Letters

Comments on "Nonthermal Effects of Extremely High-Frequency Microwaves on Chromatin Conformation in Cells *in vitro*—Dependence on Physical, Physiological, and Genetic Factors"

John M. Osepchuk and Ronald C. Petersen

As long-time workers on development of microwave safe-exposure standards, we are keenly aware of the deficient quality in many of the papers in the bioeffect literature, particularly those relating to microwave artifacts. In the November 2000 issue of this TRANSACTIONS, there are many good papers but there are also papers displaying deficiencies. We are not able to review all such deficiencies, but we restrict our comments here to the above paper,[1] which makes the extraordinary claim [1] of a significant microwave bioeffect at an incident power density of 10^{-19} W/cm^2, well below that of thermal noise in a bandwidth of practical significance.

In the above paper, Belyaev *et al.* reiterate that claim and dismiss our critique [2], but they do not demonstrate that they have monitored or controlled the level of temporal harmonic signals. These, we claim, probably play a role in their experiments, especially when they reduce the fundamental signal by as much as 100 dB, using a simple vane-type waveguide attenuator. They thereby neglect the fact that such attenuators are ineffective at harmonic frequencies in an overmoded waveguide. As we stated before [2], such extraordinary claims as theirs [1] demand extraordinary proof. They do not provide such proof.

The above paper is a broad review of a wide range of purported frequency-specific athermal effects at millimeter-wave frequencies reported in the German and Soviet/Russian literature. We do not refer to the substantial U.S. literature [3], [4] that reports failure to replicate much of the work reviewed by Belyaev *et al.*

Belyaev *et al.* refer to "successful therapy" of millimeter waves as further evidence of the validity of their effects, but that is analogous in the U.S. to stating that the booming business [5] in magnet therapy proves the validity of the alleged science basis for their business. The hard-science community, however, rejects this conclusion and even suggests that it is voodoo science [6].

The history of microwave bioeffect research is replete with examples of reports that eventually were judged as nonreplicable for various reasons [7], [8]. In the past, this disjointed record could be excused as researchers slowly learned the artifacts and other pitfalls of a new endeavor. In today's enlightened state of research, e.g., note Guy *et al.* [9] and Chou *et al.* [10], there is little justification for recurrence of such artifacts. Reviewers and editors, please take note.

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Authors' Reply

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In the above paper,[1] we analyzed various parameters, both physical and biological, which are important for the nonthermal effects of millimeter waves (MMWs). In particular, effects of MMWs on chromatin conformation have been observed at power levels well below that of thermal heating [1], [2]. The aim of these experiments was to decrease power flux density (PD) as low as possible in order to compare the observed resonance-type responses of cells at different PDs. As we have previously clearly stated, direct measurements at powers lower than 10^{-7} W/cm^2 were not available and, therefore, the PDs were calculated based on usage of calibrated attenuators. Therefore, all figures below 10^{-7} W/cm^2 must be treated as calculated values. In the absence of direct measurements, we could not exclude that the error of 2–4 orders of magnitude might occur. Therefore, the lowest power density at which the MMW effect was observed might be somewhere between the background level and 10^{-15} W/cm^2. Only direct measurements at these low

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levels might provide more exact figures and we appreciated any collaboration in this field [3]. Peterson and Osepchuk, in their attempt to dismiss nonthermal effects of microwaves, which are in apparent contradiction with safe-exposure standards, have suggested that harmonics at different modes might account for the observed effects (see [4] and the comments of Osepchuk and Peterson). However, collective evidence strongly indicated that the observed MMW effects are far beyond that of the safe-exposure standards even in unlikely case of their induction by harmonics [3]. We took all precautions against artifacts stemming from our MMW exposure and measurement methods: reflection, scattering, data analysis, influence of attenuators, contamination, vibration, etc. Neither harmonics and modes, nor other possible artifacts were able to explain these *nonthermal effects, which, in fact, disappeared with increase of PD* in some cases [5]. In addition to the evidence presented earlier [3], the results from experiments with circular-polarized MMWs showed that the observed effects depended on polarization (see the above paper, Ushakov *et al.* in preparation). Significant differences between effects of left- and right-circular polarizations, produced by two different experimental approaches, were obtained at power densities well below thermal heating. In 11 tested frequency windows, one of two circular polarizations was always more effective then the other one. Irradiation of cells with relatively low dose of X-rays inverted effective circular polarization [6]. These different effects of circular polarized MMWs could be explained neither by heating, nor by harmonics.

As it has been consistently stressed in the above paper and [1] and [2] and pointed out by Osepchuk and Petersen in their comments, the history of these investigations had examples when the reported MMW effects were not reproduced by other groups suggesting that there are some important variables that should be strictly controlled in replication studies. Reproducibility of nonthermal MMW effects in our hands provided a possibility to study the dependence of these effects on various biological and physical parameters. Finally, we compared our data with results of others and deduced spectrum of important variables, which should be controlled in order to reproduce the effects of MMW (see the above paper).

The comments of Osepchuk and Petersen display evident inconsistencies, which we will address below.

Osepchuk and Petersen claimed that we neglected well-known mechanisms of interaction of flap attenuators with microwaves at fundamental frequency and harmonics at different modes. However, it is clear from our papers and previous response that we did not neglect this issue [1]–[3]. Another type of attenuator has been used and similar results were obtained with both types of attenuation [3]. Direct power measurements were performed down to 10^{-7} W [1], [2]. All possible harmonics contributed to the measurements of power and the obtained data did not indicate that harmonics (presented in our waveguide) would not be attenuated similar to fundamental frequency [3].

We were not biased in our choice of MMW studies and did consistently refer to the U.S. literature, including negative data provided by groups of Gandi and Motzkin (see the above paper and [1] and [2]). Moreover, in the above paper, we discussed this issue and referred papers of the above authors. The statement by Osepchuk and Petersen that "substantial U.S. literature ... reports failure to replicate much of the work reviewed by Belyaev *et al.*" is evident overestimation just because only few replications of MMW effects are available (see the above paper). Even from those few replications, no hard conclusion can be deduced because not all critical parameters of original experiments were controlled (see the above paper).

We did not refer to successful MMW therapy as further evidence of validity of the MMW effects in model *in vitro* experiments. Instead, we acknowledged that understanding of mechanisms behind these *in vitro* effects might benefit further development of MMW medical applications. That is why the analogy provided by Osepchuk and Petersen is irrelevant. It has been previously shown (see [7] and [8]) and new evidence is emerging [9], [10] that microwaves do result in nonthermal biological effects under specific conditions of exposure. We would like to note that comparison of effects produced by electromagnetic fields (EMFs) at such distant frequency ranges as electromangetic low frequency (ELF) and electromagnetic high frequency (EHF) suggested similar dependences of these EMF effects on biological and physical variables [11]. Therefore, the reported in the above paper dependencies of MMW effects on physical and biological variables may also have impact on other frequency ranges in between ELF and EHF. It might be especially important because many attempts to replicate biological effects of EMF in different frequency ranges, including range of mobile microwave communications, did not reproduce those critical parameters that we deduced for ELF and MMW effects (see the above paper and [11]). Bearing in mind the importance of these critical physical and biological variables for reproducibility of EMF effects, we would suggest another analogy in response to Osepchuk and Peterson. To claim that there are no nonthermal effects of microwaves would be similar to a situation if one would use a TV set with a wrong broadcast system, e.g., PAL/SECAM instead of NTSC in the U.S., in order to conclude that ones inability to receive favorite channels would be a good evidence for absence of stable TV broadcasting.

Based on available data, we suggested that both beneficial and detrimental effects might stem from nonthermal microwave exposure depending on specific parameters (see the above paper). The nonthermal effects of microwaves would achieve wider acceptance if they could be explained by well-defined biophysical mechanisms. Knowledge of these mechanisms is necessary if we would like to evaluate biological significance of nonthermal microwave exposure based on hard science, but not on other issues including total dismissing of nonthermal effects just because of their apparent contradiction to safety-exposure standards. In today's research, the important task is to study these mechanisms [7]. Most probably, the mechanisms of nonthermal microwave effects must be based on quantum-mechanical approach and physics of nonequilibrium and nonlinear systems [12]–[14]. The experiments with nonthermal microwaves will also benefit if new technology for measurements of microwaves at super low intensities will be available.

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