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White Paper

White Paper #3

Consequences of non-isotropic behaviour of E-field Probes:

Isotropy much more important than previously thought!

Importance of Isotropy

Consequences of non-isotropic behavior of E-Field Probes

The ongoing discussion about the measurement accuracy of Electric Field Probes during EMC immunity tests continues to be an important discussion topic. The probe is after all the only absolute reference instrument on which the complete test is based and this is more than enough reason for the engineers of Raditeq Products to start a research project on this subject. The initial results of these tests are, to say the least, surprising.

Discussion around Measurement accuracy

For many years there wasn't much noteworthy news surrounding the electric field probes. In the past, the industry standard was based on cubic shaped probes operating up to frequencies of 1 GHz and stick probes for frequencies up to 40 GHz. Both types of probe were relatively large, and were battery powered. With the introduction of the first laser powered field probe, the RadiSense® in 1999, the first problems came to light. It became clear that size and shape of the probe had a huge impact on the measurement results. It also proved that the smaller the probe, the better the measurement results became and further to this, a spherical probe provided more accurate results.

Another important aspect seemed to be the position of the probe with regard to the generated field. Measurements at Physikalisch-Technische Bundesanstalt (PTB) in Berlin showed that stick probes, where the measurement elements (antenna's) are separated from the electronics, resulted in deviations of up to 100% depending on the placement of the probe in the generated field. As a consequence, a lot of calibration centres (unjustly) calibrated stick probes keeping the electronics outside of the calibration setup. This is of course very different from how the probe is used during a proper EMC measurement.

The comité Français D'Accréditation (COFRAC) has focused on the number of elements (antenna) and how sensors must be calibrated. Meanwhile some users have noticed that there are notable measurement differences between different models of probes in the same room and with the same set-up. Some suppliers, including Raditeq Instruments, have changed their design to six antenna-elements that are placed symmetrically to each other. Although this change to the probe results in a substantial improvement in comparison to older versions, it also highlighted effects and the research needed into the sensor isotropy.

Custom made research facility

As a response to the measurement (in)accuracy discussion, Raditeq started a research project on sensor isotropy. This research had the aim to get more insight into the causes which contribute to these measurement errors. The first step for Raditeq was to construct a special and custom-made anechoic calibration room. This room makes it possible to precisely and efficiently measure the characteristics of Electric field probes. Using special 3D printed parts, a fully automated system was built to accurately measure the isotropic behavior of field probes. This system makes it possible to position a field probe with a half a degree precision.

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Definitions:

Before discussions or research are started, it is important to define the relevant terms. Three parameters for this project are defined as followed:

Isotropic response: The level on which an electric field probe is capable to display the correct field level, independent of the orientation of the probe with regard to the generated field.

Rotational symmetry: The level to which an electric field probe is capable to display the correct field level, independent of the rotation around the orthogonal axis of a probe in respect to the generated field. When conducting rotational symmetry calibrations, the probe is placed under an angle of 54.7 degrees and rotated 360 degrees. This means, every 120 degrees, one of the axes is positioned perpendicular in the generated field.

Field homogeneity: Is a measure of quality of an anechoic chamber. In a high-quality chamber, the field intensity is homogeneous over a large area. The field homogeneity is determined by conducting a 16-point calibration in conformity with the EN61000-4-3. The first two definitions are both regarding the field probes. The third definition is for the anechoic chamber.

Measurements: In the calibration chamber a large number of accurate measurements have been conducted with the help of the automated measurement system and the use of the RadiMation Software. In addition, the measurement results of different parties been included in the research project.

Results

The measurements show remarkable results. The graph below shows a result of different types of E-field probes in the exact same anechoic chamber with the same measurement system with a field-strength of 50 V/m. The graph shows that at frequencies above 3 GHz huge differences arise. For example, at 4 GHz the measurement difference is between the highest of 72 V/m and the lowest of 25 V/m, a difference of 47 V/m (5.5 dB). It is a valid question – what is the real generated field, when the differences are in excess of 12dB?

Cause of errors

In the ideal situation, an E-field probe measures only the field strength of the direct path of the antenna towards the probe. However, in an anechoic chamber there are always reflections which influence the test. These reflections reach the probe through the walls and possible from other objects in the room, for example the EUT. The amplitude and the angle under which these reflections reach the probe are dependent on a number of parameters, for example; the size of the chamber, the position of the antenna and the frequency of the generated signal. Bearing this in mind, the amplitude and the angle of the reflections should be considered as an unknown. The acceptable error can be derived from the EN61000-4-3. This directive states that the field homogeneity is compliant if 75 % of the 16 points (e.g. 12 points), in a square of 1,5m x 1,5m fall within the range of 0 – +6 dB. An error of 6 dB means that the reflection may be just as strong as the direct signal. The field strength, and therefore the error, can be even higher for the remaining 25 % of the 16 points. Thus, these reflections can be even stronger than the direct signal.

Other measurements show that E-field probes with a large isotopic deviation can show a measurement error in excess of 10 dB. Due to these large isotropic errors, strong reflected signals will be registered with a large measurement error. Therefore, this measurement error is not negligible!

An often-made mistake is that there are no measurement errors if the probe is placed with one of its axes perpendicular positioned to the (polarized) generated field. This ignores the fact that (relevant) reflections reach the probe in completely random and therefore unknown angles.

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Measurement of total uncertainty

The following formula shows how the total uncertainty for a field level measurement is calculated:
Most of these contributions to measurement error are well known and are relatively small. Furthermore, these systematic

$$\text{Total Uncertainty} = \sqrt{\text{Lin}^2 + \text{Temp}^2 + \text{Iso Err}^2 + \text{Freq. resp}^2 + \text{Cal.}^2 + \text{aging}^2}$$

errors can be, (by means of software & hardware) corrected. For example, the frequency response is often corrected and the temperature in a laboratory is relatively constant. Thus, the largest contribution to the total uncertainty is the non-isotropic behavior of the probe. The applied method, the root sum of the squares, shows that the parameters with the largest relative value (contribution) dominate the total measurement uncertainty. Isotropy the dominant Parameter

Parameter	Typical Contribution (value)
Linearity	0,5 dB
Temperature	0,5 dB
Isotropy error	3 – 12 dB
Frequency response (after correction)	1 dB
Obsolescence (withing the calibration term)	0,5 dB

Unwanted deviations in the measurement values of the field strength (due to bad isotropy), during a 16-point calibration, can lead to unjustly rejections of anechoic chambers. These chambers will be forced to “improve” which results in unwanted and unnecessary high costs. Bad or non-isotropy of probes during immunity tests can also lead to so called ‘under testing’ of the EUT.

Conclusion

Our research shows that contributions due to the non-isotropic behavior of electric field probes is not fully recognized or understood. It is clear, that errors caused by the non-isotropic behavior of E-field probes are much larger than previously thought. These errors are mostly seen in the frequency range above 1 GHz. Currently the isotropic error of a probe is not specified in the range above this critical 1 GHz point. It shows that the isotropic errors have a considerable impact on the accuracy of EMC immunity testing in anechoic and mode-stir chambers. Therefore it is essential that the isotropic behavior of e-field probes is specified over the total frequency range.

Further research

This research project has not (yet) been conducted on ‘mode stir’ measurements or in reverberation chambers. It is very possible that the truly generated field in such rooms is lower than the needed field for a specific test. This is because in these type of chambers, reflections play a key role in the measurement technique. This is especially the case with mode stir that rely on the reflections from the walls that should result in an evenly distributed field. However, due to non-isotropic probes this cannot be properly measured. This can also result in these rooms under testing where the field measured is lower than the actual generated field. Further research is required to carefully and precisely measure these deviations and errors. With such research this hypothesis can be either proved or rubbished, only time will tell.

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