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Cap. Soc. Int. Ver. 100.000,00 euro

CERTIFICATE OF CALIBRATION

Item	Electric Field Probe 0.10 MHz - 3000.00 MHz
Manufacturer	NARDA S.T.S. / PMM
Model	EP330
Serial number	101WJ40510
Calibration procedure	INTERNAL PROCEDURE EP-1001-STD
Date(s) of measurements	2022-09-27
Date of emission	2022-09-27
Result of calibration	MEASUREMENT RESULTS WITHIN SPECIFICATIONS
Certificate number	22-S-13120

This document displays the procedure and the instrumental chain used to verify the compliance of the equipment under calibration to the technical characteristics required. The results shown in the next pages comes with the traceability chain of the laboratory and the related calibration certificates in their course of validity. Uncertainty declared in this document has been determined in compliance with the document EA-4/02 Expression of uncertainty of Measurement in Calibration and is expressed with a covering factor k=2, corresponding to a confidence level of about 95%.
The measurement procedure and the instrumental chain used to obtain the results shown in this document are compliant with IEEE Std.1309 Standard for Calibration of Electromagnetic Field Sensors and Probes, Excluding Antennas, from 9 kHz to 40 GHz. The measurement results are determined by the comparison with traceable standards.

Person in charge
Jan Bulli Wilkinson

Measurement operator
Ing. Marco Borrega

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LABORATORY CHAIN OF TRACEABILITY

The following table shows the equipment used for this calibration procedure along with the reference list for traceability

Equipment	Standard	Model	Calibration
Signal Generator	Frequency	Agilent N5183A	LAT 019 67260
Function/Arbitrary Waveform Generator	Frequency	Rigol DG4202	LAT 019 67271
Multimeter	A.C. Voltage	Hewlett Packard 34401A	LAT 019 67280
Power Sensor	R.F. Power	Agilent U2004A	LAT 019 67265
Power Sensor	R.F. Power	Agilent U2004A	LAT 019 67268
Power Sensor	R.F. Power	Agilent U2000A	LAT 019 67262
Directional Cuopler	R.F. Power	Agilent 772D-001	LAT 019 67275
Directional Cuopler	R.F. Power	Werlatone C6110-10	LAT 019 66278
20dB attenuator 7mm	Attenuation	Mini-Circuits BW-N20W5+	LAT 019 67252
30dB attenuator 7mm	Attenuation	Mini-Circuits UNAT-30+	LAT 019 67281
30dB attenuator 7mm	Attenuation	Mini-Circuits UNAT-30+	LAT 019 67283
30dB attenuator 7mm	Attenuation	Mini-Circuits UNAT-30+	LAT 019 67285
30dB attenuator 7mm	Attenuation	Mini-Circuits UNAT-30+	LAT 019 67286
Double Guide Horn Antenna	--	ETS Lindgren 3116B	UKAS 2020010177-1
Electric Field Probe	Electric Field	NARDA S.T.S. EP-603	LAT 008 80504716E

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METHOD OF CALIBRATION

The calibration procedure of a field strength monitor requires the generation of an electromagnetic field of a known strength, frequency and polarization. This field is called reference field.
The degree of knowledge of the characteristics of the field is directly related to the environment where it is generated: if it's possible to have the field propagate in an almost-plane wave configuration then the profile can be easily monitored through analytic calculus or reference standard.
The low frequency field (up to 300MHz) is generated inside a square section TEM cell with side of 60cm. The high frequency field (up to 40GHz) is generated inside a full anechoic chamber, through a multi-antenna radiating system.
In both cases, the probe is aligned so that the shaft is perpendicular to the measured field (see IEEE 1309 4.2.2.3 Physical minor axis alignment) in order to minimize the error introduced by the coupling between the shaft and the electromagnetic wave. Once the probe has been positioned and a field is established the field probe is rotated 360° around the physical minor axis. The orientation, with respect to the incident field at the maximum response, is used for the calibration.

CALIBRATION UNCERTAINTY

The uncertainty stated in this document does not take into account the long term stability of the monitor. For the purpose of this certificate the expanded uncertainties are given below.

Domain	Uncertainty
Frequencies up to 300MHz	12%
Frequencies from 300MHz to 3000MHz	16%

MEASUREMENT CONDITIONS

All the instruments considered in the chain, comprising the equipment under calibration, were turned on at least 15 minutes (or the minimum warm up time stated in the manual, if present) to avoid any thermal drift.
The environmental conditions of temperature and relative humidity were monitored during the entire calibration procedure.

FREQUENCY FLATNESS

Frequency flatness calibration confronts the field value shown by the equipment under test with the reference field at different frequencies.
The field generated at frequencies below 300MHz is obtained through the propagation of a TEM mode inside a TEM cell.
The field strength generated inside a TEM cell with a distance d between the outer and inner conductor, powered from a Pnet and loaded on an impedance ZTEM is given by the relation (Myron L. Crawford Generation of Standard EM Fields Using TEM Transmission Cells, November 1974)

$$E_{cal} = \frac{\sqrt{P_{net} \times Z_{tem}}}{\mathrm{d}} \left[\frac{V}{m}\right]$$

The determination of the field through mathematical means complies with IEEE Std 1309 Method B (see IEEE Std 1309 4.1 Calibration Methods).
Field generated at frequencies above 400MHz is obtained through the propagation of a plane wave inside a full anechoic chamber. The shielded enclosure surrounding the anechoic environment ensures that the field generated inside a specific volume (called quiet zone) is known and the field strength measurement is repeatable. The reference field strength is measured through a calibrated probe, and complies with IEEE Std 1309 Method A (see IEEE Std 1309 4.1 Calibration Methods).

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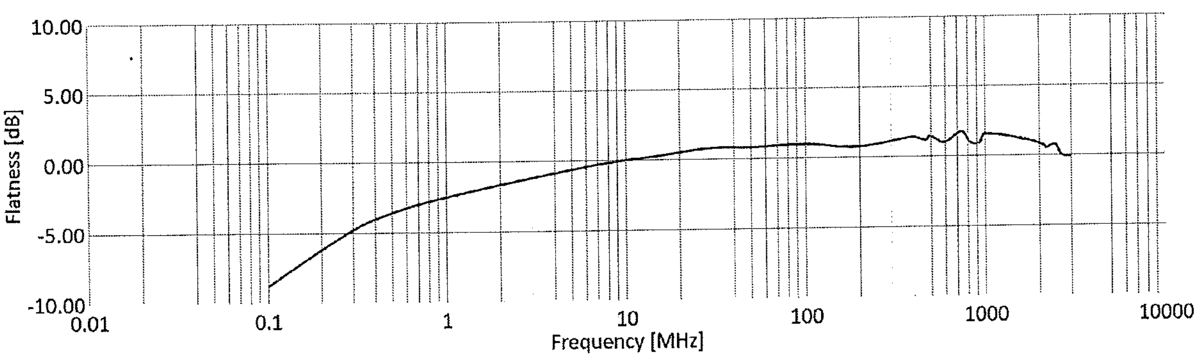
This calibration procedure determines a correction factor to be used in measurements. The actual field can be obtained by multiplying the measured field value with the correction factor. The following results were obtained from the measurements.

Frequency [MHz]	Reference Field [V/m]	Measured Field [V/m]	Correction Factor
0.1000	6	2.1800	2.7600
0.3000	6	3.4500	1.7400
0.5000	6	3.9700	1.5100
1.0000	6	4.4900	1.3400
3.0000	6	5.2200	1.1500
7.0000	6	5.8100	1.0300
10.0000	6	5.9900	1.0000
15.0000	6	6.1800	0.9700
30.0000	6	6.5800	0.9100
50.0000	6	6.5900	0.9100
100.0000	6	6.7300	0.8900
193.0000	6	6.5500	0.9200
400.0000	6	7.0600	0.8500
423.0000	6	6.9800	0.8600
470.0000	6	6.8700	0.8700
490.0000	6	7.0800	0.8500
590.0000	6	6.7300	0.8900
740.0000	6	7.3200	0.8200
835.0000	6	6.6600	0.9000
930.0000	6	6.6600	0.9000
940.0000	6	6.7200	0.8900
1000.0000	6	7.1800	0.8400
1800.0000	6	6.7600	0.8900
2150.0000	6	6.4600	0.9300
2170.0000	6	6.3900	0.9400
2450.0000	6	6.5400	0.9200
2650.0000	6	6.0000	1.0000
3000.0000	6	5.9300	1.0100



Certificate n. 22-S-13120

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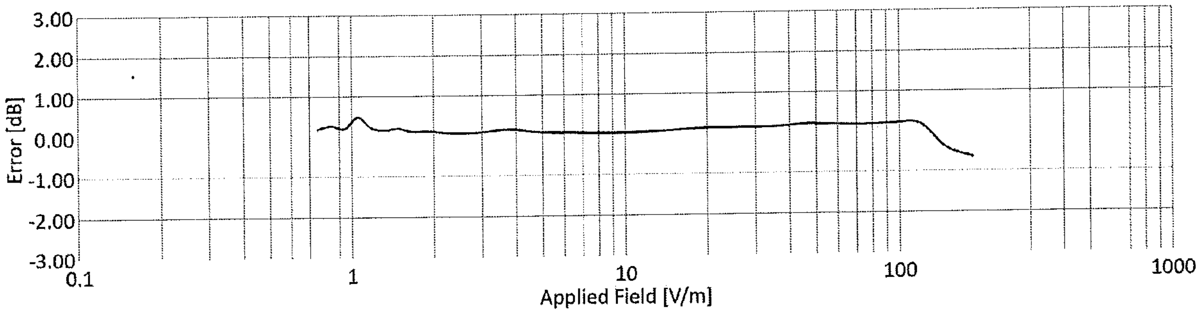
LINEARITY

E-Field measurements are obtained through the use of a series of dipoles. The RF voltage across the dipole is rectified by a diode system that suffers from linearity deviation. The probe internally compensates for this deviation through the use of correction factors. This calibration verifies the magnitude of error between an applied field and the compensated value measured by the probe.
All the measurements are done at 50MHz.

Applied Field [V/m]	Measured Field [V/m]	Error [dB]
0.7450	0.7600	0.1700
0.8360	0.8600	0.2600
0.9380	0.9600	0.1900
1.0530	1.1100	0.4800
1.1810	1.2100	0.2100
1.3250	1.3500	0.1500
1.4870	1.5200	0.1900
1.6680	1.6900	0.1100
1.8720	1.9000	0.1200
2.1010	2.1200	0.0900
2.3570	2.3700	0.0600
2.9670	2.9900	0.0800
3.7350	3.8000	0.1500
4.7030	4.7500	0.0800
5.9200	5.9500	0.0500
6.0000	6.0400	0.0600
7.4530	7.4900	0.0400
11.8130	11.8800	0.0500
18.8500	19.1400	0.1300
23.5700	23.9500	0.1400
29.6730	30.1600	0.1400
37.3560	38.0400	0.1600
47.0290	48.2000	0.2100
59.2060	60.5200	0.1900
74.5350	76.1000	0.1800
93.8350	96.0500	0.2000
118.1310	120.9500	0.2000
148.7180	141.7100	-0.4200
187.2250	173.4400	-0.6600



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ISOTROPY

Isotropic E-field probes are built with multiple dipoles on different orientations. By having at least 3 dipoles placed on mutually orthogonal directions the simultaneous reading of the dipoles ensures that the field can be evaluated disregarding of the wave polarization. An example could be:

$$E_{ISOTROPIC} = \sqrt{E_X^2 + E_Y^2 + E_Z^2}$$

The isotropy calibration verifies the magnitude of the error introduced by different directions of incidence of the field relatively to the probe orientation. The field is measured at different angles and the geometric mean of the values is computed. The deviation error is expressed by the following relation.

$$Deviation_{dB} = 20 \times \log_{10}\left(\frac{Measured\ Field}{Mean}\right)$$

All the measurements are done at 50MHz and 6 V/m.

Angle [°]	Measured Field [V/m]	Deviation [dB]
0	6.5900	0.0700
45	6.3900	-0.2000
90	6.5100	-0.0300
135	6.6300	0.1300
180	6.6200	0.1100
225	6.4100	-0.1600
270	6.4700	-0.0900
315	6.6700	0.1700