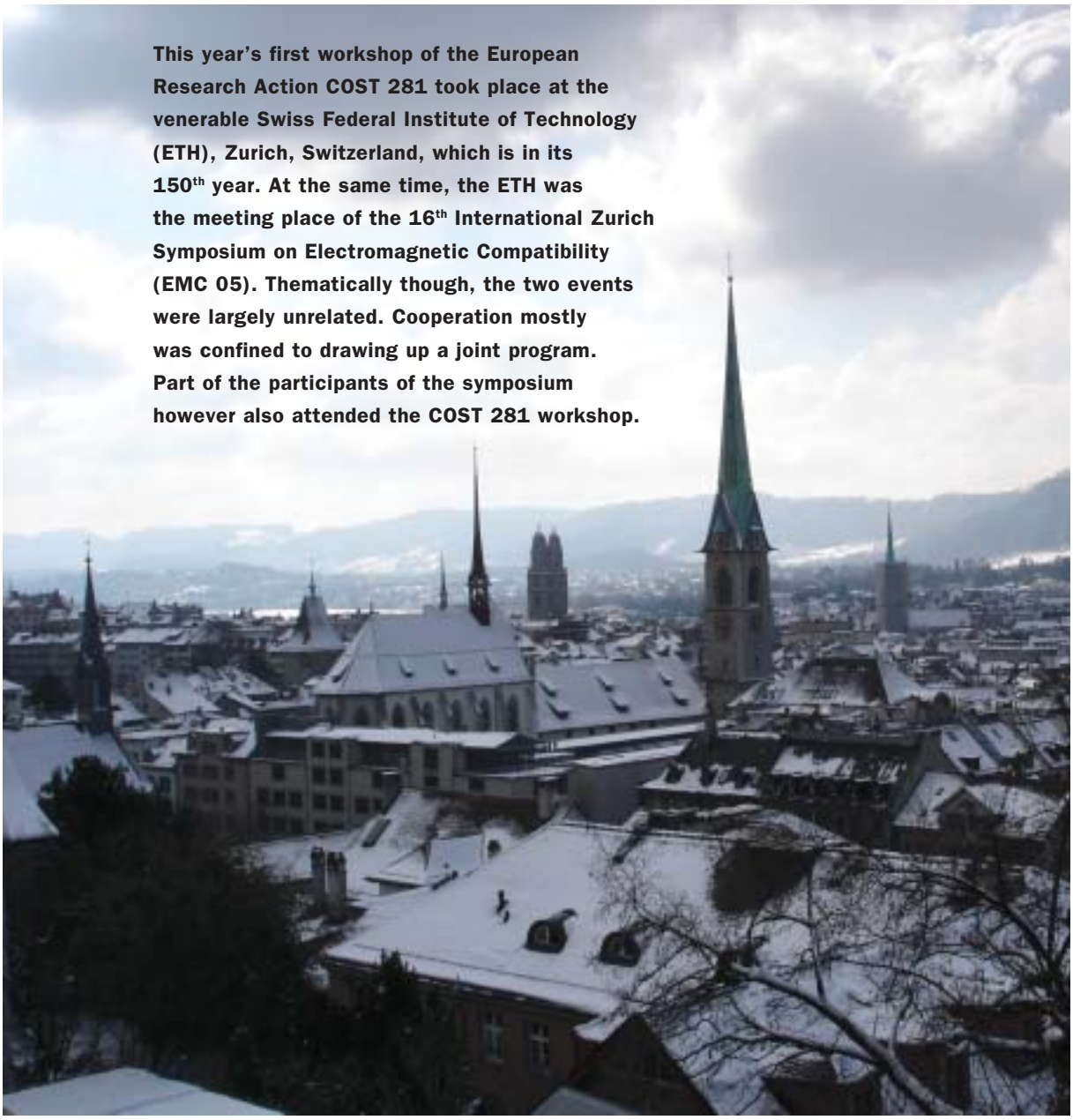
February 17 to 18, 2005, in Zurich, Switzerland

COST 281 Workshop Com

"Do sinusoidal versus non-sinusoidal waveforms make a difference?"

by Lutz Haberland



This year's first workshop of the European Research Action COST 281 took place at the venerable Swiss Federal Institute of Technology (ETH), Zurich, Switzerland, which is in its 150th year. At the same time, the ETH was the meeting place of the 16th International Zurich Symposium on Electromagnetic Compatibility (EMC 05). Thematically though, the two events were largely unrelated. Cooperation mostly was confined to drawing up a joint program. Part of the participants of the symposium however also attended the COST 281 workshop.

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Gregor Dürrenberger, the managing director of the Swiss Research Foundation on Mobile Communications, welcomed the attendees. Thanks to him and his colleague Nicole Heuberger, the local organization of the workshop, including the social dinner on the Uetliberg, were a huge success. The first session dealt with the technical and physical properties of presently used modulated radiofrequency fields. It was chaired by the director of COST 281, **Norbert Leitgeb**.

The first lecturer was **Werner Bächthold** of the ETH Zurich. He described different modulation types, putting special emphasis on mobile radio technologies and local communications networks such as WLAN, DECT and Bluetooth. He underlined that pulsation as a phenomenon did not come about with the era of mobile radio, but has been used for more than 50 years for broadcasting and transmitting television signals with similar signal characteristics.

Jørgen Bach Andersen of Aalborg University, Denmark, took a close look at the differences between signal types that are in use today, in particular the recently introduced mobile radio standard UMTS and applications expected in the future, such as ultra-wideband signals (UWB).

The second session devoted to biological effects was moderated by **Maila Hietanen** of the Finnish Institute of Occupational Health.

An overview of existing studies and prevailing concepts on effects potentially elicited by modulations of radiofrequency fields was given by **Kenneth R. Foster**, University of Pennsylvania, USA. His conclusion: There are no proven effects of modulation within the range of valid limits, with the exception of microwave hearing (thermoelastic waves are generated in the inner ear by radiofrequency pulses, which are perceived as clicking noises). There are several hypotheses on how modulated signals might be demodulated within the body, and there are some experiments during which biological responses were observed only for modulated fields. However, none of these hypotheses could be verified in experiment, and, similarly, none of the experiments finding effects have been replicated in other laboratories. Therefore, Kenneth Foster on the one hand recommends basic research toward identification of possible biophysical mechanisms, but also studies of specific new modulation types in cases where the general population will be exposed due to the introduction of related technologies.

Vijayalaxmi, University of Texas, USA, evaluated literature published on genotoxic effects of radiofrequency fields, putting the focus on potential influences of modulation. Half of the 50 studies published to this day on the topic (however, different modulations were examined and also different biological endpoints, at least in part) failed to observe effects up to a SAR of 5 W/kg; almost 20 % of experiments had a positive outcome, whereas one third was classified as non-conclusive. In this context, Vijayalaxmi remarked that as yet none of the experiments observing effects could be replicated by other laboratories; but a number of negative experiments could. She thus concluded that there is no expectation of a significant genotoxic effect produced by radiofrequency fields of up to 5 W/kg. In discussion, there was criticism on the fact that an evaluation of publications by percentages does not suffice to draw final conclusions, and

that the selected SAR of 5 W/kg was too low a threshold, since occupational part-body exposure of up to 10 W/kg is permitted.

Martin Röösli, University of Bern, Switzerland, attempted to shed light on the question of what epidemiological studies may contribute in identifying modulation specific effects. Several epidemiological studies examining the influence of various radio transmitters (such as television transmitters, mobile radio base stations, radars installations and handsets) have been made available. Although these studies often differ strongly conceptually, Röösli found there is very little evidence of existing modulation specific effects. This especially refers to analogue mobile phones used over many years. As all studies so far are lacking appropriate exposure assessment (what field strengths actually arrive in the body?) and general population is being exposed to a variety of different radiofrequency signals nowadays, the application of epidemiological studies when searching for modulation specific effects is not recommended.

The excitation of human nerves and muscles at exposure to differently modulated radiofrequency fields was investigated by **Jiri Silny** and colleagues at the University Hospital Aachen, Germany. It has been known for more than 200 years that nerves and muscles can be stimulated by low-frequency fields. Exposure limits up to about 100 kHz are largely based on this phenomenon. The Aachen researchers examined whether there are also effects on nerve excitation in the frequency range of 900 MHz to 2 GHz, and whether these effects may be affected by modulations (GSM, UTMS, 8 Hz pulsation). No effects on the electromyogram (EMG), or even a stimulation of nerves and muscles, could be found for the power range between 0.1 and 100 Watt. Some volunteers reported perceptive sensation only at an exposure of 100 Watt, the cause of which is still unclear though.

Igor Y. Belyaev of Stockholm University, Sweden, presented the results of his investigations into genotoxic effects of radiofrequency fields with different modulations and of different frequencies (GSM: approx. 900 MHz, UMTS: approx. 2 GHz, unmodulated: approx. 50 GHz). Two different methods were used: the genome structure was determined by viscosity measurements (especially in the 50 GHz experiments), and an immunofluorescence technique was used to visualize proteins linked to DNA double-strand breaks (in GSM and UMTS experiments). While damaging effects on the genome were found at 50 GHz only, within a narrow frequency bandwith, Belyaev and colleagues observed a somewhat protective influence

Attendees of the Zurich workshop

for mobile radio frequencies (less proteins indicating double-strand breaks). A convincing explanation of this discrepancy was not offered. During the following discussion, the methodology underlying viscosity measurements was criticized. None of the other working groups in the field accept it. In addition, Belyaev's conclusions regarding the need for a revision of limits and a reduction of radio emissions were objected by the majority of attendees.

The results of experiments conducted in human volunteers were presented by **Peter Achermann**, University of Zurich, Switzerland. Three different types of modulation of a 900 MHz signal were used by of his working group: unmodulated, similar to a GSM base station, and similar to a GSM handset (SAR for all signals: 1 W/kg, the latter signal containing more pulse components). All experiments (validation of sleeping EEGs/electroencephalograms, cognitive attention test and recording of the regional blood flow in the brain) performed so far found significant effects only for the signal similar to that of the handset, which were observable for a time even after exposure had stopped. As effects emerging during the recording of regional blood flow were strongest in areas not correlating with the SAR distribution in the brain and all three signals produced the same energy input (SAR), non-thermal effects are assumed. However, Achermann was not able to provide an explanation for these phenomena.

The third session of the workshop, which dealt with biological effects of different types of high-peak pulses, was chaired by **Kenneth R. Foster**.

First lecturer of the session was **Vladimir Sukhorukov,** University of Würzburg, Germany. He described the biophysical background of the biotechnological application of single pulses in the micro-(µs) and nanosecond range (ns). When selecting correspondingly high field strengths (kV/m to the MV/m range), cell membranes can be permeabilized this way and the inner cell is made accessible to manifold manipulation. Even though higher field strengths are required for the recently developed application of nansecond pulses to make the membrane permeable, manipulation of intracellular organelles becomes possible. Higher frequency pulses, i.e. in the range of 9 GHz, so-called extremely high power microwave pulses (EHPP), were examined by **Andrei G. Pakhomov** and colleagues at the US Air Force Brooks City-Base in San Antonio, USA. The pulses used in experiment induced SARs in the MW/kg to the GW/kg range; but the time-averaged SAR did not exceed the kW/kg range, since pulses were not longer than about 0.5 µs and repeated at a rate of 0.5 to 10 Hz. Thus, clear thermal biological effects are observed even with unmodulated fields. In their studies, Pakhomov and colleagues compared the effects of unmodulated fields with those of EHPP modulated fields. During exposure of nerve cells (tissue parts) of the heart and the brain (hippocampus) with spontaneous activity, no differences between the effects of differently modulated fields were found. More recent experiments with artificially stimulated nerve cells, however, show a specific influence of the EHPP fields. These tests are still ongoing; explanation attempts range from assuming artefacts produced by the electrodes to specific non-thermal effects.

The next lecturer, **Gian Piero Gallerano** from the Italian Nationaö Agency for New Technologies, Energy and the Environment (ENEA), Frascati, Italy, went even higher: into the THz range. With the free electron laser (FEL), powerful devices for this frequency range (here: 100 GHz to 10 THz) have been available in the last few years. Up to now a variety of investigations has been performed on the biological effectivity of fields, both unmodulated and pulsed. Genotoxic experiments with lymphocytes failed to indicate an effect of THz fields. Tests in liposomes (hollow spheres from cell membrane) found significant effects at a specific modulation (7 Hz pulse repeat rate) of 130 GHz fields; there were no effects for the rest of the tested modulations and unmodulated fields in this frequency range. A mechanistic explanation of this „frequency window" was not found.

The last session of the workshop addressing the topic of mechanisms and SAR applicability at pulsed modulations was chaired by **Roland Glaser**, Humboldt University, Berlin, Germany.

Iftekhar Ahmed, Bradford University, United Kingdom, presented a purely theoretical approach for the explanation of potential detector functions of biological membranes (ie, that the cell membrane might filter out e.g. the 217 Hz component of GSM modulation of a 900 MHz mobile radio signal). Based on the physical equations describing the diode function, these equations were changed so as to better correspond with assumed biological conditions. Assuming there is a direct voltage at the membrane, the newly designed equation would confirm that demodulations of modulated radiofrequency radiation take place at the membrane. There was disagreement in discussion over whether the physical characteristics of biological membranes as described in the equation really do exist.

Concluding the workshop, **Philip Chadwick** of MCL Newbury Berkshire, United Kingdom, spoke about standards for pulse modulated fields. He presented existing limits of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the approaches for their further development. All standards presently are based on validated thermal effects of unmodulated fields; specific pulse effects are considered only in cases where established effects such as microwave hearing are taken into account. So far there are no pulse specific restrictions in limits for frequencies above 10 GHz.

In summary, the workshop gave a good overview of the scientific debate over pulse specific effects from radiofrequency electromagnetic fields. Although there are no verified effects of specifically modulated fields besides microwave hearing, there are findings indicating pulse specific biological effects, which therefore should be examined more closely.

Short versions and presentations can be downloaded at (http://www.cost281.org/documents.php?node=93&dir_session=).

In connection with the workshop, the **8th Meeting of the COST 281 Management Committee** took place. The new composition of the Steering Committee was addressed. Members are now: Norbert Leitgeb, Maila Hietanen, Gunnhild Oftedal, Guglielmo d'Inzeo, Yngve Hamnerius, Gyorgy Thuroczy, Paolo Vecchia, Luc Verschaeve, Joe Wiart, Gerd Friedrich, and Theodoros Samaras.

Status reports were presented on the use of the web site www.cost281.org, cooperations with other organizations such as the FGF, EMF-Net and WHO, as all as with working groups (emerging technologies, children, dosimetry, statistics). Moreover, it was decided to support several workshops planned by other organizations for the year.

The director, Norbert Leitgeb, and his deputy, Maila Hietanen, were re-elected with an overwhelming majority.

As the activities of the Research Action COST 281 will come to an end at mid-year 2006, the need to continue work – possibly under a new name - was already confirmed during the previous meeting. Related concept papers should be written prior to the next meeting that will take place in Trondheim, Norway, October 3-4, 2005. The topics of the workshop in Trondheim will be electromagnetic influences on pregnant and health assessment of special communication signals such as TETRA.

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