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Practical Considerations for Radiated Immunities Measurement using ETS-Lindgren EMC Probes

Detectors/Modulated Field

ETS-Lindgren EMC probes (HI-6022/6122, HI-6005/6105, and HI-6053/6153) use diode detectors for rectifying electromagnetic fields. The probes are calibrated to report continuous wave (CW) root-mean-square (RMS) electric fields. For electric fields with modulations or complex field with multiple frequency components, these probes may not accurately report the instantaneous field values or the true power of the field. For commercial EMC measurements, such as fields with 1 kHz 80% AM as required in IEC 61000-4-3 (EN 61000-4-3), the field readings should be taken with the modulation off (CW or sine wave only). Please see the related standards for details.

Probe Orientation

ETS-Lindgren EMC probes, such as HI-6022/6122, HI-6005/6105, and HI-6053/6153, are designed with three orthogonal sensing elements. Ideally, the probes will be entirely isotropic, i.e. sensing electric field equally in any directions.

Because of interferences from the probe construction and other non-ideal factors, certain non-isotropic behaviors exist. These non-ideal behaviors, however, can be minimized if the end user can take certain precautions. The effect can be mitigated further by mimicking their calibration geometry in their applications. Note that calibrations for all three axes are still required. This is different from calibrating the probe only in one orientation, and producing a composite correction factor (for all three axes) based on the calibration taken in this specific setup. The composite correction method produces incorrect calibration data, as the traceable calibrated field is only valid for the intended polarization (See IEEE 1309 on methods to generate traceable electric field). The composite correction factors are not traceable to national standards.

Instead, during the calibration at ETS-Lindgren, all three axes are individually aligned (and electrically peaked) to the NIST traceable incident electric field. Correction factors are reported for each axis. The users are expected to correct the final readings based on:

$$E = \sqrt{(CF_x \cdot E_x)^2 + (CF_y \cdot E_y)^2 + (CF_z \cdot E_z)^2}$$

Where E is the electric field after correction,

$E_{x,y,z}$ are the magnitudes of the E field readings in x, y or z direction,

$CF_{x,y,z}$ are the calibration factors provided by the calibration labs.

In a typical radiated immunities application, it is best to align the probe similarly to its calibration geometry. This typically means that one axis is dominant, and reads a much higher field value than the other two. The correction factors should still be applied to x, y and z axes separately, and total field summed after the corrections based on the above equation.

For HI-6005/6105/6022/6122, the calibration geometry at ETS is as following:

- X-axis: x aligned with the polarization of the antenna; y pointed towards the transmit antenna; and z is cross polarized (in the H-field direction). See Figure 1 for illustration.

- Y-axis: y aligned with the polarization of the antenna; z pointed towards the transmit antenna; and x is cross polarized (in the H-field direction).

- Z-axis: z aligned with the polarization of the antenna; x pointed towards the transmit antenna; and y is cross polarized (in the H-field direction). See Figure 2 for illustration.

For HI-6053/6153, it can be difficult to hold them at the orthogonal angle (see Figure 3) without a special fixture. Also, the axes of these probes are hidden under protective covers. It is not always obvious how the probe elements are positioned. Because of the superior isotropic response of the HI-6053/6153 probes (better than 1 dB), it is typically not necessary to orient these two types of probes the same way as the calibration setup. For references, the calibration geometry at ETS is listed below (Probe stalk is at the orthogonal angle, i.e.54.7◦ from the vertical plane).

- X-axis: x aligned with the polarization of the antenna; y is longitudinal (in the propagation direction); and z is cross-polarized (in the H-field direction). See figures 3 and 4 for illustration.

- Y-axis: y aligned with the polarization of the antenna; z is longitudinal (in the propagation direction); and x is cross-polarized (in the H-field direction). See figures 3 and 4 for illustration.

- Z-axis: z aligned with the polarization of the antenna; x is longitudinal (in the propagation direction); and y is cross-polarized (in the H-field direction). See figures 3 and 4 for illustration.

It is important to keep the probe electronics box away from the incident electromagnetic wave. It is recommended the stalk of the probe be parallel to the E or H-field (Figure 4) to minimize any influences from the electronics box. Figure 4 shows a typical recommended setup for this type of probes during a measurement. In this setup, the electronics box is the farthest from the main beam of the antenna. The decision to align with E or H field depends on the characteristics of the transmitting antenna. If the transmitting antenna has a narrower beam width in H direction, the probe stalk should be in H field direction as well. Another technique one might consider is to use microwave absorbers around the electronics box to minimize the reflections. Note that it is generally not a good practice to align the stalk in the field propagation direction (parallel to the Poynting vector). This is because the metallic electronics box will either block or reflect the field to the sensing elements. Setup shown in Figure 5 is not recommended, as the measurement results (Figure 6) are compromised by the interference from the supporting structures.

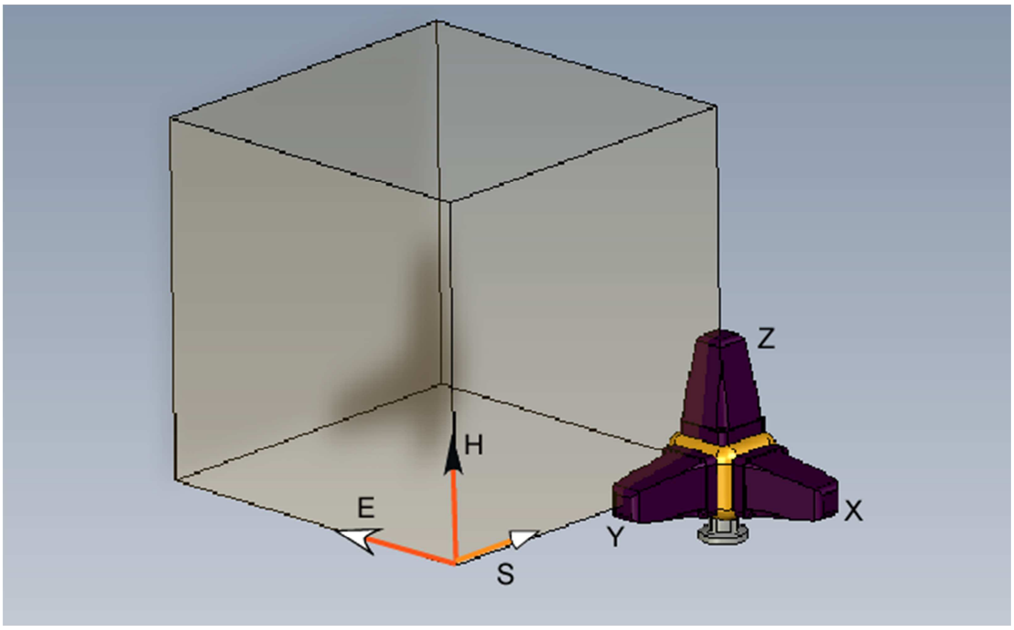

Figure 1. Measuring horizontally polarized E field: x axis aligned with the incident electric field. S denotes Poynting vector.

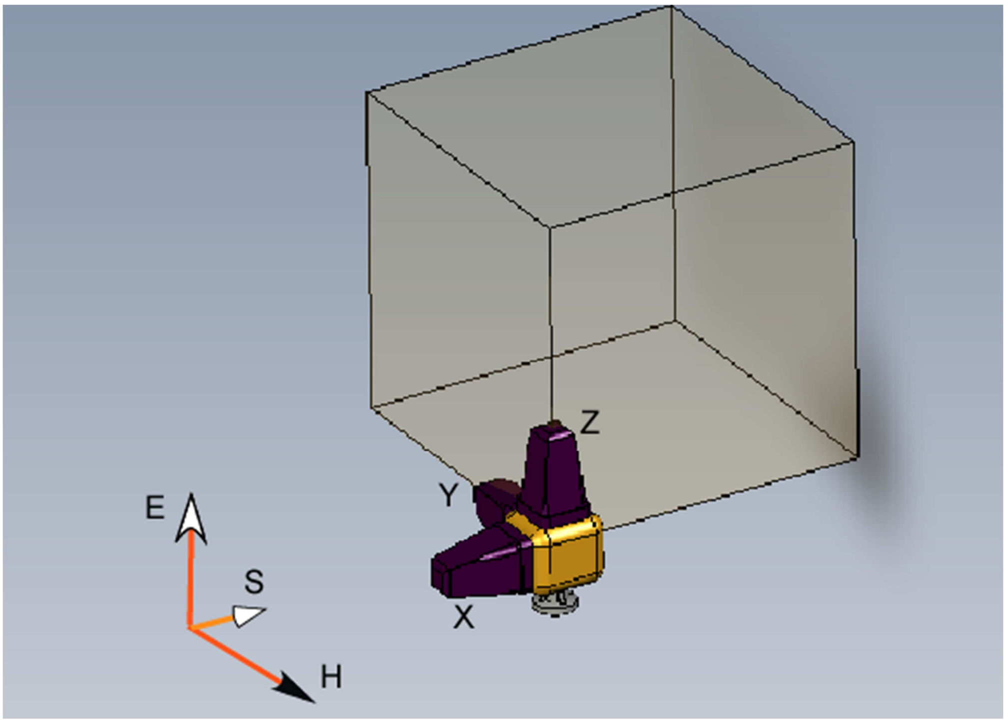

Figure 2. Measuring vertically polarized E field: z axis aligned with the incident electric field. S denotes Poynting vector.

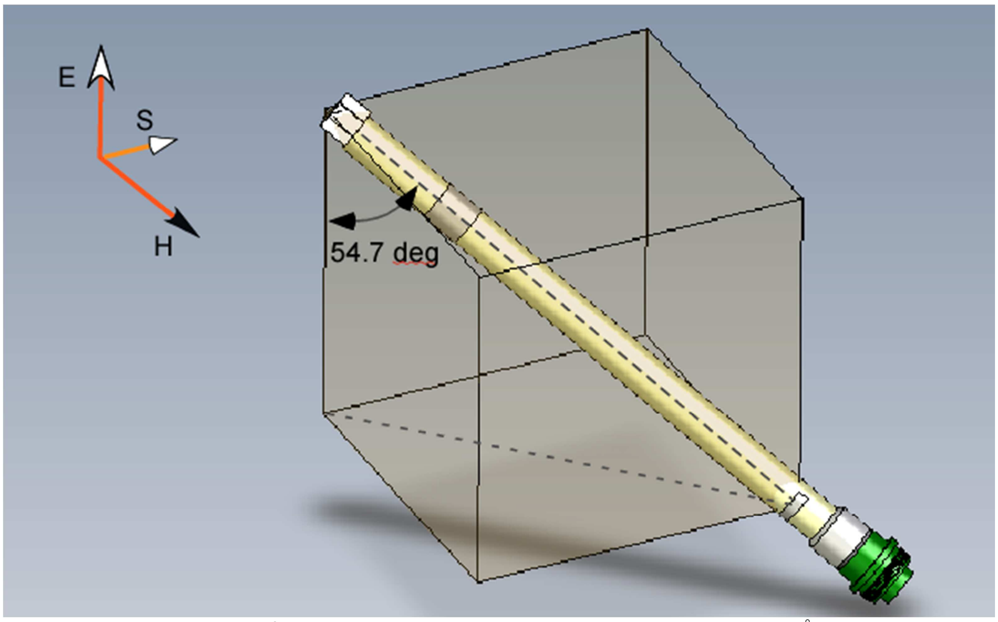

Figure 3. Orthogonal orientation of a stalk probe during calibration – probe stalk is 45° to the side, and 54.7° from the vertical line. S denotes Poynting vector.

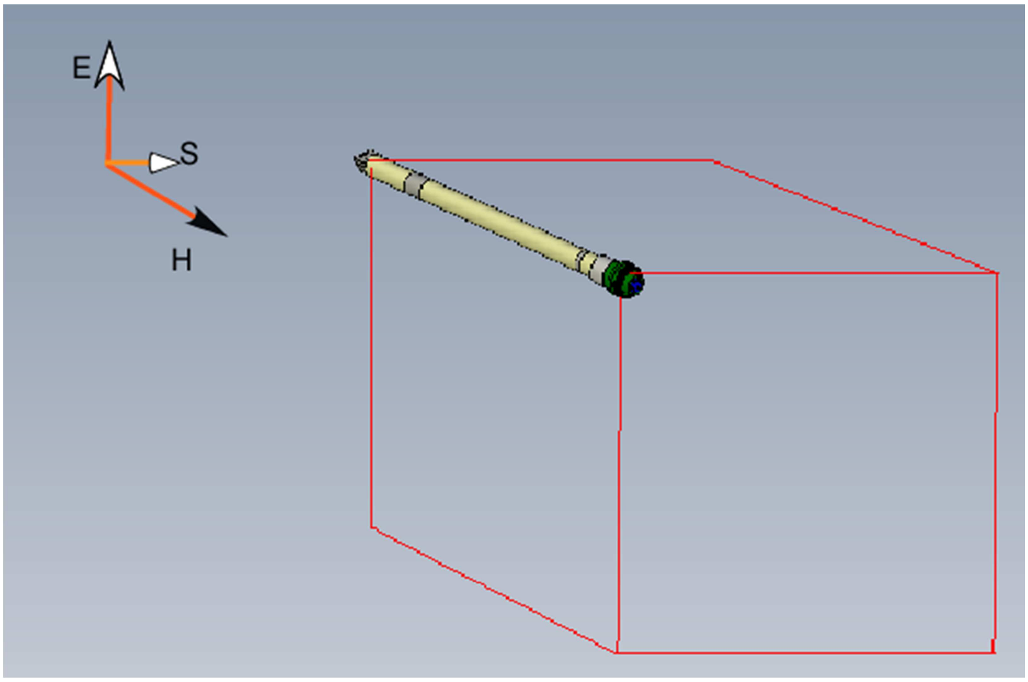

Figure 4. Recommended orientation for HI-6053/6153 stalk probes during measurements. Probe stalk is parallel to the H field, which minimizes any field pickups from the high-impedance lines inside the stalk. S denotes Poynting vector.

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Figure 5 a). The electronics box interferes with the sensor (head on position).

Figure 5 b). A handle behind an HI-6005 probe, even made of dielectric material, can interfere with the measurement. Do not orient a probe which can interfere with the measurements.

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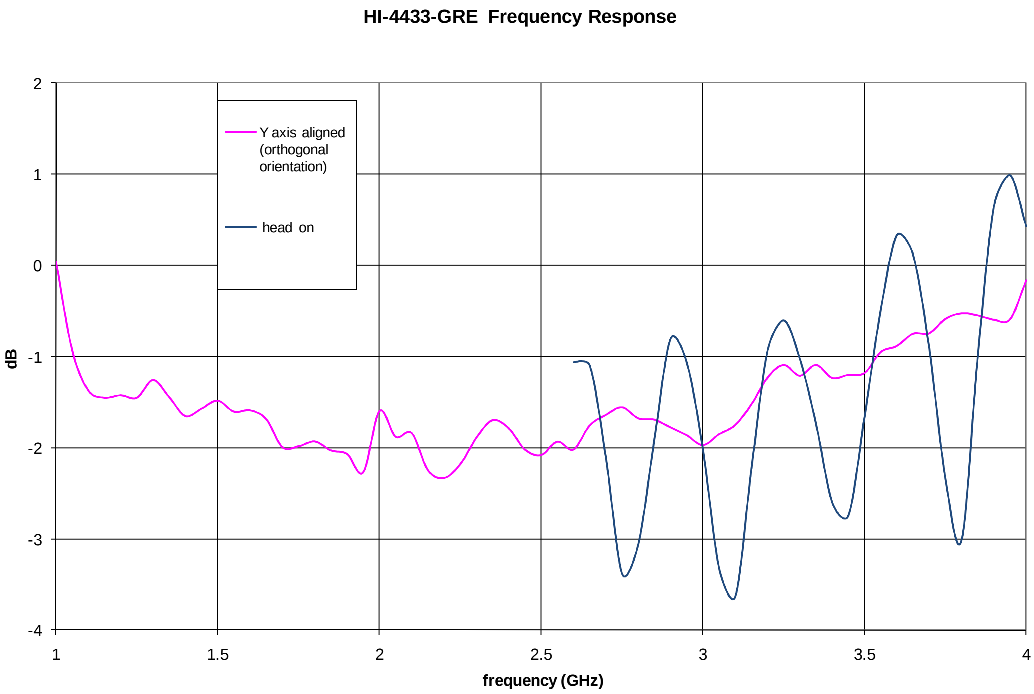

Figure 6. The frequency response of an HI-4433-GRE probe. The head on position as shown in Figure 5a shows large oscillations in frequency response data because of reflections of the electronic box. Data from an orthogonal orientation as shown in Figure 3 does not show such large oscillations.

Selecting the Best Probes for the Application

For radiated immunities applications from 10 MHz - 40 GHz, especially in an open air environment, it is recommended to select HI-6053/6153 probes. These probes provide the best isotropic response in this frequency range (provided with probe electronics positioned away from the incident field). The dynamic range is 2 V/m – 800 V/m, with an option for 1200 V/m.

For applications at lower frequencies, and/or to be used in a TEM cell device, HI-6005/6105/6022/6122 should be used. HI-6022/6122 is specified to operate from 10 kHz – 1 GHz, whereas HI-6005/6105 operates from 100 kHz to 6 GHz.

For HI-6022/6122, the isotropic response is better than +/- 0.5 dB across the frequency band. HI-6005/6105 has isotropic response of better than +/- 0.5 dB bellow 1 GHz. The isotropic response incurs approximately 0.5 dB degradation for an increase of every gigahertz. For example, between 1 -2 GHz, the isotropic response can be +/- 1 dB from the ideal. The measurement uncertainties due to the non-ideal isotropic responses can be reduced if the probes are orientated similarly to their calibration geometries as outlined in the previous section.
The self-contained (as opposed to the stalked) probes, such as HI-6005/6105/6022/6122, are convenient in many applications because there is no need to worry about the placement of the electronics boxes, and are easier to fit in TEM cell devices. The reduced isotropic performance at a higher frequency is simply a compromise as a result of exposing the metallic box in the field of sensing. The degradation in isotropic response at higher frequencies is present for any probes with similar constructions, including those from other manufactures.

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Linearity Considerations

EMC probes are expected to be accurate for the entire dynamic range of the specifications. The users typically obtain frequency response correction factors for a fixed field level (e.g. 20 V/m) from a calibration lab. The corrections are valid for other field values. This is because the linearity response of the probe changes little with frequency. Each probe (HI-6022/6122/6005/6105/6053/6153) has a customized linearity table loaded at the factory. It is just as important to check the linearity at each calibration cycle as the frequency response.