5.5 – 5.7 GHz)
ii) When band edge channels are tested, the tissue dielectric parameters must be within 5% of the required targets
c) 5.75 GHz for UNII 3, §15.247, or upper UNII 2C (above 5.65 GHz) with UNII 3 or §15.247: 5.65 – 5.85 GHz
d) SAR system validation dipoles must be calibrated within the frequency range covered by the probe calibration points required for device testing, according to KDB 865664 requirements
2) Other SAR measurement concerns that need consideration

[1] This supersedes the slide presented in October 2013 TCB workshop; also see explanation in 05/28/2013 TCB conference call minutes.

a) Influences of high peak to average power ratio OFDM signals to SAR probe calibration
b) Conservativeness of existing tissue-equivalent media dielectric parameters at 2.4 and 5 GHz for certain test separation distances and exposure conditions; according to on-going investigations in SAR measurement standards committees

Power measurement requirement considerations

1) For SAR purposes, power must be measured in each frequency band and aggregated band for the highest output power wireless mode specified for production units, including tolerance, according to channel BW, modulation and data rate to confirm the device is operating within specifications
   a) at the highest and lowest channels in the frequency band, and at the mid-band channel when there are at least 3 channels
   b) this enables the highest output power channel to be identified for DSSS and OFDM SAR measurements
   c) when the same maximum output specification applies to multiple channel BW, modulation and data rate combinations in a standalone or aggregated frequency band, select the configuration with the largest channel BW, lowest order modulation and lowest data rate
   d) these power measurement test reduction provisions are applicable only when the same maximum power and tolerance are specified for production units across all channels in a wireless mode, channel BW and frequency band
2) Power measurement is required for all configurations that require SAR measurement to enable *reported* SAR to be determined and to confirm that output power levels are within the test conditions required by KDB 447498
3) When power measurement is not required for a specific wireless configuration, the maximum output power specified and supported by production units, including tolerance, is applied to determine SAR test exclusion and reduction

SAR test reduction considerations for specific exposure conditions

1) For next to the ear, UMPC mini-tablet and hotspot mode equivalent exposure conditions (need definition for "equivalent") that require multiple test positions, an initial test position may be selected to test the highest output power channel/configuration required by the initial test configuration in the DSSS or OFDM SAR procedures to facilitate test reduction
   a) Left, right, touch and tilt head exposure test positions for the SAM phantom are considered as one head exposure condition for applying SAR test reduction
      i) Start on the side (left or right) of the SAM phantom and test position (touch or tilt) with the smallest Wi-Fi antenna to phantom test separation and maximum antenna to phantom coupling condition
         (1) When the differences in separation distance are indistinguishable, select the position with maximum antenna coupling to the SAM phantom, with respect to antenna orientation and polarization etc.
         (2) When exposure is dominated by antenna coupling, instead of antenna to phantom separation, antenna to phantom coupling must be considered first to determine the initial test position
         (3) Certain antenna details that are only available from device manufacturers may be necessary to apply this test reduction
   b) When hotspot mode or UMPC mini-tablet equivalent SAR configuration applies, start with the configuration that provides the smallest antenna or device (to be determined) to flat phantom separation and maximum antenna to phantom coupling condition
      i) for example, front or back surface vs. side edges with respect to antenna orientation and polarization
      ii) further review is needed to determine if these can be adapted for phablets ("equivalent" conditions)
   c) When it is unclear, all equivalent smallest separation and maximum coupling conditions must be considered for initial test position testing; i.e., a single initial test position cannot be established
2) When all *reported* SAR for the initial test position(s) measured according to the required DSSS or OFDM SAR measurement procedures for a wireless mode test configurations are
   a) ≤ 0.4 W/kg, further SAR measurement is not required for the DSSS or OFDM configuration in that exposure condition and frequency band
   b) > 0.4 W/kg
      i) Repeat the SAR measurement for subsequent next closest/smallest antenna to phantom separation and maximum antenna to phantom coupling test position(s) with the same wireless mode test configuration

used for the initial test position until the *reported* SAR is ≤ 0.8 W/kg or all required test positions are considered (left, right, touch, tilt or subsequent surfaces and edges)
    (1) For subsequent test positions with equivalent antenna to phantom separation or when antenna to phantom coupling dominates the exposure, select the position with maximum antenna to phantom coupling condition
    (2) When it is unclear, all equivalent conditions must be tested; i.e., a single subsequent test position cannot be established

c) For all positions/configurations from the initial test position and subsequent test configurations (SAR > 0.4 W/kg) with *reported* SAR > 0.8 W/kg, repeat these test positions/configurations on the subsequent next highest measured output channel(s) until the *reported* SAR is ≤ 1.2 W/kg or all required test channels are considered

SAR test considerations for 802.11b DSSS

1) When SAR test exclusion does not apply, 2.4 GHz 802.11b DSSS SAR is measured on the highest output power channel
    a) An initial test position may be applied to next to the ear, UMPC mini-tablet and hotspot mode equivalent exposure conditions for test reduction
    b) For other exposure conditions (not next to the ear, UMPC mini-tablet or hotspot mode), when the *reported* SAR on the highest output channel for the exposure condition is
        i) ≤ 0.8 W/kg, no further testing is required for 802.11b DSSS in that exposure condition
        ii) > 0.8 W/kg, measure SAR on the next highest measured output channel, and
            (1) when any *reported* SAR is > 1.2 W/kg, measure SAR on the 3rd channel; i.e., all channels require testing

SAR test exclusion and test reduction for 2.4 GHz OFDM (802.11g/n)

1) SAR is not required for an OFDM mode (802.11 g or n) when the specified maximum output power for production units, including tolerance, is
    a) at least 1 dB lower than DSSS and the highest *reported* SAR for DSSS is ≤ 1.2 W/kg
    b) ≤ ¼ dB higher than DSSS and
        i) highest *reported* SAR for DSSS is ≤ 0.8 W/kg or SAR test exclusion applies to DSSS

OFDM SAR measurement procedures for 2.4, (4.9) and 5 GHz bands

1) When SAR measurement is required, an initial test configuration is determined for each frequency band and aggregated band to facilitate SAR test reduction for 802.11 a/g/n/ac OFDM modes
    a) Start with the channel BW, modulation and data rate combination(s) with the highest maximum output power specified for production units, including tolerances
        i) The highest measured output channel according to power measurement results should be tested
            (1) for channels with the same measured maximum output power, measure SAR on the channel closest to mid-band
        ii) When the same maximum output specification applies to multiple channel BW, modulation and data rate combinations, select the configuration with the largest channel BW, lowest order modulation and lowest data rate
        iii) Modulation and data rate selection is mainly intended for test setup consistency
            (1) 802.11 data rates are associated with modulations
            (2) For SAR purposes, the modulations associated with sub-carriers are generally not expected to have significant impact to the OFDM channel output
2) Support for 4.94 – 4.99 GHz (part of existing KDB 247227), with respect to §§90.1213 and 90.1215, or other 802.11 related frequency bands such as §90.377 (5.85 – 5.925 GHz, OBU/RSU) etc., remain to be determined
3) Initial test configuration SAR measurement
    a) An initial test position may be applied to the initial test configuration for next to the ear, UMPC mini-tablet and hotspot mode equivalent exposure conditions to determine SAR test reduction
    b) For other exposure conditions (not next to the ear, UMPC mini-tablet or hotspot mode equivalent)

i) when the *reported* SAR of the initial test configuration is > 0.8 W/kg, repeat the initial test configuration on the subsequent next highest measured output channel(s) until the *reported* SAR is ≤ 1.2 W/kg or all required test channels are considered

4) Subsequent test configurations are determined for each frequency band and aggregated band to facilitate further test reduction for the applicable exposure conditions
   a) SAR is measured for the channel BW, modulation and data rate combination with next to highest maximum output power specified for production units, including tolerance
      i) When the next to highest specified maximum output configuration(s) is within ½ dB of the highest specified maximum output initial test configuration and the highest *reported* SAR for the initial test configuration(s) according to the initial test position or other exposure conditions is[2]
         (1) ≤ 0.8 W/kg, further SAR testing for the exposure condition in that frequency band is not required
         (2) > 0.8 and ≤ 1.2 W/kg
            (a) For all test conditions in the initial test configuration(s) with *reported* SAR > 0.8, test the channel(s) in the next highest specified output configuration that overlap(s) with the channel(s) in the initial test configuration(s) or apply the procedures required for > 1.2 W/kg in (3) below[3]
            (b) When multiple channels require testing for the next highest specified output configuration, start with the highest measured output channel and continue with subsequent highest measured output channels only when the *reported* SAR of the next highest specified output configuration at the highest measured output channel is > 1.2 W/kg
               (i) For channels with the same measured maximum output power, measure SAR on the channel closest to the center frequency of the larger channel BW channel
               (ii) Additional power measurements may be necessary to apply this step for SAR test reduction
         (3) > 1.2 W/kg, apply the initial test configuration SAR measurement procedures to the next highest output configuration
            (a) When SAR is required, power measurement is necessary to determine *reported* SAR and to identify the highest measured output channel to apply the initial test configuration
   b) SAR measurement of subsequent highest specified output configurations, besides the highest and next highest specified output configurations
      i) Apply the procedures for next highest specified output configuration by replacing
         (1) "next to highest specified output configuration" with "subsequent highest specified output configuration"
         (2) "highest specified output configuration" and "initial test configuration" with "all already tested higher output configurations"

5) 160 MHz channels must be tested when the *reported* SAR of any channel in a smaller channel BW configuration that overlaps with the 160 MHz channel is > 1.2 W/kg

SAR considerations for MIMO configurations

1) SAR for MIMO configurations are considered separately for each channel BW and frequency band or aggregated band configurations for the different exposure conditions.
2) The following may be applied to determine SAR test exclusion
   a) The aggregate maximum output power of all simultaneous transmitting antennas in the MIMO chains may be considered to determine SAR test exclusion according to the output power, frequency and distance provisions for standalone SAR in KDB 447498 or other product specific KDB procedures (this need review)
   b) When the standalone SAR test exclusion of KDB 447498 does not apply, each combination of MIMO chains may be considered separately (e.g., 2x2 as subsets of 3x3) for the MIMO configurations according to the sum of 1-g SAR or SAR to peak location ratio test exclusion described in KDB 447498 to determine simultaneous transmission SAR test exclusion

[2] Specified maximum output is the maximum output power specified for production units, including tolerance, for the applicable 802.11 wireless configuration.

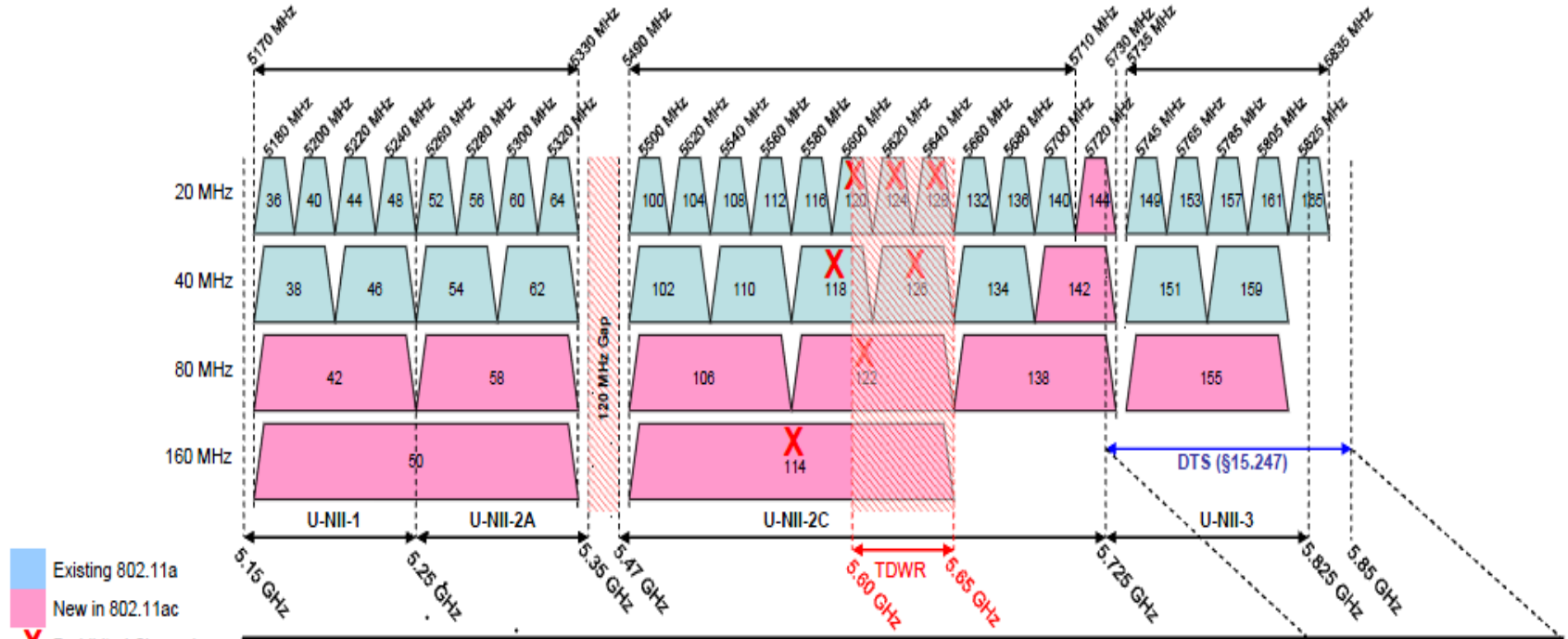
[3] Channels overlap due to differences in channel BW.

3) When SAR measurement is required for a MIMO configuration, with respect to channel BW and frequency band or aggregated band for each exposure condition, all antennas in each MIMO combination must be transmitting simultaneously at their maximum output power levels to determine SAR compliance in a single SAR measurement[4]
   a) An initial test position may be selected according to the standalone 802.11 SAR procedures for next to the ear, UMPC mini-tablet and hotspot mode equivalent conditions
   b) MIMO SAR should be measured on the highest *reported* standalone SAR channel for each MIMO chain applicable to the exposure configuration and position
      i) Need procedures to determine *reported* SAR for MIMO
   c) When the *reported* SAR for MIMO is > 1.2 W/k/kg, the channel combination(s) for the MIMO chains with subsequent next to highest aggregated standalone SAR in that exposure configuration and position should be tested until the MIMO SAR is ≤ 1.2 W/kg
   d) Further review and consideration are necessary for a) – c)
4) For SAR measurement purposes, 802.11ac VHT beam-forming implemented at the sub-carrier level is not expected to introduce significant signal coherence at the OFDM channel output of the MIMO chains; unless the antenna implementation allows or promotes focusing in the near-field, coherent signal SAR procedures are generally not required
   a) This does not apply to other types of ad hoc beam-forming or similar configurations used for 802.11ac or other 802.11 modes
5) The above MIMO SAR procedures do not apply to coherent signals
   a) The maximum worst-case SAR possible due to 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
   b) Sum of SAR and SAR to peak location ratio test exclusion do not apply to coherent MIMO chains, except when the antennas are sufficiently far apart with no noticeable overlapping SAR distributions; therefore, the SAR of one antenna has little or no contribution to the other (to be determine on a case-by-case basis through KDB inquiries)
   c) The transmission configurations required to apply the results of scalar field probes to estimate SAR according to IEC TR 62230 for coherent signals will need consideration on a case-by-case basis according to individual product design and implementation

[4] MIMO antennas on larger form factor devices that are farther apart are expected to qualify for simultaneous transmission SAR test exclusion. Testing all antennas operating in the same frequency range in a single SAR measurement reduces the number of SAR measurements and also takes into consideration interactions among the MIMO and antenna chains.

Appendix A

5 GHz 802.11 channel configurations



	U-NII Bands, §15.407 (Part 15E)				DTS, §15.247 (Part 15C)
Frequency Range (MHz)	5150-5250	5250-5350	5470-5725	5725-5825	5725-5850
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	30 dBm (1 W)
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

(For illustration only)