Draft protocol for CCEM.RF-K24.F, E-field measurements at frequencies of 1 GHz, 2.45 GHz, 10 GHz and 18 GHz and at indicated field levels of 10 V/m, 30 V/m and 100 V/m.

24 February, 2010, Version 1.7a

1. Travelling standards

The travelling standards will consist of two field probes for each loop, an Amplifier Research FL7018 probe (3 MHz to 18 GHz, laser powered with a diode detector) and an Amplifier Research FP7050 (300 MHz to 50 GHz, battery powered with a thermal detector). The use of two standards allows the comparison to continue should one standard fail. The manufacturer's instructions should be followed for both probes.

The readout unit FM7004 is a 19-inch rack unit and a laser interface FL7000 will also be supplied. Together, these will be 3U high.

1.1. Equipment (European Loop)

Probe and data transmission unit FP7050 S/N 0311660,
Probe FL7018 Star Probe 3 laser powered S/N: 0331688
Readout unit FM7004 S/N: 0331664,
Laser Probe Interface FL7000 S/N: 0331780

1.2. Equipment (Non-European Loop)

Probe and data transmission unit FP7050 S/N 0311662
Probe FL7018 Star Probe 3 laser powered S/N: 0331689
Readout unit FM7004 S/N: 0331665,
Laser Probe Interface FL7000 S/N: 0331781

The devices have a head diameter of 65 mm. The FL7018 is specified as approx. 278 x 65 x 65 mm and weighs 150 g approx. The FP7050 is specified as approx. 420 x 85 x 65 mm including base, and the probe and weighs 350 g approx. An inventory list will be supplied with the travelling standards to enable participants to check that the package is complete both on receipt and dispatch.

The comparison devices will be adequately package by NPL and it is important that this packaging is used when forwarding to the next participant. Within laboratories no packaging is required and normal careful handling by qualified personnel will suffice.

2. Measurements to be made

The correction factor of each probe is to be determined at frequencies of 1 GHz, 2.45 GHz, 10 GHz and 18 GHz and at **Indicated** field levels of 10 V/m, 30 V/m and 100 V/m. The measurements should be carried out with the indicated field strength (resultant of the 3 probe axes) as close as possible to the required values. If the indicated field strength is significantly different to the required value then a contribution should be added to the uncertainty to allow for probe non-linearity.

Appropriate laboratory environmental conditions such as ambient temperature and any other relevant measurements should be recorded. In some cases a participant may not be able to achieve all frequencies or all the field strengths required. In that case the participant should perform as many measurements as possible and report those, together with a reason for omitting the remainder.

If the required field strength value of 100 V/m cannot be achieved, the maximum available field strength shall be applied and reported. Only values measured at 100 V/m will be used to compute the KCRV.

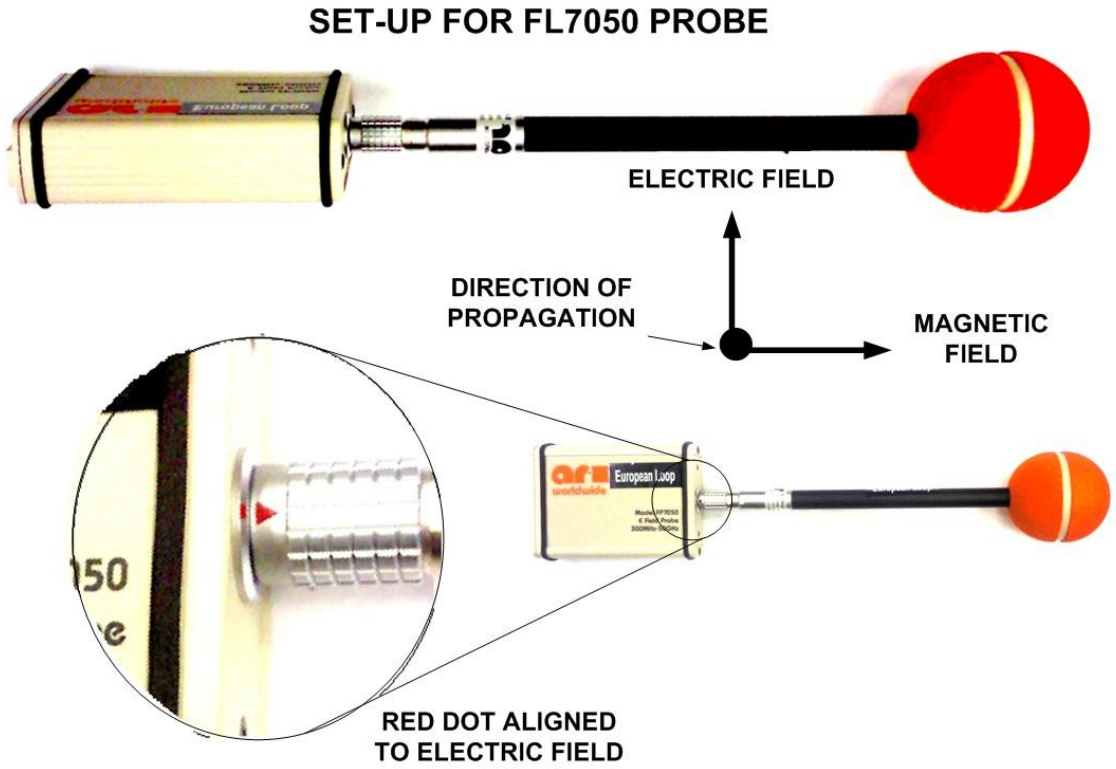
19 February, 2010, Version 1.7

The measurement technique is of course left to the discretion of each participant but it is important that the normal calibration service method employed by each of the participants is used. If a participant can offer a "special" measurement to lower uncertainty then this may be included but should be identified as a separate measurement and must not replace the normal accuracy measurement.

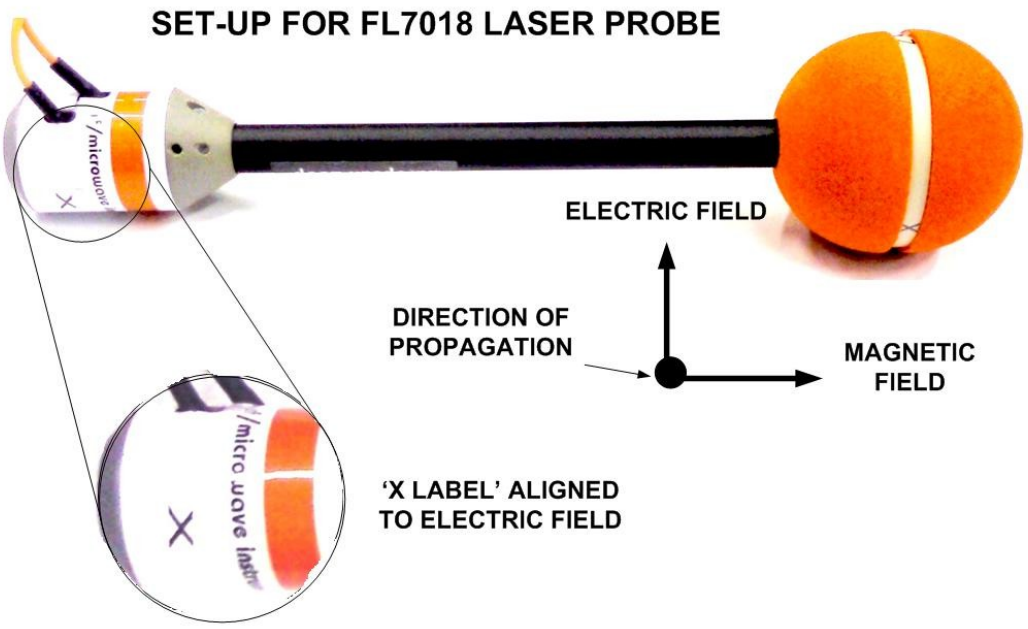
2.1. Probe orientations

The measurements should be made at one orientation only with the probe axis perpendicular to both the E-field and the direction of propagation. The features on the probes shown below indicate the correct rotational position with respect to the E-field direction.

2.1.1. FP7050



2.1.2. FP7018



2.2. Special points - FL7018

- Connect the **laser interface FL7000** via short optical fibre cable to **Channel 2** on the readout unit.
- It is important that the FL7018 probe should be powered for at least one hour before measurements are made. It has been observed that drift occurs in less than this timescale.
- Connect the readout unit via serial link cable to the computer and start the program "hi_ar.exe".

Here is an excerpt from the manual for the FL7018:

LASER RADIATION

This Class l laser product contains an embedded Class 4 laser. Under normal use, the laser radiation is completely contained within the fibre optic cables and poses no threat of exposure. Safety interlocks ensure that the laser is not activated unless the cables are properly connected.

The product is listed as a class l. Following the safety instructions the user will never be exposed to the class 4 laser.

- Safety keyed switch to activate, laser will not activate without this manual intervention.
- Low level laser loopback is monitored continually. If broken the high power laser is tumed off.
- Probe is pinged for a response every few ms, if it stops responding the high power laser is turned off.
- Safety shutter connectors. Shutters on fiber cable's connectors close instantly.

2.3. Special points - FP7050

The FP7050 probe is close to its noise floor at a field strength of **10 V/m**. Measurements at NPL and PTB have shown very poor stability at this level. **Measurements should not be made at this field strength level**, but at 30 V/m and 100 V/m only (if possible).

- Remove safety screws on transmission unit before connecting fibre optical cable.

- Connect the probe via fibre optical cable to **Channel 1** on the readout unit FM7004.
- Allow a warm up time of 10 min. before starting the measurements.
- Connect the readout unit via serial link cable to the computer and start the program 'hi_ar.exe'.
- Ensure that enough time is given (about one/two minutes) for the probe to become stabilised after the RF power is applied.

If it is not possible to use the 'hi_ar.exe' with the serial port, participants may use the 'RM Meter Reader v2' software instead to smooth and record the readings. This software connects to the laser interface using the GPIB.

If using 'RM Meter Reader v2', the following software settings should be used:

- Read from meter 0.025 s
- Average over a period 5 s
- Sample rate of meter 10 samples/second

3. Uncertainty

The principle components of the uncertainty are summarised below:

Source of uncertainty	**Type of uncertainty**
Applied power	B
Non-uniformity of the E-field, however caused	B
Impedance of any TEM cell used	B
Gain of any standard antenna used	B
Any contribution arising through non-linearity of the probe under test (see Section 2)	B
Experimental standard uncertainty of the mean of n independent measurements	A

Other uncertainties may apply to particular measurement techniques.

Information regarding the components of the uncertainty and the effective degrees of freedom of each component should be supplied. Uncertainty estimates should be carried out in accordance with the recommendations of the ISO publication "Guide to the Expression of Uncertainty in Measurement" ISBN 92-67-10188-9. Uncertainties should be evaluated for a coverage factor k = 1.

4. Reporting of results

Results should be sent to the pilot laboratory within 6 weeks of the completion of the measurements. The report should include:

- The device model and serial number
- Date of receipt of the probes
- Date of the measurements
- Date of despatch of the probes
- Frequency of measurement
- Indicated Field Strength (resultant of the 3 probe axes)
- Actual Field Strength applied
- Calculated correction factor (defined as $\frac{Actual\_field}{Indicated\_field}$)
- Uncertainty of each measurement
- A description of the measurement technique used and any theoretical corrections made
- Note giving reasons for omitting any measurements
- Laboratory temperature
- Any supplementary measurements

To aid uniformity of reporting, use the EXCEL spreadsheets "ResultsFP7050.xls" and "ResultsFP7018.xls".

5. Key Comparison Reference Value

It is proposed that the Key Comparison Reference Value will be the unweighted mean of correction factor excluding any obvious outliers. The procedure suggested in reference 1 will be used for this purpose. The two measurement loops will be linked by comparison of the KCRV for each loop and the procedure described in reference 2 will be used to link the loops.

6. Timescale

It is assumed that the intercomparison will start at the beginning of 2010. Each laboratory should ensure that the time required for their measurements and for transportation to the next laboratory should adhere to the timetable. If any laboratory foresees an extended period during which they would not be able to undertake the measurements then the pilot laboratory should be contacted to attempt to re-schedule the measurements. Once measurements are completed, an initial report containing a compilation of the results and a first attempt of interpretation will be sent to the participating laboratories for review and discussion. The draft version of the final report will be issued within three months after completion of the comparison. The final report will be issued within two months following the acceptance and/or corrections to the draft report subject to any delays in obtaining responses from participants. In the event a participant fails to respond to requests for information or clarification of any issues in a timely manner the advice of the chair of the GT-RF committee will be sought in order to avoid undue delay in completing the comparison.

7. Intercomparison pattern

With 14 participants, it is proposed to split the comparison into a European loop and a non-European loop with two standards for each loop. Both NPL and PTB will measure all four devices at the beginning and at the end of each loop. The re-measured results will be included in the overall results but the contribution to the overall results of NPL and PTB will not be weighted on account of the extra measurement set. Within each loop, both devices will travel together. Each participant will measure both devices and send them on to the next participant.

In the event of failure of a standard the pilot laboratory should be informed who will consider whether to continue the comparison with just one standard, to substitute an alternative standard or to abandon the intercomparison.

An ATA Carnet will be used for the majority of the non-European loop for customs documentation.

Each participant is responsible for insurance of the devices from arrival in their laboratory until arrival in the subsequent laboratory. The value for insurance purposes should be the current replacement value, which will be provided once known.

8. Actions and tests on receipt

Participants should advise both the Pilot laboratory and previous participant on receipt of the travelling standards. No special actions or tests are required upon receipt but the laser safety information given earlier in this document and the safety procedures given in the operator's manual must be followed. The FP7050 uses rechargeable batteries, which should be fully charged and then allowed to come to the laboratory ambient temperature before any measurements of any sort are made. Normal operational procedures for competent metrologists should be followed. The device should be switched on 30 minutes before any measurements are made.

9. Financial aspects

The travelling standards are generously provided on loan from their manufacturer, Amplifier Research and they will remain the property of Amplifier Research. Each laboratory will be responsible for the cost of their own measurements and any administrative costs they might incur, including shipping to the next facility upon completion of their measurement testing. NPL will also bear the administrative costs associated with piloting the comparison, including preparing and submitting for publication a report on the comparison. PTB have generously agreed to bear the additional costs of a second measurement of all four standards and NPL will also bear the costs of two sets of measurements of four devices.

10. Schedule

The following schedule is proposed. It allows 3 weeks for every lab to perform the measurements and either one or two weeks between labs for shipment. In general, one week is allowed for shipment, the exceptions being shipments to NIM and VNIIFTRI. It is assumed that there may be delays due to customs on those three legs of the intercomparison.

In practice, PTB and NPL may choose to perform the end-of-loop measurements of the European loop at the same time as the end-of-loop measurements of the non-European loop. Any such decision will not impact the overall schedule of the measurements for the intercomparison, which will not be finished until both loops are complete.

10.1. Loop 1 (European)

Lab	**Contact**	**Probes arrive**	**Probes depart**
NPL	David Gentle		22 January 2010
PTB	Thomas Kleine-Ostmann	1 February 2010	5 March 2010
LNE	Yannick Le Sage	15 March 2010	2 April 2010
INRIM	Michele Borsero	12 April 2010	30 April 2010
SP Technical Research Institute of Sweden	Lars Fast	10 May 2010	28 May 2010
NPL	David Gentle	7 June 2010	11 June 2010
METAS	Frédéric Pythoud	21 June 2010	9 July 2010
Czech Metrology Institute	Karel Dražil	19 July 2010	6 August 2010
VSL	Dongsheng Zhao	16 August 2010	3 September 2010
PTB	Thomas Kleine-Ostmann	13 September 2010	1 October 2010
NPL	David Gentle	11 October 2010	29 October 2010

10.2. Loop 2 (non-European)

Customs requirements have meant that it will be necessary to return the probes briefly to NPL prior to shipping to China and to Russia. An ATA carnet will be used initially for NIST, NMIA, NMIJ and KRISS.

Lab	**Contact**	**Probes arrive**	**Probes depart**
NPL	David Gentle		22 January 2010
PTB	Thomas Kleine-Ostmann	1 February 2010	5 March 2010
NIST	Dennis Camell	15 March 2010	2 April 2010
NMIA	Yu Ji	12 April 2010	30 April 2010
KRISS	No-Weon Kang	10 May 2010	28 May 2010
NMIJ	Masanobu Hirose	7 June 2010	25 June 2010
NPL	David Gentle	5 July 2010	9 July 2010
NIM	Li Dabo	26 July 2010	13 August 2010
NPL	David Gentle	23 August 2010	27 August 2010
VNIIFTRI	Kolotygin Sergey, Neustroev Sergey	13 September 2010	1 October 2010
NPL	David Adamson	11 October 2010	15 October 2010
TUBITAK-UME	Mustafa Cetintas	25 October 2010	12 November 2010
PTB	Thomas Kleine-Ostmann	22 November 2010	10 December 2010
NPL	David Gentle	20 December 2010	21 January 2011

11. Reporting

As stated in Section 4, results should be sent to the pilot laboratory within 6 weeks of the completion of the measurements. A Draft A report will be completed and circulated no later than 8 weeks after the completion of the measurements and receipt of the last set of results. A period of one month will be allowed for participant comments after which a Draft B report will be prepared and circulated. This will be done no later than 8 weeks after the circulation of the Draft A report. The final report will be completed and submitted no later than 12 weeks after the circulation of the Draft A report.

Participants will also need to provide a declaration for the Executive Report stating that they have checked their results against their CMC claims and whether these claims are supported by the results of the comparison.

12. References

1 Proposal for KCRV and degree of equivalence for GTRF key comparisons, J Randa (NIST), GT-RF/2000-12

2 http://www.bipm.org/utils/common/pdf/final_reports/EM/K8/Linking_EUROMET.EM-K8_to_CCEM-K8.pdf