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Draft Laboratory Division Publications Report

Title: General RF Exposure Policies for Equipment Authorization

Short Title: General RF Exposure Guidance

Reason: Revision: Update of General RF Exposure Procedures

Publication: 447498

Keyword/Subject: Mobile and Portable Device, RF Exposure, Equipment Authorization Procedures, 1.1307, 2.1091, and 2.1093

First Category: Radio Frequency (RF) Exposure

Second Category: General RF Safety Questions

Third Category:

Question: What are the RF exposure requirements and procedures for mobile and portable devices?

Answer: Attachment below, 447498 D01 General RF Exposure Guidance v05, describes the general RF exposure evaluation requirements and certain test guidance for mobile and portable device equipment authorization.

447498 D01 General RF Exposure Guidance v05 replaces the previous attachment, 447498 D01 Mobile Portable RF Exposure v04 * see note (2) below.

Mobile and portable device RF exposure and equipment authorization requirements are in FCC rule Sections 1.1307, 2.1091, and 2.1093.

A Mobile Multi-transmitter MPE Estimation [XLS] MPE spreadsheet is available at: http://www.fcc.gov/oet/ea/presentations/files/oct05/MPE-mobile.xls for estimating MPE limits for multiple antennas.

*** Notes:**

1) This draft (447498 General RF Exposure Guidance DR02-41164, posted on 09/12/2012 that expires on 10/16/2012) is a revision of an earlier draft (447498 General RF Exposure Guidance DR01, posted 04/23/2012 which expired on 06/30/2012). Draft documents are only posted for comment and are not in effect.

(2) This draft is expected to take effect by October 2012 when it will be included in the Knowledge Data Base (KDB 447498) as an updated attachment [1] 447498 D01 Mobile Portable RF Exposure v05 along

with the current attachment [2]447498 D01 Mobile Portable RF Exposure v04 for a transition period until January 1, 2013. During the transition period either the updated attachment [1] or the current attachment [2] must be used in its entirety to demonstrate compliance. After January 1, 2013 only the updated attachment [1] can be used.

Attachment List:

447498 D01 General RF Exposure Guidance v05

9/12/2012

Attachment 447498 D01 General RF Exposure Guidance v05

Mobile and Portable Devices RF Exposure Procedures and Equipment Authorization Policies

1. Introduction

This document is one of a collection of guidance referred to as the *published RF exposure KDB procedures*.[1] The other procedures in the collection are:

- Product related KDB publications: Mobile and Portable Devices (KDB 447498), Handset & Accessories (KDB 648474), Laptop/Notebook/Netbook & Tablet (KDB 616217), USB Dongles (KDB 447498), UMPC Mini-Tablets (KDB 941225), Occupational PTT Two-Way Radios (KDB 643646)
- Wireless technology related KDB publications: 3GPP/3GPP2 Technologies (KDB 941225), 802.11 (KDB 248227), WiMax (KDB 615223), Wireless Routers (KDB 941225), Wireless Charging Applications (KDB 680106)
- Test methodology related KDB publications: SAR Measurement and Reporting Requirements (KDB 865664)
- Equipment approval policy related KDB publications: TCB Exclusion List (KDB 628591), Permit-But-Ask (PBA) Procedures (KDB 388624), Permissive Change Policies (KDB 178919), Modular Approval Policies (KDB 996369), SAR Numbers Listing KDB 690783), etc.

This guidance document serves as an entry point for the RF exposure guidance described in the other *published RF exposure KDB procedures*, and it describes the general RF exposure evaluation requirements and certain test guidance that may be applicable to all the other procedures. In general, the *published RF exposure KDB procedures* and other FCC policies should be applied to prepare devices for equipment authorization according to mobile and portable RF exposure requirements. Guidance in the most recent revision of the *published RF exposure KDB procedures*, TCB workshop updates and OET Bulletin 65 Supplement C, whichever is the latest at the time when device testing begins, must be applied. The guidance in this document and the *published RF exposure KDB procedures* must be applied for equipment to qualify for TCB approval. Devices that are on the TCB Exclusion List must be submitted directly to the FCC for approval according to the additional guidance included in this document. Also, any applicant seeking alternative procedures may apply directly for equipment authorization to the FCC for consideration.

When it is unclear, clarifications can be obtained from the FCC Laboratory by submitting inquiries to the KDB system. The FCC should also be contacted to determine if existing test guidance is sufficient for evaluating new and evolving products. In some cases when new test procedures are under development, interim test guidance is often provided through TCB workshop updates before final publication of the KDBs.

[1] Guidance for RF exposure evaluation is available from the FCC website through Knowledge Database Publications (KDB) at www.fcc.gov/labhelp. These are collectively referred to in this document as the *published RF exposure KDB procedures* that provide RF exposure test and evaluation support for specific products, wireless technologies, test methodologies and equipment approval policies.

2. General TCB Approval Requirements

An application approved by a TCB must meet all the requirements listed in the applicable *published RF exposure KDB procedures* and the equipment approval policy documents (see 1). Any application approved by a TCB for devices that are categorically excluded from routine RF exposure evaluation must also apply the *published RF exposure KDB procedures*. When the *published RF exposure KDB procedures* are not fully applied, prior approval from the FCC is generally required to qualify for TCB approval. All deviations from these requirements must be confirmed through KDB inquiries. For applicants who want to apply alternative procedures, seeking substantial deviation from the *published RF exposure KDB procedures* or for devices that require substantial FCC involvement to complete the review and approval process, the equipment is subject to FCC approval only. These are determined during the KDB inquiry process when test requirements are considered and are typically applicable to new technologies and emerging products or devices that require substantial test and approval considerations.

3. General RF Exposure Policies for Equipment Authorization

1) The RF exposure requirements for devices operating in mobile and portable exposure conditions are different. When both exposure conditions apply to a device, compliance is determined according to the rules and policies established for both exposure conditions. Equipment authorization for devices that are categorically excluded from routine RF exposure evaluation according to §2.1091(c) and §2.1093(c), when filed directly with the FCC, are generally not required to include RF exposure test results to demonstrate compliance. In some cases, the FCC may require RF exposure testing to be performed with respect to the conditions stated in §1.1307(c) and (d).
2) Standalone and simultaneous transmission use conditions for mobile and portable exposure conditions must be determined according to the host platform and product operating configuration requirements. Transmitters approved only for use in standalone operations cannot be used in simultaneous transmission operations without further evaluation; this may be through test exclusion provisions or specific equipment approval. Except for transmitters that cannot operate in standalone configurations, when SAR measurement is required for simultaneous transmission conditions approval for standalone use is required for each individual transmitter. For devices that do not support standalone transmission, there is no measured or estimated standalone SAR result to determine simultaneous transmission SAR test exclusion. The enhanced zoom scan measurement and volume scan post-processing procedures in KDB 865664 are required to determine SAR compliance. When transmitters are approved for use in dedicated host or product configurations, according to the specific standalone and simultaneous transmission conditions tested for compliance, additional approvals are normally required for the transmitters to be used in other host and product configurations.
3) Transmitter modules must be approved according to one of the following host platform exposure conditions, with respect to the product configurations tested or evaluated for equipment approval for incorporation in qualified host products. The approved host platform exposure condition(s) must be identified on the grant of equipment certification. When transmitter modules are incorporated in host devices that qualify for RF exposure test exclusion and no other testing or equipment approval is required, the standalone and simultaneous transmission configurations and test exclusion conditions must be fully documented in the grantee's records according to Class I permissive change requirements.
    a) *Mobile exposure host* platform evaluation procedures can only be applied if all transmitters in the host devices support mobile exposure conditions. Transmitters and modules approved only for use in the *mobile exposure host* platform cannot operate in hosts and product configurations that require standalone or simultaneous transmission operations in portable exposure conditions. The

portable exposure host platform or the *mixed mobile and portable exposure* platform is required to support portable exposure conditions in qualified host configurations.

b) *Portable exposure host* platform evaluation procedures can only be applied if all transmitters in the host devices support portable exposure conditions. Transmitters and modules approved for use in the *portable exposure host* platform may be used for standalone operations in *mobile exposure host* platforms, without further equipment approval, only when the same identical transmitter and antenna required for portable exposure conditions are used.[2]

c) A *mixed mobile and portable exposure host* platform enables host devices to incorporate transmitters in qualified mobile and portable exposure conditions, for standalone and simultaneous transmission operations, by applying the *published RF exposure KDB procedures* required for the host product to address RF exposure compliance. Transmitters and modules approved for use in a *mixed mobile and portable exposure host* platform may be used for standalone and simultaneous transmission operations in mobile and/or portable exposure conditions according to the approved operating configurations and exposure conditions in qualified host configurations supported by the test results and exclusion conditions. When the mobile exposure simultaneous transmission test exclusion applies (see 7.2), a transmitter or module approved for use in the *portable exposure host* platform may be used for simultaneous transmission operations in the *mixed mobile and portable exposure host* platform according to Class I permissive change requirements without further equipment approval. When tests are required to support additional antenna or host configurations, the results must be sufficiently conservative to demonstrate compliance for all standalone and simultaneous transmission operations required by the hosts and product configurations.

4) Transmitters operating in consumer products must satisfy the general population exposure limits required for either the mobile or portable RF exposure conditions as appropriate. The test configurations used to qualify for test exclusion or used for compliance testing must be sufficiently conservative for all required operations to demonstrate compliance. The devices and accessories should be tested for normal use without requiring specific user intervention to maintain compliance. All device operating instructions and installation requirements must be supported by the test configurations and results. It is unacceptable to apply instructions as a substitute for providing test data. Caution statements or warning labels are only acceptable for alerting users to avoid exposures in certain unintended use conditions that are not required for normal operations.

5) Occupational exposure limits only apply to "*work-related*" use conditions. Users must be "*fully aware of*" and be able to "*exercise control over*" their exposure to qualify for the higher occupational exposure limits. Occupational exposure limits do not apply to consumer devices and radio services supporting public networks and Part 15 unlicensed operations. When devices are authorized in accordance with the general population exposure limits, additional equipment approval is not required to satisfy occupational exposure requirements. Mandatory RF exposure training is required for workers to qualify for occupational exposure limits. When it can be demonstrated that users are required to adhere to the training instructions and are able to mitigate compliance concerns by applying the instructions, detailed training instructions incorporated in manuals, in conjunction with conspicuous permanent labeling on the device, may be considered as acceptable training for workers to qualify a device for using for occupational exposure limits. The training information must be included in the equipment authorization application.

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[2] Any transmitter or antenna changes required to support *mobile exposure host* platform use configurations must also satisfy *portable exposure host* platform requirements and addressed accordingly through Class II permissive changes. Alternatively, the *mixed mobile and portable exposure host* platform should be applied.

6) As required by §§ 2.1033(b)(3) and 2.1033(c)(3), users and installers shall be furnished with the required operating and installation instructions. These are reviewed for acceptance during equipment approval. The applicable instructions must be provided to installers, integrators and end users to ensure proper installation and operation for meeting compliance.
   a) The instructions required for standalone products and modular transmitters are generally different due to varying host configurations; therefore, these must be considered differently to ensure RF exposure compliance for both standalone and simultaneous transmission operations. User instructions must be sufficient for the typical consumers, who are generally unskilled, to install and operate the equipment to ensure RF exposure compliance. The acceptable host platform configurations and exposure conditions approved for a modular transmitter, including any restrictions, must be fully described in the equipment approval and required OEM integration instructions.
   b) When professional installation, OEM integration or assembly by a third-party is expected, the installation instructions and assembly requirements approved for equipment approval must be provided to the integrators to clearly identify the specific requirements necessary to maintain RF exposure compliance. The grantee of a transmitter, typically the manufacturer, is responsible for ensuring installers and integrators have a clear understanding of the compliance requirements by including the required instructions and documentation with the product and, if necessary, to provide further support to fulfill grantee responsibilities for ensuring compliance. The integrators must be fully informed of their obligations and verify the resolution of any issues and concerns with each transmitter manufacturer or grantee. For transmitter modules, the different disclosures required for the entire supply chain to ensure compliance, including grantees of individual transmitters, host manufacturers and OEM/ODM integrators, and the end users, must be fully documented during equipment approval.[3]

4. General RF Exposure Test Guidance

4.1. General test requirements

1) The general test methodologies of Supplement C 01-01 to OET Bulletin 65 and IEEE Std 1528-2003 should be applied in conjunction with the *published RF exposure KDB procedures* to perform SAR measurements.[4]
2) As required by §2.1091(d)(2) and §2.1093(d)(5), RF exposure compliance must be determined at the maximum average power level, according to source-based time-averaging requirements, to determine compliance for general population exposure conditions. Unless it is specified differently in the *published RF exposure KDB procedures*, these requirements also apply to test reduction and test exclusion considerations. Time-averaged maximum conducted output power applies to SAR and, as required by §§ 2.1091(c), time-averaged ERP applies to MPE.
3) Device test samples must have the same physical, mechanical and thermal characteristics and operational tolerances expected for production units to ensure compliance. These factors often interact with each other and cannot be dealt with separately; therefore, they are considered

[3] User manuals, product integration or installation instructions and general disclosure conditions normally do not qualify for confidentiality. The rules of confidentiality typically apply to product design details that are considered as trade secrets. When applicable, such information may be included separately in the equipment approval and must be properly referenced in the non-confidential documents.

[4] While the fundamental SAR measurement concepts described in Supplement C and IEEE Std 1528 are applicable, additional test requirements in the *published RF exposure KDB procedures* must be applied to test recent generation products and wireless technologies.

collectively through testing representative device samples. Each device must be evaluated in the required operating modes and test configurations; at the maximum rated output power and within the tune-up tolerance range specified for the product, but not more than 2 dB lower than the maximum tune-up tolerance limit.[5] When tune-up tolerance is not required to be reported for equipment approval, RF exposure compliance must be determined with equivalent criteria according to the highest maximum output power allowed for production units.

4) When SAR or MPE is not measured at the maximum power level allowed for production units, the results must be scaled to the maximum tune-up tolerance limit according to the power applied to the individual channels tested to determine compliance. For simultaneous transmission, the measured aggregate SAR or MPE must be scaled according to the sum of the differences between the maximum tune-up tolerance and actual power used to test each transmitter. When SAR or MPE is measured at or scaled to the maximum tune-up tolerance limit, the results are referred to as ***reported***. At least, the highest ***reported*** results in each frequency band and all ***reported*** SAR or MPE results > 1.5 W/kg or within 5% of the applicable MPE limits, respectively, must be clearly documented in the test reports.[6] The highest ***reported*** SAR results are identified on the grant of equipment authorization according to procedures in KDB 690783.

5) The *test separation distances* required for a device to demonstrate SAR or MPE compliance must be sufficiently conservative to support the *operational separation distances* required by the device and its antennas and radiating structures. When the device itself is a radiating structure, such as cellphones and mini-UMPC devices, or when the antenna is at close proximity to users, such as those incorporated in tablets and keyboard sections of laptop computers, the *test separation distance* is determined by the smallest distance between the outer surface of the device and the user. For larger devices, as the antenna *operational separation distance* increases to where the SAR characteristics of the device and its antennas are not directly influenced by the user, such as antennas along the top or side edges of laptop computer displays, the *test separation distance* is normally determined by the closest separation between the antenna and the user. These general criteria should be applied to determine the *test separation distances* required for SAR test reduction, exclusion and measurements.

6) When the frequency channels required for SAR testing are not specified in the *published RF exposure KDB procedures*, the following should be applied to determine the number of required test channels. The test channels should be evenly spread across the transmission frequency band of each wireless mode.[7]

$$N_c = Round\left\{\left[100\left(f_{high} - f_{low}\right)/f_c\right]^{0.5} \times \left(f_c/100\right)^{0.2}\right\}, \text{ where}$$

- N_c is the number of test channels, rounded to the nearest integer;
- f_{high} and f_{low} are the highest and lowest channel frequencies within the transmission band,
- f_c is the mid-band channel frequency,
- all frequencies are in MHz.

7) Depending on the operating frequency and required antenna *test separation distance*, antenna gain usually does not apply to portable exposure conditions. Near-field exposure conditions can be highly

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[5] The range of expected maximum output power variations from the rated nominal maximum output power specified for the product or wireless mode is referred to as the tune-up tolerance in this document. All devices must be tested within the maximum tune-up tolerance range.

[6] When different tune-up tolerances are specified for different wireless modes and operating configurations, compliance must be determined separately according to the highest scaled results for each condition in each frequency band.

[7] Any further reduction in test channels must be confirmed through KDB inquiries to qualify for TCB approval.

dependent on the RF current distribution characteristics of individual transmitters, antennas and host device configurations that are not directly related to the far-field antenna gain. It would be inappropriate to assume that lower gain antennas always produce lower SAR or that testing is not required; except when it is specified in the *published RF exposure KDB procedures* for certain very low SAR conditions. When similar antennas are used, unless only if it can be demonstrated that the physical, mechanical, RF performance, SAR and radiating characteristics are the same, within acceptable tolerances, and the highest *reported* SAR for the original antenna is < 0.8 W/kg, then additional antennas must be considered separately to determine SAR compliance.[8]

8) The measurement setup used for SAR or MPE evaluation must not perturb the antennas and radiating structures of the test device or influence it in manners that are inconsistent with the required test protocols; for example, field perturbations due to apparatuses used to secure test devices that are physically very small, such as USB dongles, thin edges of devices or field scattering from nearby objects.[9] When necessary, a device should be secured with lossless foam material to provide ≥ 2.5 cm separation from the holding apparatuses to minimize potential perturbations. Scattering objects that may influence test results should be relocated or repositioned.[10]

4.2. SAR test requirements for typical exposure conditions

4.2.1. Head exposure conditions

Devices that are designed to transmit next to the ear and operate according to the handset procedures in IEEE Std 1528-2003 and OET Bulletin 65 Supplement C 01-01, or conditions described in the *published RF exposure KDB procedures* must be tested using the SAM phantom defined in IEEE Std 1528-2003. When antennas are near the bottom of a handset and the peak SAR location is located in regions of the SAM phantom where SAR probe access can be limited, the procedures in KDB 648474 must be applied. Other head exposure conditions; for example, in front of the face, should be tested using a flat phantom according to the required *published RF exposure KDB procedures*.

4.2.2. Body-worn accessory exposure conditions

1) Devices that support transmission while used with body-worn accessories must be tested for body-worn accessory SAR compliance. SAR evaluation is required for body-worn accessories supplied with the host device. The body-worn accessory test configurations must be conservative for supporting the actual use conditions expected by users. Body-worn accessories that do not contain metallic or conductive components may be tested according to worst-case exposure configurations, typically according to the smallest *test separation distance* required for the group of body-worn accessories with similar operating and exposure characteristics. All body-worn accessories containing metallic components, either supplied with the product or available as an option from the device manufacturer, must be tested in conjunction with the host device to demonstrate compliance.

2) Body-worn accessory SAR compliance must be based on a single minimum *test separation distance* for all wireless and operating modes applicable to each body-worn accessory used by the host, and according to the relevant voice and/or data mode transmissions and operations. If a body-worn

[8] A KDB inquiry with the necessary (preliminary) results and SAR distributions is required to determine if additional SAR test reduction may be considered for similar antennas.

[9] Influences of the hand holding a handset on the measured head SAR are under investigation in on-going SAR measurement standards committee projects, which could lead to different test device holding apparatus requirements for handset testing in the future.

[10] The multi-meter mode available in some SAR systems may be used to quickly determine if influences due to test device positioning, field perturbations or external objects are introducing noticeable SAR variations.

accessory supports voice only operations in its normal and expected use conditions (for example, belt-clips and holsters for cellphones), testing of data mode for body-worn compliance is not required.[11] The voice and data transmission requirements must be determined according to the wireless technologies and operating characteristics of an individual device, and must be clearly explained in test reports to support the SAR results.

3) A conservative minimum *test separation distance* for supporting off-the-shelf body-worn accessories that may be acquired by users of consumer handsets should be used to test for body-worn accessory SAR compliance. This distance is determined by the handset manufacturer, according to the requirements of Supplement C 01-01 and typical body-worn accessories that users may acquire at the time of equipment certification, to enable users to purchase aftermarket body-worn accessories with the required minimum separation. The selected *test separation distance* must be clearly explained in the SAR report to support the body-worn accessory test configurations. Devices that are designed to operate on the body of users using other accessories, such as lanyards and straps, or without requiring additional body-worn accessories, must be tested for SAR compliance using a conservative minimum *test separation distance* ≤ 5 mm to support compliance.

4) Specific information must be included in the operating manuals to enable users to select body-worn accessories that meet the minimum *test separation distance* requirements. Users must be fully informed of the operating requirements and restrictions, to the extent that the typical user can easily understand the information, to acquire the required body-worn accessories to maintain compliance. Instructions on how to place and orient a device in body-worn accessories, in accordance with the test results, should also be included in the user instructions. All supported body-worn accessory operating configurations must be clearly disclosed to users through conspicuous instructions in the user guide and user manual to ensure unsupported operations are avoided. All body-worn accessories containing metallic components must be tested for compliance and clearly identified in the operating manual. The instruction must inform users to avoid using other body-worn accessories containing metallic components to ensure RF exposure compliance.

4.2.3. Extremity exposure conditions

Devices that are designed or intended for use on extremities or mainly operated in extremity only exposure conditions; i.e., hands, wrists, feet and ankles, may require extremity SAR evaluation.[12] When the device also operates in close proximity to the user's body, SAR compliance for the body is also required. The 1-g body and 10-g extremity *SAR Exclusion Thresholds* (see 4.3) should be applied to determine SAR test requirements. When extremity SAR testing is required, a flat phantom must be used if the exposure condition is more conservative than the actual use conditions; otherwise, a KDB inquiry is required to determine the phantom and test requirements. Body SAR compliance is also tested with a flat phantom. For devices with irregular shapes or form factors that do not conform to a flat phantom, and/or unusual operating configurations and exposure conditions, a KDB inquiry is also required to determine the appropriate SAR measurement procedures.

4.2.4. Transmitters implanted in the body of a user

When the aggregate of the maximum power available at the antenna port and radiating structures of an implanted transmitter, under all operating circumstances, is ≤ 1.0 mW, SAR test exclusion may be applied. The maximum available output power requirement and worst case operating conditions must be

[11] For example, when DTM is not applicable, GPRS and EDGE may not require body-worn accessory SAR testing.

[12] Cellphones (handsets) are not normally designed to be used on extremities or operated in extremity only exposure conditions. The maximum output power levels of cellphones generally do not require extremity SAR testing to show compliance.

supported by power measurement results and fully justified in a SAR analysis report, in lieu of the SAR evaluation, according to design and implementation requirements of the device.

4.3. General SAR test reduction and exclusion guidance

4.3.1. Standalone SAR test exclusion considerations

Unless specifically required by the *published RF exposure KDB procedures*, standalone 1-g head or body and 10-g extremity SAR evaluation by measurement or numerical simulation is not required when the corresponding *SAR Exclusion Threshold* condition, listed below, is satisfied. These test exclusion conditions are based on source-based time-averaged maximum conducted output power of the RF channel requiring evaluation, adjusted for tune-up tolerance, and the minimum *test separation distance* required for the exposure conditions. When required, the conditions of other *published RF exposure KDB procedures* must also be applied in conjunction with the SAR test exclusion provisions; for example, handheld PTT two-way radios, handsets, laptops & tablets etc.

1) The 1-g and 10-g SAR test exclusion thresholds for 100 MHz to 6 GHz at *test separation distances* ≤ 50 mm are determined by:

   [(*max. power of channel, including tune-up tolerance, mW*)/(*min. test separation distance, mm*)] · [$\sqrt{f_{(GHz)}}$] ≤ 3.0 for 1-g SAR and ≤ 7.5 for 10-g extremity SAR,[13] where

   - $f_{(GHz)}$ is the RF channel transmit frequency in GHz
   - Power and distance are rounded to the nearest mW and mm before calculation[14]
   - The result is rounded to one decimal place for comparison

   The test exclusions are applicable only when the minimum *test separation distance* is ≤ 50 mm and for transmission frequencies between 100 MHz and 6 GHz. When the minimum *test separation distance* is < 5 mm, a distance of 5 mm is applied to determine SAR test exclusion. The minimum *test separation distance* is determined by the smallest distance from the antenna and radiating structures or outer surface of the device, according to the host form factor, exposure conditions and platform requirements, to any part of the body or extremity of a user or bystander (see 4.1). To qualify for SAR test exclusion, the *test separation distances* applied must be fully explained and justified by the operating configurations and exposure conditions of the transmitter and applicable host platform requirements, typically in the SAR measurement or SAR analysis report, according to the required *published RF exposure KDB procedures*. When no other RF exposure testing or reporting is required, a statement of justification and compliance must be included in the equipment approval, in lieu of the SAR report, to qualify for the SAR test exclusion.

2) At 100 MHz to 6 GHz and for *test separation distances* > 50 mm, the SAR test exclusion threshold is determined according to the following, and as illustrated in Appendix B:[15]

   - [Threshold at 50 mm in step 1) + (test separation distance - 50 mm)·($f_{(MHz)}$/15)] mW, at 100 MHz to 1500 MHz

[13] This is equivalent to [(*max. power of channel, including tune-up tolerance, mW*)/(60/$\sqrt{f_{(GHz)}}$ mW)]·[20 mm/(*min. test separation distance, mm*)] ≤ 1.0 for 1-g SAR; also see Appendix A for approximate exclusion threshold values at selected frequencies and distances.

[14] Unless stated otherwise, the same rounding requirements should be applied to all similar equations in this document.

[15] These are interim SAR test exclusion provisions. More extensive considerations are necessary to address threshold discontinuity issues related to transitioning from SAR to MPE limits at intermediate distances and different frequencies.

- [Threshold at 50 mm in step 1) + (test separation distance - 50 mm)·100] mW at > 1500 MHz and ≤ 6 GHz

3) At frequencies below 100 MHz, the following may be considered for SAR test exclusion, and as illustrated in Appendix C:[16]
   - The threshold at the corresponding test separation distance at 100 MHz in step 1) is multiplied by [1 + log(100/$f_{(MHz)}$)] for *test separation distances* > 50 mm and < 200 mm
   - The threshold at 50 mm and 100 MHz in step 1) is multiplied by ½ for *test separation distances* ≤ 50 mm
   - SAR measurement procedures are not established below 100 MHz. When SAR test exclusion cannot be applied, a KDB inquiry is required to determine SAR evaluation requirements for any test results to be acceptable.

4.3.2. Simultaneous transmission SAR test exclusion considerations

Simultaneous transmission SAR test exclusion is determined for each operating configuration and exposure condition according to the *reported* standalone SAR of each applicable simultaneous transmitting antenna. When the sum of 1-g or 10-g SAR of all simultaneously transmitting antennas in an operating mode and exposure condition combination is within the SAR limit, SAR test exclusion applies to that simultaneous transmission configuration. When the sum is greater than the SAR limit, the SAR to peak location separation ratio procedures described below may be applied to determine if simultaneous transmission SAR test exclusion applies. The maximum output power, duty factor and other applicable parameters used in the standalone SAR tests must be the same or more conservative than those required for simultaneous transmission for the test exclusion to apply. When the maximum output power used for standalone operations is reduced in an operating mode or exposure condition during simultaneous transmission, often due to SAR or other implementation requirements, the standalone SAR tested at the higher output power may be applied to determine simultaneous transmission SAR test exclusion. Alternatively, additional standalone SAR at the reduced maximum output power required for simultaneous transmission may be performed to determine simultaneous transmission SAR test exclusion according to the sum of 1-g SAR or SAR to peak location separation ratio procedures. The power level of the standalone SAR used to qualify for SAR test exclusion must be clearly explained in the SAR report. When simultaneous transmission SAR test exclusion does not apply, enlarged zoom scan measurements must be performed at the maximum output power required in the power reduction modes for simultaneous transmission, within the tune-up tolerance requirements of all transmitters, to apply the volume scan post-processing procedures.[17]

1) The transmitters and antennas in a device are typically not designed to transmit simultaneously and concurrently across multiple exposure conditions, such as head, body-worn accessories and other next to the body use conditions. The wireless modes and frequency bands required for simultaneous transmission may also vary for the different exposure conditions. In addition, some exposure conditions may require multiple test positions; such as touch and tilt on the left and right side of the head or different edges of tablets and phones. As a result, these conditions require simultaneous transmission to be evaluated according to the combinations of wireless modes and frequency bands configured to transmit simultaneously in each applicable exposure condition. In some cases, the different test positions in an exposure condition may be considered collectively to determine SAR test exclusion according to the sum of 1-g or 10-g SAR; for example, if the sum of the highest *reported* SAR of each antenna for the touch and tilt positions on both sides of the head does not exceed the

[16] See footnote 15.

[17] Within the tune-up tolerance but not more than 2 dB lower than the maximum tune-up tolerance limit.

limit. When the sum of SAR considered in this manner does not qualify for test exclusion, the individual test positions of each exposure condition should be considered separately for the sum of 1-g or 10-g SAR test exclusion. For each simultaneous transmission configuration that does not satisfy the sum of SAR test exclusion, SAR to peak location separation ratio should be evaluated to qualify for SAR test exclusion. In all cases, the *reported* standalone SAR should be applied to determine simultaneous transmission SAR test exclusion.

2) When standalone SAR test exclusion applies to an antenna that transmits simultaneously with other antennas, the standalone SAR must be estimated according to following to determine simultaneous transmission SAR test exclusion:

- (*max. power of channel, including tune-up tolerance, mW*)/(*min. test separation distance, mm*)]·[$\sqrt{f_{(GHz)}}/x$] W/kg for *test separation distances* ≤ 50 mm;

  where x = 7.5 for 1-g SAR, and x = 18.75 for 10-g SAR.

- 0.4 W/kg for 1-g SAR and 1.0 W/kg for 10-g SAR, when the *test separation distances* is > 50 mm.[18]

This SAR estimation formula has been considered, in conjunction with the *SAR Exclusion Thresholds*, to result in substantially conservative SAR values of ≤ 0.4 W/kg. When SAR is estimated, the peak SAR location is assumed to be at the feed-point or geometric center of the antenna, whichever provides a smaller *test separation distance*, and must be clearly identified in test reports. The estimated SAR is used only to determine simultaneous transmission SAR test exclusion, and it should not be reported as the standalone SAR. When SAR to peak location separation ratio test exclusion is applied, the highest reported SAR for simultaneous transmission can be based on an estimated standalone SAR. For conditions where the estimated SAR is overly conservative for certain conditions, the test lab may choose to perform standalone SAR measurements then use the measured SAR to determine simultaneous transmission SAR test exclusion. The estimated SAR values at selected frequencies, distances and power levels are illustrated in Appendix D.

3) When the sum of SAR is larger than the limit, SAR test exclusion is determined by the SAR to peak location separation ratio. The simultaneous transmitting antennas in each operating mode and exposure condition combination must be considered one pair at a time to determine the SAR to peak location separation ratio to qualify for test exclusion. The ratio is determined by $(SAR_1 + SAR_2)^{1.5}/R_i$, rounded to two decimal digits, and must be ≤ 0.04 for all antenna pairs in the configuration to qualify for SAR test exclusion. SAR_1 and SAR_2 are the highest *reported* or estimated SAR for each antenna in the pair, and R_i is the separation distance between the peak SAR locations for the antenna pair. The antennas in all antenna pairs that do not qualify for simultaneous transmission SAR test exclusion must be tested for SAR compliance according to the enlarged zoom scan and volume scan post-processing procedures in KDB 865664.

4) When standalone SAR is measured, the peak location is determined by the x, y and z coordinates of the extrapolated and interpolated results reported by the zoom scan measurement. The origin of the coordinates for data points reported by SAR systems for the SAM phantom are typically located at the ear reference point (ERP), on the inside surface of the phantom. This is also referred to as the measurement grid reference point by some systems. When SAR is measured for both antennas in the pair, the peak location separation distance is computed by the square root of $[(x_1-x_2)^2 + (y_1-y_2)^2 + (z_1-z_2)^2]$, where (x_1, y_1, z_1) and (x_2, y_2, z_2) are the coordinates of the extrapolated peak SAR locations in the zoom scans. Unless the SAR system has no provisions to compute this automatically, the peak separation distance should not be determined manually to avoid unintended errors.[19] When

[18] Until appropriate estimation criteria can be determined, a conservative estimate of 0.4 W/kg is applied.

[19] DASY 52.8.2 (961) release computes this automatically.

standalone test exclusion applies, SAR is estimated and the peak location is assumed to be at the feed-point or geometric center of the antenna. Due to curvatures on the SAM phantom, when SAR is estimated for one of the antennas in an antenna pair, the measured peak SAR location should be translated onto the test device to determine the peak location separation for the antenna pair. The ERP location on the phantom is aligned with the ERP location on the handset, with 6 mm separation in the z coordinate due to the ear spacer. A measured peak location can be translated onto the handset, with respect to the ERP location, by ignoring the 6 mm offset in the z coordinate. The assumed peak location of the antenna with estimated SAR can also be determined with respect to the ERP location on the handset. The peak location separation distance is estimated by the x and y coordinates of the peaks, referenced to the ERP location. While flat phantoms are not expected to have these issues, the same peak translation approach should be applied to determine peak location separation. When SAR is estimated for both antennas, the peak location separation should be determined by the closest physical separation of the antennas, according to the feed-point or geometric center of the antennas, whichever is more conservative. The coordinates of the peaks, whether measured or translated, should be clearly identified in the SAR report. When necessary, plots or illustrations should be included to support the distance applied to qualify for SAR test exclusion.

4.3.3. SAR test reduction considerations

SAR test reduction procedures may be applied for similar operating modes of individual wireless technologies based on time-averaged power levels; for example, due to different time slots in TDMA systems. SAR test reduction procedures cannot be applied based on operating power alone across different wireless operating modes, exposure conditions or product implementations. Variations in implementation, design and operating requirements across operating modes and implementations can result in different SAR distributions and RF exposure characteristics. The applicable SAR test reduction provisions are described separately in the product and technology specific *published RF exposure KDB procedures*.

Testing of other required channels within the operating mode of a frequency band is not required when the *reported* 1-g or 10-g SAR for the mid-band or highest output power channel is:[20]

- ≤ 0.8 W/kg or 2.0 W/kg, for 1-g or 10-g respectively, when the transmission band is ≤ 100 MHz
- ≤ 0.6 W/kg or 1.5 W/kg, for 1-g or 10-g respectively, when the transmission band is between 100 MHz and 200 MHz
- ≤ 0.4 W/kg or 1.0 W/kg, for 1-g or 10-g respectively, when the transmission band is ≥ 200 MHz

4.3.4. Area scan based 1-g SAR estimation

Some SAR systems have the provision to estimate 1-g SAR based on the interpolated results of a normally required area scan. When the implementation is based the specific polynomial fit algorithm as presented at the 29th Bioelectromagnetics Society meeting (2007)[21] and the *estimated 1-g SAR* is ≤ 1.2 W/kg, a zoom scan measurement is not required provided it is also not needed for any other purpose; for

[20] Supplement C 01-01 and IEEE Std 1528-2003 require the middle channel to be tested first. This generally applies to wireless devices that are designed to operate in technologies with tight tolerances for maximum output power variations across channels in the band. When the maximum output power variation across the required test channels is > ½ dB, instead of the middle channel, the highest output power channel must be used.

[21] Douglas, M.G., Chou, C-K., "Accurate and Fast Estimation of Volumetric SAR from Planner Scans from 30 MHz to 6 GHz," *Bioelectromagnetics Society 29th Annual Meeting*, June 2007. This is referred to as the "*estimated 1-g SAR*" for the rest of this document.

example, if the peak SAR location required for simultaneous transmission SAR test exclusion can be determined accurately by the SAR system from area scans. For occupational exposure, when allowed by the *published RF exposure KDB procedures,* the *estimated 1-g SAR* should be ≤ 6.0 W/kg to avoid zoom scan measurements. This test reduction provision can only be applied to SAR measurements where the peak SAR location(s) is distinctly identified, and all SAR levels at 1 cm surrounding the peak are ≥ 40% of the peak value.[22] There must not be any warning or alert messages due to various measurement concerns identified by the SAR system; for example, noise in measurements, peaks too close to scan boundary, peaks are too sharp, spatial resolution and uncertainty issues etc. The SAR system verification must also demonstrate that the area scan estimated 1-g SAR is within 3% of the zoom scan 1-g SAR.[23] When all the SAR results for a frequency band and wireless mode are based on *estimated 1-g SAR*, the 1-g SAR for the highest SAR configuration must be determined by a zoom scan. When supported by the SAR system, the 1-g SAR estimation procedures may be adapted for 10-g SAR measurements.

4.4. SAR evaluation using numerical simulation

SAR simulations based on the FDTD method may be used to demonstrate compliance. When other numerical computation methods are used, in accordance with specific FCC provisions, the equivalent considerations as required for the FDTD method must be applied.[24] The most recent draft IEEE P1528.1 and draft IEC 62704-1 standards must be used to perform the SAR simulation and numerical code validation.[25] Any difference in the numerical codes and algorithms, including the gram-averaging requirements, used in the SAR simulations and those required by the IEEE and IEC drafts must be fully explained in the SAR report. The differences must be demonstrated to be insignificant to ensure that the simulated results are acceptable for demonstrating compliance. While there is no restriction for the types of devices and exposure conditions to apply numerical simulations to demonstrate SAR compliance, there could be difficulties in applying numerical simulation to complex devices and exposure configurations. It may be necessary to discuss with the FCC to determine the appropriate parameters and modeling approaches required to simulate specific devices and anatomical models. The tissue dielectric parameters on the FCC/OET website should be applied to heterogeneous anatomical human models.[26] The head and body tissue dielectric parameters required for SAR measurements should be applied to homogeneous models. Due to certain simplified assumptions required to model complex transmitters, devices and anatomically-equivalent human models, and also due to the limitations associated with various modeling constraints required for SAR simulation, it is necessary to confirm the validity of transmitter and human models against field strength and/or SAR measurement results in selected SAR test configurations. The details of a transmitter model used in the simulation and its validity must be fully justified and explained in the SAR report. When applicable, comparisons of simulated and measured return loss and field strength results in free-space conditions may also be required. A detailed test report is required, similar to that required for SAR measurements and in accordance with the FDTD reporting guidelines in Supplement C 01-01.

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[22] The 1 cm margin and 40% can be approximate, provided it can be ensured that the field gradient surrounding the peak is not an issue for the algorithm to accurately estimate the 1-g SAR. When it is unclear if the algorithm is suitable for certain sharp peaks, zoom scan should be performed.

[23] The area scan based 1-g SAR estimation does not apply to SAR system verification.

[24] For example, see ET Docket No. 10-166, DA 11-192.

[25] Draft IEC 62704-1 and draft IEEE P1528.1 are joint projects; draft IEC 62704-1 is expected to replace draft IEEE P1528.1.

[26] http://transition.fcc.gov/oet/rfsafety/dielectric.html.

5. RF Exposure Guidance for Modules and Peripheral Transmitters

5.1. RF exposure equipment approval considerations

Modules and peripheral transmitters are approved for either standalone operations only, or for standalone and simultaneous transmission with other transmitters in a host.[27] The transmitters and antennas operating in a host device must remain compliant for the standalone and simultaneous transmission operations required by all host configurations. Whether additional equipment approval is required for separately approved transmitters installed in a host device or a previously approved host with integral transmitter generally depends on influences introduced by the newly added transmitter(s) to the existing transmitters, with respect to the host device form factor, transmitter/antenna configurations and exposure conditions etc. Preliminary assessment is normally required to determine if Class I or Class II permissive change requirements apply. For example; adding a modular transmitter with its antenna in the display of a laptop computer may have little or no impact to the existing transmitters when antennas are installed sufficiently far apart from each other in the host device. However, if the same transmitter module is incorporated in a mini-tablet or handset a reevaluation of the transmitters in the host is typically necessary. The same considerations also apply when adding or substituting equivalent antennas, such as the of same type and gain, for a modular transmitter.

Transmitters for installation in certain host devices that raise RF energy coupling concerns due to close proximity of the transmitters and antennas in the host device and to the users, such as cellphones cannot be approved as modules. The correct and practical approach is to test the host with all transmitters incorporated in it; therefore, certain complex influences among transmitters can be taken into consideration in the normally required SAR measurements and are inherently accounted for by the process. Similarly, when high SAR is expected due to close proximity between antennas and users, transmitters may not be approved as modules because of difficulties to ensure compliance for all host configurations that may not be easily assessed in advance.

When subsequent equipment approval is required for modules to support additional host and antenna configurations, compliance of individual transmitters may be addressed through Class II permissive changes submitted by the grantee of a corresponding transmitter to enable it to be incorporated in qualified host devices.[28] Compliance of all transmitters in a host device can be addressed through a new equipment approval filing submitted by the host device manufacturer, where all transmitters are approved under a new host FCC ID. Alternatively, the manufacturer of the host device, or the transmitter with the highest maximum output power, or the most recently added transmitter that triggers the additional approval requirements, may choose to apply for a change of FCC ID for the transmitter modules that require additional approval, and address all subsequent approval issues under its direct responsibility through Class II permissive changes, to enable the transmitter module to be incorporated in qualified host devices.[29] The host manufacturer may also consider a mixed modular and dedicated host approach, to address compliance for transmitters with higher output power and SAR in dedicated host configurations and apply the modular approach to certain low power transmitters that have low SAR or do not require any SAR testing. This also enables the presence of low power transmitters and associated influences introduced by the hardware to be taken into consideration during normal SAR testing of the higher output transmitters in the dedicated host, without requiring separate testing for the low power transmitters in the

[27] A peripheral transmitter requires a host to support its operations; it cannot operate independently by itself. Peripheral transmitters can be attached to hosts through user accessible external standard interface connections or incorporated internally within the host device.

[28] See KDB 178919, Permissive Change Policies.

[29] Change of ID requires coordination between an original grantee and the third-party applicant.

host device. The grantee of a dedicated host or the grantees of the individual modular transmitter(s) incorporated in the host are all responsible for coordinating and ensuring the final implementations are compliant.

Full or modular transmitters are approved according to the operating configurations and exposure conditions of qualified host device configurations tested for compliance. Unless a transmitter or module is designed to operate in host devices that do not support portable exposure conditions or simultaneous transmission operations, seeking equipment approval for mobile exposure conditions or standalone operations in the initial equipment approval may require new filings to qualify for other operating and exposure conditions. To avoid subsequent equipment approval requirements and complexities, it is recommended that the initial applications for equipment authorization for such transmitters take into account all the applicable operating modes. The qualified installation and use conditions must be clearly identified in the equipment approval and OEM integration requirements, including all restrictions. Appropriate grant conditions must be specified according to the following combinations of operating conditions that are applicable to the individual approval:

- When a modular transmitter is approved for use in the *mobile exposure host* platform or *portable exposure host* platform, it must be clearly identified on the grant that the transmitter is either limited to standalone operations only, or allowed for operation in both standalone and simultaneous transmission configurations, for either mobile only or portable only exposure conditions. Any restrictions in host platform configurations and operating requirements must also be identified.[30] All grants conditions must be supported by the test results and test exclusion conditions.
- When a modular transmitter is approved for use in a *mixed mobile and portable exposure host* platform, the standalone and simultaneous transmission operations allowed for the mobile and/or portable exposure conditions in qualified hosts and product configurations, must be clearly identified on the grant. Any restrictions in host platform configurations and operating requirements must also be identified. All grants conditions must be supported by the test results and test exclusion conditions.

5.2. SAR evaluation of modules and peripheral transmitters used in portable exposure conditions for standalone operations

5.2.1. General

Generic modules and peripheral transmitters are approved according to the exposure conditions tested for compliance. Generic modules may be incorporated in specific host platforms, or unknown host configurations which often have unclear exposure conditions. Peripheral transmitters can include USB dongles, and internal and external plug-in cards that operate according to standard interface connections. The typical host platforms can include certain consumer electronics products (printers, cameras, etc.), laptop/notebook/netbook and tablet computers etc. The *SAR Test Exclusion Threshold* should be applied to streamline test requirements for standalone operations. Host platform requirements and operating

[30] Standalone use in certain platform configurations may need restriction; for example, the test configurations and results for a modular transmitter may not fully support multiple standalone transmitters that do not transmit simultaneously. Transmitters and antennas in device with small form factors can influence the SAR characteristics of adjacent transmitters and antennas due to close proximity, even when they are not transmitting simultaneously; therefore, the *published RF exposure KDB procedures* for specific host types may have further testing requirements for these types of standalone transmitters and antennas to qualify for collocating in the host. When specific guidance is unavailable, these types of standalone configurations may need to be limited to low SAR conditions, or require demonstration of no SAR influence concerns; for example, the antennas are spaced > 5 cm apart.

restrictions are determined according to the highest *reported* SAR, to ensure compliance due to variations in host configurations.

5.2.2. SAR test and approval considerations

When the following procedures are applied, in conjunction with the *published RF exposure KDB procedures*, additional SAR evaluation is generally not required to incorporate modules and peripheral transmitters in qualified host platform configurations.

1) When the highest *reported* 1-g SAR is ≤ 0.4 W/kg, modules and peripheral transmitters may be approved to operate in qualified portable host exposure conditions with no restriction for most host platform configurations. [31] This applies to both OEM installed and user accessible external peripheral transmitters. A minimum *test separation distance* of 5 mm must be applied to determine test exclusion according to the *SAR Exclusion Threshold* requirements. When SAR measurement is required, the energy coupling enhancement test in 5.2.3 is required. This unrestricted host platform approval does not apply when the *reported* 1-g SAR required by the energy coupling enhancement test is > 0.45 W/kg or when a *test separation distance* greater than 5 mm is necessary to maintain compliance (for example, through specific installation requirements or restricted use conditions, which must be considered separately in other host platforms).
2) When the highest *reported* 1-g SAR is > 0.4 W/kg and ≤ 0.8 W/kg, modules and peripheral transmitters may be approved to operate in multiple host platforms. [32] When the highest *reported* 1-g SAR is > 0.8 W/kg and ≤ 1.2 W/kg, the equipment approval must be limited to a single host platform. Each host platform must be tested independently according to the *published RF exposure KDB procedures* required for the host platform to determine SAR compliance, based on the operating configurations and exposure conditions of the host family attributes and operating requirements. When specific test requirements are unavailable in the *published RF exposure KDB procedures*, the most conservative exposure conditions must be tested for each host platform, according to the operating and exposure characteristics of the host family attributes. [33] To qualify for multiple host platforms, the modular transmitter may be approved under one FCC ID, either in the initial filing or through Class II permissive changes. All subsequent Class II permissive changes must be within the scope of the defined host platform configurations and exposure conditions in the initial equipment approval.
3) When the highest *reported* 1-g SAR is > 1.2 W/kg, modules and peripheral transmitters should be limited to operate internally within the dedicated host configurations tested for compliance. It is typically not possible to restrict certain types of peripheral transmitters, such as USB dongles and external interface plug-in cards with integral antennas that operate through user accessible external interface connections to a dedicated host; therefore, transmitter design changes are often necessary for these types of peripheral transmitters to satisfy SAR compliance. Depending on the test configurations and SAR results, when only a few of the *reported* SAR values are > 1.2 W/kg and ≤ 1.4 W/kg, the PBA procedures in KDB 388624 may be applied to remove dedicated host testing for transmitters that are internal to the host or by requiring additional user instructions, caution statements

[31] See footnote 29 for concerns about incorporating multiple standalone transmitters in small form factor devices.

[32] When a host platform requires testing, the *published RF exposure KDB procedures* for the platform should be applied to determine if testing in a representative host is required. The host families within the platform should be tested independently when different host family attributes can introduce changes to SAR characteristics, due to varying operating configurations and exposure conditions where the most conservative exposure conditions are different.

[33] See footnote 32.

and warning labels for user accessible external peripheral transmitters. When a large number of the *reported* SAR results are above 1.2 W/kg, for example, more than 10% to 20% and according to conservativeness of the test results, a KDB inquiry is recommended to ensure that a PBA is acceptable. For transmitters that are internal to the host, dedicated host testing is required when the SAR is > 1.4 W/kg. Dedicated host testing cannot be applied to user accessible external peripheral transmitters; when the *reported* SAR is > 1.4 W/kg, equipment approval may be submitted directly to the FCC for case-by-case consideration.

5.2.3. Other SAR test considerations

When specific test guidance and provisions are not fully specified in the *published RF exposure KDB procedures*, the following general guidance should be used as applicable for testing modules and peripheral transmitters.

1) SAR compliance must be determined according to the minimum *test separation distance* required for all applicable operating configurations of the host platform. The test distance must be fully justified in the SAR report. All required operating restrictions must be clearly explained in test reports to support the test setup and results.
2) When certain components, operating parameters or control functions that manage the operation of the transmitter are not fully contained within the approved module or peripheral transmitter, the SAR characteristics of the transmitter and antenna can be affected by how these external functions are implemented in individual host devices. When operation and control functions are shared or provided by the host device or through other mechanisms, SAR compliance and equipment approval should be limited to the dedicated host device. These types of operations may include certain power reduction and proximity sensor functions implemented or provided by host devices.[34]
3) Peripheral transmitters that operate through user accessible external interface connections must be tested conservatively as required by the *published RF exposure KDB procedures*, or according to a minimum *test separation distance* applicable to all operating configurations and exposure conditions required by the host platform. Certain less conservative conditions that do not require testing to show compliance must be fully justified in the SAR report. A *test separation distance* of 5 mm is required for these types of peripheral transmitters to operate in host devices that transmit next to users. A test distance of 10 mm may be applied if it is confirmed through prior approval from the FCC that smaller distances are not possible for the normal operation of the host devices in a platform. When a peripheral transmitter, such as a USB dongle, must be connected to the host through an external cable or adapter, a *test separation distance* ≤ 15 mm should be applied to test the required device orientations, if it can be demonstrated that smaller separation distances are not applicable for normal operations. The same consideration also applies when a cable, adapter or accessory antenna is available for a peripheral transmitter to offer alternative connection and use conditions.

5.2.4. RF energy coupling enhancement considerations

For transmitters and modules with no host platform restrictions, it is necessary to determine if additional SAR evaluation is required due to RF energy coupling enhancements at increased *test separation distances*. For the highest *reported* SAR of each test configuration, the tip of the SAR probe is positioned at the peak SAR location of the zoom scan, at a distance of half the probe tip diameter, rounded to the nearest mm, from the phantom surface. The test device is initially positioned in direct contact with the phantom and subsequently moved away from the phantom in 5 mm increments. At least three repeated single-point SAR (not 1-g SAR) results should be measured for each device position, until the measured

[34] Approval policies for these types of operations in different host platforms may vary due to operating requirements and other RF coupling and exposure concerns; for example, handsets and tablets etc.

SAR is < 50% of that measured with the device in contact with the phantom.[35] When there is more than 15% variation in the single-point measurements at each position, more measurements are required to ensure a representative high range value is recorded. The highest of the single-point SAR values, adjusted for tune-up tolerance, should be reported for each position. When the highest measured single-point SAR among all positions is 25% greater than that measured with the device positioned at 5 mm from the phantom, a complete 1-g SAR evaluation is required for that test configuration at the device position that produced the highest single-point SAR.

5.2.5. OEM instructions

The operating and exposure characteristics of the host configurations in a platform must be substantially equivalent and clearly documented in both the equipment authorization filings and all OEM and installation instructions. Detailed OEM integration and installation requirements must be included in the equipment approval filing. These instructions should include guidance for host manufacturers and OEM integrators to provide specific information required for the end users to ensure RF exposure compliance. Grantee responsibilities and third party obligations to incorporate and use the transmitter in approved host platforms and configurations must be clearly identified in the instructions. The approved and required antenna configurations in qualified host platform(s), such as separation distances to users and other antennas, and antenna polarization and orientation requirements in different host configurations, must be fully specified in the installation requirements.

5.3. SAR evaluation of modules and peripheral transmitters used in portable exposure conditions for simultaneous transmission operations

SAR compliance for simultaneous transmission must be considered when the maximum duration of overlapping transmissions, including network hand-offs, is greater than 30 seconds. The simultaneous transmission SAR test exclusion procedures (see 4.3.2) should be considered to streamline test requirements. When simultaneous transmission SAR evaluation is required, the enlarged zoom scan measurement and volume scan post-processing procedures described in KDB 865664 must be applied to determine compliance. A KDB inquiry is required to determine simultaneous transmission SAR test exclusion and SAR measurement requirements for the following:

- When coherent signals are involved in the simultaneous transmission, such as certain phased array, beam-forming, or similar configurations.
- When the difference in maximum output power across MIMO chains is > 1 dB
- When there is more than 1 dB variation in maximum output power across all channels in a wireless mode or frequency band.[36]

6. SAR Test Guidance for Unique Hosts and Exposure Conditions

6.1. Handheld push-to-talk (PTT) two-way radios

The operating configurations of handheld PTT two-way radios generally require SAR testing for in-front-of the face and body-worn accessory exposure conditions. A duty factor of 50% should be applied to determine compliance for radios with maximum operating duty factors ≤ 50 %.[37] Radios with higher duty factors must apply the maximum duty factor supported by the device to determine compliance. For

[35] These single point measurements can generally be configured using the multi-meter or time-sweep modes available in most SAR systems, to record the measured results.

[36] All channels include those that are not required for testing. Maximum output power variations may be determined by combinations of measurements, design specifications and other analyses, etc.

[37] The 50% duty factor only applies to exposure conditions where the radio operates with a mechanical PTT button.

example, up to 100% duty factor may be required for certain radios that support operator-assisted PSTN calls, and radios with Bluetooth or voice activated transmission capabilities. When TDMA applies, the time slot inherent duty factor should also be taken into consideration. For PTT radios operating in the 100 MHz to 1 GHz range, according to general population exposure requirements, SAR test exclusion may be applied for in-front-of the face and body-worn accessory exposure conditions according to the *SAR Exclusion Threshold* conditions and duty factor compensated maximum conducted output power.[38] When a body-worn accessory is not supplied with the PTT radio, a *test separation distance* ≤ 10 mm must be applied to determine body-worn accessory SAR test exclusion. A *test separation distance* of 25 mm must be applied for in-front-of the face SAR test exclusion and SAR measurements. When body-worn accessory SAR testing is required, the body-worn accessory requirements (see 4.2.2) should be applied. PTT two-way radios that support held-to-ear operating mode must also be tested according to the exposure configurations required for handsets. This generally does not apply to cellphones with PTT options that have already been tested in more conservative configurations in applicable wireless modes for SAR compliance at 100% duty factor. When occupational exposure limits apply, the procedures in KDB 643646 are applicable.

6.2. Wrist watch and wrist-worn transmitters

Transmitters that are built-in within a wrist watch or similar wrist-worn devices typically operate in speaker mode for voice communication, with the device worn on the wrist and positioned next to the mouth. Next to the mouth exposure requires 1-g SAR, and the wrist-worn condition requires 10-g SAR.[39] The 10-g extremity and 1-g SAR test exclusions may apply to the wrist and face exposure conditions. When SAR evaluation is required, next to the mouth use is evaluated with the front of the device positioned at 10 mm from a flat phantom. The wrist bands should be strapped together to represent normal use conditions. SAR for wrist exposure is evaluated with the back of the devices positioned in direct contact against the flat phantom. The wrist bands should be unstrapped and touching the phantom. The space introduced by the watch or wrist bands and the phantom must be representative of actual use conditions; otherwise, if applicable, the neck or a curved head region of the SAM phantom may be used, provided the device positioning and SAR probe access issues have been addressed through a KDB inquiry. When other device positioning and SAR measurement considerations are necessary, a KDB inquiry is also required for the test results to be acceptable; for example, devices with electronic circuitry and/or antenna(s) incorporated in the wrist bands. These test configurations are only applicable to devices that are worn on the wrist and cannot support other use conditions; therefore, the operating restrictions must be fully demonstrated in both the test reports and user manuals.

6.3. Low transmission duty factor devices

For devices that only transmit intermittently in data mode, without any voice support, the time-averaged exposure can be low. When transmissions are sporadic and duty factor is not inherently built-in to the device, source-based time-averaging may not be easily applied. These types of operations may include location trackers, emergency alert responders, point of sales devices (POS), certain black & white display e-Readers, and devices supporting location-based services. SAR measurement is not required when an acceptable worst case or most conservative transmission duty factor is determined and the *SAR Exclusion Threshold* conditions are satisfied for the duty factor adjusted maximum output power and minimum *test separation distance* required for all applicable operating configurations. The supporting details for determining this type of transmission duty factor, with respect to the design and implementation of the

[38] Occupational handheld PTT two-way radios must apply the procedures in KDB 643646.

[39] It must be ensured that wrist operations are limited to the wrist only. Operations above the wrist require 1-g SAR compliance.

device, operating configurations and exposure conditions, must be fully documented in a SAR analysis report, to qualify for SAR test exclusion. When SAR evaluation is required, the duty factor determined in the SAR analysis may be applied to scale the measured SAR, to determine compliance.[40] Voice-mode communication generally does not qualify for low duty factor considerations; however, exceptions may be considered for certain short (e.g. < 30 seconds) and infrequent transmissions.

6.4. After-market accessories

Transmitters and devices are approved for use according to the operating configurations and RF exposure conditions evaluated at the time of equipment approval. The SAR characteristics of the host device are typically affected by the device to user test separation distance because of body-worn accessories. Some after market accessories may change the operating characteristics of the approved device. Accessories that contain transmitters may support standalone and/or simultaneous transmission modes while operating independently or with a host device. Some of the typical host devices may include handsets, music players, and other small consumer electronic devices. The accessories may include various attachments in the form of snap-on sleeves, plug-in components, host carriers containing built-in transmitters and other strap-on or carrying options that may only contain certain types of conductive passive elements.

1) When an accessory is available from the original transmitter manufacturer and does not contain any secondary transmitter, compliance of the host and accessory can be addressed using the regular Class I or Class II permissive change procedures. The SAR distribution and exposure conditions of a newly introduced accessory are generally not comparable or equivalent to the configurations tested in the original approval of a host, without testing the accessory for any SAR degradation. Accessories provided by the grantee that have potential to influence the SAR characteristics of a host, and have never been identified in previous equipment approval filings, typically require a Class II permissive change for inclusion in the equipment authorization.
2) For third-party accessories that do not contain transmitters, the accessory suppliers should consult with the host equipment manufacturer to determine accessory approval options; for example, through a Class I or Class II permissive change submitted by the host grantee. If applicable, a change of FCC ID followed by a Class II permissive change by the third-party accessory supplier may be considered.[41] The assessment required to determine whether Class I or Class II permissive change is applicable may include analysis of the relevant parameters, such as *test separation distance*, metallic content, changes to exposure conditions etc. and preliminary measurements; for example, measuring SAR for the highest SAR configurations with equivalent SAR distributions and exposure conditions reported in the earlier equipment approval.
3) Separate equipment approval is required for accessories containing transmitter(s) that are available from the host manufacturer or third-party accessory suppliers. If the transmitter in the accessory supports standalone operations, with or without the host equipment, both conditions must be assessed for RF exposure compliance. Some accessories with built-in transmitters are designed to support host devices that do not contain transmitters; therefore, separate host approval is not required. When simultaneous transmission applies, all transmitter combinations must be addressed for the accessory alone and also with the accessory operating in conjunction with the host equipment. Due to significant variations in the types of accessory and host use conditions, when the test configurations required to show compliance is unclear a KDB inquiry should be submitted to confirm the test requirements.

[40] Scaling for maximum tune-up tolerance is considered separately.

[41] Change of ID requires coordination between the original grantee and third-party.

6.5. Other consumer electronic devices

The exposure conditions of transmitters and modules incorporated in certain consumer electronic devices, such as printers, cameras and camcorders may vary according to the installation and operating configurations required by the host products. Details of the transmitter and antenna configurations, antenna to user *test separation distance*, device operating configurations, etc., are required to determine SAR test exclusion or SAR measurement requirements for each host product. When SAR tests are required, a KDB inquiry is recommended to confirm the test setup. Unless the transmitter is used in a specific/dedicated host device, the standalone and simultaneous transmission SAR procedures for transmitters and modules should be applied. These must be fully explained in the permissive change documentation or equipment approval filing.

7. RF Exposure Evaluation Guidance for Mobile Conditions

7.1. Transmitters used in mobile exposure conditions for standalone operations

Devices operating in standalone mobile exposure conditions may contain a single transmitter or multiple transmitters that do not transmit simultaneously. A minimum *test separation distance* ≥ 20 cm is required between the antenna and radiating structures of the device and nearby persons to apply mobile device exposure limits. The distance must be fully supported by the operating and installation configurations of the transmitter and its antenna(s), according to the source-based time-averaged maximum power requirements of § 2.1091(d)(2). In cases where cable losses or other attenuations are applied to determine compliance, the most conservative operating configurations and exposure conditions must be evaluated. The minimum *test separation distance* required for a device to comply with mobile exposure conditions must be clearly identified in the installation and operating instructions, for all installation and exposure conditions, to enable users and installers to comply with RF exposure requirements. For mobile devices that have the potential to operate in potable device exposure conditions, similar to the configurations described in § 2.1091(d)(4), a KDB inquiry is required to determine the SAR test requirements for demonstrating compliance.

If the categorical exclusion provision of § 2.1091(c) applies, the minimum *test separation distance* may be estimated, when applicable, by simple calculations according to plane-wave equivalent conditions, to ensure the transmitter and its antenna(s) can operate in manners that meet or exceed the estimated distance.[42] The source-based time-averaged maximum radiated power, according to the maximum antenna gain, must be applied to calculate the field strength and power density required to establish the minimum *test separation distance*. When the estimated *test separation distance* becomes overly conservative and does not support compliance, MPE measurement or computational modeling may be used to determine the required minimum separation distance.[43]

When routine evaluation is required, MPE measurement or computational modeling should be used to determine compliance.[44] Only MPE measurement qualifies for TCB approval. The following procedures should be considered when guidance is not available in the *published RF exposure KDB procedures*.

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[42] The type of calculations used to estimate the minimum test separation distance for MPE compliance must be appropriate for the type of antenna(s) and exposure conditions evaluated.

[43] Computational modeling is excluded from TCB approval.

[44] While simple calculations may be acceptable for estimating the far-field exposure conditions of fixed transmitters (§1.1307), the distances estimated with similar calculations for mobile exposure conditions (§2.1091) are often not suitable or practical for the installation conditions required for mobile devices. When routine evaluation is required for mobile exposure conditions, MPE estimates are unacceptable for TCB approval.

1) Except when certain sectors of an antenna are permanently blocked or restricted from access by the nature of the installation conditions, MPE compliance must be assessed in all directions surrounding the antenna and radiating structures of the device. When symmetrical exposure conditions are expected, for example, from an omni-directional antenna, such conditions must be clearly demonstrated in test reports to avoid testing in all directions. RF exposure evaluation equipment, with isotropic sensors designed to measure the orthogonal field components, is required to determine the total exposure field.[45] Either peak or spatially averaged results may be applied to determine compliance; and with respect to plane-wave equivalent power density limits when ≥ 300 MHz, and electric and magnetic field strength limits when < 300 MHz.
2) Depending on the radiating characteristics of an antenna, the evaluation points in horizontal planes should be along radials from the antenna that are approximately 45° apart. The direction of maximum exposure should be aligned with one of the radials. When the minimum *test separation distance* from the antenna is > 60 cm, the evaluation points should be along radials that are ≤ 30° apart. Spatial averaging is required along the longest dimension of a person's body. For exposures in the vertical orientation, spatial averaging is not required in horizontal planes and should not be applied, except when the exposed person is aligned horizontally. The evaluation points in the vertical direction should extend at least 10 cm beyond the exposed portions of a person's body (1.8 m), or until the evaluated results are < 10% of the MPE limit, for each specific exposure condition, with a spatial resolution ≤ 10 cm. For exposures next to the ground or ground plane, the evaluation points should generally be ≥ 10 cm from the ground. The evaluated points in the vertical direction should be spatially averaged to determine compliance. The same measurement criteria required for exposures in the vertical orientation should be applied to exposures in the horizontal orientation.

When the antenna of a device transmits in multiple frequency bands, users and bystanders generally would not know which frequency band is transmitting at any specific time. The most restrictive *test separation distance* among all frequency bands is required for the antenna installation to ensure compliance. When specific antennas are not identified in the installation requirements, where users and installers may choose antennas with different gain requirements, the maximum antenna gain allowed for each frequency band must be determined according to the most restrictive *test separation distance* required for all frequency bands. The required antenna type, radiating characteristics, antenna gain and the requirement of a unique minimum *test separation distance* must be fully explained in the operating and installation instructions. Installers should be cautioned that failure to comply with the specific antenna requirements can result in operations that exceed FCC RF exposure limits.

7.2. Transmitters used in mobile exposure conditions for simultaneous transmission operations

For *mobile exposure host* platform to qualify for simultaneous transmission MPE test exclusion, all transmitters and antennas in the host must qualify for standalone MPE test exclusion (see 7.1). When modular transmitters are used, the minimum *test separation distance* required for each simultaneous transmitting antenna installed in the host device must be greater than or equal to that approved for standalone transmission. When simultaneous transmission MPE test exclusion applies, transmitter modules may be incorporated in host devices according to Class I permissive change requirements to document the test exclusion conditions.[46]

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[45] Additional information on test equipment is available in OET Bulletin 65.

[46] For simple antenna configurations, the Excel spreadsheet at http://transition.fcc.gov/oet/ea/presentations/files/oct05/MPE-mobile.xls may be used to estimate the MPE compliance boundary.

Simultaneous transmission MPE test exclusion applies when the sum of the MPE ratios for all simultaneous transmitting antennas incorporated in a host device, based on calculated or measured field strengths or power density, is ≤ 1.0. The MPE ratio of each antenna is determined at the minimum *test separation distance* required by the operating configurations and exposure conditions of the host device, according to the ratio of field strengths or power density to MPE limit, at the test frequency. Either the maximum peak or spatially averaged results from measurements or numerical simulations may be used to determine the MPE ratios. Spatial averaging does not apply when MPE is estimated using simple calculations based on far-field plane-wave equivalent conditions. The antenna installation and operating requirements for the host device must meet the minimum *test separation distances* required by all antennas, in both standalone and simultaneous transmission operations, to satisfy compliance.

When one of the following test exclusion conditions is satisfied for all combinations of simultaneous transmission configurations, further equipment approval is not required to incorporate transmitter modules in host devices that operate in the *mixed mobile and portable host* platform exposure conditions. The grantee is responsible for documenting this according to Class I permissive change requirements. Antennas that qualify for standalone SAR test exclusion must apply the estimated standalone SAR to qualify for simultaneous transmission test exclusion.

- The [∑ of (the highest measured or estimated SAR for each standalone antenna configuration, adjusted for maximum tune-up tolerance) / 1.6 W/kg] + [∑ of MPE ratios] is ≤ 1.0.
- The SAR to peak location separation ratios of all simultaneous transmitting antenna pairs operating in portable exposure conditions are all ≤ 0.04 and the [∑ of MPE ratios] is ≤ 1.0.

When RF exposure test exclusion does not apply, simultaneous transmission evaluation is required for mixed mobile and portable exposure conditions. The enlarged zoom scan measurement and volume scan post-processing procedures in KDB 865664 must be applied to test the simultaneous transmitting antennas operating in portable exposure conditions for each simultaneous transmission configuration. The [(highest measured simultaneous transmission SAR, adjusted for maximum tune-up tolerance) / 1.6 W/kg] + [∑ of MPE ratios] must be ≤ 1.0; otherwise, compliance must be determined by the FCC on a case-by-case basis with respect to antenna-to-antenna and antenna-to-user separation, device form factor, operating requirements and exposure conditions, etc.

9/12/2012

Appendix A

SAR Test Exclusion Thresholds for 100 MHz – 6 GHz and ≤ 50 mm

Approximate SAR Test Exclusion Power Thresholds at Selected Frequencies and Test Separation Distances are illustrated in the following Table.

MHz	5	10	15	20	25	mm
150	39	77	116	155	194	SAR Test Exclusion Threshold (mW)
300	27	55	82	110	137	
450	22	45	67	89	112	
835	16	33	49	66	82	
900	16	32	47	63	79	
1500	12	24	37	49	61	
1900	11	22	33	44	54	
2450	10	19	29	38	48	
3600	8	16	24	32	40	
5200	7	13	20	26	33	
5400	6	13	19	26	32	
5800	6	12	19	25	31	
MHz	30	35	40	45	50	mm
150	232	271	310	349	387	SAR Test Exclusion Threshold (mW)
300	164	192	219	246	274	
450	134	157	179	201	224	
835	98	115	131	148	164	
900	95	111	126	142	158	
1500	73	86	98	110	122	
1900	65	76	87	98	109	
2450	57	67	77	86	96	
3600	47	55	63	71	79	
5200	39	46	53	59	66	
5400	39	45	52	58	65	
5800	37	44	50	56	62	

Note: 10-g Extremity SAR Test Exclusion Power Thresholds are 2.5 times higher than the 1-g SAR Test Exclusion Thresholds indicated above. These thresholds do not apply, by extrapolation or other means, to occupational exposure limits.

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Appendix B

SAR Test Exclusion Thresholds for 100 MHz – 6 GHz and > 50 mm

Approximate SAR Test Exclusion Power Thresholds at Selected Frequencies and Test Separation Distances are illustrated in the following Table.

MHz	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	cm
100	474	481	487	494	501	507	514	521	527	534	541	547	554	561	567	
150	387	397	407	417	427	437	447	457	467	477	487	497	507	517	527	
300	274	294	314	334	354	374	394	414	434	454	474	494	514	534	554	
450	224	254	284	314	344	374	404	434	464	494	524	554	584	614	644	
835	164	220	275	331	387	442	498	554	609	665	721	776	832	888	943	
900	158	218	278	338	398	458	518	578	638	698	758	818	878	938	998	
1500	122	222	322	422	522	622	722	822	922	1022	1122	1222	1322	1422	1522	mW
1900	109	209	309	409	509	609	709	809	909	1009	1109	1209	1309	1409	1509	
2450	96	196	296	396	496	596	696	796	896	996	1096	1196	1296	1396	1496	
3600	79	179	279	379	479	579	679	779	879	979	1079	1179	1279	1379	1479	
5200	66	166	266	366	466	566	666	766	866	966	1066	1166	1266	1366	1466	
5400	65	165	265	365	465	565	665	765	865	965	1065	1165	1265	1365	1465	
5800	62	162	262	362	462	562	662	762	862	962	1062	1162	1262	1362	1462	

Appendix C

SAR Test Exclusion Thresholds for < 100 MHz and < 200 mm

Approximate SAR Test Exclusion Power Thresholds at Selected Frequencies and Test Separation Distances are illustrated in the following Table.

MHz	< 5	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	cm
100	237	474	481	487	494	501	507	514	521	527	534	541	547	554	561	567	
50	308	617	625	634	643	651	660	669	677	686	695	703	712	721	729	738	
10	474	948	961	975	988	1001	1015	1028	1041	1055	1068	1081	1095	1108	1121	1135	
1	711	1422	1442	1462	1482	1502	1522	1542	1562	1582	1602	1622	1642	1662	1682	1702	mW
0.1	948	1896	1923	1949	1976	2003	2029	2056	2083	2109	2136	2163	2189	2216	2243	2269	
0.05	1019	2039	2067	2096	2125	2153	2182	2211	2239	2268	2297	2325	2354	2383	2411	2440	
0.01	1185	2370	2403	2437	2470	2503	2537	2570	2603	2637	2670	2703	2737	2770	2803	2837	

9/12/2012

Appendix D

Applying Estimated SAR for Simultaneous Transmission SAR Test Exclusion

The following Table illustrates the approximate SAR values estimated at selected frequencies, test separation distances and power levels for determining simultaneous transmission SAR test exclusion when standalone SAR is not required.

Estimated SAR higher than 0.4 W/kg do not apply; therefore, they are not indicated								
Red numbers in "mW" column are the approximate maximum output power at the *SAR Exclusion Threshold* for standalone SAR test exclusion. Top row indicates different levels of test device maximum output power								
MHz	10	25	50	100	150	200	mW	Min. Distance
150	0.1	0.3					39	5 (mm)
300	0.1	0.4					27	
450	0.2						22	
835	0.2						16	
900	0.3						16	
1500	0.3						12	
1900	0.4						11	
2450							10	
3600							8	
5100							7	
5400							6	
5800							6	
MHz	10	25	50	100	150	200	mW	
150	0.1	0.1	0.3				77	10 (mm)
300	0.1	0.2	0.4				55	
450	0.1	0.2					45	
835	0.1	0.3					33	
900	0.1	0.3					32	
1500	0.2						24	
1900	0.2						22	
2450	0.2						19	
3600	0.3						16	
5100	0.3						13	
5400	0.3						13	
5800	0.3						12	
MHz	10	25	50	100	150	200	mW	
150	0.0	0.1	0.2	0.3			116	15 (mm)
300	0.0	0.1	0.2				82	
450	0.1	0.1	0.3				67	
835	0.1	0.2					49	
900	0.1	0.2					47	
1500	0.1	0.3					37	
1900	0.1	0.3					33	
2450	0.1	0.3					29	
3600	0.2						24	
5100	0.2						20	
5400	0.2						19	
5800	0.2						19	

MHz	10	25	50	100	150	200	mW	
150	0.0	0.1	0.1	0.3	0.4		155	
300	0.0	0.1	0.2	0.4			110	
450	0.0	0.1	0.2				89	
835	0.1	0.2	0.3				66	
900	0.1	0.2	0.3				63	
1500	0.1	0.2					49	20
1900	0.1	0.2					44	(mm)
2450	0.1	0.3					38	
3600	0.1	0.3					32	
5100	0.2	0.4					27	
5400	0.2	0.4					26	
5800	0.2						25	
MHz	10	25	50	100	150	200	mW	
150	0.0	0.1	0.1	0.2	0.3		194	
300	0.0	0.1	0.1	0.3			137	
450	0.0	0.1	0.2	0.4			112	
835	0.0	0.1	0.2				82	
900	0.1	0.1	0.3				79	
1500	0.1	0.2	0.3				61	25
1900	0.1	0.2	0.4				54	(mm)
2450	0.1	0.2					48	
3600	0.1	0.3					40	
5100	0.1	0.3					33	
5400	0.1	0.3					32	
5800	0.1	0.3					31	
MHz	10	25	50	100	150	200	mW	
150	0.0	0.0	0.1	0.2	0.3	0.3	232	
300	0.0	0.1	0.1	0.2	0.4		164	
450	0.0	0.1	0.1	0.3			134	
835	0.0	0.1	0.2				98	
900	0.0	0.1	0.2				95	
1500	0.1	0.1	0.3				73	30
1900	0.1	0.2	0.3				65	(mm)
2450	0.1	0.2	0.3				57	
3600	0.1	0.2					47	
5100	0.1	0.3					40	
5400	0.1	0.3					39	
5800	0.1	0.3					37	
MHz	10	25	50	100	150	200	mW	
150	0.0	0.0	0.1	0.1	0.2	0.3	271	
300	0.0	0.1	0.1	0.2	0.3		192	
450	0.0	0.1	0.1	0.3	0.4		157	
835	0.0	0.1	0.2	0.3			115	
900	0.0	0.1	0.2	0.4			111	
1500	0.0	0.1	0.2				86	35
1900	0.1	0.1	0.3				76	(mm)
2450	0.1	0.1	0.3				67	
3600	0.1	0.2	0.4				55	
5100	0.1	0.2					46	
5400	0.1	0.2					45	
5800	0.1	0.2					44	

MHz	10	25	50	100	150	200	mW	
150	0.0	0.0	0.1	0.1	0.2	0.3	310	
300	0.0	0.0	0.1	0.2	0.3	0.4	219	
450	0.0	0.1	0.1	0.2	0.3		179	
835	0.0	0.1	0.2	0.3			131	
900	0.0	0.1	0.2	0.3			126	
1500	0.0	0.1	0.2				98	40
1900	0.0	0.1	0.2				87	(mm)
2450	0.1	0.1	0.3				77	
3600	0.1	0.2	0.3				63	
5100	0.1	0.2	0.4				53	
5400	0.1	0.2	0.4				52	
5800	0.1	0.2					50	
MHz	10	25	50	100	150	200	mW	
150	0.0	0.0	0.1	0.1	0.2	0.2	349	
300	0.0	0.0	0.1	0.2	0.2	0.3	246	
450	0.0	0.0	0.1	0.2	0.3	0.4	201	
835	0.0	0.1	0.1	0.3			148	
900	0.0	0.1	0.1	0.3			142	
1500	0.0	0.1	0.2	0.4			110	45
1900	0.0	0.1	0.2				98	(mm)
2450	0.0	0.1	0.2				86	
3600	0.1	0.1	0.3				71	
5100	0.1	0.2	0.3				60	
5400	0.1	0.2	0.3				58	
5800	0.1	0.2	0.4				56	
MHz	10	25	50	100	150	200	mW	
150	0.0	0.0	0.1	0.1	0.2	0.2	387	
300	0.0	0.0	0.1	0.1	0.2	0.3	274	
450	0.0	0.0	0.1	0.2	0.3	0.4	224	
835	0.0	0.1	0.1	0.2	0.4		164	
900	0.0	0.1	0.1	0.3	0.4		158	
1500	0.0	0.1	0.2	0.3			122	50
1900	0.0	0.1	0.2	0.4			109	(mm)
2450	0.0	0.1	0.2				96	
3600	0.1	0.1	0.3				79	
5100	0.1	0.2	0.3				66	
5400	0.1	0.2	0.3				65	
5800	0.1	0.2	0.3				62	