Isotropic E&H field analyzer EHP50C typical uncertainty and anisotropy

A brief summary

Object of this document is to complete and integrate in more detail the technical specification of the isotropic E&H field analyzer model Narda EHP50C for what concern the typical uncertainty and the anisotropy characteristics.
In the meantime is described how the uncertainty concept have to be applied in real cases when the user is performing measurements with the above mentioned analyzer.

Typical uncertainty of EHP50C

The uncertainties stated in this document have been determined according to EA-4/2 [4]
They were estimated as expanded uncertainty obtained multiplying the standard by the coverage factor k=2, corresponding to a confidence level of about 95%.
The total uncertainty of the probe derived from typical contributions of linearity, anisotropy, frequency response, temperature, relative humidity and with/without contribution of uncertainty of calibration.

Magnetic probe [(1)]	Magnetic flux density range	Total expanded uncertainty (k=2)	
		Without contribution of uncertainty of calibration U_{EHP50C} (%)	With contribution of uncertainty of calibration U_T (%)
Frequency at 50Hz	0.1µT to < 0.3µT	4.1	4.2 [(2)]
	0.3µT to < 10.0µT	3.3	3.5 [(2)]
	10.0µT to < 100µT	3.7	4.3 [(3)]
	100µT to 500µT	4.1	4.8 [(4)]
Frequency from 40 to 10kHz	0.1µT to < 0.3µT	6.5	6.7 [(5)]
	0.3µT to > 10.0µT	6.1	6.3 [(5)]

(1) The temperature range is from -10℃ to 23 ℃ and relative humidity is from 20% to 50%
(2) (5) The uncertainty of calibration used is 1,5%
(3) The uncertainty of calibration used is 2,0%
(4) The uncertainty of calibration used is 2,7%

Electric probe [6]	Electric field range	Total expanded uncertainty (k=2)	
		Without contribution of uncertainty of calibration U_{EHP50C} (%)	With contribution of uncertainty of calibration U_T (%)
Frequency at 50Hz	10 V/m to 500 V/m	7.8	8.2 [7]
	10 V/m to < 100 kV/m	8.4	8.8 [8]
Frequency from 40 to 10kHz	10 V/m to < 500 V/m	9.5	9.9 [8]

(6) The temperature range is from -10°C to 23 °C and relative humidity is from 20% to 50%
(7) The uncertainty of calibration used is 2,0%
(8) The uncertainty of calibration used is 2,5%

Explication Notes

a) If we have the certificate with different values of the uncertainty of calibration, in order to calculate the total expanded uncertainty U_T , the uncertainty of calibration has to be taken into account::

$$U_T = \sqrt{(U_{EHP\ 50C})^2 + (U_{Cal})^2}$$

b) When the environmental temperature is higher than 23 °C the contribute due to the temperature must be added quadratically to the uncertainty.

Example: if the temperature is 38°C we get a variation of 15°C in comparison to 23°C, corresponding to a variation of 0.15 dB (0.01dB/°C) equivalent to 1,74% and therefore the standard uncertainty is 1% (=0,0174/ $\sqrt{3}$).

Assuming an expanded uncertainty U_T =4.2%, $U_{TOT} = \sqrt{\left(\frac{0.042}{2}\right)^2 + (0.01)^2} = 0.0465$ is obtained.

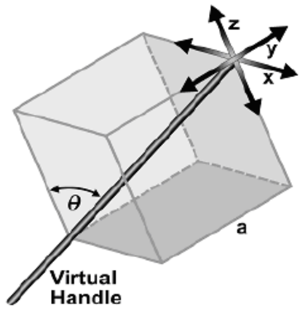
A similar calculation can be made in case the relative humidity overcomes 50%.

Anisotropy

1) The IEEE 1309-2005 [3] defined the anisotropy (A) as the maximum deviation from the geometric mean of the maximum response and minimum response when the probe is rotated around the ortho-axis (e.g. "virtual handle") as shown in the example in figure below.

$$A = 20 \cdot \log_{10}\left(\frac{S_{max}}{\sqrt{S_{max} \cdot S_{min}}}\right) \text{dB} \qquad \text{equation (1)}$$

where S is the measured amplitude in field strength units.



$$\theta = \sin^{-1}\left(\frac{\sqrt{2}\,a}{\sqrt{3}\,a}\right) = 54.7^{\circ}$$

2) The IEC 61786 [2] "Measurement of low-frequency magnetic and electric fields with regards to exposure of human beings - special requirements for instruments and guidance for measurements" don't define the anisotropy and suggest, for three-axis probes, the calibration of each axis when each element is aligned with the incident field.
The calibration should also be checked for a specific orientation where approximately there is the same indication for each one of the three axis (XYZ measurement).
Following this suggestion some laboratories find the minimum and the maximum values of the X,Y,Z and XYZ measure and calculate the anisotropy using equation (1).

3) We calculated the anisotropy with equation (1) but with 3D mesh measurements to cover 4π steradian.

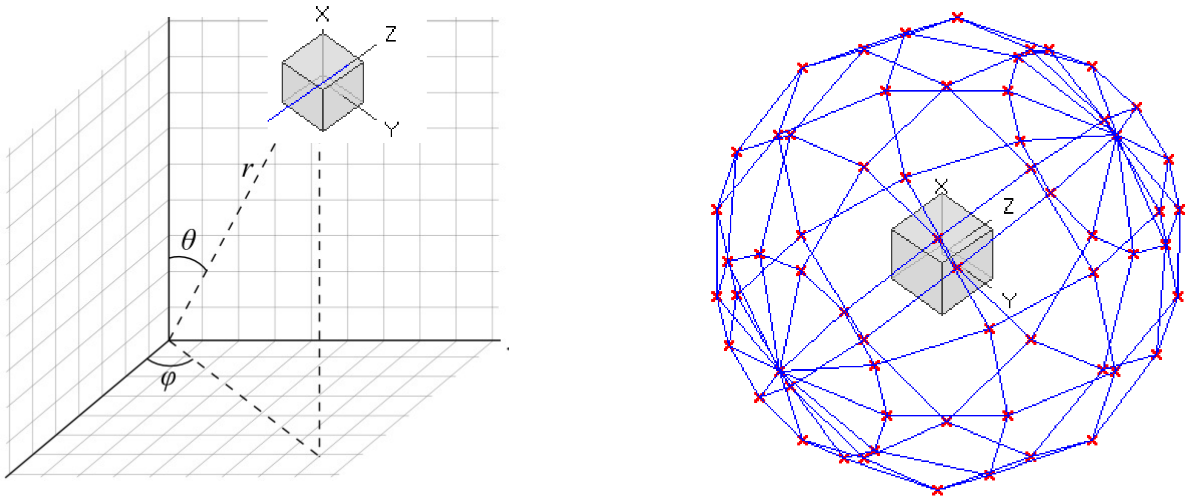


Fig. 1 - 3D mesh measurements of magnetic probe

Each x marker in the fig.1 indicates the coordinates surface of the spherical coordinates (r, θ, φ).
The anisotropy is evaluated with 30 degree steps for θ and φ, and r shows the calibration factor at each position.
The typical value of anisotropy is 1,4% (0.12 dB) for magnetic probe and 6,5% (0,54 dB) for electric probe.
The anisotropy calculated in this way is worse respect to other cases above described and it is more representative of the reality.

References

[1] ISO/IEC "Guide to the expression of uncertainty in measurement" ("GUM")1995 International Organization for Standardization.

[2] CEI-IEC 61786 "Measurement of low-frequency magnetic and electric fields with regards to exposure of human beings - special requirements for instruments and guidance for measurements" First Edition 1998-08

[3] IEEE Std 1309TM – 2005 (revision of IEEE Std 1309-1996) "IEEE Standard for Calibration of Electromagnetic Field Sensors and probes, Excluding Antennas, from 9kHz to 40GHz".

[4] EA European co-operation for Accreditation – Publication Reference EA-4/02 – December 1999