Are there specific biological effects of pulsed fields?

by Roland Glaser

The Zurich workshop of COST 281 action was titled: "Do sinusoidal versus non-sinusoidal waveforms make a difference?"
The issue at hand was to determine whether there is an actually identifiable difference between biological effects of pulsed and unpulsed fields; how something like that could be explained under a biophysical perspective; and whether this would have consequences for the setting of new exposure limits. However, the workshop's title itself was rather unspecific in addressing the topic, as the core issue was not so much the difference between sinusoidal waves versus other waveforms but potential speficities of effects elicited by short wave packets, as are typical of GSM technology and other applications of mobile radio and, of course, especially of radar.

The experience of biotechnologists, who have successfully used strong field pulses for cell manipulation for a long time, should be considered. Even though rectangular pulses are used instead of pulsed wave packets, and even if field strengths applied in biotechnology are higher by many powers of ten than the fields occurring in our engineered environment, similarities with regard to interaction mechanisms could be found in their theoretically well-established methodologies. Since Ulrich Zimmermann from Würzburg unfortunately had to cancel his lecture at short notice due to illness, his colleague Vladimir Sukhorukov presented this viewpoint. Similarly, Andrei Pakhomov from San Antonio (Texas) spoke about effects of extremely high microwave pulses. Regrettably, these two exceptionally competent and interesting lectures received low attention in discussion. The survey lecture of Ms. Vijayalaxmi (San Antonio, Texas) was discussed much more vividly. She presented a highly reliable and critical overview of all experiments performed on potential genotoxic radiofrequency field effects of in the years 1990 to 2003. The speculation Belyaev (Stockholm, Moscow) engaged in, especially his assertion that effects could be found only in the form of high-effect resonances in very narrow frequency windows, did not do much to elucidate the issue at hand.

What is the core issue? Time and again, there are publications more or less convincingly reporting biological effects of radiofrequency fields, which allegedly occur only in cases where these fields are pulsed or specifically modulated in amplitude. The previous issue of the Newsletter contained a review of the contribution of K.R. Foster and M.H. Repacholi concluding that demodulation of radiofrequency fields in biological systems, whether of the AM or the FM type, is not probable, at least so far as inherent low-frequency components would become visible in eletromagnetically significant ways. The publication was reticent about drawing conclusions on possible specific effects of pulsed fields due to other mechanisms. In his lecture, Ken Foster (Philadelphia) repeated these aspects underlining the necessity to discern "power frequency" from "signal frequency". "Power frequency" stands for the envelope curve of an amplitude modulated or pulsed signal, which eventually determines the kinetics of a potential heating of the system.

Deeper discussion of this aspect would have been desirable in Zurich, especially with the attending representatives of electric breakdown research. A rect-

angular pulse – as well as a wave packet – generates a thermal pulse in the exposed object. Under a qualitative perspective, this is the link between the effects of a GSM signal and the breakdown effects of biotechnological research. However, comparability of the – perhaps similar – envelope curve of a wave packet, a burst, with the effects of a simple rectangular pulse is very limited. The impedance characteristics of the cell membrane contradict this. A discussion appreciating this aspect more clearly would have been worthwhile. The term "edge steepness of a pulse" was used several times in lectures and discussion, eventually confusing the differences between wave packet and rectangular pulse.

Temporal and spatial courses of potential heating and its potential consequences are crucial. New knowledge about this has been acquired both in biotechnology and in molecular biology. Of particular interest is the e.g. the finding that a specific thermal effect can be achieved through radiofrequency irradiation using a gold sphere with nanometer dimensions linked with a biomolecule (Hamad-Schifferli et al., Nature 2002, **415**, 152. See also "News from Science", FGF Newsletter, 1/2003). In the meantime, molecular biology has provided evidence for a number of proteins in different cells responding to heating or cooling with high sensitivity within a narrow temperature range. Considering these insights, classic "microdosimetry" as represented by Kenneth Foster regains significance. Such insights should be used to advance the debate over "non-thermal effects" that sometimes goes round in circles.

This problem can be examplarily illustrated by a recent publication: Carefully monitored by radiofrequency technicians of the ETH Zurich, the Institute of Plant Genetics Gatersleben performed experiments with embryonic stem cells, which, cultivated in suspended droplets, were exposed for 48 hours to continuous RF fields or GSM signals (Czyz J, et al., Bioelectromagnetics 2004, **25**, 296-307; see also: "News from Science", FGF Newsletter, 4/2004). A significant increase in mRNA content of the p53-deficient cells could be proven only for exposure to the GSM signal, not for unpulsed fields. Thermal effects are excluded by the authors, as the intensity of exposure was below the ICNIRP value and test conditions had ensured precise temperature control. This may be true, considering the given average SAR of 1.5 W/kg. But what about actual intensities reached during the pulse? At a 8:1 ratio between pause and pulse length, intensity would be 12 W/kg over a half millisecond, 217 times per second. Are there possibly periodic activations of thermoreceptors in the cells due to irradiation that do not occur at 1.5 W/kg of a continuous field? How quickly do the droplets exchange heat with their surroundings, when heat conductivity and evaporative heat are taken into account? What is decisive in this – temperature variation within the whole droplet or of corresponding thermoreceptor proteins? Apparently, a number of chemophysical processes have to be included in technical engineering dose calculations.

This random example demonstrates that there is good reason to discuss potential specifities of pulsed field effects – and even more so of very short and intense pulses. Technicians should let us know what there is still in store for us with regard to pulse length, pulse sequence and pulse intensity. The Zurich workshop has shown that it is important to not only invite lecturers but also the public interested in such multidisplinary discussion and equipped with the necessary expertise. Even if not all questions could be answered during the Zurich workshop, perhaps it marks the beginnings of a debate that, in due time, will provide new knowledge.

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