State Enterprise "All-Ukrainian State Scientific and Production Center of Standardization, Metrology, Certification and Protection of Consumer" (SE "Ukrmeterteststandard")

Approved bv the chairman of TC 1.3 COOMET
Chairman of TC 1.3 COOMET
_________________ T. Kolomiets

Final Report on
COOMET Supplementary Comparison of Capacitance at 10 pF and 100 pF (COOMET.EM-S13)

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Members of comparisons:
SE "Ukrmetrteststandard", Ukraine
GUM, Poland
BelGIM, Republic of Belarus

February 2013
Kyiv, Ukraine

Table of contents

1 Introduction

The COOMET Supplementary Comparison (SC) of Capacitance at 10 pf and 100 pF (comparison identifier – COOMET.EM-S13) was conducted in the framework of COOMET 554/UA/12 project from 2012 to 2013.

This project for comparing of national standards of electrical capacitance was conducted between counties which are member laboratories of regional metrology organization COOMET and EURAMET. In this comparison take part three national metrology institutes (NMI): SE "Ukrmetrteststandard" (UMTS, Ukraine); GUM (Poland); BelGIM (Belarus).

The State Enterprise "All-Ukrainian State Scientific and Production Center of Standardization, Metrology, Certification and Protection of Consumer" (SE "Ukrmetr-teststandard"), Ukraine was selected as the pilot laboratory. Sergii Shevkun and Prof. Oleh Velychko were the comparison coordinators. The pilot laboratory is responsible for providing the travelling standard, coordinating the schedule, collecting and analyzing the comparison data, preparing the draft report, etc.

2 Participants

List of participating NMIs, countries of origin is show in Table 1.

Table 1 List of participating NMIs, countries of origin and regional organizations

NMI	Country	Regional organization
UMTS – State Enterprise "All-Ukrainian State Scientific and Production Center of Standardization, Metrology, Certification and Protection of Consumer" (SE "Ukrmeterteststandard") – **pilot**	Ukraine	COOMET
GUM – Central Office of Measures	Poland	EURAMET
BelGIM – Belarusian State Institute of Metrology	Belarus	COOMET

List of participant contact information is show in Table 2.

Table 2 List of participant contact information

NMI address	Contact name, e-mail, tel. and fax number
State Enterprise "All-Ukrainian State Scientific and Production Center of Standardization, Metrology, Certification and Protection of Consumer" (SE "Ukrmeterteststandard"–**UMTS**) – **pilot** 4, Metrologichna St. Kyiv-143, 03143, **Ukraine**	Sergii Shevkun Shevkun@ukrcsm.kiev.ua Tel./fax: +38 044 526 5568 Oleh Velychko Velychko@ukrcsm.kiev.ua Tel./fax: +38 044 526 0335

NMI address	Contact name, e-mail, tel. and fax number
Glowny Urzad Miar (**GUM**) Ul. Elektoralna 2, 00-139 Warszawa, **Poland**	Adam Maciej Ziółek a.ziolek@gum.gov.pl Tel./Fax: +48(22)5819353
Belarusian State Institute of Metrology (**BelGIM**) 93, Starovilensky trakt Minsk, 220053, **Belarus**	Elena Kazakova kazakova@belgim.by Tel.: +375 17 233 1510 Fax: +375 17 288 0938

3 Travelling standard and measurement instructions

3.1 Description of travelling standard

The selected travelling standards are 10 pF (S/N 01263) and 100 pF (S/N 01262) Andeen-Hagerling model AH11A fused silica capacitance standards, mounted in a frame model AH1100 (S/N 00086).

The AH 1100 frame provides monitoring of critical temperature control parameters such as the differences within the dual temperature sensors in each standard and internal power voltages. Each AH11A capacitance standard contains built-in precision oven with dual temperature sensor system which provides increased reliability and confidence.

The main manufacturer specifications for AH11A capacitors and AH1100 frame:
stability is better than 0.3 ppm/year;
temperature coefficient of the capacitance with respect to changes in ambient temperature is less than 0.01 ppm/°C;
hysteresis resulting from temperature cycling is less than 0.05 ppm;
hysteresis resulting from mechanical shock is less than 0.05 ppm;
AC voltage coefficient is less than 0.003 ppm/volt;
DC voltage coefficient is less than 0.0001 ppm/volt;
power line sensitivity is less than 0.0003 ppm per 1% change in power line voltage;
dissipation factor is less than 0.000 003 tan delta;
power voltage ranges: 85 to 115, 102 to 138, 187 to 253 and 204 to 276 volts rms;
power frequency: 48 to 440 Hz;
operating temperature range: 10 °C to 40 °C;
storage temperature range: minus 40 °C to +75 °C;
maximum allowable applied voltage: 250 volts peak;
operating humidity range: 0 to 85 % relative humidity, non-condensing;
AH 1100 frame size: 89 mm high and 381 mm deep behind the front panel;
total weight of AH1100 frame and two AH11A capacitors: 8.4 kg.

Shipping is simple since continuous temperature control of the ovens is not needed to maintain the stability specification. The fused-silica element is hermetically sealed in dry nitrogen. The AH 1100/11A Operation and Maintenance Manual will be included with the shipment. Participants should familiarize themselves with the operation of the standards before proceeding.

3.2 Handling of travelling standard

The travelling standard was circulated within a container, which is well furnished for the safety of the travelling standard. Upon receipt, participants were checking the container to determine if all parts on the list are present. At the end of the test, the travelling standard was carefully re-packed in the container in which it arrived.

The dimensions of the transport container are 700 mm x 520 mm x 220 mm. The container weight (including contents) is 20 kg. If this container was damaged, the travelling standard shall be re-packed in a new container that will provide adequate protection during shipment. On receipt of the travelling standard inspect the outside of the transport container for any signs of physical damage. Open the transport container and check that the contents are complete.

Was included the cable for connecting to AH11A terminals. The AH1100 frame containing the two capacitance standards should be removed from the transport case.

On completion of measurements each participant was requested to ship the travelling standard to the pilot laboratory (UMTS).

3.3 Measurement instructions

After power up of traveling standard in participating NMIs it stabilized for three days.

Measurements were performed under the following conditions:
temperature: 23 °C ± 1 °C;
relative humidity: between 30 % and 70 %;
measurement frequency: 1000 Hz (depending on laboratory’s capability);
measuring voltage for both capacitor: 100 V (RMS).

If measurement voltage differs from 100 V (RMS), the actual voltage was recorded and its effect was included in uncertainty budget of NMI measurement.

To made connections to the capacitors, participants used any of the leads and adapters, but participants are responsible for determining any necessary corrections for leads or adapters obtained the capacitance at the terminals on the AH1100 frame.

The temperature coefficient of capacitance with respect to changes in ambient laboratory temperature is less than 0.01 ppm/°C for both capacitors. No corrections were made for ambient laboratory temperature. Participants must include a component for ambient laboratory temperature in their uncertainty budget if the ambient laboratory temperature significantly differs from 20 °C.

For each measurement, the following quantities were recorded:
measurement date;
measurement frequency;
applied voltage;
measured capacitance;
measured tangent of losses (if this quantity realized in NMI);
air temperature in the vicinity of the AH1100 frame and the measuring apparatus;
AH1100 frame temperature and the oven drift reading.

If measurements were made during several days, than the mean capacitance value for each day should be provided with indication of the exact dates of measurements.

4 Uncertainty of measurement

The uncertainty was calculated following the ISO/IEC Guide 98-3:2008 “Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement” (GUM): standard uncertainties, degrees of freedom, correlations, scheme for the uncertainty evaluation.

All contributions to the uncertainty of measurement were listed separately in the report and identified as either Type A or Type B uncertainties. The overall uncertainty, as calculated from the individual uncertainties, was stated. Uncertainties were evaluated at combine standard and expanded uncertainties, and the number of effective degrees of freedom is to be reported.

The main uncertainty components were expected:
experimental standard uncertainty of the mean of N independent measurements;
uncertainty in the primary standard or working standard against which the traveling standard is measured;
uncertainty due to leads correction.

Participants included additional sources of uncertainty also.

5 Traceability to the SI

The traceability to the SI of each standard participating in the comparison was provided to pilot NMI. The participating NMIs made measurements of these travelling capacitors in terms of either their own calculable capacitor or a quantum Hall reference standard, or have traceability to other laboratories. This meant that there were a number of independent measurements of these capacitors which enabled the representation of the farad in those countries were compared.

The traceability route for the primary standard of capacitance for each NMI is given in Table 3. The majority of the laboratories obtain their unit of capacitance from a calculable capacitor either directly or via another laboratory.

6 Behaviour of the travelling standards

The UMTS as pilot laboratory has performed repeated measurements on the travelling standards 10 pF (S/N 01263) and 100 pF (S/N 01262) during the course of this comparison. From these measurements, the behaviour of the travelling standard can be seen in Figures 1 and 2.

Table 3 Traceability route for each participating NMI

NMI	Country	Traceability Route
GUM	Poland	BIPM (Quantum Hall Resistance)
UMTS	Ukraine	NIST (Calculable Capacitor)
BelGIM	Belarus	VNIIM (Calculable Capacitor)

As the values of the capacitors are time-dependent they were measured before and after each visit so that a drift curve for each one could be established.

The drift of the travelling standards by using all results weighted with the variance of the measurements was checked. The drift was negligible.

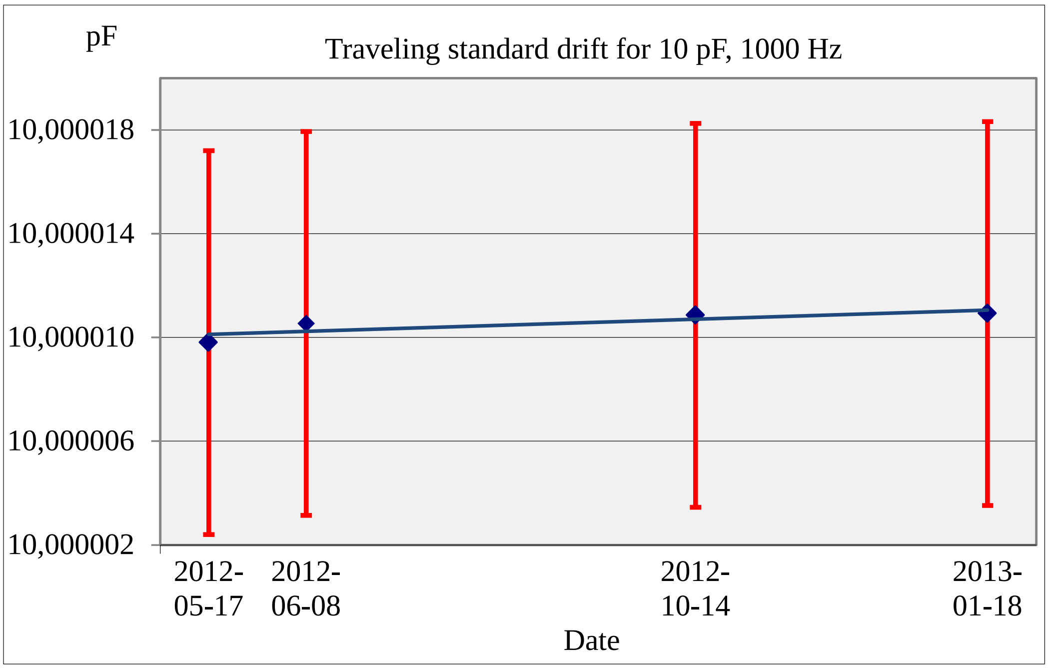

Figure 1 Behaviour of the travelling standard for 10 pF

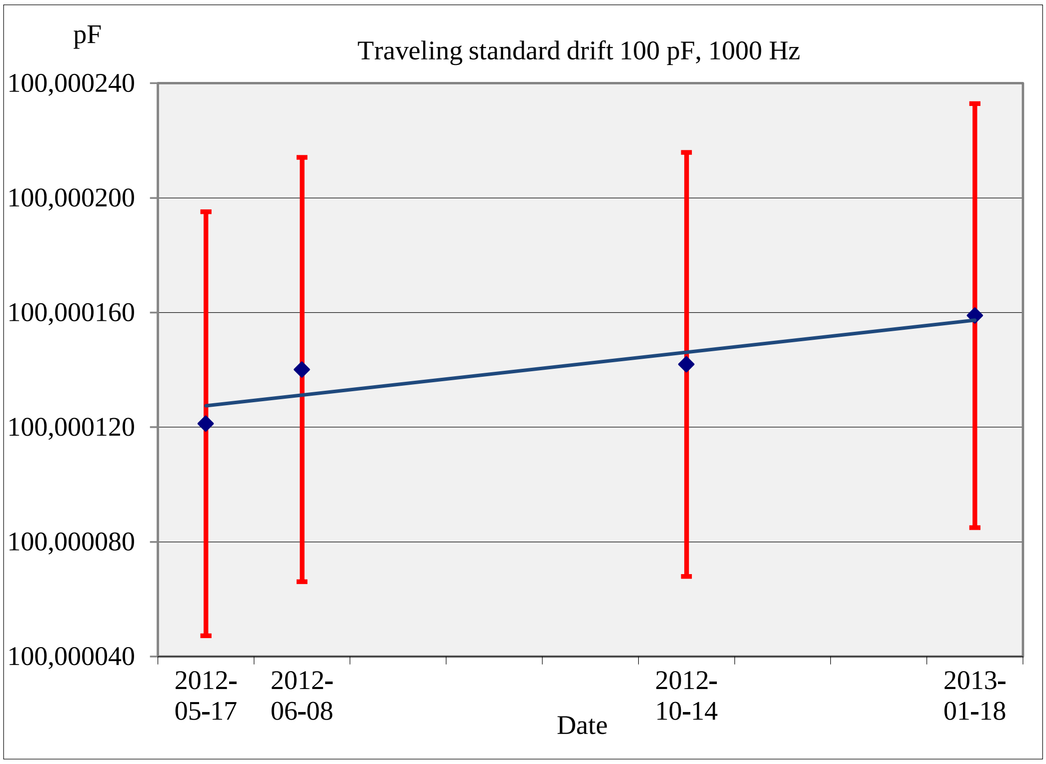

Figure 2 Behaviour of the travelling standard for 100 pF

7 Reported results

7.1 General information and data

A full measurement report containing all relevant data and uncertainty estimates was forwarded to the coordinator within six weeks of completing measurement of the capacitors. The report included a description of the measurement method (facilities and methodology), the traceability to the SI, and the results, associated uncertainty and number of degrees of freedom.

The measurement period, the measurement frequency and the applied voltage were also reported for each capacitor. Details of any corrections that have been applied (for example, bridge corrections or leads corrections) were given.

All measurement results and expended uncertainties, and additional parameters for measurement were identified with the capacitor's serial number and nominal value.

List of measurement dates of the NMI participants is show in Table 5.

Table 4 List of measurement dates of the NMI participants

NMI	Measurement dates
UMTS1, Ukraine	03–17.05.2012
GUM, Poland	24–25.05.2012
UMTS2, Ukraine	06–08.06.2012
UMTS3, Ukraine	10–12.10.2012
BelGIM, Belarus	10–11.12.2012
UMTS4, Ukraine	16–18.01.2013

Additional parameters for measurement of the NMI participants are show in Table 5.

The capacitance values and their expanded uncertainties (*U*) reported by the NMI participants for 10 pF and 100 pF at frequencies of 1000 Hz shown on Table 6. All the uncertainties quoted in this report are expanded uncertainties, having a coverage factor k = 2 which provides a level of confidence of approximately 95%.

Table 5 Additional parameters for measurement of the NMI participants

Parameter	Capacitance 10 pF		Capacitance 100 pF	
	Value	Expanded uncertainty	Value	Expanded uncertainty
GUM, Poland				
Frequency, Hz	1000	0.05	1000	0.05
Voltage, V	100.0	0.1	100.0	0.1
Ambient temperature, °C	22.0…24.0	0.5	22.0…24.0	0.5
Measure temperature, °C	29.6…30.2	0.1	29.6…30.2	0.1
Relative humidity, %	30…45	1	30…45	1

Parameter	**Capacitance 10 pF**		**Capacitance 100 pF**	
	Value	**Expanded uncertainty**	**Value**	**Expanded uncertainty**
UMTS, Ukraine				
Frequency, Hz	1000.0	$1\cdot10^{-5}$	1000.0	$1\cdot10^{-5}$
Voltage, V	100.0	0.002	100.0	0.002
Ambient temperature, °C	22.0…23.0	0.4	22.0…23.0	0.4
Measure temperature, °C	27.7…32.7	0.1	27.5…32.4	0.1
Relative humidity, %	30…40	2.3	30…40	2.3
BelGIM, Belarus				
Frequency, Hz	1000	0.06	1000	0.06
Voltage, V	60.0	0.01	60.0	0.01
Ambient temperature, °C	23.1	0.06	23.3	0.06
Measure temperature, °C	31.2	0.1	29.4	0.1
Relative humidity, %	34.4	0.48	36.9	0.48

Table 6 Deviations from nominal value for NMI participants

NMI	**10 pF**		**100 pF**	
	δC_i (μF/F)	U_i (μF/F)	δC_i (μF/F)	U_i (μF/F)
GUM	0.900	0.500	1.000	1.000
UMTS	1.053	0.768	1.405	0.792
BelGIM	1.114	2.151	1.649	2.032

7.2 Calculation of the reference value and its uncertainty

The reference value x_{ref} is calculated as the mean of participant results with COOMET.EM-S4 data are given by

$$x_{ref} = \sum_{i=1}^{N} \frac{x_i}{u^2(x_i)} \Bigg/ \sum_{i=1}^{N} \frac{1}{u^2(x_i)} \qquad (1)$$

with associated standard uncertainty

$$u^2(x_{ref}) = 1 \Bigg/ \sum_{i=1}^{N} \frac{1}{u^2(x_i)} \,. \qquad (2)$$

The calculated weighted mean of all results was x_{ref} = 0.952 µF/F with expanded uncertainty (k = 2) U_{ref} = 0.411 µF/F for 10 pF and x_{ref} = 1.283 µF/F with expanded uncertainty (k = 2) U_{ref} = 0.594 µF/F for 100 pF.

7.3 Degrees of equivalence

Only one value is reported for each NMI participants. Degrees of equivalence of the NMI participants are reported with respect to the measurement for 10 pF and 100 pF at 1000 Hz.

The degrees of equivalence of the *i*-th NMI and its expanded uncertainties with respect to the comparison reference value is estimated as

$$D_i = x_i - x_{ref} \ , \tag{3}$$

$$u^2(D_i) = u^2(x_i) + u^2(x_{ref}) \ . \tag{4}$$

The declared uncertainties are judged as confirmed if the following equation is satisfied

$$|D_i| < 2u(D_i) \ . \tag{5}$$

The degrees of equivalence of the NMI participants and its expanded uncertainties (k = 2) with respect to the KCRV for 10 pF and 100 pF at 1000 Hz are also presented in Tables 7 and the graphs in Figures 2 and 3.

Table 7 Degrees of equivalence of the NMI participants

NMI	**10 pF**		**100 pF**	
	D_i (µF/F)	$U(D_i)$ (µF/F)	D_i (µF/F)	$U(D_i)$ (µF/F)
GUM	–0.052	0.963	–0.263	1.552
UMTS	0.101	1.125	0.122	1.427
BelGIM	0.162	2.302	0.366	2.352

7.4 Results of the NMI participants

On the basis of the measurement results of COOMET.EM-S13 and corresponding uncertainties $\{x_i,\ u(x_i)\},\ i = 1,...N$ claimed by comparisons NMI participants, the χ^2 criterion value is calculated [1]

$$\chi^2 = \sum_{i=1}^{N} \frac{(x_i - x_{ref})^2}{u^2(x_i)} \ , \tag{6}$$

where:

x_i – *i*-th NMI result of the COOMET.EM-S13;

x_{ref} – reference value with transformed COOMET.EM-S13 data;

$u(x_i)$ – uncertainty of *i*-th NMI result of the COOMET.EM-S13;

N – a number participants of the COOMET.EM-S13 (N = 3).

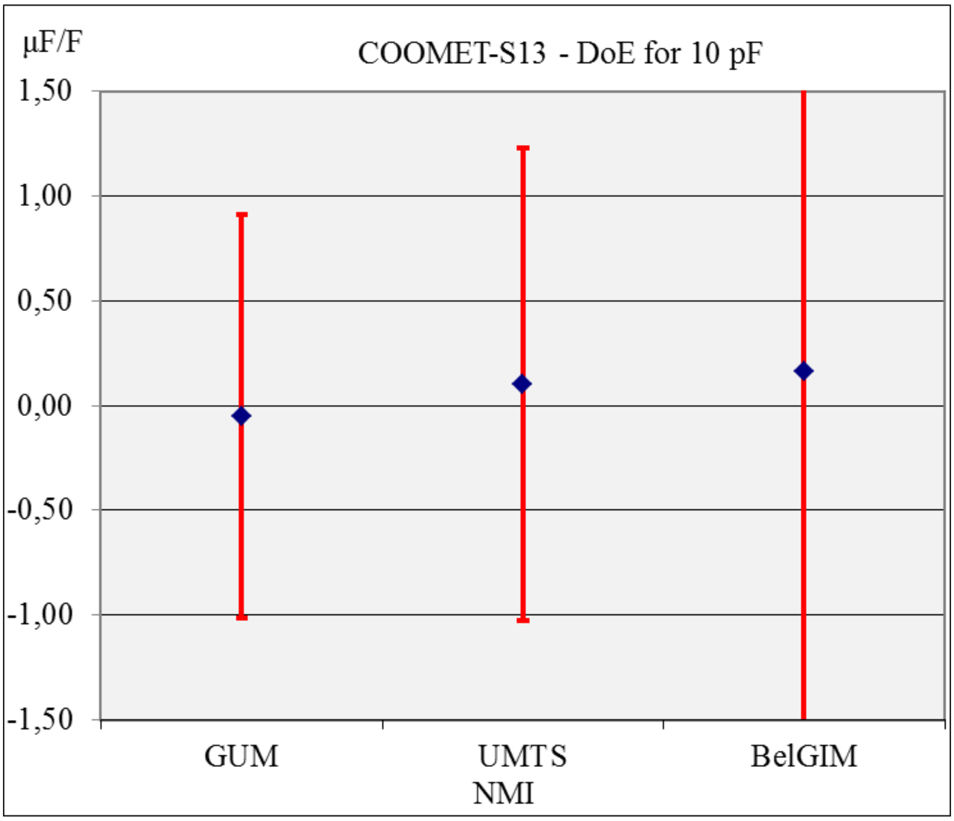

Figure 2 Degree of equivalence of the NMI participants on 10 pF

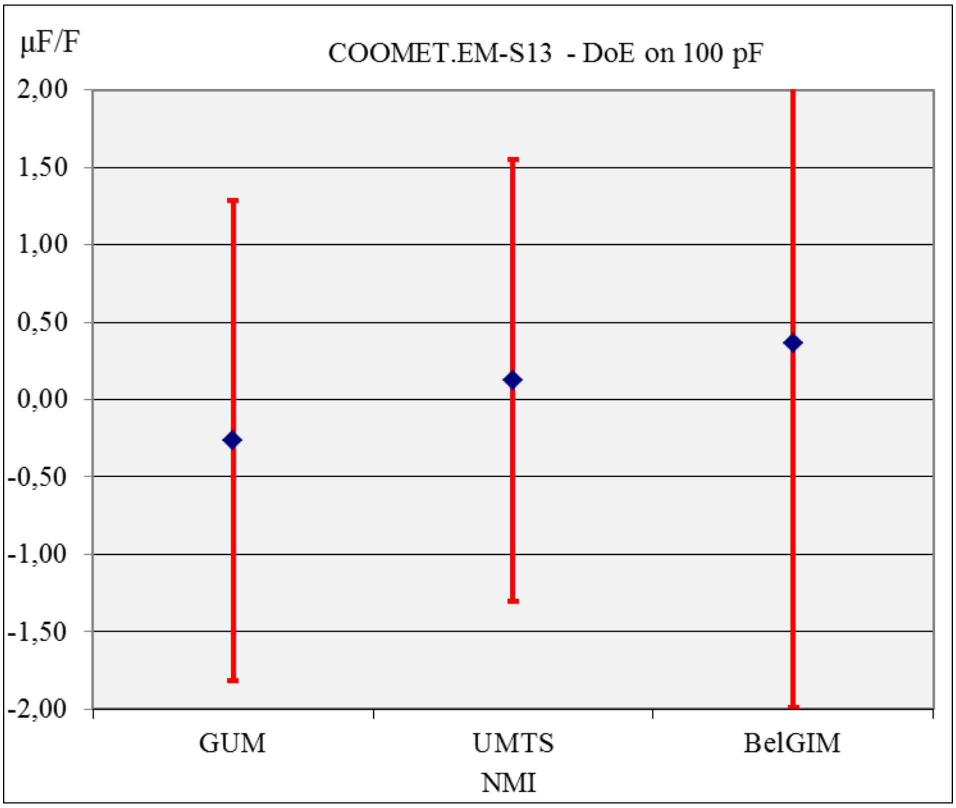

Figure 3 Degree of equivalence of the NMI participants on 100 pF

If the criterion value calculated in accordance with the data provided by NMIs doesn't exceed the critical value χ^2 with the coverage level 0.95 and the degrees of freedom

$$\chi^2 = \sum_{i=1}^{N} \frac{(x_i - x_{ref})^2}{u^2(x_i)} \prec \chi^2_{0.95}(N-1), \qquad (7)$$

then the data provided by different NMIs can be acknowledged as consistent, that is the objective confirmation of the announced uncertainties (Table 8).

Table 8 Values for criterion χ^2

Capacitance pF	χ^2	$\chi^2_{0,95}(n\text{-}1)$
10	0.064	5.9915
100	0.241	

NMI that provides maximum E_N criterion is determined

$$\max_i E_N = \frac{|x_i - x_{ref}|}{2\sqrt{u^2(x_i) - u^2(x_{ref})}}. \qquad (8)$$

Further that NMI's data is temporary excluded from the consideration, and the procedure of checking the comparisons data consistency is repeated. The sequential exclusion of data is repeated until the condition (7) is fulfilled.

The maximum E_N criterion and declared uncertainties for degrees of equivalence all NMIs for 10 pF and 100 pF are judged as confirmed by equations (7) and (8) accordingly (Table 9).

Table 9 Values for E_N criterion

Capacitance pF	NMI Participant	E_N
10	GUM	0.207
	UMTS	0.262
	BelGIM	0.151
100	GUM	0.527
	UMTS	0.308
	BelGIM	0.361

8 Summary

A supplementary comparison of capacitance at 10 pF and 100 pF has been conducted between participating COOMET member laboratories. In general there is good agreement between participating laboratories in the region for this quantity. It is expected that this comparison will be able to provide support for participants' entries in Appendix C of the Mutual Recognition Arrangement.

References

[1] COOMET R/GM/19:2008 Guidelines on COOMET supplementary comparison evaluation.

Appendix 1

Reported measurement results for each NMI laboratory

GUM (Poland)

Measurement frequency, Hz		1000.0
Measure temperature, ºC		29.6…30.2
Drift reading, ppm		–0.010…–0.016
Measurement result	Mean measurement date	24.05.2012
	Mean capacitance, pF	10.000009
	Expanded uncertainty, μF/F	0.50 (*k* = 2.0)
Measurement frequency, Hz		1000.0
Measure temperature, ºC		29.6…30.2
Drift reading, ppm		–0.067…–0.070
Measurement result	Mean measurement date	25.05.2012
	Mean capacitance, pF	100.00010
	Expanded uncertainty, μF/F	1.0 (*k* = 2.0)

UMTS (Ukraine)

Measurement frequency, Hz		1000.0
Measure temperature, ºC		27.7…32.7
Drift reading, ppm		0.015
Measurement result	Mean measurement date	14.10.2012
	Mean capacitance, pF	10.000011
	Expanded uncertainty, µF/F	0.768 (k = 2.0)
Measurement frequency, Hz		1000.0
Measure temperature, ºC		27.5…32.4
Drift reading, ppm		0.050
Measurement result	Mean measurement date	14.10.2012
	Mean capacitance, pF	100.00014
	Expanded uncertainty, µF/F	0.792 (k = 2.0)

BelGIM (Belarus)

Measurement frequency, Hz		1000.0
Measure temperature, ºC		31.2
Drift reading, ppm		–0.014
Measurement result	Mean measurement date	10.12.2012
	Mean capacitance, pF	10.000011
	Expanded uncertainty, μF/F	2.15 (k = 2.0)
Measurement frequency, Hz		1000.0
Measure temperature, ºC		29.4
Drift reading, ppm		–0.015
Measurement result	Mean measurement date	11.12.2012
	Mean capacitance, pF	100.00016
	Expanded uncertainty, μF/F	2.032 (k = 2.0)

Appendix 2

Reported measurement results for each NMI laboratory

GUM (Poland)

Quantity X_i	Estimate x_i	Standard uncertainty $u(x_i)$	Probability distribution	Method of evaluation (A, B)	Sensitivity coefficient c_i	Uncertainty contribution $c_i \cdot u(x_i)$	Degrees of freedom ν_i
10 pF							
C_W	10.0000217 pF	2.5E-06 pF	normal	A	1	2.5E-06 pF	50
ΔC_M	-0.0000127 pF	1.031E-07 pF	normal	A	1	1.031E-07 pF	$\propto$
δC_{dM}	0	5.77E-08 pF	rectang.	B	2	11.54E-08 pF	$\propto$
δC_{Tx}	0	2.31E-07 pF	rectang.	B	-1	-2.31E-07 pF	$\propto$
δC_{RW}	0	2.31E-09 pF	rectang.	B	1	2.31E-09 pF	$\propto$
C_X	10.0000090 pF						
		Combined standard uncertainty			u_c	2.514E-06 pF	
		Effective degrees of freedom			ν_{eff}	>200, k = 2	
		Expanded uncertainty ($p \approx 95$ %)			U	**5.0E-06 pF**	
100 pF							
C_W	99.99893 pF	5E-05 pF	normal	A	1	5E-05 pF	50
ΔC_M	0.001165 pF	2.17E-07 pF	normal	A	1	2.17E-07 pF	$\propto$
δC_{dM}	0	5.77E-07 pF	rectang.	B	2	11.54E-07 pF	$\propto$
δC_{Tx}	0	2.31E-06 pF	rectang.	B	-1	-2.31E-06 pF	$\propto$
δC_{RW}	0	6.755E-06 pF	rectang.	B	1	6.755E-06 pF	$\propto$
C_X	100.00010 pF						
		Combined standard uncertainty			u_c	5.05E-05 pF	
		Effective degrees of freedom			ν_{eff}	>200, k = 2	
		Expanded uncertainty ($p \approx 95$ %)			U	**1.0E-04 pF**	

Model equation that follows from the measurement setup:

$$C_X = C_W + \Delta C_M + 2\delta C_{dM} - \delta C_{Tx} + \delta C_{RW},$$

where:

C_W – value of reference standard;

ΔC_M – correction due to difference between value of measured standard and value of reference standard;

δC_{dM} – correction due to bridge resolution;

δC_{Tx} – correction due to temperature influence on measured standard;

δC_{RW} – correction due to annual drift of reference standard.

UMTS (Ukraine)

Quantity X_i	Estimate x_i	Standard uncertainty $u(x_i)$	Probability distribution	Method of evaluation (A, B)	Sensitivity coefficient c_i	Uncertainty contribution $c_i \cdot u(x_i)$
10 pF						
C_S	10.00000 pF	3.70E-06 pF	normal	B	1	3.70E-06 pF
ΔC_C	0.00001163 pF	6.1E-07 pF	normal	A	1	6.1E-07 pF
δC_{QC}	0	6.01E-08 pF	rectang.	B	2	1.2E-07 pF
δC_{Tx}	0	4.1E-07 pF	rectang.	B	-1	-4.1E-07 pF
δC_{SC}	0	1.07E-08 pF	rectang.	B	1	1.07E-08 pF
δC_{CE}	0	5.00E-07 pF	rectang.	A	1	5.00E-07 pF
δC_{γ}	-1.10E-06	5.08E-07 pF	rectang.	B	1	5.08E-07 pF
C_X	10.000011 pF					
		Combined standard uncertainty			u_c	3.841E-06 pF
		Effective degrees of freedom			ν_{eff}	>200, k = 2
		Expanded uncertainty ($p \approx 95$ %)			U	**7.682-06 pF**
100 pF						
C_S	100.00002 pF	3.70E-05 pF	normal	B	1	3.70E-05 pF
ΔC_C	0.00005403 pF	8.2E-06 pF	normal	A	1	8.2E-06 pF
δC_{QC}	0	6.01E-07 pF	rectang.	B	2	1.2E-06 pF
δC_{Tx}	0	8.3E-06 pF	rectang.	B	-1	-8.3E-06 pF
δC_{SC}	0	1.07E-08 pF	rectang.	B	1	1.07E-08 pF
δC_{CE}	0	7.90E-06 pF	rectang.	A	1	7.90E-06 pF
δC_{γ}	6.65E-05	8.50E-07 pF	rectang.	B	1	8.50E-07 pF
C_X	100.00014 pF					
		Combined standard uncertainty			u_c	3.962E-05 pF
		Effective degrees of freedom			ν_{eff}	>200, k = 2
		Expanded uncertainty ($p \approx 95$ %)			U	**7.924E-05 pF**

Model equation that follows from the measurement setup:

$$C_X = C_S + \Delta C_C + 2\delta C_{QC} - \delta C_{Tx} + \delta C_{SC} + \delta C_{CE} + \delta C_{\gamma},$$

where:

C_S – value of reference standard;

ΔC_C – correction due to difference between value of measured standard and value of reference standard;

δC_{QC} – deviation due to the quantization error of the comparator;

δC_{Tx} – correction due to temperature influence on measured standard;

δC_{SC} – correction for the sensitivity of the comparator;

δC_{CE} – error of the comparison;

δC_{γ} – correction due to annual drift of reference standard.

BelGIM (Belarus)

Quantity	Estimate, pF	+/- *r*, pF	Method of evaluation (A, B)	Distribution	Standard uncertainty, pF	Sensitivity coefficient	Contribution to the relative standard uncertainty, pF
10 pF							
C_x	10.0000572		A	Normal	0.000000173	0.99999539	0.000000173
$C_{хэт}$	9.99999506		A	Normal	0.000000178	-1.00000161	-0.000000178
$\delta C_{эт}$	0	0.000021	B	Rectangular	0.00001050	1.00000621	0.00001050
$\delta C_{н}$	0	0.000004	B	Rectangular	0.00000231	1.00000621	0.00000231
$\delta C_{КВ}$	0	0.00000005	B	Rectangular	0.00000003	0.99999539	0.00000003
Final values:	**10.000011**						**0.00011**
100 pF							
C_x	100.0008228		A	Normal	0.000000221	0.99999342	0.000000221
$C_{хэт}$	100.0001579		A	Normal	0.000000198	-1.00000007	-0.000000198
$\delta C_{эт}$	0	0.0002	B	Rectangular	0.0001	1.00000665	1.000100001
$\delta C_{н}$	0	0.000031	B	Rectangular	0.0000179	1.00000665	0.0000179
$\delta C_{КВ}$	0	0.0000005	B	Rectangular	0.00000029	0.00000029	0.00000029
Final values:	**100.00016**						**0.00010**

Mathematical model: $C_Д = \dfrac{C_{этд} + \delta C_{эт} + \delta C_{н}}{C_{хэт} + \delta C_{кв}} \left(C_x + \delta C_{кв} \right)$,

Notes:

$C_{этд}$ – value of standard measure from calibration certificate;

C_x – measured value of capacitance of transfer standard;

$C_{хэт}$ – measured value of capacitance of lab standard;

$\delta C_{эт}$ – correction due to the inaccuracy of the establishment of the actual value of the standard measure;

$\delta C_{н}$ – correction due to the non-stability of standard measure for the year;

$\delta C_{КВ}$ – correction due to the AC bridge quantizetion process.