TOPICAL: The Impact of the Schumann Resonance on Biological Cells

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Introduction

One of the most intriguing aspects of electromagnetic radiation environment of the earth is a weak electromagnetic field known as the *Schumann Resonance.* The Schumann Resonance is located in the "cavity" between the surface of the earth and the earth's ionosphere. The Schumann Resonance is created by naturally occurring lightning, and its frequency spectrum (in the *extremely low frequency*—ELF— range) is determined by the dimensions of the cavity (the circumference of the earth and the distance between the earth and the earth's ionosphere). See Figure 1. Because conditions in the earth's ionosphere change over time and naturally occurring lightning is dependent on weather, both the amplitude and the frequency spectrum of the Schumann resonance can vary, from season to season and even from day to day (Price and Melnikov 2004). The Schumann Resonance was first measured by physicists from MIT using a large antenna and sensitive battery-powered recording equipment, in 1962 (Balser and Wagner 1960). Several years prior to these measurements, the German physicist Winfried Otto Schumann correctly predicted these findings. The phenomenon, therefore, bears his name.

Fig. 1. The Schumann Resonance is a weak electromagnetic wave located in the cavity that exists between the surface of the Earth and the Earth's ionosphere. Its frequency spectrum ranges from about 7-50 Hz (with peak frequencies at about 8Hz, 15 Hz, 20 Hz and 32Hz), and its amplitude is in the pico Tesla range. No Schumann Resonance exists on the moon.

Electromagnetic Radiation Studies in Cells

Generally speaking, electromagnetic fields are considered to be non-biologically relevant. A few investigators, however, have reported an effect of weak magnetic fields (below 1 milli Tesla), created experimentally, on gene expression in bacteria (Cairo, Greenebaum, and Goodman 1998) and on heat-shock proteins (HSPs) in yeast (Weisbrot et al. 1993) and mammalian cells (Lin et al. 1997; Goodman et al. 1994). But many similar studies have been negative. In yeast, for example, a carefully conducted study of genome-scale gene expression was performed and found no evidence for an effect of 50 Hz electromagnetic fields up to 400 milli Tesla (Nakasono et al. 2003). A similar negative result was seen by another research group that studied yeast and human lymphocytes (Luceri et al. 2005).

Could *Absence* of the Schumann Resonance be a Stressor for Cells?

Up until now, all Space Biology experiments that have been conducted in space have been carried out in Low Earth Orbit (LEO), where the Schumann Resonance is present. When conducted on board the Space Shuttle and ISS, cellular experiments “feel” the Schumann Resonance just as they would on Earth. Soon, however, it may be possible to carry out cellular experiments that are *beyond the reach of the Schumann Resonance:* on the Earth’s moon. As part of the agency’s Artemis program, astronauts will soon return to the moon; it is expected that model organisms and cellular systems (prokaryotic and eukaryotic) for Space Biology research will not be far behind. The prospect of sending Space Biology experiments to the moon raises the question: *How will these systems behave in the absence of the Schumann Resonance?* Given NASA’s plans to return to the moon, ground experiments that address this question are well-warranted and timely.

Cellular Experiments in the Absence of the Schumann Resonance: Ground-based Studies at the “Berlin Magnetically Shielded Room.”

The Schumann Resonance is present everywhere on Earth. For that reason, it is very challenging to conduct experiments of any kind that are *not* exposed to the Schumann Resonance. Experimental electromagnetic field exposures on earth, for example, are almost always superimposed on background Schumann Resonance and other background electromagnetic fields which can vary substantially from one location to another. “Clean” experiments are difficult to conduct.

To perform careful experiments and to investigate what happens in the absence of the Schumann Resonance requires exceptionally rigorous shielding of electromagnetic fields. Over the last 40 years, considerable effort has been expended to create “magnetically shielded rooms,” primarily in Japan (Kelhä 1981) and in Germany (Mager 1981), so that experiments on both biological systems and physical systems can be conducted in the near-complete absence of ambient electromagnetic fields. *The Berlin Magnetically Shielded Room* (BMSR), located at the Physikalisch-Technische Bundesanstalt (the national metrology institute of Germany) is one such facility (Bork, Hahlbohm, and Klein 2001). The core of the BMSR is a cube-shaped structure with 8 shells that provides state-of-the-art electromagnetic shielding. One shell is aluminum, which acts as an eddy current shield. The remaining seven shells consist of double-layered high-permeability sheets (“Mu-metal,” a nickel–iron soft ferromagnetic alloy) with non-magnetic spacings. Considering all 8 layers, the walls of the BSMR core are more than 1 meter thick. The inside space measures 2.25 m x 2.25 m x 2.25 m, which is designed to accommodate biological studies as well as physical studies. See Figure 2.

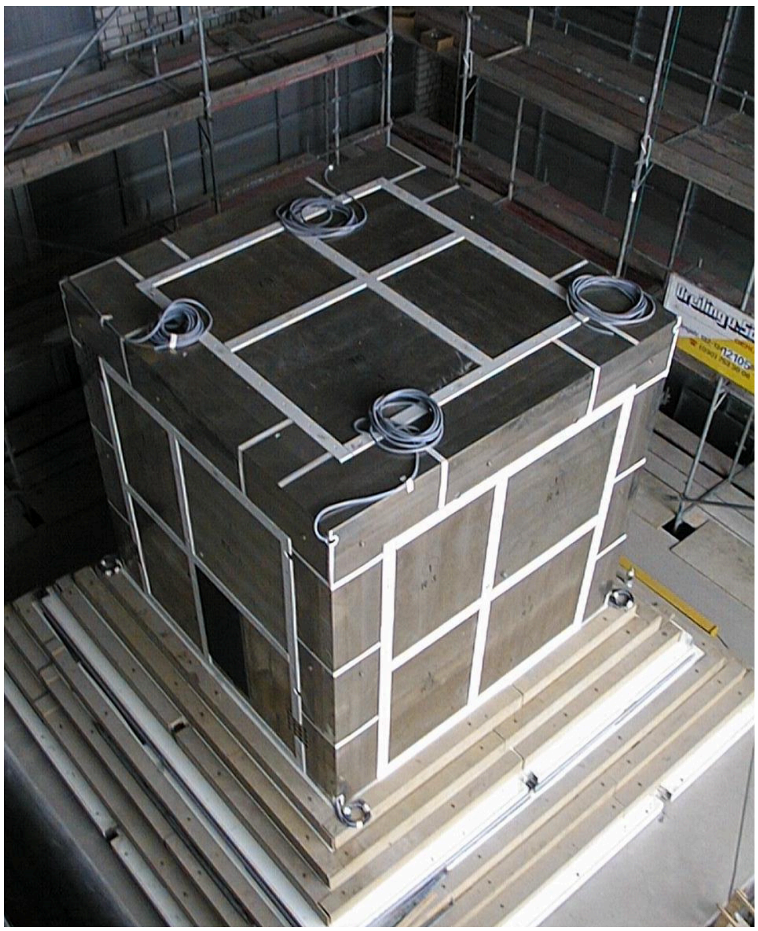

Fig. 2. *The Berlin Magnetically Shielded Room* (BMSR) is a specialized facility designed for biomagnetic studies. The space inside the rigorously shielded room measures 2.5 m x 2.5 m x 2.5 m and is designed to accommodate biological studies.

An important feature of the BMSR is a set of coils that lie outside of the 8-layered core structure. The coils compensate for the stable magnetic field of the earth, and also allow for active shielding. Active shielding contributes significantly to the high shielding factor of the BMSR.

The performance of the BMSR is excellent, especially in the low-frequency range (1-50Hz) that is most relevant to the Schumann Resonance. See Figure 3.

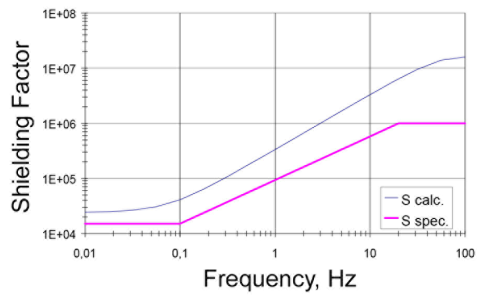

Fig. 3. Performance of the Berlin Magnetically Shielded Room

Once contructed, the performance of the *Berlin Magenticlly Sheided Room* (BMSR) (blue line) exceeded its target perfomance specifications (pink line). At 8 Hz, which is particularly relevant to the Schumann Resonance, the measured shielding factor is 3×10^6, which reduces the ambient electromagentic field strength to the low femto Tesla range. This is the best perfomance of any electromagentic shielding facility currently available today.

Recommended Experiments

In order to evaluate the behavior of cells in the absence of the Schuman Resonance, relevant to the moon (and beyond), where the Schumann Resonance does not exist, the authors of this white paper recommend that studies be done in yeast (at least initially), and that the BMSR facility (described above) be used, to provide the greatest possible shielding from ambient the Schumann Resonance and other ambient electromagnetic fields. For these ground-based studies, independent variables should include shielded versus un-shielded growth conditions, different culture media, and different yeast strains. Dependent variables should include measures of glucose metabolism, comprehensive gene expression studies and somatic mutation (genomic sequence variation) studies. Follow-on studies should be planned based on the results of these initial experiments.

Summary

NASA will soon usher in a new era of space exploration to the moon (the Artemis Program), and it is expected that Space Biology studies of cells and model organisms will soon be conducted at that location, too. On the moon, the Schumann Resonances will be absent, which may alter the behavior of cells that are sensitive to weak electromagnetic fields. In preparation for this new era of Space Biology, we recommend that studies of yeast cells be conducted on Earth at the *Berlin Magnetically Shielded Room*, in order to understand the behavior of cells in the absence of the Schumann Resonances, so that we can prepare for more definitive Space Biology experiments on the moon. For ground-based studies, independent variables should include shielded versus un-shielded growth conditions, different culture media, and different strains of cells. An initial slate of dependent variables should include cellular growth kinetics, metabolomic studies and analysis of genetic sequence variation. If these experiments are successful, follow-on studies should be conducted with other cellular systems. When lunar Space Biology facilities become available, follow-on investigations should be conducted on the moon.

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