Health Matters

A Paradigm Shift?

■ James C. Lin

Could the RadioBio initiative be suggesting a paradigm shift in the U.S. military's standard of operation procedures?

The U.S. military establishment played a huge role in influencing research on the biological effects from exposure to electromagnetic fields and waves, including RF radiation, since the inception of scientific investigation circa the mid-20th century. For most of that period, their emphasis was directed toward tissue heating by RF radiation due to body temperature elevations. They have rigorously defended against and are highly critical of research reports that suggest otherwise.

Recently, the U.S. Air Force Research Laboratory reported that whole-genome bisulfite sequencing directly following RF exposure showed immediate changes in DNA methylation patterns and early differentially methylated genes in RF-electromagnetic field-exposed keratinocytes in human skin [1]. The results highlight a potential epigenetic role in the cellular response to RF radiation. The report further suggested that the findings may potentially be developed as epigenetic biomarkers for immediate responses to RF exposure.

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DNA methylation is an epigenetic process used by cells to regulate gene expression. It is dynamic and can be triggered in response to external stimuli, such as ultraviolet exposure. The investigation exposed cultured human keratinocytes to 900-MHz RF radiation for 1 h at a low specific absorption rate (<.01 W/kg), under the environmental conditions of 37 °C, 5% CO_2, and 95% humidity in a customized exposure system. The threshold for safe RF effects is 4 W/Kg per current standards. Six common targets were identified to have both differentially methylated and differentially expressed in response to RF exposure. The specific process involved correlating global gene expression to whole-genome bisulfite sequencing. (The investigation also identified 114 genes that were significantly differentially methylated immediately following a single 1-h RF exposure.)

Beyond underlining a potential epigenetic role in the cellular response to low-level RF exposure, these results place spotlights on a rare event: a paradigm shift in a scientific investigation from a U.S. military research laboratory reporting a cytogenetic response, or more specifically, an epigenetic role in the cellular response to low-level RF exposure, potentially with major influences on gene activities.

Another example is that the U.S. Army and Air Force Research Laboratories recently conducted a computer simulation study of microwave auditory effect in an anatomical human head using the same approach employed in previous computational studies [2], [3], [4]. The computer simulation showed that for 1-GHz high-power microwave pulse exposures, substantial acoustic pressure may occur within the brain that may have implications for neuropathological consequences [5]. The simulation results were compared to previously established mechanically induced injury pressure thresholds for strain and stress associated with traumatic brain injury. The report showed the microwave exposures required are .01 and .015 GW/m^2 of peak power density for a 5-μs, 1-GHz pulse to reach the same threshold pressures of 10 and 20 kPa, respectively, for explosive blast brain and football head impact injuries.

Although the required peak power densities are high, they are achievable with existing high-power commercial and military microwave systems operating under pulsed conditions [5]. The disclosure comes as somewhat of a surprise to some, although it has been stipulated previously [6], [7]. Significantly, they also fall within the permissible "safe" limits of currently promulgated safety standards and protection guidelines. The required microwave technology is mature and, in general, commercially available in many countries, confirming the conclusion of earlier studies.

Furthermore, the study showed that to generate a tissue-injuring level of high-power microwave-induced acoustic pressure waves inside the human brain, the microwave pulse-induced temperature elevation would be substantially below the assumed threshold for RF effects (1 °C), which is again considered "safe" Therefore, it would be an allowable exposure according to currently promulgated RF and microwave safety protection guidelines.

The U.S. Defense Advanced Research Projects Agency (DARPA) issued a request for proposal in 2017 by announcing its new research initiative: "RadioBio: What Role Does Electromagnetic Signaling Have in Biological Systems?" [8], [9]. The goal of this project was to establish if purposeful signaling via electromagnetic waves between biological systems exists, and if it does, find ways to define what information is being transferred.

The goal of RadioBio is innovative and the project is intriguing. They seem to suggest a paradigm shift in the U.S. military's standard of operation procedures away from a conviction that nothing but thermal effects could be associated with electromagnetic fields and waves. The new initiatives instead appeared to allow exploration (and perhaps, exploitation) of low-level, nonthermal biological responses to RF exposure.

Furthermore, the RadioBio initiatives are beginning the process to actively search, ascertain, and study the potential role low-level electromagnetic fields and waves could possibly play in the intricate biology of living cells and organisms. The initiatives are of not only fundamental scientific importance, but also conjure up practical and technological significance. The possibilities and potential applications in data transfer, information delivery and retrieval, communication, and sensing for command and control are enormous, once the bioelectromagnetic mechanisms for weak cell-to-cell signaling and communication in living organisms are harnessed.

However, it is not readily available as to how many proposals were received or approved. It is conceivable that several classified and unclassified projects were funded through DARPA under the RadioBio program. Perhaps the recent publications from some of the military research laboratories may serve as telltales of more to come.

A case in point is the reporting of detection of RF radiation from the microorganism *Staphylococcus aureus* (*S. aureus*) in biofilms [10] (and its follow-up article [11]). The study is apparently funded by DARPA's RadioBio program.

Note that RF and electromagnetic field interactions with biofilm-associated microorganisms and *S. aureus* have been reported [12], [13]. Specifically, exposure to modulated electromagnetic fields and mobile communication RF (Wi-Fi) signals can influence the response of biofilm bacteria, leading to alterations in expression of messenger RNAs and morphological changes.

Biofilms or bacterial biofilms are comprised of microorganisms, such as S. *aureus* or *Escherichia coli* (*E. coli*), in which cells stick to each other and attach to and grow on surfaces. These adherent cells produce and form extracellular matrices of polymeric substances that result in altered phenotype of the organisms with variable growth rate and gene transcription.

The RadioBio-funded articles reported successful detection of electromagnetic radiation from *S. aureus* biofilm in the 3.18-GHz and 3.45-GHz frequency bands via a radiometer-type of detector. Both short-term and long-term variations of the radiation intensity were observed. To demonstrate that the RF signals are indeed produced by living cells, a lethal dose of zinc oxide nanopyramids (ZnO-NPY) was administered to the sample. The results showed drastic reduction in RF intensity variations of detected signals before and after ZnO-NPY treatment. This observation is essential in demonstrating the viability of *S. aureus* biofilm for the detected RF signals. However, the genesis, nature, or source of detected RF signal is obscure. It begs the question: How is the detected signal related to activity of the living bacteria biofilms? The records do not preclude the consequences of dynamic events taking place within the living bacteria biofilms, which may be construed as signals instead of artifacts.

The analogous experiments where the RF intensities measured from peptone-NaCl-glucose (PNG) media with biofilms (biofilm samples) was compared with that measured from fresh PNG media void of biofilms (PNG samples) are interesting. The many orders-of-magnitude difference in measured intensity levels between the biofilm samples and the PNG samples are unremarkable. It has been shown that *S. aureus* biofilms grown in PNG medium are more resistant to disassembly and degradation [14].

In another set of experiments, a sinusoidal signal at the RF frequency of 3.18 GHz was used to expose the biofilms. The biofilm samples were reported to exhibit stronger RF-related characteristics after being exposed to 3.18-GHz radiation. Furthermore, a similar experiment was conducted at a different frequency (6.3 GHz) for comparison. In this case, no RF radiation was detected for either exposed or unexposed biofilm samples.

The interpretation of these observations as confirmation for the existence of RF radiation generated by *S. aureus* biofilms and that they demonstrate that biofilms actively respond to external RF signals is perplexing.

The frequency bands of 3.18 GHz and 3.45 GHz for the detected RF signals are in the range of the ubiquitous ambient cellular mobile communication spectrum. In contrast, the frequency of 6.3 GHz is well separated from the 3-GHz bands and is not a commonly found spectral component in the ever present, over-the-air telecommunication domain. The issue of electromagnetic compatibility and interference or spurious RF pickup is a potential complication and would be a matter of scientific and technical concern.

Other examples of the DARPA'S RadioBio program-funded projects (apparently) include a project on "exploring the question of can organisms use RF radiation to sense their surroundings" [15] and one on "signaling and electromagnetic analysis in the cellular environment" [16].

Perhaps the appropriate message at this stage of DARPA's RadioBio projects is to stay tuned, given the prior controversies of research on biological interaction of RF radiation and the skepticism of U.S. military establishments in the past.

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