Part 18 Wireless Power Transfer Devices: Clarifications on KDB 680106v04 and ECR Processes

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Note: The views expressed in this presentation are those of the authors and may not necessarily represent the views of the Federal Communications Commission.

Contents

Introduction

Updates to be Published in KDB 680106 and KDB 951290

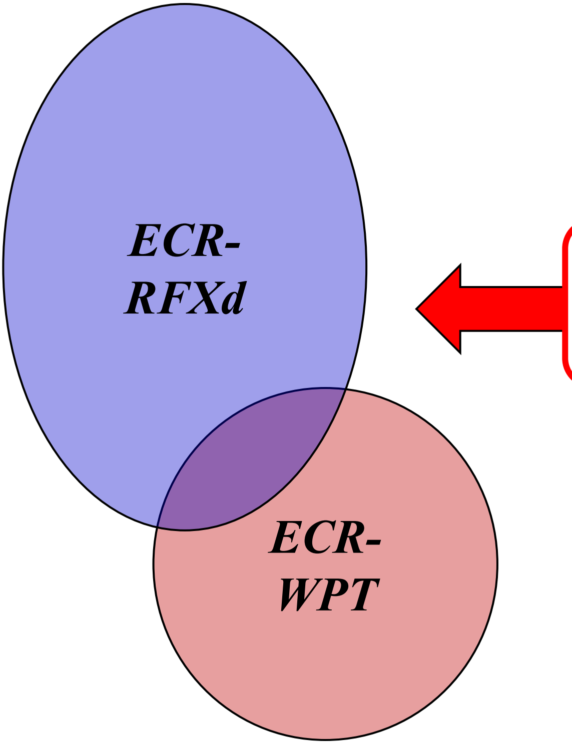
- Clarifications on the Equipment Compliance Review (ECR) process related to ECR-WPT and ECR-RFX*d* inquiries
- Addressing questions received on latest KDB Pub. 680106-v04.
- Details on the validation procedure for near-contact DUT measurements with “large” probe heads

Clarification on ECRs for WPT Designs (I)

Part 15 WPT designs are just like any other Part 15 communication device

- The requirement to submit an ECR-WPT is only for Part 18 devices
- This is motivated by concerns about the SDoC option available for all Part 18 devices, and concerns about possible proliferation of high-power devices operating in ISM bands.
- Accordingly, Part 15 WPT devices do not need an ECR-WPT (to be re-iterated in a forthcoming KDB Pub. 951290 update)
- On the other hand, ECR-RFX*d* can be submitted for any applicable RF device under any rule Part.

Clarification on ECRs for WPT Designs (II)



Different ECRs Sub-categories Serve Different Purposes

- The ECR procedure (KDB Publication 951290) includes the "*WPT*" and "*RFXd*" sub-categories
- Both may apply to a Part 18 WPT design, since *RFXd* is applicable to any RF device, including, but not limited to WPTs
- It is possible to submit two separate KDBs, one for each sub-category, or a single KDB containing the information for both sub-categories (just selecting either sub-category in the drop-down menu)

Clarification on ECRs for WPT Designs (III)

- A Wireless Power Transfer (WPT) device to be authorized under Part 18 (either via Certification or SDoC), that does not meet all the conditions in Section 5.2 of 680106-v04, requires
  - Submittal of an ECR-WPT inquiry with full description of how the device complies with all the applicable Rule Parts
  - Obtain FCC acceptance of the ECR-WPT prior proceeding with authorization
- The need of ECR-WPT may be waived only when the (Part 18) design meets all the conditions in of 680106-v04, Sect. 5.2 (same as for the old 680106-v03)

ECR-RFX*d* Clarification (I)

Definitions

- User separation distance d_U. The minimum distance from any antenna (or radiating structure) of a transmitting RF device that a person can reach, except for a transitory[1] time interval, without any physical or software alterations to the device.
- Test separation distance d_T. The minimum distance from any antenna (or radiating structure) of a transmitting RF device for which RF exposure compliance is ensured, as specified in the available Equipment Authorization documents. Example: d_T=0 cm for 2.1093-*Portable* devices

[1] "Transitory" is here considered as any not regularly recurring event with duration on the order of one second.

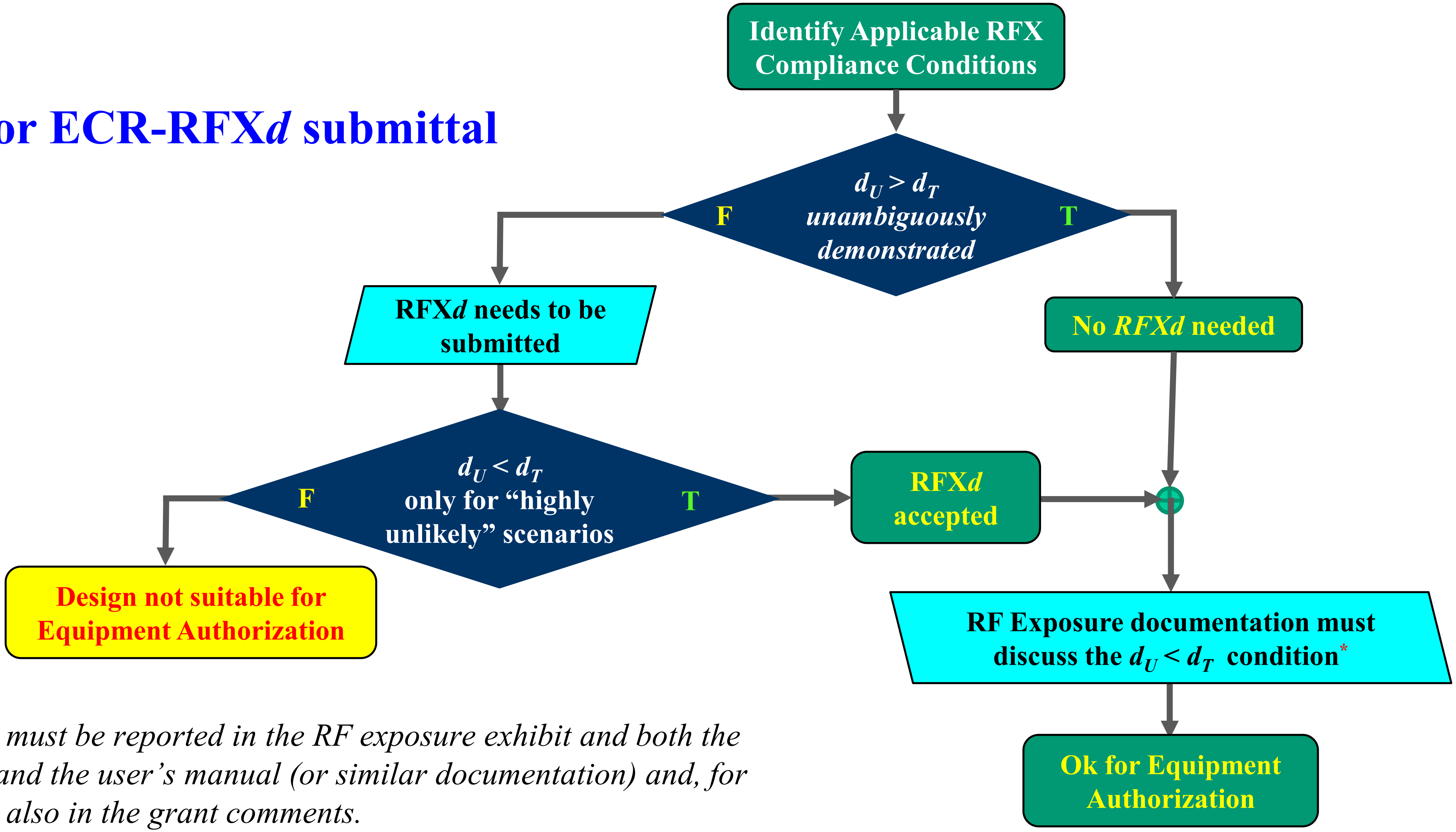
ECR-RFX*d* Clarification (II)

Definitions

- "Highly unlikely" RF exposure scenarios. Cases where a *user separation distance* d_U smaller than the *test separation distance* d_T is reached through complex/uncommon means, such as for emergency situations.
  - For instance, using a tall ladder to reach a position that normally is inaccessible, approaching a device after an event like that led to the physical destruction of access control or power control safeguards.
  - Scenarios that are not foreseeable or technically feasible based on the present technologies; for instance, an RF device that requires a 100 W power supply that becomes available in pocket-size form factor.

ECR-RFX*d* Clarification (III)

Flowchart for ECR-RFX*d* submittal



* *This information must be reported in the RF exposure exhibit and both the grant comments and the user's manual (or similar documentation) and, for certified devices, also in the grant comments.*

Update: New Format for ECR Inquiries (I)

Reminder

- ECR is to provide information that the FCC requires, not for generic questions

Table 1 – A summary of the different KDB Inquiry Types

KDB Inquiry Type	*Submitted by*	*Purpose*
General Inquiry	Anyone	To obtain clarifications on FCC Published Guidance
ECR	Applicants for Equipment Authorization	Only to provide the specific information requested by the FCC in published guidance
NAG	Applicants for Equipment Certification	To gather additional guidance on methodologies related to specific items in the PAG List
PAG/MPAG	TCBs	To address compliance and obtain approval for PAG Items

951290 D01 Equipment Compliance Review

Update: New Format for ECR Inquiries (II)

- A specific format helps to focus what is required for the inquiry submission and to facilitate faster processing
- For an ECR inquiry to be considered, applicants must follow the checklist provided in the description of each sub-category (to be clarified in KDB Pub. 951290 update)
- ECRs do not have to follow a strict format, but they must meet the requirements for the various ECR sub-categories:
  - ECR-PIA: KDB 951290, Sect. 3.1, KDB 987594-D01, Section 10.2
  - ECR-WPT: Define the Part 18 WPT design features, as per KDB680106-v04, Section 5.1 and 5.3. (Note that Section 5.2 provides the checklist for waiving the need of ECR-WPT)
  - ECR-RFX*d*: KDB 951290, Section 3.3

NUMSIM PAG (I)

Draft for Revised NUMSIM PAG Item

NUMSIM

When RF exposure compliance demonstration relies on, either fully or partially, numerical simulations/modeling techniques.

Exceptions. A NUMSIM PAG *is not required* for any of the following cases:

- Numerical computations for processing or visualizing measurement data do not require a PAG (i.e., numerical processing adds no additional physical content). For instance, computing SAR from measurements of the electric field.
- When EM fields are estimated based on measured data using an extrapolation method (e.g., field-gradient-based linear extrapolation). The rationale is that a mathematical extrapolation is performed solely based on test data without an actual simulation of the DUT. On the other hand, if test data are being used to initialize or constrain a simulation model (such as an EM field solver, regardless of its approximations), then NUMSIM is required.

NUMSIM PAG (II)

Draft Checklist for the NUMSIM PAG Item

1. Show that the simulation model provides a conservative estimate of the actual RF exposure conditions.
Example. The simulation domain is larger than what corresponds to actual conditions based on a known radiation pattern of the DUT for the applicable test separation distance, and the choice of simulated phantom parameters (such as conductivity and dielectric permittivity) is consistent with the use conditions.

2. Describe how the simulation model is used to show compliance.
Example: modeling a small volume of body tissue that is sufficient to represent the worst-case illumination conditions from the transmitter EM field.

3. Discuss how the modeling results are leveraged, directly or indirectly, to show compliance.
Example: The EM field is computed to show that the E/H ratio is small enough to consider the transmitter "predominantly magnetic," thus allowing compliance to be shown only based on magnetic field probe measurements.

4. Discuss how the model and its numerical input data have been chosen to provide a realistic simulation.
Example: The EM field is computed to show that the E/H ratio is small enough to consider the transmitter "predominantly magnetic," thus allowing compliance to be shown only based on magnetic field probe measurements.

5. Demonstrate that the results are converged from the perspective of the choice of key numerical parameters.
Example. Changes in the EM field solution (or applicable derived indicators such as SAR and Power Density) become increasingly small for smaller grid size and time steps.

6. Verify the consistency of simulated EM field vs. basic physical requirements.
Example. Continuity of perpendicular and tangential components of the EM field across a material interface, div B=0, etc.

7. Validate the model as applied to the specific DUT simulation.
Example. Compare EM solution vs. measured data and compare with theoretical predictions for applicable configurations. On the other hand, calculations or measurements for quasi-static conditions cannot be used for a full-wave simulation at higher frequencies.

NUMSIM PAG (III)

Motivation and Scope

- In general, the NUMSIM PAG is designed to gain sufficient reassurance on the reliability of simulation data leveraged to demonstrate compliance.
- The applicant needs to show how the simulated EM field, or derived indicators such as spatial averaged SAR and Power Density, provide an accurate (at least a conservative) representation of the actual conditions that a user would be exposed to.
- Typically, information about the simulation domain, grid size and time steps, frequency range, simulated phantom TSL parameters (conductivity and dielectric permittivity) are key items to support to the reliability of the simulation.

NUMSIM PAG (IV)

Validation

- NUMSIM PAG requires information about applicable code validation (pertinent test measurements and/or analytic models).
- For instance, a validation based on measurement for quasi-static conditions cannot be used for a full-wave simulation at higher frequencies.
- Even for a trusted, high-end, well-validated code that provides the correct physical answers, the issue is (as it is for all simulations) how well the numerical tool has been used to properly represent the DUT scenario.
- Details on how accurately the specific DUT scenario has been modeled, are required.

NUMSIM PAG (V)

Hybrid s/w – h/w Test Systems

- Compliance data may be provided through a combination of test measurements "augmented" via s/w data processing
- When EM fields are being estimated based on measured data using an extrapolation method (e.g., field-gradient based linear extrapolation), NUMSIM is not required; the rationale is that it is a mathematical extrapolation solely based on test data, not a true simulation of the physical DUT conditions.
- On the other hand, if test data are being used to initialize or constrain a simulation model (such as an EM field solver, regardless of its approximations), then NUMSIM is required.
- The results of the simulation, after the code/model has been vetted via NUMSIM PAG inquiry, can then be leveraged to support compliance

NUMSIM PAG (VI)

WPT Authorizations with Simulation Data

- If a device is authorized via SDoC, there is no PAG requirement and ECR-WPT Inquiry is the only avenue for vetting the simulation information.
- For consistency with the certification process, the ECR-WPT acceptance is required prior to the SDoC Equipment Authorization and will require a demonstration that the simulation results properly represent the DUT compliance scenario.
- Thus, also for SDoC, the NUMSIM Checklist is a recommended guideline for the information to be provided in the ECR-WPT, when simulations data are being used.

Field Estimates at the Tip of "Large" Probes (I)

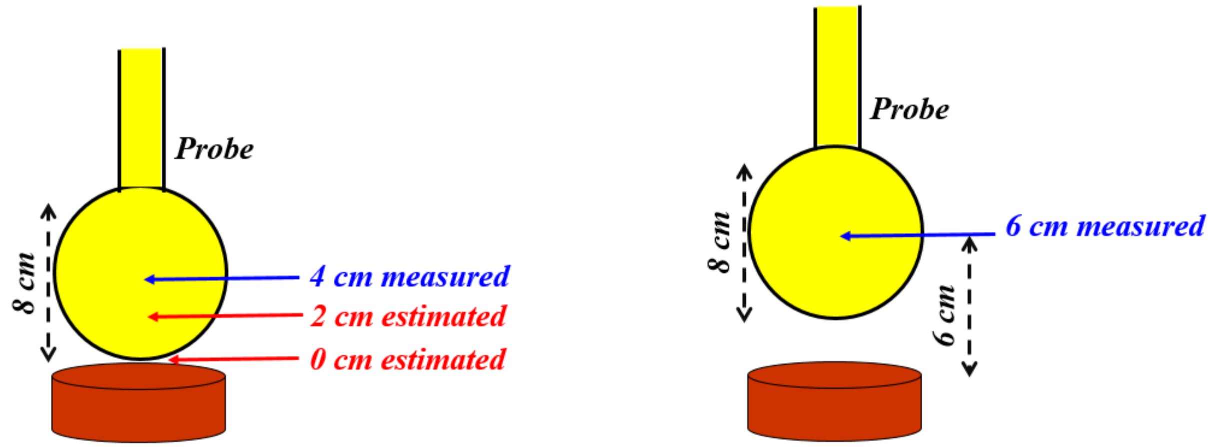
Relying on Calibrated Measurements

- A probe is measuring the electric and/or magnetic field in correspondence to its calibration point (typically the center of the probe sensor)
- Special designs (e.g., with more than one internal sensor) shall refer to manufacturer specifications and calibration certificate to specify the location for which the probe calibrated measurements are applicable
- The field at the front-edge (tip) of the probe enclosure will generally be different from the value provided by the calibrated measurements
- For RF Exposure compliance, a distance up to 5 millimeters between the probe calibration point and the measuring point is permitted
- For larger distances, the field needs to be estimated and validated

Field Estimates at the Tip of "Large" Probes (II)

Example: Probe with 4-cm Radius

- "Large size" probes may prevent the measurement of E- and/or H-fields near the surface of the radiating structure (e.g., a WPT source coil).



Probe (in yellow) measurements in points close to the WPT device (in brown). The probe radius is 4 cm, thus the closest point to the device where the field can be measured is at 4 cm from the surface (assuming probe calibration refers to the center of the sensing element structure, in this case a sphere of 4 cm radius).

Data at 0 and 2 cm must be estimated through a model, and then the model must be validated with the actual measurements at 4 and 6 cm, where the probe center can be positioned and collect valid data.

Field Estimates at the Tip of "Large" Probes (III)

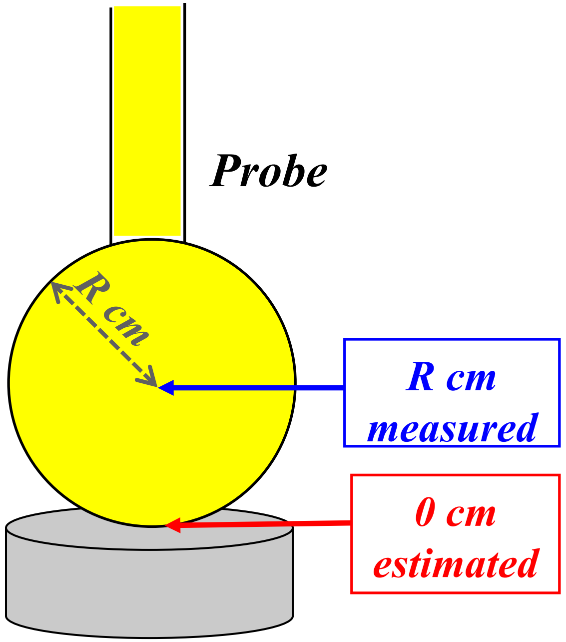
Field Estimates

- "Large size" probes may prevent the measurement of E- and/or H-fields near the surface of the radiating structure (e.g., a WPT source coil).
- In this case, the available measurements need to be supported by estimates (e.g., via formulas, numerical simulations) for the locations in correspondence of which the center of the probe cannot not be placed (due to the probe size).
- That is likely to be only the 0 cm point, or perhaps 2 cm as well, depending on the size of the probe.
- For probe radius 5 mm or less this procedure is not required (per KDB 680106)

Field Estimates at the Tip of "Large" Probes (IV)

Validation of Field Estimates

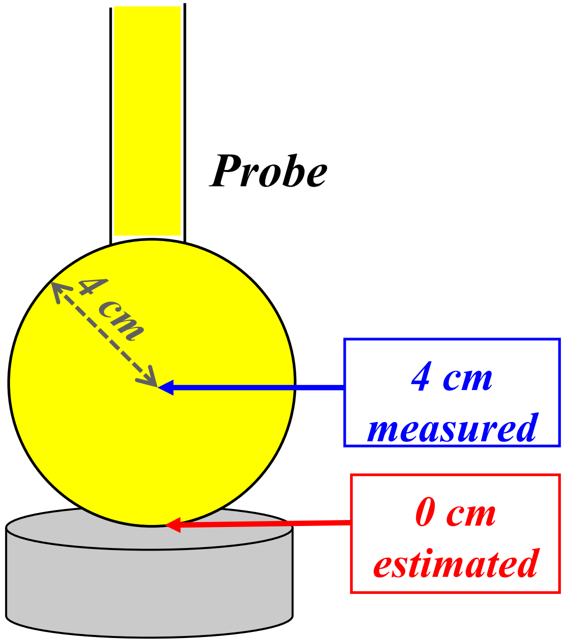
- If *R* is the probe radius and the probe tip is in contact with the coil, then the probe center is *R* cm from the coil surface.
- The probe then is measuring the field correctly at *R* cm from the surface, and only estimating the field at the 0 cm point of contact with the coil surface
- The validation requires showing that the model used to estimate the field provides data within 30% accuracy for at least the two, 2-cm-spaced closest points to where the estimates were made.
- If there is only one estimated value, then a single validation point is sufficient.



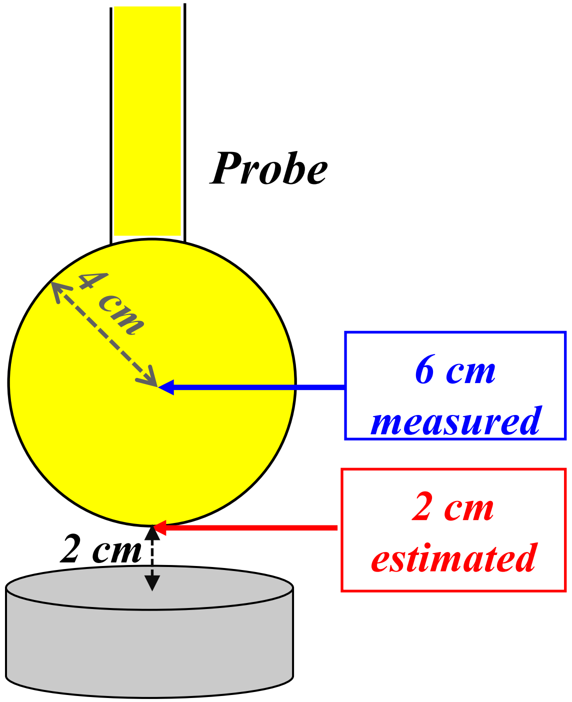
Field Estimates at the Tip of "Large" Probes (V)

Validation Example for 4 cm Probe Radius

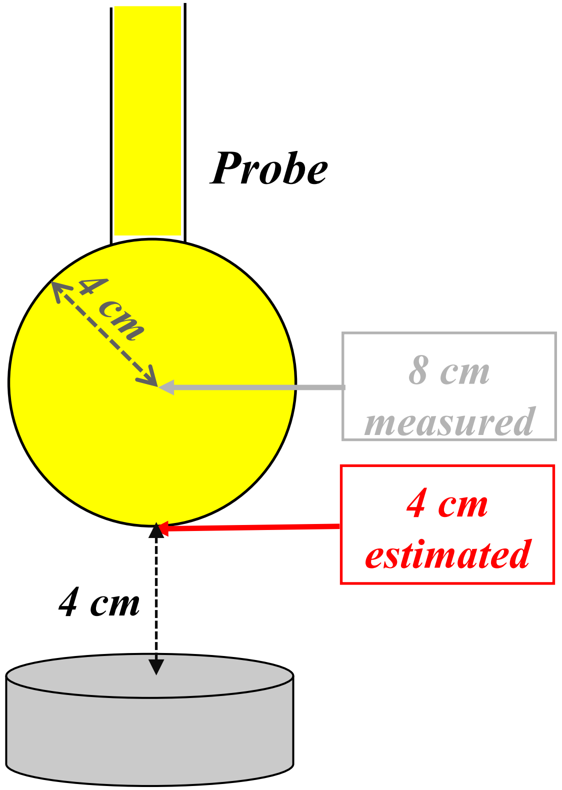
1. *Measure the field at 4 cm (closest position)*



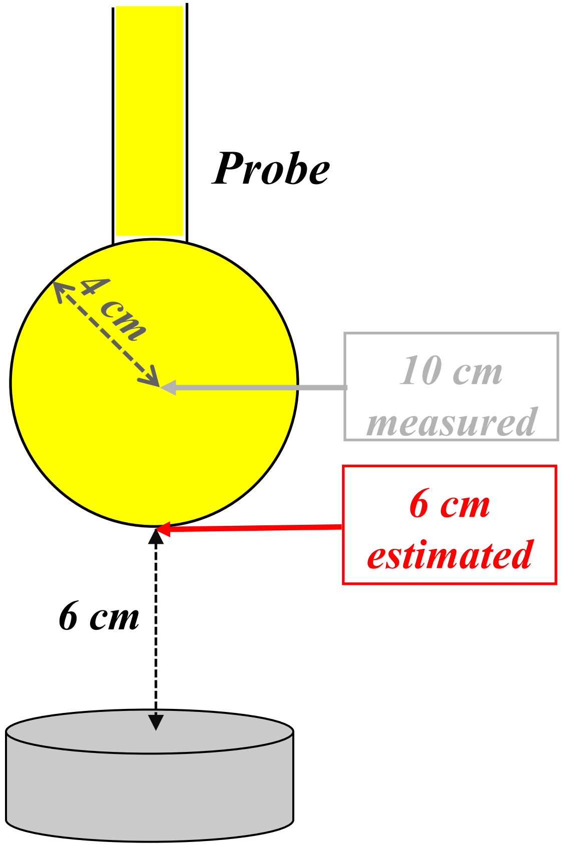
2. *Position the probe 2 cm from the DUT. Measure the field at 6 cm (probe calibration point)*



3. *Position the probe 4 cm from the DUT. Estimate the field at 4 cm.*
Compare with Step 1.



4. *Position the probe 6 cm from the DUT. Estimate the field at 6 cm.*
Compare with Step 2.



Field Estimates at the Tip of "Large" Probes (VI)

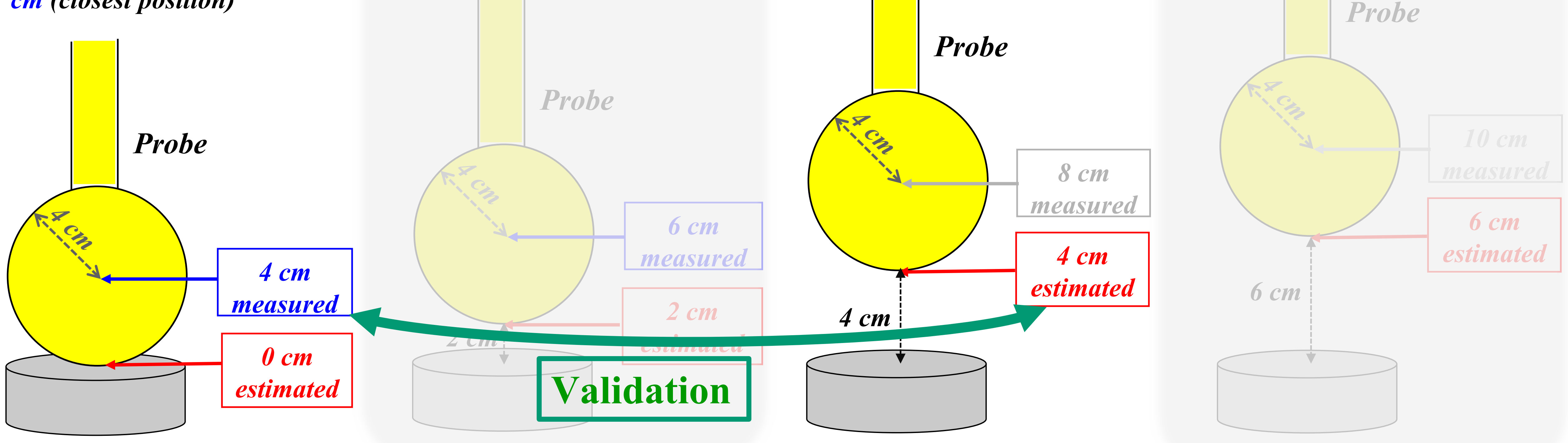
Validation Example for 4 cm Probe Radius

1. *Measure the field at 4 cm (closest position)*

2. *Position the probe 2 cm from the DUT. Measure the field at 6 cm (probe calibration point)*

3. *Position the probe 4 cm from the DUT. Estimate the field at 4 cm. Compare with Step 1.*

4. *Position the probe 6 cm from the DUT. Estimate the field at 6 cm. Compare with Step 2.*



Field Estimates at the Tip of "Large" Probes (VII)

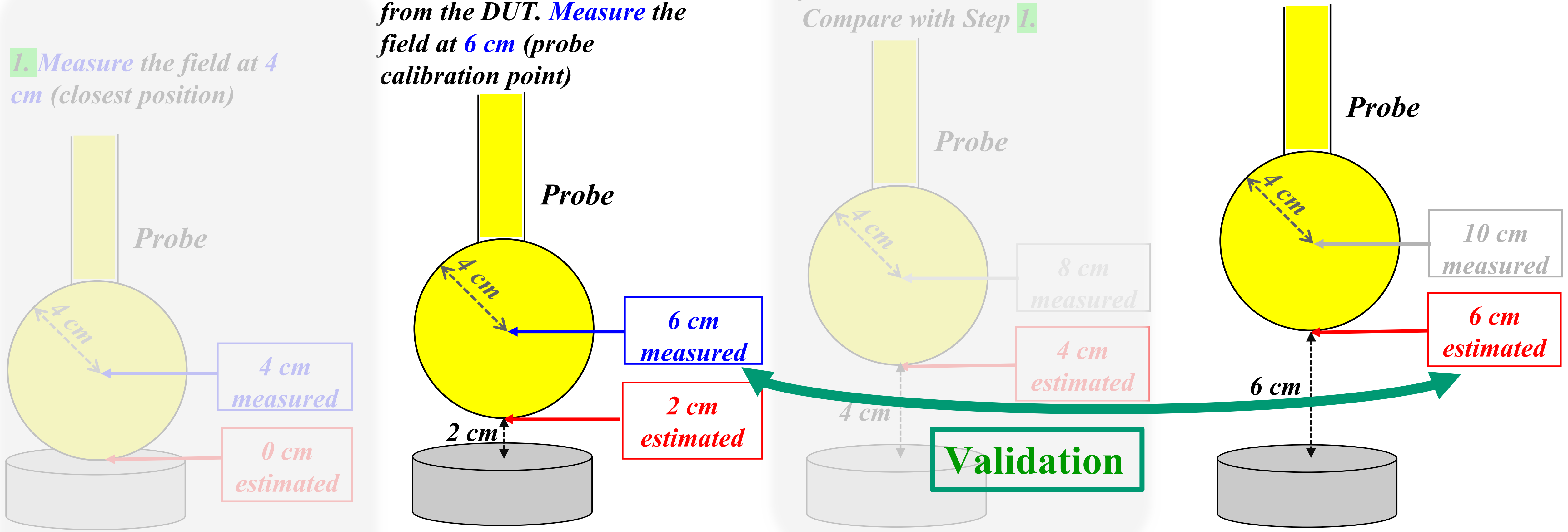
Validation Example for 4 cm Probe Radius

1. *Measure the field at 4 cm (closest position)*

2. *Position the probe 2 cm from the DUT. Measure the field at 6 cm (probe calibration point)*

3. *Position the probe 4 cm from the DUT. Estimate the field at 4 cm. Compare with Step 1.*

4. *Position the probe 6 cm from the DUT. Estimate the field at 6 cm. Compare with Step 2.*



Field Estimates at the Tip of "Large" Probes (VIII)

Description of the Validation Example for 4 cm Probe Radius

- Assume that R=4 cm. The field at 0 cm can only be estimated, but the field at 4 cm is measured exactly (at the center of the probe).
- Move the probe at 2 cm from the surface. The field at 2 cm can still only be estimated, but the field at 6 cm is measured exactly.
- Compare the estimates with the values at the same positions where the field was measured exactly (i.e., 4 cm and 6 cm)
- The difference between measurements and estimates needs to be no more than 30%.
- That validation of the estimates needs to be for the two closest points to the coil, but at least 2 cm apart (in this case they are). This is to avoid a validation at, say 2 cm and another one at 2.1 cm, that is essentially a repetition.

WPT Devices Co-located w/ Other RF Devices

- Guiding principle: FCC compliance refers to the emissions of a single RF device (possibly more than one transmitter, but characterized by a single FCC ID, or SDoC)
- KDB 680106 discusses compliance testing for the worst-case scenario WPT emissions (i.e., most challenging from EMC and RFX) while operating with a *client/load* device (that is being charged).
- Tests with maximum available nominal WPT current must be considered (typically, a “low-battery” *client* condition, e.g., 1% charge, is sufficient)
- For the same charging current, in most cases, the representative *client* device shall be chosen with a smaller, rather than larger, conductive surface (e.g., a laptop vs, small tablet), so to provide a higher “leakage” flux.

WPT Field Decreasing Beyond 1 meter (I)

Per 680106 Section 5.3-1: "*…the RF field strength of the fundamental WPT signal and of spurious emissions measured beyond one meter (electric and magnetic components) is lower than that which is measured at one meter*"

- The motivation is to ensure that the worst-case emissions are captured at closer test distances. This may become relevant for WPT-AAD with beam-forming technologies, where constructive interference patterns from antenna arrays may occur beyond the 1-meter measurement distance.
- This procedure intends to minimize design cases with "hidden" noncompliance spots, even if all measurements at close distance are compliant.
- Cases where the peak field strength occurs beyond one meter will be typically acceptable if properly documented in the ECR-WPT.

WPT Field Decreasing Beyond 1 meter (II)

- This Part 18 beam-forming related concern applies (in general) to both to spurious emissions and RF exposure, and stems from the ability to use large power in the ISM bands (while Part 15 devices are typically lower-power devices).
- The choice of the 1-m reference distance stems, in part, from constraints due to feasible beam-forming designs i.e., with practical antenna size.
- For these practically feasible beam-forming antennas (for WPT purposes) the frequencies must be high enough that distances past 1 m are already in the far field, where the beam pattern is already formed.
- Therefore, for these cases, no increase in field strength is expected at distances further away.

WPT Field Decreasing Beyond 1 meter (III)

Per 680106 Section 5.3-1:

"…(electric and magnetic components)…Both electric and magnetic field components must be measured if the one-meter location is not in the far field…"

- In the near field, the E and H fields are not related in a predictable way, thus the need to measure both for compliance purposes
- For a predominantly E-field source (e.g., GHz-bands), magnetic field measurements are not necessary, far-field conversion based on free-space impedance can be applied.
- Similarly, for a predominantly H-field source ("kHz" frequencies) the compliance measurements will be in the near field (due to the large wavelength).

WPT Field Decreasing Beyond 1 meter (IV)

- The far-field boundary definition is based on what approximation is acceptable for a plane wave in the case of surface-type antennas, or on the E/H ratio for linear antennas.
- In the most common cases, the far field distance is chosen as 2 D^2/λ for electrically large surface antennas (antenna size $D \gg \lambda$)*
- Best engineering judgment and conservative estimates shall be considered for complex or unusual antenna shapes.

(*) This corresponding to accepting a distance of $\lambda/16$ between the actual antenna wave front and a plane wave front, at a distance D/2 from the center of the antenna. For linear antennas, it is necessary to consider how close E/H is to the free space impedance: that leads to the $\lambda/3$ choice for the near-to-far field boundary [Paul, Whites, Nasar, 1998, p. 638]

Clarification about §18.305 Limits

From KDB 680106-v04, Sect. 5.3:

> *"… complying with the field strength limits in §18.305 (unwanted emission limits at 300 m and 1600 m distances*[5])
>
> ———————
>
> [5]*This may be shown via direct measurement, numerical simulation…*

- Footnote 5 applies to all emission outside the §18.301 ISM Bands.
- Not all Part 18 devices have a fundamental frequency within ISM bands; therefore, for these devices, the limits in 47 CFR 18.305(b) apply to both the fundamental (since it is not in an ISM band) and to the spurious emissions.

Clarification on Multiple Coil Systems

Per KDB 680106 Section 5.2-(2):

> *"The output power from each transmitting element (e.g., coil) is less than or equal to 15 watts."*

- Accordingly, a multiple-coil system for which the power of each coil is less than 15 W, meets the 5.2-(2) condition (if all those conditions are met an ECR-WPT is not required).

Conclusions

- Following this this presentation, a series of clarifications will be introduced in updates of the pertinent WPT and ECR KDB Publications,
- These clarifications are consistent with the present guidance
- Recent ECR-WPT Inquiries have been already answered in line with what was outlined in this presentation