Federal Communications Commission
Office of Engineering and Technology
Laboratory Division

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Draft Laboratory Division Publications Report

Title: RF Exposure Procedures and Equipment Authorization Policies for Mobile and Portable Devices

Short Title: General RF Exposure Guidance

Reason: Revision of Attachment 447498 D01 General RF Exposure Guidance

Publication: 447498

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

Overview.

This publication discusses the RF exposure requirements and procedures for mobile and portable devices, as referenced in 47 CFR Sections 1.1307, 2.1091, and 2.1093

Attachment 447498 D01 General RF Exposure Guidance v07 provides guidance pertaining to RF exposure requirements for mobile device and portable device equipment authorizations.

Attachment 447498 D02 SAR Procedures for Dongle Xmtr v02r01 provides guidance for SAR testing of USB dongle transmitters.

Attachment 447498 D03 Supplement C Cross-Reference provides a cross-reference between the discontinued OET Bulletin 65 Supplement C-0101 and the applicable KDB publications.

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

Attachment List:

447498 D01 General RF Exposure Guidance v07 *

447498 D02 SAR Procedures for Dongle Xmtr v02r01 **

447498 D03 Supplement C Cross-Reference v01 **

447498 D04 Interim General RF Exposure Guidance v01 ***

* Attachment posted for public comment as this draft publication.

** Attachments not under review and currently published in 447498.

*** See Transition Period section.

Notes to this Draft for Public Comment

The attachment "447498 D01 General RF Exposure Guidance DR05-44791" is based on the existing policies and procedures of KDB Publication 447498 D01 v06 (2015) with modifications and updates following from the rules adopted in the *Second Report and Order* (*2nd R&O*) in ET Docket No. 03-137 (FCC 19-126; paras. 17 to 118 and Appendix A; 34 FCC Rcd 11697-11742 and 11762-11781).

In addition, the attachment "447498 D01 General RF Exposure Guidance DR05-44791" addresses comments received on Draft for Public Comment "447498 D01 General RF Exposure Guidance DR04-44307" (comment period closed June 25, 2021) and other associated questions subsequently received by OET.

The effective date for the rule changes in §§ 1.1307, 2.1091, and 2.1093 established by FCC 19-126 was May 3, 2021, as stated in Public Notice DA 21-363 (Apr. 2, 2021). Modifications to various other rules adopted in FCC 19-126 went into effect on June 1, 2020.

Existing equipment authorizations remain valid and do not require specific modifications further to the FCC 19-126 rule changes.

Certification applications for new and modified equipment must follow the most recent equipment authorization policies and procedures in effect at the time of the application, this includes evaluation of applicability for permissive change procedures.

The applicability of a permissive change action needs to be evaluated according to the policies that are in effect at the time the action is taken. If a new device, or a permissive change filing, was granted under the provisions of KDB Pub. 447498 D01 v06 (2015-10), it is possible that later on, when only a newer version is in effect, the device may not be eligible for additional permissive changes if the required conditions are not met based on the new policy. In that case an additional certification filing will be required. Such cases are expected to be rare, thus introducing any "grandfathering" provisions is deemed unnecessary.

The policies and procedures in this document are not related to the ongoing rulemaking proceeding in ET Docket No. 19-226 (Notice of Proposed Rulemaking (NPRM) FCC 19-126, paras. 119 to 147 and Appendix B; 34 FCC Rcd 11742-11756 and 11782-11788). Comments on topics in the NPRM instead should be filed directly using the FCC Electronic Comment Filing System (ECFS; https://www.fcc.gov/ecfs/).

Transition Period

Attachment "447498 D04 Interim General RF Exposure Guidance v01"can be used for equipment authorization and must be used in its entirety along with any other associated revised KDB RF exposure procedures and policies (including FCC-TCB conference presentations) during a transition period in effect from August 13, 2022, until further notice.

Notification of the end of this transition period will be provided well in advance before use of any new published guidance is required.

The previous version, "447498 D01 General RF Exposure Guidance v06," may also be used during this transition period as long as the 731 Form and the related granted application are submitted to the FCC on or before the end of transition period. “447498 D01 General RF Exposure Guidance v06” must be used entirely (i.e., no mixing of old and new procedures for certification application filing(s)).

After the end of the transition period, all applications must only use new procedures which will be published as “447498 D01 General RF Exposure Guidance v07,” replacing “447498 D01 General RF Exposure Guidance v06.” This new publication 447498 D01 General RF Exposure Guidance v07 is expected to be finalized by the end of October 2022. At that time notification of a new transition period will be provided.

The only exception is for cases where certification application(s) include items subject to Pre-Approval Guidance (PAG, KDB Publication 388624) submitted by the end of the transition period. In this case, the TCB can grant the device after the end of transition period, using either “447498 D04 Interim General RF Exposure Guidance v01” or “47498 D01 General RF Exposure Guidance v06,” after the PAG is approved.

Change Notice (Draft for Public Comment)

A Change Notice listing is provided at the last page of this document.

RF Exposure Procedures and Equipment Authorization Policies for Mobile and Portable Devices

Table of Contents

1 GENERAL CONSIDERATIONS, POLICIES, AND REQUIREMENTS

1.1 OET Documentation on RF Exposure Procedures

This document, referred to as KDB Pub. 447498 D01, provides RF exposure procedures and equipment authorization policies for compliance evaluations and demonstrations to FCC exposure rules of mobile (per § 2.1091) and portable (per § 2.1093) *RF source* [Glossary] devices.[1] Additional policies, procedures, and information on *fixed RF sources* and RF exposure compliance is provided in FCC OET Bulletin 65 [Reference].

The content is arranged with Section 1 through Section 6 covering the main topics, Appendix A through Appendix ~~G~~ F providing additional details, and the Glossary explaining terms and definitions and special notations.

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This guidance describes the general RF exposure evaluation requirements, and serves as an entry point for the more specific RF exposure guidance described in the collection of KDB publications on RF exposure procedures [Reference].[2]

1.2 RF Exposure Requirements for Equipment Authorization

In general, KDB publications are applied in conjunction with other FCC rules, policies, and procedures to prepare devices for equipment authorization.[3] Guidance in the most recent revision of the KDB publications and TCB Workshop updates,[4] whichever is the latest at the time when device testing begins, must be applied.

KDB publications~~,~~ must be followed for obtaining approval of equipment certification applications, unless further guidance is provided by the FCC.

For some cases, especially for new technologies and emerging products, or devices that require substantial FCC evaluation, the certification equipment is subject to Pre-Approval Guidance (PAG) procedures, as defined in KDB Pubs. 388624 D01 and D02.

Existing equipment authorizations remain valid and do not require specific modifications further to the FCC 19-126 rule changes. Certification applications for new and modified equipment must follow the most recent equipment authorization policies and procedures in effect at the time of the application.

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[1] This document uses italics with various basic terms that are described in the Glossary.

[2] Associated guidance for RF exposure evaluations of mobile devices and portable devices, and for FCC equipment authorization policies and procedures overall, is available from the FCC website through the Knowledge Database (KDB) publications at www.fcc.gov/labhelp. These publications provide RF exposure evaluation and test support for specific products, wireless technologies, test methodologies, and equipment approval policies.

[3] The two FCC equipment authorization procedures are Supplier's Declaration of Conformity (SDoC) and certification; see 47 CFR §§ 2.906 et seq. and 2.907 et seq, respectively.

[4] See FCC OET Laboratory Division Equipment Authorization Telecommunication Certification Body (TCB) Presentations, (https://www.fcc.gov/oet/ea/presentations).

Any permissive change filing shall be evaluated based on the rules and policies in effect at the time of the filing itself. For example, a test exemption that was applicable under the version 06 of KDB Pub. 447498 may not automatically be applicable when following this new version 07 (i.e. no "grandfathering" provisions are being issued in regarding to the transition between two versions of this document).

1.3 Relation of this Document to the FCC RF Exposure Rules

The FCC RF exposure rules were amended and revised by the *2nd R&O* portion of FCC 19-126, ET Docket No. 03-137, released December 4, 2019. Under the adopted rules, unless any of the exemptions in §§ 1.1307(b)(3) (also in §§ 2.1091(c), and 2.1093(c) apply), per § 1.1307(b)(1)(i)(B) applications for equipment authorization of RF sources must contain an evaluation of the human exposure to RF showing compliance with the RF exposure limits of § 1.1310. Under the previous rules, *Routine Evaluation* [Glossary] for RF exposure compliance demonstration was required only for a list of specific radio services and operations, while others not in that list were exempt from this requirement.

The procedures provided in this document, and in other KDB publications referenced herein, are designed to meet the aforementioned requirements.

Filings for certification must always include an explicit statement of compliance with § 1.1310. Accordingly, once the RF exposure documentation filed for the purpose of granting certification has been approved following the guidance of this KDB, then that documentation is considered:

- valid as "evaluation of the human exposure to RF radiation", thus meeting the requirement of 47 CFR 1.1307(b)(1)(i)(B) for an evaluation,
- sufficient to demonstrate compliance with § 1.1310, thus meeting requirement of 47 CFR 1.1307(b)(1)(i)(B) for a statement of compliance.

This document includes summaries of the FCC RF exposure rules related to equipment authorization, primarily for mobile and portable device. In addition to basic changes stemming from the *2nd R&O*, many of the underlying specific requirements, conditions and procedures in this document remain unchanged from previous revisions. However, for clarity some content re-organization has been introduced.

1.4 Basic Concepts, Definitions, and Policies

1.4.1 RF Exposure Limits

The RF exposure guidelines adopted by the FCC are based on specific absorption rate (SAR) and maximum permissive exposure (MPE) limits. The basic restrictions for human exposure are defined by SAR limits. MPE limits are derived from the SAR limits, in terms of free-space field strength and power density. SAR compliance is determined using tissue-equivalent media, at the applicable test frequencies.

A synopsis of the applicable limits for the mobile and portable device categories is shown in Table 1. Table 1 also shows the correspondence between FCC Rules and the associated equipment authorization policies.[5] As discussed in Sec. 1.3, these policies are devised to facilitate reviews of applications for certification, in that a device that is certified following applicable policies will be also compliant to the pertinent rule.

Table 1 – RF Exposure Limits in FCC Rules and OET Equipment Authorization Policies

<table>
<tr><th>Frequency range [a]</th><th>FCC Rules</th><th>OET Equipment Authorization Policies</th></tr>
<tr><td>$f \leq 100$ kHz</td><td>N/A
(under consideration) [c]</td><td>All devices assessed case-by-case, with field strength limits of E = 83 V/m and H = 90 A/m, in all body exposure relevant positions</td></tr>
<tr><td>100 kHz $< f \leq$ 300 kHz [b]</td><td>SAR limits in
§ 1.1310 (b), (c)</td><td>MPE limits at 300 kHz in Table 1 to
§ 1.1310(e)(1): E = 614 V/m and H = 1.63 A/m</td></tr>
<tr><td rowspan="2">300 kHz $< f \leq$ 4 MHz [b]</td><td>§ 2.1091 Mobile Devices:
MPE limits in Table 1 to
§ 1.1310(e)(1) [d]</td><td rowspan="2">MPE limits in Table 1 to § 1.1310(e)(1)</td></tr>
<tr><td>§ 2.1093 Portable Devices:
SAR limits in
§ 1.1310 (b), (c)</td></tr>
<tr><td rowspan="2">4 MHz $< f \leq$ 6 GHz</td><td colspan="2">§ 2.1091 Mobile Devices:
MPE limits in Table 1 to § 1.1310(e)(1) [d]</td></tr>
<tr><td colspan="2">§ 2.1093 Portable Devices:
SAR limits in § 1.1310 (b), (c)</td></tr>
<tr><td>6 GHz $< f \leq$ 100 GHz</td><td colspan="2">MPE limits in Table 1 to § 1.1310(e)(1) [c]</td></tr>
<tr><td>100 GHz $< f \leq$ 3000 GHz</td><td colspan="2">N/A (under consideration) [c]</td></tr>
<tr><td colspan="3">[a] For all $f \leq 6$ GHz, SAR limits in §§ 1.1310 (b), (c) can always be applied where available, in place of MPE limits
[b] Policies for 100 kHz $< f \leq$ 4 MHz reflect capabilities of available SAR measurement equipment. Numerical simulations may be also acceptable, and are considered under PAG per KDB Pub. 388624
[c] NPRM, ET Docket No. 19-226; FCC 19-126, 34 FCC Rcd 11743
[d] Per § 2.1091(d)(4) SAR limits are applicable in some cases</td></tr>
</table>

1.4.2 Mobile and Portable Devices

For devices that operate at more than 20 cm distance from any person, the more complex SAR evaluation can be avoided by evaluating RF exposure compliance in terms of incident field strength MPE limits. Quantitatively, these RF exposure evaluation requirements are discussed in § 2.1091, which define the mobile device exposure conditions, while § 2.1093 discusses the portable device exposure conditions subject to SAR limits.

[5] In some cases, the FCC may require RF exposure testing or analysis to be performed pursuant to §§ 2.1091(c)(3), 2.1093(c)(3), and 1.1307 (c) and (d).

Portable devices transmitting at frequencies above 6 GHz (e.g., Part 30, Part 15 U-NII 6 GHz band) are subject to the MPE incident power density limits of § 1.1310.[6] Guidance for portable devices requiring MPE power density evaluation is provided in other OET documents.[7]

When both mobile device and portable device exposure conditions could apply, compliance is determined according to the rules and policies established for each exposure condition, based on the specific use case demonstrated for the device under consideration. In general, compliance defaults towards the most conservative option, thus certification for mobile conditions per § 2.1091 require use case demonstration based on device design and physical constraints, and generally cannot be based on simple warning statements.

When § 2.1091(d)(4) applies, i.e., there is the possibility for a device be to be operated under portable exposure conditions (more conservative than mobile-device exposure conditions), the SAR test exemption provisions may be considered, as applicable.

1.4.3 Exemptions from Equipment Authorization Records Retention

Devices with RF sources using the certification equipment authorization procedure are required to submit an application form including certain information and test data, per §§ 2.911(c) and 2.1033. *RF sources* using the SDoC equipment authorization procedure must follow the records retention requirements in accordance with § 2.938(a) through (e). Submission or specific records-retention of technical information showing the basis for RF exposure compliance is not being requested, for example, for the following types of *RF sources*.

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Commented [KO2]: [2] Using "Devices with RF Sources" may help for clarity

a) devices subject only to the SDoC equipment authorization procedure;
b) devices exempt from any equipment authorization requirement. These include, incidental radiators [§ 15.3(n)], Part 97 transmitting devices (except amplifiers [§ 2.815(b)(4)]), Part 95 RCRS transmitting devices, § 90.203(b)(3) 1427-1435 MHz transmitting devices.

See also Appendix F for other equipment types exempt from equipment authorization procedures.

1.5 Information and Instructions for Operation and Installation

As specified in §§ 2.1033(b)(3) and 2.1033(c)(3), operating and installation instructions shall be furnished to all persons who require such information for ensuring compliance (such as users and/or installers), and shall be reviewed and deemed adequate for acceptance during equipment authorization process.

[6] MPE compliance for portable devices above 6 GHz is evaluated at the minimum separation distance applicable to the operating configurations and exposure conditions of a device; the general-population/uncontrolled limit is 1 mW/cm^2 power density determined from the total field, averaged over 4 cm^2.

[7] Guidance for portable devices requiring MPE power density evaluation is provided in the TCB workshop presentations and references therein (https://www.fcc.gov/general/equipment-authorization-presentations), and per case-by-case basis in KDB inquiries. For certifications, OET accepts SAR test data (supplemented with other measured and derived PD results), for interim compliance purposes of portable devices in the 5.925-8.5 GHz band, as discussed in the "OVER6G" PAG item of KDB Pub. 388624 D02 (PAG List).

User instructions for installation, OEM integration, or assembly by a third party, including specific requirements to ensure RF exposure compliance, must be clear and tailored to target audience, whether it is limited to trained professionals or to general consumers with no assumed training on installing and operating the equipment.

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.

1.6 RF Exposure Considerations Related to Modular Transmitter Host Integration

A device may include both transmitters with Modular Approval Grants (*modular transmitters* or *Modules* [Glossary]) and its own transmitters. If *Modules* are included, the device is referred to as *host (platform)* [Glossary] and it may be authorized following the evaluation procedures for mobile configurations (per § 2.1091), but only if all the *Modules* are also authorized for mobile conditions.

If, instead, at least one *Module* that is integrated in the host device has been authorized for the *portable device* configuration, then the host device authorization must follow the (more restrictive) procedures for portable device configurations (i.e., comply with § 2.1093). A *Module* certified for the mobile configuration may be integrated in a portable host after the portable configuration requirements have been demonstrated (possibly including changes, e.g., power reductions), and a related Class II permissive change is approved.

The purpose of the policies herein discussed are to ensure RF exposure compliance for both standalone (i.e., a *Module* that operates in the host without any other transmitter in the host operating at the same time), and simultaneous transmission operations (i.e., a *Module* that operates in the host along with other host transmitters).

The acceptable host platform configurations, exposure conditions, and any restrictions approved for a *Module*, must be fully described in the equipment authorization filings, as well as in the required integration instructions, in accordance with the operation and installation information and instructions considerations of Sec. 1.5.

The grantee of the equipment authorization for a *modular transmitter*, typically the manufacturer, is responsible for ensuring that integrators have a clear understanding of the compliance requirements by including the required instructions and documentation with the product.

The module integrators must be fully informed of their obligations, and verify the resolution of any issues and concerns with each transmitter manufacturer or grantee. All the disclosures required to ensure compliance of transmitter modules must be filed for review during equipment authorization.

1.7 General Population vs. Occupational Exposure Environments

Transmitters operating in consumer products must comply with the general population/uncontrolled exposure limits required for the applicable mobile device and/or portable device RF exposure conditions.[8] Occupational/controlled exposure limits apply only when it can be shown that the conditions of § 1.1310(e)(2) are satisfied, along with §§ 2.1091(d)(3)(ii), 2.1091(d)(3)(iv), and 2.1093(d)(5), as applicable.

[8] See §§ 1.1310(e)(3) and 2.1093(d)(6).

Accordingly, occupational/controlled exposure limits only apply to "*work-related*" use conditions. Users must be "*fully aware of*" and be able to "*exercise control over*" their exposure through acceptable training to qualify for the higher occupational/controlled exposure limits. Occupational/controlled exposure limits do not apply to *consumer devices* and radio services intended for supporting public networks, or to Part 15 unlicensed operations.[9]

Mandatory RF exposure training is required for workers to qualify devices for occupational/controlled exposure limits. Detailed training instructions incorporated in user manuals, in conjunction with conspicuous permanent labeling on the device, may be considered as acceptable training to qualify workers to operate a device according to occupational exposure limits. Supporting information shall demonstrate that users are required to adhere to the training instructions and are able to mitigate compliance concerns by applying the instructions. All the aforementioned training information must be included in the equipment authorization application.

When general population/uncontrolled and occupational/controlled limits are required for different transmitters within a host device (e.g., due to radio service rules, or when the use is not specified), each transmitter shall refer to the exposure limit that applies to its corresponding use conditions.

For instance, TX1, a transmitter designed for occupational/controlled exposure environment, may be integrated with TX2, transmitter that is authorized for general population/uncontrolled use. The integrated device shall be then certified in reference to occupational exposure when TX1 is active, and for general population limits when only TX2 is active. See Sec. 3.2.1 for evaluating mixed general-population and occupational transmitter scenarios.

When devices are authorized in accordance with the general population exposure limits, additional equipment approval is not required to satisfy occupational exposure requirements (since they are less restrictive), so long as all the exposure conditions and device parameters are not modified.

In general, in order to demonstrate compliance, devices shall be tested in all their operation modes allowed by design without requiring specific interventions.

All device operating instructions and installation requirements must be consistent with the modes of operations under which compliance was demonstrated, for which the equipment was authorized.

For the purpose of establishing mobile vs. portable configuration conditions, a clear demonstration of all the reasonable use cases must be shown in the certification filings. Cautionary statements or visual warning advisories (labels, signage, etc.) for alerting users to avoid exposures for fixed RF source installations are not considered sufficient.

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[9] See §§ 1.1310(e)(3), 2.1093(d)(6), 15.407(f).

2 RF EXPOSURE REQUIREMENTS FOR EQUIPMENT AUTHORIZATION

2.1 General Conditions

2.1.1 Basic Requirements

As discussed in Sec. 1.3, this publication provides guidance for satisfying the RF exposure requirements of §§ 1.1307 and 1.1310, and must be followed for equipment authorization purposes.

By default, from an RF exposure perspective, equipment authorization can be granted only when test results are shown to meet the criteria in the "OET Equipment Authorization Policies" column of Table 1, (Sec. 1.4.1). These policies define, for different frequency ranges, the quantities to be measured and the limits to be met.

2.1.2 Test Exemptions for Equipment Authorization

RF exposure test exemptions provide a means to obtain certification with less stringent requirements on the data (measurements, or analytical/numerical modeling) needed to be shown for demonstrating compliance with the applicable limits.

When exemption conditions are leveraged in lieu of the default requirements for reporting RF exposure test data, a fully descriptive statement of justification for the applicability of the exemption(s) must be included in the equipment authorization filings.

Test exemptions apply for devices used in general population/uncontrolled exposure environments, according to the SAR, or MPE test exemption thresholds based on the device RF power. Specific test exemption thresholds for operations under occupational/controlled limits have not been established.

2.1.3 RF Source Power

In general, test exemption conditions are frequency-dependent, and are formulated in terms of source-based available maximum time-averaged output power (conducted power, or effective radiate power (ERP), when applicable, chosen in impedance-matching conditions, and for the most conservative case from the RF exposure perspective) for all design operating configurations, adjusted for tune-up tolerance, and at the minimum *test separation distance* [Glossary and Sec. 3.1.5] required for the particular RF exposure scenario under consideration.

In many cases, the power direct measurements are impractical, and a conservative estimate of the output power level is acceptable, so long as a clear description of the chosen approach is provided as part of the RF Exposure filing exhibits.

This power level may be determined by direct measurements, or estimated via a combination of analysis and manufacturer provided data. Measurements may also include effective radiated power data, so long as the proper radiation pattern that is applicable down to the minimum *test separation distance* is accounted for. Thus, in many cases of interest for RF exposure, the radiation pattern shall refer to the near-field conditions.

Commented [KO3]: [3] It's not clear how it should be determined if the radiation pattern of the radiated power is applicable in the near-field or at the test separation distance. Guidance on how to evaluate this is needed

Manufacturer data that are used to derive critical parameters used in the power evaluation (e.g., antenna pattern, RF amplifier maximum power, duty cycle) need also to be included in the filing.

2.1.4 Antenna Gain Considerations for Portable Devices

In most practical cases, the closest, most critical SAR exposure conditions are determined by electromagnetic coupling in the near-field. Near-field patterns are highly dependent on the RF current distribution on antennas and nearby structures, and impacted by host device configurations, but are not directly related to the antenna gain. The antenna gain is defined based on the far-field distribution, and does not account for mutual coupling effects between the device radiating structures and surrounding objects (such as, in the case of portable devices considered here, a human body or test phantom).

For these reasons, the determination of test exemption conditions was defined based on conducted power thresholds (see discussion in Sec. 2.1.3).

Therefore, in general, it would be inappropriate to assume that lower gain antennas always produce lower SAR, and that SAR testing is not required for that reason. Accordingly, for transmitter with the option of using more than one antenna, SAR compliance must be demonstrated independently for each antenna considered by design.

2.2 RF Exposure Test Exemptions for Single Source

2.2.1 1-mW Test Exemption

Per § 1.1307(b)(3)(i)(A), a single RF source is an *exempt RF device* (from the requirement of preparing an Environmental Assessment showing compliance to RF exposure limits) if the available maximum time-averaged power is no more than 1 mW, regardless of separation distance.

In an analogous fashion, an Equipment Authorization guideline is here provided, in that a device can obtain equipment authorization without requiring RF exposure compliance data, if it is shown to operate with maximum time-averaged power limited up to 1 mW.

This exemption applies to all operating configurations and exposure conditions, independent of radio service type, for the frequency range from 9 kHz to 100 GHz (see Table 1 in Sec. 1.4.1), regardless of fixed, mobile, or portable device exposure conditions. This is a standalone exemption (i.e., applicable only for a standalone operating transmitter on the device), and shall not be used in conjunction with exemption criteria other than those for multiple RF sources in Sec. 2.3.

Commented [KO4]: [4] In Section E.3.4.1, text states that 1 mW exemption can be considered "as well as in simultaneous transmissions (where the TER formula applies.)" Please revise this statement to clarify the 1 mW exclusion can be used in conjunction with simultaneous scenarios as described in Section E.3.4.1.

The 1 mW exemption applies at separation distances less than 0.5 cm, including where there is no separation. The 1 mW exemption is shall not be used in devices with higher-power transmitters operating in the same time-averaging period. Exposure from such higher-power transmitters would invalidate the underlying assumption that exposure from the lower-power transmitter is the only contributor to SAR in the relevant volume of tissue.

In order to leverage this exemption, a full account of how the power level was determined shall be available (as document of record, available upon FCC request, for SDoC authorizations, or filed under the RF Exposure exhibit type, in applications for certification).

2.2.2 Test Exemptions for Single Source Based on Power Thresholds Dependent on Frequency and Test Separation Distance

An exemption for the requirements of preparing an Environmental Assessment showing compliance to RF exposure SAR limits is provided in § 1.1307(b)(3)(i)(B) (see also Table 1 in Sec. 1.4.2). This exemption is applicable to the frequency range between 300 MHz and 6 GHz, is based on a power threshold that depends on both *separation distance* and frequency, and is derived from general population/uncontrolled 1-g SAR requirements.

Similarly, § 1.1307(b)(3)(i)(C) provides test exemption applicable for MPE limits. Compared to the SAR test exemption, this rule provision covers a much wider frequency range, from 300 kHz to 100 GHz, and is applicable for separation distances greater than or equal to $\lambda/2\pi$, where λ is the free-space operating wavelength. Details for these exemptions are shown in Appendix A.

Commented [KO5]: [5] For sources operating from 6-100 GHz that operate closer than lambda/2pi (for example, a 6 GHz device operating at 5 mm where lambda/2pi is ~8mm), is there an applicable exemption that can be considered? There does not appear to be an applicable exclusion when power is > 1 mW as the formula in Section A.2 is not applicable for freq > 6 GHz and Section A.1 is not applicable for distances closer than lamdba/2pi. Is it possible to extend the MPE exclusion to address distances 0 ~ lambda/2pi and/or expand Section A.2 formulas to cover higher frequencies?

In line with these § 1.1307 exemption criteria, provisions for test exemptions from the RF exposure evaluation requirements have been developed for Equipment Authorization purposes. In this case, an extension of the § 1.1307(b)(3)(i)(B) frequency range (below 300 MHz) has been devised for the exemption of the SAR testing.

Accordingly, as described in Appendix B, single power threshold function is introduced, $P_{7X}(d_{mm}, f_{MHz})$ in eq. (B.1), that encompasses all the equipment authorization cases (as reported in Table 1, Sec. 1.4.1), and provides the exemption power threshold in mW, based on the test separation distance d_{mm} in mm, and the frequency f_{MHz} in MHz.

This function then includes the exemption of § 1.1307(b)(3)(i)(B), for frequencies greater than 300 MHz, and the heuristically-derived power threshold (previously used in the v06 of this KDB publication) for frequencies less than 100 MHz.

As with the § 1.1307 Environmental Assessment exemptions, for these Equipment Authorization exemptions *test separation distances* between 0.5 cm and 40 cm, and for all RF sources in fixed, mobile, and portable device exposure conditions are considered.

Furthermore, consistently with typical use conditions and with the conservative character of the SAR test exemptions, the power thresholds considered at 0.5 cm are applicable to all distances from 0 cm to 0.5 cm.

Commented [KO6]: [6] When "SAR Test exemptions" is described here, does this only refer to the 1.1307(b)(3)(i)(B) and B.1 exemptions? How about for 1.1307(b)(3)(i)C?

When 10-g extremity SAR applies, SAR test exemption may be considered by applying a factor of 2.5 to the applicable power level thresholds.

Previous considerations (Sec. 2.1.3) apply in regard to situations where only an estimate of the conducted power can be provided.

2.3 RF Exposure Test Exemptions for Simultaneous Transmission

2.3.1 General Considerations

The following test exemptions criteria are applicable to devices that can have two or more transmitters operating at the same time. For the required evaluations, the maximum output power, duty factor, and other applicable parameters used in the determination of the exemption conditions must be the same, or corresponding to a more conservative choice, than those occurring in any operational scenario of simultaneous transmission permissible by the design of the device.

The power level used to qualify for the test exemption must be clearly justified in the RF Exposure exhibit of the application for certification. When the SAR evaluation is required, and test exemptions cannot be applied, *enlarged zoom scan* [Glossary] SAR measurements must be performed at the maximum output power required for the applicable simultaneous transmission scenarios. This power level shall account for the *tune-up tolerance* [Glossary] requirements of all transmitters, but not more than 2 dB lower than the maximum tune-up tolerance limit.

2.3.2 1-mW Test Exemption for Multiple Sources

As discussed in the Rule Exemption § 1.1307(b)(3)(ii)(A), the 1-mW exemption intended for single transmitters may also applied to simultaneous transmission conditions, within the same host device.

Proceeding similarly to the aforementioned Rule Exemption, and to what was discussed in Sec. 2.2.1, a device can obtain equipment authorization without requiring RF exposure compliance data if it is shown to operate according one of the following criteria:

a) When maximum available power of each individual transmitting antenna within the same time averaging period is ≤ 1 mW, and the nearest parts of the antenna structures of the simultaneously operating transmitters are separated by at least 2 cm.
b) When the aggregate maximum available power of all transmitting antennas is ≤ 1 mW in the same time-averaging period.

Commented [KO7]: [7] The verbiage related to "Time-averaging period" in this section could use some additional definition/clarification. Does this reference mean source-based time-averaged power?

This exemption may not be combined with any other exemption.

2.3.3 Test Exemptions for Simultaneous Transmission Based on Frequency, and Test Separation Distance-Dependent Power Thresholds

The provisions in § 1.1307(b)(3)(ii)(B) address the case of multiple source exemptions (in general for both SAR and MPE Environmental Assessment requirements) that may be considered in fixed, mobile, or portable device exposure conditions.

In a similar fashion, a device with multiple RF sources can be exempted from the requirements of RF exposure testing for the purpose of equipment authorization if the following condition is met:

$$TER = \sum_{i=0}^{N_{exe}} \frac{P_i}{P_{th,i}} + \sum_{i=0}^{N_S} \frac{\mathrm{SAR}_i}{SAR_{lim,i}} + \sum_{j=0}^{N_f} \left(\frac{\mathrm{MPE}_j}{MPE_{lim,j}}\right)^2 + \sum_{k=0}^{N_{PD}} \frac{\mathrm{MPE}_{ik}}{MPE_{lim,k}} \leq 1 \qquad (2.\,1),$$

where TER refers to a "total exposure ratio", N_{exe} is the total number of RF sources operating simultaneously (or within the same time averaging period) on a device that are being considered for the RF exposure test exemptions, P_i is the available maximum time-averaged power, or the ERP, whichever is applicable, for the i-th source, and $P_{th,i}$ is the corresponding power threshold applicable to the exemption being considered for i-th source; $P_{th,i}$ is computed based on the function $P_{7X}(d_{mm}, f_{MHz})$ in eq. (B.1) .

Commented [KO8]: [8] Equation B.1 for P7X only applies for frequencies < 300 MHz. Pth,i should apply for frequencies > 300 MHz if it meets the other exemptions in 1.1307, including the SAR and MPE based exemptions.

The remaining three sums in (2.3.3.1) are related to the number of sources that are not exempt, for which N_S, N_f, and N_{PD} referring to number of RF sources i, j, k requiring SAR, field-strength-MPE, or PD-MPE, respectively, and "*lim*" is the applicable compliance limit (see Table 1, Sec. ~~1.4.2~~1.4.1).

Commented [KO9]: [9] If exemption is applicable to both 1.1307 b)3)i)B) and 1.1307 b)3)i)C) – can either power threshold be applied when calculating the TER contribution? For example, for a source at 2.4 GHz, operating at 20mm, the exclusion threshold is 2.78 mW per 1.1307 b)3)i)B) and 7.68 mW per 1.1307 b)3)i)C). If the source power was 2 mW, would either 2/2.78 = 0.72 or 2/7.68 = 0.26 be acceptable to use in this TER calculation?

Example 1. The simplest example is for a single source, N_{exe}=1 and all $N_S = N_f = N_{PD} = 0$. In this example, the source has an estimated power of P_1 = 46 mW at 100 MHz. Based on Table B.1, there is a power threshold of 47 mW at 5 mm that is larger than P_1, thus $P_{th,1}$ = 47 mW provides an exemption for the source. Since $P_1/P_{th,1}$ = 46/47 < 1, the source is exempt, as long as the test separation distance of 5 mm can be ensured.

Commented [KO10]: [10] In Section 2.2.2, it suggests that the power thresholds at 0.5cm are applicable to all distances from 0 cm to 0.5cm. Based on that statement, would this exemption apply even at closer distances?

Example 2. In a second example, case, still with $N_S = N_f = N_{PD} = 0$, let N_{exe}=2, P_1 = 46 mW at 100 MHz, and a second source with P_2 = 100 mW at 50 MHz. While the second source would be exempt at 5 mm by itself, since from Table B.1 at 5 mm $P_{th,2}$ = 309 mW, when considered together with the source 1 the exemptions are not applicable because the condition TER = 46/47 + 100/309 is larger than 1. However, for a separation distance of 10 mm, Table B.1 yields $P_{th,1}$ = 95 mW and $P_{th,2}$ = 309 mW, then TER = 46/95 + 100/309 ≈ 0.8, thus in this case is the sources can be considered exempt.

Example 3. Finally, the case in the previous example is modified with $N_S = 1$. Now it is considered $SAR_1 = 0.32$ W/Kgkg and $SAR_{lim,1} = 1.6$ W/Kg kg (the 1-g SAR limit). Accordingly, an additional term is now contributing to the "TER budget" of Formula (2.1 3.3.1), since $SAR_1 / SAR_{lim,1} = 0.32/1.6 = 0.2$. With this term $TER_{exe} = 0.8 + 0.2 = 1$, the two sources aresimultaneous transmission testing is still exempt, but just right at the level of the allowed limit.

2.3.4 Test Exemption Based on the SAR-to-Peak Location Separation Ratio

When the exemption conditions in the previous sections do not apply, the *SAR-to-peak location separation ratio* (*SPLSR*) [Glossary] exemption procedure may be still applicable.

In this case, the simultaneously transmitting antennas in each operating mode and exposure condition combination must be considered one pair at a time to determine the *SPLSR* that qualifies for the additional test exemption. The *SPLSR* parameter is defined as

$$SPLSR = (SAR_1 + SAR_2)^{1.5}/R_i \qquad (2.2)$$

where SAR_1 and SAR_2 are the highest *reported SAR* or *estimated SAR* [Glossary] values for the two sources in the pair *i*, and R_i is the separation distance between the two sources in millimeters (see also Appendix D, Sec. D.3).For MIMO operations, all unique SAR peaks observed from the SAR measurement plots need to be considered in the SPLSR analysis to ensure Exemptions apply for all spatial simultaneous transmissions applicable.

When $SPLSR \leq 0.04$ (rounded to two decimal digits), for all antenna pairs in the configuration, then the device qualifies for 1-g SAR test exemption.

When 10-g SAR applies, the corresponding test exemption condition is $SPLSR \leq 0.10$.

AS As mentioned in Sec. 2.3.1, if any simultaneously transmitting antenna pair does not qualify for simultaneous transmission SAR test exemption, then that specific antenna pair must be tested for simultaneous SAR compliance, according to the *enlarged zoom scan* [Glossary], and volume scan post-processing procedures in KDB Pub. 865664 D01.

Commented [KO11]: [11] It may be helpful to add "For MIMO operations, all unique SAR peaks observed from the SAR measurement plots need to be considered in the SPLSR analysis to ensure Exemptions apply for all spatial simultaneous transmissions applicable." (ex. two WIFI antennas spatially apart but Cellular peaks near the slightly lower WIFI peak.)

Formatted: Highlight

Commented [KO12]: [12] It may be helpful to clarify if the intent for this procedure is for "antennas" or "modes". When certain modes share the same antenna and may transmit simultaneously there could be some differing interpretations on how to apply this guidance. We suggest that it may be more clear to change "simultaneously transmitting antennas" to "simultaneous transmissions"

3 BASIC GUIDANCE FOR RF EXPOSURE EVALUATIONS AND TEST REDUCTION

3.1 Evaluation of RF Exposure Testing Parameters for Each Transmitter

3.1.1 General Considerations on Measurements for SAR and MPE

As part of the rule changes adopted by the *2nd R&O*, and the *First Report and Order* of ET Docket No. 03-137 (FCC 13-39), §§ 1.1310(d)(4) and 2.1093(d)(3) were amended to reference KDB publications for acceptable RF exposure measurement procedures, rather than industry standards such as IEEE/IEC 62209-1528:2020, for mobile and portable devices equipment authorization purposes.

Uniform guidance and procedures for RF exposure compliance testing are given in KDB Pub. 865664 D01 for SAR,[10] and in OET Bulletin 65 [Reference] for general MPE and fixed-site RF sources. KDB Pub. 865664 D02 specifies minimum requirements for uniform reporting of RF exposure compliance technical information in equipment authorization applications. The general test methodologies described in KDB Pub. 865664 shall be applied to perform SAR measurements.

Best engineering practices shall be used for SAR or MPE evaluations, to ensure that the measurement setup does not perturb the antennas and radiating structures of the test device. For example, field perturbations may occur due to fixtures (such as clamps, holders, etc.) used to secure very small test devices, such as USB dongles, or to thin edges of devices, or due to field scattering from nearby objects. In such cases, a device shall be secured with lossless foam material to provide sufficient separation from any conducting structures, and from materials with electromagnetic characteristics significantly different from that of vacuum, so as to minimize field perturbations.[11]

3.1.2 Output Power

As required by §§ 2.1091(d)(1) and 2.1093(d)(1), RF exposure compliance must be determined at the maximum time-averaged power level, according to source-based time-averaging requirements (based on duty factor, as discussed in Sec. 2.1.3) to determine compliance for general population exposure conditions. On the other hand, time-averaging based on active power control, or similar implementations, is considered on a case-by-case basis and under PAG, as specified in KDB Pub. 388624.

Time-averaged maximum conducted output power applies to SAR and, as required by § 2.1091(c), time-averaged effective radiated power applies to MPE. These requirements also apply to test exemption considerations, as discussed in Sec. 2.1.3.

Commented [KO13]: [13] For some technologies, there may be no FCC requirement or guidance for assessing conducted power or ERP (eg: NFC at 13.56 MHz, other Part 15), and a manufacturer "tune-up" is not always available. In other cases, some ERP values required for EMC tests may not correspond to a channel power. Some guidance from the FCC may be needed in order to how the ERP should be measured specifically for the purposes of RF Exposure Exclusions, particularly when near-field exposure exemption is being considered.

Additionally, can FCC specify a broader means to characterize the transmission power level for example, including Field Strength level, Coil Current, etc?

[14] Finally, for integrated modules, it may be very difficult for the integrator to assess these power levels towards exclusion as well

3.1.3 Power Scaling

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.

[10] When new or updated standards for device RF exposure testing become available (e.g., developed by IEC TC 106 and/or IEEE ICES TC 34), updates of OET guidance documents will be considered to identify methods and procedures, or adjustments thereof if any, acceptable for use in FCC compliance testing.

[11] 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.

Some SAR measurement systems may have "power scaling" provisions to compute the 1-g SAR at a higher output power level, from measured results at a lower one.

When SAR or MPE is measured at or scaled to the maximum tune-up tolerance limit, the results are referred to as *reported SAR* or *reported MPE* [Glossary].

At minimum, the highest *reported SAR* or *MPE* results in each frequency band, and all *reported SAR or MPE* results that are either greater than 1.5 W/kg, or within 5% of the applicable MPE limits, respectively, must be clearly documented in the test reports.[12] The highest *reported SAR* results are identified on the grant of equipment authorization according to procedures in KDB Pub. 690783 D01.[13]

3.1.4 Tolerances in RF Exposure Test Methodologies

Device samples used for compliance testing must have the same physical, mechanical, and thermal characteristics, and operational tolerances as for production units.

All devices must be tested within the tune-up tolerance specification range. More specifically, each device must be evaluated for SAR or MPE compliance 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* [Glossary].

When tune-up tolerance is not required to be reported for equipment approval, RF exposure compliance must be determined using similar testing criteria, according to the highest maximum output power and tolerance allowed for production units.

The maximum output power of production units shall be within the tune-up tolerance range specified for the equipment certification. When the maximum output power of production units is lowered by widening the tune-up tolerance, additional testing may be necessary for the original test results to support compliance.

In general, known production tolerances shall be built into the compliance test, in other words, the production tolerances shall be considered in determining the magnitude of the tune-up tolerances required for a particular device (i.e., for which many units of the same device are being manufactured).

3.1.5 Test Separation Distances for SAR and MPE Evaluations

For the purposes of this document, the *test separation distances* [Glossary] required for a device to demonstrate SAR or MPE compliance must be sufficiently conservative to include all the operational scenarios that can be considered from the device design.

This minimum *test separation distance* is determined by the smallest distance from the antenna and radiating structures, or from the 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. When the device contains the antenna, the *test separation distance* is measured from the location on the device enclosure that is closer to the antenna. For *peripheral transmitters* [Glossary] and modules,[14] the antenna-

[12] 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. This applies also to simultaneous transmissions.

[13] See also KDB Pub. 865664 D01.

[14] See Section 3.4.2 for body-worn accessory SAR test configurations used by cellphones.

to-user separation distance shall be applied to determine the SAR measurement and test exemption requirements.

To qualify for test exemptions, the *test separation distances* applied must be and justified (typically in RF Exposure exhibits of the application for certification, and according to KDB Pub. 865664) by showing the actual operating configurations and exposure conditions of the transmitter, and applicable host platform requirements (e.g., as in KDB Pubs. 648474, 616217, 941225).

If RF exposure testing requirements for a specific device are covered in a KDB publication, those requirements must be satisfied before applying any SAR test exemption provisions (for example, KDB Pubs. 643646, 648474, and 616217 for handheld PTT two-way radios, handsets, and laptops and tablets, respectively).

3.1.6 Determination of the Frequencies for SAR Testing

The number of required test channels for SAR testing is determined based on an even spread across the transmission frequency band of each transmitter.[15] Accordingly, the number of test channels is given by Formula (3.1):

$$N_c = \text{Round}\left\{\left[100 \times \left(f_{\text{high}} - f_{\text{low}}\right)/f_c\right]^{0.5} \times \left(f_c/100\right)^{0.2}\right\} \quad (3.1)$$

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,
- $f_c = (f_{high} + f_{low}) / 2$ is the mid-band channel frequency
- all frequencies are expressed in MHz.

SAR testing shall be performed at the center frequency for each channel, where the channel bandwidth is computed as $B_{channel} = (f_{high} - f_{low}) / N_c$.

Commented [KO14]: [15] This sentence is confusing. What does it mean to perform SAR at the center frequency for each channel?

Commented [KO15]: [16] This formula does not result in the channel bandwidth. The channel bandwidth is determined by the protocol under testing (for example, it could be 20 MHz for LTE, 40 MHz for NR, etc). If this calculated quantity is of interest, another name or more clarification should be considered.

3.2 RF Exposure Evaluation for Simultaneous Transmission Scenarios

3.2.1 General Considerations

SAR compliance for simultaneous transmission must be considered when the maximum duration of overlapping transmissions, including network hand-offs, is greater than 30 seconds. As for single sources, when simultaneous transmission SAR evaluation is required to determine compliance the *enlarged zoom* [Glossary] scan measurement, volume scan post-processing procedures, and associated considerations described in KDB Pub. 865664 D01 must be applied.

When general population and occupational limits are applicable for different transmitters within a host device and test exemption applies for any of the transmitters subject to general population limits, compliance for simultaneous transmission is determined according to the sum of the ratios of the corresponding exposures and the applicable limits, *TER* in Formula (2.1) of Sec. 2.3.3. For these cases, evaluated SAR data should be converted to exposure ratios consistently with their applicable limit (general or occupational), before summing the ratios.

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

3.2.2 Simultaneous Transmission Scenarios with Unintentional Radiators

Per 47 CFR § 1.1307(b)(1)(i), an application for equipment authorization of any RF source, thus including unintentional radiators, must include an evaluation demonstrating compliance with § 1.1310 unless that source is exempt pursuant to 47 CFR § 1.1307(b)(3).

Accordingly, the following equipment authorization guidance provides procedures to account for the contribution of unintentional radiator sources (as defined in § 15.3(z), and here referred to as URS, for brevity) to the total RF exposure budget when that device includes one or more unintentional radiators. This policy is harmonized with the rules, yet includes provisions to minimize burdens when evaluating contributions from the unintentional radiators to RF exposure.

The general approach for assessing the RF exposure compliance of multiple simultaneously transmitting sources (regardless of whether they are URS or intentional radiators) is based on the *TER* formula (2.1), Sec. 2.3.3.

In principle, similar to the procedure for intentional radiators, the contribution of each URS can be evaluated based on its RF emissions compared to the applicable compliance thresholds defined in Table 1 of Sec. 1.4.1 (which mirrors § 1.1310). However, in consideration of the particular nature of most URS, that typically provide a very small contribution to the total electromagnetic field power that is emitted from an RF device, the RF exposure evaluation process required for equipment authorization for URS is substantially simplified, as compared to that for intentional radiators.

This guidance is applicable to both single URS (i.e., for a device where the only electromagnetic emissions between 9 kHz and 3 THz are due to the URS), as well as for end products that include other RF-source transmitters (both URS and intentional radiators): the single URS is then considered as a special case of the multiple RF source case, where the number of RF sources is just one.

Details and application examples are discussed in Appendix E.

3.3 SAR Test Reduction Guidance

3.3.1 General Considerations

SAR test reduction procedures [Glossary] allow using a particular set of test data as representative of other, similar, test conditions. This may be applied for data within different test positions (e.g., body, head, extremity), wireless modes (e.g., Wi-Fi, cellular), and frequency bands.

This test reduction process provides for the use of test data for one specific channel, while referencing that data for demonstrating compliance in other required channels for each test position of an exposure condition, within the operating mode of a frequency band. This is limited specifically to when the reported 1-g or 10-g SAR for the mid-band or highest output power channel meets any of the following conditions:[16]

Commented [KO16]: [17] In April 2022 TCB Workshop slides, guidance was given that the URS exposure only needs to be added to the total TER if the URS contribution is > 10% of the limit. It would be helpful to add that clarification to this section additionally.

Commented [KO17]: [18] Is this test reduction always applicable, even when static antenna tuning matching parameters across channels in the same band may differ? In IEC Standards, the worst case position is additionally evaluated for all channels regardless of SAR value, which may catch any higher exposure values for that band due to any custom antenna matching.

Commented [KO18]: [19] For Footnote 16: : The latest IEEE/IEC 62209-1528 requires highest power channel to be tested first instead of mid channel.

[16] SAR measurement standards such as IEEE Std 1528-2013 requires 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 > 1/2 dB, instead of the middle channel, the highest output power channel must be used.

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

3.3.2 1-g SAR Approximations Based on Area Scans for Test Reductions

Some SAR evaluation systems have the provision to approximate 1-g SAR based on the interpolated (from coarse-grid points) and extrapolated results (from surface to volumetric distribution) of a normally required complete area scan (per KDB Pub. 865664 D01). When 1-g SAR is approximated using all results from a normally required area scan, and the approximated SAR ≤ 1.0 W/kg, then zoom scan measurement is not required for that test condition. Use of this provision requires that the SAR approximation method implemented by a test system has been validated by the system manufacturer to obtain approximated SAR with an accuracy of ± 10% from the nominal value as measured using a normally required zoom scan. When all measured SAR for a frequency band, wireless mode and exposure test position combination are based on approximated SAR; i.e., maximum approximated SAR is ≤ 1.0 W/kg, a zoom scan is required for the highest approximated SAR test configuration. When unclear, users should contact the SAR system manufacturer to determine if a specific implementation fully satisfies the preceding requirement.

Commented [SL19]: [20] This 10% requirement is likely impractical for all real-use cases. We recommend input from system manufacturers on this

For purposes of applying the *SPLSR* [Glossary] approach for simultaneous transmission SAR test exemption (Sec. 2.3.4), the peak location shall be assumed to be at the phantom surface corresponding to the position indicated by the system area scan process.

For occupational exposure, zoom scan measurements are not required when the approximated 1-g SAR is less than or equal to 6.0 W/kg. When supported by the SAR measuring system, the 1-g SAR approximation procedures may be also used for 10-g SAR measurements by scaling the results according to the ratio of general population to occupational SAR limit.

For the approximated 1-g SAR to be acceptable there shall be no warning messages from the SAR measurement system during the scan. Warning conditions can happen, for example, when the system detects excessive noise in the measurements, SAR peaks too close to scan boundary, SAR peaks too sharp, or spatial resolution too low.

3.4 SAR Test Requirements for Typical Exposure Conditions

3.4.1 Head Exposure Conditions

Devices that are designed to transmit next to the ear, and operate according to the handset procedures in KDB Pub. 648474, must be tested using the *SAM phantom* [Glossary] defined in IEEE and IEC SAR measurement standards (see KDB Pub. 865664).

When antennas are near the bottom of a handset and the peak SAR location found per the area scan occurs in regions of the SAM phantom where SAR probe access can be limited, a rotated SAM phantom, or procedures in KDB Pub. 648474 D04, must be applied.

Other head exposure conditions, for example, in-front-of the face, shall be tested using a flat phantom according to the applicable KDB publication (e.g., 643646). The SAM (head) phantom is unacceptable for testing the SAR of other head and body exposure conditions. For example, testing headsets at the

SAM phantom ear location is unacceptable. Non-standard phantom measurement conditions are considered under PAG, per KDB Pub. 388624).

3.4.2 Body-worn Passive Accessory Exposure Conditions

3.4.2.1 General Considerations

RF source devices that support transmission while used with body-worn passive accessories must be tested for SAR compliance related to each body-worn condition of use. Such accessories include belt-clips, holsters, pouches, and similar passive carry accessories, for example used with cellphones.[17] SAR test guidance is provided in Sec. 5.4 for other accessories that can be attached to some types of *RF source* devices.

The general informing principle is that the selected test configurations must conservatively capture the various body-worn accessory operating configurations expected by users.

If a body-worn accessory device configuration supports only voice operations in its normal and expected use conditions (for example, belt-clips and holsters for cellphones), testing of data mode is not required for that specific accessory and *RF source* device combination. The voice and data transmission requirements must be determined according to the wireless technologies and operating characteristics of the individual device, and must be clearly explained in test reports to support the SAR results.

3.4.2.2 Test Configurations

SAR evaluations for body-worn accessory exposure conditions must be based on a single minimum *test separation distance* with the *RF source,* selected for

- all wireless and operating modes
- applicable to each body-worn accessory used by the attached device, and
- according to the relevant voice and/or data mode transmissions and operations.

A conservative minimum *test separation distance* for supporting body-worn accessories that are marketed with an *RF source* device or may be acquired by users.

This distance is determined by the *RF source* device manufacturer according to the typical body-worn accessories users may acquire at the time of equipment certification, but it cannot be more than 2.5 cm. The selected *test separation distance* must be clearly explained in the SAR report to support the body-worn accessory test configurations.

RF source devices that are designed to operate on the body of a user using lanyards or straps, or without requiring additional body-worn accessories, must be tested for SAR compliance using a conservative minimum *test separation distance* not to exceed 5 mm for all use conditions required by the device.

SAR evaluation is required for any body-worn accessories that are supplied with a device.

Body-worn accessories that do not contain conductive material structures shall be tested according to worst-case exposure configurations of the *RF source* device. For body-worn accessories with similar operating and exposure characteristics, the test can be performed for the accessory that provides the smallest *test separation distance*.

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[17] KDB Pub. 648474 D04 provides details about other SAR evaluation considerations for wireless handsets.

All body-worn accessories containing or conductive material structures, either supplied with the product, or available as an option from the device manufacturer, must be tested individually (e.g., not as a representative of a group of similar ones) in conjunction with their attached host device to demonstrate compliance.

3.4.2.3 User Instructions

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 that acquire the required body-worn accessories must be fully informed, in a way that the typical user can easily understand of the operating requirements and restrictions to maintain compliance.

Instructions on how to place and orient a device in body-worn accessories, in accordance with the test results, shall 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 that unsupported operations are avoided.

All body-worn accessories containing conductive material structures must be tested for compliance and clearly identified in the operating manual. The instructions must inform users to avoid using other body-worn accessories containing conductive material structures not specifically tested, to ensure RF exposure compliance.

3.4.3 Extremity Exposure Conditions

Devices that are designed or intended for use on extremities (i.e., hands, wrists, feet and ankles), or mainly operated in extremity-only exposure conditions, may be authorized based on extremity-only SAR evaluation. However, when the device also operates in close proximity to the user's body, SAR compliance for the body is also required.[18]

The 1-g body and 10-g extremity test exemption thresholds in Sec. 2.2 shall be applied to determine SAR test requirements. When extremity SAR testing is allowed (as opposed to the more conservative body SAR), a flat phantom shall be used.

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.

The applicability of alternative phantoms (for example, wrist or limb phantoms), and related test requirements, is covered under PAG, per KDB Pub. 388624.

When simultaneous transmission applies to extremity exposure, the test exemption provisions in Sec. 2.2 may be applied if the appropriate criteria are satisfied. As for any other SAR evaluation, for cases where no exemptions are applicable, simultaneous transmission SAR measurement is required, the enlarged zoom scan and volume scan post-processing procedures in KDB Pub. 865664 D01 shall be followed.

[18] Cellphones (handsets) are not normally designed to be used or operated in extremity only exposure conditions. The maximum output power levels of cellphones generally do not require extremity SAR testing to show compliance because the test conditions required for head and body SAR are more conservative.

3.4.4 Transmitters Implanted in the Body of a User

For body-implanted devices containing transmitters, the SAR exemption of Sec. 2.2.1 may be applicable. Implant devices that do not qualify for exemptions are considered under PAG, per KDB Pub. 388624, to determine the appropriate SAR measurement or numerical simulation procedures, or both.

3.5 SAR Evaluation Using Numerical Simulation

SAR simulations may be used to demonstrate compliance, pending approval under the PAG item NUMSIM of KDB Pub. 388624 D02.

Requirements described in the IEC/IEEE 62704 series were mostly related to the Finite Difference Time Domain (FDTD) technique, and for the frequency range of 30 MHz to 6 GHz. However, SAR simulations using other numerical techniques, such as the Finite Element Method (IEC/IEEE 62704-4 [Reference]), or the Method of Moments [Reference], and simulations of power density above 6 GHz and for mm-wave frequencies, may also be acceptable.

When numerical computation methods other than FDTD are used, the equivalent considerations as required for the FDTD method must be applied, as specified in FDTD reporting guidelines in KDB Pub. 865664 D02, and similar to IEC/IEEE 62704-1 [Reference]. In any case, a detailed description of the proposed methodology, and of the specific exposure conditions under consideration, are required as part of the PAG documentation.

This documentation shall also describe the validation of the numerical algorithm, and of its specific implementation for the case at hand, as well as provide SAR-specific details such as gram-averaging requirements, tissue dielectric parameters, anatomical models with complex exposure configurations, and models for head and body tissue dielectric parameters.[19]

Furthermore, due to the complexity of modeling transmitters, and anatomically equivalent human models, it is necessary to show in the PAG application sufficient data that validate both transmitter and human models against experimental measurements of field strength and/or SAR measurement, for test benchmark configurations.

When specific phantoms are defined (SAM or flat) for evaluating particular exposure conditions, it is required that the numerical simulations account for, models directly, the same phantom and exposure test configuration as in the actual test. This needs to be shown in the filings, and referenced in the PAG application. Anatomical (numerical) models can vary substantially, therefore, it could be problematic if different anatomical phantoms may be used where the SAR results can be higher or lower as compared to some sort of a reference (such as measurements).

[19] http://transition.fcc.gov/oet/rfsafety/dielectric.html; a KDB inquiry is required to determine tissue-equivalent dielectric parameters for frequencies not available at this link.

4 RF EXPOSURE GUIDANCE FOR TRANSMITTERS WITH MODULAR GRANT OPERATING IN HOST DEVICES

4.1 RF Exposure Considerations for Modular Grant Transmitter

4.1.1 *Modules vs.* Other Transmitters

This section applies to all transmitters authorized with FCC modular grant (see also KDB Pub. 996369 D01, here referred to as modular transmitters or *Modules*) that operate while installed on a different end-use product (referred to as a host, host product, host device, or end product).

As discussed in KDB Pub. 996369, *Module* grantees are required to make available comprehensive instructions that specify and illustrate conditions and limitations for authorized uses under the modular grant.

However, host manufacturers have responsibility to ensure that transmitters operating in a host device remain compliant in all transmission scenarios supported by all host configurations, thus including both standalone (i.e., with the *Module* operating by itself; see Sec. 4.2) and simultaneous transmission operations (see Sec. 4.3), that is the *Module* operating along with other transmitters on the host device.

4.1.2 Host Form Factor Considerations

For transmitters integrated within portable device end products characterized by a relatively small form factor, such as cellphones (subject to SAR testing for held-near-ear operations, etc.), in general SAR compliance is highly influenced by aggregate effects due to close proximities among antennas and other device structures, and the close proximity of a user. SAR test data from a separate pre-existing modular approval FCC ID generally is not relevant for compliance demonstrations of such end products.

This differs, for example, from a *Module* with its antenna added in the display of a laptop computer. In that case, an added Module with its antenna may have little or no impact on SAR compliance of an overall end product that contains other existing transmitters. However, if the same *Module* is incorporated in a smaller form factor host device, a re-evaluation of the transmitting features supported by the complete end product is generally necessary to demonstrate SAR compliance. Host integration considerations for *Modules* to be installed in hosts where they will be operating simultaneously with other transmitters is discussed in Sec. 4.3.

4.1.3 Certification Strategies and Considerations

When equipment certification approval is required for changes related to test data of transmitter modules (such as additional hosts, or antenna configurations), in some cases compliance may be addressed through Class II permissive changes submitted by the *Module* grantee.[20] This would be the case when, additional equipment certification is needed because the *Module* was granted for the mobile device category, but needs to be installed in a host to operate under portable device conditions.

The most rigorous approach is to always address compliance of all transmitters in a host using a new equipment certification filing submitted by the host manufacturer, where a new FCC ID is issued for the host product.

[20] See also KDB Pub. 178919 D01, Permissive Change Policies.

Alternatively, the host device manufacturer may choose to file for a change of FCC ID for modular transmitters that require additional approval, or for any other modular transmitter that may be deemed most critical for compliance purposes (e.g., with the highest maximum output power). At that point, any subsequent approval issue (such as permissive changes) will be under the responsibility of the host manufacturer.[21]

The host manufacturer may also consider a *modular* and *dedicated host mixed approach*. For example, as described in KDB Pub. 616217 D04, this approach allows the integrator to address compliance for transmitters with higher output power and SAR in dedicated host configurations, and to apply the modular approach to certain low power transmitters that have low SAR, or that do not require any SAR testing.

This mixed approach also simplifies the host integration of low power transmitters by taking into consideration their impact on overall RF exposure during the SAR testing of the higher power transmitters, thus without requiring separate assessment for each low power transmitter in the host device. The grantee of a dedicated host, and/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.

In general, modular transmitters are approved according to the operating configurations and exposure conditions tested for compliance to support a variety of possible (i.e., "qualified") host device configurations. The qualified installation and use conditions must be clearly identified in the equipment approval and OEM integration requirements, including all restrictions.

For instance, for modules integrated in hosts that are designed to operate as *portable* devices, the module grants shall consider applications in portable device scenarios, as well as intended or expected conditions involving simultaneous transmitter operations. Accordingly, the equipment certification records shall clearly outline the operating conditions and limitations.

When certain types of components, operating parameters, or control functions that manage the operation of a transmitter are not fully contained within an 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 a host product or through other mechanisms,[22] SAR compliance and equipment approval should be limited to a particular dedicated host device.[23] Like for any other transmitter, *Module* compliance for certification shall be always demonstrated for the most conservative conditions from an RF exposure compliance perspective, thus operating at maximum power and for all the frequency bands of operation. This will also address cases where the *Module* operations can be controlled by the host product, or through other external mechanisms.

[21] Change of ID (§ 2.931) filings require coordination between an original grantee and the third-party applicant.

[22] These types of operations include certain power reduction and proximity sensor functions, or motion detection functions implemented or provided by host devices. Approval policies for these types of operations in different host platforms (for example, tablets and laptops) may vary due to operating requirements and other RF coupling and exposure concerns. See also KDB Pub. 594280 D01 and D02 for software security requirements.

[23] See also, for example, considerations on module manufacturer and host product manufacturer responsibilities described in KDB Pubs. 616217 D04 and 996369 D04. In addition, the Commission has initiated a rulemaking including various considerations for end products incorporating certified modular transmitters in ET Docket No. 15-170 (FCC 15-92, 30 FCC Rcd 7747, paras. 60 et seq.). Further updates to test and compliance guidance and requirements for *Modules* will be determined after the final rules are adopted.

4.2 Requirements for Modular Transmitters Operating Standalone in Host Products

4.2.1 General Considerations

The following sections describe the requirements for integration of *Modules* while operating in a standalone mode within host products, i.e., while no other transmitter in the host product is transmitting at the same time. The basic consideration that is being addressed in this case is the fact that physical structures in a host product may change the RF exposure evaluation results, as compared what was obtained with the *Module* operating by itself, without any host device.

This could be the case, for instance, when conducting structures in the host are causing reflections, changing the pattern of the *Module* RF emissions.

Furthermore, placement of a *Module* in a host device with small form factor could alter the field pattern of adjacent transmitters, thus changing the RF exposure characteristics of the host, even when the *Module* is not transmitting simultaneously with other transmitters.

The requirements of this Sec. 4.2 shall be applied also for the cases (the most common ones) of *Module* integration in a host where other transmitters installed in the host may operate at the same time. For those conditions, there are, however, additional requirements that must be met, as discussed in Sec. 4.3.

4.2.2 *Module* Integration for Standalone Operations in non-Specific Host Products

A *Module* can be operated in a standalone mode (i.e., without any other host-product transmitter operating simultaneously) within any host that,[24] as long as:

- the *Module* qualifies for the "1 mW" SAR test exemption of Sec. 2.1,

or

- the *Module* highest 1-g *reported SAR* is ≤ 0.4 W/kg, the *energy coupling enhancement condition* [Glossary] of Appendix C is satisfied, and the 1-g *reported SAR* required by the *energy coupling enhancement* test is ≤ 0.45 W/kg.

4.2.3 *Module* Integration for Standalone Operations for Specific Sets of Host Products with Permissive Change Provision

A *Module* can be operated in standalone mode in a specific sets of host products (e.g., tablets, laptops), when the highest 1-g *reported SAR* is greater than 0.4 W/kg and less than or equal to 1.2 W/kg.[25]

To qualify for this SAR compliance integration scheme, the *Module* needs to be approved for specific sets of host products in the initial filing for the *Module* certification.

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[24] Transmitters and antennas in devices 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. Accordingly, KDB Pubs. 648474 and 616217 provide further testing requirements for standalone *Modules* and antennas to qualify for installation in host products.

[25] Different hosts within the specific sets of hosts shall be tested independently when SAR characteristics are expected to change due to different operating configurations.

Additional hosts may be added via Class II permissive changes, as long as the additional hosts are shown to be providing essentially the same electromagnetic environment as for the sets of hosts listed in the original *Module* certification.

4.2.4 *Module* Integration for Standalone Operations for a Single Specific Host Only

When a *Module* highest 1-g *reported SAR* is > 1.2 W/kg, equipment certification requires a PAG for case-by-case consideration.

Commented [KO20]: [21] There does not appear to be a PAG code for this scenario in 388624

4.3 *Module* Integration for Simultaneous Transmission Operations in Host Products

As mentioned in Sec. 4.2.1, standalone integration criteria for *Modules* of Sec 4.2. are not sufficient for the integration in hosts where simultaneous transmissions (due to other transmitters on the host) may occur.

To obviate to the difficulties to ensure compliance while using modular transmitters for all possible host configurations, the following provision may be applied: *Modules* that can be integrated standalone, are also allowed for installation in a portable device host product for simultaneous transmissions as long as the SPLSR condition (Sec. 2.3.4) is satisfied, when computed between the *Module* radiating structure and each antenna of the host device.

This policy practically will prevent use of *Modules* in highly integrated host devices, where close proximity between antennas and users may lead to non-compliance due to an unaccounted *Module* contribution. Therefore, as indicated also in Sec. 4.1.2, the proper approach for compact form-factor host products is to perform SAR testing with all transmitters that can be in operation at the same time in place, without relying on components having modular grants.

The procedures of Secs. 2.3, 3.2, and Appendix D shall be applied to evaluate SAR compliance for simultaneous-transmission operations of multiple transmitters operating with host products.

5 SAR TEST GUIDANCE FOR UNIQUE HOSTS AND EXPOSURE CONDITIONS

5.1 Handheld Push-to-Talk Two-way Radios

5.1.1 General

Generally, the operating configurations of handheld push-to-talk (PTT) two-way radios[26] require SAR testing for exposure conditions that consider positioning both in front of the operator's face and with a body-worn accessory (such as a holster).

A *test separation distance* no larger than 25 mm must be applied for any in-front-of the face SAR test (for the purpose of demonstrating both compliance and qualifying for an exemption).

Handheld PTT two-way radios that support held-to-ear operating mode must also be tested according to the exposure configurations required for handsets in KDB Pub. 648474 D04.[27]

For handheld PTT radios operating in the 100 MHz to 1 GHz range, according to that qualify for general population/uncontrolled exposure requirements (as discussed in Sec. 1.6.1), properly justified duty factor conditions applied to the maximum conducted output power, for a given time-averaging window, may lead to reduction of the effective power and may qualify for SAR test exemption. For handheld PTT two-way radios operating above 1 GHz,[28]~~[31]~~ a KDB inquiry must be submitted to obtain FCC approval for the SAR test procedures.

5.1.2 Duty Factor Considerations

For radios that operate with a mechanical PTT button, in consideration of typical average use conditions, a duty factor of 50% shall be applied to determine compliance.[28] However, for radios where typical use conditions lead to operations at higher duty factors, compliance shall be shown under the maximum duty factor (up to 100%) that reflects the most conservative conditions.

For PTT radios with Bluetooth or voice activated transmission capabilities a duty factor of 75% shall be applied, as a conservative use-case estimate of an uneven transmit-receive pattern in the communication between two operators. When time-division multiple access (TDMA) technology is used, a duty factor consistent with the time slot partitioning shall be taken into consideration.

When duty factor estimates are based on subjective, or use-dependent considerations (e.g., not related to built-in design features), the PAG item DUTFCT may be applicable (see KDB Pub. 388624 D02).

5.1.3 Test Conditions with Body-Worn Accessories

In general, when body-worn with accessory operations are supported by a device, SAR testing per the requirements in Sec. 3.4.2 shall be applied. For manufacturer-provided body worn accessories, the actual separation distance between the antenna and the operator body can be considered, so long as it is no larger than 25 mm.

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[26] Typically handheld PTT two-way radios operate under Part 90, Part 95, Part 80.

[27] This provision does not apply to cellphones with PTT options, since cellphones must be tested in more conservative configurations that include SAR compliance at 100% duty factor.

[28] Typically half-duplex voice communications.

When a body-worn accessory is not supplied by the PTT radio manufacturer, a *test separation distance* no larger than 5 mm (consistently with as prescribed for other portable-device handsets), must be considered to determine body-worn accessory SAR test exemption and evaluation while including the duty factor. This distance is chosen, conservatively, to account for a variety of typical device shape designs.

When occupational/controlled exposure limits qualify, the procedures in KDB Pub. 643646 D01 are required.

5.2 Wristwatch and Wrist-Worn Transmitters

5.2.1 SAR Evaluation

Transmitters that are built-in within a wristwatch, or similar wrist-worn devices, typically operate in "speakerphone mode" for voice communication, with the device worn on the wrist and positioned next to the mouth. Operations next to the mouth requires 1-g SAR measurement, while the wrist-worn condition requires 10-g extremity SAR measurement.[29]

SAR test exemptions for 10-g extremity with the wrist, and 1-g with face exposure condition need to be applied. When SAR evaluation is required, next-to-mouth use is evaluated with the front of the device positioned at 10 mm from a flat phantom to measure head SAR. The wrist bands shall be strapped together to represent normal use conditions.

SAR for wrist exposure is evaluated with the back of the device positioned in direct contact against a flat phantom. The wrist bands shall be unstrapped and touching the phantom. The space introduced between the transmitter and the flat phantom must be representative of actual use conditions.

5.2.2 Wrist-worn Device Test Conditions that Require PAG

Per KDB Pub. 388624 D02 (item PHANTM), a PAG following the proper preliminary inquiry is required for the device positioning and related SAR probe access issues when any variation of the KDB published test procedures is being considered. This includes, but is not limited to, the following test configurations:

- neck, or a curved head region of the SAM phantom

- alternative phantoms that are designed for testing specific product and associated exposure conditions for example, a wrist or limb phantom.

- other device positioning; for example, devices with rigid wrist bands or electronic circuitry and/or antenna(s) incorporated in the wrist bands.

These test configurations are applicable only to devices that are worn on the wrist and cannot support other use conditions. Accordingly, it is a compliance requirement that the operating restrictions must be fully demonstrated in both the test reports and user manuals.

5.3 Duty Factor Considerations

For devices without any voice support that transmit only intermittently in data mode, the time-averaged RF exposure can be very low, as compared to the peak level. These types of operations may include

[29] It must be ensured that wrist operations are limited to the wrist only. Operations with a device worn on the arm above the wrist require 1-g body SAR compliance.

location trackers, emergency alert responders, point of sales (POS) devices, some black-and-white display e-readers, and devices supporting location-based services.

Voice-mode communication generally does not qualify for duty factor considerations; however, exceptions may be considered for documented cases of very short (e.g. seconds) and infrequent transmissions. For these situations, a PAG according to KDB Pub. 388624 D02 (item DUTFCT) shall be submitted. Once a duty factor has been established, if the SAR test exemption does not qualify and a SAR evaluation is required to demonstrate compliance, that duty factor may be applied to scale the measured SAR.[30] In general, when a defined transmission duty factor cannot be inherently associated with the device operations, the source-based time-averaging process for SAR evaluation can still be applied if an acceptable worst case (i.e. most conservative) transmission duty factor can be determined.

In these cases, the source-based time-averaging process for SAR evaluation can be applied, and possibly leading to SAR test exemption conditions (Sec. **Error! Reference source not found.**~~2.2.2~~) with the minimum *test separation distance* required for all applicable operating configurations. For these cases, the duty factor shall be either consider the worst-case scenario (up to 100 %, if necessary) or requires PAG submission per KDB Pub. 388624 D02.

For all these cases, the supporting details for determining the duty factor, in reference to the full range of operating configurations and exposure conditions, must be fully documented in a SAR analysis report, according to KDB Pub. 865664 D02.

5.4 Accessories for RF Devices

5.4.1 General Remarks

RF source devices equipped with transmitters (which includes, but is not limited to, mass-produced consumer electronic devices) may be provisioned with accessories, e.g., in the form of snap-on sleeves, holders, plug-in components, etc. Some of these accessories may also contain built-in transmitters, or attachments that contain passive radiating structures or antenna elements.

In general, accessories that contain transmitters may support standalone and/or simultaneous transmission while operating independently or with the device they are connected to (here referred to as “target device”). Body-worn accessories may impact the SAR characteristics of the target device due to changes in the actual antenna-to-user *test separation distance*. For these reasons, accessories may change the operating characteristics of a device beyond the approved limits. Manufacturers may choose to consider such accessories in their device certification process.

In most cases, only OEM-provided accessories (the original equipment manufacturer, OEM, refers here to the target device which the accessory is connected to) could be considered in the original test compliance process. Exceptions are related to cases when specific commercial agreements between different manufacturers exist. For non-OEM accessories, as well as OEM accessories made available after the initial certification of the target device, a new certification would be required. These matters are discussed in detail for example in KDB Pub. 648474 D04.

5.4.2 OEM Accessories without RF Transmitters

When a new accessory becomes available from the original equipment manufacturer (OEM, referring to the host device where the transmitter is located) and does not contain any transmitter, compliance of the host and accessory may be addressed according to Class I or Class II permissive change procedures (see KDB Pub. 178919).

[30] Scaling for maximum tune-up tolerance must be considered separately.

In general, the SAR distribution and exposure conditions of the original device tested without the introduced accessory may differ from the case with the accessory (e.g., due to presence of metal structures in the accessory, changes to possible exposure conditions, and of the applicable *test separation distance*.

The permissive change process may only be pursued by the device grantee (the OEM), but may also cover non-OEM accessories, i.e., from third-party manufacturers. The only other option available to the third-party accessory manufacturers is that of seeking a change of FCC ID followed by a Class II permissive change (where now the third-party accessory manufacturer has also become the grantee of the device). This process shall be done in accordance with § 2.931, and requires coordination between an original grantee and the third-party applicant.

5.4.3 Accessories with RF Transmitters

Accessories containing transmitter(s), either made available from the target device OEM, or through a third-party, are typically devices that obtain their own equipment authorization.

In general, but not necessarily, the accessory may also support standalone operations, i.e., may be able to operate both with and without the target device; however, in this context the accessory is qualified as such due to its specific design oriented to support the operation of another (target) device.

Accordingly, the certification of the accessory will require a grant comment specifying that "*the RF transmitter on this device has not been tested for FCC compliance while operating in connection to another a target device*" (or equivalent wording).

For devices either certified or authorized using SDoC, the same statement shall be also provided in the product user's manual, or with any other related annex documentation.

If the accessory manufacturer chooses to test their product with one or more target devices, this shall include operation for simultaneous transmissions (i.e., accessory and target transmitters both operating, in whatever combination allowed by design), with the target(s) also operating at maximum power. For instance, one may consider a wireless charger (the accessory) connected to a handset (the target) transmitting with LTE plus WLAN in hotspot mode, etc.

When these target devices are tested, then a list of models for which compliance was demonstrated may be added to the previously mentioned grant comment statement.

Accessories with built-in transmitters that are designed to support target devices without transmitters, are to be considered as per Sec. 5.4.2, since now the accessory assumes the role of the actual target device. In practice, for the context of this policy, the "accessory" and "target" nomenclature does not have an inherent meaning, and these considerations can be generalized to any device that is designed to operate with device, with no specific hierarchy between the two; i.e., devices interacting in a peer-to-peer fashion.

6 EVALUATION GUIDANCE FOR MOBILE DEVICE RF EXPOSURE CONDITIONS

6.1 General Considerations for Transmitters Used in Mobile Device Exposure Conditions

6.1.1 Mobile Devices

Devices operating in standalone exposure conditions refer to those devices that either contain a single transmitter, or multiple transmitters that do not transmit simultaneously.

Mobile devices, as defined in § 2.1091 along with their applicable RF exposure limits, are characterized by the requirement of maintaining a minimum *test separation distance* ≥ 20 cm between any radiating structure of the device and nearby persons.

This *test separation distance* requirement must be defined for the most conservative exposure conditions, and must be fully supported for all 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).

For situations as described in § 2.1091(d)(4), or in general when devices designed for mobile operations have the potential to operate in portable device (per § 2.1093) exposure conditions, compliance must be demonstrated for those specific portable conditions, since they represent the worst-case scenario from the RF exposure perspective.

6.1.2 Exemptions from Compliance Testing

The guidance of Sec. 2 is used to determine test exemptions for all fixed, mobile or portable devices. For instance, as applicable, the 1-mW test exemption (Sec. 2.2.1), as well as both SAR test and MPE test exemption criteria (Secs. 2.2.2 ~~2.2.2 and 2.2.3~~) may be used.

In cases where cable losses or other attenuations are applied to determine compliance, the most conservative operating configurations and exposure conditions must be evaluated.

When applying the test exemption provisions of Sec. 2, the minimum *test separation distance* is used to determine if the device qualifies. When a device does not qualify for those test exemptions, the applicable limits of Sec. 1.4.1 - Table 1 shall be used to determine compliance, either via MPE measurement, or through numerical simulation.

It is also to be noted that, when numerical simulation is used for RF exposure evaluations, a PAG is required, as described in KDB Pub. 388624.

6.1.3 Simplified MPE Estimate for Qualified Fixed Installations

For § 2.1091 mobile devices that are installed to operate in stationary configurations (for example, on walls or ceiling), a grant certification for fixed transmitter is allowed. For these cases, MPE compliance evaluations shall be provided according to a conservatively defined minimum *test separation distance* that reflects the worst-case exposure conditions. These evaluations are filed as part of the exhibits that are required to be approved for certification purposes. When numerical simulations is used, the PAG procedure, as detailed in KDB Pub. 388624 D02, is required.

6.2 MPE Measurement Guidelines for Mobile Devices

6.2.1 Antenna Considerations

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.

Testing in all directions may be avoided when symmetry considerations can be invoked, for example, in the case of an omni-directional antenna. These conditions must be clearly demonstrated in test reports.

For the purpose of equipment authorization, as specified in Table 1, plane-wave equivalent power density limits can be considered for frequencies greater than or equal to 300 MHz, while electric and magnetic field strength limits are imposed for frequencies less than 300 MHz.

Information about RF exposure evaluation equipment and procedures is available in the latest edition of OET Bulletin 65.

6.2.2 Spatial Averaging

For non-directional antennas, MPE evaluation points shall be along radials extending from the antenna (axis) that are no more than 30° apart. The estimated direction of the maximum exposure (e.g., based on the antenna geometry) shall be aligned with one of the radials along which the measurements are performed. When the measurements on two contiguous 30-deg radial differ by more than 2 dB, then a measurement on the radial in between should be also considered, and iterate the process until this 2 dB condition is met.

For exposures conditions referring to a standing person, spatial averaging of the MPE data along the vertical direction can be applied to determine the MPE to be used for compliance, using 1.8 m as representative of the longest dimension of a typical adult. In this case spatial averaging is not required on horizontal planes.

Similarly, spatial averaging along the horizontal planes can be applied for situations where the exposed person is aligned horizontally (e.g., a patient in a medical facility). In general, spatial averaging can be applied along the longest dimension referred to the typical orientation of a person's body, for the given exposure scenarios under consideration.

For each specific exposure condition, the evaluation points along the longest dimension (e.g., vertical) shall use a spatial resolution of 10 cm or less, and shall extend at least 10 cm beyond the exposed portions of a person's body, or until the evaluated results are less than 10% of the MPE limit. For exposures occurring next to the ground or next to a ground plane, the evaluation points shall be at least 10 cm above the ground.

6.2.3 Tests for Devices with Multiple Frequencies and Antennas

When the antenna of a device transmits in multiple frequency bands, the most restrictive *test separation distance* among all frequency bands is required to ensure compliance for the antenna installation.

When specific antennas are not identified in the installation requirements, for instance when different antennas or antennas with different gain requirements can be used, the maximum antenna gain allowed for each frequency band must be determined according to the most restrictive *test separation distance* required for all of the frequency bands.

The required antenna type, radiating characteristics, antenna gain, and the requirement of a unique minimum *test separation distance* must all 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.

6.3 Transmitters Used in Mobile Device Exposure Conditions for Simultaneous Operations

In order to determine if a mobile device with multiple transmitters qualifies for simultaneous transmission test exemption, the basic approach is to evaluate MPE compliance for each transmitter, either by measurement or computational modeling (the latter being subject to PAG). In this way one can assess if each transmitter qualifies for the standalone test exemptions of Sec. 2.2.

When applicable, a less restrictive approach is to use the simultaneous transmission test exemption procedure described in Sec. 2.3.

When transmitter modules are incorporated in host devices that qualify for RF exposure test exemption and no other testing or equipment approval is required, the standalone and simultaneous transmission configurations and test exemption conditions processed by the grantee via Class I permissive changes.

Appendix A
Test Exemptions for Single RF Sources - § 1.1307(b)(3)

A.1 MPE Test Exemption in § 1.1307

An exemption from the requirements evaluation of compliance with the MPE exposure limits in § 1.1310 is provided in § 1.1307(b)(1)(i)(B) based on a frequency and separation-distance dependent power threshold.

An exemption from the Environmental Assessment requirements of evaluation of compliance with the MPE exposure limits in § 1.1310 is provided in § 1.1307(b)(1)(i)(B), based on a frequency and separation-distance dependent power threshold. These thresholds were derived from the basic specifications on Maximum Permissible Exposure (MPE) considered for the FCC rules in § 1.1310(e)(1), thus the nomenclature "MPE Test exemption."

This exemption is applicable if effective radiated power (ERP) of the RF device is less than the ERP_{20cm} in Formula (A.1.1), repeated from § 2.1091(c)(1) and § 1.1307(b)(1)(i)(B):

(A.1.1)

In alternative, the ERP threshold may be established based on the Table A.1.1 (repeated directly from the § 1.1307(b)(1)(i)(B)), when the minimum separation distance from the body of a nearby person at which the source operates, is at least λ/2π, where λ is the free-space operating wavelength in meters.

TABLE A.1.1—Exemption THRESHOLDS FOR SINGLE RF SOURCES

RF Source Frequency			Minimum Distance			Threshold ERP
f_L MHz		f_H MHz	$\lambda_L / 2\pi$		$\lambda_H / 2\pi$	W
0.3	–	1.34	159 m	–	35.6 m	1,920 R^2
1.34	–	30	35.6 m	–	1.6 m	3,450 R^2/f^2
30	–	300	1.6 m	–	159 mm	3.83 R^2
300	–	1,500	159 mm	–	31.8 mm	0.0128 $R^2 f$
1,500	–	100,000	31.8 mm	–	0.5 mm	19.2R^2

Subscripts L and H are low and high; λ is wavelength.
From § 1.1307(b)(3)(i)(C), modified by adding Minimum Distance columns.

Table A.1.1 applies to any RF source (i.e., single fixed, mobile, and portable transmitters), and specifies power and distance criteria for each of the five frequency ranges used for the MPE limits. The thresholds are based on the general population MPE limits with a single perfect reflection, outside of the reactive near-field, and in the main beam of the radiator. If the ERP is not easily obtained, then the available

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Commented [KO21]: [22] Per 1.1307(b)(3)(i)(B) - this formula is applicable between 20 cm and 40cm and not generally for all distances. This limitation should be clarified unless the intent was to expand the exclusion.

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Commented [KO23]: [24] For sources operating from 6-100 GHz that operate closer than lambda/2pi (for example, a 6 GHz device operating at 5 mm where lambda/2pi is ~8mm), is there an applicable exemption that can be considered? There does not appear to be an applicable exclusion when power is > 1 mW as the formula in Section A.2 is not applicable for freq > 6 GHz and Section A.1 is not applicable for distances closer than lamdba/2pi. Is it possible to extend the MPE exclusion to address distances 0 ~ lambda/2pi and/or expand Section A.2 formulas to cover higher frequencies?

maximum time-averaged power may be used (i.e., without consideration of ERP) only if the physical dimensions of the radiating structure(s) do not exceed the electrical length of λ/4 or if the antenna gain is less than that of a half-wave dipole (1.64 linear value).

If the ERP of a single RF source is not easily obtained, then the available maximum time-averaged power may be used in lieu of ERP if the physical dimensions of the radiating structure(s) do not exceed the electrical length of λ/4 or if the antenna gain is less than that of a half-wave dipole (1.64 linear value).

Commented [KO24]: [25] These paragraphs appear to be repeated?

A.2 SAR Test Exemption in § 1.1307

Exemptions from an environmental assessment showing compliance to SAR limits in § 1.1310 are derived based on frequency, power, and separation distance of the RF source. These exemptions are assessed through a formula that defines the thresholds for either available maximum time-averaged power or maximum time-averaged ERP, whichever is greater.

If the ERP of a device is not easily determined, such as for a portable device with a small form factor, the applicant may use the available maximum time-averaged power exclusively if the device antenna or radiating structure does not exceed an electrical length of λ/4.

As for devices with antennas of length greater than λ/4 where the gain is not well defined, but always less than that of a half-wave dipole (length λ/2), the available maximum time-averaged power generated by the device may be used in place of the maximum time-averaged ERP, where that value is not known.

The separation distance is the smallest distance from any part of the antenna or radiating structure for all persons, during operation at the applicable ERP. In the case of mobile or portable devices, the separation distance is from the outer housing of the device where it is closest to the antenna.

The exemption formula of § 1.1307(b)(3)(i)(B) shall only be used at separation distances from 0.5 cm to 40 cm and at frequencies from 0.3 GHz to 6 GHz (inclusive). This formula applies for single fixed, mobile, and portable RF sources with available maximum time-averaged power or effective radiated power (ERP), whichever is greater, of less than or equal to the power threshold in mW, here referred to as $P_{1.1307}(d_{cm}, f_{GHz})$ and expressed as

Commented [KO25]: [26] This statement should be harmonized with section 2.2.2 text which indicates that the threshold at 0.5cm is applicable for all distances 0 to 0.5 cm

(A.2.1),

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where d_{cm} is the distance in *cm*, f_{GHz} is the frequency in GHz, and Formula (A.2.2) is the same as in Formula (A.1.1), repeated here for convenience)

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(A.2.2),

and

(A.2.3)

SAR test exemptions are constant at separation distances between 20 cm and 40 cm to avoid discontinuities in the threshold when transitioning between SAR-based and MPE-based exemption criteria at 40 cm, considering the importance of reflections.[31]

Examples for computed values are shown in Table A.2.1, for illustration only.

When 10-g extremity SAR applies, SAR test exemptions may be considered by applying a factor of 2.5 to the SAR-based exemption thresholds.

Table A.2.1—Example Power Thresholds (mW)

		Distance (mm)									
		5	10	15	20	25	30	35	40	45	50
Frequency (MHz)	300	39	65	88	110	129	148	166	184	201	217
	450	22	44	67	89	112	135	158	180	203	226
	835	9	25	44	66	90	116	145	175	207	240
	1900	3	12	26	44	66	92	122	157	195	236
	2450	3	10	22	38	59	83	111	143	179	219
	3600	2	8	18	32	49	71	96	125	158	195
	5800	1	6	14	25	40	58	80	106	136	169

[31] Order, 34 FCCR 11711, para. 46, n. 137.

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Appendix B
Equipment Authorization RF Exposure Test Exemptions

B.1 Exemption Power Threshold Extended to frequencies below 300 MHz

In KDB Pub. 447498-v06, power thresholds were established for SAR exemption purposes from 100 kHz up to 6 GHz. The formulas that provided the exemption levels were derived from best fit of measured and simulated emission conditions covering a wide range of realistic application scenarios.

In § 1.1307 an exemption criterion from the environmental assessment requirement is provided for the frequency range from 300 MHz to 6 GHz. The same formulation of § 1.1307 is followed in this document, for to define the conditions under which SAR evaluation will be not required for the purpose of equipment authorization.

Furthermore, the two aforementioned exemptions are merged, by extending in a continuous fashion the formulas § 1.1307 below 300 MHz, and joining, still continuously, the "v06" prescriptions at and below 100 MHz, and down to 100 kHz, that is the lower limit for which SAR represents a suitable evaluation of the RF exposure effects.

Accordingly, a power threshold function P_{7X}, extended to cover the frequency range from 100 kHz to 6 GHz, and measured in mW, is then defined as:

$$P_{7X}(d_{mm}, f_{MHz}) := \begin{cases} P_{6S}(d_{mm}, f_{MHz}) & f_{MHz} \le 100 \\ P_{6to7}(d_{mm}, f_{MHz}) & 100 < f_{MHz} \le 300 \\ P_{7}(d_{mm}, f_{MHz}) & 300 < f_{MHz} \end{cases} \quad \text{(B.1),}$$

Commented [KO26]: [27] From Equation B.1, it seems P7x covers frequencies < 300 MHz and below. But throughout this document, it's indicated that P7x covers up to 6 GHz. For completeness, the frequencies between 300-6 GHz should be clarified in this formula

where the different terms are defined as follows:

- d_{mm} is the distance in *mm*
- f_{MHz} is the frequency in MHz
- P_{6S} is a "smoothed" version (as shown further in Sec. B.3) of the power threshold in mW defined in KDB Pub. 447498 v06 Sec. 4.3.1, and in Sec. B.2.
- P_{6to7} is a transition function (in mW) between P_{6S} and P_7 , also further defined in Sec. B.5
- P_7 is the power threshold in mW defined in KDB Pub. 447498 v07 before this extension below 300 MHz, as further detailed in Sec. B.4.

Commented [KO27]: [28] For simplicity, can the mid channel frequency of the transmission band be used in the calculations in this document when determining the exclusion levels? Or must the frequency within the transmission band that results in most conservative exclusion be considered? With the complex formulas being used, the relationship between frequency and exclusion level may not be easily identified.

A plot of the function P_{7X} is shown in Fig. B.1.

The definition of the P_{7X} reflects the complexity of the exemption criteria previously developed (for the mentioned "v06") that heuristically include a wide range of both frequencies and separation distances.

The details of the P_{7X} derivation are discussed in the following sections, but for a more immediate application one shall refer to the following Tables B.1 through B.4, that provide the expressions to apply for the different ranges of frequency and separation distance, along with pre-calculated values of P_{7X} for sample set of parameter.

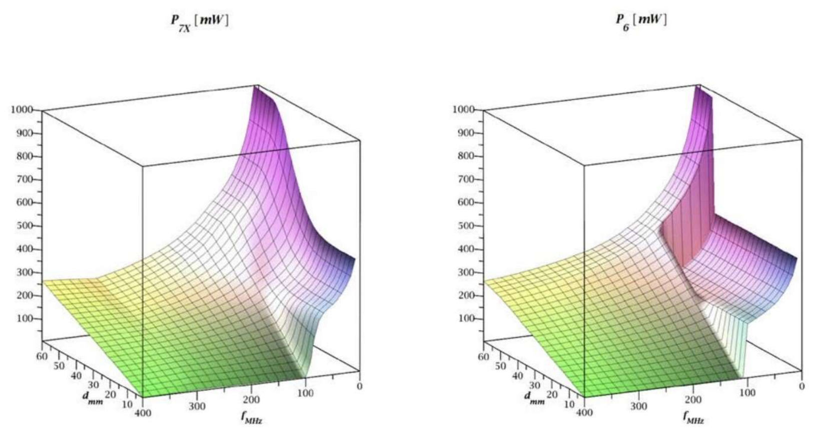

***Fig. B.1** – $P_{7X}(d_{mm}, f_{MHz})$, the "extended" power threshold for SAR test exemptions, vs. $P_6(d_{mm}, f_{MHz})$, that is to the power threshold version in v06 of this publication*

– Table B.1 –

$P_{7X}(f_{MHz}, d_{mm})$ – Exemption power threshold in mW for less than 100 MHz

$f_{MHz} \leq 100$

$d_{mm} \leq 50$

$$P_{7X}(d_{mm}, f_{MHz}) = S_f(f_{MHz}) \cdot P_{431a}(d_{mm}, f_{MHz}) + (1 - S_f(f_{MHz})) \cdot S_d(d_{mm})\, P_{431b1}(50., 100.) \cdot \left(1 + log10\left(\frac{100.}{f_{MHz}}\right)\right)$$

Calculated values of $P_{7X}(d_{mm}, f_{MHz})$ in mW

MHz	*5*	*10*	*15*	*20*	*25*	*30*	*35*	*40*	*45*	*50 mm*
10	474	475	478	487	513	570	667	792	904	949
25	380	381	383	390	411	457	534	635	724	760
50	309	309	311	317	334	371	434	515	588	617
75	249	254	260	270	287	321	376	445	507	535
100	47	95	142	190	237	285	332	379	427	474

$50 < d_{mm}$

$$P_{7X}(d_{mm}, f_{MHz}) = S_f(f_{MHz}) \cdot P_{431b1}(d_{mm}, f_{MHz}) + (1 - S_f(f_{MHz})) \cdot P_{431b1}(d_{mm}, 100.) \cdot \left(1 + log10\left(\frac{100.}{f_{MHz}}\right)\right)$$

Calculated values of $P_{7X}(d_{mm}, f_{MHz})$ in mW

MHz	*50*	*60*	*70*	*80*	*90*	*100*	*110*	*120*	*130*	*140*	*150*	*160*	*170*	*180*	*190*	*200 mm*
10	949	962	975	989	1002	1015	1029	1042	1055	1069	1082	1095	1109	1122	1135	1149
25	760	771	781	792	803	813	824	835	845	856	867	877	888	899	909	920
50	617	626	634	643	652	661	669	678	687	695	704	713	721	730	739	747
75	535	542	549	557	564	571	579	586	593	600	608	615	622	630	637	644
100	474	481	488	494	501	508	514	521	528	534	541	548	554	561	568	574

where

$$S_f(f_{MHz}) = e^{-\frac{(f_{MHz} - 100)^2}{250}} \qquad S_d(d_{mm}) = \frac{1}{2} + \frac{e^{-\frac{(d_{mm} - 50)^2}{250}}}{2}$$

$$P_{431a}(d_{mm}, f_{MHz}) = \frac{3\, d_{mm}}{\sqrt{f_{MHz}/1000}} \qquad P_{431b1}(d_{mm}, f_{MHz}) = \frac{d_{mm}}{\sqrt{f_{MHz}/1000}} + \frac{(d_{mm} - 50) \cdot f_{MHz}}{150}$$

150

– Table B.2 –

$P_{7X}(f_{MHz},d_{mm})$: exemption power threshold in mW between 100 MHz and 300 MHz

$$100 < f_{MHz} \leq 300$$

$$P_{7X}(d_{mm}, f_{MHz}) = P_{100}(d_{mm}) \cdot \left(\frac{P_{100}(d_{mm})}{P_{300}(d_{mm})}\right)^{\ln(100.)/\ln(3.)} \cdot f_{MHz}^{-\frac{\ln(100.)}{\ln(3.)} \cdot \left(\log_{100}\left(\frac{P_{100}(d_{mm})}{P_{300}(d_{mm})}\right)\right)}$$

where

$d_{mm} \leq 50$

$$P_{100}(d_{mm}) = 9.486832980\, d_{mm} \qquad P_{300}(d_{mm}) = 11.68186040\, d_{mm}^{0.7471607990}$$

Calculated values of $P_{7X}(d_{mm}, f_{MHz})$ in mW

MHz	5	10	15	20	25	30	35	40	45	50 mm
100	47	95	142	190	237	285	332	379	427	474
150	44	83	119	155	190	224	257	290	323	356
200	42	75	105	134	162	189	215	240	265	290
250	40	69	96	120	143	165	187	207	228	247
300	39	65	88	110	129	148	166	184	201	217

$50 < d_{mm} \leq 200$

$$P_{100}(d_{mm}) = 441.0083157 + 0.6666666667\, d_{mm} \qquad P_{300}(d_{mm}) = 11.68186040\, d_{mm}^{0.7471607990}$$

Calculated values of $P_{7X}(d_{mm}, f_{MHz})$ in mW

MHz	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200 mm
100	474	569	664	759	854	949	1044	1138	1233	1328	1423	1518	1613	1708	1802	1897
150	356	419	482	544	606	667	727	786	846	904	963	1021	1078	1136	1193	1250
200	290	338	385	430	475	519	562	605	647	689	730	770	811	850	890	929
250	247	286	322	358	393	427	461	493	526	557	588	619	650	680	709	738
300	217	249	279	309	337	365	392	418	444	469	494	518	542	566	589	612

$200 < d_{mm}$

$$P_{100}(d_{mm}) = 441.0083157 + 0.6666666667\, d_{mm} \qquad P_{300}(d_{mm}) = 612.$$

Calculated values of $P_{7X}(d_{mm}, f_{MHz})$ in mW

MHz	200	210	220	230	240	250 mm
100	1897	1992	2087	2182	2277	2372
150	1250	1306	1362	1418	1474	1530
200	929	968	1007	1045	1083	1121
250	738	767	796	825	853	881
300	612	635	657	679	701	723

– *Table B.3* –

$P_{7X}(f_{MHz}, d_{mm})$: exemption power threshold in mW between 300 MHz and 1500 MHz

$300 < f_{MHz} \le 1500$

$d_{mm} \le 200$

$$P_{7X}(d_{mm}, f_{MHz}) = 2.040 \cdot f_{MHz} \cdot (d_{mm}/200)^{-\log_{10}\left(\frac{60}{2.040 \cdot f_{MHz} \cdot \sqrt{f_{MHz}/1000}}\right)}$$

Calculated values of $P_{7X}(d_{mm}, f_{MHz})$ in mW

MHz	5	10	15	20	25	30	35	40	45	50 mm
300	39	65	88	110	129	148	166	184	201	217
400	26	50	73	95	117	139	160	181	202	223
500	19	40	62	85	108	131	155	179	204	228
600	15	34	55	77	101	126	151	178	205	232
700	12	29	49	72	96	121	148	176	206	236
800	10	26	45	67	91	118	146	175	206	239
900	8	23	42	63	88	114	143	174	207	242
1000	7	21	39	60	84	112	141	173	208	244
1100	6	19	36	57	82	109	140	173	208	246
1200	6	17	34	55	79	107	138	172	209	248
1300	5	16	32	53	77	105	136	171	209	250
1400	4	15	31	51	75	103	135	171	210	252
1500	4	14	29	49	73	101	134	170	210	254

$200 < d_{mm}$

$$P_{7X}(d_{mm}, f_{MHz}) = 2.040 \cdot f_{MHz}$$

Calculated values of $P_{7X}(d_{mm}, f_{MHz})$ in mW

MHz	200	210	220	230	240	250 mm
300	612	635	657	679	701	723
400	816	854	892	930	968	1005
500	1020	1075	1131	1186	1242	1298
600	1224	1224	1224	1224	1224	1224
700	1428	1428	1428	1428	1428	1428
800	1632	1632	1632	1632	1632	1632
900	1836	1836	1836	1836	1836	1836
1000	2040	2040	2040	2040	2040	2040
1100	2244	2244	2244	2244	2244	2244
1200	2448	2448	2448	2448	2448	2448
1300	2652	2652	2652	2652	2652	2652
1400	2856	2856	2856	2856	2856	2856
1500	3060	3060	3060	3060	3060	3060

– Table B.4 –

$P_{7X}(f_{MHz},d_{mm})$: exemption power threshold in mW between 1500 MHz and 6000 MHz

$1500 < f_{MHz} \le 6000$	
$d_{mm} \le 200$	$P_{7X}(d_{mm}, f_{MHz}) = 3060 \cdot (d_{mm}/200)^{-\log_{10}\left(\frac{60}{3060 \cdot \sqrt{f_{MHz}/1000}}\right)}$ **Calculated values of $P_{7X}(d_{mm}, f_{MHz})$ in mW**
$200 < d_{mm}$	$P_{7X}(d_{mm}, f_{MHz}) = 3060$

Calculated values of $P_{7X}(d_{mm}, f_{MHz})$ in mW:

MHz	5	10	15	20	25	30	35	40	45	50 mm
1500	4	14	29	49	73	101	134	170	210	254
2000	3	12	25	42	64	90	120	154	191	233
2450	3	10	22	38	59	83	111	143	179	219
3000	2	9	20	35	53	76	103	133	168	206
4000	2	7	17	30	47	68	92	121	153	189
5000	2	6	15	27	42	62	85	112	142	177
6000	1	6	13	24	39	57	79	105	134	167

B.2 Definition of P_6, the Power Threshold in KDB Pub. 447498 D01 v06

Commented [SL28]: [29] Pls mark as informative "Please note that Formulas in B.1 should be used for Filings and the following is informative only." Or remove -- to avoid confusion

The function P_{7X} in Formula (B.1) for frequencies at or below 100 MHz is defined based on the function P_{6S}, that is in turn based on the power threshold exemption function that was defined in KDB Pub. 447498 v06 (Sec. 4.3.1), that is here referred to as P_6, and discussed in detail in this section. The modifications that led from P_6 to P_{6S} are shown in Sec. B.3.

The function P_6 is on the of the exemption power threshold (in mW) defined in KDB Pub. 447498 v06 (Sec.4.3.1). P_6 can be written in a compact form as:

$$P_6(d_{mm}, f_{MHz}) := \begin{cases} P_{431ab}(d_{mm}, f_{MHz}) & f_{MHz} > 100 \\ P_{431c}(d_{mm}, f_{MHz}) & f_{MHz} \le 100 \end{cases} \quad \text{(B.2.1),}$$

where

$$P_{431ab}(d_{mm}, f_{MHz}) := \begin{cases} P_{431a}(d_{mm}, f_{MHz}) & d_{mm} \le 50 \\ P_{431b}(d_{mm}, f_{MHz}) & d_{mm} > 50 \end{cases} \quad \text{(B.2.2),}$$

$$P_{431a}(d_{mm}, f_{MHz}) := \frac{3\, d_{mm}}{\sqrt{f_{MHz}/1000}} \quad \text{(B.2.3),}$$

$$P_{431b}(d_{mm}, f_{MHz}) := \begin{cases} P_{431b1}(d_{mm}, f_{MHz}) & f_{MHz} \leq 1500 \\ P_{431b2}(d_{mm}, f_{MHz}) & f_{MHz} > 1500 \end{cases} \quad \text{(B.2.4),}$$

$$P_{431b1}(d_{mm}, f_{MHz}) := P_{431a}(50, f_{MHz}) + \frac{(d_{mm} - 50) \cdot f_{MHz}}{150} = \frac{3 \cdot 50}{\sqrt{f_{MHz}/1000}} + \frac{(d_{mm} - 50) \cdot f_{MHz}}{150} \quad \text{(B.2.5),}$$

$$P_{431b2}(d_{mm}, f_{MHz}) := P_{431a}(50, f_{MHz}) + (d_{mm} - 50) \cdot 10 = \frac{3 \cdot 50}{\sqrt{f_{MHz}/1000}} + (d_{mm} - 50) \cdot 10 \quad \text{(B.2.6),}$$

$$P_{431c}(d_{mm}, f_{MHz}) := \begin{cases} P_{431b1}(d_{mm}, 100.) \cdot \left(1. + \log10\left(\frac{100.}{f_{MHz}}\right)\right) & d_{mm} > 50 \\ 0.5\, P_{431b1}(50., 100.) \cdot \left(1. + \log10\left(\frac{100.}{f_{MHz}}\right)\right) & d_{mm} \leq 50 \end{cases} \quad \text{(B.2.7).}$$

B.3 Definition of P_{6S}

Commented [SL29]: [30] Pls mark as informative "Please note that Formulas in B.1 should be used for Filings and the following is informative only." Or remove -- to avoid confusion

The function P_{6S} is simply a "smoothed" version of P_6, designed to eliminate the discontinuities for d_{mm}=50 and f_{MHz}=100.

The discontinuities in the power threshold function in P_6 can be eliminated by imposing continuous transitions in the definitions. In this case, the smoothing functions S_f for the variable f_{MHz}, and S_d, for the variable d_{mm} were chosen as follows:

$$S_f(f_{MHz}) := exp\left(-10 \frac{(f_{MHz} - f_{\max})^2}{\Delta f^2}\right) \quad \text{(B.3.1),}$$

$$S_d(d_{mm}) := 0.5 + 0.5 \cdot exp\left(-10 \frac{(d_{mm} - d_{\max})^2}{\Delta d^2}\right) \quad \text{(B.3.2).}$$

The plots for these functions are shown in Figure B.3.1.

$$S_f(f_{MHz}) := exp\left(-10\frac{(f_{MHz}-f_{\max})^2}{\Delta f^2}\right) \qquad S_d(d_{mm}) := 0.5 + 0.5\cdot exp\left(-10\frac{(d_{mm}-d_{\max})^2}{\Delta d^2}\right)$$

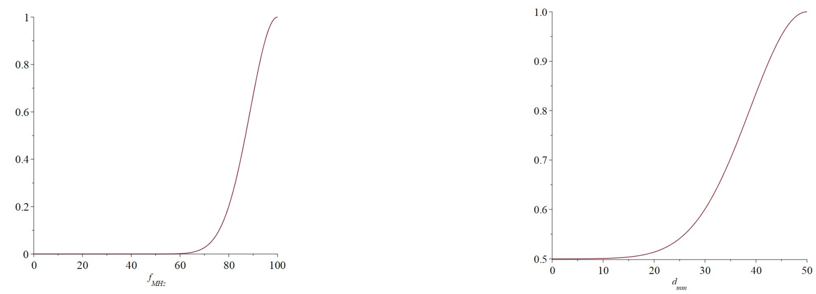

Figure B.3.1 – Plots for the smoothing functions S_f and S_d used in the definition of P_{6S}

A modified power threshold function P_{6S}, a version of P_6 without discontinuities, can be then defined as:

$$P_{6S}(d_{mm}, f_{MHz}) := \begin{cases} P_{431a}(d_{mm}, f_{MHz}) & d_{mm} \le 50 \textbf{ and } f_{MHz} > 100 \\ P_{431b1}(d_{mm}, f_{MHz}) & d_{mm} > 50 \textbf{ and } 100 < f_{MHz} \le 1500 \\ P_{431b2}(d_{mm}, f_{MHz}) & d_{mm} > 50 \textbf{ and } f_{MHz} > 1500 \\ S_f(f_{MHz})\cdot P_{431a}(d_{mm}, f_{MHz}) + (1 - S_f(f_{MHz}))\cdot S_d(d_{mm})\, P_{431b1}(50., 100.)\cdot\left(1. + log10\left(\frac{100.}{f_{MHz}}\right)\right) & d_{mm} \le 50 \textbf{ and } f_{MHz} \le 100 \\ S_f(f_{MHz})\cdot P_{431b1}(d_{mm}, f_{MHz}) + (1 - S_f(f_{MHz}))\cdot P_{431b1}(d_{mm}, 100.)\cdot\left(1. + log10\left(\frac{100.}{f_{MHz}}\right)\right) & d_{mm} > 50 \textbf{ and } f_{MHz} \le 100 \end{cases} \quad \text{(B.3.3)}$$

In (B.3.3) P_{6S} is shown for all the possible ranges of the parameters d_{mm} and f_{MHz}, however in the of P_{7X} (B.1) only the $f_{MHz} \le 100$ is necessary. The effect of the smoothing function is shown in Fig. B.2.

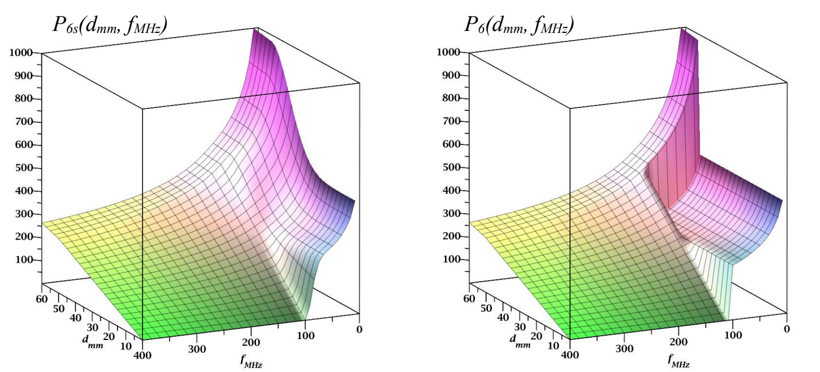

Fig. B.2 –Smoothed function $P_{6s}(d_{mm}, f_{MHz})$ (left), vs. the original definition of P_6 (right)

B.4 Definition of P_7

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The definition of P_7 follows that of the power threshold exemption function for requirements of environmental evaluation in 47 CFR § 1.1307, as in Sec. A.2, where the power threshold function $P_{1.1307}(d_{cm}, f_{GHz})$ was introduced for the exemption criterion limited to the 300 MHz $\leq f \leq$ 6 GHz frequency range, 0.5 cm $\leq d \leq$ 40 cm.

P_7 is simply the $P_{1.1307}$ following unit conversion to *mm* and *MHz*, for consistency with the other expressions in this section, thus defined as:

$$P_7(d_{mm}, f_{MHz}) := \begin{cases} ERP(f_{MHz}) \cdot (d_{mm}/200)^{x(f_{MHz})} & d_{mm} < 200 \\ ERP(f_{MHz}) & d_{mm} \geq 200 \end{cases} \quad \text{(B.4.1)},$$

where

$$ERP(f_{MHz}) := \begin{cases} 2.040 \cdot f_{MHz} & f_{MHz} < 1500 \\ 3060 & f_{MHz} \geq 1500 \end{cases} \quad \text{(B.4.2)},$$

and

$$x(f_{MHz}) := -\log_{10}\left(\frac{60}{ERP(f_{MHz}) \cdot \sqrt{f_{MHz}/1000}}\right) \quad \text{(B.4.3)}.$$

B.5 Definition of P_{6to7}

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The function P_{6to7} is a transition function, (in mW) is defined as

$$P_{6to7}(d_{mm}, f_{MHz}) := \frac{\alpha(d_{mm})}{f_{MHz}^{\beta(d_{mm})}} \quad \text{(B.5.1)},$$

where the functions $\alpha(d_{mm})$ and $\beta(d_{mm})$ can be determined by imposing that P_{6to7} is equal to P_{6S} at 100 MHz and P_7 at 300 MHz. These constraints can be written as:

$$\begin{aligned} P_{6to7}(d_{mm}, 100) &\triangleq P_{100}(d_{mm}) = P_{6S}(d_{mm}, 100.) \\ P_{6to7}(d_{mm}, 300) &\triangleq P_{300}(d_{mm}) = P_7(d_{mm}, 300.) \end{aligned} \quad \text{(B.5.2)}.$$

By replacing the Formula (B.5.1) definition of P_{6to7} in Formula (B.5.2), it can be shown that one possible solution for $\alpha(d_{mm})$ and $\beta(d_{mm})$ is

$$\alpha(d_{mm}) := P_{100}(d_{mm}) \cdot \left(\frac{P_{100}(d_{mm})}{P_{300}(d_{mm})}\right)^{\ln(100.)/\ln(3.)}$$

(B.5.3),

$$\beta\left(d_{mm}\right) := \frac{\ln(100.)}{\ln(3.)}\log_{100}\left(\frac{P_{100}\left(d_{mm}\right)}{P_{300}\left(d_{mm}\right)}\right) \quad \text{(B.5.4).}$$

Appendix C
RF Energy Coupling Enhancement Condition

As described in Sec. 4.2.3, transmitters with SAR ≤ 0.4 W/kg can be integrated in host platforms without further restrictions only if they also satisfy an additional condition referred to as a test of the *RF energy coupling enhancement.*

This condition is designed to verify that the low SAR value (*i.e.,* ≤ 0.4 W/kg) that was measured at the prescribed minimum test separation distance (≤ 5 mm) continues decreasing when the separation distance gets larger.

The SAR tests of the transmitter (typically applicable for modules) in general are repeated for each possible configuration in which the module is designed to operate (e.g., different power levels, frequencies), and shall be performed according to the following steps.

a) The highest *reported SAR* is determined via SAR zoom scan for each test configuration per Sec. 4.2.3.
b) For each highest SAR condition of Step a), the tip of the SAR probe is positioned at the corresponding highest SAR (transverse) location of the zoom scan measured per Sec. 4.2.3 requirements, at a distance from the phantom surface less than or equal to half the probe tip diameter (or closest specified for the probe), rounded to the nearest mm.
c) The EUT (*i.e.*, the transmitter/module) is initially positioned in direct contact with the phantom, then subsequently moved away from the phantom in 5 mm spacing increments.
d) For each EUT position increment of Step c), single-point SAR (not gram-averaged), adjusted for tune-up tolerance, shall be recorded.[32]
   At least three repeated single-point (not zoom-scan gram-averaged) SAR results shall be measured at each EUT increment position. When there is more than 15% variation in the single-point measurements SAR results at each position, additional repeated measurements are required for that position, to ensure a representative high -range value is recorded.
e) The process can be terminated when the measured single-point SAR falls below 50% of that recorded with the device in contact with the phantom.
f) All the SAR measurements collected for the positions at 10 mm and beyond from the phantom are then examined to identify those points with SAR larger than 25% of the value measured at 5 mm.
g) If there are positions identified in Step f), for the highest measured single-point SAR ~~condition~~ distance among all these positions an additional complete 1-g SAR evaluation is required at that distance.

Commented [SL32]: [33] Perhaps specifying "when to stop" is needed. For example, until 3 consecutive measurements are within 15% of each other

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

Appendix D
SAR Estimations for
Simultaneous Transmission Test Exemptions

D.1 Estimated SAR

When an antenna qualifies for test exemption in single transmitter/antenna mode, its actual SAR value may not be available, because it was not required to be measured.

In this case, the SAR contribution of that antenna to simultaneous transmission must be estimated relative to the SAR or MPE test exemption criteria for the applicable terms in the *TER* expression, eq. (2.1), by multiplying the corresponding ratio by the SAR limit of 0.4 W/kg for 1-g SAR.[33] This is referred to as *estimated SAR.*

Commented [KO33]: [34] It would be helpful to clarify when estimated SAR can be used. For example, is it applicable only when the SAR limits apply? or could this also be used > 6 GHz when the MPE-PD limits are applicable?

For instance, a given antenna may qualify for a SAR test exemption according to Sec. B.1, with $P_{ant} < P_{7X}$, where P_{ant} is maximum time-averaged power or effective radiated power (ERP), whichever is applicable, and P_{7X} is exemption power threshold defined in eq. (B.1.1). Then, the *estimated SAR* is computed as $SAR_{est} = 0.4 \cdot P_{ant} / P_{7X}$ [W/kg].

Commented [KO34]: [35] This is inconsistent with formula 2.1. In Formula 2.1, a 0.25 is not considered when calculating the TER. So by using formula 2.1, a contribution just below the exclusion level would correlate to near 100% of the limit, whereas using this formula would only contribute 25%.

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 antenna separation distance, and this location must be clearly identified in test reports. The estimated SAR is used only to determine simultaneous transmission SAR test exemption, and it shall not be reported as the standalone SAR.

D.2 Using Standalone SAR Values

When the SAR to peak location separation ratio test exemption is applied, the highest *reported SAR* for simultaneous transmission can be a~~n~~ standalone *estimated SAR* so long as it refers to the largest among all the simultaneously transmitting antennas (see also KDB Pub. 690783 D01 requirements for listing simultaneous-transmit SAR on grants).

For situations where the *estimated SAR* leads to potential calculated simultaneous non-compliance via TER, then one can perform a standalone SAR evaluation, and then use that value to determine simultaneous-transmission SAR test exemption.

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D.3 Peak Location Determination

When standalone SAR is evaluated, the peak location is determined by the *x, y, z* coordinates of the results reported by the zoom scan measurement, or area scan measurement when area scan based 1-g SAR estimation is applicable. These results may need further data processing to identify the actual peak locations, since these location will not, in general, correspond where the probe was positioned to collect data.

Commented [KO35]: [36] It may be helpful to add "For MIMO operations, all unique SAR peaks observed from the SAR measurement plots need to be considered in the SPLSR analysis to ensure Exemptions apply for all spatial simultaneous transmissions applicable." (ex. two WIFI antennas spatially apart but Cellular peaks near the slightly lower WIFI peak. Using this text SPLSR might pass with one peak but not with the second)

Some SAR systems may have provisions to compute peak location separation distance automatically: in that case, however, it must be verified that the peak location separation distance is determined according to the correct 1-g peak SAR locations to avoid errors in noisy SAR distributions with several relative peaks near each other.

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

When SAR is estimated for both antennas considered in a pairwise *SPLSR* analysis, the peak location separation shall 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.

D.4 SAM Phantom Special Considerations

For the SAM phantom, the origin of the coordinates for data points reported by SAR systems is typically located at the *ear reference point*, on the inside surface of the phantom. This is also referred to as the *measurement grid reference point* by some systems.

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 shall be translated onto the test device, to determine the peak location separation for the antenna pair.

The *ear reference point* location on the phantom is meant to be aligned with the location of the acoustic output on a handset, with 6 mm separation (measured along the direction perpendicular to the phantom) in due to the phantom ear spacer. A measured peak location can be translated onto the handset, with respect to the *ear reference point* location, by ignoring the 6 mm offset in the z coordinate.

The assumed peak location of the antenna for estimated SAR can also be determined with respect to the *ear reference point* location on the handset. The peak location separation distance is estimated by the *x, y* coordinates of the peaks, with respect to the *ear reference point* location. While flat phantoms are not expected to have these issues, the same peak translation approach shall be applied to determine peak location separation.

The coordinates of the peaks, whether measured or translated, shall be clearly identified in the SAR report. When necessary, plots or illustrations shall be included to support the distance applied to qualify for SAR test exemption.

Appendix E
Unintentional Radiators

E.1 General Considerations

There may be situations, e.g., with emissions from multiple RF sources operating simultaneously, where the unintentional radiator(s) (URS) contributions may be sufficient to result in a device being out of compliance with the RF exposure limits.

However, in most cases, unintentional radiators provide a small contribution to the applicable RF exposure figure of merit considered for compliance. This figure of merit can be SAR, MPE or, more generally, the *total exposure ratio, TER,* combined quantity, defined in eq. 2.1, Sec. 2.3.3.

E.2 Use of Supplier's Declaration of Conformity for Authorization of Unintentional Radiator Sources

According to 47 CFR 15.101(a), see also KDB Pub. 896810 D01 SDoC v02, most unintentional radiators can be authorized via Supplier's Declaration of Conformity (SDoC). Accordingly, evaluating the RF exposure contributions for URS, can be either performed as part of the SDoC, or included as exhibits for the device certification process.

The evaluation procedures described in this section, including test exemptions, are applicable to both SDoC and certification processes. In the case when SDoC is chosen, the records for these evaluations shall be retained by the SDoC responsible party (in many cases, the manufacturer).

Per § 2.947(f), these evaluations need to be performed with all the transmitters installed in the device operating, and for all the different modes of operations by design.

The following example illustrates these options in more detail. A device includes both URS and intentional radiators, and is considered a composite device according to 47 CFR 2.947(f). A device certification (a single FCC ID) is provided to include all the intentional radiators, while equipment authorization for the URS present in the device is provided via SDoC.

In this case, the exhibits filed for certification shall report RF exposure evaluation results that also include the contributions of those URS on the device that are operating while the other intentional radiators are also operating (to represent what is occurring in normal design conditions). These URS contributions, even if the URS are independently authorized via SDoC, need to be shown in the RF exposure certification exhibit as part of the total RF exposure "budget" calculation via the *TER* formula (2.1), Sec. 2.3.3, unless a URS qualifies for an exemption.

However, the list of URS that qualify for exemption also needs to be provided in the RF exposure certification exhibit. On the other hand, details on estimates and test data related to the evaluation of URS under SDoC are not required to be included of the certification exhibits.

Similarly, the SDoC documentation of record retained by the SDoC responsible party shall include the reference to the certification of the intentional radiators present on the device (e.g. providing the FCC ID, and showing the overall compliance resulting from the total RF exposure calculation in the *TER* formula). The responsible party is not required to submit this SDoC documentation unless specifically requested by the Commission, pursuant to § 2.945. The SDoC report shall include details on the evaluations (and/or exemptions, as applicable) that pertain to the URS that have been considered for SDoC.

E.3 Evaluation of Unintentional Radiator Source Contributions to RF Exposure

E.3.1 General approach

The RF exposure evaluation for URS is performed through a few steps, designed for a limited set of cases where RF exposure testing is required. After all the URS have been identified, a general assessment of their contribution to the total RF exposure will be made to establish if any URS can be accounted for through the evaluation of other intentional radiators. For the remaining URS, the qualification for exemption from RF exposure testing is then evaluated.

Only a very limited set of special cases is expected, in general, to require evaluation via RF exposure test data collection. For those cases, the URS contributions shall be accounted for in the TER formula, along with other intentional radiators, for the calculation of the overall RF exposure "budget" resulting from all the radiators present on the device.

A flowchart of the process for the URS RF exposure evaluation is shown in Fig. E.1

E.3.2 URS Characterization

All the URS present on the device need to be identified and characterized based on their fundamental frequency, mode of operation (e.g., simultaneous transmission with other radiators), and location within the device (that impacts the minimum separation distance, based on form factor, and typical use/installation cases). For the purpose of these RF exposure evaluations, the basic URS characterization refers to its fundamental frequency, regardless of the wave shape.

For example, a digital circuit with a 1 GHz clock is considered as a 1 GHz source, regardless of the actual waveform and duty cycle.

E.3.3 URS Included in the Intentional Radiator Evaluation

Some URS may operate in the same ~~frequency~~ probe validity range of ~~another~~ (at least one) intentional radiator, and operate at the same time (e.g., because the URS provide essential functions for the operation of the intentional radiator, and they are automatically energized when the intentional radiator is transmitting).

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In this case, the URS contribution is considered to be included in the evaluation of the intentional radiator (evaluated in accordance with the guidelines of Table 1, Sec. 1.4.1).

For example, a digital logic clock operates at 100 MHz, and simultaneously with a 900 MHz transmitter that requires SAR evaluation. The contribution of the URS is then considered as implicitly being part of the SAR evaluation conducted for the 900 MHz transmitter (~~because the procedure for this frequency range covers 4 MHz to 6 GHz, and so long as a SAR evaluation equipment that includes that frequency range is used~~assuming 100 MHz is within the SAR probe specification range, and the 900 MHz SAR probe conversion factors are conservative with respect to 100 MHz). No further evaluation of that particular URS is then required.

It should be noted that because the SAR evaluation in this case is performed with reference to two sources (the URS and the 900 MHz one), the position of closest approach to both sources needs to be tested. This is a general requirement (regardless of URS considerations), unless it can be shown that the field strength in one particular position qualifies as the worst-case scenario from an RF exposure perspective.

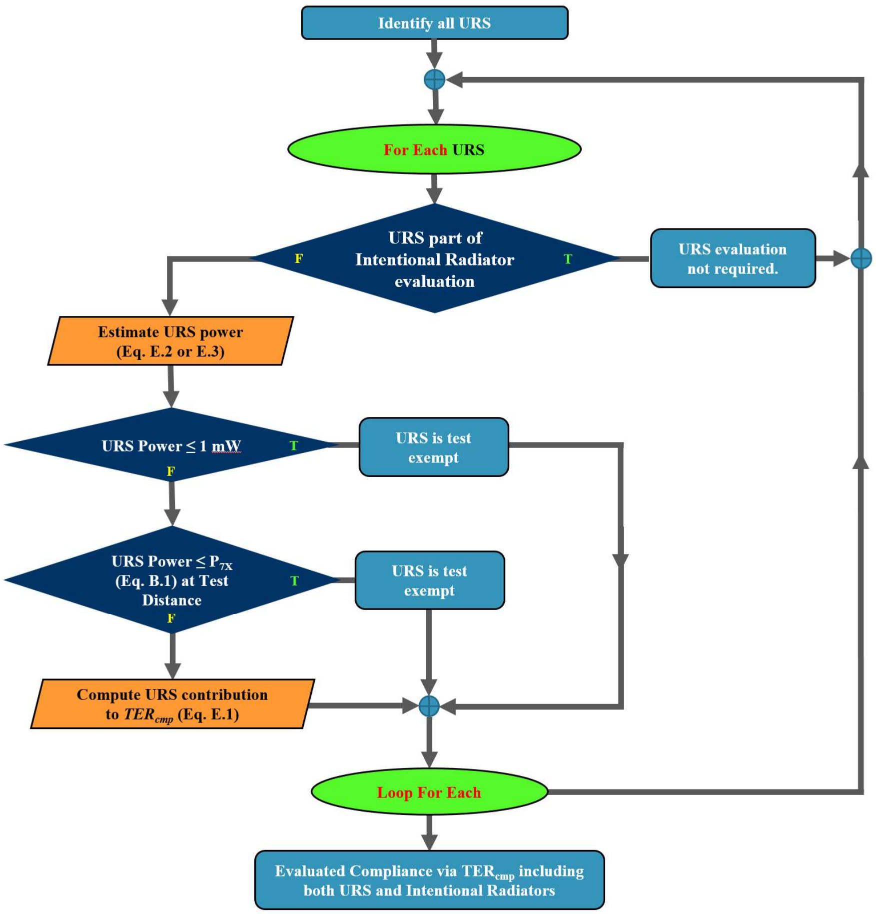

Figure E.1 - Flowchart of the process for RF exposure evaluation of URS

Commented [KO36]: [37] Flow chart may need revision to clarify the following points:
[38] -A flow chart or additions to this flow chart on how to "Identify all URS" would be helpful
[39] -applicability of the 1 mW exemption in standalone vs simultaneous scenarios
[40] -P7x (Equation B.1) covers frequencies < 300 MHz only. For URS operating > 300 MHz, can the exemptions discussed in Section A.1 and A.2 be used? If so, this should be clarified
[41] -Addition of the April 2022 TCB Workshop guidance saying that URS exposure only needs to be added to the total TER if the URS Exposure is > 10% of the limit.
[42] -Flow chart is currently missing a test option to evaluate the URS
[43] -The option to "Compute URS" Exposure references Equation E.1 which does not appear to exist in this document

E.3.4 URS Not Included in the Intentional Radiator Evaluation

E.3.4.1 Single-Source, Test Exemptions for URS

URS that are not part of the RF exposure evaluation of any intentional radiator need to be included in the "*TER* budget", along with contributions from the intentional radiators, unless they qualify for an exemption that has been devised specifically for URS.

When several URS are present, the most accurate RF exposure evaluation is obtained by including the sum of the contributions from all URS in the total TER for the device. However, this sum can be approximated by considering only the URS that do not fall under single-source exemption criteria, as discussed in the following paragraphs.

The URS single-source test exemptions are based on the estimated total electromagnetic field power emitted by the URS, as if it were operating stand-alone. When the URS qualifies for an exemption, its contribution to the total RF exposure level is considered negligible and does not need to be reported.

In addition, due to the typically small total impact the URS of most devices has on RF exposure compliance, URS that qualify for a single source exemption are considered exempt from being included in the total TER evaluation when operating in simultaneous transmission scenarios.

In order to facilitate the application of these exemption criteria, specific provisions for obtaining an easy estimate of the URS radiated power have been devised, as detailed in the next section.

The single-source criteria URS that can be considered exempt are similar to the stand-alone test exemptions considered for intentional radiators (Sec. 2.2), as follows:

- *1 mW exemption*

  If the total URS radiated power is estimated as 1 mW or less, the URS is exempt from being accounted for in RF exposure evaluation, both for devices where the URS operates in stand-alone conditions (with no other transmitter on the device activated), as well as in simultaneous transmissions (where the TER formula applies).

- *Exemptions Based on Power Thresholds Dependent on Frequency and Test Separation Distance*

  URS exemptions can be also determined based on both estimated URS radiated power, and applicable test distance for the URS, that is the minimum demonstrated distance from a person's body, in the same use conditions considered for all other radiators installed in the device. When the conditions in Tables and formulas in Appendix B are met, the URS is exempt from being included in the RF exposure evaluation of the device.

Commented [KO37]: [44] This contradicts earlier statements that the 1 mW exemption cannot be used together with other higher power transmitters

E.3.4.2 Radiated Power Estimate for URS Exemptions

The following two approaches can be used for estimating the URS radiated power:

- *Small dipole formula*

  The URS emissions in this case are approximated by considering an equivalent small dipole. For this purpose, based on the URS characteristics and operational conditions, estimates of the URS RF current I_0, equivalent dipole length l , and frequency f are required. Then, the URS radiated power is approximated by the expression of the power emitted by a small dipole as [e.g., Balanis, 2005]:

$$P_{rad} = \frac{\eta \pi}{3 c^2} \left(I_0 l f \right)^2 \quad \text{(E.2)},$$

  where η≈377 Ω, c is the speed of the light, and all the quantities are expressed in S.I. units.

- *Power Estimate Based on Electric Field Strength Measurements*

  Alternatively, and solely for the purpose of establishing applicability of a URS exemption, the radiated power can be also estimated from a measurement of the electric field in the far field (referred to the URS fundamental frequency), and along the direction of maximum strength.

  In this case, the URS radiated power can be approximated by that of an isotropic radiator. By

Commented [SL38]: [45] Small Dipole approximation only works when the structure is < Lambda/10. But how would one know what structure acts as an antenna at a particular frequency? For example, maybe an URS 100 MHz may be emitted on a Cellular antenna or a trace on a PCB or wire that resonates at 100 MHz…

integrating the time-averaged Poynting vector $S=E^2/(2\,\eta)$ over a sphere of surface $4\,\pi\,r^2$), this radiated power is expressed as:

$$P_{rad} = \frac{2\,E^2\,\pi\,r^2}{\eta} \quad \text{(E.3)},$$

where P_{rad} is the power averaged over a wave period, E is the maximum amplitude of the sinusoidal wave, and r is the distance of the measurement point in the far field from to the center of symmetry of the URS radiating structure.

The electric field needs to be measured in conditions of free-space propagation, without reflections or near-field absorption by dissipative materials that would otherwise affect the outgoing power flow at a larger distance. The direction of the maximum electric field can be estimated based on the geometrical features of the radiating structure, and corroborated by a few spot checks taken along the principal symmetry axes of the device.

In these conditions, the near field provides only non-radiative terms that are not contributing to the average power flow, and the total radiated power computed via integration of the Poynting vector is independent on the integration surface enclosing an antenna. Thus, the integration can be performed in the far field of the antenna, resulting in a simpler calculation.

E.~~4~~3.~~4.3~~ URS ~~Requiring~~ RF Exposure Testing

When ~~a~~URS testing is performed, (for example, when URS does not qualify for a test exemption or when calculation is undesirable), ~~its~~ the contribution to the total RF exposure needs to be evaluated in the same manner as an intentional radiator, thus in accordance with the requirements in Table 1, Sec. 1.4. Accordingly, SAR or MPE evaluations need to be performed at the applicable minimum test separation distance that is established consistent with the minimum test separation distance for the other radiators present in the device.

For simultaneous emissions from different sources, the URS contributions shall be included in the *TER* Formula (2.1) if URS > 10% of the RF Exposure FCC limit. It should be noted that the first term of the *r.h.s.* of (2.1), i.e. the summation to N_{exe} , is limited to the exempt intentional radiator sources. This is because of the special policy for URS in 3.4.1, that allows to neglect all the contributions of exempt URS, even if operating simultaneously.

E.~~5~~4 Examples for URS Exemption Estimates

Example 1 - *1 mW Exemption for Fast Microprocessor CPU*

Assuming that the estimated URS parameters for the small dipole formulas are $I_0 = 0.1$ A, $l = 0.01$ m, and frequency $f = 3.6{\cdot}10^9$ Hz, applying the small dipole formula in the previous section yields:

$$P_{rad} = \frac{\eta\,\pi}{3\,c^2}\left(I_0\,l\,f\right)^2 = 0.0568 \quad \text{(E.4)}.$$

Thus, the radiated power is about 57 mW, and the URS does not qualify for the 1 mW exemption.

Example 2 - *MPE Test exemption for a Fast Microprocessor CPU*

Commented [SL39]: [46] Similar to the short dipole method shortcomings, "geometric features of the radiating device" are not necessarily known unless we consider worst-case and assume the whole EUT is the "radiating feature"

Commented [SL40]: [47] Suggest to make this its own optional section (for when characterization is not practical, undesirable or when test exemption does not qualify)

Commented [KO41]: [48] A manufacturer could always choose to test rather than apply test exemption

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Commented [KO42]: [49] In April 2022 TCB Workshop slides, guidance was given that the URS exposure only needs to be added to the total TER if the URS contribution is > 10% of the limit.

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Commented [KO43]: [50] It might help to spell out "right hand side" as some may not be familiar with this short hand

For a frequency of 3.6 GHz, in order to be able to apply Table A.1.1 the following condition must be satisfied: $R > \lambda/(2\ \pi) \approx 0.013$.

Because the estimated power in the previous example was $P_{rad} = 0.0568$ W, one can determine R from the expression in Table A.1.1, i.e., $19.2\ R^2 = 0.0568$, that yields $R = 0.054$ m. Therefore, R=0.054 m is the distance that needs to be demonstrated in all operating conditions for the exemption to be allowed. This is an acceptable choice for applying the single source thresholds in the Table A.1.1 to determine is the device is exempt from evaluation This exemption is applicable because R is larger than $\lambda/(2\ \pi) \approx 0.013$ m, as computed in the preceding paragraph.

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Commented [KO44]: [51] R in 1.1307 is defined as the separation distance "minimum separation distance (R in meters) from the body of a nearby person for the frequency." Given the power and the frequency, the calculated R= 0.054 m mean that this radiator is excluded only if a 0.054 m can be maintained? R > lambda/(2pi) only seems relevant to determine the validity of the exclusion. Perhaps it would be clearer to add "R=0.054m is the distance that needs to be demonstrated in all operating conditions for the exemption to be allowed. "

Example 3 - *SAR test exemption for Fast Microprocessor CPU*

For a frequency of 3.6 GHz, one can use Formula (B.1) in Appendix B, or the Table A.2.1 criteria. Since the estimated power is about $P_{rad} = 0.0568\ W \approx 57$ mW, one can consider an interpolation from the Table A.2.1 values for 3600 MHz, that is between 25 mm (corresponding to 49 mW), and 30 mm (corresponding to 71 mW). A linear interpolation yields a minimum distance of about 27 mm. That is the distance that needs to be demonstrated in all operating conditions for the exemption to be allowed.

Commented [KO45]: [52] Formula B.1 in Appendix B covers frequencies < 300 GHz. It's a bit unclear how to apply this to a URS at 3.6 GHz

Commented [KO46]: [53] Table A.2.1 is shown as an illustrative example table of power thresholds. Should linear interpolation of the values in Table A.2.1 be used to calculate the exemptions or should the exact values be calculated using Equation A.2.1? The results are slightly different (27 vs 28 mm)

Appendix F
RF Exposure Considerations for SDoC, Certification-Optional, and Equipment-Authorization-Exempt Equipment

1) RF sources not subject to nor using equipment authorization (EA) certification (§ 2.907 et seq.), or not subject to any Part 2 Subpart J EA requirements (EA-exempt)

   a) Equipment subject to and using EA-SDoC procedure (§ 2.906 et seq.)
      (except see list-item 3) for WPT requesting Part 18 EA)

      As part of § 2.938(b) records-retention, include RF exposure exemption info (§ 1.1307(b)(1)(i)(A)) or RF exposure compliance statement (§ 1.1307(b)(1)(i)(B)), whichever is applicable.

   b) Equipment exempt from any EA requirements.

      i) Routine submission of technical information showing the basis for RF exposure compliance or RF exposure evaluation exemption is not applicable.
      ii) Example equipment types:
         - Part 15 incidental radiators (§§ 15.3(n), 15.13, 15.5)
         - Part 15 receivers that operate (tune) outside of 30-960 MHz (§§ 15.101(b), 15.15, 15.5)
         - Part 15 digital-device portion of a licensed transmitter or a 15-C intentional radiator end product (§ 2.1), and that is used only to enable operation of transmitting function and does not control additional functions or capabilities (§§ 15.3(k), 15.15, 15.5)
         - Part 18 non-consumer medical magnetic resonance (MR) equipment (§§ 18.121, 18.111, 18.109)
         - Part 90 1427-1435 MHz transmitting devices (§ 90.203(b)(3))
         - Part 95 Subpart C RCRS 26-28 MHz transmitting devices (§§ 95.735, 95.335(a))
         - Part 97 transmitting devices (except amplifiers [§ 97.315])
         - EM (RF) sources below 9 kHz (below 8.3 kHz)[34]

2) RF sources (RF devices) subject to SDoC but using optional certification (§ 2.906(c))

   a) Submission of technical information showing the basis for RF exposure compliance or RF exposure evaluation exemption shall follow certification policies, in accordance with § 2.906(c).
   b) Example equipment types:
         - Part 15 Subpart B (15-B) unintentional radiators (§§ 15.3(z), 15.101(a), 15.11)
         - Part 18 consumer microwave ovens (§§ 18.203(a), 18.313)
         - Part 18 WPT devices—see list-item 3)

[34] § 15.3(u) *Radio frequency (RF) energy*. Electromagnetic energy at any frequency in the radio spectrum between 9 kHz and 3,000,000 MHz; FCC 19-126, docket no. 19-226, para. 123, 34 FCCR 11744, "…Accordingly, we propose to adopt limits on E_i similar to these ICNIRP 2010 guidelines in our rules for frequencies between 3 kHz to 10 MHz. We do not propose to apply these guidelines below 3 kHz because our table of frequency allocations begins at 8.3 kHz and there are no established provisions for devices to operate at lower frequencies. n330 …"

- Transmitters used in fixed point-to-point microwave and point-to-multipoint Part 30 radio services (§ 30.201(c)) (subject to (obsolete) "Verification" equipment authorization procedure)
- Transmitters used in private-operational fixed and common-carrier fixed-point-to-point microwave and point-to-multipoint Part 101 radio services (§ 101.139(a))
- See also equipment types listed in Appendix C of KDB Pub. 896810 D01 (v02)

3) Wireless-power transfer (WPT) RF sources requesting EA (SDoC or certification, as applicable) under Part 18 are subject to the requirements and document references in KDB Pub. 680106.

   Before EA, KDB inquiry submission is required for Part 18 WPT devices that do not qualify for the inductive-WPT device evaluation exclusion criteria in 5) b) of KDB Pub. 680106 D01 v03r01. The pre-EA KDB inquiry shall include details of device design and operating configurations, and RF exposure evaluation (§ 18.313) test plan and preliminary field strength, power density, or SAR measurement (or computational modeling, as applicable) results. Device-specific EA requirements and exposure evaluation suitability will be determined based on FCC review of the pre-EA KDB, for determining whether SDoC under Part 18 may qualify, or if TCB certification without or with PAG (§ 2.964) may be appropriate.

Glossary

Terms and definitions used in the published RF exposure KDBs are provided in this glossary.

Available Maximum Time-Averaged Power – Maximum available RF power (into a matched load) for an RF source, as averaged over a time-averaging period

Coherent Signals – Signals characterized by a fixed phase relationship.

Continuous Exposure – Maximum time-averaged exposure at a given location for an RF source and assumes that exposure may take place indefinitely. The exposure limits in § 1.1310 are used to establish the spatial regions where mitigation measures are necessary assuming continuous exposure as prescribed in § 1.1307(b)(4).

Effective Radiated Power (ERP) – The product of the maximum antenna gain which is the largest far-field power gain relative to a dipole in any direction for each transverse polarization component, and the maximum delivered time-averaged power which is the largest net power delivered or supplied to an antenna as averaged over a time-averaging period. ERP is summed over two polarizations, when present.

End Product – A completed electronic device that has received all requisite FCC approvals and is suitable for marketing. [47 CFR § 2.1(c)]

Energy Coupling Enhancement Condition – A condition designed to verify that the low SAR value that was measured at the prescribed minimum test separation distance continues to decrease when the separation distances gets larger.

Enlarged Zoom Scan – A scan performed with a SAR evaluation system to provide higher resolution data points

Commented [KO47]: [54] In the context of this document, "Enlarged Zoom Scan" seems to generally be used as a large scan for combination with other scans to evaluate simultaneous transmission scenarios ("volume scan") and does not require any enhanced resolution. We suggest to update this definition to "A large zoom scan performed with the intent of spatially summing the SAR distributions of two or more scans."

Estimated SAR – See Appendix D.

Exempt RF Device – A source(s) is solely from the obligation to perform a routine environmental evaluation to demonstrate compliance with the RF exposure limits in § 1.1310; it is not exemption from the equipment authorization procedures described in 47 CFR Part 2, not exemption from general obligations of compliance with the RF exposure limits in § 1.1310 of this chapter, and not exemption from determination of whether there is no significant effect on the quality of the human environment under § 1.1306.

Fixed RF Source – A RF source is one that is physically secured at one location, even temporarily, and is not able to be easily moved to another location while radiating;

Host Platform – A type or family of devices that can host transmitters (either modular or not)

Host Platform Exposure Condition – Any host exposure corresponding to mobile, portable exposure, or mixed mobile-portable categories

Modular Transmitters – Transmitters certified for use as a module.

Minimum Test Separation Distance – A *test separation distance* 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.

Operational Separation Distance – Separation distance between the transmitter antenna (or radiating structure) and the user in typical conditions of operation

Peripheral Transmitter – A transmitter that requires a host product to support its operations and cannot operate independently by itself. Peripheral transmitters can be attached to hosts through user accessible external standard interface connections, or can be incorporated internally within a host device.

Plane-wave equivalent power density – The square of the root-mean-square (rms) electric field strength divided by the impedance of free space (377 ohms).

Reported SAR, Reported MPE – SAR or MPE measured at or scaled to the maximum tune-up tolerance limit

Routine Environmental Evaluation, Routine Evaluation – Evaluation of the EM field, or EM power flux density in comparison with FCC limits set for RF exposure

Radiating Structure – An unshielded RF current-carrying conductor that generates an RF reactive near electric or magnetic field and/or radiates an RF electromagnetic wave. It is the component of an RF source that transmits, generates, or reradiates RF fields, such as an antenna, aperture, coil, or plate.

RF source – FCC-regulated equipment that transmits or generates RF fields or waves, whether intentionally or unintentionally, via one or more radiating structure(s). Multiple RF sources may exist in a single device.

SAM Phantom – Specific Anthropomorphic Mannequin phantom

SAR to Peak Location Separation Ratio (SPLSR) – See Sec. 2.3.4

Source-Based Time Averaging – A time average of instantaneous exposure over a period that is based on an inherent property or duty-cycle of a device to ensure compliance with the continuous exposure limits.

Test Separation Distance – For RF exposure evaluations is the minimum distance in any direction from any part of a radiating structure and any part of the body of a nearby person exposed to the RF emission.

Total Exposure Ratio –See Sec. 2.3.3.

Tune-up Tolerance – The range of expected maximum output power variations from the rated nominal maximum output power specified for the product or wireless mode.

References

[1] Related KDB Publications

a) Product related KDB publications:
- Mobile and Portable Devices (KDB 447498)
- USB Dongles (KDB 447498)
- Laptop/Notebook/Netbook & Tablet Devices (KDB 616217)
- Occupational PTT Two-Way Radios (KDB 643646)
- Handsets & Accessories (KDB 648474)
- UMPC Mini-Tablets (KDB 941225)

b) Wireless technology related KDB publications:
- 802.11 (KDB 248227)
- WiMax (KDB 615223)
- Wireless Power Transfer Applications (KDB 680106)
- 3GPP/3GPP2 Technologies (KDB 941225)
- Wireless Routers (KDB 941225)

c) Test methodology related KDB publications:
- SAR Measurement and Reporting Requirements (KDB 865664)
- Mapping OET B 65 Supplement C to IEEE Std 1528-2013 (KDB 447498)

d) Equipment approval policy related KDB publications:
- Permissive Change Policies (KDB 178919)
- Pre-Approval Guidance (PAG) Procedures and PAG List (KDB 388624)
- Grant Frequency Listings (KDB 634817)
- SAR Numbers Grant Listings (KDB 690783)
- Modular Approval Policies (KDB 996369), etc.

[2] DA 21-363; OFFICE OF ENGINEERING AND TECHNOLOGY ANNOUNCES MAY 3, 2021 AS THE EFFECTIVE DATE FOR RF EXPOSURE RULE CHANGES AND BEGINNING OF THE TWO-YEAR REVIEW PERIOD FOR EXISTING PARTIES; ET Docket No. 19-226; Released: April 2, 2021; 86 FR 20456[35]

[35] Various facilities and operations have a two-year review period until May 3, 2023, for determining compliance with the RF exposure new rules.

[3] FCC 13-39, FIRST REPORT AND ORDER, FURTHER NOTICE OF PROPOSED RULE MAKING, AND NOTICE OF INQUIRY; Proposed Changes in the Commission's Rules Regarding Human Exposure to Radiofrequency Electromagnetic Fields, ET Docket No. 03-137; Reassessment of Federal Communications Commission Radiofrequency Exposure Limits and Policies, ET Docket No. 13-84; Released: March 29, 2013; 28 FCC Rcd 3498

[4] FCC 19-126, RESOLUTION OF NOTICE OF INQUIRY, SECOND REPORT AND ORDER, NOTICE OF PROPOSED RULEMAKING, AND MEMORANDUM OPINION AND ORDER; Proposed Changes in the Commission's Rules Regarding Human Exposure to Radiofrequency Electromagnetic Fields, ET Docket No. 03-137; Reassessment of Federal Communications Commission Radiofrequency Exposure Limits and Policies, ET Docket No. 13-84; Targeted Changes to the Commission's Rules Regarding Human Exposure to Radiofrequency Electromagnetic Fields, ET Docket No. 19-226; Released: December 4, 2019; 34 FCC Rcd 11687. Published in the Federal Register on April 1, 2020, at 85 FR 18131 (ET Docket Nos. 03-137 and 13-84), and on April 6, 2020, at 85 FR 19117 (ET Docket No. 19-226)

[5] OET Bulletin 65, "Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields," https://www.fcc.gov/general/oet-bulletins-line

[6] IEC/IEEE 62704-1, Determining the peak spatial-average specific absorption rate (SAR) in the human body from wireless communications devices, 30 MHz to 6 GHz – Part 1: General requirements for using the finite-difference time-domain (FDTD) method for SAR calculations

[7] IEC/IEEE 62704-4, Determining the peak spatial-average specific absorption rate (SAR) in the human body from wireless communication devices, 30 MHz to 6 GHz – Part 4: General requirements for using the finite element method for SAR calculations

[8] Balanis, C. A. (2005). *Antenna theory: Analysis and design* (3rd ed.). John Wiley.

Change Notice (Draft for Public Comment)

09/10/2021: 447498 D01 General RF Exposure Guidance DR04-44409 (Draft for Public Comment) replaces 447498 D01 General RF Exposure Guidance DR04-44307 (Draft for Public Comment).

> Update transition period information.

11/29/2021: 447498 D04 Interim General RF Exposure Guidance v01 replaces 447498 D01 General RF Exposure Guidance DR04-44449 (Draft for Public Comment).

> Update transition period information; cite 1.1307(b)(3)(i) not (ii) in 2.1.3 and 2.1.4; math sign correction for f_c in 3.1.6; minor re-wording in 3.1.7; clarifications amended in 4.2 and 4.3; 6.2.2 clarified; rule cross-references updated in Annex C; second paragraph added in E.1; IEC/IEEE documents added in References.

08/17/2022: 447498 D01 General RF Exposure Guidance DR05-44791 (Draft for Public Comment).