Report on the SIM Photometry and Radiometry Key Comparison of Spectral Regular Transmittance (SIM.PR-K6.2010)

Final Report
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Introduction

The Consultative Committee for Photometry and Radiometry (CCPR) organizes measurement comparisons of several 'key' measurement scales in support of the Mutual Recognition Arrangement (MRA). Because participation in CCPR key comparisons is limited to 12 laboratories, the Regional Metrology Organizations (RMOs) facilitate corresponding key comparisons at a smaller scale to allow its participants' results to be linked to those of the CCPR comparison in terms of equivalence (through the key comparison reference value). In this way, RMOs assist national metrology institutes in fulfilling their obligations under the MRA.

The CCPR initiated planning in 2008 for a key comparison of spectral regular transmittance, later designated CCPR-K6.2010. While CCPR-K6.2010 was still in progress, the SIM Photometry and Radiometry (PR) Technical Committee began planning the SIM.PR-K6.2010 comparison in 2012, and the committee appointed the National Institute of Standards and Technology (NIST) of USA as the pilot laboratory and NIST and the National Research Council (NRC) of Canada as the link laboratories.

The announcement of the SIM.PR-K6.2010 comparison was posted on the BIPM KCDB in November 2016. The list of participant laboratories is provided in Table 1. Initiation of the SIM.PR-K6.2010 comparison began promptly following approval of the final report for CCPR-K6.2010 [1].

Table 1. Participating laboratories in SIM.PR-K6.2010 for spectral regular transmittance

RMO	Participating Laboratories	Economy	Primary Contact
SIM	National Institute of Standards and Technology (NIST)	USA	Catherine Cooksey
	National Research Council of Canada (NRC)	Canada	Joanne Zwinkels
	Centro Nacional de Metrología (CENAM)	Mexico	Carlos Matamoros Garcia
	Instituto Nacional de Metrología de Colombia (INM)	Colombia	Juliana Serna Saiz
	Instituto Nacional de Metrologia, Inovação e Tecnologia (INMETRO)	Brazil	Giovanna Borghi
APMP	Center for Measurement Standards/ Industrial Technology Research Institute (CMS/ITRI)	Chinese Taipei	Wen-Chun Liu
	National Institute of Metrology (NIM)	China	Zheng Chundi
	National Institute of Metrology (NIMT)	Thailand	Rojana Leecharoen

Comparison Measurements

The technical protocol for SIM.PR-K6.2010 (see Appendix A) was based on the technical protocol for CCPR-K6.2010 [2]. The comparison was accomplished through measurements of sets of standard filters, and the measurement sequence followed a star pattern: pilot-participant-pilot. Accordingly, the pilot measured all sets of comparison standards first. Then, each participant measured a single set of comparison standards. Finally, the pilot measured all sets a second time. Thus, the total number of measurement rounds is three. The schedule for the comparison is detailed in Table 2.

Table 2. Schedule for comparison measurements

Dates	Activity
December 2016 to March 2017	First measurements by pilot (Round 1)
March 2017	Comparison standards shipped to each participant
March 2017 to June 2017	Measurements by participants (Round 2)
April 2017 to June 2017	Comparison standards return from each participant
August 2017 to November 2017*	Second measurement by pilot (Round 3)

*Select filters and wavelengths were re-measured by the pilot in February 2018.

It is noted that the CCPR-K6.2010 comparison included an extra two rounds of measurements involving both the pilot and participants. The number of rounds for SIM.PR-K6.2010 was reduced from CCPR-K6.2010 to ease the burden on the pilot and speed the time of the comparison.

The pilot and the participants measured the spectral transmittance of each comparison standard according to the parameters listed in Table 3. When the measurement parameters deviated from those listed in the table, participants were expected to make appropriate corrections to their transmittance values and/or account for the deviations in their uncertainty budgets. The pilot provided participants with the temperature coefficients for the comparison standards and their corresponding uncertainties [3].

Table 3. Parameters for the comparison measurements.

Parameter	Comparison Value
Angle of Incidence (°)	0
Diameter of Beam (mm)	17
Wavelength (nm)	380, 400, 500, 600, 700, 800, 900, 1000
Bandwidth (nm)	1
Temperature (°C)	23
Relative Humidity (%)	< 60

Each laboratory measured the transmittance of the comparison standards independently several times during its measurement round. The number of measurements completed was consistent with the

laboratory's usual process and was stated in each laboratory's report (see Appendix B). The reported transmittance values were the average of these measurements.

Each laboratory estimated its measurement uncertainty according to the ISO Guide to the Expression of Uncertainty in Measurement [4]. For optimal comparability, each laboratory evaluated uncertainty contributions for a list of principal influence parameters provided in the SIM.PR-K6.2010 Technical Protocol (see Appendix A). The laboratory included contributions for additional parameters as needed based on its specific facility. All values were reported as absolute uncertainties with a coverage factor of $k = 1$.

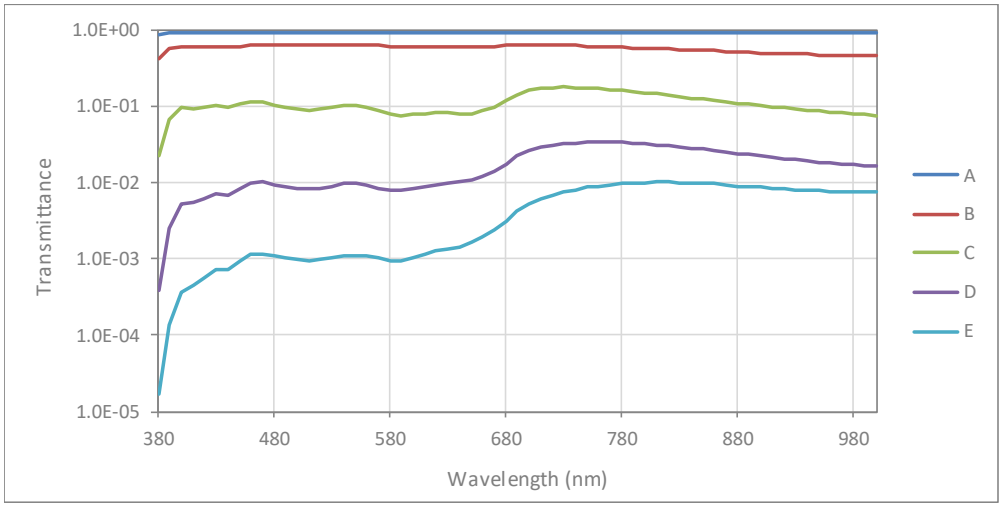
Description of Comparison Standards

The sets of comparison standards used in this comparison were previously used in both the original CCPR-K6 and the CCPR-K6.2010 comparisons [1,5]. Each participant received a separate set of standards to minimize the time needed for the completion of the comparison. Each set consisted of 5 neutral coloured glass filters, which have dimensions of 50 mm by 50 mm. Table 4 summarizes the main characteristics of each filter, and the nominal transmittance spectra of the filters are shown in Figure 1.

Table 4. Characteristics of the comparison filters

Filter Identifier	Type of Glass	Nominal Thickness (mm)	Nominal Transmittance (%) at 546 nm
A	BK 7	4.0	92
B	NG 11	2.0	50
C	NG 5	3.9	10
D	NG 4	3.9	1.0
E	NG 3	3.1	0.1

Figure 1. Nominal transmittance spectra of the comparison filters



Each filter was identified by a letter (filter identifier) and a number (set number) engraved in the top left corner outside the area used for measurement. To allow for the comparison standards to be used again in future comparisons, with a low risk of the results of this comparison being referred to by future participants, the set numbers of filters used are not published in this report.

Laboratories were permitted to remove dust from the filters using a stream of dry gas. However, participants were instructed not to clean the filters without approval from the pilot.

The pilot and participants commonly reported the appearance of dust on the filters following shipping. One participant reported the appearance of fingerprints along the edges of several filters in the set. None of the fingerprints occurred within the measurement area, so measurement of that filter set proceeded as planned. Another participant reported the appearance of a fingerprint in the measurement area of filter A and a fingerprint and nonuniform surface film in the measurement area of filter D. The pilot sent replacement A and D filters to the participant.

Participant Facilities

All participants provided descriptions of their facilities and these are included with the participant reports in Appendix B.

Pre-Draft A Process

The pre-Draft A process serves several purposes. First, it allows participants to review their own reported results to determine if the pilot has made any clerical errors. Second, it allows all participants to review each other's uncertainty budgets and send comments or ask questions about a participant's budget. Finally, it allows participants the opportunity to review relative data and assess the stability of the comparison standards and the internal consistency of a laboratory's measurements.

No laboratories made changes to their results, and no comments on the uncertainty budgets were received.

The relative data for the pilot can be found in Appendix C. The relative data is intended to show the stability of the comparison standards before and after travel between laboratories and the internal consistency of measurements for each laboratory. Because the SIM.PR-K6.2010 Technical Protocol (see Appendix A) specifies two rounds of measurements by the pilot and only one round of measurements by the participant, the plots in Appendix C show only the relative data of the pilot for each participant's comparison set.

The final reported data and uncertainty budgets for the pilot and participants can be found in Appendices D and E, respectively.

Analysis Method

The degrees of equivalence (DoE) for NIST (pilot, link) and NRC (non-pilot, link) to the key comparison reference value (KCRV) were determined during CCPR-K6.2010 [1]. The analysis technique used in SIM.PR-K6.2010 served to link the measurement results of this comparison to those of the CCPR-K6.2010, thereby, producing DoE's for each participant to the CCPR-K6.2010's KCRV.

Each of the 40 transmittance measurements (5 filters × 8 wavelengths) was considered an independent comparison of standards. Thus, each participant has, at most, 40 DoE's. These DoE's are the best estimate of a systematic offset of that participant's measurements has from the KCRV.

The analysis technique used in SIM.PR-K6.2010 was a combination of the recommended approach in CCPR G6, Appendix A.2.3, *For the link of non-link laboratories when the pilot is a link laboratory* [6] and a Monte Carlo calculation as described in JCGM 101:2008, *Evaluation of measurement data – Supplement 1 to the "Guide to the expression of uncertainty in measurement" – Propagation of distributions using a Monte Carlo method* [7].

First, the degree of equivalence for each non-link participant D_α was calculated with respect to the link laboratories, NIST and NRC, using:

$$D_{\alpha(NIST)} = D_{NIST} + (\tau_\alpha - \tau_{NIST}) \tag{1}$$

$$D_{\alpha(NRC)} = D_{NRC} + (\tau_{NIST} - \tau_{NRC}) + (\tau_\alpha - \tau_{NIST}) \tag{2}$$

Where D_{NIST} and D_{NRC} were the degree of equivalences for NIST and NRC, respectively, as reported in the CCPR-K6.2010 final report [1]. The transmittance values τ were the values measured by the laboratories during the SIM.PR-K6.2010 comparison (see Appendix D).

Second, the uncertainties for these DoE's, $u(D_{\alpha(NIST)})$ and $u(D_{\alpha(NRC)})$, were obtained using Monte Carlo propagation. This calculation included the total uncertainties and covariances of D_{NIST} and D_{NRC} as reported in the CCPR-K6.2010 final report [1] as well as the total uncertainty (including both Type A and Type B uncertainties) of each transmittance value measured during the SIM.PR-K6.2010 comparison (see Appendix E).

Next, weights W_{NIST} and W_{NRC} for the link laboratories were calculated such that the following condition was met:

$$W_{NIST} + W_{NRC} = 1 \tag{3}$$

The weights were defined as:

$$W_{NIST} = \frac{\bar{W}}{\bar{\sigma}^2_{NIST} - u^2_{NIST,r,RMO} - s^2_{RMO}} \tag{4}$$

$$W_{NRC} = \frac{\bar{W}}{\bar{\sigma}^2_{NRC} + u^2_{NIST,r,RMO}} \tag{5}$$

Where

$$\bar{W} = \frac{(\bar{\sigma}^2_{NRC} + u^2_{NIST,r,RMO})(\bar{\sigma}^2_{NIST} - u^2_{NIST,r,RMO} - s^2_{RMO})}{\bar{\sigma}^2_{NIST} + \bar{\sigma}^2_{NRC} - s^2_{RMO}} \tag{6}$$

$$\bar{\sigma}^2_{NIST} = s^2_{KC} + s^2_{RMO} + u^2_{NIST,st} + u^2_{NIST,r,KC} + u^2_{NIST,r,RMO} \tag{7}$$

$$\bar{\sigma}^2_{NRC} = s^2_{KC} + s^2_{RMO} + u^2_{NRC,st} + u^2_{NRC,r,KC} + u^2_{NRC,r,RMO} \tag{8}$$

Equations 4 through 8 depended on the following uncertainties. The standard uncertainties associated with uncorrelated (random) effects for NIST and NRC during CCPR-K6.2010 were $u_{NIST,r,KC}$ and $u_{NRC,r,KC}$, respectively, and were determined from the values reported in the CCPR-K6.2010 final report [1]. The corresponding uncertainties for NIST and NRC during SIM.PR-K6.2010 were $u_{NIST,r,RMO}$ and $u_{NRC,r,RMO}$, respectively, and were determined from the values reported in Appendix E. The standard transfer uncertainty for CCPR-K6.2010, s_{KC}, was the uncertainty added during the key comparison to obtain consistency between the comparison results using the Mandel-Paule approach. Similarly, the standard transfer uncertainty for SIM.PR-K6.2010, s_{RMO}, was the uncertainty added during this comparison to obtain consistency between the NIST results. For these calculations, $s_{RMO} = 0$. The standard uncertainties associated with the reproducibility of NIST's and NRC's scales between the CCPR-K6.2010 and SIM.PR-K6.2010 comparisons were $u_{NIST,st}$ and $u_{NRC,st}$. The values for all the standard uncertainties mentioned above can be found in Appendix F.

Finally, the degree of equivalence for each non-link participant D_α was calculated according to the absolute-difference model:

$$D_\alpha = W_{NIST} D_{\alpha(NIST)} + W_{NRC} D_{\alpha(NRC)} \tag{9}$$

The combined standard uncertainty of the DoE, $u(D_\alpha)$, was calculated by standard propagation of the uncertainties $u(D_{\alpha(NIST)})$ and $u(D_{\alpha(NRC)})$. In this way, all the uncertainties and covariances contributing to $D_{\alpha(NIST)}$ and $D_{\alpha(NRC)}$ were accounted for in the evaluation of the uncertainty of D_α.

The final uncertainty is given as an expanded uncertainty with a coverage factor of $k = 2$:

$$U(D_\alpha) = 2u(D_\alpha) \tag{10}$$

The Monte Carlo calculation was programmed in OpenBUGS, a software application for Bayesian modelling [8].

Comparison Results

The comparison results, DoE and its expanded uncertainty, for all non-link participants are shown for all filters and wavelengths in Figures 1 through 5 and tabulated in Tables 5 through 9.

Conclusion

According to the Technical Supplement of the Mutual Recognition Arrangement (MRA) [9], key comparisons provide the technical basis for the arrangement. The technical deliverables of an RMO key comparison are the DoE of each participating laboratory to the KCRV of the CCPR comparison and its expanded uncertainty. These results then form the basis upon which entries in the Calibration and Measurement Capabilities (CMC) database are evaluated and validated.

The results indicate that most of the participants have the capability to measure spectral regular transmittance and evaluate their uncertainty budgets adequately. There are some cases of non-equivalence that will require further investigation on the part of the participants.

It is important to note that the CCPR-K6.2010 comparison included an extra two rounds of measurements involving both the pilot and participants, while the number of rounds for SIM.PR-K6.2010 was reduced to ease the burden on the pilot and speed the time of the comparison. The

relative data found in Appendix C show that the comparison standards were stable throughout the period of comparison measurements. However, because the participants were only able to measure their comparison set once, participants were unable to evaluate the internal consistency of their measurements. Thus, it is recognized that reducing the number of rounds of measurements has precluded information that is potentially useful for participants in evaluating their results and estimating their uncertainties.

Figure 2. Final results for degree of equivalence and its expanded (k = 2) uncertainty for SIM.PR-K6.2010 for Filter A

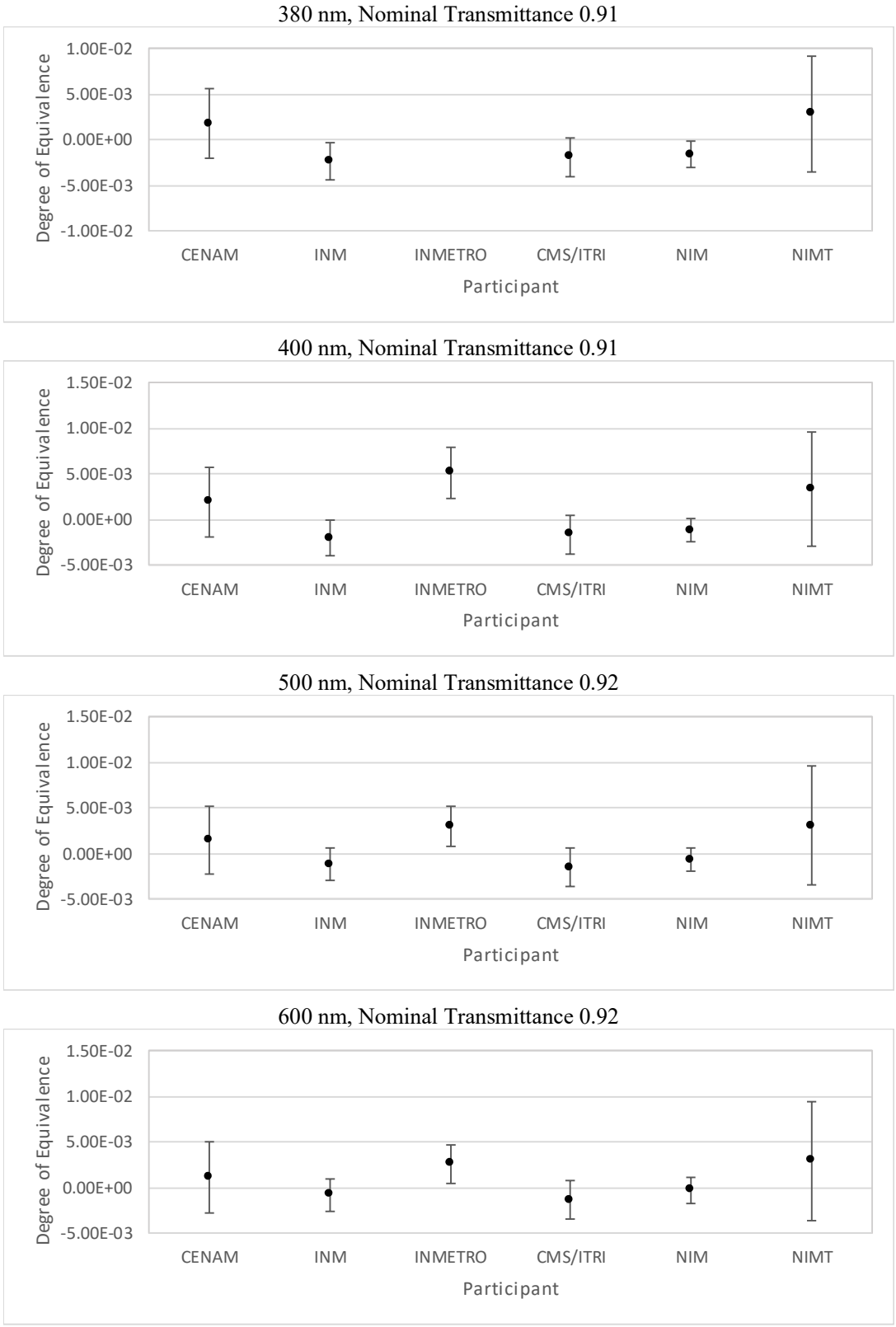


Figure 2. (cont.) Final results for degree of equivalence and its expanded ($k = 2$) uncertainty for SIM.PR-K6.2010 for Filter A

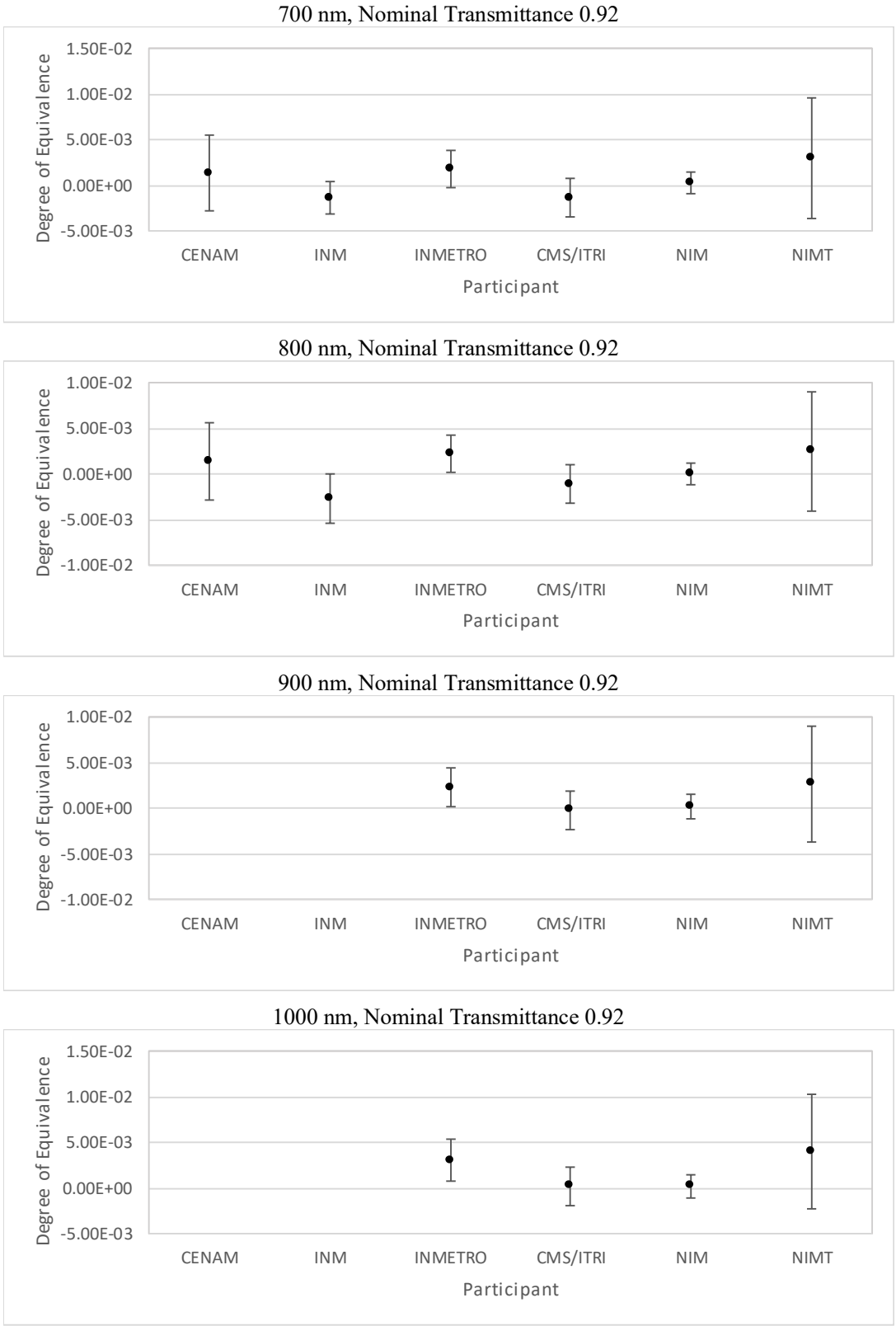


Figure 3. Final results for degree of equivalence and its expanded (k = 2) uncertainty for SIM.PR-K6.2010 for Filter B

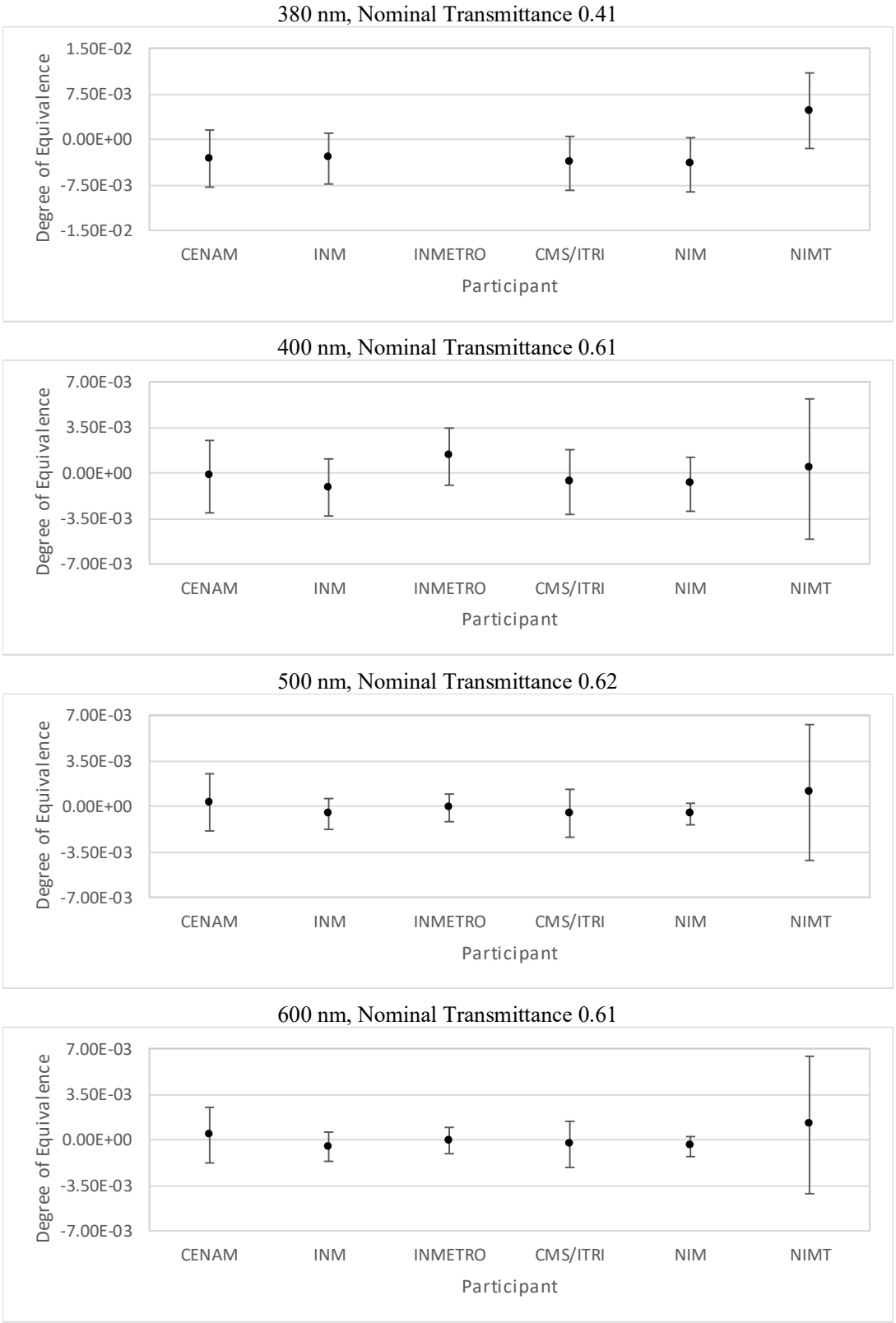


Figure 3. (cont.) Final results for degree of equivalence and its expanded ($k = 2$) uncertainty for SIM.PR-K6.2010 for Filter B

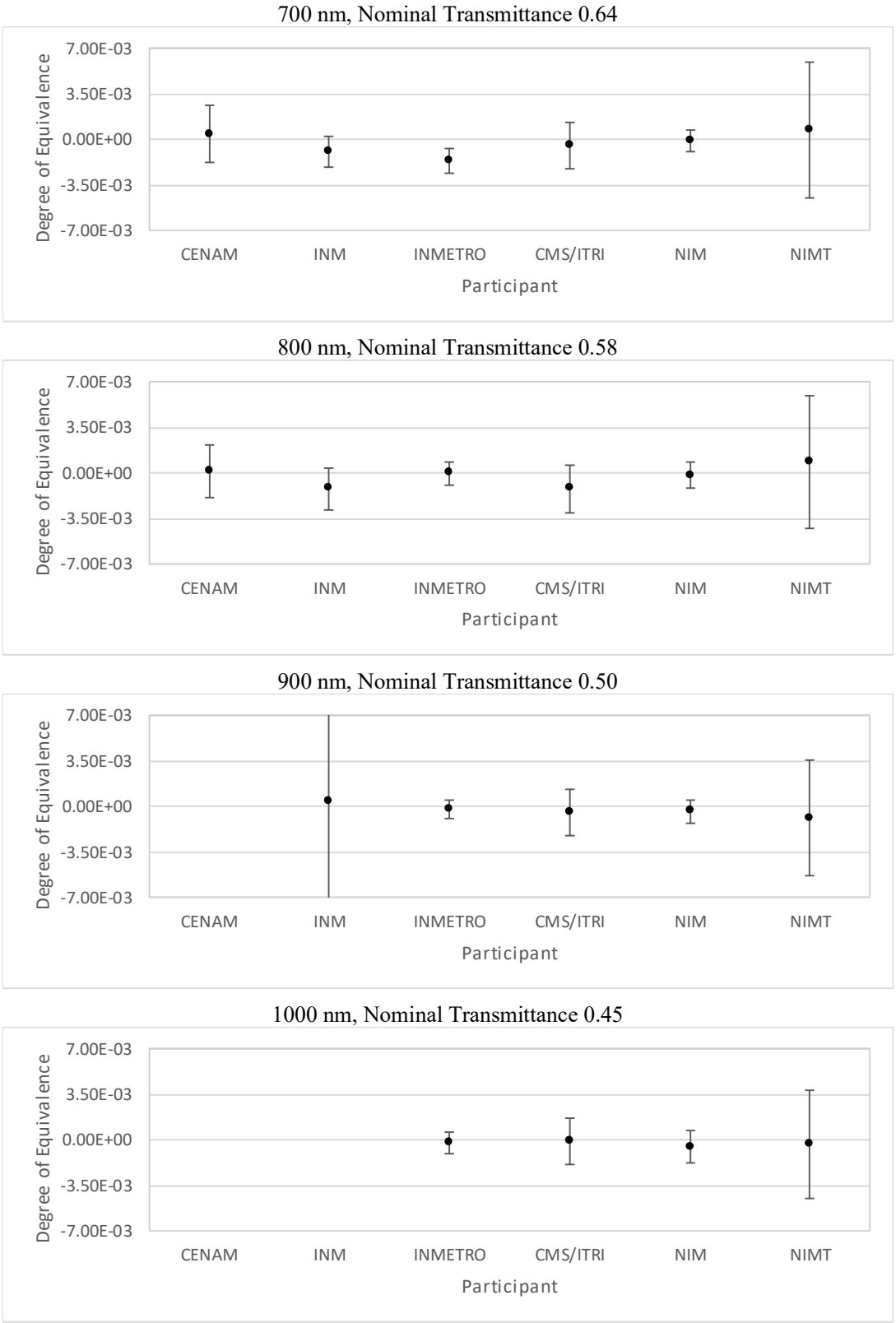


Figure 4. Final results for degree of equivalence and its expanded (k = 2) uncertainty for SIM.PR-K6.2010 for Filter C

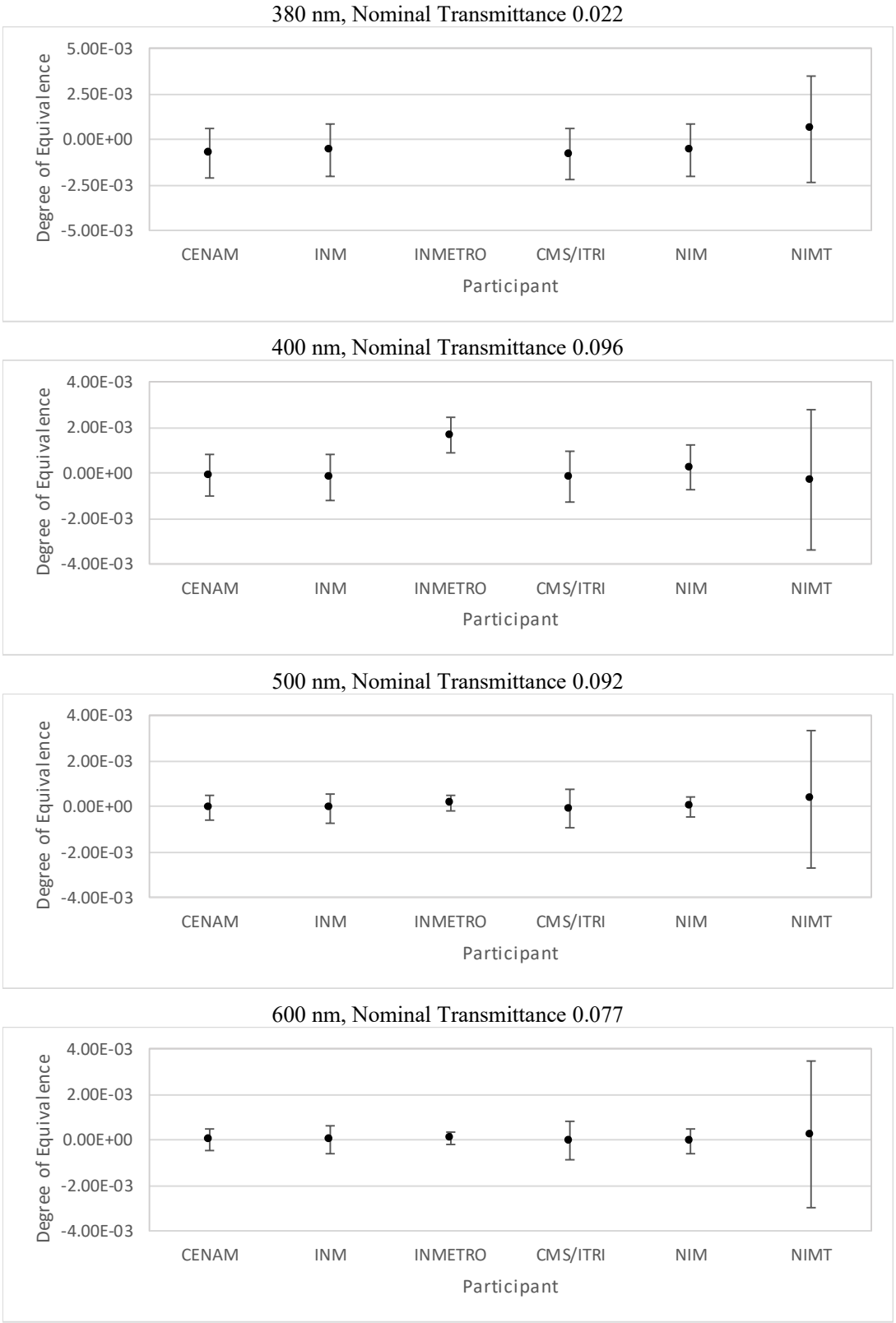


Figure 4. (cont.) Final results for degree of equivalence and its expanded ($k = 2$) uncertainty for SIM.PR-K6.2010 for Filter C

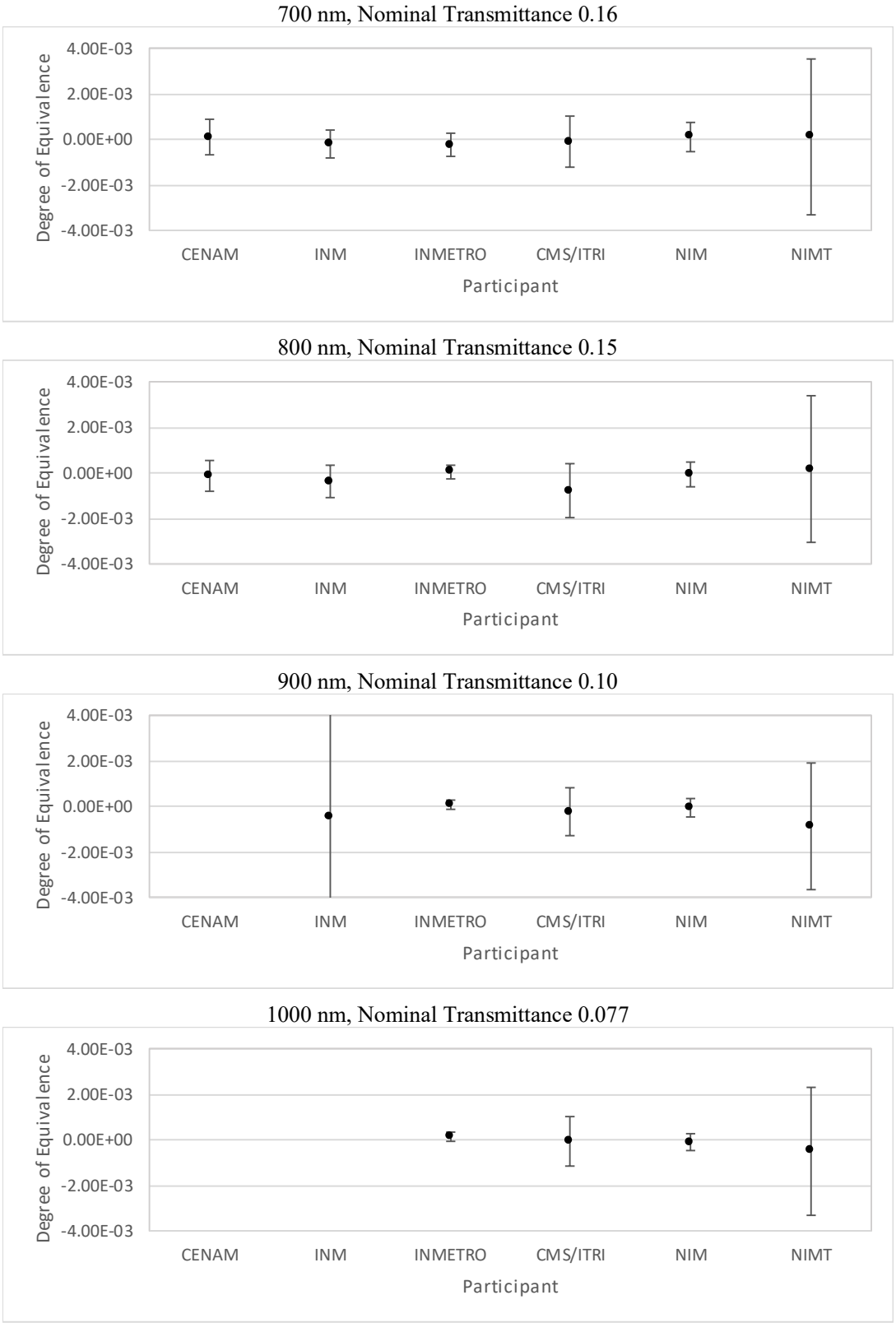


Figure 5. Final results for degree of equivalence and its expanded (k = 2) uncertainty for SIM.PR-K6.2010 for Filter D

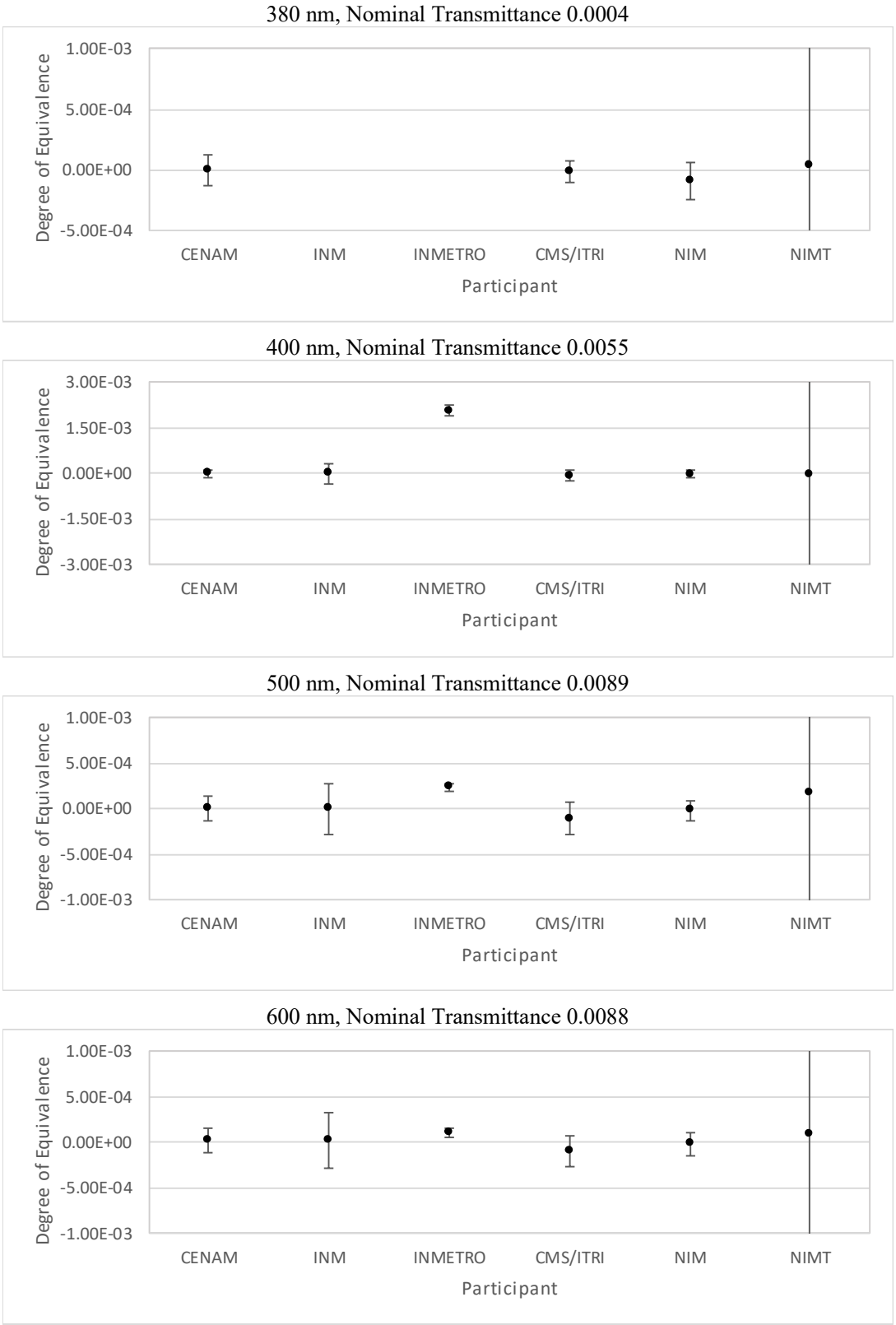


Figure 5. (cont.) Final results for degree of equivalence and its expanded ($k = 2$) uncertainty for SIM.PR-K6.2010 for Filter D

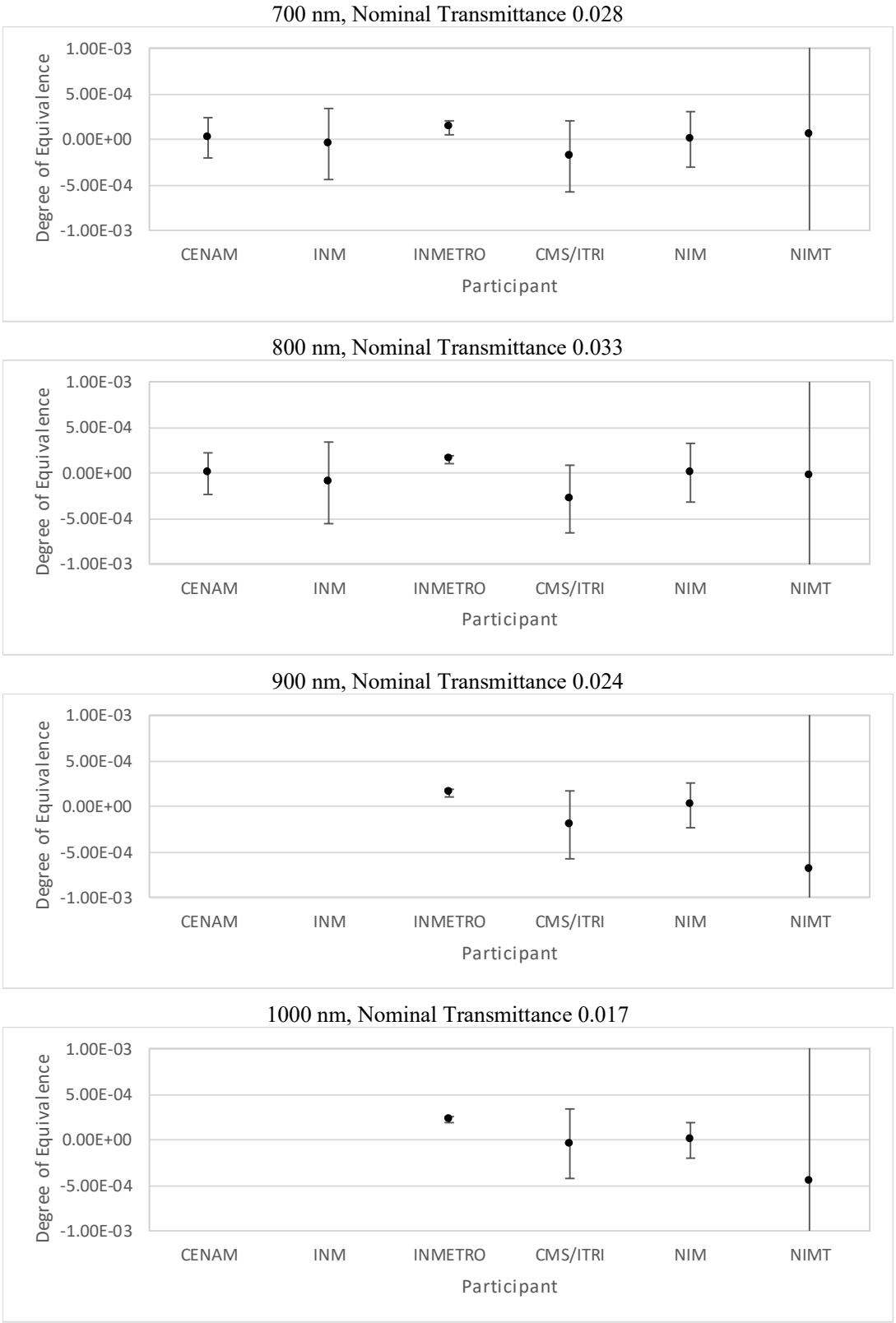


Figure 6. Final results for degree of equivalence and its expanded (k = 2) uncertainty for SIM.PR-K6.2010 for Filter E

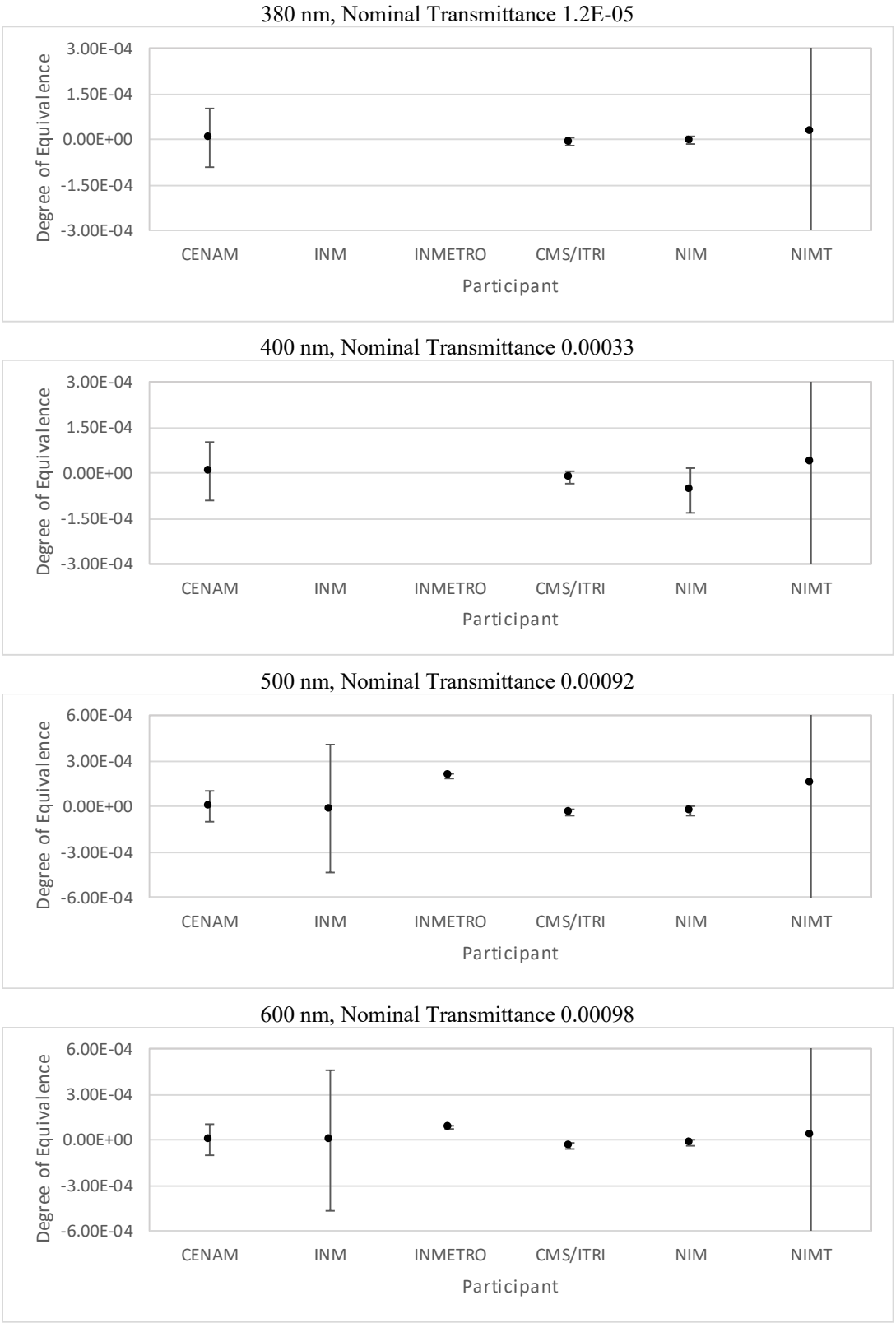


Figure 6. (cont.) Final results for degree of equivalence and its expanded ($k = 2$) uncertainty for SIM.PR-K6.2010 for Filter E

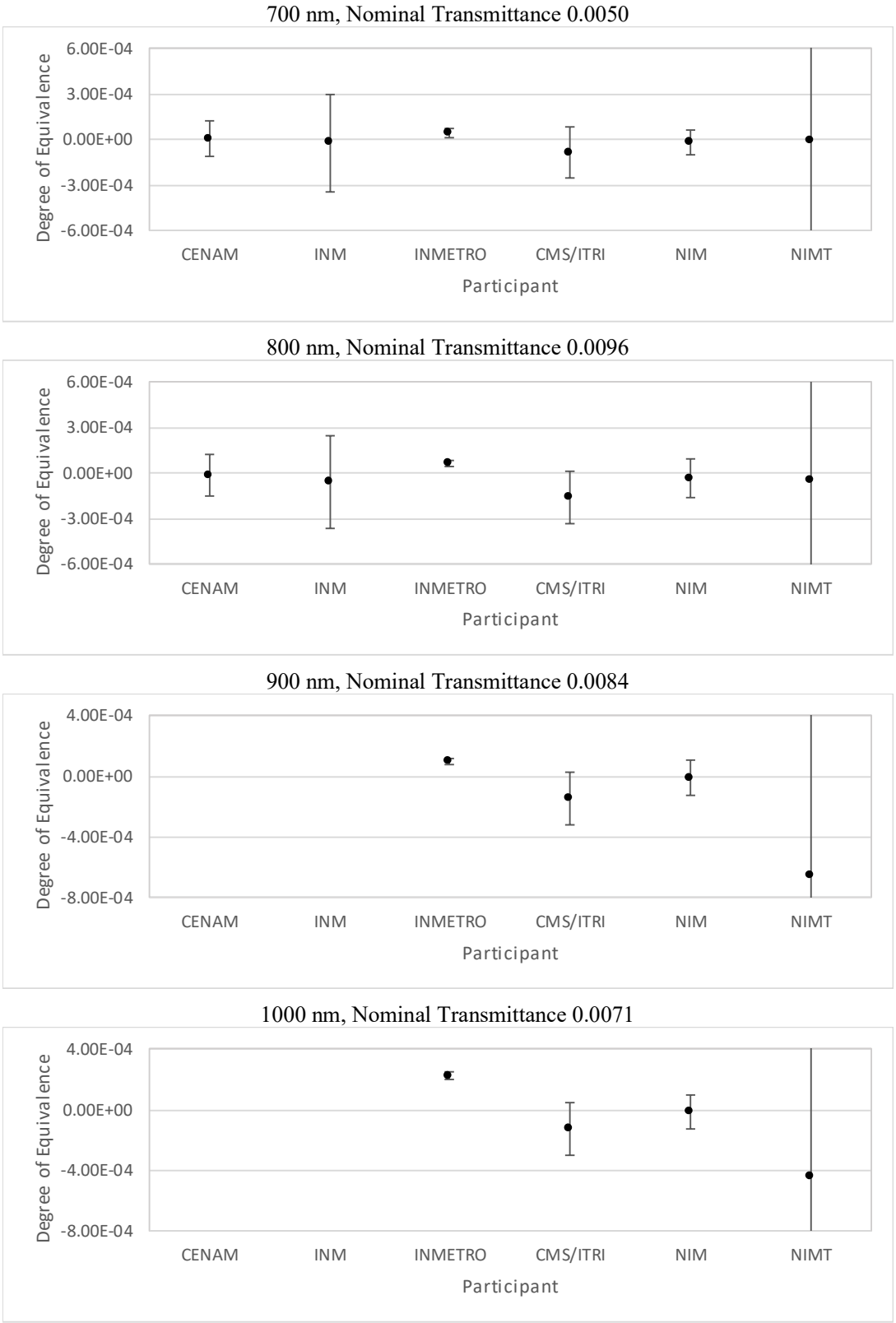


Table 5. Final results for degree of equivalence (DoE) and its expanded ($k = 2$) uncertainty for SIM.PR-K6.2010 for Filter A

Wavelength (nm)		380	400	500	600	700	800	900	1000
Nominal Transmittance		0.91	0.91	0.92	0.92	0.92	0.92	0.92	0.92
CENAM	DoE	1.80E-03	1.95E-03	1.48E-03	1.12E-03	1.34E-03	1.34E-03	-	-
	U(DoE)	3.83E-03	3.82E-03	3.80E-03	3.88E-03	4.15E-03	4.22E-03	-	-
INM	DoE	-2.32E-03	-2.03E-03	-1.16E-03	-7.90E-04	-1.36E-03	-2.65E-03	-	-
	U(DoE)	2.01E-03	1.96E-03	1.76E-03	1.72E-03	1.74E-03	2.77E-03	-	-
INMETRO	DoE	-	5.14E-03	2.99E-03	2.61E-03	1.82E-03	2.19E-03	2.30E-03	3.07E-03
	U(DoE)	-	2.75E-03	2.21E-03	2.16E-03	2.05E-03	2.03E-03	2.06E-03	2.24E-03
CMS/ITRI	DoE	-1.89E-03	-1.64E-03	-1.52E-03	-1.37E-03	-1.39E-03	-1.11E-03	-1.80E-04	2.39E-04
	U(DoE)	2.18E-03	2.17E-03	2.11E-03	2.12E-03	2.12E-03	2.14E-03	2.15E-03	2.15E-03
NIM	DoE	-1.60E-03	-1.18E-03	-6.38E-04	-2.62E-04	3.08E-04	1.43E-05	2.07E-04	2.79E-04
	U(DoE)	1.44E-03	1.31E-03	1.25E-03	1.45E-03	1.23E-03	1.24E-03	1.29E-03	1.26E-03
NIMT	DoE	2.87E-03	3.36E-03	3.09E-03	2.95E-03	3.01E-03	2.52E-03	2.70E-03	4.01E-03
	U(DoE)	6.34E-03	6.34E-03	6.55E-03	6.48E-03	6.56E-03	6.56E-03	6.31E-03	6.28E-03

Table 6. Final results for degree of equivalence (DoE) and its expanded ($k = 2$) uncertainty for SIM.PR-K6.2010 for Filter B

Wavelength (nm)		380	400	500	600	700	800	900	1000
Nominal Transmittance		0.41	0.61	0.62	0.61	0.64	0.58	0.50	0.45
CENAM	DoE	-3.13E-03	-2.20E-04	3.12E-04	3.76E-04	3.99E-04	1.68E-04	-	-
	U(DoE)	4.58E-03	2.79E-03	2.21E-03	2.14E-03	2.21E-03	2.03E-03	-	-
INM	DoE	-3.09E-03	-1.14E-03	-5.74E-04	-5.16E-04	-9.35E-04	-1.20E-03	3.64E-04	-
	U(DoE)	4.27E-03	2.19E-03	1.19E-03	1.15E-03	1.15E-03	1.59E-03	1.98E-02	-
INMETRO	DoE	-	1.30E-03	-9.13E-05	-4.19E-05	-1.64E-03	-2.96E-05	-2.10E-04	-1.58E-04
	U(DoE)	-	2.20E-03	1.12E-03	9.92E-04	9.83E-04	8.48E-04	7.33E-04	8.36E-04
CMS/ITRI	DoE	-3.85E-03	-6.95E-04	-5.22E-04	-3.51E-04	-4.46E-04	-1.22E-03	-4.32E-04	-5.22E-05
	U(DoE)	4.45E-03	2.47E-03	1.80E-03	1.75E-03	1.72E-03	1.85E-03	1.74E-03	1.76E-03
NIM	DoE	-4.09E-03	-8.28E-04	-5.31E-04	-4.58E-04	-1.33E-04	-1.63E-04	-3.30E-04	-5.08E-04
	U(DoE)	4.51E-03	2.09E-03	8.47E-04	7.70E-04	8.37E-04	1.04E-03	8.88E-04	1.22E-03
NIMT	DoE	4.70E-03	3.28E-04	1.09E-03	1.16E-03	7.28E-04	8.51E-04	-8.79E-04	-3.28E-04
	U(DoE)	-3.85E-03	5.41E-03	5.25E-03	5.23E-03	5.18E-03	5.05E-03	4.45E-03	4.20E-03

Table 7. Final results for degree of equivalence (DoE) and its expanded ($k = 2$) uncertainty for SIM.PR-K6.2010 for Filter C

Wavelength (nm)		380	400	500	600	700	800	900	1000
Nominal Transmittance		0.022	0.096	0.092	0.077	0.16	0.15	0.10	0.077
CENAM	DoE	-7.49E-04	-9.14E-05	-7.49E-05	2.57E-05	1.13E-04	-1.37E-04	-	-
	U(DoE)	1.37E-03	8.92E-04	5.36E-04	4.58E-04	7.79E-04	6.80E-04	-	-
INM	DoE	-5.72E-04	-1.83E-04	-5.48E-05	1.36E-05	-1.66E-04	-3.77E-04	-4.71E-04	-
	U(DoE)	1.41E-03	1.04E-03	6.41E-04	6.19E-04	6.04E-04	7.23E-04	7.47E-03	-
INMETRO	DoE	-	1.65E-03	1.66E-04	6.67E-05	-2.51E-04	7.09E-05	5.71E-05	1.31E-04
	U(DoE)	-	7.70E-04	3.33E-04	2.64E-04	5.07E-04	2.97E-04	2.10E-04	1.92E-04
CMS/ITRI	DoE	-8.03E-04	-1.71E-04	-1.04E-04	-2.52E-05	-1.04E-04	-7.78E-04	-2.25E-04	-6.61E-05
	U(DoE)	1.40E-03	1.13E-03	8.62E-04	8.42E-04	1.13E-03	1.19E-03	1.07E-03	1.08E-03
NIM	DoE	-5.48E-04	2.49E-04	2.95E-06	-5.10E-05	1.26E-04	-2.63E-05	-3.91E-05	-9.26E-05
	U(DoE)	1.43E-03	9.67E-04	4.52E-04	5.19E-04	6.39E-04	5.45E-04	4.01E-04	3.84E-04
NIMT	DoE	5.89E-04	-2.99E-04	3.36E-04	2.45E-04	1.18E-04	1.72E-04	-8.80E-04	-4.72E-04
	U(DoE)	2.92E-03	3.09E-03	3.01E-03	3.24E-03	3.42E-03	3.22E-03	2.76E-03	2.80E-03

Table 8. Final results for degree of equivalence (DoE) and its expanded ($k = 2$) uncertainty for SIM.PR-K6.2010 for Filter D

Wavelength (nm)		380	400	500	600	700	800	900	1000
Nominal Transmittance		0.0004	0.0055	0.0089	0.0088	0.028	0.033	0.024	0.017
CENAM	DoE	2.26E-06	1.17E-06	1.97E-06	1.73E-05	2.33E-05	-8.49E-07	-	-
	U(DoE)	1.25E-04	1.31E-04	1.31E-04	1.35E-04	2.14E-04	2.26E-04	-	-
INM	DoE	-	-7.51E-06	-2.66E-06	2.17E-05	-4.52E-05	-1.06E-04	-	-
	U(DoE)	-	3.31E-04	2.84E-04	3.11E-04	3.86E-04	4.56E-04	-	-
INMETRO	DoE	-	2.07E-03	2.34E-04	1.08E-04	1.33E-04	1.54E-04	1.48E-04	2.28E-04
	U(DoE)	-	1.67E-04	4.21E-05	5.34E-05	8.02E-05	4.18E-05	4.27E-05	3.20E-05
CMS/ITRI	DoE	-1.35E-05	-7.18E-05	-1.09E-04	-9.76E-05	-1.79E-04	-2.81E-04	-2.02E-04	-4.54E-05
	U(DoE)	8.28E-05	1.76E-04	1.73E-04	1.77E-04	3.86E-04	3.76E-04	3.78E-04	3.81E-04
NIM	DoE	-9.49E-05	-1.31E-05	-2.00E-05	-2.14E-05	2.90E-06	5.99E-06	1.35E-05	-2.60E-06
	U(DoE)	1.53E-04	1.38E-04	1.12E-04	1.35E-04	3.03E-04	3.23E-04	2.49E-04	1.96E-04
NIMT	DoE	4.03E-05	-3.96E-05	1.75E-04	8.40E-05	4.90E-05	-2.43E-05	-6.85E-04	-4.51E-04
	U(DoE)	2.98E-03	3.60E-03	3.02E-03	3.54E-03	2.99E-03	2.99E-03	2.59E-03	2.57E-03

Table 9. Final results for degree of equivalence (DoE) and its expanded ($k = 2$) uncertainty for SIM.PR-K6.2010 for Filter E

Wavelength (nm)		380	400	500	600	700	800	900	1000
Nominal Transmittance		1.2E-05	0.00033	0.00092	0.0050	0.0050	0.0096	0.0084	0.0071
CENAM	DoE	6.28E-06	7.87E-06	2.30E-06	4.03E-06	6.02E-06	-1.31E-05	-	-
	U(DoE)	9.62E-05	9.71E-05	9.81E-05	9.89E-05	1.16E-04	1.33E-04	-	-
INM	DoE	-	-	-1.34E-05	-1.16E-06	-2.09E-05	-5.64E-05	-	-
	U(DoE)	-	-	4.24E-04	4.60E-04	3.22E-04	3.04E-04	-	-
INMETRO	DoE	-	-	2.01E-04	8.10E-05	4.64E-05	6.40E-05	9.62E-05	2.21E-04
	U(DoE)	-	-	1.37E-05	1.05E-05	2.89E-05	2.30E-05	1.97E-05	2.42E-05
CMS/ITRI	DoE	-7.09E-06	-1.53E-05	-3.58E-05	-3.49E-05	-8.43E-05	-1.60E-04	-1.48E-04	-1.26E-04
	U(DoE)	1.25E-05	2.02E-05	1.80E-05	2.12E-05	1.68E-04	1.75E-04	1.71E-04	1.69E-04
NIM	DoE	-3.07E-06	-5.66E-05	-2.47E-05	-1.86E-05	-1.70E-05	-3.44E-05	-1.10E-05	-1.69E-05
	U(DoE)	1.30E-05	7.29E-05	2.92E-05	2.26E-05	8.07E-05	1.30E-04	1.17E-04	1.11E-04
NIMT	DoE	2.69E-05	3.77E-05	1.51E-04	3.37E-05	-1.24E-05	-4.89E-05	-6.53E-04	-4.44E-04
	U(DoE)	3.20E-03	4.63E-03	2.96E-03	4.40E-03	3.21E-03	2.78E-03	2.61E-03	2.80E-03

Notes:

a) Columns with dashes indicate that transmittance values at these wavelengths were either not measured or not reported.

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Disclaimer

Certain commercial equipment, instruments, or materials are identified in this report and its appendices in order to specify the measurement procedure adequately. Such identification is not intended to imply recommendation or endorsement by NIST, nor is it intended to imply that the materials or equipment identified are necessarily the best available for the purpose.

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