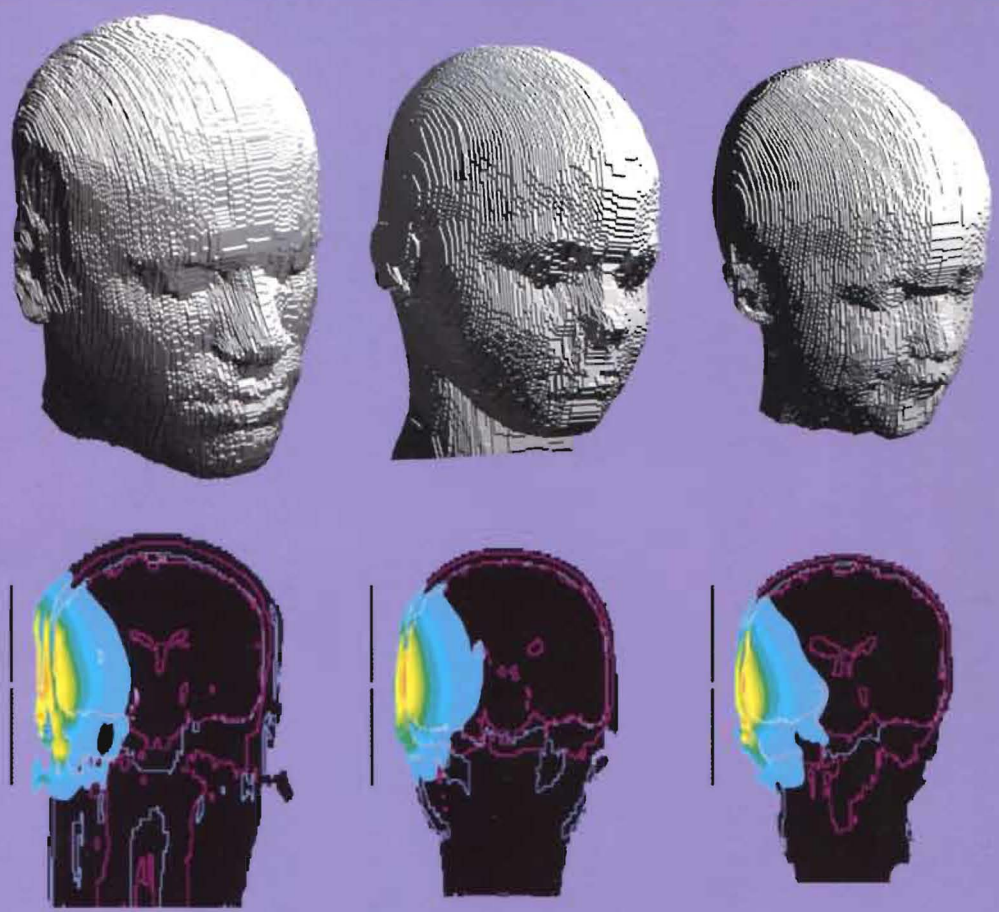
Laboratory for EMF and
Microwave Electronics

Annual Progress Report 1996



BIOEM/EMC Group

Contents

Cover page: MRI based phantoms of adults and children used for absorption studies (see page 14).

Preface

This is the first annual progress report of the BIOEM/EMC research group, which was founded in 1993 as the third subgroup of the Laboratory of EMF and Microwave Electronics. Originally having only two members, the scope of the group's activities has continuously expanded, largely thanks to the generous support received from industry partners.

The aim of this progress report is to inform our partners and colleagues of the activities and achievements during the past year. Most importantly, however, we use this opportunity to express our gratitude to all the institutions, companies and persons who have continued to generously sponsor, support and fund our various activities.

Our explicit thanks go out to our long-lasting and most faithful partners Motorola Inc. (USA), DeTeMobil (Germany) and Swiss Telecom PTT (Switzerland). The success of our activities would not have been possible without their continued generous support. We also wish to thank the other partners listed in this report. We owe our thanks to the Swiss Confederation for its support through the research programs of ETH, SPP and KTI.

This past year would also not have been so successful without the cooperation and fruitful discussions with our research partners - for this too we are deeply grateful.

I would also like to thank all the members of our group for their tremendous efforts and their commitment to research of rigourous quality, as well as all those individuals at the ETH who have continued to support our activities in a multitude of ways.

Niels Kuster

Group Members 1996

Michelle Bunge (Administration, part-time 10%)
Michael Burkhardt (PhD Student)
Benedict De Silva (Copy Editor, part-time 5%)
Ralph Kästle (Post-Doc, until 12/1996)
Jeroen Keijzer (Mechanical Engineer, part-time 30%)
Georg Klaus (PhD, Lecturer)
Niels Kuster (Professor)
Klaus Meier (PhD Student, until 7/1996)
Katja Pokovic (PhD Student)
Thomas Schmid (Project Leader, part-time 50%)
Frank Schönborn (PhD Student, since 6/1996)
Magnus Sundberg (Visiting Scientist, since 12/1996)
Thomas Schwitter (Graphics/Layout, part-time 30%)
Roger Tay (External PhD Student at Motorola Inc., USA)
Ondrej Voles (PhD Student, since 12/1996)

Guests 1996

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CETELCO, Denmark

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Motorola Inc., USA

Dr. Ulrich Dersch
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Mr. Bernhard Eicher
Swiss Telecom PTT, Switzerland

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Ericsson Mobile Communications, Sweden

Mr. Klemens Martin
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Mr. Masao Sano
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Dr. Michael Schüller
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Mr. Masaru Takahashi
MITC, Japan

Dr. Motoshi Tanaka
Akita University, Japan

Prof. Masanari Taniguchi
Meijo University, Japan

Dr. Art Thansandote
Health Canada, Canada

Overview

Introduction

Ever since the beginning of 1993, when the use of portable cellular phones became an issue of public health concern, exposure and health risk assessment has become one of the main focuses of our activities. We have always committed ourselves to using the highest standards of scientific rigor to determine the maximum exposure and health risk, applying the most advanced and sensitive techniques. This approach has not always been received with much enthusiasm from all quarters. However, most of industry by now also realizes that longterm public confidence in wireless technology is a delicate thing that can only be kept alive by objective research done by completely independent organizations of repute. We commend the farsightedness of those companies which stood by this concept right from the outset.

Progress in Exposure Assessment

Near Field Scanners

By the end of 1994 the development of the first near field scanner enabling accurate dosimetric and near-field evaluations had been largely completed. Growing interest in this product led to the grounding of the spin-off company Schmid & Partner Engineering AG (SPEAG), which quickly turned the prototype DASY1 into the commercial product DASY2. The company, whose activities are briefly described in this report, is currently focusing their efforts on the development of DASY3, which is scheduled to be launched in mid 1997.

Phantoms for Compliance Testing

Since little data on the dependence of absorption on anatomic features was availiable, it was not possible to define or establish up-front which phantom would be suitable for compliance testing. It was also clear from the beginning that the exposure assessed with any given phantom should not underestimate the maximum exposure occurring within a reasonable cross-section of the mobile phone user population, including children. The implications of this problem have been intensively studied during the last two years, resulting in several publications on topics including: 1) the dependence of EM energy absorption at 900 and 1800 MHz, 2) the effect of external metallic accessories and 3) metallic implants, and 4) the differences in the absorption between children and adults. A generic phantom was developed based on the findings of these studies, and data from a detailed anatomical study of the area around the ear. Compliance testing of cellular phones performed with this phantom guarantee that the exposure of at least 90% of actual users will not be underestimated. Data on the shape of the phantom is now publicly available, and SPEAG has integrated this phantom as well as a very precise phone positioner into its product line.

Calibration Procedures

The package consisting of the scanner, phantom and the refined calibration procedure, developed in 1995, is an ideal and accurate dosimetric evaluation system for testing compliance with any safety standard defined in terms of the specific absorption rate (SAR). Further improvements are still needed in the area of error analysis and traceability of the calibration. Ongoing research projects are currently tackling these areas.

Dosimetric Evaluation

In 1996 the group performed several dosimetric evaluations of commercial cellular phones or prototypes for companies in Europe and Japan.

Near Field Evaluation

Near-Field Scanner

Our experience has clearly demonstrated the meaningfulness of accurate near-field evaluations in free space. DASY3 will provide further functionality for such evaluations.

Electric and Magnetic Near-Field Probes

Together with our industrial partners and funding from KTI, the fourth generation of isotropic E- and H-field probes are currently being developed. These will outperform the best E-field probes currently commercially available from SPEAG in terms of spatial resolution, frequency range and isotropy. Probes optimized for special media will become commercially available before autumn 1997.

Computational Techniques

EMSIM Platform

During the past year the group has found the way back to its roots in electromagnetic computations. Under the auspices of the Swiss priority program "Micro & Nano System Technology (MINAST)" the development and implementation of the electromagnetic simulation

(EMSIM) platform was initiated in collaboration with the Institute for Integrated Systems at ETH and several industrial partners. The scheduled cold start led to some delays, due to difficulties in finding appropriate PhD students. The project is scheduled to be completed in late 1998.

CAD Tool for Antenna Design

The focus of work in this area for the next two to three years will be the implementation of an efficient CAD tool for antenna design based on the EMSIM kernel.

Health Risk Assessment

Exposure Setups

In retrospect, many of the biological experiments conducted with great meticulousness have turned out to be of limited value due to major shortcomings in the exposure setup. Because of our considerable experience in experimental as well as numerical dosimetry, we have begun to support biological research groups around the world in developing optimized setups to ensure the most sensitive experiments possible – the objective being to fulfill stringent exposure requirements without the need for significant departures from the experimental protocol. This includes the use of well-established cell lines or animal models that have been shown to be highly sensitive in their response to other physical or chemical agents and are well characterized with respect to possible artifacts. We will continue to provide this service over the next few years.

In Vivo and In Vitro Experiments

During the past four years we have participated in some important *in vivo* and *in vitro* experiments conducted at the Research Center of the Department of Veterans Affairs in Loma Linda CA, Washington University and at the Max Planck Institute in Cologne. The objectives of these experiments have been to evaluate possible acute and chronic effects in the central nervous system. These experiments, conducted by independent laboratories with the highest standards of scientific rigor, have greatly helped to clarify several open questions with regard to health risks and have served to improve public confidence in modern wireless communications technology.

Other Activities

Commissions

Results and findings such as these, acquired from scientific research can only benefit technology and society if they are rapidly translated into international and national standards and regulations. We therefore actively support standardization agencies and commissions in Europe, USA and Japan by providing them with data and actively participating in the deliberations of these organizations.

Consulting Services

We continue to offer our know-how in dosimetric assessments, near-field measurements and antenna design to various companies in the USA, Europe and Japan. We also provide our partners with the latest information on regulations and scientific progress.

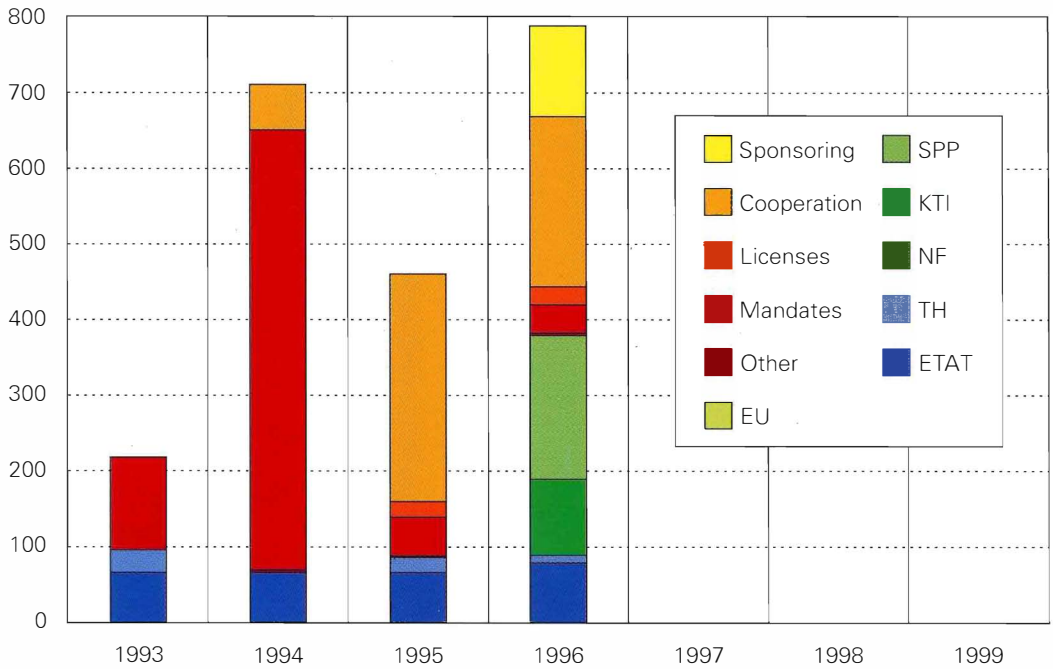
Publications

In the past few years the volume of our publications in scientific journals did not quite reflect the volume of our research activities, since much of our resources were absorbed by providing services to industry and in the founding of the spin-off company SPEAG. In 1996 we were able to increase our publication output, as the enclosed statistics shows. The highlight was the publication of the book "Mobile Communications Safety", written by the most distinguished scientists in the field, summarizing the state of knowledge of this controversial field. A complete list of the 1996 publications is given at the end of this report.

Courses

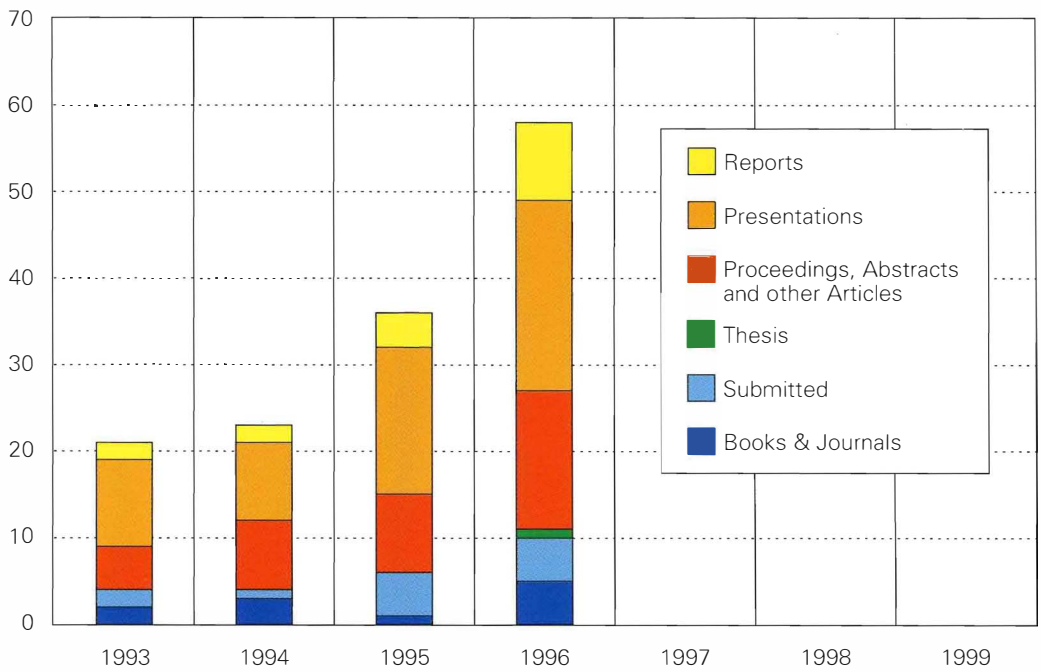
A two semester course on Electromagnetic Compatibility deals with all classical concepts of EMC and the concept of safety standards. This course is becoming increasingly popular since becoming better coordinated with the degree program in 1995.

Development of Funding (kSFr)

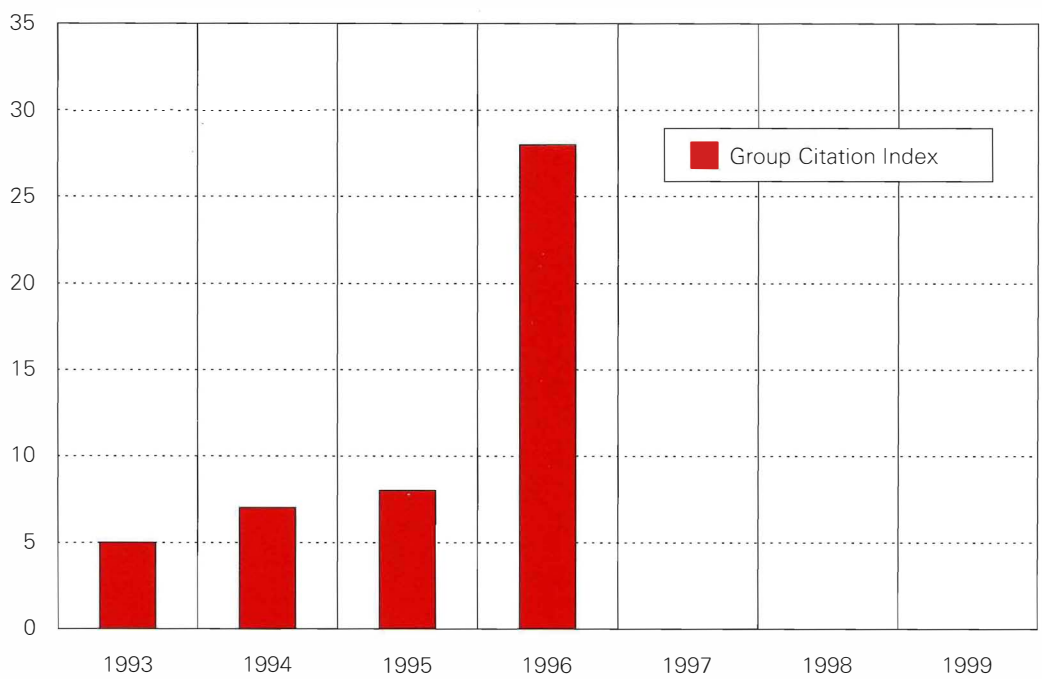


Included is funding received through: sponsoring, cooperations, mandates and other assignments from the industry; research projects of the European Union (EU); the research funds of the Federal Government: Swiss Priority Program (SPP), Commission for Technology and Innovation (KTI) and the Swiss National Fund (NF); the ETH research program (TH), as well as the basic support provided by the university (ETAT).

Development of Publications



Group Citation Index



Selected Projects 1996

Electromagnetic Simulation Platform for Microsystems and Wireless Technology

Funds
Swiss Priority Program in Micro & Nano Systems Technology (SPP MINAST)

Partners
Integrated Systems Laboratory
ISE AG Zurich
SPEAG Zurich
Huber & Suhner AG
Telekom PTT

Background

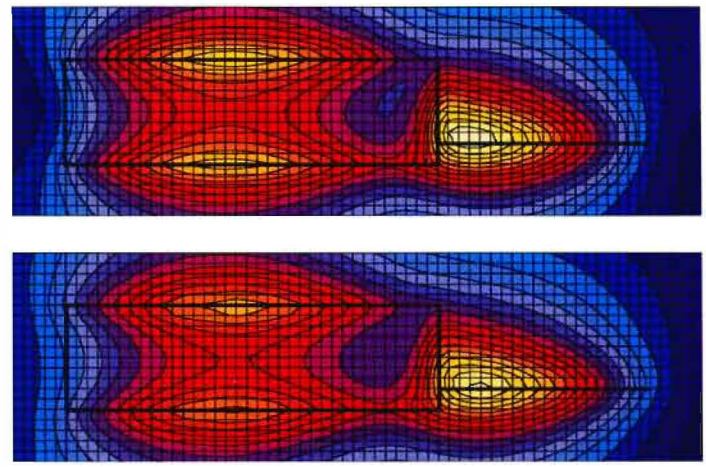
The accurate modeling of electromagnetic effects, which in the past was only a matter of academic interest, is now becoming an increasingly important issue in the design of advanced commercial microelectronic devices and systems. The rapidly increasing level of integration and miniaturization of microelectronic systems requires exact knowledge on such parasitic effects as cross-talk, coupling, radiation and irradiation. The accurate simulation of these electromagnetic effects is necessary to be able to reliably predict the behavior of microelectronic systems. Microelectronic systems also either rely on or have built-in wireless technology features. Miniaturization and limitation of the power consumption of devices pose great challenges that can only be mastered by designing efficient antennas for use in complex environments. Together with the Integrated Systems Laboratory and four partners from industry, our group is currently developing an electromagnetic simulation platform to analyze and optimize microelectronic systems.

Objectives

The objective of this project is to develop a robust and flexible platform for electromagnetic computations. The wide range of applications envisaged requires a hybrid simulation system that offers several simulation techniques to perform fullwave, quasi stationary and electrostatic simulations.

Methods

The platform consists of several computational kernels. Rigorous electromagnetic fullwave simulations are to be performed using the Finite-Difference-Time-Domain (FDTD) Technique. This technique allows the simulation of complex configurations by way of discretizing space. Since the computation is performed in the time domain, signal behavior can be easily simulated. Further kernels based on the Finite Element Technique and the Generalized Multipole Technique can be used for specialized purposes. The integration of all these features into the same platform allows the use of the same set of preprocesssing, post-processing and visualization tools. Data obtained by the different simulation techniques can be easily exchanged on the simulation platform, e.g., using data from a quasi stationary simulation as the excitation source for a full wave simulation. The integration of each simulation technique into an optimization loop enables the structure being investigated to be optimized with respect to a well characterized set of parameters.



Simulated (top) and measured (bottom) H-field distribution 5 mm above a generic phone. The measurement was performed with the near field scanner DASY2 by SPEAG, the simulation was performed using the FDTD technique.

Results and Discussion

The implementation of the FDTD kernel is in an advanced stage, allowing the full wave simulation of a wide range of electromagnetic applications. Its design is fully object-oriented, allowing further flexible modular development. Using a near field scanner for experimental verification, various benchmarking tasks for radiation problems have been performed together with our industrial partner SPEAG.
The kernel is currently being integrated into a graphical user-interface by ISE AG. This tool combines various discretization, simulation and visualization tools.

Antenna Optimization in Handheld MTE

Funds
Motorola Inc.
ETH

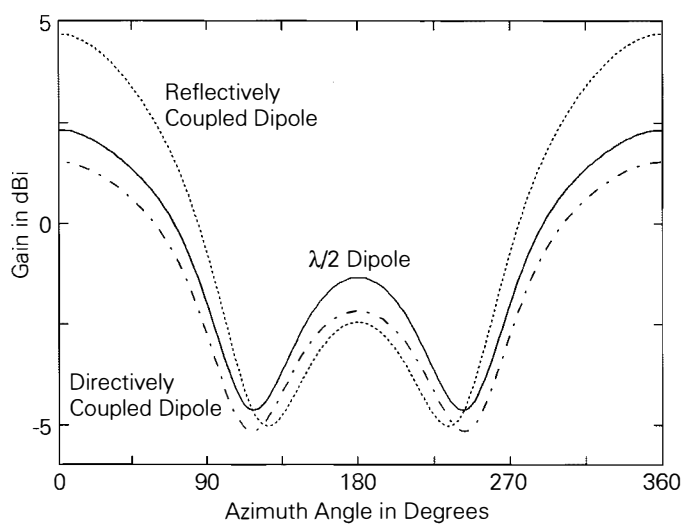
Partners
Motorola's Corporate Electromagnetics Research Laboratory, Ft. Lauderdale

Background

Ever since cellular phone services were introduced, the industry has made significant progress in greatly reducing the size and weight of hand-held mobile telecommunications equipment (MTE). Performance and functionality have been vastly improved. However, with a couple of exceptions, the antenna configurations have remained basically the same. In some cases helical antennas and monopole antennas of reduced length have been employed. Shorter antennas and reduced separation between the antenna and the head can result in much higher levels of energy loss, due to absorption in the head of the user. Up to 70% of the power available at the feed point of the antenna can be absorbed by the user's head.

Improving radiation efficiency can provide advantages such as longer talk time or smaller and lighter batteries. A comparison of current commercial devices shows that a significant reduction in absorption results in increased efficiency even with conventional designs.

An obvious design approach that ensures compactness and reduced exposure is through use of planar directional antennas built into the side of the MTE furthest from the head. Although studies have shown that such antennas significantly reduce the absorption in the user's head, there are difficulties with regard to their design. For example, effective design measures must be implemented to prevent the users from covering the antenna when holding or shouldering the phone. A further difficulty is in achieving the required bandwidth and efficiency for such a small device. Nevertheless, the first devices equipped with such antennas were successfully introduced to the market in 1996.



The radiation pattern of dipole structures combined with parasitic elements in the vicinity of a head phantom demonstrate that significantly improved efficiency can be obtained even with simple antenna concepts.

Objectives

The objective is a series of studies to develop antennas for handheld devices with improved overall performance. These studies will be performed utilizing the near-field scanners DASY2&3 and the antenna CAD tool currently being developed in the EMSIM project.

The objective of the study completed in 1996 was to investigate the most important citeria for designing antennas with improved efficiency.

Methods

The study was performed using a λ/2 dipole antenna combined with a director or a reflector for operation in close vicinity to a very lossy scatterer. The main investigations were performed with the simulation tool 3DMMP, the results of which were verified by FDTD stimulations as well as by near-field measurements with DASY2 and far field measurements in an anechoic chamber.

Results and Discussion

This study showed that the most important factor in improving antenna efficiency is not primarily enhanced directivity but a minimized H-field at the user's face. This is explained by the inductive, as opposed to radiative, nature of the absorption mechanism in biological bodies in the near field of antennas. For example, for a reflectively coupled dipole at a distance of 2 cm from the head, the spatial peak SAR in the head is reduced by 4.7 dB and the effective radiation efficiency is improved from 34% to 71%. In addition, the driving point impedance is less dependent on the position of the antenna with respect to the scatterer. These results are much better than could be expected considering the directivity of this structure. The suitability of this structure and other approaches will be studied in future projects.

Differences in Exposure between Adults and Children

Funds
Telecom PTT
DeTeMobil
ETH

Partners
Research & Technology Center Telekom

Background

The testing of mobile phones for compliance with safety standards is currently performed only with phantoms representing the heads of adults. Additional studies on absorption in children's heads have become necessary, since recent studies [O. P. Gandhi *et al.*, Vol-MTT 44, No. 10, pp. 1884-97, 1996] claim significant differences in the absorption of adults and children.

Objectives

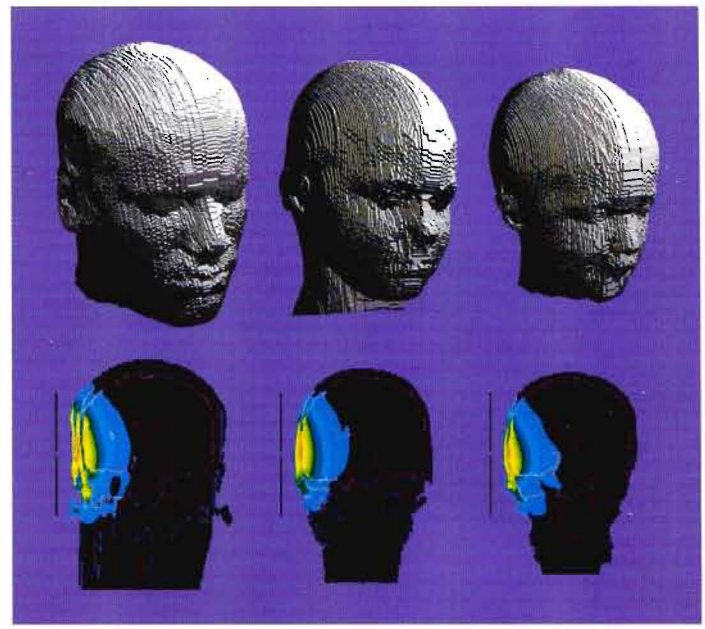
The objective of this study was to investigate possible differences of the SAR distribution and averaged SAR values for anatomically realistic children's phantoms as compared to those for phantoms derived from adults.

Methods

Two head phantoms of children of the ages of three and seven were developed for this study based on data from MRI scans. Ten tissue types were distinguished and the simulations were performed at a spatial resolution of 1x2x2 mm^3. Simulations of four adult heads with similar spatial resolutions were already available, three of which are described in [Hombach *et al.*, Vol-MTT 44, No. 10, pp. 1865-73, 1996]. Since the objective was to evaluate the differences in absorption between the heads of children and adults, it was essential to have a well defined source at a well defined distance from the head. A 0.45λ dipole was chosen and oriented parallel to the body's axis. The numerical simulations were performed with the software tool MAFIA, which is based on the FDTD-like Finite-Integration-Technique.

Results and Discussion

The spatial peak SAR values averaged over 1g and 10g of tissue and normalized to an antenna feedpoint current of 100 mA were 3.8 mW/g and 2.8 mW/g for the 3 year old child and 4.0 mW/g and 2.9 mW/g for the 7 year old child. These values are within the ranges of 3.4 ±16% mW/g and 2.7 ±14% mW/g found for the four adult head phantoms. The small differences are due to anatomical variations. As expected, the ratio of absorbed to emitted power decreases with decreasing head size. The dependency of the SAR_{1g} and SAR_{10g} values to the distance of the antenna was the same for the adult and child phantoms.
[Gandhi *et al.*] simulated the children's heads by scaling down an adult's head. Since the anatomy of such a head greatly differs from the anatomy of a child's head, scaled-down heads were simulated as well, to explore the reasons for the differences. The adult phantom was scaled-down using three scaling factors (0.93, 0.88, 0.67)



Various MRI based phantoms have been developed for adults as well as for a 7 year and a 3 year old child. Although the size and tissue distribution of the head phantoms are quite different, the SAR distribution for the same excitation is hardly altered, and results in similar spatial peak SAR values.

to create head phantoms of reduced size, corresponding approximately to heads of a 7 year old, a 3 year old child, and a small baby. The SAR distributions in the scaled down head phantoms differ from that in the full scale phantom only in terms of shifts in maxima and minima caused by shifts in the location of the different tissues due to the scaling. There was no significant difference in the spatial peak SAR values.
In summary there are no significant differences between adults and children in the way electromagnetic fields at 900 MHz and 1800 MHz are absorbed. For identical excitation the SAR_{1g} and SAR_{10g} values are not higher for children than for adults, i.e., it is sufficient to perform compliance tests with a shell phantom representing the worst-case shape of an adult head.

Generic Twin Phantom

Funds
Schmid & Partner Engineering AG
ETH

Partners
Research & Technology Center Telekom
Schmid & Partner Engineering AG

Introduction
Various phantoms have been proposed or are already in current use for compliance testing. However, none of these has been designed with the goal of either representing a reasonable cross-section of MTE users or accounting for uncertainties with respect to the maximum exposure within such a group. For example, differing ear thicknesses ranging from 4 mm to 10 mm are used, which can distort the spatial peak SAR values by 3 - 6 dB.

Objective
Development of a phantom for which the uncertainty within the user group can been assessed.

Methods
Homogeneous phantoms have been proven to be suitable for compliance testing. Although variations in the shape of the head do not lead to changes in the absorption mechanism, e.g., by focusing effects, they determine the distance between the currents on the device and the skin for any given MTE position which is defined in terms of the angular orientation with respect to the axis of the auditory canal. In order to obtain a phantom providing minimum distances, an anatomical study was performed. The group selected consisted of 33 men and 19 women between the ages of 20 and 52, mainly European, but from different ethnic groups. The head circumferences varied from 55 cm to 61 cm, which is in good agreement with results obtained in wider ranging medical surveys. The shape of the head in the ear region (16 x 15 cm) was determined using a specially constructed measurement device. The evaluation criterion was the 10%-percentile of the distance between the auditory canal and each of the measured points. The precision of the measurements as well as that of the positioning of the head within the device was tested and found to be better than ±10%. The thickness of the pressed ear was determined in a similar manner.
In the next step, a generic human shell phantom was constructed by fitting the 10%-percentile surface to a human CAD phantom, whereby this surface was rendered in an area of approximately 12x12 cm around the ear with a precision of better than ±1 mm. This generic head shape ensures simulation of the exposure of about 90% of the users and also provides appropriate scattering conditions for the electromagnetic fields of the phone. A twin phantom was constructed by joining a mirror image of the CAD phantom to the original at the base of the torso. This allows for dosimetric assessments of left and right-hand usage of the phone with a single phantom. Based on this CAD phantom, fiberglass shells with a thickness of 2 ±0.2 mm have been manufactured. The ear was simulated by adding a spacer on the shell to obtain the 10% percentile thickness of the ear between the tissue simulating liquid and the earpiece of the phone.
Since the precise placement of the device with respect to the phantom is very critical, a special positioning device has been constructed, which enables the rotation of the MTE by ±180° around the axis of the auditory canal and from 75° up to 105° with respect to the axis normal to the axis of the auditory canal.

Generic Twin Phantom including the device to position the mobile phone as required by standards.

Results and Discussion
The dosimetric evaluation performed with the new phantom does not underestimate the actual exposure in approximately 90% of the MTE users world-wide. The uncertainty caused by positioning the device has also been reduced to < ±6% (standard deviation). The combination with DASY2 or DASY3 enables the reliable and efficient evaluation of the spatial peak SAR values induced by any handheld mobile phone with known precision.

Studies of CNS Effects Caused by Mobile Phone Exposure

Funds
Motorola Inc.
ETH

Partners
Max-Planck-Institute for Neurological Research, Cologne
Institute for Neuropathology, University of Heidelberg
Department of Veterans Affairs, Research Center, Loma Linda

Background

There are reports of *in vivo* and *in vitro* studies that suggested that continous and pulsed microwave exposure leads to the modulation of neuronal activity and influence on signal transduction pathways in the brain. These effects may be associated with alterations in gene expression, which can lead to potential degenerative processes in the central nervous system (CNS).

Objectives

Studies of the effects of electromagnetic field exposure of the GSM cellular phone system on the expression of immediate early genes (IEG) and the stress gene (hsp 70) at the transcriptional and translational level.

Methods

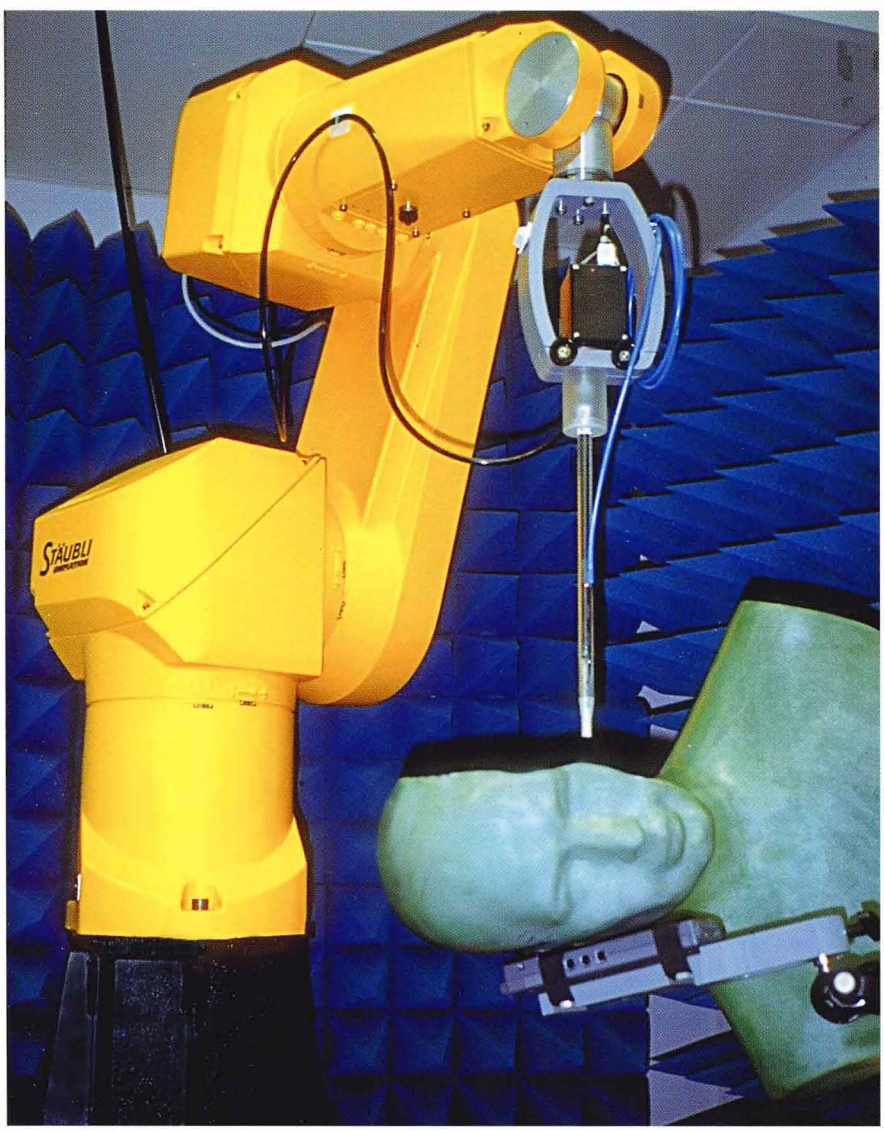
During the exposure the rats were arranged in a ventilated plexiglass carrousel around a centrally located antenna. Each rat was kept in a tube-like structure with its head towards the antenna. This setup allows good control of the exposure level of the brain while the exposure level of the whole animal is well below the thermal threshold. A discretized model of the setup, including a phantom of a rat based on MRI scans, was developed. Simulations were performed to evaluate the SAR distribution and its dependence on parameters such as the exact position and the size of the animal. Experimental validation was done through measurement of the SAR at selected points of a rat cadaver with a miniaturized temperature probe. The detailed dosimetry made it possible to subject the rats to exposure under well known specific absorption rates (SAR) of the brain approximately corresponding to 1) the maximum exposure permitted for workers (SAR=10 mW/g), 2) the maximum exposure permitted for commercial GSM devices in Europe (SAR=2 mW/g), and 3) the average exposure of the user from a GSM phone operating in the DTX mode and at the highest power level (SAR=0.4 mW/g). Five groups of rats (30 animals in each group) were investigated: one free moving, one sham exposed immobilized control group and three groups with different doses of GSM exposure for 4 h (0.3 mW/g, 5 mW/g, 7.5 mW/g). Three different survival times were chosen, 0 h, 24 h and 7 days. Representative members of different IEG subclasses (c-fos, c-jun) and hsp 70 mRNA were studied using 35 labeled antisense oligonucleotids. To semiquantitatively estimate the mRNA concentrations, the optical densities of autoradiographic films were measured in eight regions of interest. Induction of seven IEG encoded proteins (c-FOS, FOS B, c-JUN, JUN B, JUN D, KROX-20, KROX-24) and stress protein HSP 70 were investigated using specific polyclonal antibodies against individual IEGs or a monoclonal mouse antibody directed against the inducible form of HSP 70.

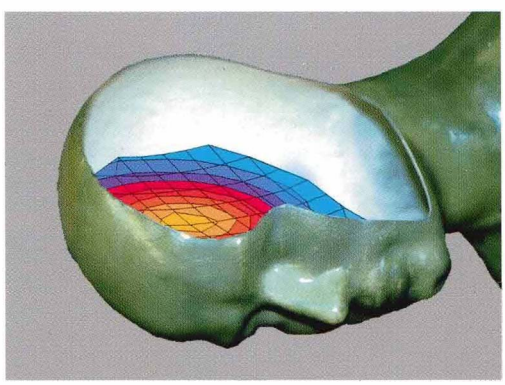
Results and Discussion

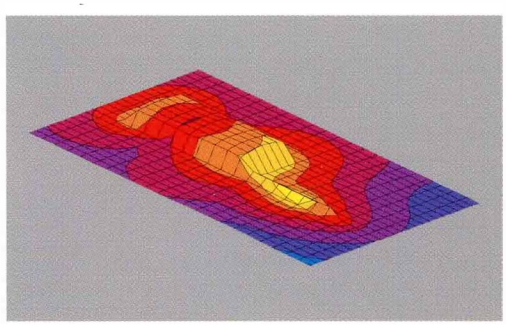
Immediately after GSM exposure, semiquantitative evaluation of in situ hybridizations exhibited a slight induction of hsp 70 mRNA in the cerebellum and hippocampus only for the highest exposure level of SAR=7.5 mW/g. A slightly increased expression of c-fos mRNA was observed in the cerebellum, neocortex and piriform cortex of all groups subjected to immobilization, but no upregulation was found for different exposure conditions. The c-jun mRNA did not increase in any of the experimental groups. 24 h after exposure, immunocytochemical expression of HSP 70, FOS, JUN and KROX proteins was unaltered.
Acute high intensity microwave exposure of immobilized rats up to SAR=7.5 mW/g for 4 h induces some minor stress response on the mRNA level but does not result in abnormalities of the corresponding protein product. The data, therefore, do not support the hypothesis that microwaves emitted by mobile telephones have a major impact on the expression of IEGs and stress genes. However, in the present study the effects of chronic microwave exposure or of the combined exposure with other noxious conditions were not assessed. Further experiments are, therefore, required to dismiss completely the possibility that mobile telephony poses a health risk to the central nervous system.
Our group was also involved in the study of the brain tumor incidence in rats chronically exposed to digital cellular telephone fields, whereby the tumors were initiated by the chemical carcinogen ENU. This study used a similar setup but exposed the rats 4 hours daily during their entire life-span of 220 days. It was performed under the guidance of Prof Dr. Ross Adey at the Department of Veterans Affairs, Research Center in Loma Linda, USA.

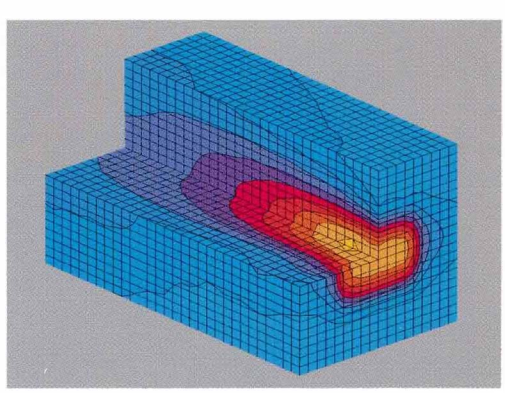
Spin-Off
Schmid & Partner Engineering AG

Schmid & Partner Engineering AG (SPEAG) was founded in 1994 as a spin-off enterprise of the Swiss Federal Institute of Technology in Zurich (ETH). The founders are those engineers who developed the first Dosimetric Assessment System (DASY1) designed for compliance testing of handheld mobile communications equipment (MTE). DASY2 is the successor of DASY1 and the first product marketed by SPEAG in summer 1995. It has now been installed in over 20 different laboratories worldwide, among them the most prominent manufacturers in Europe, USA and Japan. DASY has proven to be very accurate, reliable and easy-to-use, as well as providing highly valuable design analysis for handheld MTE. In particular, the extended capabilities for near field measurements in free space provide very efficient detection and analysis of deficiencies in RF design during the early stages of device and antenna prototype development. DASY2 has become the most widely used system for compliance testing of mobile phones, favored by the leading manufacturers and service providers worldwide. The development of the new product line DASY3 started in early 1996 and will completely replace DASY2 in summer 1997. It will provide increased performance at a lower price.









Research Partners & Consulting Activities 1996

Industry Partners

Motorola, USA
Nokia Mobile Phones, Finland
Ericsson Mobile Communications, Sweden
Lucent Technologies, USA
Sagem, France
Matsushita, Japan
Ascom, Switzerland
Telecom PTT, Switzerland
DeTeMobil, Germany
E-Plus, Germany
Integrated Systems Engineering AG, Switzerland
Schmid & Partner Engineering AG, Switzerland

Universities & Research Labs

Institut für Integrierte Systeme, ETHZ, Switzerland
Institut für Geophysik, ETHZ, Switzerland
Neurologische Klinik und Poliklinik, UNIZ, Switzerland
Institut für Mikrobiologie, UNI Bern, Switzerland
Max Planck Institute for Neurological Research, Cologne, Germany
Institute for Neuropathology, University of Heidelberg, Germany
Forschungs- und Technologiezentrum der Telekom, Darmstadt, Germany
Institute for Mobile and Satallite Technology, Germany
CSELT, Research Center, Torino, Italy
Motorola's Corporate Electromagnetics Research Laboratory, Ft. Lauderdale, USA
Department of Information Technology, University of Gent, Belgium
Calmers University of Technology, Sweden
Department of Veterans Affairs, Research Center, Loma Linda, USA
Washington University, St. Louis, USA
University of Tokyo, Japan
Metropolitan University of Tokyo, Japan
Nagoya Institute of Technology, Japan

Commissions

WHO
ICNIRP
IEEE Standards Coordinating Committee 28
IEEE Standards Coordinating Committee 34
CENELEC TC211
MCCC of COST244
Commision for Medical Issues of the Swiss Electrical Power Association
Delegate of the Swiss Academy of Science in Commission K of URSI
Chair of Module 4 of the Swiss Priority Program MINAST

List of Publications 1996

Books

[1] Niels Kuster, Quirino Balzano and James C. Lin, "Mobile Communications Safety", Chapman & Hall, London, 1996.

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[2] Thomas Schmid, Oliver Egger and Niels Kuster, "Automated E-field scanning system for dosimetric assessments", IEEE Transactions on Microwave Theory and Techn., vol. 44, p. 105-113, Jan. 1996.

[3] Volker Hombach, Klaus Meier, Michael Burkhardt, Eberhard Kühn and Niels Kuster, "The dependence of EM energy absorption upon human head modeling at 900 MHz", IEEE Transactions on Microwave Theory and Techniques, vol. 44, no. 10, p. 1865-1873, Oct. 1996.

[4] Klaus Meier, Michael Burkhardt, Thomas Schmid and Niels Kuster, "Broadband calibration of E-field probes in lossy media", IEEE Transactions on Microwave Theory and Techniques, vol. 44, no. 10, p. 1954-1962, Oct. 1996.

[5] Michael Burkhardt, Katja Pokovic, Marcel Gnos, Thomas Schmid and Niels Kuster, "Numerical and experimental dosimetry of Petri dish exposure setups", Journal of the Bioelectromagnetic Society, vol. 17, no. 6, p. 483-493, 1996.

[6] Niels Kuster and Quirino Balzano, "Experimental and numerical dosimetry", in Mobile Communications Safety, Niels Kuster, Quirino Balzano, and James C. Lin (Eds) p. 13-64. Chapman & Hall, London, 1996.

[7] Michael Burkhardt, Yuri Spinelli and Niels Kuster, "Exposure setup to test CNS efects of wireless communications systems", in Health Physics, 1997, in press.

[8] Niels Kuster, Ralph Kästle and Thomas Schmid, "Dosimetric evaluation of mobile communications equipment with known precision (invited)", IEICE Transactions on Communications, 1997, in press.

[9] K. Fritze, C. Wiessner, N. Kuster, C. Sommer, P. Gass, D. M. Hermann, M. Kiessling and K.-A. Hossmann, "Effect of GSM microwave exposure on the genomic response of the rat brain", Neuroscience, 1997, in press.

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[11] Frank Schönborn, Michael Burkhardt and Niels Kuster, "Differences of EM energy absorption between adults and children", Health Physics, 1997, in press.

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[13] Katja Pokovic, Michael Burkhardt and Niels Kuster, "Evaluation of in vitro exposure systems for wireless communications", in Proceedings of the European Bioelectromagnetics Associsation, Nancy, France, February 29 - March 3, 1996.

[14] W.R. Adey, C.V. Byus, W. Haggren, C.D. Cain, R.J. Higgins, R.J. Jones, C.J. Kean, N. Kuster, A. MacMurray, J.L. Phillips, R.B. Stagg and G. Zimmermann, "Brain tumor incidence in rats chronically exposed to digital cellular telepohne fields in an initiation-promotion model", in Proceedings of the 18th Annual Meeting of the Bioelectromagnetics Society, Vicotria, Canada, June 9-14, 1996, p. 27.

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[16] Katja Pokovic, Michael Burkhardt, Marcel Gnos, Thomas Schmid and Niels Kuster, "Suitability of TEM cells for in vitro experiments at wireless communication frequencies", in Proceedings of the 18th Annual Meeting of the Bioelectromagnetics Society, Victoria, Canada, June 9-14, 1996, p. 59.

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[22] Christoph Wiessner, K. Fritze, B. Schmitz, Niels Kuster and K.A. Hossman, "Acute effects of GSM signals on the rat CNS (invited)", in 15th General Assembly of the International Union of Radio Science (URSI), Lille, France, Aug. 1996, p. 565.

[23] Thomas Schmid, Oliver Egger and Niels Kuster, "Automated close near-field scanner", in 25th General Assembly of the International Union of Radio Science (URSI), Lille, France, Aug. 1996, p. 607.

[24] Niels Kuster, "Experimental dosimetry: A basis for certification of mobile communications equipment (invited)", in 25th General Assembly of the International Union of Radio Science (URSI), Lille, France, Aug. 1996, p. 754.

[25] Michael Burkhardt, Lars. H. Bomholt and Niels Kuster, "Hybrid simulation platform for bioelectromagnetic applications, (invited)", in 25th General Assembly of the Interantional Union of Radio Science (URSI), Lille, France, Aug. 1996, p. 760.

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[28] Klaus Meier, "Scientific Basis for Dosimetric Compliance Tests of Mobile Telecommunications Equipment",PhD Thesis, Diss. ETH No. 11722, 1996.

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