NPL National Physical Laboratory

Electromagnetic *News*

A National Measurement Newsletter

Winter 2004/2005 | Issue 2

ANAMET power splitter travels 39,000 miles - see page 4

Contents:

Welcome to the second issue of Electromagnetic News. In our first issue we asked you to provide us with feedback to let us know what you would like to see in future issues. As a result we have included articles about other National Measurement System programmes that may be of interest, upcoming events and ways to access the knowledge that is produced by the scientists working at NPL.

We placed all returned questionnaires in a prize draw and are happy to announce that the winner of this was Mr Anthony Johnson in Cumbria, who receives an NPL electron tree. Many thanks to everyone who gave us their input, please continue to do this either through our website or by coming along to our meetings so that we can make sure you are getting the information that helps your business.

If you would like to submit articles to future issues of this newsletter, please let us know by contacting us at *electromagnetic@npl.co.uk*

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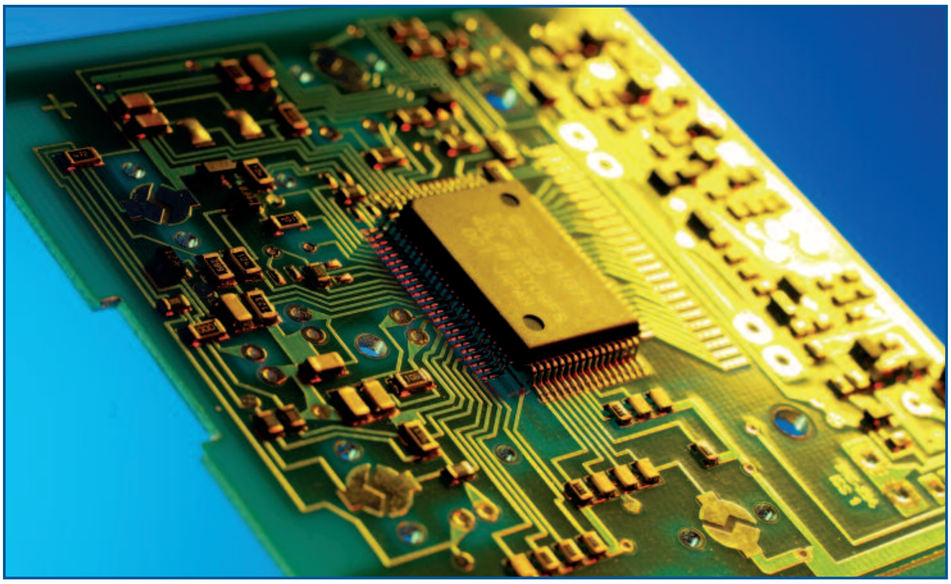
www.npl.co.uk/electromagnetic

dti FUNDED BY THE DTI

NPL Interactive Workshop: Printed Circuit Boards in High Frequency (HF) and High Density Interconnects (HDI) Applications

Two of NPL's Metrology Clubs are joining together to organise this interactive workshop on Printed Circuit Boards (PCBs), which will be held on Thursday 5th May 2005 at NPL. The two clubs are the EMMA-Club (the Electromagnetic Materials Measurements and Applications Club) and SSTC (the Soldering Science Technology Club).



Typical printed circuit board for consumer electronics applications

EMMA-Club covers all aspects of dielectric and electromagnetic materials measurements at RF and microwave frequencies while SSTC is concerned with the soldering processes and reliability of PCB interconnectivity. We hope that this interdisciplinary event will be of interest to all professionals who work with PCBs.

We believe that the timing of this workshop is opportune. Under the pressure of technical progress electronics manufacturers are finding it necessary to use ever-higher packaging densities in their circuits, while faster operation of the applications and higher information transfer rates require ever-faster circuits. Thus, while automotive electronics formerly worked in the MHz frequency range, there is a growing requirement to implement circuits operating at GHz frequencies. Higher frequencies require both newer and better performance materials and better measurement methods for characterising and optimising circuits. These issues will be covered in this workshop along with other topics to be selected from the following:

- Dielectric properties of substrates
- Moisture take-up in substrates and its effects on circuit performance
- Loss measurements in PCB substrates - new methodologies
- Anisotropy in substrates
- CAF (Conductive Anodic Filamentation)
- LTCC test methods
- Embedded passives
- Frequency domain characterisation of circuits and PCBs
- Time domain characterisation of circuits and PCBs
- Standard test methods
- Effects of solder mask on impedance
- Robustness of PCB structures with μvias

In all of these areas the measurement of circuit parameters, their effects on performance and their optimisation will be of interest.

Papers and informal contributions on these and related topics are invited. Please also let us know about other issues you would like the workshop to cover. It is planned that there will be discussion sessions at the workshop which will investigate ways in which NPL and the National Measurement System (NMS) can help industry to solve PCB-related measurement and optimisation problems. If we find that it is not possible to cover all topics of interest in one day, another event can be held to address further issues of interest.

We would very much like to see you at this event, so if you are interested please contact Gill or visit our club websites:

EMMA Club:

www.npl.co.uk/electromagnetic/clubs/emma

and SSTC:

www.npl.co.uk/ei/clubs

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Redefining the Kilogram

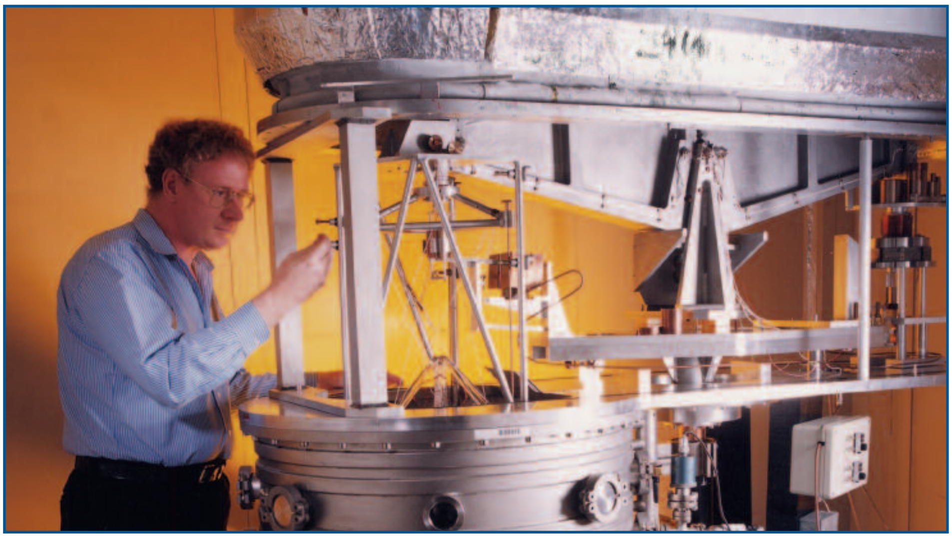
The kilogram is the last remaining artefact standard in the SI system. The metre, which was once defined as the distance between two fine marks on a platinum–iridium bar, and the second, which used to be related to the rotation of the Earth, are now both defined in terms of physical and atomic constants.

The metre was redefined in 1983 to be the length of the path travelled by light in a vacuum during a time interval of 1/299 792 458th of a second. The second was redefined in 1966 as the duration of 9192 631 770 periods of the radiation emitted by an electron when it falls between certain energy levels of the caesium-133 atom. These types of definition allow researchers to make measurements in SI units without the need for a direct comparison with a single "master standard". This is precisely what we need for the kilogram.

There are, in fact, many ways of redefining the kilogram in terms of fundamental constants or atomic masses. However, a successful definition also has to be practical. In other words, we need a method for measuring masses in the kilogram range with a high enough accuracy to replace the existing material standard. For the kilogram this actually turns out to be an accuracy of at least 10 µg in 1 kg if it is to provide a significant improvement over the existing system.

One approach to redefining the kilogram is currently embodied in a device known as a Watt Balance. Devised by Bryan Kibble at NPL, the Watt Balance matches the weight of an object to an electromagnetic force produced by a coil of current-carrying wire in a strong magnetic field. The weight of the object, mg, where m is its mass and g is the acceleration due to gravity, is then equal to the force on the wire: Bil, where B is the magnetic flux density, i is the current and l is the length of the wire.

The quantities m, g and i can be measured with high accuracy, but B and l are almost impossible to measure directly. However, by moving the coil in the flux at a velocity u and measuring the voltage V that is generated, it is possible to eliminate the product Bl using the relationship $V=Blu$. In other words, electrical and mechanical power are related though the equation $Vi=mgu$, which gives the Watt Balance its name. By rearranging this equation we can derive the mass of the object: $m=Vi/gu$. By measuring V using the Josephson effect and i using a combination of the Josephson and Quantum Hall effects the mass m can be measured in terms of the metre, the second and a constant of nature, Planck's constant.



Ian Robinson and NPL's Moving Coil Watt Balance

Because the Watt Balance experiment relates mass to a physical constant, it removes the obvious logical problem of defining a quantity in terms of a physical object that may gain or lose material. However, this is not to say that the apparatus has no drawbacks. In common with all mechanical measurements that aim for this level of accuracy, the challenges are in the detail. For example the magnetic flux density and the geometry of the coil must remain constant during the experiment. For the NPL Watt Balance, this means that the temperature of the permanent magnet has to be stable to better than 10 µK.

There are three operational Watt Balances in existence: one at NPL, one at the US National Institute of Standards and Technology (NIST) in Gaithersburg, and another at the Swiss Federal Office of Metrology and Accreditation (METAS) in Bern. Both NPL and NIST have published values of Planck's constant using Watt Balances that are operated in air, rather than a vacuum, based on the existing value of the kilogram. The NPL result from 1988 was $6.6260682 \times 10^{-34}$ Js with an uncertainty of 2 parts in 10^7, and the NIST result 10 years later was in agreement at $6.6260689 \times 10^{-34}$ Js with an uncertainty of 0.9 parts in 10^7.

Further results are expected from the NPL, NIST and METAS groups in the near future, so it is an exciting time for all concerned.

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The full version of this article appeared previously in *Physics World*. To see the full version please visit:

http://physicsweb.org/articles/world/17/5/8/1

ANAMET Intercomparison Complete

Another ANAMET measurement comparison exercise has just been successfully completed. The ANAMET Club focuses on RF, microwave and millimetre-wave measurements, and this particular exercise examined measurements of the voltage standing wave ratios (VSWRs) and output tracking of a commercial power splitter from 1 GHz to 18 GHz in 1 GHz steps.

The ANAMET power splitter visited 17 laboratories around the world

This included measuring the often difficult to determine effective match of the output ports of the splitter. An example of when this is encountered is when a splitter is used in a levelling or ratio measurement mode.

These parameters often form part of the specification for such devices and need to be determined routinely by measurement labs in the industry. Power splitters are used throughout the RF and microwave world in applications ranging from communications base stations right through to the highest precision test benches and calibration laboratories.

The aim of these ANAMET measurement comparisons is not only to have a positive effect on good measurement practice within the RF and microwave community, but also to provide invaluable assistance to the participants in identifying hitherto unknown problems with their measurements and test set ups. Participation in international comparison exercises such as this can also be useful in accreditation processes.

17 labs from around the world took part in this exercise, including 8 National Measurement Institutes and 6 UKAS-accredited laboratories. In fact during the 2 years it took to complete the exercise, the device travelled over 39,000 miles, which must be a record amount of travelling for a humble power splitter!

The results of the comparison are published as ANAMET Report 047.

To receive a copy of this report and for further information please contact
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Reduce Interference with Accurate Phase Noise Measurements

Measurement of phase noise is essential to the design and development of systems for communications. Good phase noise measurement supports the development of improved equipment such as low phase noise oscillators that are used in mobile telephone systems to reduce levels of interference.

The Good Practice Guide to Phase Noise Measurement published by NPL addresses common problems encountered when measuring phase noise and estimating associated uncertainties to improve your understanding of the instability of signal sources in the frequency domain. It also provides background on the general principles of phase noise measurements and the relevance of phase noise to the communications sector.

An electronic version of this guide is available for free – please visit our website.

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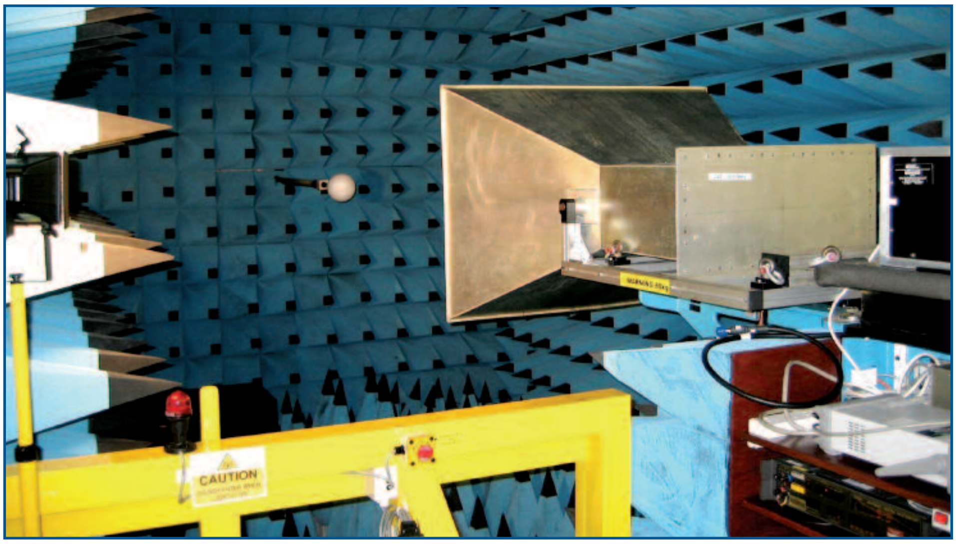
www.npl.co.uk/electromagnetic/publications/

A New Anechoic Chamber for Power Flux Density and Field Strength Measurements

Over the past twenty years, NPL has established itself as a world leader in the evaluation and calibration of power flux density (PFD) and field strength probes. Field probes are used as radiation hazard monitors in safety applications including measurements to EN50366: 2003, and as electric and magnetic field sensors to carry out EMC immunity measurements to EN61000-4-3.



NPL's new anechoic facility for the calibration of field strength probes.

The current frequency range covered by the NPL facilities is 20 Hz to 45.5 GHz and requires the use of a range of TEM Cells and Anechoic Chambers. The frequency range between 250 MHz and 2.4 GHz is particularly problematical, as single mode TEM cells become too small for the majority of commercially available probes and low reflectivity Anechoic Chambers are large and costly. NPL originally addressed this problem by designing a Tapered TEM Cell similar to the later GTEM cell but optimised for high frequencies using 1.5 m pyramidal microwave absorber as the load. Power conversion to higher non-TEM modes was minimised by careful design of the tapered inner conductor and preferentially attenuated by the removal of one side of the outer conductor. Nevertheless, above 500 MHz, the effects of higher order modes, excited by the discontinuity of the DUT, dominated the measurement uncertainty.

With the advent of EMC testing at the 3G frequencies (0.9, 1.8 and 2.2 GHz), many companies found that they could use their existing 1 GHz probes up to 2.2 GHz with only a modest increase in uncertainty due to antenna imbalance. This gave NPL, as a calibration laboratory, a problem in that many of these probes were electrically too large at these frequencies for testing in the Tapered Cell. At the same time, there was an increased demand for calibrations at lower field strengths involving larger antenna elements and the almost universal introduction of optical transmitters, which increased the electrical size of many types of probes, making them unsuitable for calibration in the Tapered Cell.

NPL has provided a solution to this problem by constructing a new larger anechoic facility dedicated to PFD and field strength measurements. The new chamber is 6 m long, 4.5 m wide and 4.5 m high and achieves a quiet zone large enough to accommodate all field probes including short active dipoles and allows comprehensive testing at different orientations and field polarisations. Multi-path reflections are less than 2% at 250 MHz, using 0.9 m pyramidal absorber. Field strengths of up to 250 V/m can be generated using three coaxially fed, ridged guide antennas covering the range 250 MHz to 2.5 GHz. Above these frequencies the new chamber can accommodate existing waveguide antenna systems normally used in a smaller facility covering the frequency range 2.45 GHz to 45.5 GHz.

The new facility reduces measurement uncertainties for existing probes. The typical uncertainty in field strength for the frequency range 250 MHz to 2.45 GHz is reduced from 1 dB to less than 0.7 dB for a 95% confidence level (k=2).

The facility is ideal for prototype testing, including probe antenna pattern measurements, and for calibrating probes with larger physical and or electrical size. The facility is also available for hire.

NPL Tapered TEM Cell used for calibrating field probes from 180 MHz to 2.5 GHz

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NPL Provides Confidence in Mobile Phone Measurements

When you use a mobile phone, some of the transmitted radiowaves are absorbed in your head. SAR (or Specific Absorption Rate) is a measure of how effectively this radiowave energy is absorbed.

Guidelines limit the maximum SAR that is allowed, to prevent significant heating of the tissues in the head. Manufacturers must test their phones to make sure that they do not exceed these limits.

SAR measurements are made using a "phantom" head, which is filled with a liquid that mimics the electrical properties of human head tissues.

However the heating effect of the radiowaves in the liquid is too small to measure using a thermometer. Therefore the measurements are made using a special probe, which directly measures the intensity of the electric field inside the liquid. This can be used to determine the SAR.

The SAR from a phone is measured under laboratory conditions according to an internationally agreed test procedure. This ensures that the SAR measurement obtained is an over-estimate of the actual SAR for most phone users. For the tests, the phone is set to transmit its maximum possible power. Hence the SAR measured will always exceed the upper limit of normal SAR exposure levels. In day-to-day use the phone will reduce its power level when there is a good reception at the base station. This reduces the SAR, and makes the battery last longer.

NPL is one of two National Standards Laboratories in the world that has standards for calibrating SAR probes. This ensures that we can have confidence in the phone measurements made in the UK. NPL also measures the electrical properties of the liquids used in the phantom head and, in conjunction with Bristol University, has developed new and improved liquids for these measurements.

A considerable amount of research is being conducted into possible health effects associated with mobile phones, or base stations. In the UK, the Department of Trade and Industry, the Department of Health and the mobile phone industry are co-funding the Mobile Telecommunications and Health Research (MTHR) programme, which is looking into this issue. NPL advises researchers in the MTHR programme on how to expose samples or volunteers to known levels of radiowaves. It is essential that the level of SAR used in the experiments is known accurately. Inaccurate exposure levels may lead to conflicting results when other researchers try to repeat the work. Many of the systems used for the experiments in the MTHR program have been calibrated at NPL, thus increasing confidence in the accuracy of these measurements.

For further technical information about NPL's work in this area, please contact

E-mail: electromagnetic@npl.co.uk

The next FREEMET meeting on RF Safety Measurement, Management and Compliance will include a session on SAR measurement. Please see the article on page 8 for further information.

BEMC 2005
Teddington 14 to 17 November 2005

Papers are now being accepted for the 2005 British Electromagnetic Measurement Conference (BEMC), which will focus on how industry can benefit from developments in electromagnetic measurement.

This event will combine oral presentations with hands-on laboratory demonstrations enabling participants both to present work in this area and to gather information directly applicable to their organisations' needs. There will also be a poster session for discussion of current topics.

The programme will include:

- Measurements for RF and microwave technologies, including communications and Health and Safety
- DC and Low Frequency electrical and magnetic measurements supporting manufacturing and other activities, including power conversion and measurement
- Good laboratory practice, uncertainty, conformance with regulation
- Self calibrating instruments, Internet-Enabled Metrology, Software for measurement, mathematical modelling
- Future electromagnetic measurement challenges such as Bio-electrical, MEMs, THz and displays technologies

The conference will also include tailored workshop sessions where smaller interactive discussions will be centred around NPL's Good Practice Guides and other topics.

To submit work for presentation at this conference, please follow the guidelines at www.bemc2005.npl.co.uk. The deadline for submission is 31st March 2005.

BEMC 2005 will provide an excellent opportunity to network with colleagues from many organisations, making the event invaluable for anyone interested in electromagnetic measurements.

An exhibition will be held alongside the conference enabling all delegates to view information from key companies and organisations related to electromagnetic measurement. Additionally sponsorship opportunities exist.

BEMC 2005 will be held at NPL's state-of-the-art laboratory enabling delegates to view the research facilities and practical demonstrations in addition to technical sessions.

For further information on any aspect of this conference please contact the BEMC Conference Office:

c/o Clare Melton
Tel: + 44 20 8943 6327
E-mail: clare.melton@npl.co.uk

www.bemc2005.npl.co.uk

Popular EMC Antenna Guide Update

This guide has just been extensively updated to further address the calibration of antennas in the frequency range 30 Hz to 40 GHz.

In updating this document NPL have used their experience of measuring antennas factor (or gain) of monopole, loop, dipole, biconical, log-periodic and horn antennas which are used for emission testing on open area test sites and in fully anechoic chambers. Guidance is given on the assessment of uncertainties in their use for radiated emission measurements according to EMC standards. Sections on horn and rod antennas have been expanded, and more detail has been given on calibration methods and uncertainties. New sections on TEM cells, the calibration of loop antennas and designing ground planes have also been added to make this an invaluable source of information for any company involved in these measurements.

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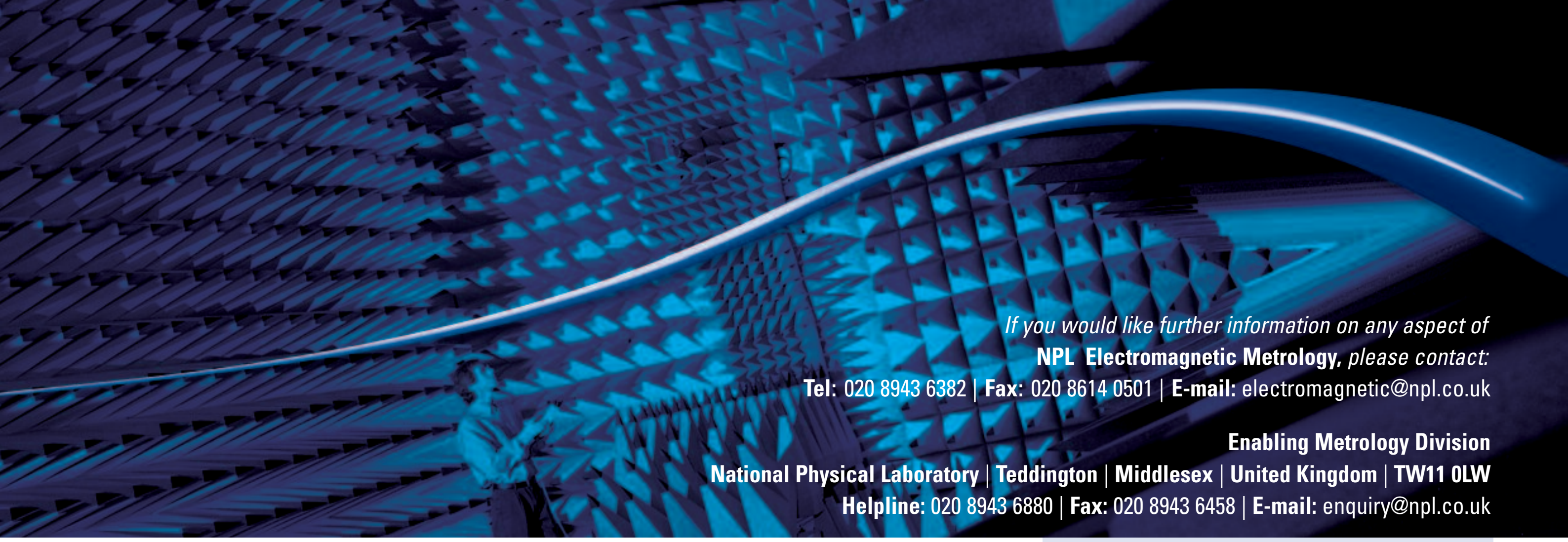

If you would like further information on any aspect of **NPL Electromagnetic Metrology,** *please contact:*
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FREEMET Meeting RF Safety Measurement, Management and Compliance 28 April 2005

The incorporation of electromagnetic fields into the Physical Agents Directive (PAD) has substantial implications for all businesses and premises operating electronic equipment. Previously there was no legal requirement to comply with the guidelines laid down by the International Committee on Non-Ionising Radiation Protection (ICNIRP). This change will make compliance mandatory. In addition, advances in technology have led to new measurement challenges for those involved in measurement and management of RF safety.

NPL are hosting a one-day event, in association with the FREEMET club to bring together measurement experts and practitioners to address the issues raised by these developments. Delegates will learn about these measurement challenges and how to comply with the new Directive.

This meeting will provide an overview of the implications of the changes to the PAD. Drawing on the experience of scientists actively involved in RF measurement and safety management we will look at the options available in measuring and monitoring equipment. There will be a session on Specific Absorption Rate, which is the key indicator to determine how effectively radiowave energy is absorbed in the human body.

FREEMET provides a forum for organisations and individuals to exchange of information and experience with the aim of increasing confidence in Free Field Radio Frequency and Microwave measurements.

www.npl.co.uk/freemet

Forthcoming events

28 April 2005, FREEMET at NPL
Theme: RF Safety Measurement, Management and Compliance

5 May 2005, EMMA-Club/SSTC at NPL
Theme: Printed Circuit Boards in Today's High Frequency (HF) and High Density Interconnects (HDI) Applications

9 - 13 May 2005, IEE Microwave Summer School at NPL

11 May 2005, Free-Space Optics Safety Workshop at NPL

12 May 2005, FOTON UK
Theme: Fibre to the Home

8 June 2005, DC & LF Club
Theme: Software in Measurement

15 - 16 September 2005, ANAMET

21 - 23 September 2005, OFMC – Europe's leading conference for measurements for optical fibres and optoelectronics.

14 - 17 November 2005, BEMC 2005 at NPL

7 December 2005, DC & LF Club
Theme: Power Quality

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For further information, event details and contacts visit the website: www.npl.co.uk/electromagnetic/

5603/AAR/?k/0305