Testing WPT with MAGPy V2.4+

APPLICATION NOTE

Testing Compliance with ISED SPR-002 Issue 2

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Testing Compliance of WPT Devices with MAGPy V2.4+ According to ISED SPR-002 Issue 2

1 Scope of this Document

This application note provides guidance on how to apply MAGPy V2.4+ for demonstration of compliance with ISED SPR-002 issue 2 [1]. MAGPy V2.4+ can be used in the following scenarios:

- demonstration of compliance with the basic restrictions (BR), i.e., induced fields ($E_{ind-peak}$ and psSAR1g/10g), for devices under test (DUT) with coil structures larger than 100 mm according to Tier 3 of Draft IEC/IEEE 63184 [2] (for coils smaller than 100 mm, MAGPy V2.4+ provides reliable but not conclusive results of compliance),
- demonstration of compliance with the reference levels (RL), i.e., the incident electric (E-) and magnetic (H-) fields, according to Tier 2 of Draft IEC/IEEE 63184 [2],
- validation of the DUT model for simulation-based assessments with BR.

The MAGPy V2.4+ system supports two compliance evaluation locations: probe center and probe tip. It is the only system that can accurately assess the fields at the probe tip (i.e., at the flat surface of the probe) with a reliable field extrapolation, as the probe not only measures the amplitude but also the gradient of the H-field. This enables the assessment at the surface of the DUT.

However, the more accurate measurements are in the probe center, i.e., 18.5 mm from the flat surface of the probe. These measurements are direct measurements without extrapolation. Hence, it is advised to set the evaluation location to:

- the probe tip, if the compliance location is $<$ 18.5 mm from the DUT, and
- the probe center, if the compliance location is $\geq$18.5 mm from the DUT.

> **Note:** The most accurate method with the least overestimation to demonstrate compliance is DASY8/6 Module WPT V2.4+, whereby guidance is provided in [3]. This requires testing in a dedicated laboratory whereas MAGPy V2.4+ can also be applied *in situ*.

2 Summary of ISED SPR-002 issue 2

2.1 Scope and Method

The scope of ISED SPR-002 issue 2 [1] encompasses:

- assessments against the radiofrequency (RF) exposure limits to prevent both nerve stimulation (NS) and thermal effects;

- assessments against both RL and BR;
- measurement-based and computational assessments.

The method to assess the BR by measurements is on top of the assessment method hierarchy (see Figure 1.1). It is the first choice as it is the method with the least overestimation. The second choice is the assessment against BR by computational assessments or simulations, and the 3rd and 4th choices are assessments against RL by measurements and simulations, respectively.

Note: Any computational method can never be more accurate than the measurement method used to determine the incident field at the surface of the DUT for the validation of the DUT model. It is a practical fact that the validation of the DUT model governs the uncertainty assessment of computational methods.

Note: Determination of the coverage factor usually requires hundreds of the simulations with anatomical models to have sufficient statistical power [4].

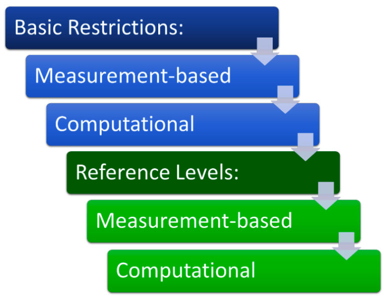

Figure 1.1: Assessment method hierarchy specified in [1]

2.2 Instrumentation Requirements

Section 5 of ISED SPR-002 issue 2 [1] sets out the general requirement for compliance testing of wireless power transfer (WPT) devices. In particular, it requires assessments at the closest distance a person may be exposed (i.e., this often corresponds to touch position, especially for NS-based assessments). In Section 6, ISED SPR-002 issue 2 refers to RSS-102 [5] regarding the requirements for measurement-based assessments against BR for the specific absorption rate (SAR), whereas it will define the requirements for measurement-based assessments against BR for the induced E-field in a future issue. It should be noted that ISED SPR-002 issue 2 had been defined before the novel MAGPy V2.4+ and DASY8/6 Module WPT V2.4+ technologies had been released.

Section 7 of ISED SPR-002 issue 2 provides the requirements for measurement-based assessments against RL. In particular, it specifies the detailed requirements of the probe and the sensor (called antenna in [1]) inside the probe in Sections 7.1.6 and 7.1.7 respectively. A comparison of the specifications of the MAGPy probe Version 2 with these requirements is provided in Table 1.1.

Section 8 of ISED SPR-002 issue 2 provides the requirements for simulation-based assessments. In Section 8.3.4, it suggests the same material properties for the tissue-simulating liquid as Draft IEC/IEEE 63184 [2]. In Section 8.3.5, it specifies the requirements for computational uncertainty analysis, including those for measurements for validating the numerical DUT model. A separate application note is available offering guidance for demonstration of compliance by simulations [6].

Note: The sensor size requirement $D_p \leq d_{meas}/1.7$ does not apply to MAGPy V2.4+ in most cases as shown in Sections 3.1 and 3.2.

	Sensitivity [A/m or V/m]	Ampl. flatness [dB]	Linear range [A/m or V/m]	Linearity error [dB]	Sensor size [mm]	Isotropy [dB]
SPR-002 issue 2	H: ≤1 A/m E: ≤1 V/m	≤1	defined as a function of RL	≤0.5	$\leq d_{meas}/1.7$[a]	≤1
MAGPy probe V2	H: 0.1 A/m E: 0.08 V/m	<0.2 (typ.)	H: 0.1–3200 A/m E: 0.1–2000 V/m	H: <0.2 (typ.) E: <0.5 (typ.)	H: 10 mm E: 50 mm	<0.5 (typ.)

[a] ISED SPR-002 issue 2 defines the sensor size requirement as a function of the distance relative to the center of the sensor, i.e., $D_p \leq d_{meas}/1.7$, in order to limit the errors due to the spatial averaging over the sensor in high gradient fields.

Table 1.1: Comparison of the specifications of MAGPy probe Version 2 with the probe and sensor requirements outlined in ISED SPR-002 issue 2 [1].

3 Compliance of MAGPy V2.4+ with ISED SPR-002 issue 2

3.1 Measurement of the Incident H-Field

3.1.1 $d_{meas} < 18.5$ mm

For field measurements at distances <18.5 mm, the compliance location in MAGPy V2.4+ shall be set to probe tip. MAGPy V2.4+ enables assessment of the H-field at the surface of the probe as the probe has information of the field gradient and considers the averaging over the sensor size when the extrapolation function is determined using the measured fields of all eight isotropic sensors and the measured gradient. Hence, MAGPy V2.4+ can be applied to determine the incident H-field at the surface of the DUT. This measurement can be considered to be fully compatible with ISED SPR-002 issue 2 [1] and does not require any additional consideration. The H-field value at the probe surface (also called probe tip in the MAGPy software) including the associated uncertainty can be directly used to validate the DUT model for simulation-based assessments [6].

3.1.2 $d_{meas} \geq 18.5$ mm

For field measurements at distances ≥ 18.5 mm, the compliance location in MAGPy V2.4+ shall be set to probe center. In these cases, the minimum distance requirement of [1], i.e., $d_{meas} \geq 1.7 D_p$, is readily met.

3.2 Measurement of the Incident E-Field

The centers of the isotropic E-field sensors (implemented as dipole/monopole) are in the probe center. The dipole/monopole arms have been designed to provide maximal sensitivity and enable determining if the incident E-field from a source is local or not. The sensors are calibrated for uniform E-field or fields with linear gradients. If the fields induced by the incident E-field cannot be neglected (see Section 3.3), the evaluation needs to be performed according to Section 7 of ISED SPR-002 issue 2 and applying the requirement $d_{meas} \geq 1.7 D_p$.

3.3 Determination If the E-Field Exposure Can Be Neglected

In case of inductive sources, the fields induced in the human body or its surrogate phantom are dominated by the incident H-field. It can be evaluated if the incident E-field is local and can be neglected with the following procedure:

- demonstrate that the field impedance at 30 mm from the DUT is $< 37.7\,\Omega$ for all cases where the H-field is higher than RL,
- demonstrate that the maximum induced fields due to the incident E-field (determined at the location of the maximum incident E-field, and estimated with the approximation published in [7] after taking the 23 dB worst-case underestimation of the incident E-field into account [8]) are much smaller than the induced fields due to the incident H-field there.

3.4 Assessment of Compliance with BR

MAGPy V2.4+ has the big advantage that it offers direct demonstration of compliance with BR for devices with coil structures larger than 100 mm at any distance (including $d_{meas} \leq 18.5$ mm) and any DUT at distances $d_{meas} > 18.5$ mm.

Note: Section 6.2 of ISED SPR-002 issue 2 [1] states that an inquiry to ISED is required for a measurement-based assessment against the basic restriction for the induced electric (E-)field. We recommend stating in the inquiry that *"The evaluation is performed according to the attached Application Note "Testing Compliance of WPT Devices with MAGPy V2.4+ According to ISED SPR-002 Issue 2" issued by SPEAG."*

3.5 Differences between Evaluations with DASY Modules and MAGPy V2.4+

The DASY8/6 Module SAR V16.2+ and DASY8/6 Module WPT V2.4+ offer the most accurate methods to determine compliance of WPT devices in accordance with ISED SPR-002 issue 2 [1] but require a laboratory environment. DASY8/6 based evaluations are performed according to Tier 4 of [2] without overestimation, and can be performed for any WPT devices with coil structures not larger than 900 mm×900 mm. For details about how to make the compliance testing with DASY8/6 Module SAR and Module WPT, see the Application Note [3].

MAGPy V2.4+ is the most accurate instrument to evaluate WPT devices *in situ*. It is suited for devices with coil structures larger than 100 mm (double the probe diameter). It may be used for smaller DUT if the uncertainty is properly developed and assessed for the specific DUT.

4 Procedure for Frequencies 3 kHz–10 MHz

4.1 System Requirements

The MAGPy V2.4+ handheld system is a all-in-one device which includes all the necessary hardware (MAGPy-8H3D+E3D Version 2 probe) and software (MAGPy V2.4+ Desktop and Backend).

4.2 Measurement Procedure for Compliance Evaluation with RL

The workflow to demonstrate compliance with RL is illustrated in Figure 1.2. More information/illustration about the relevant operations can be found in Section 3 of the MAGPy Manual [9] and Figure 1.3–1.5. This procedure corresponds to Tier 2 of [2].

4.2.1 Uncertainty

The uncertainties ($k = 2$) of the incident H-fields measured with MAGPy V2.4+ at the probe tip and probe center are typically $< 35.7\%$ and $< 13.9\%$ respectively. The uncertainty ($k = 2$) of the incident E-field measured with MAGPy V2.4+ is typically $< 24.4\%$ (valid for uniform E-field or fields with linear gradients). Detailed uncertainty budgets can be found in Section 8 of the MAGPy Manual [9].

Prepare system

- Select the relevant standard (incl. health effect (electrostimulation/thermal/combined) and exposure scenario (general-public/occupational)) (Manual Section 3.4)
- Check the H-field spectrum of the DUT and set the peak frequency search range (Manual Section 3.3)
- Perform a preliminary scan to find a location with high incident fields
- Check default parameters of time-domain slicing and adjust if needed (Figure 1.3a)
- Confirm the multifrequency assessment is enabled (If other frequency components are at least 30 dB lower than the fundamental frequency component and/or are below the probe sensitivity, they will automatically be neglected) (Figure 1.3b)

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Search for the worst-case probe location

- Display results in ABS mode (Manual Section 3.7)
- Select the probe tip and the probe center as the compliance location for distances < 18.5 mm and ≥ 18.5 mm respectively (Figure 1.3b)
- Clear the display (Manual Section 3.7)
- Scan the exposure characterization space around the DUT to find the probe location resulting in the maximum H-field (Manual Section 3.6) (it is recommended to rotate the probe around its axis by 45 degree to confirm the maximum H-field value)

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Extract compliance evaluation results

- Display results in REL mode (Manual Section 3.7)
- Note the maximum relative value for the incident H-field at the worst-case probe location; if it is negative (i.e., the maximum H-field is below the corresponding safety limit), the compliance of the DUT has been successfully demonstrated (Manual Section 3.6)
- Investigate if the E-field exposure is local and can be neglected by checking if the E/H ratios at 30 mm from the DUT surface are much smaller than the free-space wave impedance 377 Ω and if the E-field induced by the maximum incident E-field is much smaller than that induced by the incident H-field there. If the above conditions are met, compliance is conclusively demonstrated.
- If the E-field exposure cannot be neglected, measure the incident E-field according to the ISED requirement, i.e., at $d_{meas} = 85$ mm (meeting the requirement $d_{meas} \geq 1.7 D_p$, where $D_p = 50$ mm for the E-field sensors in MAGPy V2 probe) and extrapolate the field to the DUT surface and estimate the total uncertainty.
- Save results by taking screenshots and/or exporting data in terms of CSV/JSON files (Manual Section 3.9)

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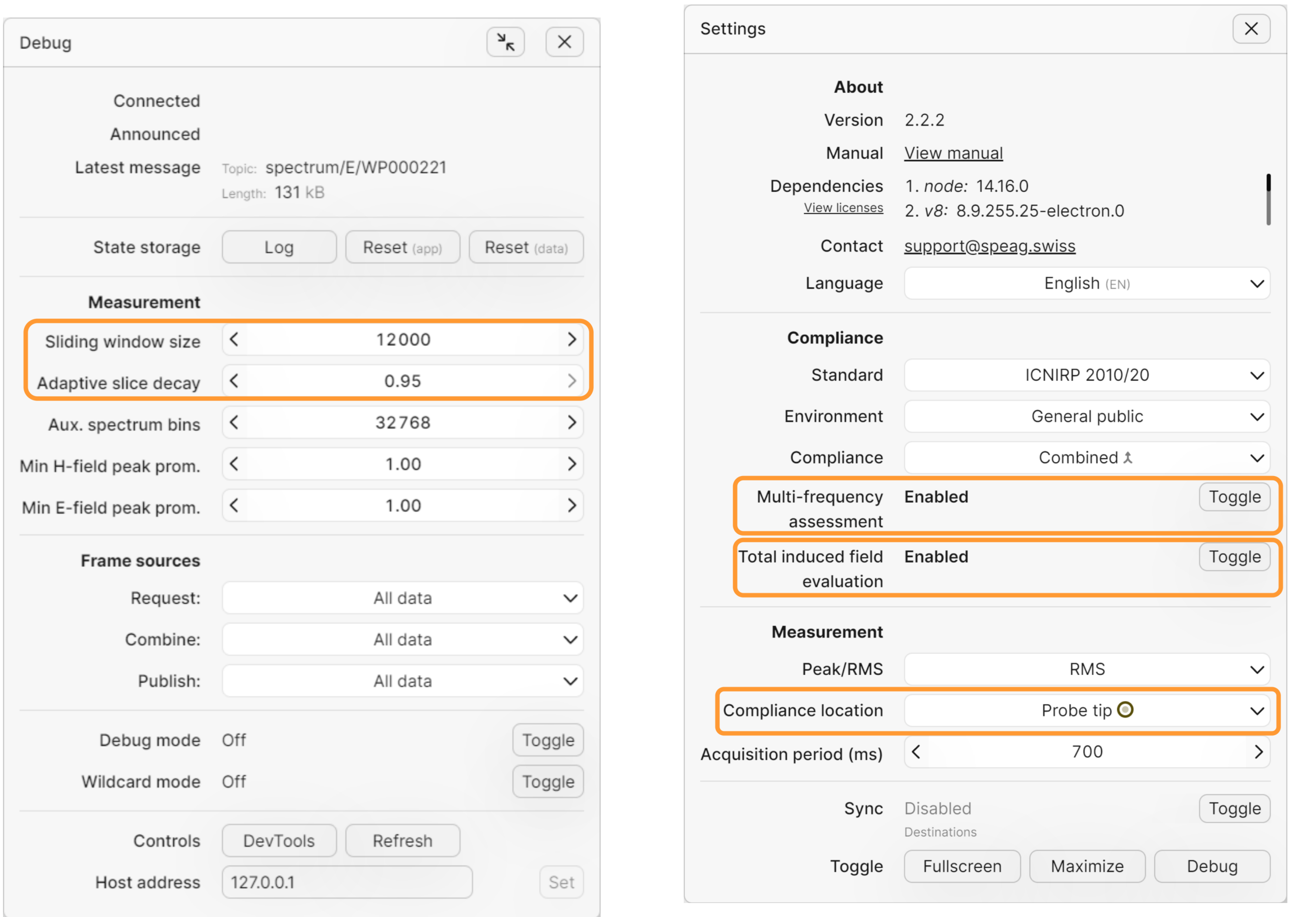
Investigate the transient behavior of the emissions during receiver removal

- Check the incident fields in the time domain at the worst-case probe location (Figure 1.5), and scale the compliance evaluation results if appropriate

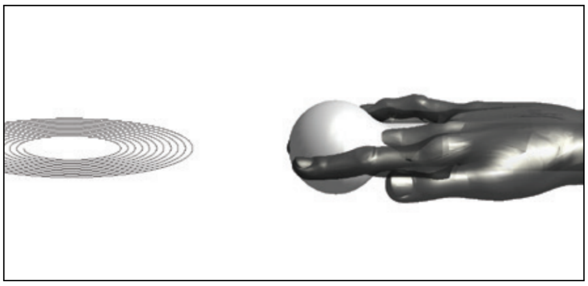
Figure 1.2: Step-by-step measurement procedure of MAGPy for compliance evaluation against RL. If the demonstration of compliance fails, it is recommended to evaluate the compliance of the device against BR (see Section 4.3).



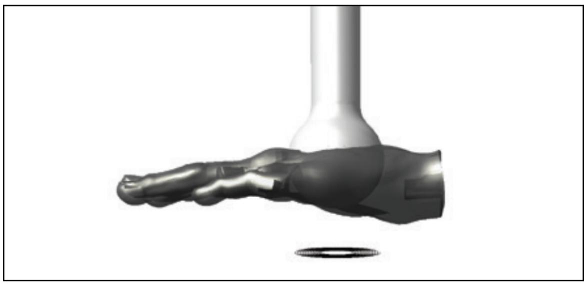
(a) Time-domain slicing setting

(b) Multi-freq. assessment, total field evaluation and compliance location setting

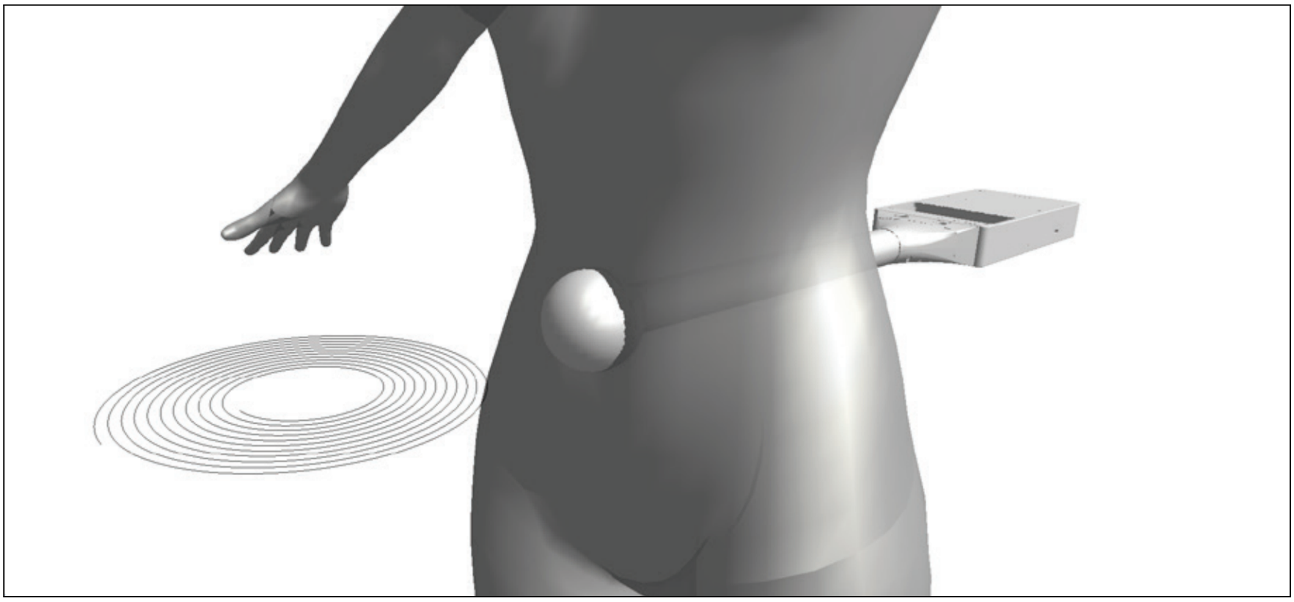
Figure 1.3: Settings of the time-domain slicing parameters, the multifrequency assessment option, the total field evaluation option, and the compliance location



(a) The hand reaches towards a magnetic field source from the side.



(b) The hand is placed on top of a magnetic field source (e.g., mobile charger).



(c) The whole body is in close proximity to the field source.

Figure 1.4: Exposure evaluation scenarios

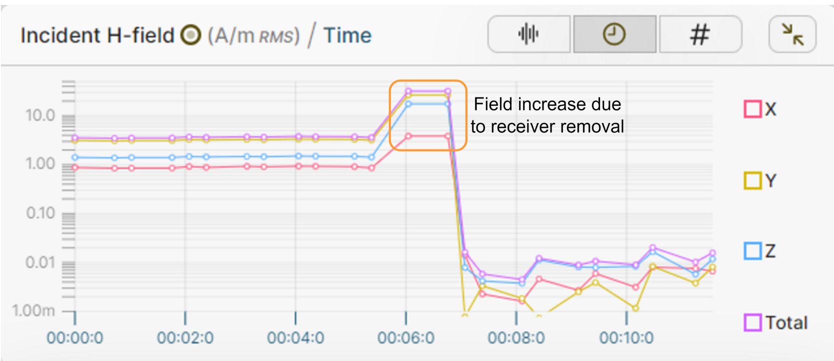


Figure 1.5: The time-domain plot of the incident H-field in the MAGPy graphical user interface. The data were recorded from a commercial wireless charger while removing the smartphone placed on the charger. The same procedure can also be used to monitor the stability of the source.

4.3 Measurement Procedure for Compliance Evaluations with BR

The workflow to demonstrate compliance with BR is illustrated in Figure 1.6. More information/illustration about the relevant operations can be found in Section 3 of the MAGPy Manual [9] and Figure 1.3–1.5. This procedure corresponds to Tier 3 of [2].

Prepare system

- Select the relevant standard (incl. health effect (electrostimulation/thermal/combined) and exposure scenario (general-public/occupational)) (Manual Section 3.4)
- Check the H-field spectrum of the DUT and set the peak frequency search range (Manual Section 3.3)
- Perform a preliminary scan to find a location with high incident fields
- Check default parameters of time-domain slicing and adjust if needed (Figure 1.3a)
- Confirm the multifrequency assessment is enabled (If other frequency components are at least 30 dB lower than the fundamental frequency component and/or are below the probe sensitivity, they will automatically be neglected) (Figure 1.3b)
- Confirm the total induced field evaluation is enabled (Figure 1.3b)

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Search for the worst-case probe location and orientation

- Display results in ABS mode (Manual Section 3.7)
- Select the probe tip and the probe center as the compliance location for distances < 18.5 mm and ≥ 18.5 mm respectively (Figure 1.3b)
- Clear the display (Manual Section 3.7)
- Scan the exposure characterization space around the DUT and rotate the probe axis in all directions along which a user or bystander may approach the DUT (note that the body surface is always normal to the probe axis, see Figure 1.4) to find the probe location and orientation resulting in the maximum induced fields (Manual Section 3.5) (it is recommended to rotate the probe around its axis by 45 degree to confirm the maximum induced field values)

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Extract compliance evaluation results

- Display results in REL mode (Manual Section 3.7)
- Note the maximum relative values for the induced fields at the worst-case location and orientation; if all of them are negative (i.e., the maximum induced fields are below the corresponding safety limits), then the compliance of the DUT has been successfully demonstrated (Manual Section 3.5)
- Investigate if the E-field exposure is local and can be neglected by checking if the E/H ratios at 30 mm from the DUT surface are much smaller than the free-space wave impedance 377 Ω and the E-field induced by the maximum incident E-field is much smaller than that induced by the incident H-field there. If the E-field exposure cannot be neglected, a rigorous compliance testing should be made with DASY8/6 Module SAR.
- Save results by taking screenshots and/or exporting data in terms of CSV/JSON files (Manual Section 3.9)

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Investigate the transient behavior of the emissions during receiver removal

- Check the incident fields in the time domain at the worst-case location and orientation (Figure 1.5), and scale the compliance evaluation results if appropriate

Figure 1.6: Step-by-step measurement procedure of MAGPy for compliance evaluation against BR. If the demonstration of compliance fails, it is recommended to evaluate the compliance of the device using the more accurate procedures based on DASY8/6 modules offering less overestimation [3].

4.3.1 Uncertainty

As the assessment of the induced fields using the generic gradient source mode (GGSM) method [10] had been designed to be always conservative if the contribution by the incident E-field can be neglected, the uncertainty of the assessment does not need to be considered.

4.4 Measurement Procedure for DUT Model Validation

The workflow to validate the DUT model which can be used in simulation-based assessments against BR is illustrated in Figure 1.7. More information can be found in Section 3.5 of [6].

Prepare system

- Check the H-field spectrum of the DUT and set the peak frequency search range (Manual Section 3.3)
- Perform a preliminary scan to find a location with high incident fields
- Check default parameters of time-domain slicing and adjust if needed (Figure 1.3a)

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Measure incident fields at validation points

- Determine the validation points according to [6]
- Display results in ABS mode (Manual Section 3.7)
- Select the probe tip or probe center as the compliance location for distances ≤18.5 mm and >18.5 mm respectively (Figure 1.3b)
- Clear the display (Manual Section 3.7)
- Mark down the incident H-field measured at each validation point (it is recommended to rotate the probe around its axis by 45 degree to confirm the H-field value)
- Repeat the above steps to obtain results for all validation points

Figure 1.7: Step-by-step measurement procedure of MAGPy for the validation of the numerical DUT model.

4.4.1 Uncertainty

The uncertainties of the measured incident H-field and E-field are the same as those presented in Section 4.2.1.

5 Conclusion

This application note provides guidance on how MAGPy V2.4+ is used for measurement-based assessments against RL and BR in the frequency range 3 kHz–10 MHz and the validation of the DUT model for simulation-based assessments. A separate Application Note is available for DASY8/6 Module SAR V16.2+ and WPT V2.4+ [3].

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