COAXIAL CURRENT SHUNTS FROM 1 mA TO 100 A

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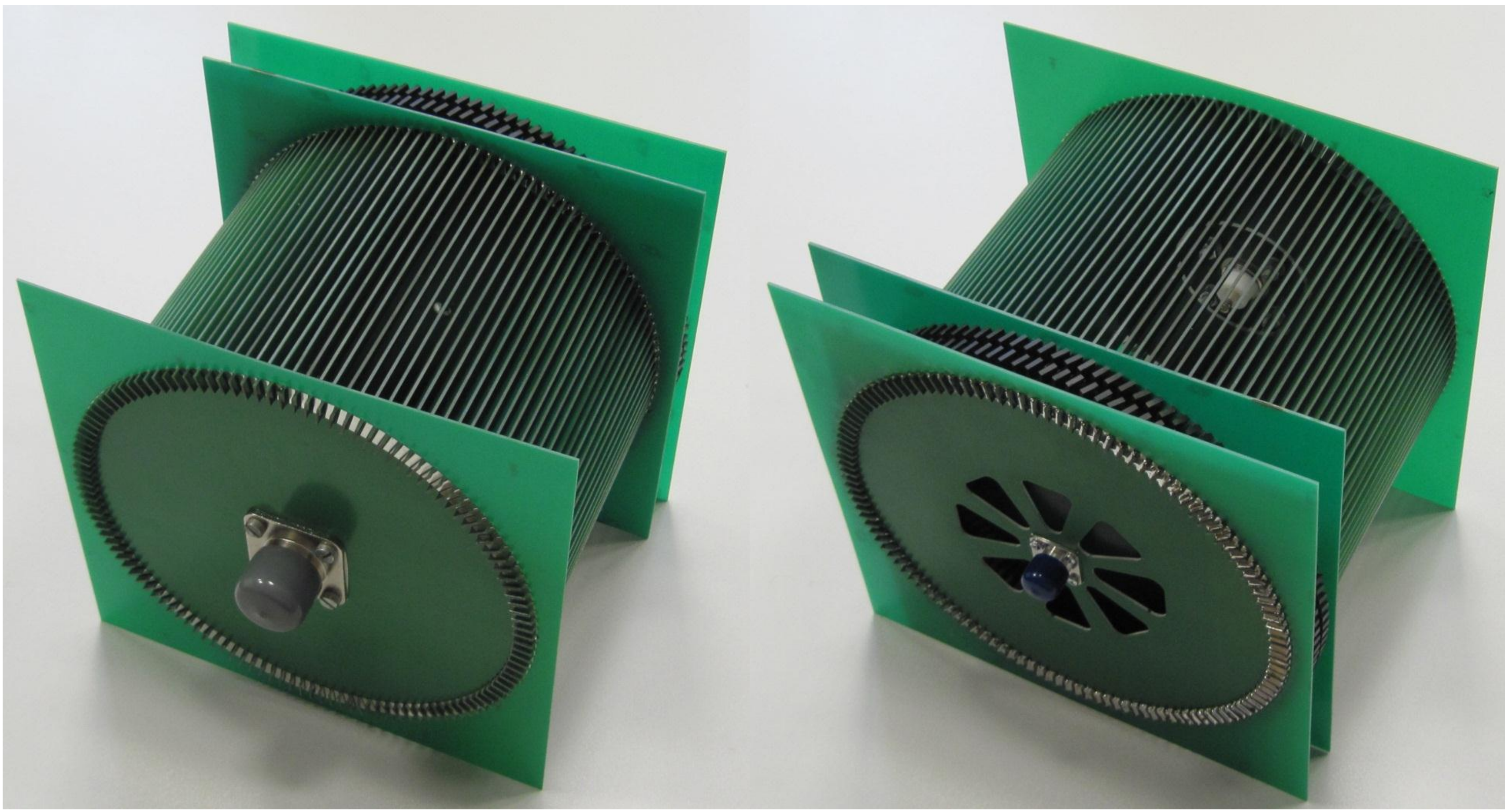
1 Coaxial current shunts

A series of 14 current shunts have been built and evaluated (50 A and 100 A shunt still in process of evaluation) for direct AC current measurement:

- 100 µA
- 300 µA
- 1 mA
- 3 mA
- 10 mA
- 30 mA
- 100 mA
- 300 mA
- 1 A
- 5 A
- 10 A
- 20 A
- 50 A
- 100 A



2 Technical data

shunt	*Φ* [mm]	*lenght* [mm]	number of crossbars	number of resistors	value of one resistor	input resistance
100 µA	80	180	14	14	100000 Ω	7140 Ω
300 µA	80	180	14	14	33000 Ω	2140 Ω
1 mA	80	180	14	14	10000 Ω	714 Ω
3 mA	80	180	14	14	3300 Ω	236 Ω
10 mA	80	180	14	14	1000 Ω	71,4 Ω
30 mA	80	180	14	14	330 Ω	23,6 Ω
100 mA	80	180	14	14	100 Ω	7,14 Ω
300 mA	80	180	14	14	30 Ω	2,14 Ω
1 A	80	180	14	14	10 Ω	0,714 Ω
5 A	150	180	70	70	10 Ω	0,143 Ω
10 A	150	180	70	140	10 Ω	0,0714 Ω
20 A	150	180	70	140	5 Ω	0,036 Ω
50 A	260	210	125	250	5 Ω	0,020 Ω
100 A	260	210	125	500	5 Ω	0,010 Ω

Alpha metal foil resistors, 0.1% accuracy; temperature coefficient: 5 ppm/°C; power coefficient: 0.09°C/mW; rated power: 0.5 W.

3 ac/dc difference

Measured in PTB:

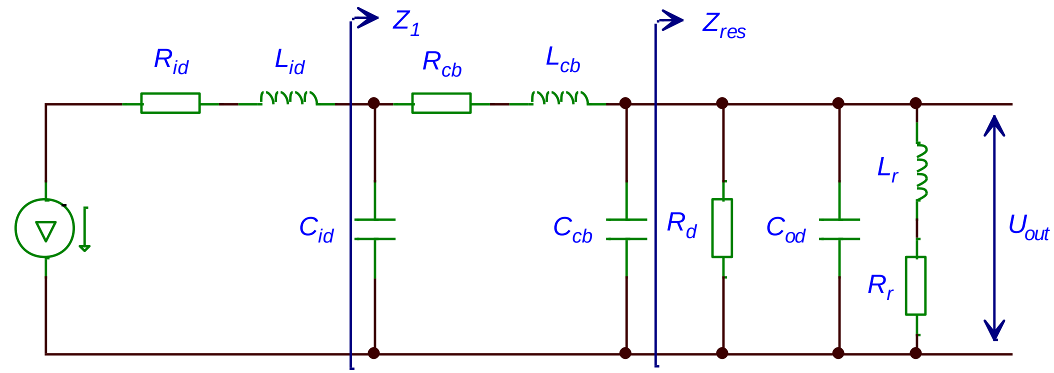
shunt	ac/dc difference [ppm]					uncertainty [ppm]				
	10 [Hz]	40 [Hz]	1 [kHz]	10 [kHz]	30 [kHz]	10 [Hz]	40 [Hz]	1 [kHz]	10 [kHz]	30 [kHz]
10 mA	-3	-1	1	10	45	4	4	4	4	4
30 mA	-2	0	0	5	21	4	4	4	4	4
100 mA	1	0	0	2	11	6	6	6	6	6
300 mA	0	0	0	2	2	6	6	6	6	6
1 A	3	2	-1	1	-1	7	7	7	7	7
5 A	1	0	0	0	0	16	15	12	12	25
10 A	-8	2	-1	5	23	20	20	20	20	50
20 A	-9	-2	0	4	29	30	30	30	40	60

4 dc resistance and drift

shunt		dc resistance		uncertainty [ppm]	slope [ppm/year]	uncertainty [ppm]
100	μA	7,142933	kΩ	5,0	6,9	3,0
300	μA	2,357144	kΩ	5,0	9,4	3,0
1	mA	714,2735	Ω	5,0	8,6	3,0
3	mA	235,7106	Ω	5,0	8,2	3,0
10	mA	71,43327	Ω	5,0	4,2	3,0
30	mA	23,57363	Ω	5,0	9,7	3,0
100	mA	7,143405	Ω	5,0	4,8	3,0
300	mA	2,142592	Ω	5,0	5,1	3,0
1	A	714,0713	mΩ	5,0	3,1	3,0
5	A	142,8182	mΩ	5,0	9,3	3,0
10	A	71,44417	mΩ	5,0	7,8	3,0
20	A	35,71516	mΩ	10,0	4,9	3,0

5 Modelling

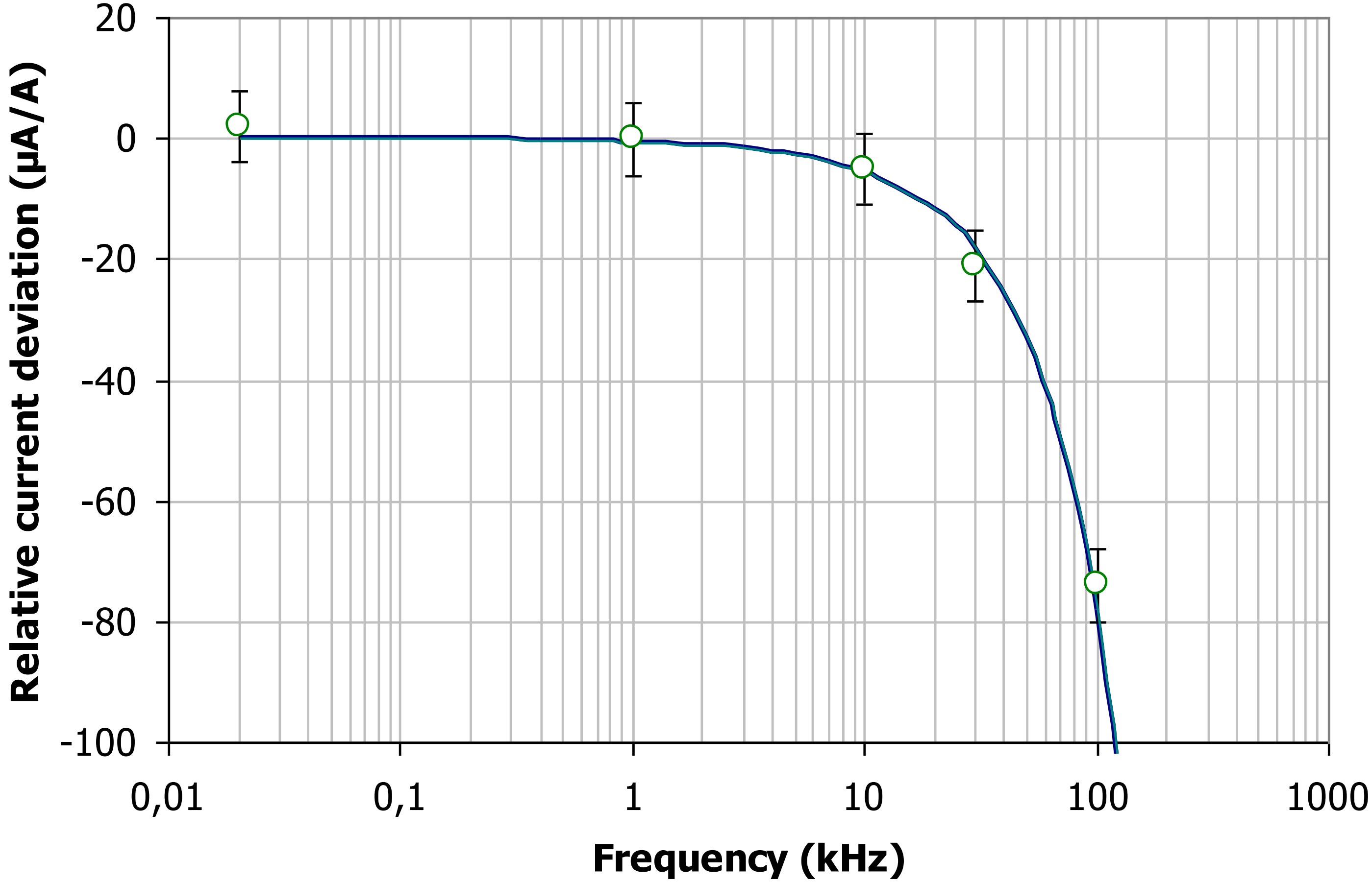
$$I_{in} = U_{out}\frac{1+s\left(C_{cb}+C_{od}\right)Z_{res}}{Z_{res}\left(1-sC_{id}Z_1\right)}$$



Lumped element model of the shunt.
Elements with index 'id' corresponds to input disc,
'cb' to cross-bars,
'od' to output disc and
'r' to resistors.

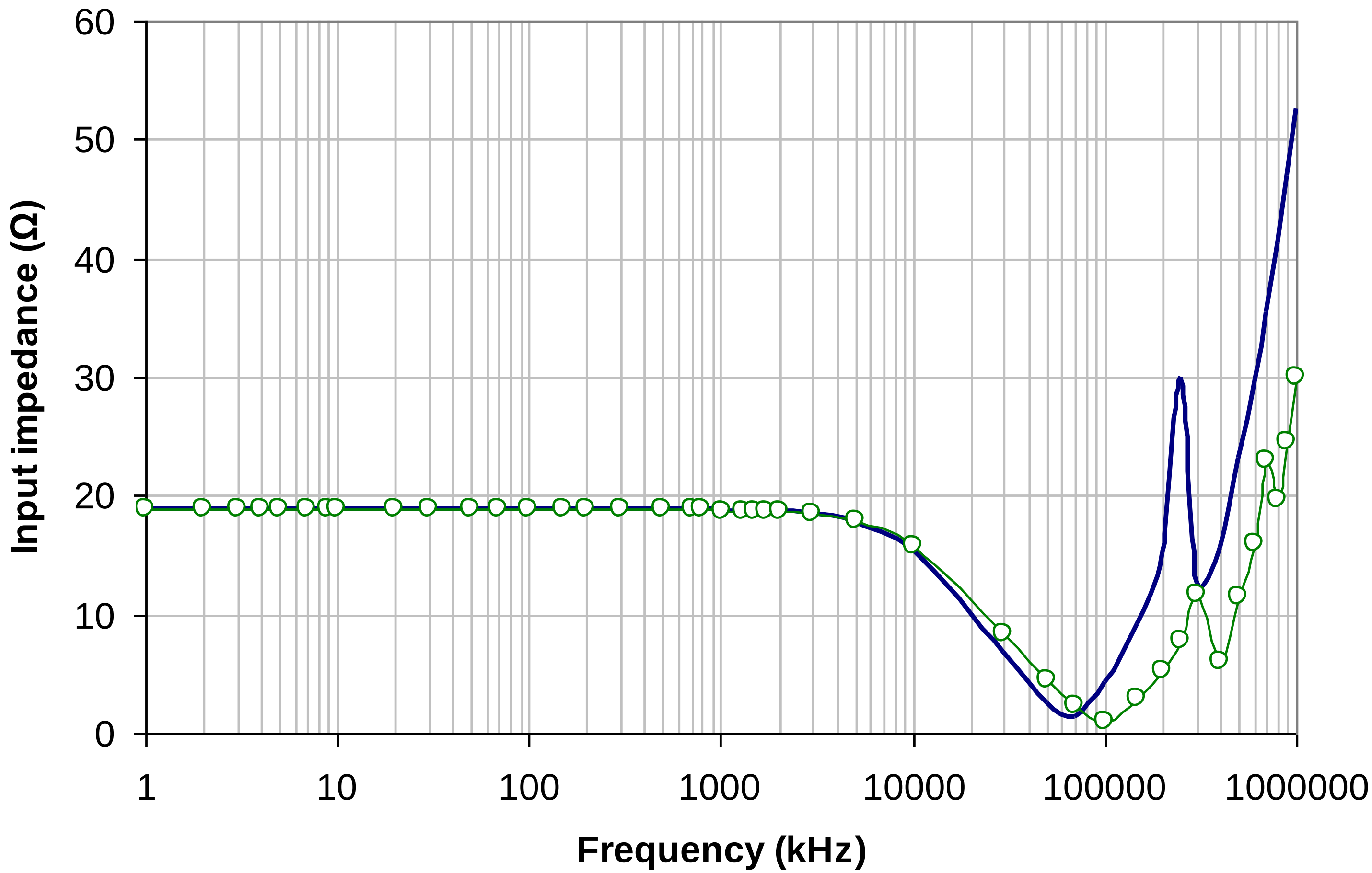
Parameter	10 mA shunt	30 mA shunt	
R_{id} – input disc resistance	0.28 mΩ	0.28 mΩ	calc.
R_{cb} – cross-bars resistance	6.2 mΩ	6.2 mΩ	
R_r – shunt resistance	71.43 Ω	23.57 Ω	
C_{id} – input disc capacitance	113 pF	113 pF	
C_{cb} – cross-bars capacitance	437 pF	437 pF	
C_{od} – output disc capacitance	6.3 pF	6.3 pF	
L_{id} – input disc inductance	8.6 nH	8.6 nH	meas.
L_{cb} – cross-bars inductance	3.6 nH	3.6 nH	
L_r – shunt resistors inductance	0.71 nH	0.71 nH	

6 Modelling



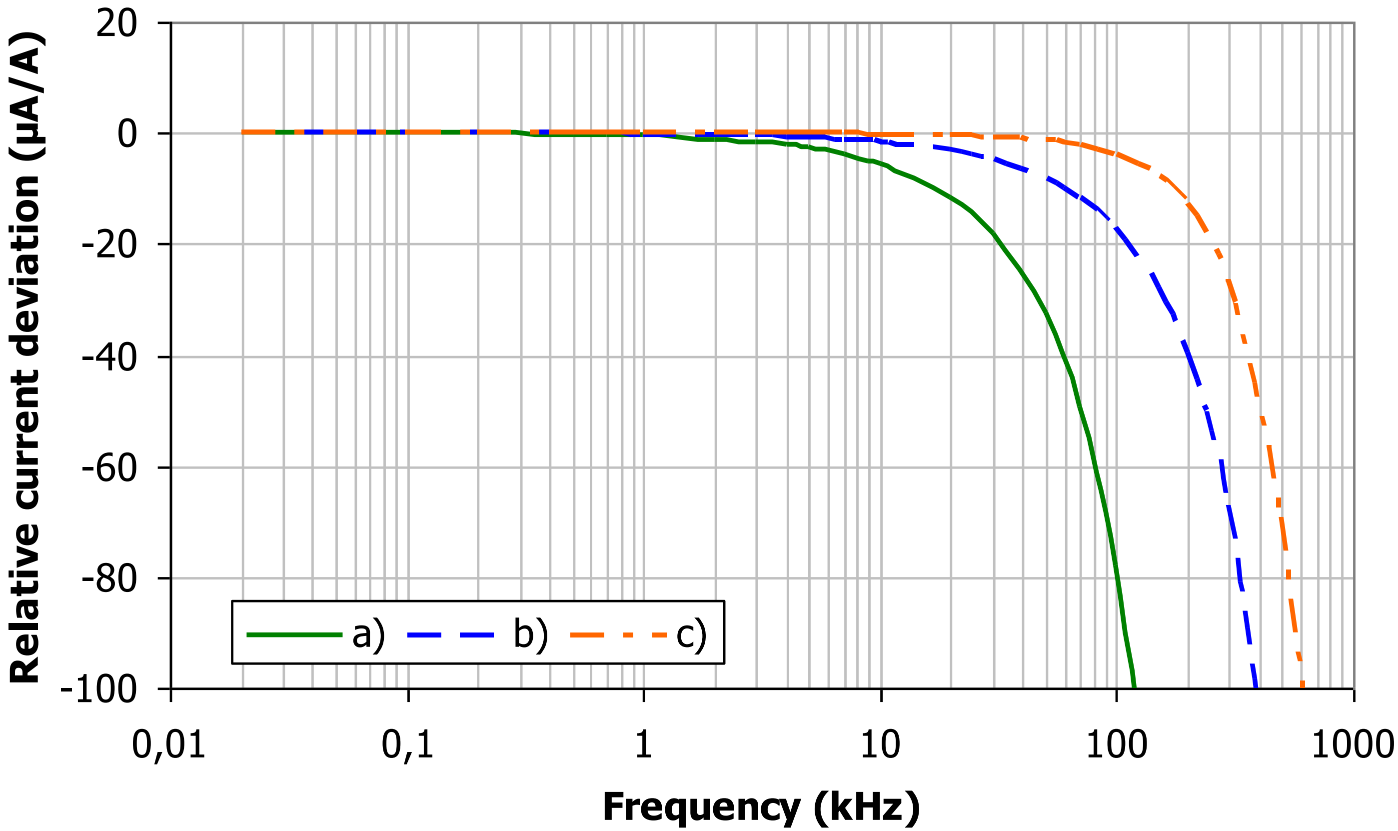
Measured (circles with corresponding ± 6 µA/A uncertainty bars) and caluclated (solid line) frequncy response of 30 mA current shunt. Measurement were performed up to 100 kHz.

Modelling



Measured (line with circles) and caluclated (solid line) input impedance for 30 mA coaxial shunt at frequencies up to 1 GHz. The output of the shunt was left open.

Modelling



Calculated frequency responses for a) original design, b) design with ten times shorter cross-bars and c) design with both ten times shorter cross-bars and PCB material with ten times lower dissipation factor.

9 Measurement capabilities

- Revised, expanded and improved measurement capabilities (2σ) for direct measurement of ac current:

	Frequency					
shunt	10 Hz	20 Hz	40 Hz	1 kHz	10 kHz	30 kHz
10 mA	55	45	30	30	30	35
30 mA	55	45	30	30	30	35
100 mA	55	45	30	30	30	35
300 mA	55	45	30	30	30	35
1 A	55	45	30	30	30	35
5 A	60	50	35	35	35	35
10 A	60	55	40	40	40	55
20 A	70	65	55	55	65	80

10 Dissemination: publications and presentations

1. B. Voljč, M. Lindič; Measurement of AC current with coaxial current shunts; CPEM 2008.
2. B. Voljč, M. Lindič, R. Lapuh: Analysis, evaluation and verification of ac current measurement with coaxial shunts method; International Electrotechnical and Computer Science Conference (ERK) 2008, Slovenia.
3. B.Voljč, M. Lindič, R. Lapuh: Verification of ac current measurement using coaxial current shunts; IMECO 2008.
4. R. Lapuh: Phase sensitive sine fitting algorithm for asynchronously sampled data; IMECO 2008.
5. B. Voljč, M. Lindič, R. Lapuh: Direct Measurement of AC Current by Measuring the Voltage Drop on the Coaxial Current Shunt; IEEE Trans. Instrum. Meas., Vol. 58, Nr. 4, April 2009.
6. R. Lapuh: Asynchronously sampled multi-harmonic signal estimation algorithm; I2MTC 2009.
7. R. Lapuh: Phase sensitive frequency estimator for asynchronously sampled data; ERK 2009.
8. B. Voljc, M. Lindic: Measurement of ac voltage with thermal converters; ERK 2009.
9. G. C. Bosco, M. Garcocz, K. Lind, U. Pogliano, G. Rietveld, V. Tarrasso, B. Voljc, V. N. Zachovalova: Phase comparison of high current shunts up to 100 kHz; CPEM 2010.
10. V. Tarrasso, V. N. Zachovalova, M. Garcocz, K. Lind, T. Mansten, U. Pogliano, G. Rietveld, B. Voljc: A survey of current shunts for ac power measurement; CPEM 2010.
11. B. Pinter, M. Lindic, B. Voljc, Z. Svetik, R. Lapuh: Modeling of ac/dc current shunts; CPEM 2010.

11 Dissemination: publications and presentations

12. B. Voljc, M. Lindic, B. Pinter, Z. Svetik, R. Lapuh: Direct measurement of ac current with coaxial current shunts down to 1 mA; CPEM 2010.
13. R. Lapuh, M. Lindic, B. Voljc, B. Pinter, Z. Svetik: Digital oscilloscope calibration using asynchronous sampled signal estimation; CPEM 2010.
14. R. Lapuh, U. Pogliano, P. S. Wright, J. Hallstrom: Comparison od asynchronous sampling correction algorithms for power quality measurement under realistic conditions; CPEM 2010.
15. B. Voljc, M. Lindic, B. Pinter, Z. Svetik, R. Lapuh: Direct measurement of ac current in range from 1 mA to 20 A; ERK 2009.
16. R. Lapuh: Interpolated phase sensitive frequency estimator for fast estimation of harmonically distorted signals; ERK 2009.
17. B. Pinter, M. Lindic, B. Voljc, Z. Svetik, R. Lapuh: Simulation of frequency response of coaxial current shuns; ERK 2009.
18. R. Lapuh, B. Pinter, Z. Svetik, M. Lindic, B. Voljc: Digital oscilloscope calibration using asynchronous sampled signal estimation; IEEE Trans. Instrum. Meas., accepted.
19. R. Lapuh: Phase estimation of asynchronous sampled signal using interpolated three-parameter sinewave fit technique; I2MTC 2011, accepted.
20. R. Lapuh, B.Voljc, B. Pinter, M. Lindic, Z.Svetik: Analysis and improvements of precision coaxial current shunts for direct measurement of ac current; I2MTC 2011, accepted.