



**Federal Communications Commission
Office of Engineering and Technology
Laboratory Division**

October 23, 2015

**SAR EVALUATION CONSIDERATIONS
FOR LAPTOP, NOTEBOOK, NETBOOK AND TABLET COMPUTERS**

1. INTRODUCTION

This document describes the SAR requirements for laptop and tablet computers. For the purposes of this procedure, the laptop platform also includes devices commonly referred to as notebook and netbook computers. The procedures are applicable only when the overall diagonal dimension of the keyboard and/or display section of a laptop or tablet is > 20 cm.¹ The RF exposure test requirements for transmitters and antennas operating in standalone and simultaneous transmission configurations are applied in conjunction with the test reduction and exclusion provisions in KDB Publication 447498 D01. In addition, KDB Publication 447498 D01 also includes a list of other KDB Publications that are referred to as the “*published RF exposure KDB procedures*”, which must be used for testing the different wireless technologies, as applicable.² These equipment approval guidelines are only applicable for incorporating transmitters and modules in laptop and tablet computers that operate in the 698 MHz to 6 GHz bands.

These test requirements are aimed at streamlining the test and approval process for incorporating transmitters and modules in recent generation laptop and tablet computers. The procedures also provide a framework for establishing the documentation and disclosure requirements listed in KDB Publication 447498 D01 for the supply chain, including grantees of individual transmitters, host manufacturers and OEM/ODM integrators, and end users to satisfy RF exposure compliance. Two host platforms are considered for incorporating transmitter modules into host devices, the laptop and tablet platforms. The laptop platform includes laptop, notebook and netbook computers. The tablet platform applies to tablets and certain laptop computer configurations that can also operate in tablet mode, including “2-in-1” type of tablets and those using detachable keyboards. When the test configurations and minimum test separation distances applicable to the tablet platform are more conservative than that required for the laptop platform, transmitters approved for tablet platform can also be used in the laptop platform.

2. GENERAL SAR TEST CONSIDERATIONS

When multiple transmitters are incorporated in a host computer, the aggregate exposure is dependent on the antenna configurations in each host implementation. The RF exposure conditions evaluated for individual transmitter modules must be sufficiently conservative to enable the transmitters to be incorporated in a multitude of host configurations for both standalone and simultaneous transmission operations without requiring additional equipment approval. The RF exposure conditions for laptop computers are generally associated with the antennas installed in the display screen and keyboard compartment. The exposure conditions for tablet computers are normally associated with the entire

¹ The UMPC mini-tablet procedures in KDB Publication 941225 D07 should be applied when diagonal dimensions are ≤ 20 cm. While market definitions of products may change over time, the general rule of 20 cm diagonal dimension should be used to determine appropriate procedures for products. Regardless of device dimensions, when next to the ear voice calls are supported the smart phone and phablets procedures in KDB Publication 648474 D04 must be applied.

² See KDB Publication 447498 D01 for *published RF exposure KDB procedures*.

tablet; if a non-detachable keyboard exists it would be folded below the display and considered as an integral part of the tablet device for testing. The procedures may be extended to detachable wireless keyboards and certain docking stations that may operate next to the user.³ Additional SAR test reduction and exclusion criteria for standalone and simultaneous transmission operations may be established conservatively, in conjunction with the SAR test exclusion thresholds discussed in KDB Publication 447498 D01, according to these operating configurations and exposure conditions, and with respect to the maximum output power of each transmitter, antenna proximity to users and other simultaneous transmitting antennas installed in the host.

The operating characteristics and exposure conditions of transmitters are expected to vary in different host configurations. Modular transmitters incorporated in a typical host computer are usually supplied by different vendors; each typically supports a different type of wireless technology. In addition, a host manufacturer may choose to have multiple suppliers for a specific type of transmitter, sometimes with certain design variations, requiring different antennas or varying antenna configurations in different host models. The normally required KDB procedures may not apply to this type of transmitter variations. A KDB inquiry should be submitted to determine the test and approval requirements.

3. EQUIPMENT APPROVAL AND RF EXPOSURE TESTING APPROACHES

3.1. General

Transmitters certified as modules may be incorporated in qualified laptop and tablet hosts without the need for further equipment approval by using the “*modular approach*” described below.⁴ Alternatively, the host manufacturer may choose to use the “*dedicated host approach*” to apply for equipment approval for the host device and all transmitters incorporated in it under one FCC ID.⁵ In this case, the grantee of the host device is solely responsible for the installation, operation and disclosure requirements of all transmitters incorporated in the host device. In some cases, a *mixed approach* may also be used by the different responsible parties to apply the requirements of both the modular and dedicated host approaches to streamline the testing and approval process to incorporate transmitters in qualified host devices.

3.2. Modular approach

When applying the *modular approach*, host manufacturers and OEM integrators are required to adhere to all installation requirements and operating restrictions to incorporate transmitters in host devices. The transmitter manufacturers must each provide the relevant instructions required for the module to ensure compliance in all subsequent integration and use configurations. The transmitter manufacturer is also responsible for ensuring integrators have a clear understanding of the compliance requirements and, if necessary, to provide further assistance to fulfill grantee responsibilities. The integrators must be fully informed of their obligations; and must verify the resolution of any issues and concerns with each transmitter manufacturer. The disclosure requirements for the entire supply chain, including sample user operating instructions for the host devices, must be fully documented for a transmitter module and submitted for equipment approval.⁶

³ A KDB inquiry is recommended to determine the SAR test requirements for these.

⁴ In applying the *modular approach* the integrator may not have to perform further tests on the transmitter; however, the integrator is still responsible for the overall compliance of the host device, including meeting any other compliance requirements for such hosts.

⁵ The *dedicated host approach* requires all transmitters to be approved under one FCC ID. This is different than testing in representative host configurations using an equivalent or specific host, where a transmitter or module is approved independently under its own FCC ID.

⁶ Disclosure requirements are specified by the grantee; the actual disclosure is implemented by the integrators according to the disclosure requirements.

The *modular approach* is applied to incorporate transmitters and modules in qualified laptop and tablet hosts. The SAR procedures in KDB Publication 447498 D01 for transmitters and modules are used to determine if a modular transmitter may be approved for use in single and multiple host platforms, and with or without host platform restrictions. When the *test separation distances* and test setups described in this document for the laptop and tablet host platforms are satisfied by the antenna and host configurations and the highest *reported* SAR for a host platform is ≤ 0.8 W/kg, testing in representative hosts is optional for the *modular approach*.⁷ When the highest *reported* SAR based on the test separation distances and test setups required in this document is > 0.8 W/kg, the required platform test separation distance may be relaxed by testing in representative host configurations to enable the higher SAR conditions to qualify under the *modular approach* according to specific installation and operating restrictions.⁸ The *reported* SAR for the representative host configurations must be > 0.8 W/kg and ≤ 1.2 W/kg to qualify for the relaxation.⁹ When the highest *reported* SAR for the representative host configurations is > 1.2 W/kg and ≤ 1.4 W/kg, with only a few of the SAR results in this range, a KDB inquiry is required to determine if the test results are sufficiently conservative to ensure compliance without the dedicated host requirements.¹⁰ When the *reported* SAR is > 1.4 W/kg, the *dedicated host approach* is required for equipment approval; the *modular approach* does not apply.¹¹

Testing in representative host configurations can provide host manufacturers the option to include certain host configurations which otherwise may raise SAR concerns. When SAR is tested in representative host devices and the highest *reported* standalone SAR for certain specific operating configurations and exposure conditions are ≤ 1.2 W/kg, the additional tests of a transmitter module in one or more representative host configurations may be performed to allow the transmitter to be incorporated in similar or less conservative host configurations and exposure conditions supported by the same test requirements for that host platform.¹² It is expected that many of the higher SAR conditions may not be easily tested in the initial equipment approval when certain specific antenna or host configurations are not clearly defined in early-on host product implementations. There may be circumstances where the generic host platform test configurations, without a representative host, could be overly conservative for certain antenna or operating configurations. By testing available host configurations on an incremental basis to add optional configurations through Class II permissive changes, the qualified host configurations and exposure conditions can be expanded according to the following procedures:

- a) The module transmitter manufacturer must update the OEM integration instructions and installation requirements for each subsequent Class II permissive change to include the additional antenna and host configurations. These are reviewed for acceptance during equipment approval.
- b) The type of material surrounding the antenna location for the hosts used in the tests must be similar to those required in the actual implementations. Separate hosts should be tested to support different materials surrounding the antenna that are likely to introduce SAR differences; for example, non-conductive plastics vs. conductive plastic or metallic materials. These should be clearly identified in

⁷ *Reported* SAR is the measured SAR adjusted for maximum tune-up tolerance (See KDB Publication 447498 D01).

⁸ Testing in representative host test configurations enables the transmitter module to be used in similar host configurations without requiring a dedicated host approval.

⁹ This is to maintain conservative exposure conditions while reducing excessive Class II permissive changes.

¹⁰ A KDB inquiry is required when the *reported* SAR for a transmitter module is > 1.2 W/kg and the device is not tested in a dedicated host to determine if there are additional compliance concerns.

¹¹ When tested in and approved for a dedicated host, a PAG is not required.

¹² The *test separation distance*, antenna to host enclosure distance, antenna orientation and polarization etc. should all be taken into consideration to determine if a representative host test configuration can be applied to another host in the same platform with similar configurations.

the OEM installation requirements.

- c) The SAR test considerations for substituting equivalent antennas, such as the same type and gain, are described in KDB Publication 447498 D01. Any operating restrictions to be relaxed and/or configurations to be added through subsequent host testing and Class II permissive changes must be clearly identified in the installation requirements; for example:
 - 1) To enable antennas to be installed in specific or new configurations according to adjacent edge SAR results for qualified laptop keyboard or tablet configurations. Note: the two ends of an antenna associated with different adjacent edges on a host should be treated separately for antennas with asymmetrical structures or radiating characteristics.
 - 2) To allow antennas with asymmetrical physical structures or radiating characteristics to be installed in hosts requiring different antenna rotation or orientation configurations.
- d) When the simultaneous transmission SAR test exclusion provisions in KDB Publication 447498 D01 are satisfied and no additional SAR testing is required for the host configurations, additional equipment approval is not required. The grantee is responsible for maintaining all Class I permissive change records. When simultaneous transmission SAR or MPE testing is required, the test and equipment approval procedures in KDB Publication 447498 D01 for modular transmitters and mobile and portable exposure conditions must be applied to incorporate modular transmitters in qualified host devices.
- e) Host manufacturers and OEM integrators must be instructed to apply the simultaneous transmission SAR test evaluation and exclusion provisions in KDB Publication 447498 D01 for transmitters/antennas operating from external card slots and/or interface connections to determine compliance for the host computer configurations. Transmitters with external interface connections cannot be restricted to specific host devices; the SAR for this type of user accessible external peripheral transmitters (for example, ExpressCard, Card Bus and USB devices), must be assumed to be 1.6 W/kg for the compliance analysis. The host manufacturer must ensure the minimum separation distance determined by the SAR to peak location separation ratio criteria in KDB Publication 447498 D01 is satisfied to avoid additional equipment approval requirements due to these user accessible transmitters. The analysis must be based on conservative test separation distance considerations and clearly explained in the SAR report and OEM integration requirements.

3.3. Dedicated host approach

When the *dedicated host approach* is applied, compliance for all transmitters in the host device must be addressed by the host manufacturer or grantee, for both standalone and simultaneous transmission operations with respect to the transmitter and antenna installation requirements and operating configurations of the specific host device. Compliance for simultaneous transmission due to external user accessible peripheral transmitters that plug into external card slots and interface connections must also be addressed, according to the requirements described for the *modular approach*.

3.4. Mixed approach

When the *mixed approach* is applied, requirements for both modular and dedicated host approaches must be considered for the corresponding transmitters to be incorporated in the host device. *Modular approach* applies to transmitters with modular approval and *dedicated host approach* applies to the other transmitters incorporated in the host device.

4. HOST PLATFORMS

4.1. General

Regardless of simultaneous transmission operations all transmitters must be evaluated independently for standalone SAR compliance according to the required rules and policies to determine RF exposure

compliance for use in laptop and tablet host platforms.¹³ Transmitters and modules incorporated in host devices that operate in both laptop and tablet host platforms must satisfy the requirements for both platforms and be tested according to the modular transmitter procedures in KDB Publication 447498 D01.

For feet and edge bumpers or similar protrusions incorporated in laptop and tablet host devices, if the antenna location can be positioned against the user during normal use and the additional separation introduced by such protrusions between the outer housing and a flat phantom is > 5 mm or when the *reported* SAR with the protrusions in place is > 1.2 W/kg, a KDB inquiry is required to determine if additional SAR measurements in more conservative test configurations are necessary. The KDB inquiry is not required if the feet, bumpers or protrusions can be easily removed with no other modifications to enable SAR testing with the device in direct contact with the phantom.

When applying the *modular approach*, the host manufacturer or OEM integrator must ensure the transmitters and modules are each qualified for incorporation into the host device. If a transmitter does not qualify for incorporation in certain host configurations, additional equipment approval is required for that modular transmitter. The host manufacturers and OEM integrators should first evaluate the SAR test exclusion provisions in KDB Publication 447498 D01, to incorporate transmitters and antennas using host configurations that do not require further testing, to meet standalone and simultaneous transmission SAR compliance requirements. The final assembly and integration in the host must comply with the specific instructions and requirements of all transmitters and modules provided by each grantee for incorporation in qualified hosts. When further testing is required for simultaneous transmission, the approval procedures described in KDB Publication 447498 D01 must be followed to determine which responsible party should be addressing the compliance concerns.

A transmitter module must be tested for SAR compliance according to the laptop or tablet platform test requirements without using a representative host in the initial equipment approval. These test results are used, either during the initial filing or in subsequent Class II permissive change approvals, to determine if additional testing with representative hosts is required for certain specific configurations with SAR > 0.8 W/kg. The initial testing without representative hosts is required to apply the *modular approach*, before additional testing with representative host are considered to support higher SAR configurations. The more conservative test separation distances required initially by the *modular approach* for generic host platform testing without representative hosts can be relaxed to enable the higher SAR conditions to apply the *modular approach* through representative host testing when the highest SAR is ≤ 1.2 W/kg without restricting the transmitter module to operate in a specific dedicated host. All SAR data, for testing with and without representative hosts, must be included in SAR reports, to determine host platform qualifications.

4.2. Laptop host platform test requirements

The required minimum test separation distance for incorporating transmitters and antennas into laptop, notebook and netbook computer displays is determined with the display screen opened at an angle of 90° to the keyboard compartment. If a computer has other operating configurations that require a different or more conservative display to keyboard angle for normal use, a KDB inquiry should be submitted to determine the test requirements. When antennas are incorporated in the keyboard section of a laptop computer, SAR is required for the bottom surface of the keyboard.¹⁴ Provided tablet use conditions are not supported by the laptop computer, SAR tests for bystander exposure from the edges of the keyboard

¹³ When an individual transmitter is designed only for simultaneous transmission with no provision for standalone operations, a justification must be provided to clearly demonstrate that standalone SAR tests are not required. Without standalone SAR, simultaneous transmission SAR test exclusion cannot be applied. The enlarged zoom scan measurements and volume scan post-processing procedures in KDB Publication 865664 D01 are required. Also see item b) in clause 3 of KDB Publication 447498 D01.

¹⁴ *Test separation distance* is determined according to item e) in 4.1 of KDB Publication 447498 D01.

and display screen of laptop computers are generally not required. However, when edge testing is necessary, the similar concerns for simultaneous transmission on adjacent or multiple edges described for tablets near the end of 4.3 also apply.

When the *modular approach* is applied, transmitters and modules must be tested initially without using a representative host for incorporation in the display and/or keyboard of qualified laptop computers for standalone use according to the following minimum *test separation distance* and antenna installation requirements. The separation distance required for incorporation in qualified hosts is described in KDB Publication 447498 D01; item e) of 4.1 and item a) of 5.2.2 etc.

- a) ≤ 25 mm between the antenna and user for incorporation in laptop display screens¹⁵
- b) ≤ 5 mm between the antenna and user; only when incorporation in the keyboard compartment is required by the hosts, for bottom surface and edge exposure conditions
- c) the antennas used by the host must have been tested for equipment approval or qualify for SAR test exclusion
- d) the antenna polarization, physical orientation, rotation and installation configurations used by the host must have been tested for compliance for the required display and/or keyboard installation conditions and *test separation distance*(s) or qualify for SAR test exclusion
- e) when the *SAR Test Exclusion Threshold* in KDB Publication 447498 D01 applies, a minimum *test separation distance* of 25 mm is required to determine test exclusion for the display, and 5 mm for the keyboard compartment

The higher SAR conditions tested in representative host configurations are only applicable to hosts that satisfy such test configurations, with respect to the use conditions and restrictions approved for such host configurations.

4.3. Tablet host platform test requirements

Some 2-in-1 tablets may operate with the display folded on top of the keyboard. Most recent tablets are designed with an interactive display that may not require a physical keyboard. Both configurations are used in similar manners and require SAR evaluation for the back surface and edges of the tablet. For keyboards that can be unfolded like a laptop, the procedures for laptop platform should also be applied. When the tablet keyboard can be detached from the display screen and also contains a wireless transmitter, SAR testing for the keyboard alone may be required. The antennas in tablets are typically located near the back (bottom) surface and/or along the edges of the devices; therefore, SAR evaluation is required for these configurations. Exposures from antennas through the front (top) surface of the display section of a full-size tablet, away from the edges, are generally limited to the user's hands. Exposures to hands for typical consumer transmitters used in tablets are not expected to exceed the extremity SAR limit; therefore, SAR evaluation for the front surface of tablet display screens are generally not necessary, except for tablets that are designed to require continuous operations with the hand(s) next to the antenna(s). When voice mode is supported on a tablet and it is limited to speaker mode or headset operations only, additional SAR testing for this type of voice use is not required. For other voice mode operations, including phablet configurations and next to the ear use, when it is unclear a KDB inquiry should be submitted to determine SAR test requirements.¹⁶

For most tablets, the display orientation may rotate to enable viewing in portrait and landscape modes; in general two each, primary and secondary. In some device configurations, the display may be disabled in

¹⁵ Test distances indicated in this document as \leq a threshold distance are "not to exceed" distances; small test distances may be necessary for more conservative exposure conditions required by the host configurations.

¹⁶ Next to the ear operation is generally not expected for tablets with overall diagonal dimension > 20 cm. However, when next to the ear voice mode is supported, regardless of the overall dimension, phablets must be tested according to the requirements described in KDB Publication 648474 D04.

selected orientations to discourage users from rotating a tablet edge containing an antenna towards the user. As tablet designs continue to expand, to provide the flexibility needed to support interactive use, the display orientations can become unclear and user-transparent for some applications and use conditions. Disabling the display in certain orientations may no longer be sufficient to ensure RF exposure compliance. Tablets may use various sensing mechanisms to determine display rotation while the device is positioned in or transitioning through different vertical and horizontal orientations and various tilted conditions. During interactive use, the transmissions from antenna(s) incorporated along an edge associated with a disabled display orientation may continue to transmit through some of these spatial orientations or at certain tilt angles when the tablet edge is at close proximity to its users or nearby persons. Unless there are acceptable means to ensure compliance; for example, by reducing the maximum output power instead of disabling a certain display orientation to obviate SAR testing, the transmitter should be disabled for these circumstances to ensure compliance.

Both the back surface and edges of tablets can operate directly next to users; hence, higher SAR is generally expected and the *modular approach* may only be possible for the lower power transmitters incorporated in tablets. When higher output power transmitters are incorporated in tablets and the SAR of the modular transmitter in the required tablet test configurations is > 1.2 W/kg but ≤ 1.4 W/kg, where only a few of the SAR results are in this range, a KDB inquiry is required to determine if the test results are sufficiently conservative to ensure compliance without requiring further dedicated host approval requirements. When the SAR is > 1.4 W/kg, approval in a dedicated host is required. While all transmitters may be addressed in a single FCC ID for approval using the *dedicated host approach*, the *mixed approach* can generally be applied to incorporate lower power transmitters in tablets.

When the *modular approach* is used, transmitters and modules must be initially tested for standalone operations in generic host conditions according to the following minimum *test separation distance* and antenna installation requirements for incorporation in the tablet platform. The separation distance required for incorporation in qualified hosts is described in KDB Publication 447498 D01; item e) of 4.1 and item a) of 5.2.2 etc.

- a) ≤ 5 mm between the antenna and user for both back surface and edge exposure conditions¹⁷
- b) the antennas used by the host must have been tested for equipment approval or qualify for SAR test exclusion
- c) the antenna polarization, physical orientation, rotation and installation configurations used by the host must have been tested for compliance or qualify for test exclusion
- d) when the *SAR Test Exclusion Threshold* in KDB Publication 447498 D01 applies, a *test separation distance* of 5 mm is required to determine test exclusion for the tablet platform

The antennas embedded in tablets are typically ≤ 5 mm from the outer housing. The required antenna to user *test separation distance* is a “not to exceed test” distance required to apply the modular approach. Instead of the typical zero gap tablet edge test requirement between the edge of a tablet and the user, when an antenna has been tested at ≤ 5 mm according to the *modular approach* it can be incorporated into tablets with at least twice the tested distance from the outer housing of the tablet edge; otherwise, the tablet edge zero gap test requirement applies. When the *dedicated host approach* is applied, the back surface and edges of the tablet should be tested for SAR compliance with the tablet touching the phantom.¹⁸ The *SAR Test Exclusion Threshold* in KDB Publication 447498 D01 can be applied to

¹⁷ See footnote 15.

¹⁸ The *test separation distance* used to determine SAR test exclusion for the back (bottom) surface and tablet edges that contain an antenna should be determined from the outer housing of the tablet, according to item e) in 4.1 of KDB Publication 447498 D01.

determine SAR test exclusion for adjacent edge configurations.¹⁹ The closest distance from the antenna to an adjacent tablet edge is used to determine if SAR testing is required for the adjacent edges, with the adjacent edge positioned against the phantom and the edge containing the antenna positioned perpendicular to the phantom.

For tablets with a curved or contoured back surface or edge construction, if the antenna location can be positioned against the user during normal use and the additional separation introduced by the contour against a flat phantom is > 5 mm or when the *reported* SAR is > 1.2 W/kg, a KDB inquiry is required to determine the applicable tablet test setup requirements.²⁰ When proximity or other sensors are incorporated on the back surface or edges of a tablet, near the curved or contoured regions, additional considerations are required besides the sensor triggering and coverage procedures provided in this document. A KDB inquiry is recommended to ensure the proper tablet test setups are used. In both cases the KDB inquiry must clearly describe the device shape and its operational configurations.

The simultaneous transmission SAR test procedures described in KDB Publication 447498 D01 should be applied to determine if the test exclusion provisions can be used or the enlarged zoom scan measurement and volume scan post-processing procedures are required. SAR test exclusion must be determined separately for the back surface and each edge, according to the simultaneous transmission requirements for each exposure position, which may involve antennas transmitting simultaneously on adjacent or multiple edges. When antennas on adjacent edges are considered for SAR to peak location separation ratio test exclusion, the peak SAR locations reported by the SAR measurement system referencing different physical phantom and device locations should not be used. The peak location separation must be determined manually with respect to a common origin on the device; for example, with respect to the same physical edge location of the tablet and reference point on the phantom. The details must be clearly explained in the test reports to support the test setup.

The hotspot mode SAR procedures (KDB Publication 941225 D06) for handsets and UMPC mini-tablet procedures generally do not apply to the full-size tablet devices described in this document. The standalone and simultaneous transmission SAR tests required for tablets are more conservative than the hotspot mode use configurations; therefore, additional testing for hotspot SAR is not required when the procedures in this document are applied. Hotspot mode is just a subset of the simultaneous transmission configurations applicable to certain categories of hosts and devices. This does not obviate the simultaneous transmission SAR test requirements for the other operating and exposure conditions applicable to a tablet.

5. MODULAR APPROACH SAR TEST SETUP CONSIDERATIONS

5.1. General

The options available for incorporating transmitter modules in qualified host configurations are determined by the test conditions applied to individual transmitters during equipment certification. Transmitters and modules intended for incorporation in laptop and tablet host computer platforms using the *modular approach* must follow the requirements defined in this document, and according to the standalone and simultaneous transmission test procedures for transmitter modules in KDB Publication 447498 D01. The *SAR Test Exclusion Threshold* in KDB Publication 447498 D01 should be used to determine if SAR testing is required for the test configurations.

¹⁹ The *test separation distance* for SAR test exclusion of adjacent edges is determined by the closest distance between the antenna and outer housing on the adjacent edge of the device.

²⁰ Also see feet, bumper and protrusion concerns in 4.1.

5.2. Standalone SAR testing

For modular transmitters to qualify for incorporation into these platforms, the separation distances required for laptop and tablet host platform testing, without using a representative host, must be applied to determine SAR compliance.²¹ The following general guidance should be used to measure the standalone SAR of transmitter modules when testing with the transmitter and antenna outside of a representative host.

- a) The transmitter should be controlled by a representative host computer or an equivalent testing platform and operating with the actual firmware, software drivers and other associated device operating software required for testing the wireless technologies. When the antenna is detached from the module, the transmitter generally does not contribute to the SAR; therefore, the transmitter should be installed within the host or an equivalent testing platform and operate remotely from the antenna for the SAR testing, with cable loss properly accounted for.
- b) All tested configurations and supported antenna installation requirements must be clearly identified in the SAR report, and OEM integration and installation instructions, such as physical antenna orientation and rotational configurations, installation in defined locations of the host device in the platform, minimum and maximum antenna cable lengths, and other restrictions.
- c) For implementations that require an antenna to be connected to the transmitter through RF cable(s), the antenna assembly, which is typically the standalone antenna, must be tested independently for SAR. When the cable length or type does not meet the installation requirements, permissive changes may be required to address compliance issues according to the actual implementations.
 - 1) The same type of antenna cable specified in the installation requirements must be used to connect the antenna to the transmitter for testing. The shortest antenna cable required by the host platform(s) must be used in the SAR tests, with the antenna located at least 10 cm away from the host computer or equivalent testing platform and other supporting equipment in the SAR measurement setup. When the shortest cable cannot be used in the SAR setup, the measured SAR must be scaled up to account for cable loss differences. The antenna cable must be routed and oriented according to the actual implementations.
 - 2) The antennas must be tested in the mounting and installation orientations supported by the actual implementations used in the host platform. Testing in both horizontal and vertical mounting orientations are required for installation in horizontal and vertical edges of laptop and tablet computers. These test configurations also address the parallel and perpendicular configurations in adjacent edge exposure conditions. When the antenna structure is asymmetrical and can be rotated with respect to the antenna axis for installation in hosts, where an antenna surface can be mounted facing in, out, up or down in the host device, these rotational configurations should be considered for testing and fully defined in the installation instructions.
 - 3) The antenna must be mounted on lossless foam material for SAR testing to qualify for installation in hosts with low-loss materials near the antenna. The antenna must be mounted on conductive material with similar characteristics as those used by the hosts, to qualify for installation in hosts with such material near the antenna. The range of acceptable antenna backing/mounting/support material properties or exact requirements must be clearly justified and specified in the OEM installation requirements.
- d) The following apply to implementations where the antenna is built-in as an integral part of the transmitter or module; therefore, the antenna is fixed and cannot be re-oriented with respect to the transmitter assembly.
 - 1) The transmitter/antenna assembly must be tested in all installation orientations and rotations

²¹ Testing without a representative host means the antenna or transmitter and antenna combination are not installed within a host for SAR testing. However, a host is still required for the transmitter to operate.

required by the host computer configurations. The transmitter/antenna assembly should be tested independently as a detached assembly, outside of the host device, located at least 10 cm away from the host computer or equivalent testing platform and other supporting equipment used in the SAR measurement setup. The interface cable required for connecting the assembly to the host computer or equivalent testing platform must be routed and oriented according to the actual implementations. If an interface cable is only required for testing, but not used in the actual implementations, the cable should be oriented perpendicular to the E-field to minimize field perturbation during the SAR measurements.

- 2) If it is not feasible to test the transmitter/antenna assembly outside of the host device or with an equivalent testing platform, the installation must be limited to the host configurations tested and clearly identified in the installation instructions and requirements.

5.3. Simultaneous transmission SAR test exclusion and compliance requirements

When transmitters and antennas transmit simultaneously in laptop and tablet computers, the following procedures must be applied by the host manufacturers and OEM integrators, in conjunction with the requirements in KDB Publication 447498 D01, to determine simultaneous transmission SAR test exclusion and to qualify for Class I permissive change. All simultaneous transmission configurations must be clearly identified in the Class I permissive change documentation and kept in the responsible party's records. The following information must be included:

- a) FCC ID of each transmitter, maximum average conducted output power in each transmission mode and frequency band, operating configurations and exposure conditions approved for the individual transmitters.
- b) Applicable antenna configurations; as identified in diagrams, drawings and/or photos, including the range of antenna-to-user and antenna-to-antenna separation distances required for each transmitter.
- c) The model and type of host device(s), physical dimensions, and antenna locations in each host.
- d) The antenna manufacturer(s) and antenna specification details.
- e) Other relevant information and restrictions required by the equipment certifications of the individual transmitters for the host to be fully compliant.
- f) Calculations, analyses and explanations showing how simultaneous transmission SAR exclusion applies; therefore, Class I permissive change applies.
- g) When multiple equipment approval grants exist for a transmitter (for example, multiple Class II permissive changes), the grant date(s) and other details for the specific grant(s) that apply to the specific configuration(s) must be fully identified in the Class I permissive change. Similar considerations may also apply when multiple Class I permissive changes are involved.

When simultaneous transmission SAR measurement is required, separate equipment approval is necessary. This should be evaluated with respect to the approval considerations described for the *modular approach*, *dedicated host approach*, *mixed approach* and other requirements in KDB Publication 447498 D01.

6. PROXIMITY SENSOR CONSIDERATIONS

6.1. General

Given the operating configurations and exposure conditions permitted by tablets, proximity sensors and other device position detecting mechanisms are often used in host devices to reduce the maximum output power in selected wireless modes and operating configurations to ensure SAR compliance. Depending on the design and construction of individual tablets, single or multiple sensors may be used to trigger power reduction. A sensor can be collocated or overlapping with a specific antenna or located adjacent to one or more antennas to facilitate triggering. The power reduction can be implemented for any combinations of the back surface and edges of a tablet. Existing proximity sensors are typically triggered by capacitance

changes due to objects in the vicinity of the sensing element. If similar sensor triggering implementations are used in other designs, the similar test procedures may be adapted for such designs with justification included in the test documentation; otherwise, a KDB inquiry is required to determine the test requirements.²² The triggering sensitivity for objects approaching and retracting from the sensor can be different; therefore, the separation distances for activating power reduction and returning to maximum power may vary because of hysteresis effects. In addition, the triggering distance can also be influenced by triggering sensitivity, which is normally adjusted and set according to individual tablet implementations, or external conditions.

When sensors are designed to provide tablet back surface and/or edge sensing coverage in multiple directions, orientations and different tilt angles, the triggering sensitivity can vary for the different conditions. The triggering variations and hysteresis effect must be evaluated separately according to the tissue-equivalent medium required for each frequency band, to identify the proper SAR *test separation distances*. If it can be demonstrated that sensor triggering does not change with different tissue-equivalent media, when appropriate, the triggering tests may be performed using the tissue-equivalent medium required for the highest frequency band.²³ The most conservative triggering distance expected for production units, including hysteresis effects, must be used in the SAR measurements. The triggering conditions for both normal maximum output power and reduced maximum output power must be confirmed for the sensor and antenna combinations to verify proper triggering at the specified triggering distances. The smallest separation distance determined by the sensor triggering and sensor coverage for normal and tilt positions in 6.2, 6.3 and 6.4 for back surface and edge triggering conditions, minus 1 mm, must be used as the *test separation distance* for SAR testing.

Due to varying operating characteristics of proximity sensor designs and substantially flexible interactive use conditions required by tablets, it must be verified that the transmitter does not resume to normal full power when the tablet is tilted with respect to an edge while maintaining the sensor triggering distance. These conditions must be verified for a range of tilt angles to determine if triggering distance should be further reduced to maintain triggering. When the following sensor triggering distances and antenna/sensor coverage procedures are insufficient or inapplicable for the specific device implementation, a KDB inquiry is required to determine the test requirements. In addition, the default power level for sensor failure and malfunctioning, including all compliance concerns, must be fully addressed in the SAR report for the proximity sensor implementation to be acceptable. Test setup photos, the required power measurement and triggering distance results for supporting sensor triggering, sensor coverage and sensor sensitivity (capacitance/mm at triggering distance) should be tabulated and illustrated in the SAR report.

6.2. Procedures for determining proximity sensor triggering distances

The following procedures should be applied to determine proximity sensor triggering distances for the back surface and individual edges of a tablet. Conducted power is monitored qualitatively to identify the general triggering characteristics and recorded quantitatively, versus spacing, as required by the procedures. Since longer RF cables may be required for the conducted power measurements, cable losses must be accounted for to determine output power. Unless there is built-in test software that reports the triggering conditions and enables the power levels to be confirmed separately, monitoring of conducted power during the triggering tests typically requires internal access to the antenna ports inside the tablet, which may interfere with the triggering tests; therefore, the test setup should be clearly described in the

²² The proximity sensor procedures in this document only apply to detection of objects in the vicinity of an antenna. The procedures cannot be applied directly to proximity sensors used for human movement detection.

²³ Alternatively, if it can be demonstrated that water can provide equivalent results, the sensor triggering and coverage tests may be performed with water provided it is fully justified in the SAR report with supporting data.

SAR report to support the results.

- a) The relevant transmitter should be set to operate at its normal maximum output power.
- b) The entire back surface or edge of the tablet is positioned below a flat phantom filled with the required tissue-equivalent medium, and positioned at least 20 mm further than the distance that triggers power reduction.²⁴
- c) It should be ensured that the cables required for power measurements are not interfering with the proximity sensor. Cable losses should be properly compensated to report the measured power results.²⁵
- d) The back surface or edge is moved toward the phantom in 3 mm steps until the sensor triggers.
- e) The back surface or edge is then moved back (further away) from the phantom by at least 5 mm or until maximum output power is returned to the normal maximum level.
- f) The back surface or edge is again moved toward the phantom, but in 1 mm steps, until it is at least 5 mm past the triggering point or touching the phantom. If 1 mm resolution is not suitable for the sensor triggering sensitivity, a KDB inquiry should be submitted to determine alternative test configurations.
- g) If the tablet is not touching the phantom, it is moved in 3 mm steps until it touches the phantom to confirm that the sensor remains triggered and the maximum power stays reduced.
- h) The process is then reversed by moving the tablet away from the phantom according to steps d) to g), to determine triggering release, until it is at least 10 mm beyond the point that triggers the return of normal maximum power.
- i) The measured output power within ± 5 mm of the triggering points, or until the tablet is touching the phantom, for movements to and from the phantom should be tabulated in the SAR report.
- j) If the sensor design and implementation allow additional variations for triggering distance tolerances, multiple samples should be tested to determine the most conservative distance required for SAR evaluation.
- k) To ensure all production units are compliant, it is generally necessary to reduce the triggering distance determined from the triggering tests by 1 mm, or more if it is necessary, and use the smallest distance for movements to and from the phantom, minus 1 mm, as the sensor triggering distance for determining the SAR measurement distance.

6.3. Procedures for determining antenna and proximity sensor coverage

Proximity sensors are not normally designed to cover the entire back surface or edges of a tablet. The sensing regions are usually limited to areas near the sensor element. If a sensor is spatially offset from the antenna(s), it is necessary to verify sensor triggering for conditions where the antenna is next to the user but the sensor is laterally further away to ensure sensor coverage is sufficient for reducing the power to maintain compliance. Except when the SAR test exclusion provisions of KDB Publication 447498 D01 are applied, or when SAR is tested at the normal full power for the tablet edges, if an antenna is located near the corner of a tablet, the adjacent edges within 50 mm from the corner antenna must be tested for sensor triggering coverage. Depending on how the antenna and sensor are overlapping, if the required procedures cannot be fully applied, a KDB inquiry must be submitted to determine sensor coverage test procedures. The following are used to determine if additional SAR measurements may be necessary due

²⁴ A single medium type may be used if it can be demonstrated that the different media have no influence to sensor triggering.

²⁵ A KDB inquiry is required for other power measurement methods to be acceptable.

to sensor and antenna offset.²⁶ These procedures do not apply and are not required for configurations where the antenna and sensor are collocated and the peak SAR location is overlapping with the sensor.

- a) The back surface or edge of the tablet is positioned at a test separation distance less than or equal to the distance required for back surface or edge triggering, with both the antenna and sensor pad located at least 20 mm laterally outside the edge (boundary) of the phantom, along the direction of maximum antenna and sensor offset. For the back surface, if the direction of maximum offset is not aligned with the tablet coordinates (physical edges) the tablet test position would not be aligned with the phantom coordinates (orientations). Each applicable tablet edge should be positioned perpendicularly to the phantom to determine sensor coverage. For antennas and/or sensors located near the corner of a tablet, both adjacent edges must be considered.
- b) The similar sequence of steps applied to determine sensor triggering distance in 6.2 are used to verify back surface and edge sensor coverage by moving the tablet (sensor and antenna) horizontally toward the phantom while maintaining the same vertical separation between the back surface or edge and the phantom.
- c) After the exact location where triggering of power reduction is determined, with respect to the sensor and antenna, the tablet movement should be continued, in 3 mm increments, until both the sensor and antenna(s) are fully under the phantom and at least 20 mm inside the phantom edge.
- d) The process is then repeated from the opposite direction, starting at the other end of the maximum antenna and sensor offset, by rotating the tablet 180° along the vertical axis.
- e) The triggering points should be documented graphically, with the antenna and sensor clearly identified, along with all relevant dimensions.
- f) If the subsequently measured peak SAR location for the antenna is not between the triggering points, established by the sensor coverage tests from opposite ends of the antenna and sensor, additional SAR tests may be required for conditions where only part of the back surface or edge of a tablet corresponding to the antenna is in proximity to the user and the sensor may not be triggering as desired. A KDB inquiry must be submitted by the test lab to determine if additional tests are required and the proper test configurations to use for testing. This may include situations where the sensor coverage region is too small for the antenna, the sensor is located too far away from the antenna, the sensor location is insufficient to cover multiple antennas or the antenna is at the corner of a tablet etc.

6.4. Procedures for determining tablet tilt angle influences to proximity sensor triggering

- a) The influence of table tilt angles to proximity sensor triggering is determined by positioning each tablet edge that contains a transmitting antenna, perpendicular to the flat phantom, at the smallest sensor triggering test distance determined in 6.2 and 6.3 by rotating the tablet around the edge next to the phantom in $\leq 10^\circ$ increments until the tablet is $\pm 45^\circ$ or more from the vertical position at 0° .
- b) If sensor triggering is released and normal maximum output power is restored within the $\pm 45^\circ$ range, the procedures in step a) should be repeated by reducing the tablet to phantom separation distance by 1 mm until the proximity sensor no longer releases triggering, and maximum output power remains in the reduced mode.
- c) The smallest separation distance determined in steps a) and b), minus 1 mm, is the sensor triggering distance for tablet tilt coverage. The smallest separation distance determined in 6.2, 6.3 and 6.4 for each triggering condition minus 1 mm should be used in the SAR measurements.

6.5. Modular transmitter manufacturer and host manufacturer responsibilities

²⁶ Depending on the antenna and sensor offset, if a test separation distance smaller than that determined by the triggering distance procedures can extend the coverage area to include the peak SAR location, a smaller test separation distance may be considered to avoid additional SAR tests.

When a transmitter requires a proximity sensor or other detection mechanisms to trigger power reduction and the *modular approach* is used, additional equipment approval requirements apply. The sensing mechanism is generally not an integral part of the transmitter module because power reduction triggering requirements are usually dependent on the individual tablet requirements; therefore, the compliance responsibilities fall on both the host or tablet manufacturer and the module grantee. Under such circumstances, the implementation, operation and control of sensor triggering to determine transmitter output power may not be fully controlled by the transmitter manufacturer (grantee). The preferred equipment approval approach is to have all transmitters authorized under a single FCC ID for the host tablet, to address the host-specific requirements. Alternatively, the change of ID (§ 2.933) procedure may be used to obtain a new FCC ID, which incorporates the modular transmitter in a specific tablet, with certain control functions residing outside the transmitter, and implemented by the tablet manufacturer according to the grantee's specifications. After the change of ID, a subsequent Class II permissive change (§ 2.1043) is required to incorporate the transmitter into the tablet, detailing the joint responsibility between the tablet host and transmitter manufacturers and all conditions of implementation, for ensuring compliance. The new FCC ID (from the §§ 2.933 and 2.1043 filings) is only applicable to the specific tablet host implementation and for the specific type of sensor and antenna configurations, which must be clearly identified in the subsequent permissive changes. Any inapplicable grant conditions inherited from the change of ID that could introduce conflicts should be omitted. A separate FCC ID is required for each tablet with different sensor and antenna configurations. This approach gets very complex for hosts using multiple suppliers for a modular transmitter resulting in multiple third-party relationships. In such cases using a unique FCC ID for the host or tablet should be considered. If that is not feasible, the parties should consult the FCC.

Change Notice

10/24/2012: This is a new revision of KDB Publication 616217

5/23/2013: Relevant comments for 04/05/2013 draft have been taken into consideration.

10/23/2015: 616217 D04 SAR for laptop and tablets v01r02 replaces 616217 D04 SAR for laptop and tablets v01r01. Update numbering format and cross-references to other KDB publications. Update per FCC-14-208 changes to FCC TCB program.