UDK 621.3:(53+54+621+66)(05)(497.1)=00 ISSN 0352-9045

INFORMACIJE MIDEM 4-2004

Strokovno društvo za mikroelektroniko elektronske sestavne dele in materiale

Strokovna revija za mikroelektroniko, elektronske sestavne dele in materiale
Journal of Microelectronics, Electronic Components and Materials

INFORMACIJE MIDEM, LETNIK 34, ŠT. 4(112), LJUBLJANA, december 2004

MIDEM
DRUŠTVO-SOCIETY
IMAPS Slovenia Chapter

40th INTERNATIONAL CONFERENCE
ON MICROELECTRONICS, DEVICES AND MATERIALS
and the WORKSHOP on
Non-ionizing Electromagnetic Fields

September 29.- October 01.2004
Maribor, Slovenia

UDK 621.3:(53+54+621+66)(05)(497.1)=00 ISSN 0352-9045

INFORMACIJE MIDEM 4 ○ 2004

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INFORMACIJE MIDEM VOLUME 34, NO. 4(112), LJUBLJANA, DECEMBER 2004

Revija izhaja trimesečno (marec, junij, september, december). Izdaja strokovno društvo za mikroelektroniko, elektronske sestavne dele in materiale - MIDEM.
Published quarterly (march, june, september, december) by Society for Microelectronics, Electronic Components and Materials - MIDEM.

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Letna naročnina znaša 12.000,00 SIT, cena posamezne številke je 3000,00 SIT. Člani in sponzorji MIDEM prejemajo Informacije MIDEM brezplačno.
Annual subscription rate is EUR 100, separate issue is EUR 25. MIDEM members and Society sponsors receive Informacije MIDEM for free.

Znanstveni svet za tehnične vede I je podal pozitivno mnenje o reviji kot znanstveno strokovni reviji za mikroelektroniko, elektronske sestavne dele in materiale. Izdajo revije sofinanci rajo Ministrstvo za znanost in tehnologijo in sponzorji društva.
Scientific Council for Technical Sciences of Slovene Ministry of Science and Technology has recognized Informacije MIDEM as scientific Journal for microelectronics, electronic components and materials.
Publishing of the Journal is financed by Slovene Ministry of Science and Technology and by Society sponsors.

Znanstveno strokovne prispevke objavljene v Informacijah MIDEM zajemamo v podatkovne baze COBISS in INSPEC.

Prispevke iz revije zajema ISI® v naslednje svoje produkte: Sci Search®, Research Alert® in Materials Science Citation Index™

Scientific and professional papers published in Informacije MIDEM are assessed into COBISS and INSPEC databases.

The Journal is indexed by ISI® for Sci Search®, Research Alert® and Material Science Citation Index™

Po mnenju Ministrstva za informiranje št.23/300-92 šteje glasilo Informacije MIDEM med proizvode informativnega značaja.

Grafična priprava in tisk
Printed by

BIRO M, Ljubljana

Naklada
Circulation

1000 izvodov
1000 issues

Poštnina plačana pri pošti 1102 Ljubljana
Slovenia Taxe Percue

UDK621.3:(53+54+621+66), ISSN0352-9045 | Informacije MIDEM 35(2004)4, Ljubljana

VSEBINA CONTENT

Obnovitev članstva v strokovnem društvu MIDEM in iz tega izhajajoče ugodnosti in obveznosti

Spoštovani,

V svojem več desetletij dolgem obstoju in delovanju smo si prizadevali narediti društvo privlačno in koristno vsem članom.Z delovanjem društva ste se srečali tudi vi in se odločili, da se v društvo včlanite. Življenske poti, zaposlitev in strokovno zanimanje pa se z leti spreminjajo, najrazličnejši dogodki, izzivi in odločitve so vas morda usmerili v povsem druga področja in vaš interes za delovanje ali članstvo v društvu se je z leti močno spremenil, morda izginil. Morda pa vas aktivnosti društva kljub temu še vedno zanimajo, če ne drugače, kot spomin na prijetne čase, ki smo jih skupaj preživeli. Spremenili so se tudi naslovi in način komuniciranja.

Ker je seznam članstva postal dolg, očitno pa je, da mnogi nekdanji člani nimajo več interesa za sodelovanje v društvu, se je Izvršilni odbor društva odločil, da stanje članstva uredi in **vas zato prosi, da izpolnite in nam pošljete obrazec priložen na koncu revije.**

Naj vas ponovno spomnimo na ugodnosti, ki izhajajo iz vašega članstva. Kot član strokovnega društva prejemate revijo »Informacije MIDEM«, povabljeni ste na strokovne konference, kjer lahko predstavite svoje raziskovalne in razvojne dosežke ali srečate stare znance in nove, povabljene predavatelje s področja, ki vas zanima. O svojih dosežkih in problemih lahko poročate v strokovni reviji, ki ima ugleden IMPACT faktor.S svojimi predlogi lahko usmerjate delovanje društva.

Vaša obveza je plačilo članarine 25 EUR na leto. Članarino lahko plačate na transakcijski račun društva pri A-banki : 051008010631192. Pri nakazilu ne pozabite navesti svojega imena!

Upamo, da vas delovanje društva še vedno zanima in da boste članstvo obnovili. Žal pa bomo morali dosedanje člane, ki članstva ne boste obnovili do konca leta 2004, brisati iz seznama članstva.

Prijavnice pošljite na naslov:

MIDEM pri MIKROIKS

Stegne 11

1521 Ljubljana

Ljubljana, december 2004

Izvršilni odbor društva

AN INSIGHT VIEW OF CURRENT SEMICONDUCTOR DEVELOPMENTS

Werner Reczek

Infineon Technologies Austria AG, Villach, Austria

INVITED PAPER
MIDEM 2004 CONFERENCE
29.09.04 - 01.10.04, Maribor, Slovenia

Key words: semiconductors, semiconductor market, market cycles, technological leadership, Infineon Technologies

Abstract: The Semiconductor market is a very cyclical market. For the last 40 years it has been characterized by two words: change and speed! The compound annual growth rate has averaged 15 percent, but business cycles have been far more extreme, with some increases of 50% and decreases of 35%. Like all other companies in this market, Infineon Technologies has to cope with these challenges and opportunities. One key factor in order to meet the requirements of the market is the permanent focus upon a wide range of products on a very innovative level. This characterizes Infineon: maintaining a very high level of R&D investment, even during the past recession, to retain technological leadership, bringing added customer value.

Pogled na trenutno stanje razvoja področja polprevodnikov

Kjučne besede: polprevodniki, trg polprevodnikov, cikličnost trga, tehnološki primat, Infineon Technologies

Izvleček: Trg polprevodnikov je zelo cikličen trg. V zadnjih štiridesetih letih ga lahko opišemo z dvema besedama : sprememba in hitrost ! Skupna letna rast je bila v povprečju 15%, poslovni cikli pa so bili bolj izraziti, z maksimalno rastjo do 50% in padcem do 35%. Podobno kot druga podjetja na tem trgu, se je tudi Infineon Technologies moral kosati s temi izzivi in priložnostmi. Eden ključnih faktorjev pri naporih za zadovoljevanje takšnega trga je vzdrževanje visoke ravni inovativnosti pri širokem spektru proizvodov. Za Infineon je značilno : vzdrževanje visokega nivoja investicij v raziskave in razvoj, celo med zadnjim obdobjem recesije, z namenom obdržati tehnološki primat in povečevati dodano vrednost v izdelkih.

1. Cyclicality in the semiconductor market

The Semiconductor market is a very cyclical market. For the last 40 years it has been characterized by two words: change and speed! The compound annual growth rate has averaged 15 percent, but business cycles have been far more extreme, with some increases of 50% and decreases of 35%. Like all other companies in this market, Infineon Technologies has to cope with these challenges and opportunities. One key factor in order to meet the requirements of the market is the permanent focus upon a wide range of products on a very innovative level. This characterizes Infineon: maintaining a very high level of R&D investment, even during the past recession, to retain technological leadership, bringing added customer value.

2. Infineon in the market

Infineon Technologies AG, Munich, Germany, offers semiconductor and system solutions for the automotive and industrial sectors, with applications in wired communications markets, secure mobile solutions as well as memory products. With a global presence, Infineon operates in the U.S. from San Jose, CA, in the Asia-Pacific region from Singapore and in Japan from Tokyo. For the fiscal year 2003, the company achieved sales of Euro 6.15 billion with about 32,900 employees (incl. 6,100 R&D staff) worldwide, as of Dec 31, 2003. Infineon is listed on the DAX index of Frankfurt Stock Exchange and on the New York Stock Exchange (ticker symbol: IFX).

Infineon Technologies Austria AG headquarters is in Villach with development centers in Villach, Graz and Linz. There is also a sales office in Vienna. Infineon Technologies Austria AG achieved sales of Euro 533 million with about 2,600 employees in the FY 2003. This fact of having manufacturing and R&D at one site is providing for very short feedback loops and improving time to market. To further strengthen this benefit, Infineon Technologies has decided to transfer the worldwide activities for Power Management & Supply from Munich to Villach, enlarging the current existing center of competence.

Infineon has jumped two positions in the ranking of worldwide semiconductor suppliers. According to the American market research institute, IC Insights, it is now number five. The figures are based on the first six months of 2004. Infineon is the only one of the ten leading semiconductor companies that managed to improve its position. With sales growth of 35 percent compared to the previous six months, we are actually two percentage points above the average growth of the ten U.S., Japan, Europe, Korea and Taiwan companies. In the first six months of FY 2004 we were able to achieve sales of around 4.4 billion dollars.

3. Current semiconductor developments

As already mentioned above, focus upon technology is very important during downturns. Thus, a wide range of new products and applications emerge. Among these Ambient Technology is playing a key roll for many forthcoming developments described as follows: Ambient Intelligence is the vision that technology will become invisible, embedded in our natural surroundings, present whenever we need it, enabled by simple and effortless interactions, attuned to all our senses, adaptive to users and context, and autonomously acting. High quality information access and personalized content must be available to everybody, anywhere, and at any time.

While in the 70's one computer served many users, and in the 90's the personal computer served humans on a one-to-one basis, today more than one computing device serves each user. This trend towards distributed electronic intelligence will likely prevail in the near future.

Infineon hopes to convert Ambient Intelligence applications, in the next 5 years, into the appropriate markets. As an example, a low-cost wireless network is presented for Ambient Intelligence environments (that creates the necessary link between the user and distributed electronics). Smart homes and hotel room infrastructures are among the first examples where this vision may become reality. We are presently investigating chances for applications of Smart RFID tags that represent possible solutions for distributed intelligence. An "edutainment" device for children has been developed as an innovation study for a natural and intuitive computer interface.

Infineon is working on a packaging and interconnect technology for deep textile integration of electronics. An interconnect and packaging technology is demonstrated using a polyester narrow fabric with several warp threads replaced by copper wires which are coated with silver and polyester. A thin flexible printed circuit board (PCB) is then attached to the polyester fabric. Then the module is encapsulated for mechanical protection. The complete unit is molded forming a hermetically sealed casing that protects it against mechanical and chemical stress.

Another example is a demonstration of a speech-controlled MP3 player system which is based on a DSP/µC-two-processor system. The user can control the music player either by speaker-independent voice recognition or by means of the keypad.

The Techtextil prize for innovation was written out on the occasion of the Techtextil 2003 for the 7th annual by the organizing committee of the Techtextil Symposium. Outstanding achievements were awarded in research, material and product development as well as new technologies.

"Fault-tolerant Integration Concept of Microelectronics in Smart Textiles" by Christl Lauterbach, Stefan Jung, Thomas Sturm, Rupert Glaser, and Werner Weber, Infineon Technologies AG, Corporate Research, received the Tech-Textil Innovation award 2003 in the category "Integration of new technologies". The work is concerned with the direct installation of inexpensive Microsystems into textile structures.

On 26th April 2002, Infineon presented for the first time, prototypes of functional, durable and everyday life-suited implementations of microelectronics circuits in "smart" textiles and/or clothes. Thus, a smooth transition for, and reliable integration of electronic functionality into articles of clothing is now available - Wearable Electronics. Highly integrated chips and sensors with lowest capacity are inserted or interwoven directly into textile fabrics, making possible the complete integration of electronic applications into articles of clothing. Thus Infineon presented the basic technology to textile manufacturers and clothing designers who were able to convert it to visionary, innovative and inexpensive products.

The chips and very small sensors are applied in special frames on the textile fabric. Fine interwoven conductive strips provide for the electrical connections. The multiplicity of conceivable applications fields includes Infotainment and communications, in addition, logistics, medicine and security. Accordingly broadly is also the chip Portfolio of Infineon, which can be used for different textile-electronic applications. In addition, among other things, the Portfolio includes microcontroller and DSPs, Bluetooth, GPS and GSM solutions, memory cards, RFID solutions as well as biometric sensors.

The researchers of Infineon developed a self-contained embedded-microcontroller-net, which can be integrated into floor coverings. Together with sensors, it can be used with LEDs as signposts/guides or advertising media. "The electronic carpet" is also good for the control of air conditioning systems and fire signaling systems.

But that's not all: equipped with appropriate sensors, such a fabric can be built for instance into floors or walls and afterward, it can supply information about condition and load of materials. Thus the system makes possible early recognition of breaks and tears in building materials and fabrics.

The smart floor covering works through microelectronics modules which are embedded in braids of the carpet in the form of a "checkerboard". Each chip is connected to its four adjacent "neighbors" by electrically conductive threads, which creates a network that enables the flow of information. The more chips in a given square of smart carpet, the more sensitive it becomes.

Another interesting aspect of the technology is it's self-organizing, or self-learning, nature. Though chips are pressure, water and heat resistant, if one fails the carpet can identify the failure and is able to compensate automatically and reorganizes all other chips on the grid so that data is no longer set via paths that include the failing module. Not only does this help with faults, but it also offers the possibility to cut the "intelligent" carpeting to virtually any shape and size without damaging the electronic network within it. It still remains operational, which strains the "smart carpet" bears. However it is washable.

Example:

The demonstrator developed by Infineon incorporates robust encapsulated integrated capacitive sensors that act as touch detectors and LEDs as display elements. A carpet equipped with these chips and with this electronic architecture could thus be used as a motion or fire detector. The more densely the sensor elements are arranged, the more precise the results of measurement. At the same time, the integrated LEDs support use of the high-tech carpet as a control system that can be used in public buildings to mark walking routes and control the flow of visitors or to mark escape routes in an emergency.

In order to evaluate the information supplied by the microcontrollers, individually adapted programs can be written. Thanks to this flexible solution, the possible fields of application are virtually limitless.

The chips are interconnected by means of extremely fine signal and data conductors that are woven into a braided material that acts as the carrier. This interconnecting woven material can be the base layer or an intermediate layer of a carpet or of any other textile material. Each chip communicates via a self-learning and self-organizing network with its immediate neighbor and uses a software algorithm to ascertain its own position. If an element within the network is faulty, the chips automatically search for new ways in order to maintain the communication. Since the coordinates are stored in the chip and the entire carpet network is self-organizing, a faulty semiconductor element or a damaged connection does not impair the network's ability to function. The self-organizing nature of the material allows it to be cut to size in order to fit a specific area or a desired shape. Once it is cut and installed, the information network is connected via a data interface to existing systems, such as the alarm, air-conditioning or IT system.

Further Example:

Another potential field of application for the new high-tech textiles is the building industry, where sensors could be used as a means of detecting faults in concrete at an early stage. The water and heat-resistant chips could be integrated into columns, floors and walls, where they could collate information about the condition of the building material. Information gathered in this way could then be evaluated by means of a laptop computer connected to an interface of the concrete carrier. This would also allow static investigations to be performed faster and more cost-efficiently.

Application in the field of advertising and information is also conceivable for the concepts of "intelligent" textiles developed by Infineon. By way of example, when integrated into tent roofs or Zeppelin (airship) and balloon covers, the controllable LEDs as well as other display elements could be used to convey advertising messages.

Example:

The Hub (O'Neill's snowboard winter jacket with Infineon state-of-the-art technology).

For Infineon, the jacket marks its debut in the promising future "wearable electronics" market, which, according to forecasts, will bring in revenues of over one billion euros in the year 2007 alone.

This article of clothing targets the dynamic market segment of snowboarders and winter sports enthusiasts. The removable Infineon chip module is embedded in the inside of the high-tech jacket in a hard-shell holder, which protects it from physical damage and moisture. The mp3 files are loaded on the module via a USB connector. A textile keyboard built into the arm of the jacket is used for controlling the player. The player's electronics are connected via conductors sewn directly into the cloth of the jacket. The battery offers eight hours of playtime. The 128-megabyte memory provides enough space for all titles on a CD with outstanding sound quality. What is more, thanks to the Bluetooth module integrated in the jacket, cell phoning is even possible: The microphone is built into the collar; the headphones are tucked away in the helmet.

Infineon has already been in contact with over 200 companies in the textile industry regarding specific projects in the area of intelligent textiles.

The Hub will be available in retail stores along with the 2004/2005 winter collection.

Rosner mp3blue

The German clothing manufacturer Rosner from the Bavarian city of Ingolstadt and Infineon Technologies AG presented, on 26th July 2004, a jointly developed product: A men's jacket called "mp3blue" that features built-in functions such as "mobile telephony via Bluetooth" and "MP3 player". The electronics are an integral part of the clothing. The electronic features are controlled by a textile keyboard incorporated on the sleeve.

A new self-service library is yet another innovation that has been made possible by an Infineon complete solution using 300,000 radio chips. The my-d RFID (Radio Frequency Identification) chips have now been embedded in 240,000 books and 60,000 CDs and DVDs at a Vienna library. The library's users now only have to place their choices on the check-out table and insert their library card into a card reader. A radio system, built into the table, reads the content of the RFID chips and registers the details. This eliminates waiting periods, especially since the new process can register several library transactions at once. The chips, with up to ten kilobits of memory, can include much more information than conventional barcodes. We developed the system together with ekz, a library provider from Reutlingen, Germany, and the Swiss company Bibliotheca Library Systems AG and have equipped further libraries in Austria, Switzerland, Belgium, and Germany.

4. An insight outlook about: What will be?

Generally, cyclicality in the market will continue, peaks of ups and downs will probably increase! Further strong focus in revenue forecasts is inescapable. Regional competition between Asia and Europe will increase, market pressure upon costs and productivity. One of the key factors is to meet the requirements of the customers. New consumer applications will shape and increase the worldwide market. A broad portfolio of new products will change everybody´s life!

In this article various technology demonstrators were presented which consistently aim at improving the interaction between the human individual and information technology. Although we focused on the application-specific technologies to be explored and developed, at this point we want to emphasize the challenges mainstream Si-based technology pose to technology innovation. Indeed the progress of the latter is not automatic. Major creativity and hard work are necessary to maintain a constant rate of progress in this field. It was the goal of this paper to show that this endeavor is worth the effort. The described projects may open the way to promising applications that may lead to completely new fields of application for microelectronic technologies in just a few years' time.

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Prispelo (Arrived): 10.09.2004 Sprejeto (Accepted): 30.11.2004

BASIC EMC PHENOMENA AND WORLDWIDE EMC REGULATION

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INVITED PAPER
MIDEM 2004 CONFERENCE
29.09.04 - 01.10.04, Maribor, Slovenia

Key words: electromagnetic compatibility, EMC, EMI sources, EMC regulation, compliance to regulation

Abstract: This article provides an overview of EMC standards and their use for verifying compliance with worldwide regulations. The article shows some fundamental concepts of electromagnetic compatibility. Describes the regulation in Europe , USA, and other markets, use of standards, basic EMC phenomena, EMC sources and victims and EMC test procedures.

Osnovni EMC pojavi in zakonodaja na področju EMC

Kjučne besede: elektromagnetna kompatibilnost, EMC, izvori EMI, EMC zakonodaja, EMC ustreznost

Izvleček: V prispevku podajamo pregled EMC standardov in njihovo uporabo pri preverjanju ustreznosti glede na svetovno zakonodajo. Podajamo tudi nekaj osnovnih konceptov elektromagnetne kompatibilnosti. Opišemo zakonodajo v Evropi, ZDA in na drugih trgih ter opišemo uporabo standardov, osnovne EMC pojave, izvore in žrtve EMC motenj ter EMC testne procedure.

1. Introduction

Many electronic engineers heard first time for EMC, when the product they designed has serious problems of electromagnetic compatibility. The Electromagnetic compatibility (EMC) became one of the most important technical characteristics of new electronic devices for free access on global markets. The article describes:

- Worldwide regulation like U.S. FCC requirements and European EC Directives, VCCI approval in Japan.
- Harmonised and voluntary Standards
- Basic standards
- EMC phenomena: low frequency emission (harmonic, flicker), radio-frequency emission, immunity: ESD, fast transients, surge, RF fields.

This article provides an overview of EMC standards and their use for verifying compliance with regulations.

2. Worldwide regulation and EMC phenomena

EMC is defined as the ability of equipment to function satisfactorily in its electromagnetic environment without introducing intolerable disturbances to anything in that environment. EMC requirements concern two basic concepts: emissions and immunity or susceptibility. Electromagnetic disturbance is any phenomenon that may degrade the performance of a device, equipment, or system, or adversely affect living or inert matter. Electromagnetic interference (EMI) is the degradation of the performance of a device, transmission channel, or system caused by an electromagnetic disturbance. Disturbances may represent low-frequency (LF) and/or high-frequency (HF) phenomena, as well as broadband and/or narrowband. Broadband disturbances can originate from commutator motors, ignition systems, arc welding equipment, etc.; narrowband from digital electronic circuitry, switched-mode power supplies, and radio communication equipment. Computers have often been reported to cause interference with radio services, including police, aeronautical and broadcast services. On the other hand, radio transmission by a high-frequency carrier, such as a 900 MHz cellular or a 1.8 GHz DCS, can cause problems in computers and all electrical circuits because the carriers are easily picked up by cables and apertures functioning as antennas and are demodulated in electronic circuits by different nonlinear electromagnetic phenomena.

In industry, it is assumed that electronic control systems can be used in conjunction with interfering switching operations, motor drives, high-frequency ovens, welding equipment, etc. In a car, electronic automatic systems must function when we use our mobile phone or meet other vehicles (with interfering ignition systems). An electronically controlled wheelchair is presumed to function normally even when the person sitting in the chair uses a mobile phone or a portable PC. We demand that life-supporting electromedical apparatus in a hospital function safely even near high-frequency-radiating surgical equipment.

2.1 Worldwide regulation on EMC

The regulation can be mandatory like in USA, Russia, Europe, Australia, and China or voluntary, like in Japan.

Let's see differences in the regulation approach in some bigger markets.

2.1.1 US Requirements

Only radio-frequency disturbances are regulated in the USA for most of devices. The general EMC requirements in the U.S. are set by the Federal Communications Commission (FCC). Mandatory FCC requirements primarily concern computing devices, defined as any electronic device or system that generates and uses timing pulses at a rate in excess of 9kHz and uses digital techniques. FCC Part 15 covers radio frequency devices capable of emitting RF energy in the range of 9 kHz—200 GHz. Testing should be done according to ANSI C63.4-1992.

Part 18 covers industrial, scientific, and medical (ISM) equipment, defined as any device that uses radio waves for industrial, scientific, or medical purposes and is not intended for radio communications. While most FCC regulations only concern emissions, FDA also requires immunity for certain life-support equipment. FCC Parts 15 and 18 include regulations as well as technical aspects and limits. FCC Part 68, which governs the technical requirements for registration of telecom terminal equipment, includes lightning surge tests (surge immunity).

FCC Part 15 currently has three different procedures for showing conformance:

Procedure of verification: where the manufacturer or the importer files a test report showing compliance. Procedure of verification is applicable for many digital devices and power supplies, which are not dedicated to be used in PC.

Procedure of certification: which requires a review of the application by the FCC, and the use of a unique FCC identification number. Procedure of certification is used e.g. for CB receivers or scan receivers.

Procedure of declaration of Conformity (DoC), which requires that tests are performed by a test lab accredited by A2LA or NVLAP (other accredited labs may also be accepted). Doc procedure is used e.g. for personal computers and peripherals.

2.1.2 EU Requirements

The European EMC Directive, 89/336/EEC, sets out the legal requirements on EMC for principally all electric/electronic equipment to be placed or used in the Common Market of European Economic Area. The European legislation covers emissions as well as immunity.

The EMC requirements are valid for apparatus and systems placed on the market as complete units. Components such as resistors or transistors are not included. However, components with a direct function to the end-user, like plug-in PC boards, are regarded as equivalent to apparatus and have to follow the same rules as other devices.

New Approach European Directives only set out essential requirements and legal aspects. Technical aspects are dealt with in specific standards. These standards are developed by specific bodies, such as CENELEC or ETSI, and are harmonized to the directives by the action of the European Commission. The harmonised standards are published in official journal of EU and public available: http://europa.eu.int/comm/enterprise/newapproach/standardization/harmstds/reflist/emc.html

The EMC Directive itself, however, is based on a presumption principle, which means that a product that meets the requirements of the harmonized standards is also presumed to meet the essential requirements of the EMC Directive.

2.1.3 EMC requirements in Russia federation

Free access to the Russian market is allowed only for products certified by GOST R accredited certification bodies. The requirements for GOST R certification are: safety, EMC and hygienically requirements for some products. The certification is based on test reports from accredited test laboratories. Most of GOST R standards are same as IEC standards. Russian legislation covers emissions and immunity. Technical requirements are same as European for many products.

2.1.4. Australian and NZ requirements

To comply with the EMC regulatory arrangements, Australian and New Zealand suppliers must satisfy four basic requirements:

Ensure that the product complies with the appropriate mandated EMC standard, make and hold a DoC, prepare and keep compliance records, label the product with the C-Tick mark.

European harmonised standards, international IEC CISPR standards or AS/NZ standards are mandatory.

A company or person wishing to use the C-Tick mark must make a written application to the ACA (Australian Communication Authority).

2.2 Standardization

Under the General Agreement on Tariffs and Trade (GATT) and its successor, the World Trade Organization (WTO), member countries are obliged to adopt international standards for national use wherever possible. International standards concerning EMC are primarily developed by the International Electrotechnical Commission (IEC: TC77 and CISPR).

The International Organization has also published some specific EMC standards for Standardization (ISO). North American EMC standards are published by the FCC, the American National Standards Institute (ANSI), and the Institute of Electrical and Electronics Engineers (IEEE). EMC are developed by the European Committee for Electrotechnical Standardization (CENELEC).

Regulations and standards concerning telecom and radio transmitting equipment are published by the International Telecommunications Union (ITU) and the European Telecommunications Standards Institute (ETSI).

International and European EMC standards are to a great extent becoming harmonized, due to the fact that many EN standards are based on IEC and/or CISPR standards. Russian standards are published by GOST R .

EMC standards are continuously being developed and revised. It is therefore important to keep track of standards' publication dates, in addition to knowing if a new standard is to be expected in the near future and when an old standard is no longer valid.

Standard Requirements

Standards are principally divided into the following main groups: Generic, basic and product (product family) standard

Basic Standards

Basic standards describe EMC phenomena and test methods. One of series of basic standards for immunity are IEC 61000-4-X, which were then translated into European standards as EN 61000-4-X.

Product and Product Family Standards

These are applicable for specific product types, which are specified within the scope of the standard.

In addition to these standard documents, there are also standards offering guidance on installation techniques, or a code of practice, for example the IEC 61000 series, Part 5 (IEC 61000-5-X).

EMC Standards Classification

Generic standards have two environmental classes:

1. Residential, commercial, and light industrial environments, including domestic, office, laboratory, and light industrial environments where the apparatus or system is connected to the public mains.
2. Industrial environments, meaning "heavy" industrial environments with separate transformer stations for mains supply, usually with equipment spread over some distance.

Which Standards Apply?

A product standard is one that covers many EMC requirements for a certain product type. In some cases, product standards also cover electrical safety requirements. A product standard takes preference over all other standards. If some EMC phenomena is not covered by product standards , generic standard should be used for that phenomena. (e.g. immunity, low frequency emission) Once it is determined that a product is within the scope of an applicable product family standard concerning emissions and/or immunity, then that standard should be followed. The Guide 25 published by CENELEC can be used for proper harmonised standards decision: http://www.cenelec.org/NR/rdonlyres/0BD1127F-9C5C-4FB8-8854-17905BF7ABAC/0/CENELECGuide25.PDF

Generic/General Standards

If no product family standard is applicable, one must follow the suitable generic or general standard, which in turn refers to different basic standards. Some of the product family standards are also referred to in other standards, which consequently gives them characteristics of basic standards.

The generic standards include:

EN 61000-6-3: Emissions standard for residential, commercial, and light industrial environments.

EN 61000-6-4: Emissions standard for industrial environments.

EN 61000-6-1: Immunity standard for residential, commercial, and light industrial environments.

EN 61000-6-2: Immunity standard for industrial environments.

EMC standard that covers emissions and immunity for medical equipment is EN 60601-1-2, the collateral standard for medical equipment. In addition to this collateral standard, there are a number of product standards covering safety and EMC for specific medical equipment, like EN 60601-2-24, which covers infusion pumps and controllers.

As far as the emissions requirements are concerned, the generic standard is more rigorous in regard to light industrial environments than on heavy industry, which as a rule is already rather electro-magnetically contaminated. As far as the immunity requirements are concerned, the situation is the opposite. Interference immunity must be hardier in heavy industrial environments.

What then is applicable in mixed or special environments? When using the generic standards it is recommended to begin with the most strict requirements, which means that the equipment should be classified according to the "worst" combination, such as EN 61000-6-3/EN 61000-6-2.

2.3. EMC phenomena and EMC test procedures from basic standards

Basic Immunity Standards describes the EMC phenomena and test procedures. From historical reasons there are not particular basic standards for emission phenomena.

The procedures in some product family standards are deemed to be equivalent for basic standards.

2.3.1 Low frequency emissions - harmonics and flicker

Many electrical devices could change the quality of electrical energy by non-linear current response and fast changes of power consumption. The limits for all equipment with rated current under 16 A are regulating by standards EN 61000-3-2. Measuring of low frequency emission requires non electro-magnetically polluted sources. Harmonics are measured with harmonic analysers. Frequency range of interest starts at 50 Hz and stops at 2 kHZ.

2.3.2 Radio frequency emissions – conducted and radiated method

Many electrical and electronic devices are sources of radiofrequency disturbances. (Spark-ignition motors, commutation motors, all digital devices and so on). Radio disturbances have many propagation paths: conductive, capacitive, inductive and radiated. Conductive path is predominant at lower frequencies (150kHz to 30MHz) and radiated path is predominant at higher frequencies (above 30MHZ).

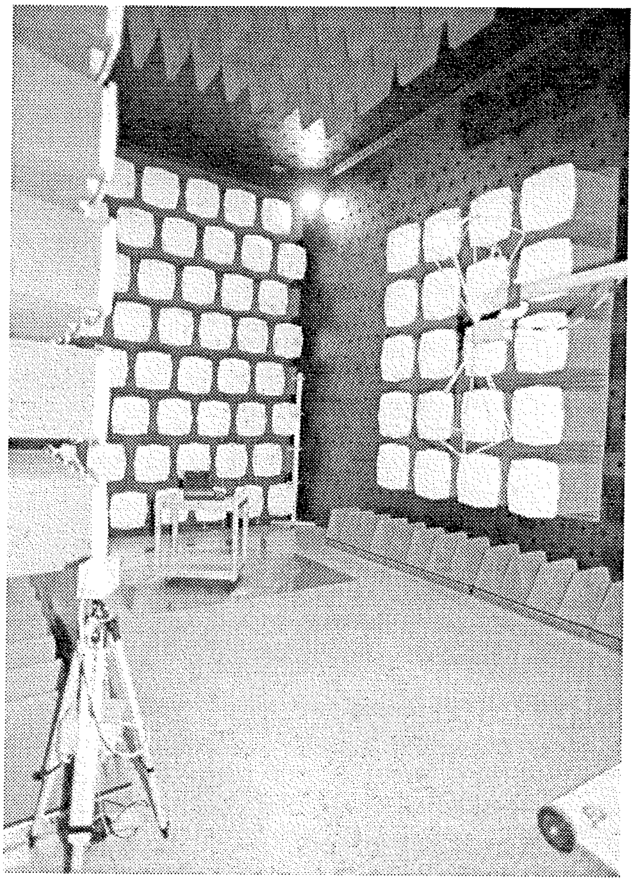

Figure 1: Anechoic chamber in Slovenian institute of Quality and Metrology. Testing according to EN 55022 on 3m distances and immunity according to EN 61000-4-3 up to 3GHz.

2.3.3 Immunity to electrostatic discharges (ESD)

This test relates to equipment, systems, sub-systems and peripherals which may be involved in static electricity discharges owing to environmental and installations conditions, such as low relative humidity, use of low-conductivity (artificial-fiber) carpets, vinyl garments, etc., which may exist in allocations classified in standards relevant to electrical and electronic equipment.

The problem of protecting equipment against the discharge of static electricity has gained considerable importance for manufacturers and users.

The extensive use of microelectronic components has emphasized the need to define the aspects of the problem and to seek a solution in order to enhance products/system reliability.

The problem of static electricity accumulation and subsequent discharges becomes more relevant for uncontrolled environments and the widespread application of equipment and systems in a wide range of industrial plants.

Electrostatic discharges are applied to the EUT at points and surfaces which are normally accessible to the operator. These discharges are also applied to the metal coupling planes. The voltage levels are increased gradually until the maximum severity level selected is reached. Discharges to the EUT and coupling plane are performed at a minimum of 1 second intervals at each polarity. The minimum of 10 discharges at each polarity are initially performed and increased to 30 discharges as the voltages increase in severity so as to evaluate the performance of the EUT.

2.3.4 Immunity to Radiated, radio frequency electromagnetic fields (RF fields).

Most electronic equipment is, in some manner, affected by electromagnetic radiation. This radiation is frequently generated by such sources as the small hand-held radio transceivers that are used by operating, maintenance and security personnel, fixed-station radio and television transmitters, vehicle radio transmitters, and various industrial electromagnetic sources.

In recent years there has been a significant increase in the use or radio telephones and other radio transmitters operating at frequencies between 0.8 GHz and 3 GHz. Many of these services use modulation techniques with a non-constant envelope (e.g. TDMA).

The EUT is subjected to a field strength of 3 V/m or 10 V/m from 80 MHz to 1000 MHz. This frequency range is 80% amplitude modulated with a 1 kHz sine wave. The signal generator provides the modulated frequency at a step rate of 1% of fundamental to the RF amplifier. The EUT is also subjected to a pulsed 900 MHz field at 200 Hz. The dwell time at each frequency is not less than the time necessary for the EUT to be exercised, and able to respond. The RF amplifier provides the necessary power to the antenna to establish the field levels as monitored by the field probe or power monitor. The anechoic chamber is calibrated according to the criteria as per EN 61000-4-3 for 16 points. The antenna is positioned 3 meters from all four faces of the EUT and is oriented in horizontal and vertical polarization.

2.3.5 Immunity to electrical fast transients/burst (EFT).

The repetitive fast transient test is a test with bursts consisting of a number of fast transients, coupled into power supply, control and signal ports of electrical and electronic equipment. Significant for the test are the short rise time, the repetition rate and the low energy of the transients.

Test voltages of up to 4 kV in positive and negative polarities are applied to the A/C power leads and up to 2 kV is applied to the I/O cables. The test voltages are at a 5 kHz pulse repetition frequency and applied for 60 seconds to each power supply terminal including protective earth and every combination of these terminals. The coupling clamp is used to apply up to 2 kV to the I/O cables.

2.3.6 Immunity to surges (1, 2 μs/50 μs).

These tests relate to the immunity requirements for equipment to unidirectional surges caused by overvoltages from switching and lightning transients. Several test levels are defined which relate to different environment and installation conditions. These requirements are developed for and are applicable to electrical and electronic equipment.

System switching transients can be separated into transients associated with:

The major mechanisms by which lightning produced surge voltages are the following:

A direct lightning stroke to an external circuit (outdoor) injecting high currents producing voltages by either flowing through earth resistance of flowing through the impedance of the external circuit;

An indirect lightning stroke (i.e. a stroke between or within clouds or to nearby objects which produces electromagnetic fields) that induces voltages/currents on the conductors outside and/or inside a building;

Lightning earth current flow resulting from nearby direct-to-earth discharges coupling into the common earth paths of the earthing system of the installation.

The rapid change of voltage and flow of current which may occur when a protector is excited may couple into internal circuits.

Test voltages of up to 4 kV are applied synchronized to the voltage phase at zero-crossing and peak value of the A.C. voltage wave (positive and negative). The surges are applied line to line and line to earth. When testing line to earth the test voltage is applied successively between each of the lines and earth. All lower levels including the selected test level is tested.

2.3.7 Immunity to conducted disturbances induced by radio frequency fields.

The source of disturbance covered by this test is basically an electromagnetic field, coming from intended RF transmitters, that may act on the whole length of cables connected to an installed equipment. The dimensions of the disturbed equipment, mostly a sub-part of a larger system, are assumed to be small compared with the wavelengths involved. The in-going and out-going leads: e.g. mains, communication lines, interface cables, behave as passive receiving antenna networks because they can be several wavelengths long.

Between those cable networks, the susceptible equipment is exposed to currents flowing "through" the equipment. Cable systems connected to an equipment are assumed to be in resonant mode (l /4, l /2 open or folded dipoles) and as such are represented by coupling and decoupling devices having common-mode impedance or 150W with respect to a ground reference plane.

This test subjects the EUT to a source of disturbance comprising electric and magnetic fields, simulating those coming from intentional RF transmitters. These disturbing fields (E and H) are approximated by the electric and magnetic near-fields resulting from the voltages and currents caused by the test set-up.

The EUT is subjected to an electromotive force (e.m.f.) of 3 V or 10 V from 150 kHz to 80 MHz. This frequency range is 80% amplitude modulated with a 1 kHz sine wave. The signal generator provides the modulated frequency at a step rate of 1% of fundamental to the RF amplifier. The dwell time at each frequency is not less than the time necessary for the EUT to be exercised, and able to respond. Clamp injection on all cables of the EUT is used to couple the e.m.f. to the EUT.

2.3.8 Immunity to magnetic fields

The magnetic fields to which equipment is subjected may influence the reliable operation of equipment and systems.

These tests are intended to demonstrate the immunity of equipment when subjected to power frequency magnetic fields related to the specific locations and installation condition of the equipment (e.g. proximity of equipment to the disturbance source). The power frequency magnetic field is generated by power frequency current in conductors or, more seldom, from other devices (e.g. leakage of transformers) in the proximity of equipment.

The EUT is subjected to a continuous magnetic field of 3 A/m or 10 A/m by use of an induction coil of standard dimensions 1m x 1m. The induction coil is then rotated by 90° in order to expose the EUT to the test field with different orientations. Three orthogonal planes are tested. The dwell time at each frequency is not less than the time necessary for the EUT to be exercised, and able to respond.

The preferential range of test levels, respectively for continuous and short duration application of magnetic field, applicable to distribution networks at 50 Hz and 60 Hz, is given below.

2.3.9 Immunity to voltage dips and short interruptions

Electrical and electronic equipment may be affected by voltage dips, short interruptions or voltage variations of power supply.

Voltage dips and short interruptions are caused by faults in the network, in installations or by a sudden large change of load. In certain cases, two or more consecutive dips or interruptions may occur. Voltage variations are caused by the continuously varying loads connected to the network.

These phenomena are random in nature and can be characterized in terms of the deviation from the rated voltage and duration. Voltage dips and short interruptions are not always abrupt, because of the reaction time of rotating machines and protection elements connected to the power supply network. If large mains networks are disconnected (local within a plant or wide area within a region) the voltage will only decrease gradually due to the many rotating machines, which are connected to the mains networks. For a short period, the rotating machines will operate as generators sending power into the network. Some equipment is more sensitive to gradual variations in voltage than to abrupt change. Most data-processing equipment has built-in power-fail detectors in order to protect and save the data in internal memory so that after the mains voltage has been restored, the equipment will start up in the correct way. Some power-fail detectors will not react sufficiently fast on a gradual decrease of the mains voltage. Therefore, the d.c. voltage to the power-fail detector is activated and data will be lost or distorted. When the mains voltage is restored, the data-processing equipment will not be able to restart correctly before it has been re-programmed.

Consequently, different types of tests are specified to simulate the effects of abrupt change voltage, and, optionally, for the reasons explained above, a type test is specified also for gradual voltage change. This test is to be used only for particular and justified cases.

The EUT is tested for test levels of 30%, 60% and >95% below the rated voltage for the equipment. The duration of the dips/interruptions are 10ms, 100ms and 5000ms respectively. Five dips are performed for each test level at a rate of one dip per minute. The changes in supply voltage occur at zero crossing of the voltage.

3. Conclusion

The article has been written as short guide for manufacturers and suppliers of devices and systems sold and installed in global markets. Market requirements for European, American, Russian and Australian market have been presented. Basic EMC phenomena and test procedures have been evaluated and described in connection with international and regional standardization. Manufacturers and suppliers can get first overview of EMC through this article. However because of complex thematic and test procedures, the further cooperation with professional organisation is strongly recommended. The professional organisations, which are most, deeply informed and competent for EMC questions are EMC competent bodies of EU and accredited laboratories that have in accreditation scope also testing for your products. Competent bodies can be found on the Internet address: http://europa.eu.int/comm/enterprise/electr_equipment/emc/cblist.htm#Slovenia

4. References

/1/ COUNCIL DIRECTIVE of 3 May 1989 on the approximation of the laws of the Member States relating to electromagnetic compatibility (89/336/EEC)

/2/ Guidelines on the application of Directive 89/336/EEC: http://europa.eu.int/comm/enterprise/electr_equipment/emc/guides/chapone.htm

/3/ List of harmonised standards to the directive 89/336/EEC: http://europa.eu.int/comm/enterprise/newapproach/standardization/harmstds/reflist/emc.html

/4/ CENELEC Gude 25: http://www.cenelec.org/NR/rdonlyres/0BD1127F-9C5C-4FB8-8854-17905BF7ABAC/0/CENELECGuide25.PDF

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Prispelo (Arrived): 10.09.2004 Sprejeto (Accepted): 30.11.2004

THE NEW, MODERN, INTEGRATED APPROACH TO AN EFFECTIVE, EXTERNAL AND INTERNAL, LIGHTNING AND OVERVOLTAGE PROTECTION

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INVITED PAPER
MIDEM 2004 CONFERENCE
29.09.04 - 01.10.04, Maribor, Slovenia

Key words: atmospheric discharge, lightning stroke, lightning protection, overvoltage protection,

Abstract: Overvoltage protection requires a comprehensive, systematic approach: understanding atmospheric discharges and the origin of lightning; the way of catching the stroke and conducting it to the earth; and protecting the building, equipment and people against its influence. For simulation of a lightning stroke in the laboratory, two basic transient-current wave shapes are used: 10/350 µs and 8/20 µs. These waves are also used as the criteria for current absorption over overvoltage protection elements, and cover most of the events of lightning.

Nov, moderen, integriran pristop k učinkoviti, zunanji in notranji zaščiti proti prenapetosti in streli

Kjučne besede: atmosferske razelektritve, udar strele, zaščlita pred strelo, prenapetostna zaščita,

Izvleček: Zaščita pred prenapetostjo zahteva celovit sistemski pristop, razumevanje atmosferskih razelektritev in izvor strel, načina zajema udara strele in njenega vodenje v zemljo ter razumevanje zaščite zgradbe, opreme in ljudi pred njenimi vplivi. Za simulacijo udara strele v laboratoriju uporabljamo dve osnovni obliki tokovnega impulza : 10/350 us in 8/20 us. Oba dokaj ustrezno opišeta ta naravni pojav in ju uporabljamo kot kriterij pri oceni zmogljivosti absorpcije toka skozi prenapetostne zaščitne elemente.

1. Introduction

The overvoltage level, as the consequence of atmospheric discharge, has to be reduced to a sufficiently low safety value for electric and electronic devices. The main reason for involving external protection is that it conducts half of the lightning value into the earthing system and is prescribed as mandatory in the majority of European countries.

The lightning discharge happens when a quasi-static electric field between the cloud and the earth creates a stepped conductor and moves progressively from the cloud to the earth. The down-conductor approaches the earth and the electric field increases to the point of initiation of the upward-streamers. The upward-conductor propagates towards the down-conductor to complete the ionised path between the cloud and the earth. When the field strength at lightning terminals reaches the critical breakdown threshold, the streamer is launched towards the approaching conductor and both connect the lightning channel.

An air terminal, which is mounted on the highest point of the building, provides the preferred attachment point for the lightning discharge and controls the passage of the substantial atmospheric discharge current safely to the earth. The earthing is important for personal safety, equipment protection (essential to the proper operation of SPDs) and lightning dissipation.

2. Methods of protection

To cover systematically and efficiently all effects of atmospheric discharge, a six-level protection plan is used, composed of the following steps:

1. Capture the lightning stroke by a designed air terminal at a preferred point;
2. Conduct the lightning to the earth via a designed down-conductor;
3. Dissipate the energy into the earth with minimal rise of the earth potential;
4. Bind to create an equipotential ground plane and eliminate the earth loops by the lowest possible impedance of the earthing system;
5. Protect the incoming power circuits, the building, the people and the equipment at the power supply side;
6. Protect the telecommunication and data circuits to prevent equipment damage and the cost of operational downtime.

The six-level protection plan can handle almost any situation, and provide solutions e.g. for ships or boats and yachts, for oil platforms, oil refineries, gas pipelines, common small family houses as well as tall buildings. Other protection solutions cover TV- tower antenna systems, industry, hospitals with very sophisticated electronic equipment, railway centres, photovoltaic systems, wind power electro generators, water power plants, etc.

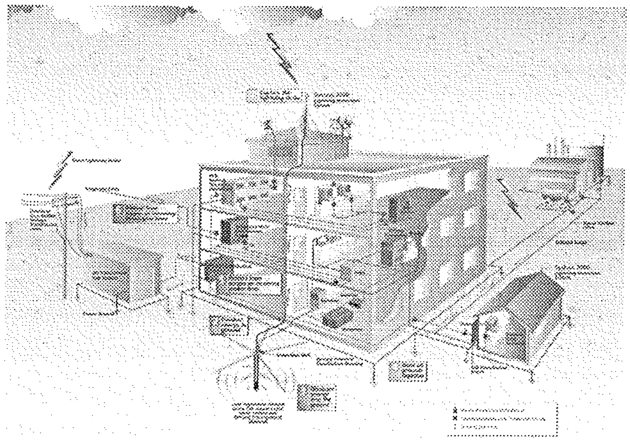

Fig. 1: *Telecommunication centre protected by six system points.*

There are many other cases of protecting small telecommunication centres with different equipment such as digital telephone exchanges and main distribution frame, power supply, broad-band terminals, such as ADSL, ISDN, and radio equipment for global mobile telephone systems.

2.1 Capture the lightning stroke by a designed air terminal at a preferred point

The most commonly used are the lightning rods of the Franklin-type system. Many of them and many down-conductors must be used on tall and large buildings to obtain protection zones in 1 and 2 with local Faraday cages on concrete.

The new approach is presented by an active up-conductor functioning in dynasphere, and one special down-conductor in the system 3000.

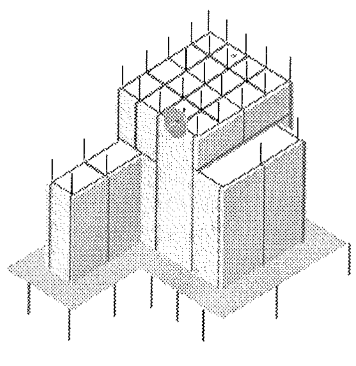

Fig. 2: *Franklin-type system*

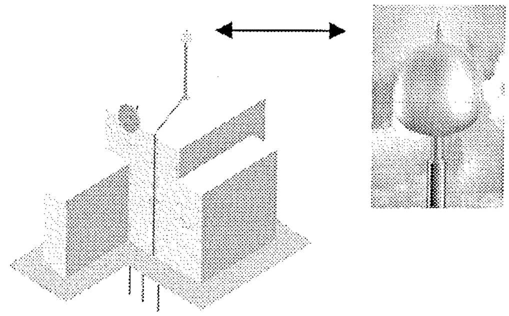

Fig. 3: *Dynasphere system 3000*

The difference between them lies in creating an ambient electric field high in the sharp upper point:

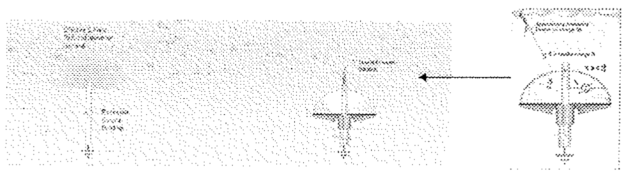

Fig. 4: *Franklin rod on the left, and dynasphere on the right.*

The corona on a Franklin rod masks the ambient electric field, while a dynasphere does not, and the electric field from a dynasphere is high enough to support the lightning leader's propagation.

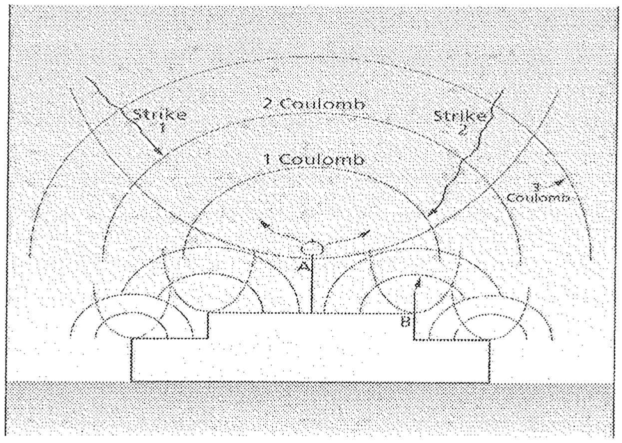

Fig. 5: *With dynasphere a greater volume of lightning capture collection of potential stroke points on a structure (building) is possible.*

2.2 Conduct the lightning to the earth via a designed down-conductor

The down-conductor with high impedance creates dissipation and high inductivity. The armoured earthing cable has 50-times lower impedance and creates no inductive voltages. To prevent inductive effects of the lightning over the down-conductor and diminish the inductivity and resistance of the down-conductor, the earth conductor is composed of twisted Cu wires, special isolation and shielding.

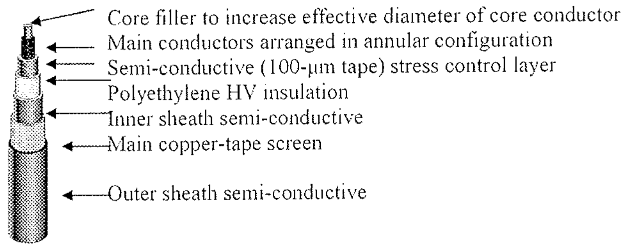

Fig. 6: A core shielded down-conductor. Screened, insulated down-conductors convey the lightning discharge current to the earth with minimal danger of side flashing.

2.3 Dissipate the energy into the earth with minimal rise of the earth potential

The connections must have an appropriate mass and material resistant to corrosion, in order to maintain the original low resistance for as long as 40 years. The rod's resistance depends on the length, the surroundings and the integrity of joints. Very important for the earthing is soil resistivity that ranges from 1 Ohm to 50 Ohm per meter in loam and up to 10,000 Ohm per meter in limestone or granite and basalt. Here the effect of temperature is to be considered. With low temperatures, the resistivity of the soil increases dramatically.

2.4 Bind to create an equipotential ground plane and eliminate the earth loops by low impedance of the earthing system

Bonding means interconnecting of all earth electrode systems: the electrical earthing system, the lightning earthing system, the cable-earthing system and the telecommunications earthing system. This connection of all conductive objects, internal and external, to the facility, will ensure a voltage difference close to zero during the rise of earth potential.

The interconnecting components: earth bars, earth plates, ring earthings; fence and gate jumpers; equipotential mesh and mats; masts, water pipe clamps; transient earth clamps.

2.5 Protect the incoming power circuits, the building, the people and the equipment at the power supply side

The installation, coordination and isolation categories and classification of the lightning and overvoltage arresters in the power supply net

In the protection zone 0/1 at the building entrance before the electrical counter or after it, depending on the rules of the electrical distribution company, the SPDs for direct lightning stroke of Class I are installed. The varistor SPDs Class II follow in the distributor box in the protection zone 1, and the Class III SPDs before the protected equipment. The SPDs must sustain the isolation coordinates from 6 kV, 4 kV, 2.5 kV to 1.5 kV, always in step with the residual voltage U_{res} for the next lower category. Thus, according to the IEC standard 616431, Class I SPDs must have residual voltage < 4 kV, Class II SPDs < 2.5 kV and Class III < 1.5 kV.

Choose and design. The Surge Protection Devices must include the following starting parameters:

The bases are given in the risk assessment according to the IEC 62305-2 Ed. 1 draft standard's maximum connecting voltage:

a. Expected loading of transient appearance. Impulse current, I_{imp} and rated surge current;
b. Desired protection level U_p or permitted residual voltage due to the protected equipment or installation;
c. In the case of damaging the power system, which occurs at temporary overvoltage TOV from the mains and telecommunication system, what situation can be expected?
d. Coordination with other SPDs and fuses in the protection system;
e. Maximum permissible current;
f. Frequency ranges;
g. Contact fields between SPDs, lines and equipment;

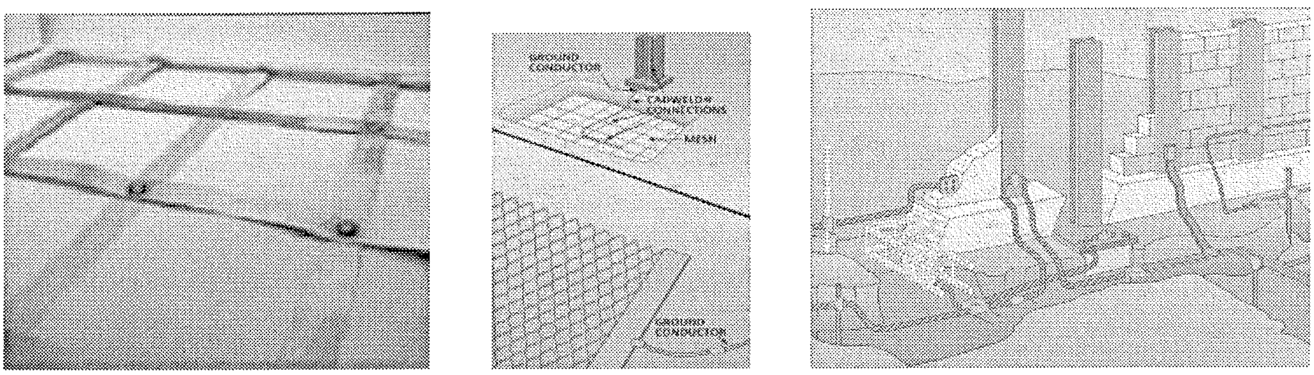

Fig. 7: Examples of earthing

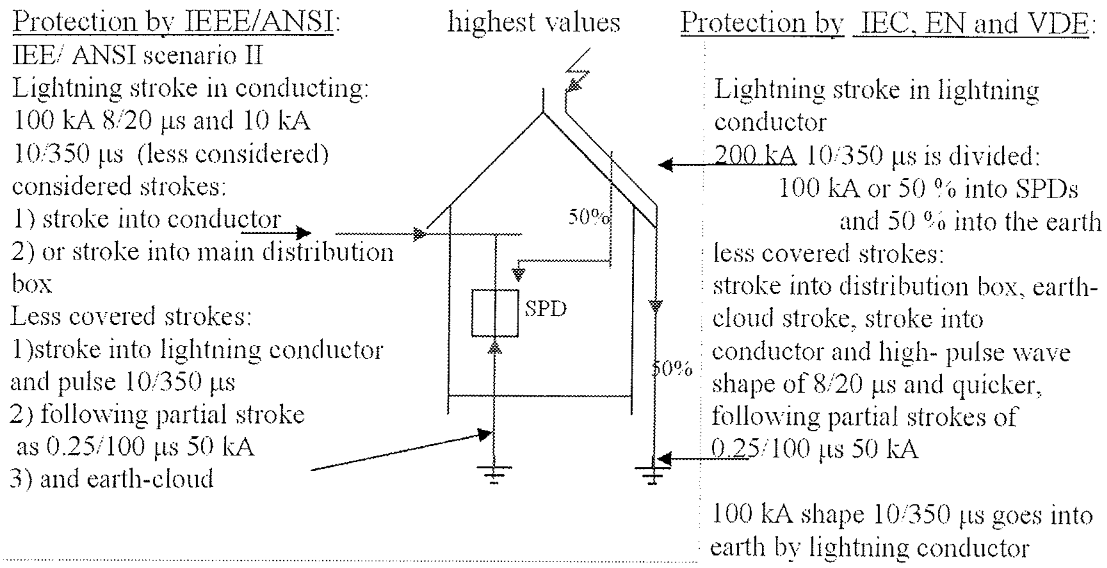

Fig. 8: The main difference between the IEC standard by TC 81 and the IEEE/ANSI standard. The IEC standard protects against lightning stroke into a lightning conductor that conducts half of the current value into the earth and the other half is disposed by metal conductors. The IEEE standard protects against lightning strokes that come through conductors into the building, and strokes from the earth to SPDs.

First the structure of the building must be considered and where the protection is required.

SPDs in power systems:

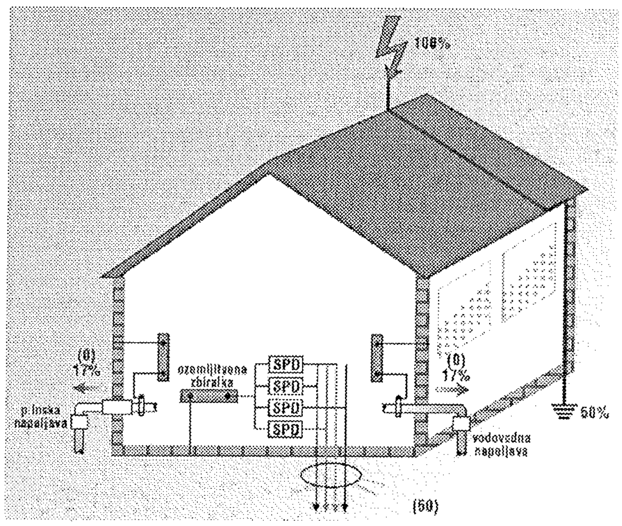

Fig. 9: Examples of diversion of lightning current into the external services (TT system IEC 61643-12) in the building.

In the case of a very rare 200 kA direct lightning stroke of a pulse of 10/350 µs shape into the building, 50 % or 100 kA would go to the ring earth electrode through points 1-4 of the protection plan, 17 % or 34 kA to the metal water pipe and 17 % to the metal gas pipe. The remaining 16 % or 32 kA would go into two SPDs with 8 % or 16 kA each on the phase and neutral conductor. In the case there are no metal pipes, 50 % would go to the earthing ring and 50 % or 100 kA would go to the SPDs.

The device is composed of five groups of 5 x 6.5 kA 8/20 µs varistors and five tripolar gas tubes on five thermal disconnection fuses. Such device can be replaced in future by a double-sided single-varistor SPD in combination with a new gas tube. The dimensions of the above-mentioned American SPD are 882,000 mm^3. Ours has 94,000 mm^3.

The selection of protecting level U_p depends on the maximum continuous operating voltage U_c of the protecting elements and SPD, and on the testing IEC category current pulses:

I_{imp}	Class I	test with wave shape - 10/350 µs
I_n	Class II	test with wave shape - 8/20 µs
U_c	Class III	test with wave shape - combination of 1.2/50 µs and 10/350 µs

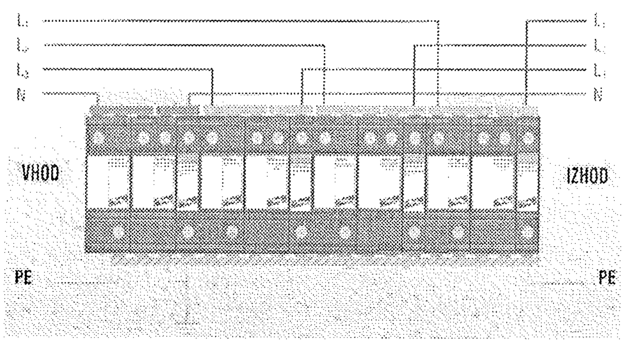

Fig. 11: For the rural net with 36 A in TNC-S systems with four-pole protection SPDs for I_{imp} total 100 kA 10/350 µs are used in three steps: lightning arrester - Class I; inductive coupling - 36 A; and varistor - Class II for each conductor. Total width of the 63 A version is 26 TE to 30 TE, depending on the producer, or 432 mm to ca 500 mm, and up to 2,200,000 mm^3.

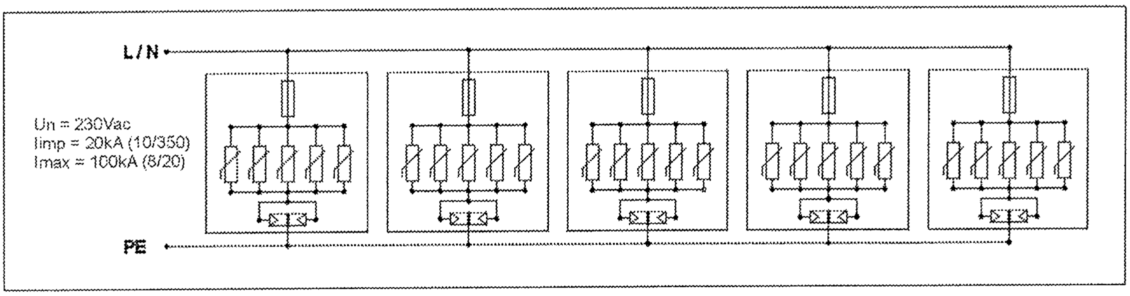

Fig. 10: Electric circuit of the one-pole active SPD with different protection components. The SPD for one conductor, developed in America and Australia, has 100 kA 8/20 μs capability and 20 kA of 10/350 μs.

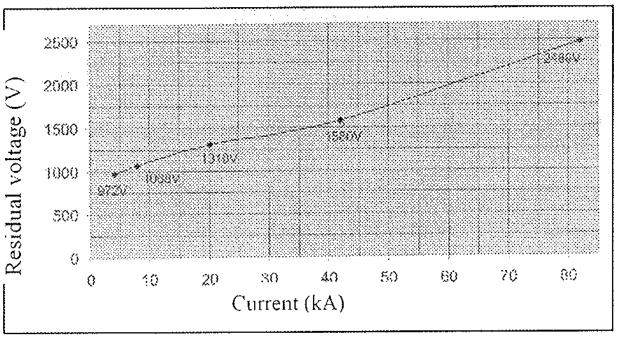

Fig. 12: Diagram of a varistor SPD's residual voltage

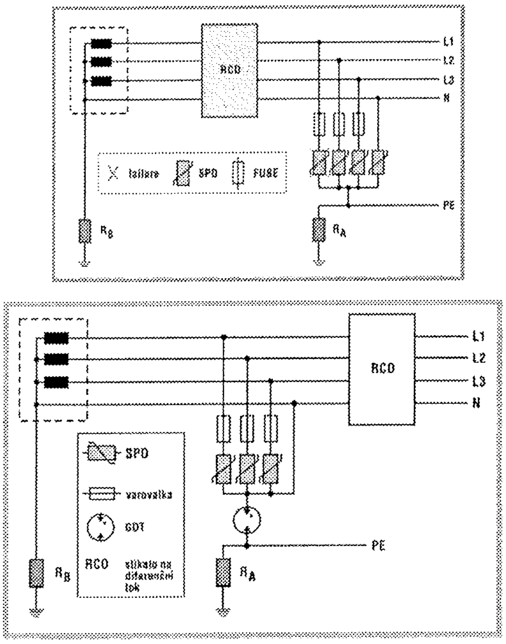

Fig. 13: The correlation between the SPD and the protecting elements in TT systems

2.6 Protect the telecommunication and data circuits to prevent equipment damage and the cost of operational downtime

SPDs in IT systems

The information technology is considered to sustain lesser strokes and SPDs of maximum 40 kA 8/20 μs pulse.

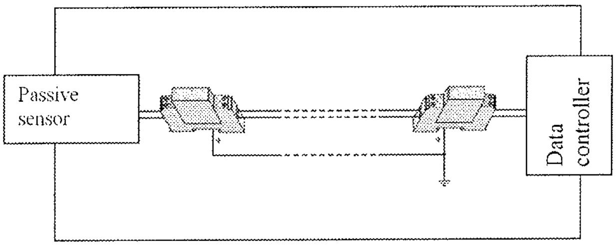

Fig. 14: Protection by SPDs in information

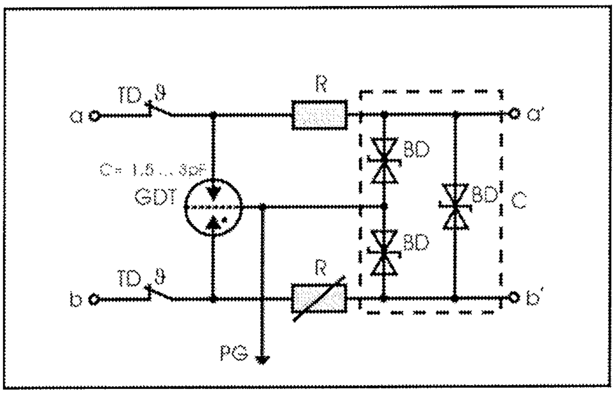

Fig. 15: Typical information protection circuit

SPDs in Telecommunications

If a telephone exchange has many telecommunication lines 2.5 to 5 kA of 8/20 μs per conductor would do. However, external lightning protection in points one to four and a properly chosen point five for power supply protection must be completed. Telecom equipment is also highly endangered from the power supply side. It often includes very tall aerials that attract the direct stroke of lightning into the building.

In such cases, in a well-protected building with pipe metal lines and protection Faraday cages, only gas tube GDT protection with current protection for possible "power contact" from the mains is allowed, according to the ITUT standards K20 and K44. For terminal protection at least 10 or 20 kA 8/20 μs pulse rigidity is recommended and SPD protection in several stages to lower the residual voltage.

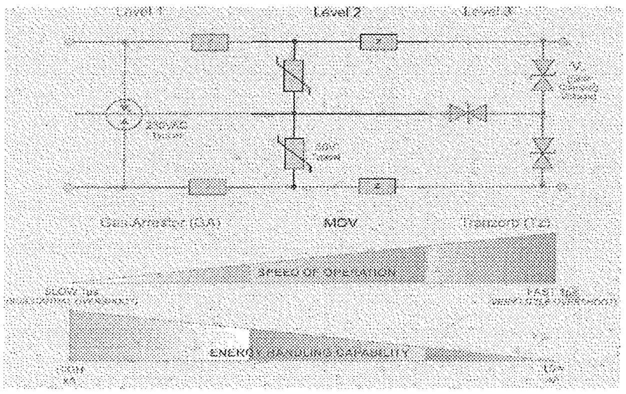

Fig. 16: The working conditions of protecting elements in telecommunications along the line. Coordinated components lower the residual voltage before the entry of the protected equipment.

SPDs as equipotential sparks based on own Gas Discharge Tubes (GDTs)

When the equipotential levels on the earthing electrodes from different buildings are not the same as usual, the electrodes should be connected together by a conductor.

In such a case a galvanic current would flow and, with time, damage the electrodes by corrosion. To prevent this, SPDs must be inserted between the electrodes and the lightning. They are available in two versions: incapsulated in an insulation tube or open.

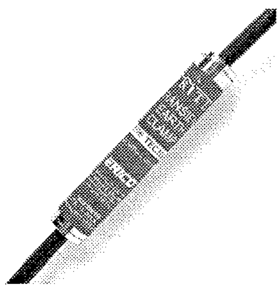

Fig. 17. Own earth 100 kA gas discharge tube

Fig. 18. Incapsulated in insulation tube

3. Conclusion

Statistical level of maximum atmosphere discharges / international standards:

Parameter	Protection class		
	I	II	III-IV
Pulse current I (kA):	200	150	100
Energy W/R (MJ/Ω):	10	5,6	2,5
Charge (pulse) (As):	100	75	50
Charge (duration) (As):	200	150	100
Effectively:	98%	95%	80-90%

Insurance companies statistically survey the damages caused by discharge and overvoltage. In Germany, the average costs in the apartment buildings through the years were given by GDV e V, Berlin, in 2001. The average costs of the damages through overvoltages in the past years in Germany were ca 30 %. However, 19 % came from unknown causes, and half of the probability 51% could also be attributed to overvoltages.

A brief comparison between different SPD components:

spark gaps, metal-oxide varistors and semiconductive protective elements, quick diodes and thyristors

- Self-standing spark gaps open in ca 1 μs' time and the residual voltage is high, ca 4 V;
- Varistors open in 0.0025 μs, the residual voltage at U_n of a 320 V varistor is lower, with ca 1000 V on the same I_{imp} 25 kA 10/350 μs; and
- Quick diodes open in picoseconds, but deal with lower powers and voltages only.

Spark gaps have a huge potential of current and energy, but they frequently provoke high short currents after ionisation. These, coming from the mains, are very often several times higher than the lightning current itself that opens the spark gap. After a certain period of strokes, the metallization of the internal parts of airgaps can be expected. Because of their voltage-depending characteristics, varistors do not have the follow-up current inconvenience, but with strokes they lose their properties and must have thermal protection against fire and TOV. To avoid thermal runaway and destruction, they should be over-dimensioned.

Protective quick-response diodes are still too weak in energy consumption and are mostly used in groups to multiply their capabilities, or with other protection components.

Thyristors work like switches. After clamping voltage, the voltage to continue the high conductivity is very low. Stroke values of ca 300 A at 10/700 μs on 300 V thyristors are common, but the self-extinguishing effects for mains protection applications are not properly present.

Thus the best way is to combine the good and the bad properties of each component in an SPD. To explain all existing solutions would be a long story.

First of all, some modelling of the lightning protection system is new:

Modelling of the lightning channel;

Modelling of the lightning protection structure;

Modelling of the earth conductor;

The first leads to modelling the current of lightning and the electric field due to the lightning stroke. The lightning protection structure is modelled similarly to the static state on protected zones. The incoming current is the base of mathematical simulation and calculation of the earth resistance or transient impedance.

The present-day procedures for lightning protection are based on a lightning channel in the frequency domain, lightning catching rods and earthing structures. The transient impedance of the earthing electrode was calculated by approximation of the conductor line. The problem of the earthing impedance can be modelled precisely only through the model of the antenna theory, where the radiation principles are really involved.

The new, complete model is based on the frequency and time analysis. The latter is more practical and less sophisticated, since the transformation from one into the other would cause several ten thousands of transformations.

4 References

/1/ Kristian Leonard Chrzan: "*Wysokonapięciowe Ograniczniki Przepięć*" D.W.Edukacyne Wroclaw 2003

/2/ A.Pregelj,V.Murko,A.Pirih,F.Brecelj,M.Bizjak:"*Razvoj energetskih plinskih odvodnikov*"; 5. konferenca o materialih in tehnologijah 2003-12-22

/3/ V.Murko: "*New systems of lightning and overvoltage protection*".Predavanje v Bialsko Bialem in Czsenstohowi Poljska junij 2003

/4/ VisacroS.;SilveiraF.H.: "*Evaluation of current distribution alonge the discharge channel by an electromagnetic model*" (1a.6) ICLP 2002 Cracow, Poland, pp 42-45

/5/ Hasse P., Zehlman P.: "*Lightning currents and overvoltages arrester for universal use*" (6.p.8) ICLP 2002 Cracow, Poland, pp 516-520

/6/ "*Facility Electrical Protection*" ERICO 2003

/7/ WadaA.;AsakawaA.;ShindoT.:"*Luminous phenomenon during upward leader development - lightning observational results at 200 m high chimney*" (1a.1) ICLP 2002 Cracow, Poland, pp 3-7

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Prispelo (Arrived): 10.09.2004 *Sprejeto (Accepted): 30.11.2004*

BIOLOGICAL AND HEALTH RELEVANT EFFECTS FROM EXPOSURE TO HIGH-FREQUENCY EMF

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INVITED PAPER
MIDEM 2004 CONFERENCE
29.09.04 - 01.10.04, Maribor, Slovenia

Key words: high frequency electromagnetic fields, HF EMF, health effects of EMF, protection against EMF, athermal effects of EMF

Abstract: Electromagnetic fields are a constant companion of modern civilisation. It is undeniable that modern life is unthinkable without its ubiquitous presence. However, it is the responsibility of science to implement these technical achievements in such a way as to minimise adverse effects to humans and the environment. Concerning potential biological and health effects of high-frequency electromagnetic fields there exists a scientific controversy lasting for almost 50 years. There is agreement that immediate, acute reactions from increased temperatures due to absorption of electromagnetic energy exist and that adverse outcomes or even death may occur as a consequence of these thermal effects. However, there is disagreement about the existence of non-thermal or athermal effects and the role for human health of low-level exposures that do not result in a relevant temperature increase.

Epidemiological studies (especially about brain tumours and leukaemia) point to a moderately increased risk in subjects exposed to diverse types of high-frequency electromagnetic fields. Particularly prolonged exposure to mobile telephones seems to be associated with an elevated risk to develop brain tumours and maybe other malignancies localised in the head.

Animal experiments provide at most limited support to the assumption of a carcinogenic potential of high-frequency electromagnetic fields. However, most studies have severe methodological limitations and cannot contribute to risk assessment.

Biološke in zdravstvene posledice zaradi izpostavitve visokofrekvenčnim elektromagnetnim poljem

Kjučne besede: visokofrekvenčna elektromagnetna polja, vpliv EMF na zdravje, zaščita pred EMF, atermični vplivi EMF

Izvleček: Elektromagnetna polja so stalen spremljevalec moderne civilizacije. Ne moremo zanikati, da si modernega življenja ne znamo več predstavljati brez njihove prisotnosti. Odgovornost znanosti je, da vpelje tehnološke dosežke na ta način, da zmanjša njihove škodljive vplive na ljudi in okolje. Glede možnega vpliva visokofrekvenčnih elektromagnetnih polj na biološke sisteme in zdravje v znanstvenih krogih v zadnjih petdesetih letih vladajo nasprotujoča si mnenja. Obstaja strinjanje, da je možna takojšnja, akutna reakcija na povečanje temperature zaradi absorpcije elektromagnetne energije, ki lahko povzroči škodljive posledice ali celo smrt. Obstaja pa dvom, da nizkoenergijska sevanja, ki ne povzročajo povišanja temperature prizadenejo človekovo zdravje, oz. da taka sevanja sploh lahko imajo atermične efekte.

Epidemiološke študije (še posebej o možganskih tumorjih in levkemiji) kažejo na nekoliko povečan rizik pri osebah, ki so bile izpostavljene različnim visokofrekvenčnim elektromagnetnim poljem. Še posebej daljša izpostavljenost mobilnim telefonom kaže na povečan rizik razvoja možganskih tumorjev in mogoče še kakšnih drugih malignih tvorb v glavi.

Tudi poskusi na živalih nam podajajo omejene dokaze, ki bi podprli predpostavko o potencialni karcinogenosti visokofrekvenčnih elektromagnetnih polj. Večini študij lahko očitamo resne metodološke omejitve in le redke bistveno prispevajo k oceni rizika.

1. Introduction

Nothing is more central to modern technologies than electromagnetic fields (EMF). Since the middle of the 19th century electricity gradually replaced the steam engine and already a few years after Heinrich Hertz's experiments in the 1880ies demonstrating that EMF have exactly the properties predicted by Maxwell's equations (that unified the theories of electricity, magnetism and optics) radio broadcasting stations started to transmit regular programs all over the world. Military purposes accelerated the development of powerful and efficient radar technologies as well as applications of radio frequency (RF) fields during world war II. Miniaturisation of electric circuits made necessary by space flights led to the digital revolution we do experience in our days. Introduction of computer technology into telecommunication began to fundamentally change our habits in the 1990ies due to the introduction of digital cellular telephones. This process turned a whole branch of industry upside down, and rapidly changed a system (the analogue wired telephony) that remained almost unchanged for about 100 years.

All these new applications supplied us not only with a lot of new tools but changed also our environment. While the steam and smoke of the early days of industrialisation could be seen and smelt, and in some areas like the German Ruhrgebiet or the Manchester area hid the sun like a big cloud, emissions from these new facilities, like broadcasting towers, radar stations and high-voltage lines, can neither be seen nor smelt and therefore were more or less neglected. Only few critical comments concerning potential adverse health effects of EMFs can be found before the early 1950ies.

During world war II some physicians noted health relevant reactions in radar personnel and therefore safety limits were introduced in some countries for military (and also in some occupational) areas. In 1953 a report of McLaughin /1/ about a cluster of leukaemia cases accusing radar exposure as a potential cause was answered with disbelief by the scientific community. Also research from Boysen /2/ in rabbits demonstrating haemorrhage and tissue necrosis in almost all organs from exposure to a 300 MHz RF field was answered with scepticism by the scientific community, although the microwave oven was already invented and tissue heating from high frequency exposures should have been expected.

In 1957 a case of death from an unknown amount of microwave energy had a great media coverage and led, in the Western World, to the onset of serious research and raising of research funds. In a sense this sad event can be said to be the starting point of the EMF controversy as well as of co-ordinated research. Barron and Baraff /3/, physicians at Lockheed Aircraft Corporation, published a study initiated by these startling findings in the influential Journal of the American Medical Association in 1958 comparing radar personnel with unexposed controls concerning differential blood count and other parameters. Authors concluded that there is no reason for concern as long as the precautionary measures (defining an area that exceeds a power density of 131 W/m^2 that should not be accessed) are observed. However, taking a closer look at their data a significant difference in monocytes and eosinophils between workers exposed for four years or longer and controls can be detected. This effect was obscured by combining the data from the whole workforce, the majority of which was employed for one or two years only. Already this first human study revealed a rather superficial consideration of facts in some parts of the scientific literature.

2. Effects of high frequency EMF

During the 1960s and 1970s the pioneering work of several groups of researchers clarified some of the basic problems of the interaction between high-frequency EMF and biological tissues. The strong frequency dependency of the interaction reflected by different relaxation modes was one of the key findings, although the microscopic reasons for the macroscopic differences in dielectric constants or conductivity spanning several orders of magnitude for the frequency range between several hundred Hz and several GHz are less well understood. Schwan /4/ concluded in 1978: "Among the established effects in biological systems the most important is heat development but direct field interaction with membranes, biopolymers, and biological fluids are all possible". Despite these various possibilities the focus was on the most simple and prominent effect: elevated temperatures from absorption of electromagnetic energy. Subsequently the concept of specific energy absorption formed the basis for exposure standards in most western countries. A different approach was followed in the former Soviet Union, China, and many other eastern countries: they started from observations in humans and studied biological reaction in animals and isolated tissues without basing their research on a thermal effects concept but were interested in health relevant effects in a broader sense. Furthermore, completely different models of the interaction of EMFs with biological molecules and tissues were developed that were recognised only recently by western scientists (e.g. resonance phenomena in the presence of the earth magnetic field and weak alternating magnetic fields).

Only for power-frequency fields there was some public awareness, especially concerning high-voltage lines. High-frequency fields were almost completely neglected by the media until the advent of modern telecommunication that was accompanied by the installation of thousands of mobile-phone base-stations in the midst of densely populated areas. The controversy about potential adverse health effects from exposure to high-frequency EMF, that was more or less confined to the scientific community, extended to the political and economical sphere which made the task to come to a balanced conclusion not easier. Furthermore, preventive concepts that were developed in the past 50 years and guided decisions about exposure standards for environmental and occupational pollutants were not or not fully adopted for EMFs.

2.1 Dosimetry

The guidelines /5/ of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) date back to the deliberations of the subcommittee of the Institute of Electrical and Electronics Engineers (IEEE) that prepared the exposure standard for the American National Standards Institute and is known as the IEEE standard C95.1 /6/. Although ICNIRP deviated in several points from the IEEE standard, the basic concept of issuing a single basic restriction that is formulated in terms of the specific energy absorption rate (SAR) for the total range of high-frequencies up to about 10 GHz and deriving at reference levels by using the relationship between frequency of the incident field and SAR, has been adopted.

SAR is defined as the time derivative of specific energy absorption (SA). SA is defined as the quotient of the incremental energy absorbed by, or dissipated in, an incremental mass. SAR is proportional to the square of the internal electrical field strengths and also proportional to the temperature increase in the exposed organism or tissue. The SAR concept is characterised by the view that SAR is the fundamental dosimetric parameter in the frequency range from 10 MHz to about 10 GHz from which exposure limits can be derived, as expressed by ICNIRP /5/: "...these guidelines are based on short-term, immediate health effects such as ... elevated temperatures resulting from absorption of energy during exposure to EMF." (p.496). The great strength of this concept is its independence from characteristics of the incident field. However, it is a macroscopic concept and introduces a gross simplification, maybe an oversimplification, even if only energy deposition is concerned.

Due to the complex structure of biological tissues with grossly different dielectric properties an exact computation of SAR or SA is impossible. Therefore, for computational purposes as well as for the operationalisation of measurements simplifications are necessary. Usually measurements are conducted using phantoms filled with an electrolyte gel or liquid with defined dielectric properties. This procedure will result, at least for electrolytes which are deliberately chosen to give conservative estimates, in an upper limit for the SAR. However, this statement holds only for a big enough volume element and for exposures that are within one frequency range only (that is, not consisting of simultaneous exposure to several EMFs with strongly different frequencies). The multi-layer structure and specific form of tissues result in a considerable heterogeneity of absorption, which could not be completely accounted for by these measurements. It has to be borne in mind that as the field travels through tissues its wavelength and direction changes and the more so the higher the absorption. The depth of penetration into tissues is inversely related to the rate of absorption, thus tissues embedded into fat or bony structures will be exposed to higher internal field strengths as tissues that are surrounded by liquids. However, the measurement of the dielectric properties of tissues is very complicated and if done outside the living organism the rapid loss of extra- and intracellular fluid will result in a hardly quantifiable bias. The best currently available data concerning these properties can be found in Gabriel et al. /7,8/. However, recent measurements /9,10/ indicate that the values used so far may not be correct.

On the other hand computational methods like FDTD (finite difference time domain) could in principle be used to assess the distribution of energy absorption within the body. But also such methods have their limitations. Even if data from computerised tomography are utilised, the necessary simplifications that have to be applied in order to keep computational efforts within reasonable limits are apparent. Besides the mentioned fundamental limitations the measurement (and computational) errors have to be considered. At present it seems that even the best equipment results in a net coefficient of variation of not much less than 30%, a figure that seems untenable for regulatory purposes.

The main criticism however is related to the focus on the energetic aspect. The interaction of the electromagnetic field with the organism is restricted to the ensemble effect of the resulting increase of the kinetic and rotational energy of charged and polarized particles, which is reflected by a temperature increase. In the WHO Environmental Health Criteria from 1981 it is said about SAR that "it may not be the only factor, e.g. frequency and/or modulation of the radiation field may strongly affect biological effects. Consequently, the nature of the radiation fields should always be considered in addition to the SAR" (UNEP/WHO/IRPA /11/, p.45).

SAR is a rate. Hence the question arises about the role of duration of exposure. Using SAR as a basis for exposure limitations, implies that exposure duration plays no decisive role. While this is questionable for low intensities, it is surely wrong for high exposures. If the exposure exceeds the capacity of the organism to dissipate the heat induced by the absorption of electromagnetic energy, tissue damage and even death may occur. Thermal death could result from severe hemorrhage and tissue damage or from cardiac failure. Results from earlier studies /12-17/ on thermal death are summarized in fig 1. Data from four species indicate that time to thermal death is roughly inversely related to SAR. Hence thermal death occurs (over a wide frequency range) at a constant SA value. This value is approximately 95 kJ kg^{-1}. However, the data are compatible with an SAR asymptote of 2 to 5 W kg^{-1} (indicating that SAR values below this range would not result in thermal death even at indefinite exposure duration). This is in line with the observation that exposure at about 4 W kg^{-1} leads after a steep temperature increase to a steady state. However, it is not known how long this steady state can be maintained and whether the regulatory efforts of the organism results in any long term adverse effects.

Another point which is also of importance (and which led Italy not to adopt the SAR concept in its regulations) is the fact that while it is intrinsically an effect meter (that is a biophysiological response variable) it is practically impossible to demonstrate the compliance with any standard expressed in its terms in the exposed individual. In occupational medicine there are similar measures (biological tolerance limits), however, in these cases it could be shown for every exposed subject whether or not the limit has been exceeded.

It has been argued that SAR is important due to the possibility to compare exposures between species and frequencies. However, as has been stated in UNEP/WHO/IRPA / 11/: "...SAR alone cannot be used for the extrapolation of effects from one biological system to another, or for the extrapolation of biological effects from one frequency to another." (p.45). The problem here could be readily demonstrated by reference to the discussion concerning the applicability of results from animal experiments to human exposures. Should exposures be scaled to parallel relative absorption (for every pair of species A and B, e.g. mice and humans, there is a unique function S of frequency that results in equal relative absorption rates: SARr,A(f)=SARr,B(S(f)) in W kg-1 (W m-2)-1 for all frequencies f within a certain interval)? Using the same frequency for both species will generally result in completely different patterns of absorption within the organisms, using the scaled frequency will make the pattern more similar, however, the frequency 'seen' by the cells will be different. This issue cannot be resolved without a sound theory of the mechanisms underlying the effect in question. If only SAR counts then it is completely irrelevant which frequency is chosen for the experiments as long as the SAR is held constant within reasonable limits. If frequency counts then the SAR concept is invalid because SAR is a function of frequency. It should be noted that these arguments are, ceteris paribus, also applicable to local absorption rates.

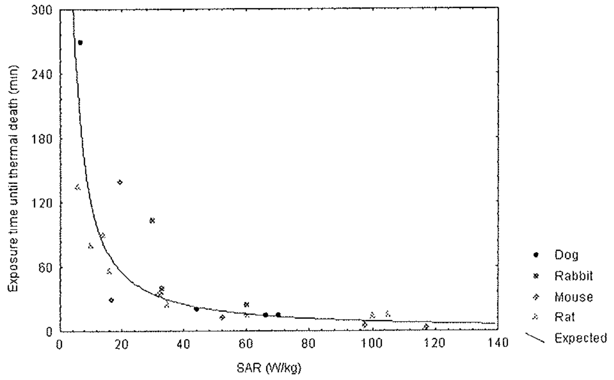

Figure 1: Relationship between SAR and time until thermal death for four species. Expected time to thermal death computed as inverse function of SAR

The strongest argument against the SAR concept might be formulated as follows: If there is a unique relationship between the incident electromagnetic field and SAR then SAR is superfluous and could readily be replaced by the far more precise measurement of external field strength. If there is no unique relationship then the properties of the relationship between body and field responsible for the lack of uniqueness will reduce the credibility of SAR estimates based on crude models as those generally applied. Hence the SAR concept is either easily dispensed of or inapplicable due to practical limitations.

2.2 Epidemiological Studies

Because most epidemiological studies relevant to public health are retrospective, exposure assessment is usually a weak point. Often exposure is categorised in classes (e.g. high, medium, low exposure) or is only dichotomised (exposed vs. non-exposed). The problem in the study of high-frequency EMFs, however, is additionally complicated by the fact, that it is not known which exposure parameters are associated with a possible outcome. Quantitative assessment of exposure is useless without this knowledge. It has frequently been stated (e.g. /18/) that epidemiological studies should give sufficiently comprehensive information about exposure to allow the determination of the relevant dosimetric parameters (that is of SAR in the case of high-frequency EMF). While a more detailed presentation of exposure characteristics should definitely be supported, it should be borne in mind that SAR cannot be considered an established dosimetric parameter for long-term and complex exposure conditions. In real life exposure conditions, the incident EMF, changes all the time in many aspects: in its intensity, direction, spectrum, wave form etc. There is no evidence that equal SAR from different combinations of exposure parameters results in equal long-term effects. Hence it is too early to condense exposure conditions into such a quantity. On several occasions ICNIRP pointed to the problem of exposure assessment without specifically justifying why results from studies that "...suffer from very poor assessment of exposure..." (p.504), that "...generally lack quantitative exposure assessment" (p.504) should be doubted. In fact, the same deficiencies are apparent in many studies on asbestos exposure, on formaldehyde, on passive smoking to name but a few with similar public awareness. All that is needed in epidemiological studies is a gradient of exposures. The steeper the gradient the higher the probability to detect an elevated risk if actually there is one. Furthermore, it should be stressed that in most cases exposure misclassification leads to a bias towards the null hypothesis of no association. Poor exposure assessment could therefore be an argument against studies reporting no effect. The evidence from studies reporting a significant risk, provided the study meets basic principles of scientific conduct, can only be dismissed by other evidence supporting the assumption that the deviation occurred by chance or by demonstrating empirically that the risk enhancement is due to the action of confounding factors. Only postulating such hypothetical factors does not conform to scientific reasoning.

Table 1 gives an overview of the results of epidemiological studies that investigated brain tumours as a major endpoint. Before 2000 studies were either dedicated to the analysis of occupational radio-frequency (RF) or microwave (MW) exposure or to exposures from emissions of radio or television towers. In the years thereafter studies focused on a potential brain tumour risk from exposures to mobile phones.

The major problem in these latter studies is the comparatively short period of time such devices are used on a greater scale. Brain tumours, like most other malignancies, need long times to develop, and decades of exposure may be necessary to consistently detect an increased risk. In the majority of investigations mobile phone use was short (less than two to three years) in most subjects included in the studies. It is of significance that in those few studies that approached meaningful latencies in a considerable proportion of study participants an increased risk was observed.

It has been argued that it is unlikely that microwave exposure from mobile telephone use induces brain tumours, rather a promotional effect may occur. Therefore, it was stated, also short and recent exposures may have an effect that could be detected in epidemiological studies. While it is in line with experimental research that microwaves at low intensities do not induce genetic alterations, a contribution of MW exposure during initiation phase is still possible. Furthermore, it is neglecting basic features of the process of carcinogenesis if it is assumed that recent exposures play a role in promotional processes. One has to differentiate between promotion of a precancerous cell clone and growth of an already established tumour. It is possible that factors that affect promotion do also have an impact on tumour growth, however, brain tumours of high malignancy have such a fast growth rate that it is impossible to detect an influence of any factor in an epidemiological investigation. Hence an influence on growth rate can only be detected for low grade slowly growing tumours. Therefore, the predominance of high-grade tumours in some of the investigations will reduce the determined risk.

If the predominant effect of exposure to MW is on growth rate the expected effect on estimates of incidence ratios will be small due to the short exposure duration. The shift in age-incidence function can only be a fraction of the exposure duration and hence is a function of the population gradient of the age-incidence relationship which is small for brain tumours. However, if an effect on promotion is assumed (with or without affecting the growth rate of an established lesion) and the exposure is early and long-term then the expected effect on incidence is high, higher even than for factors that induce genetic alterations.

Overall, from 18 studies on brain tumour risk and exposure to high-frequency EMFs 13 found elevated risks 6 of which were statistically significant. This is a clear indication of a possible association and warrants further study.

Except brain tumours malignancies of the haematopoietic and lymphatic tissues have been studied in several investigations. The focus on these types of malignancies is due to the pioneering research of Wertheimer and Leeper /40/ on a possible association between childhood cancer and low-frequency magnetic fields. Lymphatic and haematopoietic malignancies were predominantly studied in occupationally exposed subjects or people exposures to radio or TV towers.

Twelve of 16 studies reported increased risks at least for some subgroups, eight of which were statistically significant. For childhood leukaemia the most vulnerable period seems to be the foetal and perinatal period. Unfortunately no study has focused on the time point of exposure. Ecological studies are in general not easily assessed because of a number of potential biases that cannot always be avoid-

Table 1: Synopsis of studies assessing brain tumour risk of exposure to high-frequency EMF

Reference	Study type	No of cases	Exposure		Result
Thomas et al. [19]	CC	435	occupational RF	RR	1.6 [1.0-2.4]
Selvin et al. [20]	E	35	TV tower	RR	1.2 [0.7-1.9]
Tynes et al. [21]	pC	3	occupational RF	SIR	0.6 [0.1-1.8]
Armstrong et al. [22]	nCC	9	occupational PEMF	OR	1.9 [0.5-7.6]
Szmigielski [23]	rC	~47	military (pulsed) RF/MW	SIR	1.9 [1.1-3.5]
Beall et al. [24]	nCC	149	VDT development work	OR	1.3 [0.9-1.9]
Grayson [25]	nCC	230	military RF/MW	OR	1.4 [1.0-1.9]
Hocking et al. [26]	E	30	3 TV towers	$rR_{children}$	0.7 [0.3-2.1]
		600		rR_{adults}	0.8 [0.6-1.1]
Dolk et al. [27]	E	17	TV/FM radio tower	SIR	1.3 [0.8-2.3]
Lagorio et al. [28]	rC	1	dielectric heat sealers	SMR	10 [0.3-55.7]
Finkelstein [29]	rC	16	police radar (possible)	SMR	0.8 [0.5-1.4]
Morgan et al. [30]	rC	51	occupational RF	$rR_{high\ exp.}$	1.1 [0.3-2.7]
Hardell et al. [31-33]	CC	233	mobile telephones	OR	1.0 [0.7-1.4]
		13[a)]	ipsilateral use		2.6 [1.0-6.7]
Muscat et al. [34]	CC	469	mobile telephones	OR	0.9 [0.6-1.2]
Inskip et al. [35]	CC	782	mobile telephones	OR	1.0 [0.6-1.5]
Johansen et al. [36]	pC	154	mobile telephones	$SIR_{>2\ y}$	1.2 [0.6-1.6]
Auvinen et al. [37]	CC	398	mobile telephones	OR_{analog}	1.6 [1.1-2.3]
Hardell et al. [38-39]	CC	1429	mobile telephones	OR_{analog}	1.3 [1.0-1.6]
		93[a)]	ipsilateral use		1.8 [1.3-2.5]

[a)] number of cases of discordant pairs

CC...case-control, E...ecological, pC...population based cohort, nCC...nested case-control, rC...retrospective cohort, RR...relative risk, SIR,SMR...standardized incidence/mortality ratio, OR...odds ratio, rR...rate ratio ed. Nevertheless a moderately elevated risk for development of malignancies of the haematopoietic and lymphatic tissues can be inferred from the evidence compiled so far.

There is only weak support of the assumption of a carcinogenic potential of high-frequency EMFs from long-term animal experiments. There are about 25 studies that can be evaluated. Almost all of them have serious limitations that make an overall assessment impossible. Especially insufficient numbers of animals, an unsuitable choice of induction methods with a too steep decline of survival or too high rates of incidence may be responsible for the predominantly negative findings. None of the studies was conducted according to the recommendations of the US National Toxicological Program.

3. Conclusion

There is a decade long controversy about the existence of long-term low-level effects of high-frequency EMFs. According to the thermal effects principle no health relevant effect can occur without substantial increase of body or tissue temperature from absorption of electromagnetic energy. Therefore the specific energy absorption rate (SAR) is considered the basic dosimetric quantity that is also the focus of exposure guidelines for the protection of human health.

The critique against this concept can be summarised as follows:

- SAR is a macroscopic concept while effects may be due to microscopic interactions at the level of membranes or biomolecules
- SAR cannot account for the complex composition of tissues and gives at best an upper limit within rather big volume elements
- The problem of simultaneous exposure to fields of very different frequencies (e.g. short waves and microwaves) is unresolved with respect to SAR measurement
- SAR establishes an equivalence that has never been empirically demonstrated to be valid, to the contrary for high exposure it is surely invalid, whether it holds for low levels of exposure is unclear
- For thermal death there exists an inverse relationship between SAR and time to death, indicating that exposure duration plays a decisive role, hence SAR as a rate cannot be the basis for calculating exposure limits (if thermal effects are considered SA is definitely the better option!)
- Compliance with a limit value expressed in terms of SAR cannot be demonstrated in the exposed individual
- Measurement and calculation methods of SAR are complicated and result in a high coefficient of variation.

Table 2: Synopsis of studies assessing risk of exposure to high-frequency EMF with respect to haematopoietic and lymphatic neoplasms

Reference	Study type	No of cases	Exposure	Result	
Robinette et al. [41]	rC	49	military radar	SMRr	2.0 [0.9-4.5]
Milham [42]	rC	89	amateur radio	SMR	1.2 [1.0-1.5]
Muhm [43]	rC	2	electromagnetic pulse	SMR	3.3 [0.4-12.0]
Selvin et al. [20]	E	51	TV tower	RR	1.0 [0.7-1.4]
Tynes et al. [21]	pC	9	occupational RF	SIR	2.9 [1.3-5.4]
Armstrong et al. [22]	nCC	807	occupational PEMF	OR	1.0 [0.5-1.9]
Szmigielski [23]	rC	~155	military (pulsed) RF/MW	SIR	6.3 [3.1-14.3]
Mascarinec et al. [44]	E	12	military radio tower	SIR	2.1 [1.1-3.7]
Hocking et al. [26]	E	59	3 TV towers	$rR_{children}$	2.3 [1.4-4.0]
		847		rR_{adults}	1.2 [1.0-1.4]
Dolk et al. [27]	E	45	TV/FM radio tower	$SIR_{0\text{-}2km}$	1.2 [0.9-1.6]
		51		$SIR_{1\text{-}5km}$	1.4 [1.1-1.9]
		935		$SIR_{0\text{-}10km}$	1.0 [1.0-1.1]
Dolk et al. [45]	E	759	20 TV/FM radio towers	$SIR_{1\text{-}5km}$	1.1 [1.0-1.2]
Lagorio et al. [28]	rC	1	dielectric heat sealers	SMR	5.0 [0.1-27.9]
Finkelstein [29]	rC	20	police radar (possible)	SMR	0.7 [0.4-1.0]
Morgan et al. [30]	rC	203	occupational RF	$rR_{high\ exp.}$	0.7 [0.3-1.5]
Johansen et al. [36]	pC	84	mobile telephones	$SIR_{>2\ y}$	1.5 [0.5-3.2]
Michelozzi et al. [46]	E	40	radio station	SMR_{adults}	1.8 [0.3-5.5]
		8		$SIR_{children}$	2.2 [1.0-4.1]

E...ecological, pC...population based cohort, nCC...nested case-control, rC...retrospective cohort, RR...relative risk, SIR,SMR...standardized incidence/mortality ratio, SMRr...ratio of SMR, OR...odds ratio, rR...rate ratio

Evidence from epidemiological investigations, most of which have focused on brain tumours or leukaemia, points to a moderate risk associated with occupational or environmental exposure to high-frequency EMFs. Mobile phone use, in particular, may be associated with a slight increase of the risk to develop brain tumours or other malignancies localised in the head. Support of these epidemiological findings from animal experiments is weak, which may be due to the non-existence of a risk or to methodological limitations apparent in most of these studies.

4. References

/1/ J.R. McLaughin, *A Survey of Possible Health Hazards from Exposure to Microwave Radiation*. Hughes Aircraft Corporation, Culver City, 1953

/2/ J.E. Boysen, Hyperthermic and pathologic effects of electromagnetic radiation (350 Mc), *A.M.A. Arch Indust Hyg.* 7, 1953, 516-525.

/3/ C.I. Barron, and A.A. Baraff, Medical considerations of exposure to microwaves (radar). *J.A.M.A.* 168, 1958, 1194-1999.

/4/ H.P. Schwan, Classical theory of microwave interaction with biological systems, In L.S. Taylor, and Y. Cheung (eds.) *Proceedings of a Workshop on the Physical Basis of Electromagnetic Interactions with Biological Systems*, US DHEW document No. HEW-FDA 78-8055.

/5/ International Commission on Non-Ionizing Radiation Protection (ICNIRP), Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz). *Health Phys.* 74. 1998, 494-522.

/6/ Institute of Electrical and Electronics Engineers (IEEE), *IEEE standard for safety levels with respect to human exposure to radio frequency electromagnetic fields, 3 kHz to 300 GHz*. IEEE Std C95.1, 1999 Edition.

/7/ S. Gabriel, R.W. Lau, C. Gabriel, The dielectric properties of biological tissues: II. Measurements in the frequency range 10 Hz to 20 GHz. *Phys Med Biol.* 41, 1996, 2251-2269.

/8/ S. Gabriel, R.W. Lau, C. Gabriel, The dielectric properties of biological tissues: III. Parametric models for the dielectric spectrum of tissues. *Phys Med Biol.* 41, 1996, 2271-2293.

/9/ G. Schmid, G. Neubauer, P.R. Mazal, Dielectric properties of human brain tissue measured less than 10 h postmortem at frequencies from 800 to 2450 MHz. *Bioelectromagnetics* 24, 2003, 423-430.

/10/ G. Schmid, G. Neubauer, U.M. Illievich, F. Alesch, Dielectric properties of porcine brain tissue in the transition from life to death at frequencies from 800 to 1900 MHz. *Bioelectromagnetics* 24. 2003, 413-422.

/11/ United Nations Environment Programme/World Health Organization/International Radiation Protection Association (UNEP/WHO/IRPA). *Radiofrequency and Microwaves.* World Health Organization, Geneva, Environmental Health Criteria 16, 1981.

/12/ T.S. Ely, D.E. Goldman, Y.Z. Hearon, R.B. Williams, and H.M. Carpenter, *Heating Characteristics of Laboratory Animals Exposed to Ten Centimeter Microwaves.* Naval Medical Research Institute, Bethesda, Rep. NM 001.256).

/13/ T.S. Ely, and D.E. Goldman, Heat exchange characteristics of animals exposed to 10 centimeter microwave. *IRE Trans Med Electron,* 4, 1956, 38-49.

/14/ C. Addington, F. Fisher, R. Neubauer, C. Osborne, Y. Sarkees, and G. Swartz, Thermal effects of 200 megacycles (cw) irradiation as related to shape, location and orientation in the field. In *Proceedings of the 2nd Tri-Service Conference on the Biological Effects of Microwave Energy,* ASTIA Document No. AD 131477, 1958.

/15/ W.B. Deichmann, Biological effects of microwave radiation of 24 000 megacycles. *Arch Toxicol*, 22, 1966, 24-35.

/16/ Z.V. Gordon, Problems of industrial hygiene and the biological effects of electromagnetic superhigh frequency fields, Medicina, Moscow, 1966 /English translation in NASA Rep. TT-F-633, 1976/

/17/ S.M. Michaelson, J.W. Howland, and W.B. Deichman, Response of the dog to 24,000 and 1285 MHz microwave exposure. *Ind Med,* 40, 1971, 18-23.

/18/ J.H. Bernhardt, ICNIRP initiatives. *Radiat Prot Dosimetry,* 83, 1-2, 1999, 5-7.

/19/ T.L. Thomas, P.D. Stolley, A. Sternhagen, E.T.H. Fontham, M.L. Bleeker, P.A. Stewart, and R.N. Hoover, Brain tumour mortality risk among men with electrical and electronic jobs: a case-control study. *J. Nat. Cancer Inst*, 79, 1987, 233-238.

/20/ S. Selvin, J. Schulman, and D.W. Merrill, Distance and risk measures for the analysis of spatial data: a study of childhood cancers. *Soc. Sci. Med,* 34, 1992, 769-777.

/21/ T. Tynes, A. Andersen, and F. Langmark, Incidence of cancer in Norwegian workers potentially exposed to electromagnetic fields. *Am. J. Epidemiol,* 136, 1992, 81-88.

/22/ B. Armstrong, G. Theriault, P. Guenel, J. Deadman, M. Goldberg, and P. Heroux, Association between exposure to pulsed electromagnetic fields and cancer in electrical utility workers in Quebec, Canada, and France. *Am. J. Epidemiol,* 140, 1994, 805-820.

/23/ S. Szmigielski, Cancer morbidity in subjects occupationally exposed to high frequency (radiofrequency and microwave) electromagnetic radiation. *Sci. Total Environ,* 180, 1996, 9-17.

/24/ C. Beall, E. Delzell, P. Cole, and I. Brill, Brain tumors among electronic industry workers. *Epidemiology,* 7, 1996,125-130.

/25/ J.K. Grayson, Radiation exposure, socioeconomic status, and brain tumor risk in the US Air Force: a nested case-control study. *Am. J. Epidemiol,* 143, 1996, 480-486.

/26/ B. Hocking, I.R. Gordon, M.L. Grain, and G.E. Hatfield, Cancer incidence and mortality and proximity to TV towers. *Med. J. Aust,* 165, 1996, 601-605.

/27/ H. Dolk, G. Shaddick, P. Walls, C. Grundy, B. Thakrar, I. Kleinschmidt, and P. Elliott, Cancer incidence near radio and television transmitters in Great Britain, Part I. Sutton Coldfield Transmitter. *Am. J. Epidemiol,* 145, 1997, 1-9.

/28/ S. Lagorio, S. Rossi, P. Vecchia, M. De Santis, L. Bastianini, M. Fusilli, A. Ferrucci, E. Desideri, and P. Comba, Mortality of plastic-ware workers exposed to radiofrequencies. *Bioelectromagnetics*, 18, 1997, 418-421.

/29/ M.M. Finkelstein, Cancer incidence among Ontario police officers. *Am. J. Ind. Med,* 34, 1998, 157-162.

/30/ R.W. Morgan, M.A. Kelsh, K. Zhao, K.A. Exuzides, S. Heringer, and W. Negrete, Radiofrequency exposure and mortality from cancer of the brain and lymphatic/hematopoietic systems. *Epidemiology* 11, 2000,118-127.

/31/ L. Hardell, L. Näsman, A. Pihlson, and A. Hallquist, Use of cellular telephones and the risk for brain tumors: A case-control study. *Int. J. Oncol,* 15, 1999, 113-116.

/32/ L. Hardell, L. Näsman, A. Pihlson, and A. Hallquist, Case-control study on radiology work, medical x-ray investigations, and use of cellular telephones as risk factors for brain tumors. *MedGenMed* May 4. (http://www.medscape.com/Medscape/GeneralMedicine/journal2000/v02.n03/mgm0504.hard/mgm0)

/33/ L. Hardell, K. Hansson Mild, A. Pihlson, and A. Hallquist, Ionizing radiation, cellular telephones and the risk for brain tumours. *Eur. J. Cancer Prev,* 10, 2001, 523-529.

/34/ J.E. Muscat, M.G. Malkin, S. Thompson, R.E. Shore, S.D. Stellman, D. McRee, A.I. Neugut, and E.L. Wynder, Handheld cellular telephone use and risk of brain cancer. *J.Am.Med.Assoc,* 284, 2000, 3001-3007.

/35/ P.D. Inskip, R.E. Tarone, E.E. Hatch, T.C. Wilcosky, W.R. Shapiro, R.G. Selker, H.A. Fine, P.M. Black, J.S. Loeffler, and M.S. Linet, Cellular-telephone use and brain tumors. *New Engl. J. Med,* 344, 2001, 79-86.

/36/ C. Johansen, J.D. Boice, Jr., J.K. McLaughlin, and J.H. Olsen, Cellular telephones and cancer - a nationwide cohort study in Denmark. *J. Natl .Cancer Inst,* 93, 2001, 203-207.

/37/ A. Auvinen, M. Hietanen, R. Luukonen, and R.S. Koskela, Brain tumors and salivary gland cancers among cellular telephone users. *Epidemiology,* 13, 2002, 356-359.

/38/ L. Hardell, K. Hansson Mild, and M. Carlberg, Case-control study on the use of cellular and cordless phones and the risk for malignant brain tumours. *Int. J. Radiat. Biol,* 78, 2002, 931-936.

/39/ L. Hardell, A. Hallquist, K. Hansson Mild, M. Carlberg, A. Pİhlson, and A. Lilja, Cellular and cordless telephones and the risk for brain tumours. *Eur. J. Cancer Prev,* 11, 2002, 377-386.

/40/ N. Wertheimer, and E. Leeper, Electrical wiring configuration and childhood cancer, *Am.J.Epidemiol,* 109, 1979, 273-284.

/41/ C.D. Robinette, C. Silverman, and S. Jablon, Effects upon health of occupational exposure to microwave radiation (radar). *Am.J.Epidemiol,* 112, 1980, 39-53.

/42/ S. Milham, Increased mortality in amateur radio operators due to lymphatic and hematopoietic malignancies. *Am.J.Epidemiol,* 127, 1988, 50-54.

/43/ J.M. Muhm, Mortality investigation of workers in an electromagnetic pulse test program. *J. Occup. Med,* 34, 1992, 287-292.

/44/ G. Maskarinec, J. Cooper, and L. Swygert, Investigation of increased incidence in childhood leukemia near radio towers in Hawaii: preliminary observations. *J. Environ. Pathol. Toxicol. Oncol,* 13, 1994, 33-37.

/45/ H. Dolk, P. Elliot, G. Shaddick, P. Walls, and B. Thakrar, Cancer incidence near radio and television transmitters in Great Britain, Part II. All high-power transmitters. *Am. J. Epidemiol,* 145, 1997, 10-17.

/46/ P. Michelozzi, A. Capon, U. Kirchmayer, F. Forastiere, A. Biggeri, A. Barca, and C.A. Perucci, Adult and childhood leukemia near a high-power radio station in Rome, Italy. *Am. J. Epidmiol,* 155, 2002, 1096-1103.

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Prispelo (Arrived): 10.09.2004 *Sprejeto (Accepted): 30.11.2004*

ELECTROMAGNETIC FIELDS DOSIMETRY

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INVITED PAPER
MIDEM 2004 CONFERENCE
29.09.04 - 01.10.04, Maribor, Slovenia

Key words: EMF dosimetry, EMF standards, EMF effects to humans

Abstract: In the last three decades, the use of devices that emit radiofrequency (RF)[1] electromagnetic fields has increased dramatically. The proliferation of RF devices has been accompanied by increased concern about ensuring the safety of their use. Throughout the world many organizations, both government and non-government, have established RF safety standards or guidelines for exposure. Because of different criteria, the former USSR and some of the Eastern European countries have more stringent safety standards than most Western countries. Differences in the exposure limit values in electromagnetic field (EMF) standards between some Eastern European and those of Western countries are over two orders of magnitude. These differences have raised concerns about the lack of uniformity and have led to public concern and distrust about EMF exposures from the increased use of various EMF sources in the living and working environment. Thus, better methods are needed to properly measure, extrapolate or relate effects observed in animals to those expected to be found in people. The resulting data could lead to modification of existing safety standards or setting of new safety standards. Accurate dosimetry represents an essential element of the research in determining the biological effects of electromagnetic fields.

Dozimetrija elektromagnetnih polj

Kjučne besede: dozimetrija elektromagnetnih polj, EMF standardi, vplivi EMF na ljudi

Izvleček: V zadnjih treh desetletjih smo priča dramatičnega povečanja rabe naprav, ki oddajajo radiofrekvenčna (RF) elektromagnetna polja (EMF). Povečano rabo RF naprav je spremljala povečana skrb glede zagotavljanja njihove varne rabe. Mnoge vladne, oz. nevladne organizacije po svetu so pripravile varnostne standarde in priporočila za RF obsevanje. Zaradi različnih kriterijev imajo bivše države ZSSR in nekatere vzhodnoevropske države strožje varnostne standarde kot večina zahodnoevropskih držav. Razlike v limitnih ekspozicijskih vrednostih v EMF standardih med zahodnoevropskimi in nekaterimi vzhodnoevropskimi državami so tudi več kot dva reda velikosti. Te razlike so povzročile zaskrbljenost zaradi neusklajenosti standardov in so privedle do javnega dvoma in nezaupanja do izpostavljanja EMF sevanju kot posledica povečane rabe različnih naprav, ki so izvori tega sevanja v delovnem in življenjskem okolju. Zaradi tega potrebujemo boljše metode za ustrezne meritve, ekstrapolacijo in primerjavo vplivov opaženih pri živalih s tistimi, ki jih pričakujemo pri ljudeh. Tako pridobljeni podatki lahko vodijo k spremembi obstoječih varnostnih standardov ali k zasnovi novih. Točna dozimetrija predstavlja ključni element pri raziskavah za določanje bioloških učinkov elektromagnetnih polj.

Introduction

Electromagnetic energy is absorbed non-uniformly in biological tissues (D'Andrea et al. 1977, 1985; Gandhi et al., 1979). Furthermore, a large number of factors such as a body's shape and position as well as its orientation in the field will produce new non-uniform distributions (Durney et al., 1978; Gandhi, 1974). In short, there is no single answer to the question, "How much electromagnetic field (EMF) energy will be absorbed?" Nevertheless, in order to make safe use of EMF emitting devices, a number of techniques for measuring EMF exposure have been devised. Unfortunately, all have limitations. It is understandable then, why the development of mathematical dosimetry modeling techniques and sufficiently powerful computer hardware has resulted in the rapid adoption of dosimetry modeling as a principle tool in determining EMF exposure.

Computer-based dosimetry modeling provides great advantages by returning more information about an exposure than empirical techniques and with considerably less effort. But before this tool transitions into the hands of health safety officers and system designers, it must be verified under a wide variety of conditions using available analytical and empirical dosimetry techniques to verify its accuracy and limitations.

The state of empirical dosimetry has recently been reviewed (Chou et al., 1996) and is described in detail in the Radiofrequency Radiation Dosimetry Handbook (Durney et al., 1986). It is important to briefly review the techniques, as these will be the source of the empirical verification of any EMF dosimetry model.

Empirical Dosimetry

Baseline temperature measurements. Since absorbed EMF energy produces heat, measuring changes in temperature is the principal means of measuring EMF dose.

1 The radiofrequency portion of the electromagnetic spectrum extends over a wide range of frequencies, from about 10 kHz to 300 GHz.

To measure changes, a baseline temperature is required. One method is to allow the sample to equilibrate to the ambient temperature of the exposure chamber. An extended equilibration time is possible with stable samples; however, with biological specimens a long equilibration time is accompanied by changes in permittivity properties. An alternative procedure (Gambrill et al., 1993; Lu et al., 1993), which avoids this problem, is used with unstable samples such as biological tissues. Baseline temperature data is collected for a few minutes before and after the exposure. The average rate of temperature change during the non-exposure periods can be subtracted from the rate of change during exposure. The result is the rate of temperature change produced by the exposure. Using the specific heat for tissue of 0.84, a 1-degree C/minute temperature change is equal to a raw SAR of 58.6 W/kg (Durney et al., 1986). The raw SAR is then divided by the incident field intensity at the site of the measurement to convert to normalized SAR (W/kg/mW/cm^2). In this way, temperature changes due to other factors are isolated from changes due to EMF exposure. This allows the use of thermally unstable samples such as fresh carcasses.

Exposure parameters. In order to maximize sensitivity to temperature changes resulting from EMF exposure and minimize the effects of other factors several considerations must be taken into account when selecting exposure parameters. First, power levels should be selected to produce as rapid a temperature rise as can be accurately detected, in other words, a relatively high incident power. Second, the exposure duration should be as brief as possible. The goal is to minimize the effects of thermal diffusion. Third, the temperature of the sample should be kept within the optimal sensitivity range of the thermometers being used. This may make it necessary to allow the sample to cool between exposures.

Measurement Techniques: Infrared Thermometry. A thermographic camera (We use a Radiance I from Amber Engineering, Goleta, CA) can be use to measure temperatures and ultimately SAR across the visible surface of an object (Mason, 1999). Since the camera is non-invasive it can be used in addition to other measurement techniques. A comparison of rendered three-dimensional SAR data and an infrared image can provide dramatic confirmation of finite-difference time-domain (FDTD) output (See Figure 1). Some samples (e.g., spheres and phantoms) can be constructed so that they can be quickly split after an exposure and scanned to visualize the temperatures over surface of the split. Care must be taken to ensure that the surfaces of the split had good electrical contact during the exposure.

Measurement Techniques: Calorimetry. Whole-body averaged SAR in phantoms and animal carcasses can be determined by twin-well calorimetry (Phillips et al., 1975, Blackman and Black, 1977; Allen and Hunt, 1979; Chou et al., 1984). Two identical samples are brought to temperature equilibrium. One is then exposed. Immediately after exposure, both are placed in the calorimeter wells. The calorimeter measures the heat diffusion for the exposed and unexposed samples, the difference is the amount of EMF energy absorbed by the exposed sample.

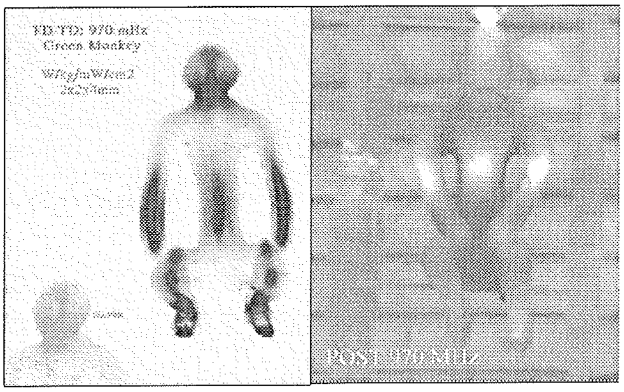

Figure 1. The right panel shows infrared images of a monkey phantom exposed to 970 MHz. Higher temperatures are shown as white. On the left is a rendered image of the results of an FDTD analysis at the same frequency. Very low SARs are transparent, slightly higher SARs are purple, with the highest SARs shown as red. Both images show higher SARs in the arms, torso, ankles and neck. The very white area at the top of the phantom's head (right panel) is an artifact at the opening where the phantom was filled.

Measurement Techniques: Temperature Probes. Non-perturbing temperature probes are inserted into locations of interest. Baseline, exposure, and post-exposure temperatures are collected. Ideally, the temperature at the site of the probes will rise approximately one degree C during the exposure. These data are then analyzed as described above to convert the temperature data to normalized SAR. Results for a phantom monkey at three frequencies are shown in Figure 2. FDTD predictions were used to guide the placement of the temperature probes.

Implantable E-field probes. This type of probe can be inserted into a sample in the same manner as the non-perturbing temperature probes just described. However, these probes measure the intensity of the E-field at the location of the probe. SAR can be directly calculated from the E-field (SAR = s÷E÷^{2}/rm ; where s=conductivity in siemens/meter, ÷E÷ is the electric-field strength in RMS volts/meter and rm is the mass density in kilograms/cubic meter). In addition, these measurements can be performed very quickly and at very low powers, so over heating of target is not an issue. The disadvantage of these probes is their lack of stability. Measurements are sensitive to many factors that would not alter a temperature-based system. As such these measurements must be performed with extreme care. Furthermore, the current generation of probes is quite large relative to the non-perturbing temperature probes; this increases the difficulty of using these probes with biological samples.

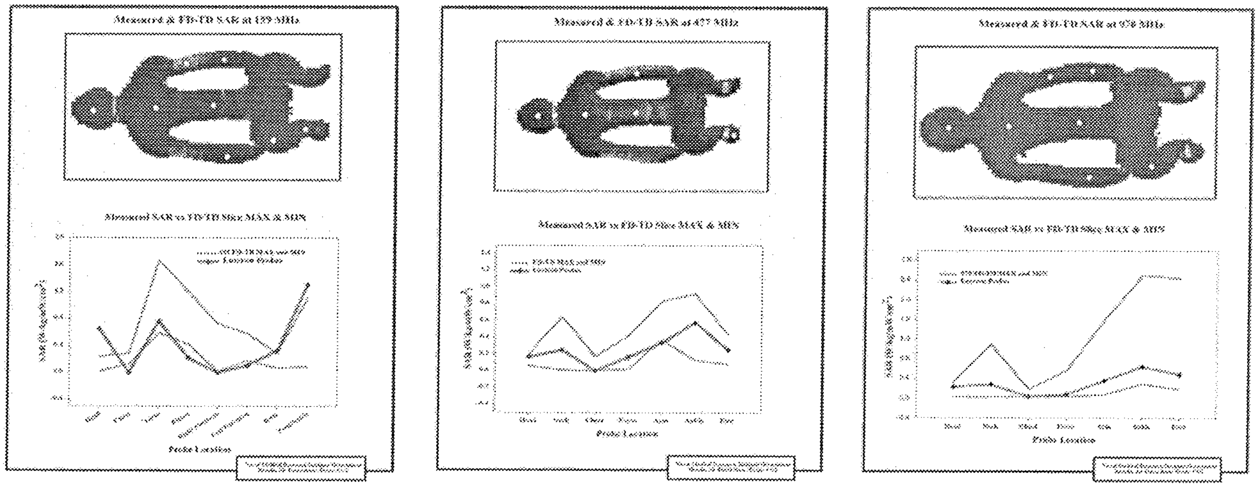

Figure 2. Three panels comparing FDTD results (rendered images and gray lines) to temperature probe data (red lines) at eight locations (yellow dots on images). The gray lines represent the range of SAR values in the area corresponding to the temperature probe location.

Dosimetry Samples

Cadavers. When the questions being address concern only SAR, a cadaver is preferable to a live animal, because a live animal's thermoregulatory system will confound temperature-based SAR measurements. However, the tissue will become dehydrated over time so it is best not to wait too long after euthanization. If local SARs are to be measured, temperature probes will be implanted and temperatures recorded before, during and after exposures.

Spheres. The geometry of a sphere is artificial but very useful. Data collected from a homogeneous or multi-layered sphere are a useful test of the predictions of FDTD. The MIE procedure provides an important mathematically exact reference value for the sphere, which is easily modeled in both FDTD and the laboratory. First derived by Mie (1908), this scattering solution is widely used in EMF and optics. Harrington (1961) gives the exact solution in detail, and programs are available giving the exact near- and far-field results to which we can compare the FDTD results. At NHRC-DET, we use a program developed by Bell et al. (1977). Finally, because the MIE solution provides an exact value, sphere data can be used to measure error in the empirical values as well

Phantoms. Phantoms are constructed of an EMF-transparent fabric sewn into the desired shape and filled with a tissue-equivalent material. A variety of material recipes have been characterized for different simulated organs (muscle, fat, brain and bone) and a range of frequencies (Guy, 1971; and Chou et al., 1984). Using the same mold, it is possible to place temperature probes in the same locations from session to session. Measuring SAR in phantoms is more reproducible, more convenient, and reduces the number of animals required. The whole-body SAR values with the rhesus monkey phantom are a good approximation of results observed with other methods. However, the localized SARs of the homogeneous phantom differ significantly from the structurally complex carcass and live animal. This difference must be taken into account in bioeffects studies.

Computer dosimetry models

The empirical methods described in the previous section have been the primary source of dosimetry data. However, these methods are labor intensive and may not be easily applicable to humans. In efforts to get more dosimetry information investigators have developed a number of techniques such as the use of phantoms. These techniques make the collection of dosimetry data more efficient. However, each also holds some compromises. In the case of the phantom, it is homogeneous and only roughly shaped like the object it models. Other phantoms have been more realistic, but these are also more difficult to construct. It is not surprising that finite-difference models and high-resolution anatomical data sets would be readily adopted.

The method most frequently used in EMF bioeffects dosimetry is the FDTD. As a finite difference algorithm, FDTD has the advantage of being able to analyze a wide variety of geometries. Unlike finite element or method of moments, FDTD can be more efficiently applied to the very large problems such as a segmented version of the Visible Human male. These advantages have led to the phenomenal growth in the application and development.

FDTD. The FDTD method was originated by Yee (1966) and later developed further by Taflove and colleagues (1975, 1990); Holland (1977), and Kunz and Lee (1978). As more powerful computers became more widely available, use of the FDTD method has increased exponentially

(Shlager, K.L. and Schneider, 1995 and http://www.fdtd.org). Its use in bioelectromagnetics has increased as well by Gandhi and others (Gandhi, 1994; Stuchly and Gandhi, 2000; Dimbylow, 1997). In addition, FDTD is widely used by makers of cell phones to calculate head exposures during cell phone use.

The FDTD method is not limited to bioeffects research it has been extensively used to model antenna, waveguides, and military hardware. Unlike its main competitors, the method of moments (MOM) (Harrington, 1968) and finite element method (FEM) (MacNeal, 1991), the FDTD method is scalable, i.e., the CPU time behaves linear in the problem size N. The MOM and FEM methods require matrix inversions (albeit sparse matrices in FEM) and thus scale as N^3. The MOM method is primarily useful for problems with conducting surfaces, but difficult to apply to permittivity problems of interest here. Its practical limitation is to systems less than 10^6 cells. The FEM method, with its irregular cell structure, is difficult to parallelize efficiently. The FDTD method with its rectangular cell structure is easy to parallelize, and, in the case of the problem at hand, is compatible with the cellular data formats of the monkey and human anatomical models. The main disadvantages of FDTD are object resolution and absorbing boundary conditions (also in FEM), but sophisticated versions of the FDTD method have been developed to handle these problems (Taflove, 1995). On the whole, we judge the FDTD approach to be the best to model the complex biological systems of interest.

Figure 3. Rendering of SAR results at 918MHz using FDTD and 3mm man model.

FDTD Code. The FDTD program used at Brooks AFB is based on code originally developed by Kunz and Luebbers (1993). It has been used to predict whole-body SAR and SAR distributions in spheres, monkey phantom, rhesus monkey, and human models. These models were developed jointly by NHRC-DET and AFRL/HEDR. This FDTD program has been extensively used in the last few years to predict SAR in various models as part of ongoing bioeffects research. Continued development of the code by Luebbers and others has resulted in a commercial product XFDTD (www.remcom.com).

We have made a number of modifications to the original code. We added more materials types to include all of Camellia Gabriel's types and some non-biological materials. The permittivity properties of each of the tissue types are set according to data and fits published by Gabriel (1996). Sample output for 918 MHz with the 3-mm version of the man model is show in Figure 3. The modified code reads the anatomical model files and outputs a 3-D normalized SAR file; mean, minimum, and maximum SARs for each tissue type; and each Z-plane slice. Finally, there is an extensive log file and all file names reflect run parameters. The code has been parallelized using the message-passing interface (MPI) library, which allows for larger and more complex data sets to be modeled. The advantage of using the MPI is that the code can run on parallel computer systems composed of networks of computers. These may be networked workstations, or massively parallel systems such as Linux-based Beowulf systems. These systems are easily constructed of inexpensive PC-hardware.

The Visible Human Project: Male Data Set

The human model is based on the photographic data from Visible Human Project created by the National Library of Medicine (www.nlm.nih.gov/research/visible/visible_human.html) and the University of Colorado Health Science Center (www.uchsc.edu/sm/chs/). A computer-segmented set of the photographic images was created by National University of Singapore and Johns Hopkins University. We limited the number of tissue types based on their size in the body and availability of permittivity properties. Each of the 1878 slices in the XY plane was coded by hand using Adobe Photoshop ™ and a palette of colors that represented the 40 tissue types (See Mason et al, 1995, 1999 for a complete description). It is the largest of the anatomical data sets we have created at 374 million voxels (1878 by 340 by 586). Each voxel is a cube 1 mm on a side. There are two improvements planned to enhance the usability of this data. First, the eyes will be opened. And second, the feet will be rotated and flattened slightly on the bottom to allow the model to make good contact with a ground plain or simulated shoe material. Modeling EMF exposures with this model will require approximately 18 GB of computer memory for FDTD. Smaller versions of this data set with resolutions of 2, 3, 5, 10 and 22 mm have been created and are suitable for some applications. These require considerably less memory but this savings comes at a cost. As the voxel size increases small organs may be distorted or lost, some symmetries may be affected, organs will change mass slightly and the continuity of elongated structures may be disrupted. These reduced resolution models are created automatically. The process would be as follows for creating a 3-mm anatomical model from a 1-mm model. Layers of air are added to one or more sides of the model volume to make the size of the model an even multiple of the 3 mm. The reduction would then take a cube of 3 by 3 by 3 one-millimeter voxels and based on the most common type in that cube create the single three-millimeter voxel. This process would be repeated for each 3 by 3 by 3 set of 1-mm voxels.

International INITIATIVE - GLOBAL EMF Dosimetry Project

One of the most useful documents in bioelectromagnetics is the Air Force Radiofrequency Radiation Dosimetry Handbook. Now in its 4th edition (Durney et al., 1986), the handbook describes, the principles and techniques for establishing RFR dose. It is a standard in radio frequency dosimetry. The International EMF Dosimetry Project was envisioned as the means of producing the next version of the dosimetry handbook.

The International EMF Dosimetry Project (www.emfdosimetry.org) was established as an international resource that provides state-of-the-science knowledge on EMF dosimetry. This project originated during the North Atlantic Treaty Organization (NATO) Advanced Research Workshop on ***Radio Frequency Radiation Dosimetry and Its Relationship to the Biological Effects of Electromagnetic Fields*** held at Gozd Martuljek, Slovenia, October, 1998.

The overall project goals of the International EMF Dosimetry Project are to promote the field of EMF dosimetry by creating internationally-accepted EMF Dosimetry Handbook and software that describe how EMF dosimetry measurements and calculations should be performed. By employing an open international forum, the Internet, the project should proceed rapidly, at low cost, and the results should be accepted internationally. This project could serve as the common ground for harmonizing EMF exposure standards that are currently unique to most countries.

Potential results of this project include: facilitation of international EMF research efforts and collaborations; assistance in EMF dosimetry predictions and measurements; development of an international research community that will identify EMF dosimetry research areas where further data are required; and rapid and easily accessible communication amongst researchers to avoid duplication of research efforts and maximize research dollars. These results should permit more timely responses to the dosimetry requirements of the EMF community.

References

/1./ Allen SJ, Hunt WD, Calorimetric measurements of microwave energy absorption by mice after simultaneous exposure of 18 animals. *Radio Science* 14(65):1-4, 1979.

/2./ Bell EL, Cohoon DK, and Penn JW. *Mie: A fortran program for computing power deposition in spherical dielectrics through application of Mie theory*, USAF School of Aerospace Medicine, Brooks AFB, TX, Rep. SAM-TR-77-11, 1977.

/3./ Blackman CF, Black JA, Measurement of microwave radiation absorbed by biological systems. 2. Analysis by Dewar-flask calorimetry. *Radio Science* 12(65):9-14, 1977.

/4./ Chou CK, Bassen H, Osepchuk J, Balzano Q, Petersen R, Meltz M, Cleveland R, Lin JC, Heynick L Radio frequency electromagnetic exposure: tutorial review on experimental dosimetry. *Bioelectromagnetics*. 1996;17(3):195-208.

/5./ Chou CK, Chen GW, Guy AW, Luk KH, Formulas for preparing phantom muscle tissue at various radiofrequencies. *Bioelectromagnetics* 5:435-441,1984.

/6./ D'Andrea, J.A.; Gandhi, O.P.; Lords, J.L. Behavioral and thermal effects of microwave radiation at resonant and nonresonant wavelengths. *Radio Sci.* 12(6S): 251-256; 1977.

/7./ D'Andrea, J.A.; Emmerson, R.Y.; Bailey, C.M.; Olsen, R.G.; Gandhi, O.P. Microwave radiation absorption in the rat: Frequency-dependent SAR distribution in body and tail. *Bioelectromagnetics* 6: 199-206; 1985.

/8./ Dimbylow PJ, FDTD calculations of the whole-body averaged SAR in an anatomically realistic voxel model of the human body from 1 MHz to 1 GHz. *Physics in Medicine and Biology*, Vol 42, pp. 479-490, 1997.

/9./ Durney, C.H.; Johnson, C.C.; Barber, P.W.; Massoudi, H.; Iskander, M.F.; Lords, J.L.; Ryser, D.K.; Allen, S.J.; Mitchell, J.C. *Radiofrequency radiation dosimetry handbook*. SAM-TR-78-22, Brooks Air Force Base, San Antonio, TX, 1978.

/10./ Gabriel C. *Compilation of the Dielectric Properties of Body Tissue at RF and Microwave Frequencies*, Brooks AFB, TX: Armstrong Laboratory Report, AL/OE-TR-1996-0037, 1996.

/11./ Gambrill, C.S. DeAngelis M.L., Lu S-T. Error analysis of a thermometric microwave-dosimetry procedure. In: Blank M, editor. *Electricity and magnetism in biology and medicine*, San Franscisco: San Francisco Proess. 593-595.

/12./ Gandhi, O.P.; Hagmann, M.J.; D'Andrea, J.A. Partbody and multibody effects on absorption of radio frequency electromagnetic energy by animals and by models of man. *Radio Sci.* 14(6S): 15-22, 1979.

/13./ Gandhi O.P., Some Numerical Methods for Dosimetry: ELF to microwave frequencies. *Radio Science*, Vol. 29, November, 1994.

/14./ Gandhi, O.P. Polarization and frequency effects on whole animal energy absorption of RF energy. *Proc. IEEE* 62: 1171-1175, 1974.

/15./ Guy AW, Analyses of electromagnetic fields induced in biological tissues by thermographic studies on equivalent phantom models. *IEEE Trans Microwave Theor Tech* 19:205-214, 1971.

/16./ Harrington, R.F., *"Field Computation by Moments Method"*, The Macmillan Company, New York, 1968.

/17./ Harrington, R.F., *"Time Harmonic Electromagnetic Fields"*, McGraw-Hill Book Company, New York, 1961, pp. 264-316.

/18./ Holland R. THREDE: A fore-field EMP coupling and scattering code, *IEEE Transactions on Nuclear Science*, Vol. 24, p. 2416, 1977.

/19./ Kunz K.S., and K.M. Lee. A three-dimensional finite-difference solution of the external response of an aircraft to a complex transient EM environment, 1. The method and it's implementation. *IEEE Transactions on Electromagnetic Compatibility*, Vol. 20, p. 328, 1978.

/20./ Kunz, KS and Luebbers RJ. "*The Finite Difference Time Doman Method for Electromagnetics*", CRC Press, Inc., Boca Raton, FL, 1993.

/21./ Lu S-T, DeAngelis ML, Gambrill CS. Ocular microwave thermometric dosimetry and thermometry in the rabbit. In: Blank M, editor. *Electricity and magnetism in biology and medicine.* San Francisco: San Francisco Press, Inc. 675-678; 1993.

/22./ MacNeal BE, editor, *"MSC/EMAS Modeling Guide"*, The MacNeal-Schwendler Corporation, 1991.

/23./ Mason PM, Ziriax JM, Hurt WD, D'Andrea JW. 3-Dimensional models for EMF dosimetry. In *Electricity and Magnetism in Biology and Medicine* edited by Bersani, Kluwer Academic/Plenum Publishers, 1999.

/24./ Mason PM, Walters TJ, Fanton JW, Erwin DN, Gao JH, Roby JW, Lott KA, Lott LE, Blystone RV. Database created from magnetic resonance images of a Sprague-Dawley rat, rhesus monkey, and pigmy goat. *FASEB J.*, 9:434-440, 1995.

/25./ Mason PM, IR mapping for greater radiation safety. *Electronics Tech Briefs*, 11-13 April 1999.

/26./ Mie G. Contributions to the optics of diffusing media. *Ann Physik*, 25,1908.

/27./ Phillips RD, Hunt EL, King NW, Field measurements of absorbed dose and biologic dosimetry of microwaves. *Ann NY Acad Sci* 247:499-509, 1975.

/28./ **Shlager, K.L. and Schneider, J.B., A Selective Survey of the Finite-Difference Time-Domain Literature. *IEEE Antennas and Propagation Magazine*, 37:4, pp. 39-56, 1995.**

/29./ Smith, W., Anderson, W., Haftel, M.I., Kuo, E., Rosen, M., and Uhlmann, J. Goal-oriented computational steering, *Proceedings of the SPIE Conference on Enabling Technology for Simulation Science*, SPIE Vol. 3936, p. 250, 1999.

/30./ Stuchly MA, Gandhi OP Inter-laboratory comparison of numerical dosimetry for human exposure to 60 Hz electric and magnetic fields. *Bioelectromagnetics* 2000 Apr; 21(3):167-74

/31./ Taflove, A. and M. E. Brodwin, Computation of the electromagnetic fields and induced temperatures within a model of the microwave irradiated human eye, *IEEE Transactions on Microwave Theory and Techniques,* MTT-23, 888, 1975.

/32./ Taflove, A. and K. R. Umashankar, The finite-difference time-domain method for numerical modeling of electromagnetic wave interactions with arbitrary structures, Chapter 8 in *Progress in Electromagnetics Research, PIER 2*, Michael A. Morgan, Editor, Elsevier Science Publishing Company, New York, 1990.

/33./ Taflove, A. *"Computational Electrodynamics - The Finite-Difference-Time_Domain Method"*, Artech House, Boston, 1995.

/34./ Yee, K.S., Numerical solution of initial boundary value problems involving Maxwell's equations in isotropic media. *IEEE Transactions on Antennas and Propagation*, Vol. 14, p. 302, 1966.

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Prispelo (Arrived): 10.09.2004 *Sprejeto (Accepted): 30.11.2004*

APLIKACIJSKI ČLANEK
APPLICATION ARTICLE

Murata's PTC, NTC Thermistors Respond to Safety Requirements

Apart from the strong demand for electronic products that are small, thin and light, the markets for electronic devices and systems also require that these devices must adopt enhanced functions and faster speed. To meet this demand, electronic components are made smaller and in multi-layer on the board to fully utilize high density mounting technology. Furthermore, electronic parts that have shrunk in size must be able to perform at the upper limits of their rated values.

With these market needs, heat radiation from parts increases on the board so much so that it is very difficult to ensure sufficient heat radiation. In view of this, measures for heat radiation have become more important than ever. This article focuses on Murata Manufacturing Co., Ltd.'s PTC thermistors (Posistors) and its NTC thermistors, both of which are used as temperature-sensing devices.

Thermistor

The thermistor is a resistor that exhibits a very sharp change in resistance according to temperature change. Thermistors are classified into two types – the NTC (Negative Temperature Coefficient) thermistor whose resistance value decreases according to temperature rise, and the PTC (Positive Temperature Coefficient) thermistor whose resistance value rises sharply when the temperature rises above a certain limit (Fig. 1). Murata uses Posistor as trade name for its PTC thermistors. These two kinds of thermistors are used for different purposes, displaying their own characteristics, to detect the temperature of systems and equipment as a whole, the temperature of boards and also the temperature of parts, for instance, FETs.

The Posistor, whose change in resistance value is very sharp within a specified temperature range, is characterized by the fact that it can directly control power devices such as transistors and FETs. In contrast, characteristically, the NTC thermistor is excellent in temperature-sensing accuracy, although it requires a somewhat complex circuit, and is capable of temperature controls over a wide temperature range.

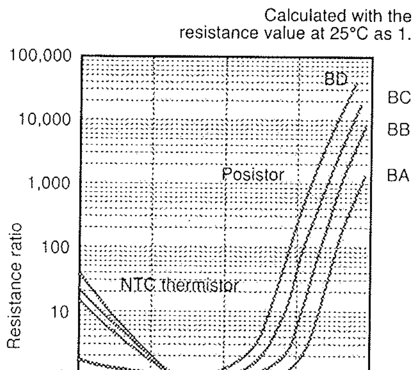

Fig. 1: Resistance ratio-temperature characteristics of thermistors

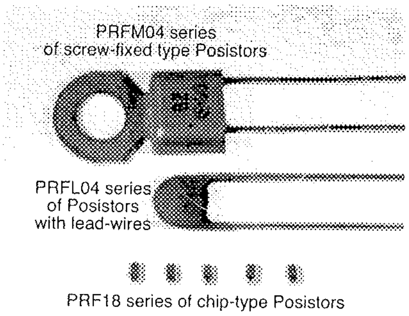

Photo 1: External view of overheating-sensing Posistors

Posistor

The Posistor is a ceramic device made by sintering barium titanate with an addition of extremely small amounts of rare earth elements (Y, La, etc.). Characteristically, its resistance value rises sharply when it is heated above a certain temperature. This temperature characteristic can be set over a wide range by properly selecting the kinds and amounts of additives to this ceramic body. For the purpose of sensing the overheating of electronic equipment, Posistors whose detection temperatures are set at 60°C~120°C are extensively used.

By utilizing this characteristic, an overheating prevention circuit can be easily devised by which the speed of a fan is increased or the output power is suppressed when the temperature of a circuit board or others reaches a specified level. The typical cases in which transistors are used as switching devices are shown (Fig. 2, Fig

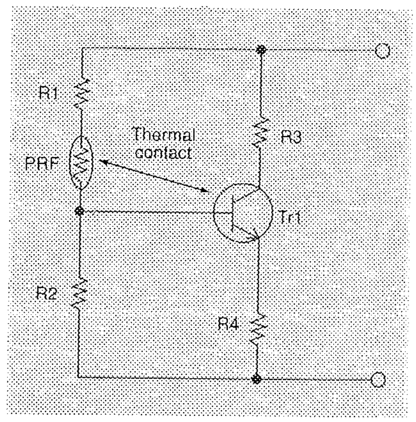

Fig. 2: Circuit pattern for a Posistor (Example 1)

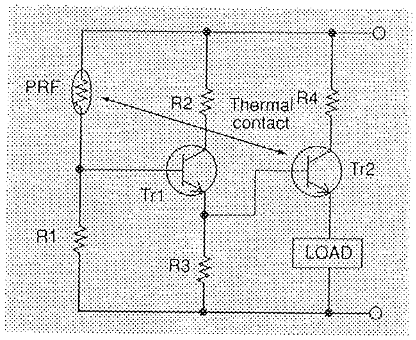

Fig. 3: Circuit pattern for a Posistor (Example 2)

3). In case abnormal heat is generated in a power transistor due to various causes such as increased output current or heat radiation trouble, the resistance value of the thermally coupled Posistor rises sharply before the power transistor reaches the limit of its tolerable temperature, to lower its current, and thus the collector current of Tr1 and Tr2 is suppressed, as shown in Figs. 2 and 3, respectively. This way, serious trouble, fuming and firing can be prevented. Various kinds of power supplies, DC/DC converters and other electronic devices are provided with this function.

The Posistor is resettable and returns to its original low resistance value when the temperature goes down, so that it can be used repeatedly, and unlike a temperature fuse, it does not need to be exchanged for a new one. Furthermore, without a contact point, there is no possibility of it causing contact failures or generating noise, a trouble that is liable to occur in a bimetal.

Posistors for temperature sensing are offered in two types, a lead-wire type and a surface-mountable type. Shown in Photo 1 are the external views of a disc type, which can detect the temperature of the surrounding environment, a type with a screw fixing terminal, which can be screwed on to a heat sink or others, and a surface-mountable type that senses the temperature of the board. These types can be selected according to the mounting forms adopted for electronic equipment.

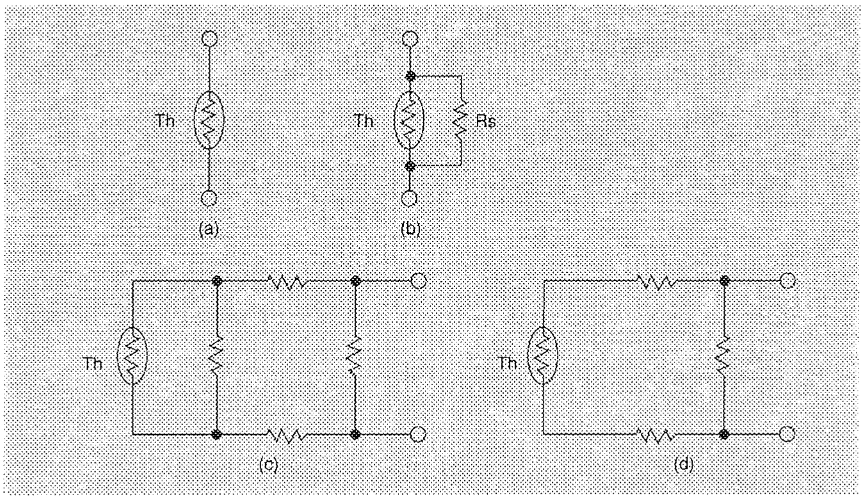

Fig. 4: Connection methods of NTC thermistors

Table 1: Ratings of chip-type PRF18 series

Product no.	Characteristic	Resistance value (at +25°C)	Sensing temperature at 4.7kΩ	Max. voltage	Operating temperature range
PRF18AS471QB1RB	AS	470Ω± 50%	145± 5°C	DC32V	-20~ + 160°C
PRF18AR471QB1RB	AR		135± 5°C		-20~ + 150°C
PRF18BA471QB1RB	BA		125± 5°C		-20~ + 140°C
PRF18BB471QB1RB	BB		115± 5°C		-20~ + 130°C
PRF18BC471QB1RB	BC		105± 5°C		-20~ + 120°C
PRF18BD471QB1RB	BD		95± 5°C		-20~ + 110°C
PRF18BE471QB1RB	BE		85± 5°C		-20~ + 100°C
PRF18BF471QB1RB	BF		75± 5°C		-20~ + 90°C
PRF18BG471QB1RB	BG		65± 5°C		-20~ + 80°C

AS~BE-characteristic thermistors are UL1434-certified products.

Table 2: Ratings of chip-type NCP15 series (excerpts)

Product no.	Resistance value (at +25°C)	B-constant (25/50°C)	Max. operating current (25°C,mA)	Operating temperature range
NCP15XF101□03RC	100Ω	3,250K ± 3%	3.10	-40 ~ +125°C
NCP15XQ471□03RC	470Ω	3,650K ± 3%	1.40	
NCP15XQ102□03RC	1,000Ω	3,650K ± 3%	1.00	
NCP15XM472□03RC	4,700Ω	3,500K ± 3%	0.46	
NCP15XH103□03RC	10,000Ω	3,380K ± 3%	0.31	
NCP15WB473□03RC	47,000Ω	4,050K ± 3%	0.17	
NCP15WF104□03RC	100,000Ω	4,250K ± 3%	0.10	
NCP15WM474□03RC	470,000Ω	4,500K ± 3%	0.04	

Note: The blanks are to be filled by resistance value deviation marks (J: ±5%, K: ±10%). Products with a resistance value deviation of ±1% (F) are also offered. When a maximum allowable current is impressed, the thermistor radiates 1°C of heat.

The temperature-sensing accuracy of these types is set at ±5°C of a sensed temperature, while the temperature-sensing range is set at 55°C~105°C for the lead-wire type and at a step of 10°C between 85°C and 145°C for the surface-mountable type. As an example, the ratings of a surface-mountable type Posistor are listed in Table 1. These types are being supplied with lead-free external terminals for the purpose of reducing substances harmful to the environment.

At present, the company is making efforts to develop narrow-deviation and small-sized Posistors and will continue to endeavor too, in the future, to diversify the assortment of Posistors.

NTC Thermistors

The NTC thermistor is a ceramic-type temperature-sensing resistor made of the sintered oxides of transition metals (Mn, Ni, Fe, Cu, etc.). It has a negative temperature coefficient, that is, its resistance value decreases as the temperature rises. NTC thermistors have a wide range of se-

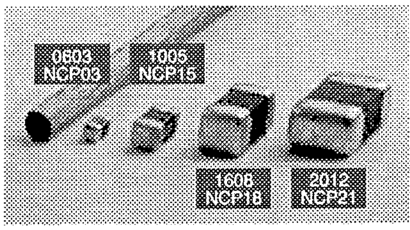

Photo 2: External view of chip-type NTC thermistors

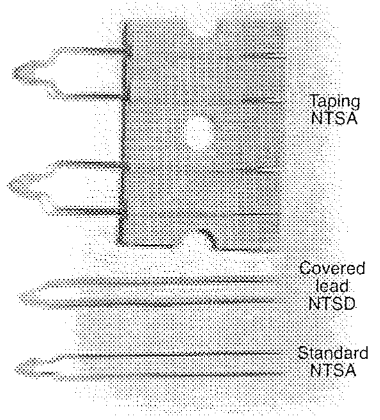

Photo 3: External view of lead-wire type NTC thermistors

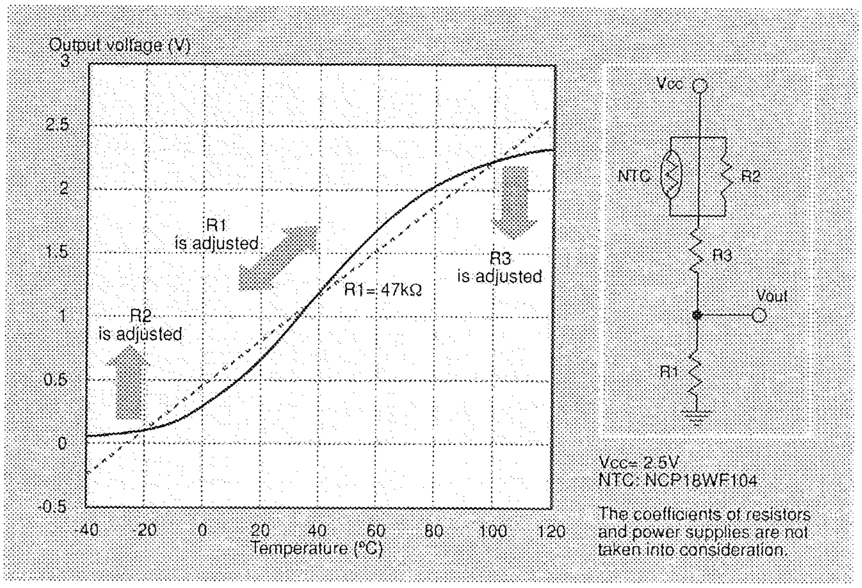

Fig. 6: Output voltage-temperature characteristics

lectable resistance values so that they can be designed with relative ease, and the change of their resistance values relative to temperature change is as large as 3.0~5.3 percent/°C. Because of these characteristics, they are extensively used for electronic equipment as general-purpose temperature sensors. These characteristics are explained below.

Fig. 4(a): The resistance value-temperature characteristics of a thermistor can be used without alteration, with large gain secured.

Fig. 4 (b): The resistance value-temperature characteristics can be easily linearized (Refer to Fig. 5).

Fig. 4 (c) (d): The resistance value-temperature characteristics can be linearized over a wide temperature range.

It is possible to upgrade the temperature-sensing accuracy of NTC thermistors to ±1°C within a range of -40°C~+75°C. In actual circuits, they are designed so as to ensure a sensing accuracy of ±3°C within a temperature range of 0°C~+70°C, even when the scattering of characteristics of power supply voltage regulators and other devices is taken into consideration.

Fig. 6 illustrates the examples of simple connections of NTC thermistors and the adjustment of output voltage-temperature curves.

It is possible to improve the sensitivity of a NTC thermistor within an operating temperature range and obtain a necessary voltage by properly combining resistors in parallel and series arrangement, and thereby to enable it to exhibit performance comparable to a general-purpose sensor IC in temperature-sensing accuracy and dynamic range.

As for their product types, the company supplies a lead-wire type (NTSA series, 3.0 × 1.6mm) and a chip-type. The chip-type has already been made lead-free (Photos 2 and 3). The company plans to expand the series of small-sized products (0.6 × 0.3mm) and add a B-constant variation to its product line.

Future Development

Electronic equipment that meet market needs for comfortable and convenient use will be required in the future to respond to more challenging market needs, apart from safety requirements. In further developing its Posistors and NTC thermistors as temperature-sensing devices, an important factor for product safety, Murata Manufacturing will endeavor to expand its lineup by confirming and meeting the required specifications of a variety of equipment, and expand the possible applications of its thermistors.

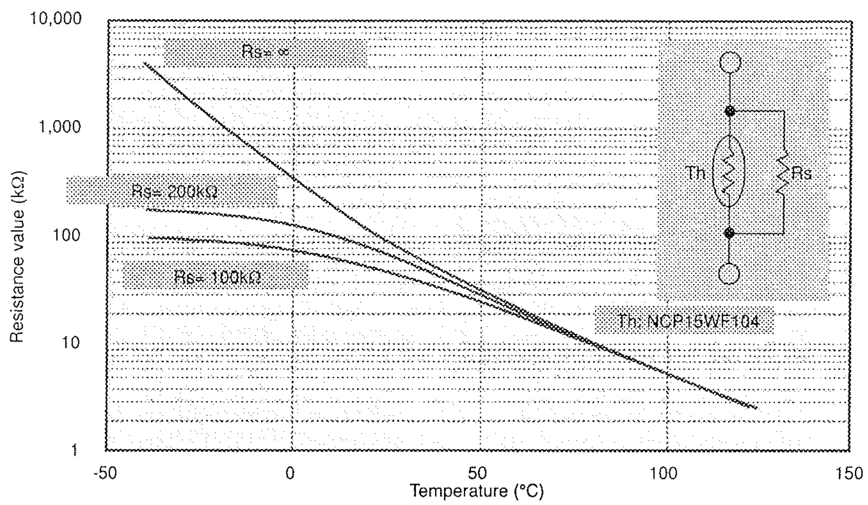

Fig. 5: The linearization of the resistance-temperature characteristic of thermistors by means of resistors in parallel arrangement

About This Article

The author, Tetsuya Kawamoto, holds the position of Chief of the Product Engineering Section in the Thermistor Products Department of the Device Products Division at Murata Manufacturing Co., Ltd.'s Yasu plant.

Konferenca MIDEM 2004 - poročilo
Conference MIDEM 2004 - REPORT

CONFERENCE MIDEM 2004 - REPORT

The 40th **International Conference on Microelectronics, Devices and Materials, MIDEM 2004,** was held in Maribor, from the twenty nineth of September to the first of October 2004. The conference continued the tradition of annual international conferences organised by MIDEM, Society for Microelectronics, Devices and Materials, Ljubljana, Slovenia.

44 papers and six invited presentations in seven sessions and in included workshop on Non-ionizing Electromagnetic Fields : From Overvoltage, Overcurrent and Electrostatic Discharge protection to Bioeffects, were presented during three days from Wednesday to Friday. The presentations at the Conference were grouped in the following Sessions: Integrated Circuits; Electronics; Device Physics, Modelling and Technology; Workshop; Optoelectronics; Thick and Thin Films; Ceramics Metals and Composites.

All invited papers are presented in this issue of the Journal.

This year, the workshop was focused on the ways and means of protection against disturbances originating from various non-ionizing electromagnetic fields (EMF). The presented papers were focused upon such topics as electromagnetic compatibility, overvoltage protection and overcurrent protection and discussed the current development in devices and equipment for protection in telecommunications, information technologies, power generation and power transmission and the like. In addition, the problems related to the effect of non-ionizing EMF on biological systems were being also addressed, and an up to date overwiev of the important sources, the dosimetry and the effects detrimental to human health were presented in largely the tutorial section of the Workshop.

The Workshop was jointly organized by the MIDEM Society of Slovenia and the Chair of Applied Physics, Faculty of Civil Engineering University of Maribor.

A list of participants is added to this report.

CONFERENCE MIDEM 2004 PARTICIPANTS

	NAME	COMPANY - INSTITUTION	ADDRESS	P. CODE	CITY	
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4	BELAVIČ DARKO	HIPOT-HYB d.o.o	TRUBARJEVA 7	8310	ŠENTJERNEJ	SLO
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8	ČERNIVEC GREGOR	FAKULTETA ZA ELEKTROTEHNIKO	TRŽAŠKA 25	1000	LJUBLJANA	SLO
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11	GLAŽAR BOŠTJAN	FAKULTETA ZA ELEKTROTEHNIKO	TRŽAŠKA 25	1000	LJUBLJANA	SLO
12	GOLJEVŠČEK JERNEJ	FAKULTETA ZA ELEKTROTEHNIKO	TRŽAŠKA 25	1000	LJUBLJANA	SLO
13	HOLC JANEZ	INSTITUT JOŽEF STEFAN	JAMOVA 39	1000	LJUBLJANA	SLO
14	HROVAT MARKO	INSTITUT JOŽEF STEFAN	JAMOVA 39	1000	LJUBLJANA	SLO
15	KOPAČ FRANCI	FAKULTETA ZA ELEKTROTEHNIKO	TRŽAŠKA 25	1000	LJUBLJANA	SLO
16	KOPLAN FRANC	MAGNETI D.D.	STEGNE 37	1000	LJUBLJANA	SLO
17	KOPRIVŠEK MITJA	ETI D.D.	OBREZIJA 5	1411	IZLAKE	SLO
18	KORIČIĆ MARKO	FAKULTETA ZA ELEKTROTEHNIKO	UNSKA 3	10000	ZAGREB	CRO
19	KOROŠAK DEAN	FAKULTETA ZA GRADBENIŠTVO	SMETANOVA 17	2000	MARIBOR	SLO
20	KOSEC MARIJA	INSTITUT JOŽEF STEFAN	JAMOVA 39	1000	LJUBLJANA	SLO
21	KOTNIK TADEJ	FAKULTETA ZA ELEKTROTEHNIKO	TRŽAŠKA 25	1000	LJUBLJANA	SLO

22	KOVAČ GREGOR	SIQ	TRŽAŠKA 2	1000	LJUBLJANA	SLO
23	KOŽELJ MATJAŽ	INSTITUT JOŽEF STEFAN	JAMOVA 39	1000	LJUBLJANA	SLO
24	KRIŽAJ DEJAN	FAKULTETA ZA ELEKTROTEHNIKO	TRŽAŠKA 25	1000	LJUBLJANA	SLO
25	KUNDI MICHAEL	INSTITUTE OF ENVIRONMENTAL HEALTH	KINDERSPITACH. 15	1095	VIENNA	A
26	MAČEK MARIJAN	FAKULTETA ZA ELEKTROTEHNIKO	TRŽAŠKA 25	1000	LJUBLJANA	SLO
27	MAČEK SREČKO	INSTITUT JOŽEF STEFAN	JAMOVA 39	1000	LJUBLJANA	SLO
28	MALIČ BARBARA	INSTITUT JOŽEF STEFAN	JAMOVA 39	1000	LJUBLJANA	SLO
29	MARINČ MARTIN	ISKRA TELA - SEM	C. DVEH CESARJEV 403	1000	LJUBLJANA	SLO
30	MARTINJAK MATEJ	ISKRA EMECO D.,D.	SAVSKA LOKA 4	4000	KRANJ	SLO
31	MERC UROŠ	FAKULTETA ZA ELEKTROTEHNIKO	TRŽAŠKA 25	1000	LJUBLJANA	SLO
32	MIELCAREK WITOLD	ELECTROTECHNICAL INSTITUT	UL. M. CURIE SKTLADOWSKIEJ 55/61	50-639	WROCLAW	PL
33	MOŽEK MATEJ	FAKULTETA ZA ELEKTROTEHNIKO	TRŽAŠKA 25	1000	LJUBLJANA	SLO
34	PERNE JOŽEF	ISKRAEMECO	SAVSKA LOKA 4	4000	KRANJ	SLO
35	PIRIH ANDREJ	ISKRA ZAŠČITE	STEGNE 35	1000	LJUBLJANA	SLO
36	PODRŽAJ JURIJ	FAKULTETA ZA ELEKTROTEHNIKO	TRŽAŠKA 25	1000	LJUBLJANA	SLO
37	PREGELJ ANDRAJ	ISKRA ZAŠČITE	STEGNE 35	1000	LJUBLJANA	SLO
38	PROCIOW KRYSTYNA	ELECTROTECHNICAL INSTITUT	UL. M. CURIE SKTLADOWSKIEJ 55/61	50-639	WROCLAW	PL
39	RAIČ DUŠAN	FAKULTETA ZA ELEKTROTEHNIKO	TRŽAŠKA 25	1000	LJUBLJANA	SLO
40	RECZEK WERNER	INFINEON TECHNOLOGIES AUSTRIA	SIEMENS STRASSE 2	9500	VILLACH	A
41	RESNIK DRAGO	FAKULTETA ZA ELEKTROTEHNIKO	TRŽAŠKA 25	1000	LJUBLJANA	SLO
42	ROČAK DUBRAVKA	INSTITUT JOŽEF STEFAN	JAMOVA 39	1000	LJUBLJANA	SLO
43	SANTO ZARNIK MARINA	INSTITUT JOŽEF STEFAN	JAMOVA 39	1000	LJUBLJANA	SLO
44	SLOKAN MILAN	MIDEM	DUNAJSKA 10	1000	LJUBLJANA	SLO
45	SMOLE FRANC	FAKULTETA ZA ELEKTROTEHNIKO	TRŽAŠKA 25	1000	LJUBLJANA	SLO
46	STRLE DRAGO	FAKULTETA ZA ELEKTROTEHNIKO	TRŽAŠKA 25	1000	LJUBLJANA	SLO
47	ŠEGULA MATJAŽ	ISKRA EMECO D.,D.	SAVSKA LOKA 4	4000	KRANJ	SLO
48	ŠORLI IZTOK	MIDEM	DUNAJSKA 10	1000	LJUBLJANA	SLO
49	ŠTRAUS BOJAN	ISKRA KONDENZATORJI D.D	VAJDOVA 71	8333	SEMIČ	SLO
50	TOPIČ MARKO	FAKULTETA ZA ELEKTROTEHNIKO	TRŽAŠKA 25	1000	LJUBLJANA	SLO
51	TRONTELJ JANEZ	FAKULTETA ZA ELEKTROTEHNIKO	TRŽAŠKA 25	1000	LJUBLJANA	SLO
52	VRTAČNIK DANILO	FAKULTETA ZA ELEKTROTEHNIKO	TRŽAŠKA 25	1000	LJUBLJANA	SLO
53	VUKADINOVIČ MIŠO	FAKULTETA ZA ELEKTROTEHNIKO	TRŽAŠKA 25	1000	LJUBLJANA	SLO
54	ŽAUCER MATEJA	MIDEM	DUNAJSKA 10	1000	LJUBLJANA	SLO
55	ŽUNIČ ANDREJ	FAKULTETA ZA ELEKTROTEHNIKO	TRŽAŠKA 25	1000	LJUBLJANA	SLO

Priznanja društva MIDEM
MIDEM Society Awards

Predsednica društva dr.Marija Kosec je podelila priznanja društva MIDEM

Med konferenčno večerjo je predsednica društva MIDEM podelila priznanja institucijam in posameznikom, ki so v preteklih letih na kakršenkoli način zaznamovali in podprli delo društva ter močno prispevali k razvoju njegove dejavnosti.

Prejemniki priznanj so institucije : Institut Jožef Stefan iz Ljubljane, Fakulteta za elektrotehniko iz Ljubljane, Mikroiks d.o.o. iz Ljubljane, Iskra EMECO d.o.o. iz Kranja in Hipot-Hyb d.o.o. iz Šentjerneja.

Prejemniki priznanj posamezniki so : Franc Jan, Dr.Rudolf Ročak, mag.Milan Slokan, prof.dr.Jože Furlan in prof.dr.Lojze Trontelj.

Ob tej priložnosti se je Milan Slokan spomnil prvih let raziskovalnega dela na področju elektronskih sestavnih delov. Njegov govor objavljamo v celoti.

Drage kolegice in kolegi!

Vesel sem, da sem ob taki častitljivi obletnici, kot je 40. konferenca MIDEM še lahko v vaši družbi. Moram reči, da v Sloveniji ni prav mnogo skupnosti in ljudi, ki bi se kdaj spomnili minulega dela svojih kolegov in jim to javno priznali. Mislim, da je pri nas v MIDEM ta pozornost zasluga naše prizadevne predsednice in članov izvršilnega odbora MIDEM. Iz srca se vam zahvaljujem za prijaznost in želim vsem članom tudi v bodoče še mnogo uspešnih in plodnih let v korist naše stroke in Slovenije.

Ob tej priliki ne morem mimo spominov in podatkov za prva leta raziskovalnega in razvojnega dela ter uvajanja poskusnih proizvodenj elektronskih sestavnih delov ter mikroelektronike in materialov za nje v Sloveniji, kjer sem bil od leta 1948 tudi jaz osebno udeležen. Morda bodo ti podatki zanimivi za marsikaterega udeleženca konference, ker niso več toliko znani. Žal se pri tem nisem mogel izogniti tudi svojim osebnim spominom, kar mi ne zamerite.

V Inštitutu za elektrozveze (IEV) v Ljubljani, ki ga je po osvoboditvi ustanovil Rudi Jančar in ga je vsa leta do združitve z Iskro v letu 1961 kot direktor tudi vodil, s programom za razvoj domače proizvodnje elektronskih naprav za zveze, so malo pred mojim povratkom s služenja vojaškega roka leta 1948 ustanovili kemijski laboratorij, da bi se ukvarjal z osvajanjem domačih materialov in tehnoloških postopkov za proizvodnjo elektronskih sestavnih delov. Prostore je imel v bivši lekarni Bahovec na Kongresnem trgu v Ljubljani, delalo pa je v njem šest do osem ljudi, ki so bili vsi, razen enega, študentje. Delali so na razvoju keramičnih teles za upore, oglenih plastnih uporov in elektronskih kondenzatorjev. Inštitut je potreboval vodjo tega laboratorija, jaz pa sem to delo prevzel oktobra 1948, ker se je nekako navezovalo na moje dotedanje izkušnje v kemijski industriji.

Prva naloga mi je bila, da v teku leta 1949 opredelimo minimalni razvojni program na osvajanju domačih elektronskih elementov in materialov, saj smo morali v času pritiska Informbiroja in Zahoda poiskati domače resurse. Pogoj za to pa je bila na prvem mestu kadrovska okrepitev s sodelavci, pri čemer mi je izredno pomagal prof. Drago Leskovšek na fizikalno-kemijskem oddelku fakultete za naravoslovje in tehnologijo v Ljubljani, ki mi je, ker smo z njim najtesneje sodelovali, v letih 1949 in 1950 priporočil več izredno sposobnih študentov, ki so se z vsem ognjem vrgli na reševanje postavljenih nalog. Tako smo le dve leti po izumu prvega germanijevega transistorja v Bellovih laboratorijih v Ameriki tudi pri nas delali na osvajanju polprevodniške tehnologije. Naš prvi točkasti transistor je bil izdelan iz drobcev domačega *ferosilicija tovarne v Jajcu, na katerem smo poiskali točke ojačenja. Pričeli smo tudi z razvojem feritov, ki jih je tik pred vojno patentiral Philips. Patentom smo se izognili s tem, da smo osvojili tako imenovani mokri postopek. (O tem bi seveda lahko več povedala naša aktivna kolegica Meta Limpel!). Delo na keramiki se je nadaljevalo z razvojem kolutastih keramičnih kondenzatorjev. Prav tako smo uspešno nadaljevali z osvajanjem tehnologije oglenih plastnih uporov in izvedli prvo poskusno proizvodnjo v kleti IEV, od koder je Ludvik Simonič prenesel poskusne naprave v Šentjernej, kjer se je v novo zgrajeni tovarni že leta 1951 pričela redna proizvodnja. Poskusno proizvodnjo elektrolitskih kondenzatorjev smo preselili v Pržan, od tam pa kasneje, ko so v Pržanu rabili prostor, v Vižmarje. Poskusna proizvodnja feritov je najprej našla prostor v stari mizarski delavnici v Črnučah, nato pa že kot redna proizvodnja v poslopju v Šiški pri stari cerkvi. Polprevodniška skupina se je preselila, ko je rabila več prostora v leseno barako na Jamovi cesti, po požaru, ki je barako z opremo vred uničil, pa v stransko poslopje Kemijskega inštituta Boris Kidrič.*

Vse to je spadalo pod kemijski laboratorij, saj smo v poskusnih proizvodnjah hkrati izpopolnjevali tehnološke postopke in že dobavljali izdelke naročnikom v razvoju in proizvodnji elektronskih naprav. Pomisliti moramo, da takrat v Jugoslaviji ni bilo nobenega drugega proizvajalca elektronskih elementov, saj je bila pred vojno elektronika monopol tujih podjetij.

Danes se čudim, kako smo uspeli večino zastavljenih nalog uspešno končati in prenesti v proizvodnjo. Skrivnost uspeha je bila v domiselnosti in zagnanosti mladih strokovnjakov, ki so delali na nalogah. Razen tega smo imeli delovne skupine, kjer so družno delali kemiki, fiziki, metalurgi, elektrotehniki in strojniki od študentov, inženirjev, tehnikov in laborantov. Našli smo staro primerno opremo in izdelovali novo. Poiskali smo pomoč naših rojakov v tujini, da smo si lahko ogledali proizvodnjo elektronskih delov. V naslednjih letih pa smo začeli sodelovati na mednarodni ravni. Tako smo v desetletju 1950-60 vzpostavili tesne stike ter povezali raziskave in razvoj na primer s francoskim nacionalnim poštnim inštitutom za študij telekomunikacij (CNET) in s francoskim nacionalnim centrom za znanstvene raziskave (CNRS) v Parizu. Nekaj let kasneje smo začeli tesno sodelovati s poljskim državnim inštitutom za telekomunikacije v Varšavi.

Leta 1950, ko je dobil kemijski laboratorij že trdno organizacijsko osnovo in dokaj jasno opredeljen program, je bilo v njem zaposlenih od 20 do 25 sodelavcev. Od tedaj dalje je laboratorij neprestano rasel in se kadrovsko krepil, saj smo začenjali z novimi programi. Pričeli smo z razvojem domačih anorganskih in organskih materialov, ki so jih potrebovale proizvodnje v IEV, kasneje v Telekomunikacijah. Razvijali smo prve srebrne in živosrebrne baterije, kasneje v letih 1955-57 pa smo osvojili takozvane baterije za radio sonde, ki jih je rabila meteorološka služba. Sredi petdesetih let smo na doma izdelani napravi izdelovali prve metalplastne upore.

Skupaj z zunanjimi sodelavci sem medtem iskal možnosti za izkoriščanje razpoložljivih surovinskih virov in za njihovo oplemenitenje: na primer za pridobivanje germanija, indija, srebrnega prahu za srebrilne paste, itd. Delali smo tudi na razvoju organskih materialov, raznih lakov, zalivk in podobno. Po letu 1955 smo pristopali tudi že k razvoju nekemijskih sestavnih delov, na primer kremenovih frekvenčnih enot, ta laboratorij je bil tudi v Črnučah in je kasneje prerasel v poskusno proizvodnjo. Ni čudno, da je po nekako sedmih letih v začetku čisto kemijski laboratorij prerasel v Kemijsko-fizikalni laboratorij, oziroma kasneje v oddelek, nato pa v Kemijsko-fizikalni sektor IEV, ki sem ga vodil kot pomočnik glavnega direktorja.

Večina programov je izšla iz hotenja, da izpolnimo velikansko vrzel ter zaostanek med proizvodnjo elektronskih sestavnih delov v razvitem svetu in doma. Da je bilo naše delo uspešno, pa je bilo pogojeno z izredno raziskovalno in razvojno klimo v IEV, kjer sem užival popolno zaupanje, podporo in priznanje vodstva IEV, posebej seveda direktorja Rudija Jančarja, človeka izrednega formata in vizionarja, ki je bil obenem tudi človek izredne topline.

Najlepše in najkrajše našteje rezultate osvajanja sestavnih delov v IEV katalog, ki je izšel leta 1960 in je navajal izdelke, ki so bili v prodaji, na 37 straneh. Preveč bi porabil časa, če bi jih vse našteval. Ponosen pa sem, če lahko rečem, da je večina le-teh izšla iz kemijskega laboratorija IEV, razen navitih kondenzatorjev, litih magnetov ter vakuumskih izdelkov.

Mikroelektroniko smo začeli osvajati leta 1962 v Zavodu za avtomatizacijo z direktorjem Francem Dobnikarjem pod vodstvom prof. Tavzesa in dr. Zalarja, ki smo ga mi napotili v Ameriko na specializacijo. (O razvoju mikroelektronike bi seveda lahko največ povedal Franci Jan). Vendar bom s tem ta pomanjkljivi pregled prvih začetkov osvajanja elektronskih sestavnih delov v Sloveniji v IEV do leta 1961 zaključil, saj menim da je razvoj v Iskrinem inštitutu ZZA od leta 1961 dalje pri nas že bolj znan. Opravičujem se, če sem bil že dotlej precej dolg. Mislim pa, da je ob tej priliki prav, če omenim, da nam ni bilo vseeno, kako se razvija strokovno delo ter kadri le doma, temveč smo imeli pred očmi nujnost povezovanja in uveljavljanja v okviru združevanja v strokovnih organizacijah. Ker smo bili v Sloveniji edini od začetka nastanka Jugoslavije, ki smo se ukvarjali z elektronskimi sestavnimi deli in materiali, je bilo naravno, da smo, v okviru Jugoslovanske zveze za ETAN v Sloveniji ustanovili Zvezni strokovni odbor za elektronske sestavne dele in materiale SSOSD, ki je pozneje prerasel v Strokovno sekcijo za elektronske sestavne dele, mikroelektroniko in materiale, ki je bila, kot veste, predhodnica društva MIDEM. Razumljivo je, da je organizacija strokovnih kon-

ferenc ter posvetovanj zelo pomembna dejavnost strokovnih društev, kar dokazuje tudi današnja častitljiva obletnica. Tega smo se zavedali tudi mi v Ljubljani, saj so bile pri nas že pred ustanovitvijo ETAN-a organizirane prve prireditve s področja telekomunikacij, avtomatizacije in elektronskih sestavnih delov.

Med drugim smo leta 1959 organizirali v Ljubljani posebno posvetovanje, kjer smo pregledali dotedanje razvojne in proizvodne načrte in si začrtali bodoči kratkoročni in dolgoročni program za področje elektronskih sestavnih delov in materialov. Žal pa o tem ne obstaja več nobena dokumentacija.

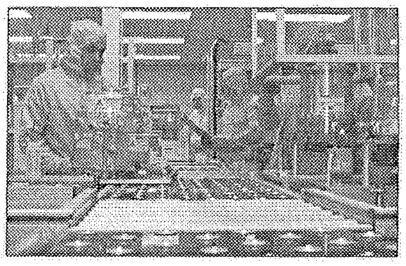
Ko ste poslušali moje podatke in spomine, moram reči z malo nostalgije, da sem najbolj užival prvih 15 let, ko sem lahko precej neposredno delal in vplival na nastajanje in vzpodbujanje rasti elektronskih sestavnih delov in materialov v Sloveniji, čeprav so mi ta lepa in včasih težka leta minila, ne da bi se zavedal, da so v njih moja mladost in zrela leta. Vendar sem tudi izven službenih obveznosti z veseljem in entuziazmom sodeloval v društveni dejavnosti, saj sem se zavedal, da je v prijateljstvu in slogi moč.

Miran Slokan
Maribor, september 2004

NOVICE
NEWS

UK pump remanufacturing site opens

BOC EDWARDS has opened a new European pump remanufacturing facility at Crawley; UK. The Ł1.2mn facility includes decontamination facilities, two flow-lines, a clean room and an award winning wastewater-recycling plant.



Remanufacturing involves decontamination, dismantling, cleaning, checking, replacing worn parts, reassembling and finally testing before the pump is returned to the customer or held in stock as a service replacement.

Although vacuum pumps typically run for three to five years without a factory service, processes involving corrosive gases (typical in semiconductor manufacture) or large amounts of dust require more frequent maintenance. The new site employs 120 people and operates seven days a week

Slovakian scientists scanning for partners

THE SLOVAK Institute of Physics has developed and constructed a scanning capacitance scanning probe microscope (SPM) technique. While capacitance capabilities are offered by commercial SPIVIs, the new technique is based on a different patented principle that promises greater analytical possibilities.

The Slovakian microscope can be operated in normal atmosphere or in liquids, unlike the vacuum conditions required by scanning electron

microscopes (SEMs). The technique is suited to imaging conducting surfaces, with resolutions down to lOnm, or surfaces coated by insulating films where the resolution is somewhat reduced.

For analysis of semiconductor structures, scanning capacitance microscopy is seen as the only non-destructive analysis tool, with resolutions meeting requirements for future 1C generations.

The Slovakian scientists are seeking joint venture and license agreements with partners.

Euroaea

Dual beams for power processing

THE HIGHEST capacity ion beam accelerator facility in the world was officially opened at EBIS in Oxfordshire, UK.

The Ł2mn Tandem 5MV ion beam accelerator is designed principally to meet the needs of the power semiconductor processing industry. EBIS is the only site in the world to provide both electron and ion beam treatment.

The dual service will enable the facility to reduce work-in-progress by up to 20%, saving manufacturers at least a week or more in production time, it is estimated.

The new production facility will be used to improve semiconductor efficiency through carrier lifetime control. Electron and ion beam treatments used in combination can result in optimised switching characteristics.

The new accelerator is supplied by National Electrostatics replacing a machine developed by the United Kingdom Atomic Energy Authority (UKAEA) at Harwell in the 1960s. Power semiconductor processing covers applications ranging from dimmer switches through to heavy industrial electrical equipment.

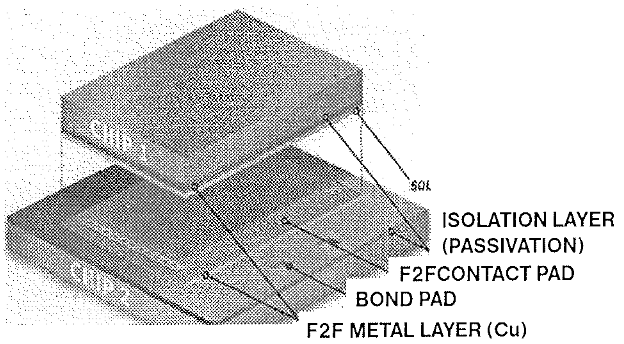
EBIS also provides other services based on its ion beam capability. These include real-time wear measurement (RWM) technology, invented at Harwell and used to develop next generation automotive lubricants and low-emission engines.

Face-to-face for 20MByte chip card security control

INFINEON TECHNOLOGIES is using a "chip-sandwich" technique that involves face-to-face (F2F) interconnection to design chip card ICs for use in mobile communications. One aim is to offer more than 100 times the memory capacity of today's chip cards with only double the chip area.

The German company claims the world's first chip card security controller using the innovative F2F technology, offering IMByte of memory capacity, manufactured on a 130nm process. The first application is expected to be a IMByte security controller for SIM cards (GSM, UMTS).

Infineon believes that it can build an ISO-compliant chip card microcontroller offering up to 20MByte of memory, which is expected to be available in the second half of 2006.



Without extra-wirebonding, the F2F chips are mechanically and electrically interconnected via the hundreds of chip contact pads, resulting in higher performance and memory capacity on the same chip area, while at the same time fitting into a standard chip card specific package.

Tool suppliers EV Group and Datacon Technology have agreed joint development of advanced-chip-to-wafer (AC2W) technology based on the F2F approach. AC2W can integrate various device technologies such as ICs and micro-electromechanical systems (MEMS). The new platform has already been installed at Infineon.

The R&D to create the technology was carried out in a joint R&D project combining Datacon's expertise in chipbonding and key flip-chip bonding technologies with the wafer-level know-how of the EV Group.

ERRATA

From:
Dr. Marjan Jenko,

First author of the paper "Designing inductors for a frequency dependent Q-factor", published in the 2nd issue of vol. 34 (2/2004)

To:
Dr. Iztok Šorli,

Editor of the Informacije MIDEM, Journal of Microelectronics, Electronic Components and Materials

Dear Dr. Šorli,

We would like you to publish the corrections of the *errata* we had in the properly formatted version of the paper "Designing inductors for a frequency dependent Q-factor":

Page 85, first column, equation (18), third line, above the first fraction line, instead of $2\pi\rho_w\sigma_w^2 dL$, it should be $\pi\sigma_w\delta_w dL$.

Page 85, first column, equation (21), instead of $\exp\left(\frac{-p}{\delta_w}\right)$, it should be $\exp\left(\frac{-p}{\delta_p}\right)$.

Page 85, first column, second to last paragraph, instead of "is a function of eight variables (three geometric variables, four material constants and frequency)", it should read "is a function of six variables (three geometric variables, two material constants and frequency)".

Page 85, first column, the second to last expression, instead of $R_0 = f\left(dL, a, w; \sigma_w, \sigma_p, \delta_w, \delta_p; f\right)$, it should be $R_0 = f\left(dL, a, w; \sigma_w, \delta_w; f\right)$.

Page 85, second column, for δ_{Cu} and δ_{Ni} the unit is *m*, not *mm*. In the sixth expression, above the first fraction line, it is 0.0096 instead of 0.0088.

Page 85, second column, text in the center of the column, instead of "in the range of 0 to 0.07 mm" it should read "in the range of 0 to 0.007 mm".

Page 85, the third line from the bottom, instead of "70 µm" it should be "7 µm".

Page 85, Figure 2, and page 86, Figure 3, instead of $p\,[mm]$ it should be $10p\,[mm]$.

Page 85, reference 8, the words "(nelinearnost plazme)" are to be erased.

We apologise for the typos in the delivered formatted paper.

Marjan Jenko
January 2005

Informacije MIDEM
Strokovna revija za mikroelektroniko, elektronske sestavine dele in materiale

NAVODILA AVTORJEM

Informacije MIDEM je znanstveno-strokovno-društvena publikacija Strokovnega društva za mikroelektroniko, elektronske sestavne dele in materiale - MIDEM. Revija objavlja prispevke s področja mikroelektronike, elektronskih sestavnih delov in materialov. Ob oddaji člankov morajo avtorji predlagati uredništvu razvrstitev dela v skladu s tipologijo za vodenje bibliografij v okviru sistema COBISS.
Znanstveni in strokovni prispevki bodo recenzirani.

Znanstveno-strokovni prispevki morajo biti pripravljeni na naslednji način:

1. Naslov dela, imena in priimki avtorjev brez titul, imena institucij in firm
2. Ključne besede in povzetek (največ 250 besed).
3. Naslov dela v angleščini.
4. Ključne besede v angleščini (Key words) in podaljšani povzetek (Extended Abstract) v anglešcčini, če je članek napisan v slovenščini
5. Uvod, glavni del, zaključek, zahvale, dodatki in literatura v skladu z IMRAD shemo (Introduction, Methods, Results And Discsussion).
6. Polna imena in priimki avtorjev s titulami, naslovi institucij in firm, v katerih so zaposleni ter tel./Fax/Email podatki.
7. Prispevki naj bodo oblikovani enostransko na A4 straneh v enem stolpcu z dvojnim razmikom, velikost črk namanj 12pt. Priporočena dolžina članka je 12-15 strani brez slik.

Ostali prispevki, kot so poljudni cčlanki, aplikacijski članki, novice iz stroke, vesti iz delovnih organizacij, inštitutov in fakultet, obvestila o akcijah društva MIDEM in njegovih članov ter drugi prispevki so dobrodošli.

Ostala splošna navodila

1. V članku je potrebno uporabljati SI sistem enot oz. v oklepaju navesti alternativne enote.
2. Risbe je potrebno izdelati ali iztiskati na belem papirju. Širina risb naj bo do 7.5 oz.15 cm. Vsaka risba, tabela ali fotografija naj ima številko in podnapis, ki označuje njeno vsebino. Risb, tabel in fotografij ni potrebno lepiti med tekst, ampak jih je potrebno ločeno priložiti članku. V tekstu je treba označiti mesto, kjer jih je potrebno vstaviti.
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Informacije MIDEM
Journal of Microelectronics, Electronic Components and Materials

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