Technical protocol of APMP TCAUV key comparison on ultrasonic power APMP.AUV.U-K3,

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1. Introduction

At the APMP TCAUV meeting in Beijing, China in September 2015, and the CCAUV meeting in Sèvres, France in November 2015, KRISS proposed to prepare and proceed with the APMP RMO key comparison (KC) subsequent to CIPM comparison CCAUV.U-K3.1. During 2016 - 2017, some participating NMIs in the APMP region have had the necessary time to upgrade their measurement systems and procedures. During this period, KRISS conducted an informal comparison to assist in upgrading the systems of those NMIs by using the transducer of KRISS 2 MHz 14 LN, as well as to test whether the ultrasonic transducer manufactured by KRISS has performance to be used for international comparison. At the APMP TCAUV meeting in New Delhi, India in November 2017, two NMIs mentioned the potential for participation, and NPL India and NIM China announced their decision to participate in this comparison in March 2018. Hence, we have created places in the schedule. Now, all potential participants are ready to participate in this regional KC. This comparison was prepared for linking to CCAUV.U-K3. Almost all of the contents are prepared to match the two protocols of CCAUV.U-K3 and CCAUV.U-K3.1 except for actual frequency and schedule. Two newly involved participants showed that their results were consistent in the uncertainty range common in the previous CCAUV.U-K3 and CCAUV.U-K3.1 key comparisons, respectively and they wish to prove their improvements by the aid of this comparison. Expecting to obtain a more reliable linking reference value of this comparison, PTB Germany as a representative of another regional metrology organization was invited.

Participants

The following list contains the participants of this comparison:

· KRISS, Korea as pilot and linking laboratory
· PTB, Germany as invited linking laboratory
· NPLI, India as linking laboratory
· NIM, China as linking laboratory
· NMIJ, Japan
· NIMT, Thailand

2. Device

An ultrasonic standard transducer is circulated. Its identification number is KRISS 2 MHz 7 LN. The circular front face contains the active element which is a gold-plated, air-backed, narrowband, half-wave resonant lithium niobate crystal of coaxial electrode design. The transducer rear is provided with a (female) BNC connector for the excitation voltage. The central lead of the connector is directly connected with the rear, “hot” electrode of the crystal. This means that the transducer does not contain any electronic components and is not matched to 50 Ω. The transducer is of cylindrical shape, 30 mm diameter, about 102 mm in length, and with a mass of about 114 g. The transducer front is covered by a red rubber cap. The transducer is intended for operation at its fundamental resonance, in the third, fifth, and seventh harmonics. The transducer must not be used for any other purpose than the measurements within this key comparison.

3. Time schedule

The timetable is presented in Table 1. Each participating laboratory has been allocated a 6-week period in the schedule. Two weeks (#1 and #2) are provided for transportation, customs and arrival. Three weeks (#3 - #5) are provided for measurements. The remaining one week (#6) is for analysis of the data and potential re-measurements, where it seems necessary and especially for any preparations for dispatching of the transducer to the next participant on schedule. It is mandatory for all participants to meet the respective deadlines in the time table below and to fulfill the following actions:

- Before measurements of the respective NMI, i.e. before “Starting date” (column 3 in Table 1), all participants are recommended to send their preliminary uncertainty budget to the pilot institute including all amendments (see section 8 and Annex A).
- From the “Dispatching date” of the previous participant (column 5), the responsibility for timeliness is with the following participant. This means the participant has to make sure that the previous participant has sent its ‘dispatch note’ (see Annex A) – if not, the participant should insist at the previous participant with a respective “Reminding note” email (see Annex A).
- On arrival of the transducer, the participant must send an “Arrival note” e-mail (see Annex A) to all participants.
- From “Starting date” (column 3 in Table 1), the participant should start the measurements.
- On “Finishing date” (column 4), the participant should have finished measurements.
- On “Dispatching date” (column 5), the transducer has to leave the participants institute and a “Dispatch note” e-mail (see Annex A) must be sent to all participants.

- On "Reporting date" at the latest, all final results (i.e. the basic reporting sheet in a mandatory format as well as the detailed reporting sheet in an optional format) must be sent to the pilot institute (see section 7 and Annexes A, B, C)

It is essential to all participating laboratories to keep the schedule on time.

Table 1. Time schedule of the comparison

No.	Calibration Laboratory	Starting date	Finishing date	Dispatch date	Reporting date
1	KRISS, Korea	16-July-18	6-Aug-18	13-Aug-18	17-Sep-18
2	NMIJ, Japan	27-Aug-18	17-Sep-18	24-Sep-18	29-Oct-18
3	NIMT, Thailand	8-Oct-18	29-Oct-18	5-Nov-18	10-Dec-18
4	KRISS, Korea	19-Nov-18	10-Dec-18	17-Dec-18	21-Jan-19
5	NPLI, India	31-Dec-18	21-Jan-19	28-Jan-19	4-Mar-19
6	NIM, China	11-Feb-19	4-Mar-19	11-Mar-19	15-April-19
7	KRISS, Korea	25-Mar-19	15-April-19	22-April-19	27-May-19
8	PTB, Germany	6-May-19	27-May-19	3-June-19	8-July-19
9	KRISS, Korea	17-June-19	8-July-19	-	19-Aug-19

4. Transportation

Responsibility for "transport" rests with the preceding laboratory. One option is to carry the device by hand, by qualified metrology personnel. In this case and when an aircraft is used, the device must be transported in the passenger cabin, not in the luggage hold. If hand-carrying is not possible because of financial or other restrictions, air freight shipping may be considered, but the participant is responsible for the necessary precautions. It must be ensured that the device is transported in a pressurized and temperature-controlled hold, i.e. under conditions equal to those in the cabin of a passenger-carrying airplane.

The device is accompanied by an ATA carnet. Responsibility for compliance with the customs regulations rests with the participants. The value of the device is 5,000,000 KRW (Approx. 3452 US$).

The device is accommodated in a box. The pilot laboratory constructed a small circular thermo-jug which keeps the transducer away from strong environmental changes. Nevertheless, large temperature changes or sudden shocks should be avoided all time. The pilot laboratory provides a data logger with pressure and temperature sensors which must be put into the box near to the thermos-jug. Brief instructions for handling the thermo-jug will be provided in the box. The data logger should be kept On-state during the comparison period. Don't remove the instructions from the box. The box as such is not a transport container of sufficient stability and it must be protected during transportation. During the carriage by hand, the box is to be placed in a bag (taking, however, the maximum dimensions for hand baggage into account). If shipped, the box must be packed in a stable container, protected by additional shock-damping material, and warning notes must be attached to the package.

Each participating institute is responsible for its own costs for the measurements, transportation and any customs charges as well as any damage that may occur within its country.

5. Conditions of use

The device must be handled with care, i.e., only by qualified metrology personnel. Avoid any mechanical shock. Avoid any pressure (or negative pressure) on the front face of the transducer. “Water” is to be understood as distilled or deionized water throughout this protocol. Of course, the front cap added to the transducer is not intended for use in water. One of the gold electrodes of the lithium niobate crystal forms the front face of the transducer. There are no shielding or matching layers. The front face of the transducer is subject to damage by contact with any material other than water, lens cleaning tissue, or the front cap provided with the transducer. For the measurements of this key comparison, the transducer must be coupled directly to water, to nothing else. The use of a coupling membrane or coupling gel is prohibited. If it appears necessary to clean the front face, soft rinsing with water is the primary option, but organic solvents and lens cleaning tissues may be used as well, though with extreme care. If organic solvents are applied, their use must be restricted to short periods, otherwise the sealing material at the crystal rim might be damaged. Water drops left on the front face should be removed by softly touching the surface with a soft tissue. The transducer face should not be wiped mechanically. Any movement tangential to the transducer surface involves the risk of producing scratches or of removing gold particles (unfortunately, gold is a rather soft material).

No temporal limits to the duration of water contact have so far been found necessary, but unnecessarily long water contact should, however, be avoided, if possible. Lithium niobate is sensitive to temperature gradients. Temperature shocks of any kind should be avoided. The front face and the lateral parts of the transducer housing are waterproof under normal conditions. The electric connector on the rear is not waterproof. It must be kept away from water in any time. If the entire transducer is to be submerged, this connector must be protected by a method which prevents water from reaching the connector. One method that has been found to work well involves the use of surgical rubber tubing, longer than the distance from the transducer to the water line. The use of any sealing device or material inside the cable or transducer connector is strictly prohibited.

The voltage at the transducer input shall not exceed 60 V (RMS, AC or DC) when the transducer is in water. At and below the "medium" power level (see below), no temporal limits to the duration of transducer operation have so far been found necessary, but unnecessary transducer operation at the "high" level (see below) should be avoided. Nevertheless, switch the transducer on only for measurements. Make sure that the transducer is not fed with electrical signals when you do not use it for a measurement. At the "high" level (see below), transducer operation must be intermittent. Power-on intervals must not exceed 25 seconds each, and must be followed by power-off intervals at least five times longer in duration. For example, a 10 second power-on interval must be followed by a 50 second power-off interval.

No voltage should be applied when the transducer is in air. If really necessary, the voltage must not, however, exceed 3 V (RMS).

6. Measurements

The task is to measure the total, time-averaged ultrasonic output power (P_{out}) emitted by the transducer under specified conditions of electrical excitation (see below) into an anechoic (i.e., free-field) water load. The water temperature must be measured and reported. It should be as close as possible to 21.5 °C. The difference should not exceed ± 2.0 °C. The use of degassed water is highly recommended and is mandatory at the "high" level where the oxygen content is to be measured and reported.

The participants are free to apply their own ultrasonic power measurement method as long as it is a primary one, and in most cases this will be the radiation force balance method according to IEC 61161. The output power relates to the transducer surface (zero distance), and if the measurements are carried out at finite distances, the participant must derive the zero-distance result from the measurement redluts. In connection with this derivation or with other corrections, participants may wish to know the structure of the ultrasonic field of the transducer. They are free to perform field scans but these are not necessary. It is sufficient to know that the field is unfocussed and piston-like in sufficient approximation. The nominal beam diameter which is the diameter of the rear, "hot" electrode is 22.0 mm.

A continuous-wave, sinusoidal excitation voltage must be applied to the transducer and measured by the participant. There are four voltage levels, namely "very low", "low", "medium", and "high". The specified RMS voltage values (U_s) and the specified frequency values (f_s) are given in Table 2. The actual frequency (f_a) is to be reported, and it must agree with the specified one to within ± 0.0010 MHz.

The actual, RMS transducer input voltage (U_{in}) must be measured and reported by the participant using his own methods and instruments. It is to agree with the respective specified voltage (U_s) of Table 2 to within ± 5 %.

In each case, at least four independent measurements are to be carried out and taken into account in the final result. "Independent" is intended to mean that measurement vessel and target are disassembled and reassembled and that the water is changed. Measurements using different targets are also independent, of course.

If a participant uses a measurement method where the temporal voltage waveform is not of the continuous-wave and sinusoidal type, the laboratory must transform the results obtained accordingly and report them in a form which makes direct comparison with the continuous-wave results possible.

In each case, the electro-acoustic radiation conductance G must be calculated according to

$$G = P_{out}/(U_{in}^2). \quad (1)$$

It is expressed in siemens or decimal submultiples of this unit, for example in millisiemens (mS). The input voltage U_{in} refers to the transducer input and is to be measured at a point as near as possible to the transducer input connector. If the voltage is measured at a remote point, the participant is responsible for correcting this.

Note 1 - The U_s values of Table 2 do not exactly correspond to nominal ultrasonic power values that may have been mentioned during the preparations for this key comparison.

Table 2. Specified values.

f_s [MHz]	level	U_s [V]
1.8830	Very low	1.25
	Medium	13.5
	High	50.0
6.3218	Very low	1.20
	Low	4.00
10.6118	Very Low	1.25
	Low	4.00
14.8845	Low	3.70

7. Reporting

The results shall be reported to the pilot institute within six weeks at the latest after the measurements of the respective participant were completed. A complete report contains two parts:

A) Basic reporting sheet in mandatory format

It is mandatory to use the reporting sheet given in Annex B to report the final radiation conductance values, their uncertainties and expanded uncertainties. The values in this sheet will be used for the further processing of the data at the pilot institute. It is mandatory to send a signed copy of this sheet to the pilot lab – either as a hardcopy via postal mail or as a scanned document by e-mail or fax. This signed copy serves as a reference and can be used to find and avoid computer errors during data processing. In doubt the paper copy numbers will be used as original values.

B) Detailed report in optional format

The detailed report shall contain a description of the measurement method applied and of the equipment used. The following details, among other things, are important:

- The equipment used for the generation of the excitation voltage;
- The RF voltmeter(s) used for measuring the input voltage, and their calibration;
- Water properties, water volume;
- How the measurements were performed, power-on-power-off intervals etc.
- How the zero-distance results were derived from results obtained at finite distances;
- Formulas used and calculation methods; possibly, considerations relating to non-plane field structure;
- Full uncertainty budgets with an explanation of the details;
- Method applied to measure the ultrasonic power and all relevant practical details.

In the case of a radiation force balance these would be:

- Arrangement of the balance set-up;
- Type of the balance;
- All relevant details of the target(s) used, including the target size.

All observations which might be important for the interpretation of the results should be reported. The values of the following quantities shall be reported (see also Table in Annex C below; the number in square brackets indicates the column in this table):

- Actual frequency, f_a in MHz [4];
- Water temperature, t in °C [5];
- Oxygen content of the water in mg/L [6];

- RMS value of the input voltage to the transducer, U_{in} in V [7];
- Time-averaged ultrasonic power, P_{meas} in mW or W [8], measured at the distance (d);
- Distance, d of the measurement plane from the transducer surface, in mm [9];
- Output power, P_{out} in mW or W [10];
- Electroacoustic radiation conductance, G in mS [11];
- Standard uncertainty u_G in % [12];
- Expanded uncertainty ku_G in % [13].

The results can be reported in the format of the table given in Annex C, but this is optional.

However, any other reporting format should meet the following requirements:

- The individual measurements should be reported.

- All measurements should be numbered consecutively (e.g. column 1 / A: “identification number”), according to the time sequence of the measurements.

- Particular characteristics of any measurement should be indicated, for example the target type if different targets are used. (e. g. Column 3 / C “characterization”).

- All entries must also state the relevant unit.

- The final, average results shall be clearly indicated.

8. Uncertainties

The final measurement result is radiation conductance, *G*. The associated measurement uncertainty shall be stated in the measurement report. Both values, i.e., standard uncertainty and expanded uncertainty (at a level of confidence of 95 %), shall be stated. For the evaluation of the measurement uncertainty, reference should be made to the BIPM/IEC/ISO “Guide to the expression of uncertainty in measurement”.

For preparing the final report it is useful to have a separate document containing the final uncertainty budget for the measurements. Please do not include the budget into a flowing document.

The CIPM rules require uncertainty budgets to be submitted with the final results. A preliminary budget of every participant has to be submitted before the participant starts with the measurements. Any changes will, however, be accepted if the pilot laboratory receives them before sending the transducer to the participant (see section 3 and Annex A).

9. Linking with CCAUV.U-K3

In order to make a direct comparison possible between previous comparisons (CCAUV.U-K3 and CCAUV.U-K3.1) and the present key comparison APMP.AUV.U-K3, the results of APMP.AUV.U-K3 will be linked to those of CCAUV.U-K3. Among the laboratories to participate in the present comparison, the laboratories that have already participated in the previous CIPM Key Comparison (CCAUV.U-K3 and CCAUV.U-K3.1) are PTB, KRISS, NPLI, and NIM. For better comparability between this regional KC and the CIPM KC, our artifact transducer will be also calibrated by PTB, the pilot laboratory of both previous CIPM KCs, during this key comparison and their calibration results will be used for the linking. Therefore, KRISS, NPLI, NIM, and PTB will do roles as the linking laboratories.

With reference to the linking procedure described in [1,2], the linking will be conducted as follows:

In the key comparison CCAUV.U-K3, the reference values to link were given in its final report. From the reported reference values $\bar{G}_{C,p}$ for frequency and power specification (FPS), p, and the associated standard uncertainties $u(\bar{G}_{C,p})$ will be used to drive linking values of the key comparison. In here, the subscript C stands for "CCAUV.U-K3". The weighted mean was used to determine the key comparison reference value (KCRV).

Then, from the measured results of the linking laboratories in the key comparison APMP.AUV.U-K3, the weighted mean $\tilde{G}_{A,p}$ and the standard uncertainty $u(\tilde{G}_{A,p})$ for FPS p will be calculated as

[1] C. Elster, A. Link, and W. Wöger, "Proposal for linking the results of CIPM and RMP key comparisons.", Metrologia, pp. 189-194, 2003.

[2] J. Haller, C. Koch, R. Costa-Felix, P. Dubey, G. Durando, Y. T. Kim, M. Yoshioka, "Final report on key comparison CCAUV.U-K3.1.", pp. 1-47, 2016.

$$\tilde{G}_{A,p} = \frac{\sum_{l=1}^{L}\left\{ G_{A,p,l} / u^2(G_{A,p,l}) \right\}}{\sum_{l=1}^{L}\left\{ 1 / u^2(G_{A,p,l}) \right\}}, \tag{2a}$$

$$u^2(\tilde{G}_{A,p}) = \left\{ \sum_{l=1}^{L} \frac{1}{u^2(G_{A,p,l})} \right\}^{-1}, \tag{2b}$$

where $G_{A,p,l}$ denotes the radiation conductance for FPS p (p = 1, … , 8) reported by the linking laboratory l (l = 1, … , L) and $u(G_{A,p,l})$, the associated standard uncertainty. The subscript A stands for “APMP.AUV.U-K3”. If outlying results exist in the results of linking laboratories, they should be excluded for the calculation of $\tilde{G}_{A,p}$. Note that the symbol $(\widetilde{G})$, which indicates the weighted mean for the linking laboratories only, should be distinguished from $\bar{G}$, which indicates the weighted mean for all participants.

The radiation conductance $G_{A,p,k}$ for FPS p reported by the participant k (k = 1, … , m) in APMP.AUV.U-K3 can now be transformed into the quantity that is directly comparable with the corresponding KCRV in CCAUV.U-K3 by using the following transformation factor,

$$r_p = \frac{\bar{G}_{C,p}}{\tilde{G}_{A,p}}. \tag{3a}$$

The associated relative standard uncertainty $u_{rel}(r_p)$ can be calculated as follows:

$$u_{\mathrm{rel}}^2(r_p) = u_{\mathrm{rel}}^2(\bar{G}_{C,p}) + u_{\mathrm{rel}}^2(\tilde{G}_{A,p}) - 2 \cdot u_{\mathrm{rel}}(\bar{G}_{C,p}) \cdot u_{\mathrm{rel}}(\tilde{G}_{A,p}) \cdot \sum_{l=1}^{L} \frac{\bar{G}_{C,p}}{|G_{C,p,l}|} \cdot \frac{\tilde{G}_{A,p}}{|G_{A,p,l}|} \cdot \frac{u_{\mathrm{rel}}(\bar{G}_{C,p})}{u_{\mathrm{rel}}(G_{C,p,l})} \cdot \frac{u_{\mathrm{rel}}(\tilde{G}_{A,p})}{u_{\mathrm{rel}}(G_{A,p,l})} \cdot \rho_{p,l} \tag{3b}$$

where $\rho_{p,l}$ is a correlation coefficient between the measured results in the two key comparisons by the linking laboratory l for FPS p; ρ = 0 for no correlation while ρ = 1 for perfect correlation (see [1, 2] for more details). The correlation coefficient only gives an influence on the relative uncertainty while does not on the transformation factor (r_p). If the high reproducibility of measurements can be guaranteed by the linking laboratories, the correlation coefficient should be close to 1.

The transformed radiation conductance can be written as

$$\dot{G}_{C,p,k} = r_p G_{A,p,k}, \tag{4a}$$

with the associated relative standard uncertainty,

$$u_{\mathrm{rel}}^2\left(\dot{G}_{C,p,k}\right) = u_{\mathrm{rel}}^2\left(r_p\right) + u_{\mathrm{rel}}^2\left(G_{A,p,k}\right) + 2 \cdot \frac{u\left(r_p, G_{A,p,k}\right)}{r_p \cdot G_{A,p,k}} \tag{4b}$$

where

$$u\left(r_p, G_{A,p,k}\right) = \begin{cases} -\bar{G}_{C,p} \cdot u_{\mathrm{rel}}^2\left(\tilde{G}_{A,p}\right) + r_p \cdot \bar{G}_{C,p} \cdot u_{\mathrm{rel}}^2\left(\bar{G}_{C,p}\right) \cdot \frac{\left|G_{A,p,k}\right|}{\left|G_{C,p,k}\right|} \cdot \frac{u_{\mathrm{rel}}\left(G_{A,p,k}\right)}{u_{\mathrm{rel}}\left(G_{C,p,k}\right)} \cdot \rho_{p,k} \\ \qquad \text{for } k = 1, \dots, L \\ u\left(r_p, G_{A,p,k}\right) = 0, \quad \text{otherwise.} \end{cases} \tag{4c}$$

The relative linking uncertainty $u_{\mathrm{rel}}\left(r_p\right)$ is usually expected to be small compared with the relative uncertainties of $u_{\mathrm{rel}}\left(G_{A,p,k}\right)$. Therefore, the particular choice of the correlation coefficient ρ should not be strongly influence on the uncertainties of the transformed quantities, as reported in [2].

The degrees of equivalence can be evaluated for the transformed radiation conductances compared to the KCRV in CCAUV.U-K3 by the following difference for FPS p:

$$d_{p,k} = \dot{G}_{C,p,k} - \bar{G}_{C,p}. \tag{5a}$$

The associated relative expanded uncertainty is

$$u_{\mathrm{rel}}^2\left(d_{p,k}\right) = \left(\dot{G}_{C,p,k}\right)^2 \cdot u_{\mathrm{rel}}^2\left(\dot{G}_{C,p,k}\right) + \left(\bar{G}_{C,p}\right)^2 \cdot u_{\mathrm{rel}}^2\left(\bar{G}_{C,p}\right) - 2 \cdot u\left(\dot{G}_{C,p,k}, \bar{G}_{C,p}\right) \tag{5b}$$

with

$$u\left(\dot{G}_{C,p,k}, \bar{G}_{C,p}\right) = \frac{G_{A,p,k}}{\tilde{G}_{A,p}} \cdot \left(\bar{G}_{C,p}\right)^2 \cdot u_{\mathrm{rel}}^2\left(\bar{G}_{C,p}\right) + \left(\bar{G}_{C,p}\right)^3 \cdot u_{\mathrm{rel}}^2\left(\bar{G}_{C,p}\right) \tag{5c}$$

$$\cdot \sum_{l=1}^{L} \frac{\left|G_{A,p,l}\right|}{\left|G_{C,p,l}\right|} \cdot \frac{u_{\mathrm{rel}}\left(G_{A,p,l}\right)}{u_{\mathrm{rel}}\left(G_{C,p,l}\right)} \cdot \left[\frac{\delta_{kl}}{\tilde{G}_{A,p}} - \frac{G_{A,p,k} u_{\mathrm{rel}}^2\left(\tilde{G}_{A,p}\right)}{\left(G_{A,p,l}\right)^2 u_{\mathrm{rel}}^2\left(G_{A,p,l}\right)}\right] \cdot \rho_{p,l}$$

where $\delta_{kl} = 1$ for k = l, and 0 otherwise.

10. Addresses of the participants and indication of responsible contact persons

10.1 KRISS – Korea Research Institute of Standards and Science (Pilot)

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10.5 NPLI – National Physical Laboratory India

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Annex A: Mandatory communications

Although the following procedure (especially A.2, A.3 and A.4) admittedly will increase e-mail traffic, it is mandatory to follow this procedure, so that every participant is always aware of the current status of the comparison. It is explicitly intended to avoid any delays by making the comparisons progress transparently to every participant.

A.1 Uncertainty budget

All participants must send their preliminary uncertainty budgets to the pilot institute before their respective “Starting date“ via e-mail. Possible corrections must also be sent to the pilot institute before the respective participants “Starting date” (see Table 1). Final budgets must be sent together with the results reported by the participant.

A.2 Arrival note

After arrival of the device, the participating institute shall inform the pilot institute of this by e-mail with cc to all participants. Immediately after receipt, the participating institute shall check the device for any damage. The crucial part is the radiating crystal of the transducer. The front electrode of the crystal can be seen and inspected after removal of the front cap. Obvious damages must be mentioned in the Arrival note.

A.3 Dispatch note

At the day the device leaves the participant’s institute, the participating institute shall inform the pilot institute of this by e-mail with cc to all participants.

A.4 Reminding note

As the responsibility of timeliness always lies with the next participant, each participant shall send a reminding note to the previous participant with cc to all participants, if the transducer has not been sent one week before his starting date (see Table 1).

A.5 Reporting

Each participant must send his final results to the pilot institute at the latest six weeks after the measurements, i.e. at the participants “Reporting date” (see Table 1). Details of the formatting requirements are given in section 7.

Annex B: Basic reporting sheet (mandatory format)

Participant (short)	
Participant (long)	
Responsible person (name)	
Address 1	
Address 2	
Address 3	
Telephone	
Mail address	
Measuring dates	

f_s [MHz]	level	G [mS]	u_G [%]	$k \cdot u_G$ [%]
1.8830	very low			
	medium			
	high			
6.3218	very low			
	low			
10.6118	very low			
	low			
14.8845	low			

Place, date and signature

Annex C: Detail reporting sheet (optional format)

1	2	3	4	5	6	7	8	9	10	11	12	13
id. No.	meas.date	charact.	f_a	t	ox. cont.	U_{in}	P_{meas}	d	P_{out}	G	u_G	$k\ u_G$
			MHz	°C	mg/L	V	mW or W	mm	mW or W	mS	%	%