Meeting of the CCEM Working Group on Radio Frequency Quantities - GT-RF, BIPM, Sèvres, 12 and 13 March, 2007.

News from the RF and Microwave Laboratories at the National Physical Laboratory, UK, 14 February 2007.

1. Measurement Services, CMCs and NPL Measurement Clubs

In the RF and Microwave areas, NPL is continuing to support all of its established capabilities. Improved measurement capability in a number of areas is reflected in updated CMCs that have recently been submitted to Euromet:

- Improved uncertainties for some Power Flux Density Measurements
- Improved uncertainties and measurement frequency ranges for RF & Microwave power in waveguide
- An S-parameter measurement capability at frequencies up to 7.5 GHz for components fitted with 7-16 connectors
- An S-parameter measurement capability at frequencies up to 65 GHz for components fitted with 1.85 mm connectors.

In addition to these, enhanced measurement services are being offered on the iPIMMS internet-based network analyser calibration service and for dielectric measurements on thin-film materials. There is now a capability for measuring pulsed power-density in free-space and measurement services are being offered for the first time at THz frequencies, using the NPL Terahertz pulse imaging system.

NPL has traditionally run a range of metrology clubs covering RF and Microwave interests, including *ANAMET* (for ANAs), *EMMA-Club* (electromagnetic materials) and *Freemet* (free-field measurements), some of which have members from other NMIs. As from October 2006 these clubs have been amalgamated into one umbrella *"Electromagnetics Club",* as this will facilitate participation for members with interests in a number of different metrological fields. *ANAMET* will continue as a special interest group under this umbrella.

2. Research and Development

The UK government's R & D activities at NPL have traditionally been funded in three-year programmes. The new Electromagnetics Programme (which also covers DC and Low Frequency (LF) measurements) has recently started - it runs from October 2006 until September 2009. A significant change from the previous programmes is that *all* of the R & D projects in the New Programme are collaborative: NPL will be working closely with industry, academic laboratories and other NMIs. Major development projects approved for this Programme fall into five Themes: '*Wireless Communications'*, '*Health and Exposure'*, '*Instrumentation, Control and Innovative Sensor Technologies'* and '*Electromagnetic Interactions with Materials',* and *'Traceability to SI'*. There are major RF and Microwave projects in the the first four of these Theme areas. They are described in Sections 2.1 – 2.4, below while Section 2.5 summarises smaller extension and development projects.

2.1 Wireless Communication Theme

There are three RF and Microwave projects under this Theme:

Traceable Waveform Metrology for Wireless Communications. To enable engineers to gain a better understanding of issues associated with complex modulation schemes in a crowded spectrum, measurement approaches that can be relied upon to give quantified information are being developed in this project. Methods of signal capture and processing will be studied to establish their traceability to international standards and to evaluate associated uncertainties and error mechanisms.

This project aims to deliver:

- Traceable waveform capture, demodulation and data retrieval for current spectrum usage and modulation.
- Traceability and uncertainty analysis for instruments including parameters such as pulsed power, error vector magnitude, adjacent channel suppression/leakage, bit error rate.
- Techniques to measure beyond the capability of current instruments. These measurements will include: higher frequency and lower power coverage, and higher bandwidth transmission than are currently available, thereby supporting instrument development as well as spectrum governance. Schemes under consideration include wide multi-band orthogonal frequency-division multiplexing (MOFDM) and direct sequence and pulsed Ultra Wide Band (UWB).

Metrology for Small Antennas and Smart Antennas Available spectrum limitations and limited power available for handheld mobile devices are driving the development of novel antennae designs. Existing NPL antenna ranges are not ideally suited for characterising such antennas.

The aims of this project are to:

- Investigate the measurement challenges presented by small, smart, semi-smart and UWB antennas. These are likely to include antennas for Body Area Networks and antennas with passive or active metamaterials and high-impedance surfaces.
- Define, develop and validate the new measurement techniques and standards required to meet and overcome the challenges identified above. In particular the following are to be developed:
  - A capability for measuring small antennas non-invasively in the range 400 MHz to 6 GHz. The facility will be used to assess performance of body-mounted antennas.
  - A capability for assessing the performance of smart antennas, including antennas operating in the 60 GHz band.
  - A capability to measure the performance of UWB antennas and the design of a UWB standard antenna for metrological use.

Signal Propagation and Data Transfer in Wireless Networks The use of wireless sensor networks (WSN's) is rapidly growing. The ability to understand the reliability of these networks and the data that propagates through them needs to be developed.

The aims of this project are to:

- Assess multi-path transmission channels and quantify fading, selectivity and inter-system interference.

- Determine the effect of data rates and signal protocol on emission and immunity limits and recommend improvements to EMC measurement methods, the quantification of uncertainties, and EMC standards themselves.
- Develop and apply models to quantify levels of confidence and criticality of signal transmission in the presence of interference and dynamic environments.

2.2 Health and Exposure Theme

With increasing use of technologies based on broadcast signals, RF exposure of the public and employees is a continuing concern. In Europe exposure levels for the latter will be limited by the European Union's *Physical Agents (EMF) Directive* from 2008 onwards. This project aims to ensure that traceable standards will be available to ensure that such safety requirements can be met. There is one RF & Microwave project in this theme:

Free-field Exposure and Dosimetry for Communications, Medical and RF Processing Applications. This project aims to address Health and Exposure requirements in the fields of communications (e.g. assessment of fields near antennas), MRI, RFID, medical research and treatment (e.g. hyperthermia) and RF processing (e.g. polymer processing and welding).

The aims of this project are to:

- Establish comprehensive coverage for field strength (free space) measurements from 10 Hz to 100 GHz, and for SAR (Specific Absorption Rate) measurements at all ISM (Industrial Scientific and Medical) frequencies and communications frequencies in the range 10 MHz to 6 GHz.
- To provide facilities for assessing probe response to multi-frequency and broadband signals for ISM and communications applications.

2.3 Instrumentation, Control and Innovative Sensor Technologies

The RF and Microwave Project that lies in this field relates to Terahertz metrology:

Terahertz Validation and Sensing at the Micro and Nanoscale:

The three measured parameters addressed in this project are:

- *Penetration:* Capabilities will be developed to measure penetration depth into materials – this also entails measurement of refractive index, and reflection and absorption in bulk and multi-layered structures.
- *Emissivity:* THz radiation is emitted naturally by objects depending on their temperature and emissivity at the relevant frequencies. Capability will be developed to quantify the emissivity by measuring the emitted power in the first instance at selected wavelengths.
- *Scattering:* In addition to reflection and absorption, some of the power incident on a sample is scattered. Capability will be developed to measure the scattered radiation from materials at different angles and with different time delays.

2.4 Electromagnetic Interactions with Materials

All modern RF & Microwave technologies bring electromagnetic fields into contact with dielectrics and active materials. EM materials metrology is therefore central to practical RF and Microwave applications. There are growing requirements for materials to be better characterised in order to provide reliable data as an input for electromagnetic modelling and design. There is one RF and Microwave project in this theme:

Probing of the Electromagnetic Properties of Materials at the Small Scale There are growing applications for dielectric measurement at resolution scales of ~10μm in a number of technical areas including: electronics, multifunctional material devlopment, microwave processing and microdosimetry.

The aims of this project are to:

- Gain experience of this field by using an existing dielectric probe system. Experience gained will allow assessments to be made of the measurement performance, faults and modelling accuracy of current designs of near-field scanning dielectric probing systems.
- New probe designs will be created and measurements will be performed for our collaborators in this project.

2.5 Smaller Development Projects

These projects have been set up mainly to extend existing capabilities. They are also classified under the Theme headings described above.

Wireless Communications:

- Support for the GTEM users group

Health & Exposure Theme:

- Development of rotating mounts for power density and field probe characterisation
- Capabilities for 5.2 and 5.8 GHz SAR probe characterisation, hemispherical isotropy of SAR probes and dipole validation for SAR.

Electromagnetic Interactions with Materials

- Electromagnetic Properties of Materials for Microwave Processing Applications.
- Updating the existing NPL publication on the properties of dielectric reference liquids: improved uncertainties.

Traceability to SI:

- Measurements to support fast electronics on printed circuit boards.
- Measurement services for STP and UTP data cabling
- Dielectric waveguide measurement system to 300 GHz.
- Cryogenic Millimetric Noise Standards
- Improvement of RF Power coaxial uncertainties up to 50 MHz.

RNC