3.1 Calibration and Measurement Capabilities

The Calibration and Measurement Capabilities (CMCs) of the division 2 are based on the Appendix C of the BIPM database. They are being reviewed in a two-step process whereas in the first step a 100 percent review by the members of EURAMET takes place followed by a statistical check by Regional Metrology Organizations (RMOs) under the supervision of the *Joint Committees of the BIPM and the Regions (JCRB)* of the CIPM. The CMC entries can be viewed in the following list. Each entry is directly linked to the corresponding entry of the BIPM database.

Calibration services outside of the CIPM MRA (without CMC entries in the BIPM database) are only offered as additional services to a certain extent by the division 2. Furthermore, internal calibration services in the field of Electricity, Temperature and Humidity are provided for all divisions of the PTB.

The CMC entries listed in Appendix C of the BIPM database are divided into the following chapters:

Chapter	Title	Remarks
1 DC voltage	1.1 DC voltage sources	-
	1.2 DC voltage meters	-
	1.3 DC voltage ratios	-
2 DC resistance	2.1 DC resistance standards and sources	-
	2.2 DC resistance meters	-
	2.3 DC resistance ratios	no records
3 DC current	3.1 DC current sources	-
	3.2 DC current meters	-
	3.3 DC current ratios	-
4 Impedance (up to the MHz range)	4.1 AC resistance	-
	4.2 Capacitance	-
	4.3 Inductance	-
5 AC voltage (up to the MHz range)	5.1 AC/DC voltage transfer	-
	5.2 AC voltage up to 1100 V	-
	5.3 AC voltage ratio up to 1100 V, attenuation and gain	-
6 AC current	6.1 AC/DC current transfer	-
	6.2 AC current up to 100 A	-
	6.3 AC current ratio up to 100 A	-

7 AC power	7.1 AC power and energy	-
8 High voltage and current	8.1 High DC voltage	-
	8.2 High voltage impedance	-
	8.3 AC high voltage and voltage transformers	-
	8.4 Pulsed high voltage and current	-
	8.5 Electric discharge	-
	8.6 High AC current and current transformers	-
	8.7 High DC current	no records
9 Other DC and low frequency measurements	9.1 Electric charge	no records
	9.2 Phase angle	-
	9.3 Current and voltage waveform	no records
10 Electric and magnetic fields	10.1 Electric fields below 50 kHz	-
	10.2 Magnetic fields below 50 kHz	-
	10.3 Electromagnetic fields above 50 kHz	-
	10.4 EMC, Immunity	only PTB in-house
	10.5 EMC, Emission	only PTB in-house
	10.6 EMC, Test Procedures	only PTB in-house
11 Radio frequency measurements	11.1 Radio frequency power	-
	11.2 Scalar RF reflection coefficient and attenuation	-
	11.3 Scattering parameters	-
	11.4 Noise	no records
	11.5 Antenna properties	no records
	11.6 Signal and pulse characteristics	-
	11.7 Radio frequency voltage and current	-
	11.8 Lumped impedance/admittance (using RF techniques)	no records
	11.9 Characteristic impedance	-

12 Measurements on materials	12.1 Electrical conductivity	-
	12.2 Dielectric properties	no records
	12.3 Soft magnetic sheet and powder materials	-
	12.4 Soft magnetic bulk material	-
	12.5 Feebly magnetic, paramagnetic and diamagnetic material	-
	12.6 Hard magnetic material	-
	12.7 Magnetic data storage media	no records

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Additional Services

Quantity	Instrument or Artifact	Method of Measurement	Minimum value	Maximum value	Units	Parameter	Specifications	Value	Units	Coverage Factor	Level of Confi-dence	Is the expanded uncertainty a relative one?
Phase angle	Power meter	Sampling System	-π	+π	rad	Voltage, current, frequen-cy	30V to 240V 0,005A to 100A 16,7Hz to 1000Hz	20 - 400	µrad	2	95%	Yes
Signal and pulse characteristics: step response	Electrical pulse-generator or optical photodiode	70 GHz sampling oscilloscope, femtosecond laser (only for photodiode)	-0.1 (multivariate quantity)	1.5 (multivariate quantity)	Voltage versus time	Band-width	1 GHz to 5 GHz	0.005 to 0.1 (multiva-riate quantity)	Voltage versus time	2	95 %	No
DC-Power	Power meter		1,5	1,2E6	Watt	Voltage, current,	10 V to 1000 V 0,002 A to 1200 A	50 - 210	µW/W	2	95%	No
Signal and pulse characteristics: step response	50 GHz, 70 GHz, and 100 GHz sampling oscillo-scopes	Optoelectronic time-domain measurements based on femtosecond lasers	-0.1 (multivariate quantity)	1.5 (multivariate quantity)	Voltage versus time	Type of coaxial connector	1.85 mm or 1.0 mm	Typically between 0.005 - 0.3 (multivariate quantity, depends on MC simulations)	Voltage versus time	2	95%	No

Signal and pulse characteristics: step response	**Ultrafast photodiode**	**Optoelectronic time-domain measurements based on femtosecond lasers**	**-0.1 (multivariate quantity)**	**1.5 (multivariate quantity)**		**Nominal band-width, type of coaxial connec-tor, excita-tion wave-length**	**70 GHz or 100 GHz, 1.85 mm or 1.0 mm, 1550 nm**	**Typically between 0.005 - 0.3 (multivariate quantity, depends on MC simulations)**		**2**	**95%**	**No**
Hard magnetic material: Remanent magnetic flux density Br, remanent magnetic polarisation J_r	**Permanent magnetic material cylinder**	**Electromagnet, coil system, Fluxmeter**	**0,1**	**2**	**T**			**0,001 to 0,02**		**2**	**95%**	**Yes**
Hard magnetic material: Coercivity H_{cB}	**Permanent magnetic material cylinder**	**Electromagnet, coil system, Fluxmeter**	**1**	**1000**	**kA/m**			**0,003 to 0,01**		**2**	**95%**	**Yes**
Hard magnetic material: Coercivity H_{cJ}	**Permanent magnetic material cylinder**	**Electromagnet, coil system, Fluxmeter**	**1**	**2300**	**kA/m**			**0,003 to 0,01**		**2**	**95%**	**Yes**
Hard magnetic material: Maximum Energy product (B·H)max	**Permanent magnetic material cylinder**	**Electromagnet, coil system, Fluxmeter**	**5**	**500**	**kJ/m³**			**0,005 to 0,02**		**2**	**95%**	**Yes**

Antenna gain	**Antenna**	**Vector Network Analyzer**	**10**	**316**		**Connec-tor: N (50 Ohm) PC 2.4 (50 Ohm) Wave-guide Wave-guide**	**1 to 18 GHz 1 to 50 GHz 50 to 75 GHz 75 to 110 GHz**	**0,035 0,035 0,072 1,12**		**2**	**95%**	**No**
Power density	**Security scanner**	**Spectrum analyzator**	**1E-8**	**10**	**mW/ cm²**	**Frequen-cy**	**3 GHz to 11 GHz 50 GHz to 110 GHz**	**0,32**		**2**	**95%**	**Yes**
AC-Power	**Power Analyzer**	**Direct Comparison**	**3**	**3360**	**VA**	**Voltage, Current, Frequen-cy, |cos(phi)|**	**30 V to 240 V, 0,1 A to 14 A, 15 Hz to 20 kHz, 0 to 1**	**6,5E-5 6,5E-5 to 1,4E-3 6,5E-5 to 1,4E-3**	**VA/VA, W/VA, var/VA**	**2**	**95%**	**No**
DC-Current	**Current Sensors, Calibrators**	**Direct Comparison**	**0,5**	**1200**	**A**			**100 to 200**	**µA / A**	**2**	**95%**	**No**

Relative permittivity	**Split-cylinder resonator**	**Transmission measurement of TE0np resonances**	**1**	**100**	**-**	**temperature, Humi-dity, resonant frequencies (depending on dielectric properties and sample thickness)**	**23 ±0,5°C, 50±10%, 2 - 30 GHz**	**3%**		**2**	**95%**	**Yes**
Loss tangent	**Split-cylinder resonator**	**Transmission measurement of TE0np resonances**	**0.00005**	**0.01**	**-**	**Temperature, Humi-dity, resonant frequencies (depending on dielectric properties and sample thickness)**	**23 ±0,5°C, 50±10%, 2 - 30 GHz**	**0.0001**		**2**	**95%**	**No**
DC resistance standards and sources: intermediate values	**Fixed resistor**	**CCC**	**1E+07**	**1E+07**	**Ω**	**Temperature**	**15 °C to 30 °C**	**0.2**	**µΩ/Ω**	**2**	**95 %**	**Yes**
DC current meters: low values	**Nano-ampere-meter**	**Charging of a capacitor, active transresistance (ULCA)**	**1E-15**	**1E-9**	**A**			**60000 to 4**	**µA/A**	**2**	**95 %**	**Yes**

DC current sources: low values	**Current generator**	**active transresistance (ULCA)**	**1E-13**	**1E-09**	**A**			**360 to 4**	**µA/A**	**2**	**95 %**	**Yes**
DC current: Current ratio	**Ultrastable Low-noise Current Amplifier Type N688S ("noise-optimized")**	**Calibration with cryogenic current comparator (14-bit)**	**1000:1**	**1000:1**		**Tempera-ture**	**19 °C to 27 °C**	**7.5E-8**		**2**	**95%**	**Yes**
DC resistance: Transresistance	**Ultrastable Low-noise Current Amplifier Type N688S ("noise-optimized")**	**Calibration with cryogenic current comparator (14-bit) and standard resistor**	**1E6**	**1E6**	**Ω**	**Tempera-ture**	**19 °C to 27 °C**	**30**	**nOhm/ Ohm**	**2**	**95%**	**Yes**
DC current: Current ratio	**Ultrastable Low-noise Current Amplifier Type C259E ("low-current")**	**Calibration with cryogenic current comparator (14-bit)**	**1000:1**	**1000:1**		**Tempera-ture**	**19 °C to 27 °C**	**2.1E-6**		**2**	**95%**	**Yes**
DC resistance: Transresistance	**Ultrastable Low-noise Current Amplifier Type C259E ("low-current")**	**Calibration with cryogenic current comparator (14-bit) and standard resistor**	**5E6**	**5E6**	**Ω**	**Tempera-ture**	**19 °C to 27 °C**	**75**	**nOhm/ Ohm**	**2**	**95%**	**Yes**

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