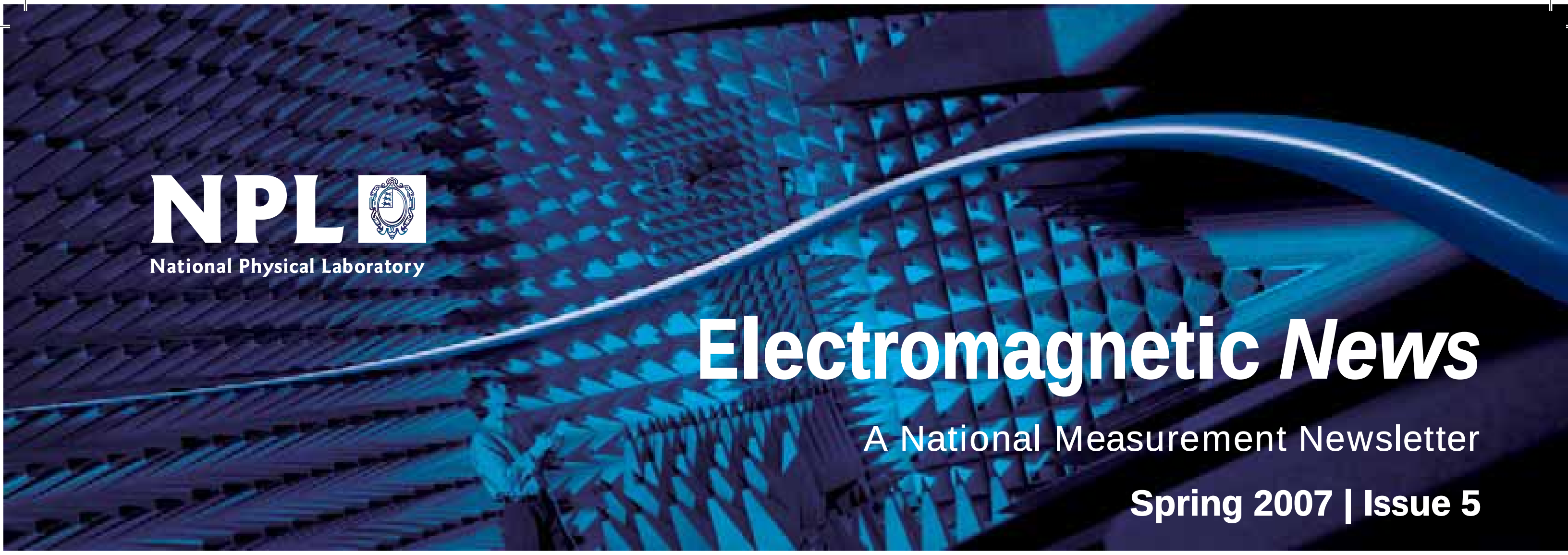

NPL National Physical Laboratory

Electromagnetic *News*

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Innovation in the new Electromagnetic Programme

Improving capability in modelling and simulation, together with the ability to design novel materials, drives a hunger for accurate and reliable data on the electromagnetic properties of materials. In addition, the context of a real world (as opposed to ideal world) environment, the requirement for measurements at a range of length scales, starting at the micro/nano scale, and the potential of higher frequencies, including those in the THz region, need to be factored into the equation.

This newsletter discusses the following:

- Wireless Communication
- Health and Exposure
- Instrumentation, Control and Innovative Sensor Technologies
- Electromagnetic Interactions with Materials
- Traceability to SI

Health and Exposure

Much has been said in the press about the effects of electromagnetic radiation on people, in particular about the use of mobile phones and the placement of masts. However, the arguments also extend to medical tools such as MRI, to RF and Microwave industrial processing, and the ever-increasing number of sources that are present in our environment such as Radio Frequency Identification (RFID).

1. Free-field Exposure and Dosimetry for Communications, Medical and RF Processing Applications

This project will allow compliance with exposure limits and relevant legislation to be demonstrated, in particular the EU Physical Agents (EMF) Directive, which comes into effect in 2008. In addition, it aims to address Health and Exposure requirements in the fields of communications (e.g. assessment of fields near antennae), MRI, RFID, medical research and treatment (e.g. hyperthermia), RF processing (e.g. polymer processing and welding).

The aims of this project are to:

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

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Wireless Communication

As our society moves further into the age of information and control unimpeded by wires, there is increasing demand for useable spectrum, including better, reliable, utilisation of the existing spectrum. There are three projects that address some of these issues:

1. Traceable Waveform Metrology for Wireless Communications

For engineers to have a better understanding of issues relating to complex modulation schemes and a crowded spectrum, measurements that can be relied upon to give quantified information need to be made. To enable this, methods of signal capture and processing need to be understood to appreciate their traceability to national (and thereby international) standards and the 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, vector error, adjacent channel suppression/leakage, bit error rate.
- Techniques to measure beyond the capability of current instruments. These measurements will include: higher frequencies, lower power, and higher bandwidth transmission than are currently possible, 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).

2. Metrology for Small Antennae and Smart Antennae

Limitations of the available spectrum as well as the transmission power available (especially for handheld mobile devices where battery life is a key driver) necessitate the use of novel antenna designs. Characterisation of these devices leads to better models and therefore improved designs in the future.

The aims of this project are to:

- Investigate the measurement challenges imposed by the new emerging technologies of small, smart, semi-smart and UWB antennae. These are likely to include Body Area Networks and antennae 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 facility for measuring small antennae non-invasively in the range 400 MHz to 6 GHz (possibly up to 10 GHz). The facility will be used to assess performance of body-mounted antennae.
- A capability for assessing the performance of smart antennae, including antennae operating in the 60 GHz band.
- A capability to measure the performance of UWB antennae and the design of a UWB standard antenna.

3. Signal Propagation and Data Transfer in Wireless Networks

The use of wireless sensor networks (WSNs) is rapidly growing due to their relative low cost and the ability to develop or shrink on an ad-hoc basis. The ability to understand the reliability of these networks and the data that propagates through them needs to be developed. One key error mechanism is the electromagnetic environment in which they operate.

The aims of this project are to:

- Assess multi-path in 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, quantification of uncertainties, EMC standards.
- Develop models to quantify levels of confidence and criticality of signal transmission in the presence of interference and dynamic environments and apply these to at least two practical examples.

Instrumentation, Control and Innovative Sensor Technologies

Any measurement requires a sensor to detect what is being measured, instrumentation to process the sensor data and a feedback loop to respond to the measurement. The majority of measurement and control systems rely on good electrical measurement and signal processing in real time on an uncontrollable input: the real world.

1. High-precision Traceable Sampling and Waveform Analysis of Non-sinusoidal, Dynamic and Non-stationary Signals for Real-time Applications

To capture complex signals that are truly representative of real, rather than ideal or average, conditions and then process the data into meaningful information whilst understanding the uncertainty contributions to the measurement is a non-trivial task.

The aims of this project are to:

- Develop an asynchronous system suitable for the isolated digitisation of noisy, non stationary signals in the real world environment. Key to the system will be the development of asynchronous techniques and the associated propagation uncertainty through the DSP algorithms that are required for non-stationary signal analysis. The designs and techniques developed in this project will be relevant to a wide range of applications that require waveform metrology with an uncertainty basis. It is intended to apply the techniques using a case study (currently the monitoring of renewable energy sources) followed by further studies in the future.

2. Terahertz Validation and Sensing at the Micro and Nanoscale

The UK has developed a unique Terahertz (THz) industry, addressing issues raised by the security, pharmaceuticals and health diagnosis markets. The success or failure of current THz trials at 'customer' sites will directly affect the size of the future UK THz business, and measurement confidence has been identified as a key parameter. To address this, standards and traceability are required.
The three aspects of this project are:

• Penetration:

This addresses the most fundamental new capability requirements and therefore is scheduled to be delivered in the early parts of the project. Capabilities that will be developed in the determination of penetration depth include measurement of refractive index, 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 and therefore distributed over a range of directions from many scattering surfaces in the sample under test. This objective develops capability to measure the scattered radiation at different angles and time delay by rotating either the sample or the detector and understanding how to reconstruct the complex patterns to provide reference materials for future calibration.

Electromagnetic Interactions with Materials

Developments in materials science, coupled with ever increasing computing power, enable us to model the behaviour of materials in real world environments. To enable this, these materials need to be better characterised in order to provide reliable data as an input to the models. This, in turn, requires new measurement tools and techniques

1. Magnetic Properties of Bulk Materials for Applications in Operational Environments

The use of magnetic materials in harsh environments is nothing new. However the drive for increased energy efficiency, amongst other factors, is leading the requirement for a better understanding of their behaviour under operational conditions, so that more efficient designs can be realised.

The aims of this project are to:

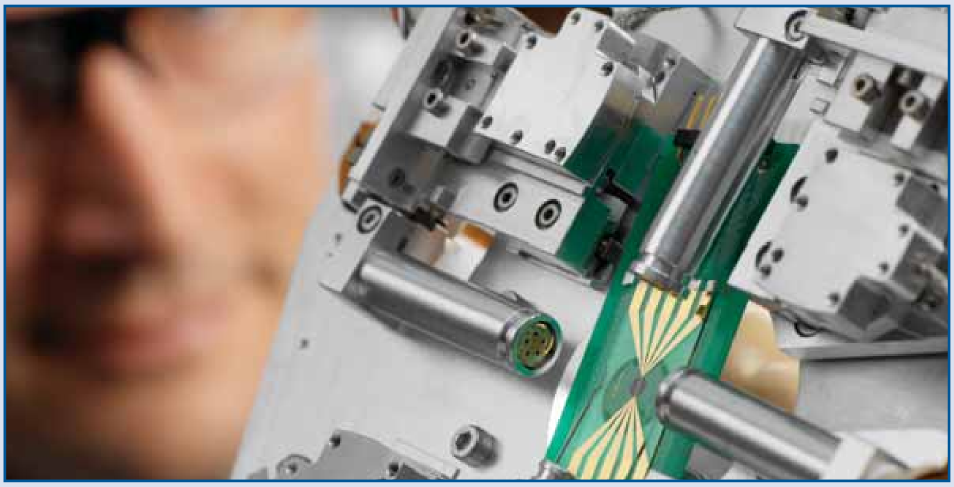
- Develop a set of AC measurement techniques using an open circuit approach that can be applied at room temperature.
- Extend to 200 °C with zero applied stress.
- Combine elevated temperatures and stresses at 200 °C and ± 250 MPa applied stress. Measurements for these conditions are expected to meet the requirements of automotive users of magnetic materials.
- Aspire to extend the target to 450 °C and ± 450 MPa applied stress. These measurements are of interest to the Aerospace industry.

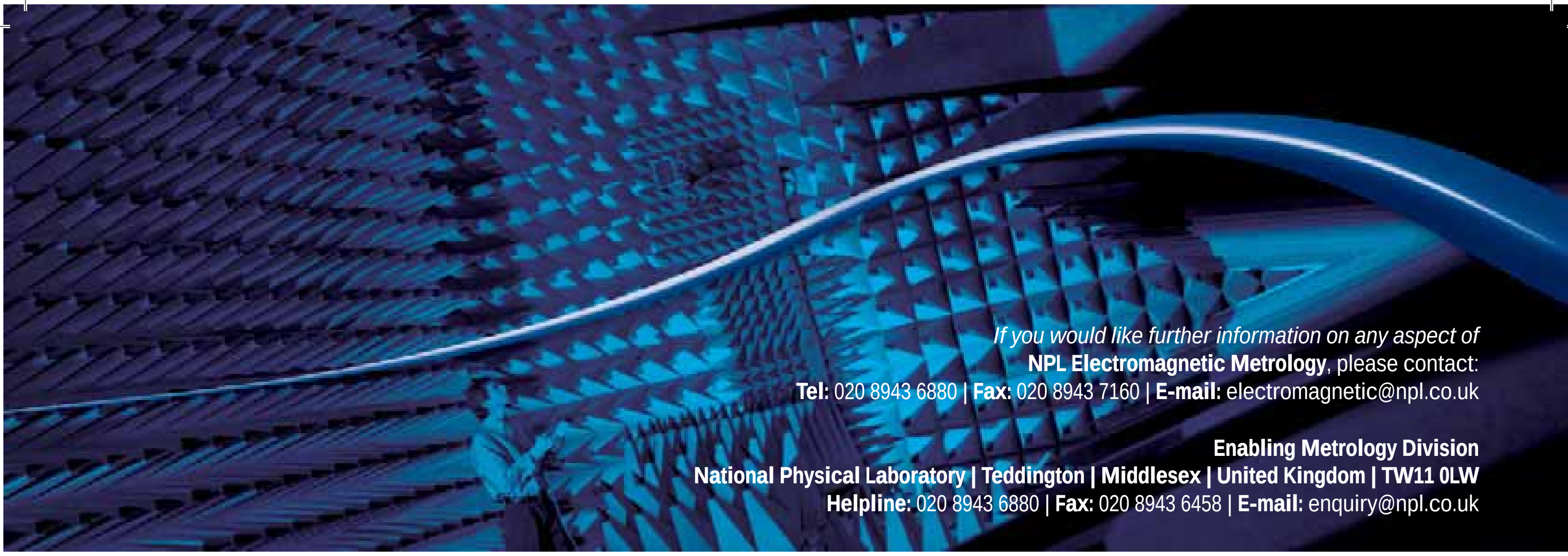
2. Probing of the Electromagnetic Properties of Materials at the Small Scale

There are severe metrological problems presented by (currently untraceable) surface scanning microwave dielectric probes at resolution scales of ~10 µm. The results of these types of measurement will support the Small and Smart Antenna Project, and projects in the Materials Programme, such as measurements on functional materials.

The aims of this project are to:

- Gain experience of using an existing dielectric microscopy system to allow assessments to be made of the measurement performance, faults and modelling accuracy of current designs of near-field scanning dielectric microscope systems.
- Create new probe designs, in the first instance to optimise their potential for NMS projects in the Electrical and Materials programmes and for our collaborators.
- Contribute to the cross-NMS programme of metrological research to establish electromagnetic properties of materials across the spectrum.





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Traceability to SI

Supporting the SI, and providing traceability to the SI, are cornerstones of NPL's existence. The SI unit for Electrical Measurement is the Ampere and currently this is maintained at d.c. for everyday use from the Volt and the Ohm. Each of these is determined against quantum reference standards; a Josephson reference for the Volt and the Quantum Hall Resistance (QHR) for the Ohm.

1. Single Electron Transport in Electrical Metrology

Josephson and QHR effects occur at cryogenic temperatures, thus restricting their use to a limited number of laboratories around the world that have both the skill to operate them and the resources to own such systems. However, in theory, it should be possible to create a quantum current device, based on the transport of single electrons that operates at room temperature thus making it suitable for inclusion into everyday instrumentation ultimately leading to the handheld quantum-based multimeter.

The aim of this project is to fabricate Single Electron Transport (SET) devices using silicon and develop practical quantum current standards. In particular, emphasis will be put on increasing the operating temperature of the devices, and increasing the current output. From a successful realisation of the standard, a consistency check, known as the 'metrological triangle' will be performed which will verify the correct operation of the established quantum standards of voltage and resistance, and provide input to the planned re-definition of SI units in 2011. The metrological triangle has been a goal of NMIs since the adoption of the quantum standards in 1990.
The aim of this project is to:

- Pursue an innovative approach to metrological SET based on silicon technology, with the aim of developing SET pumps with a current output of 1 nA or higher. Silicon fabrication technology is now available with the required small size resolution (5 10 nm), and silicon SET devices do not suffer from random charge effects as do metal-oxide devices.

2. SI Traceability for Low Frequency Voltages

At present only voltage standards with a steady, or d.c., output are measured directly in terms of the Josephson effect. Transfer of these standards to alternating voltages and currents is achieved through heating an element, known as a thermal converter, with both d.c. and a.c. and relating the two by maintaining an equal power dissipation in the element. This project aims to create an a.c. standard of voltage that is directly traceable to the Josephson effect, thereby creating an a.c. quantum reference for voltage.

The aims of this project are to:

- Develop a reference system based on quantum standards to underpin electrical metrology in the 10 mHz to 100 Hz band.
- Shorten or eliminate traceability chains back to conventional basic standards.
- Provide reference systems and intellectual property that can be used by developers of precision measurement systems, where high performance electrical measurement is an integral part.