

TOPICAL: The Impact of the Schumann Resonances on Human and
Mammalian Physiology

*Ground-based Investigations to Support Human and Mammalian
Studies Beyond Low Earth Orbit*

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Authors:

Viktor Stolc, Ph.D., NASA Ames Research Center
Maurice Ohayon, M.D., D.Sc., Ph.D., Stanford University Medical School
Friedemann Freund, Ph.D., SETI Institute
David J. Loftus, M.D., Ph.D., NASA Ames Research Center

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The Impact of the Schumann Resonances on Human and Mammalian Physiology

Introduction

One of the most intriguing aspects of Earth's electromagnetic radiation environment is a weak electromagnetic field known as the *Schumann Resonances*. The Schumann Resonances form standing waves in the spherical "cavity" between the surface of the Earth and the underside of the Earth's ionosphere, created and maintained by lightning strikes worldwide. Their frequency spectrum in the *extremely low frequency* (ELF) range is determined by the dimensions of the cavity formed between the Earth's surface and the ionosphere (see Figure 1). Both the amplitude and frequency of the Schumann resonances vary from day to day, even hourly, due primarily to the effects of solar storms on Earth's ionosphere, also known as geomagnetic anomalies ¹. Early attempts to explain the Schumann Resonances date back to the work by Heaviside and Kennelly (1902). Their existence was proven by Appleton and Barnett (1925). However, a complete explanation was only provided by Schumann in 1952-1954 ², followed by extensive observational characterization by physicists at MIT using a large antenna and sensitive battery-powered recording equipment ³.

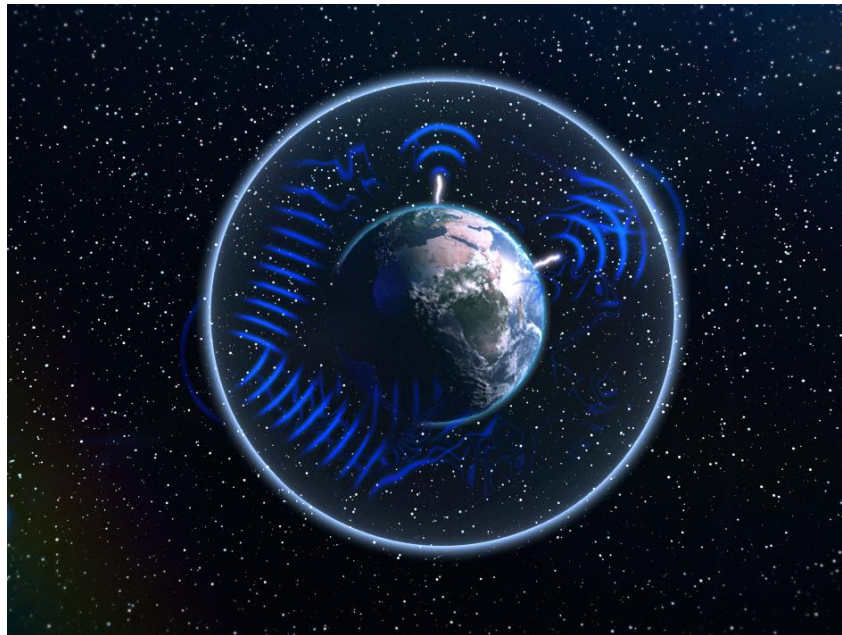


Fig. 1. The Schumann Resonances are a weak electromagnetic standing wave and its harmonics formed in the spherical cavity between the surface of the Earth and Earth's ionosphere. Their frequencies lie at 7.83 Hz (fundamental), 14.3, 20.8, 27.3 and 33.8 Hz. Their amplitudes fall into the picoTesla range. There are no Schumann Resonances on the moon since the moon lies well beyond the Earth's ionosphere.

Electromagnetic Radiation Effects on Humans

Many studies have been published describing a broad range of physiological, psychological, and behavioral changes associated with changes or disturbances in the geomagnetic activity (e.g. by solar storm activity) or non-natural sources ⁴⁻⁷. In a recent effort to investigate this phenomenon, scientists measured heart rate variability (HRV) in 10 volunteers who went about their daily lives while undergoing continuous heart rate monitoring ⁸. Although the statistical effect size was small, significant correlations have been found between the group's HRV and the solar wind speed, Kp, Ap, solar radio flux, cosmic ray counts, Schumann Resonance power, and intensity variations in the magnetic field. In a follow-up investigation, a study was conducted in which HRV was measured in volunteer human subjects over the course of 5 weeks while simultaneously collecting environmental data ⁹. Changes in the cosmic ray flux and solar radio flux, and in the Schumann Resonance power were found to be correlated with increased HRV and parasympathetic activity.

In a recent study in a metropolitan area in Spain, an epidemiological approach was used to examine cardiovascular related hospital admissions over the course of a year. Using an *Event Coincidence Analysis* statistical method, the investigators observed clustered events for the 1st and the 3rd Schumann Resonance frequencies (ECA shuffle-surrogate test $p = .01$ and $p < .01$)¹⁰. A related finding in a previous study is the observation geomagnetic activity correlated with the heart attack incidence rate in 14 large hospitals in St Petersburg for the period 1989-1990 ¹¹.

Collectively, these findings support the hypothesis that weakly energetic environmental phenomena can affect human physiology, with clinical significance.

Electromagnetic Radiation Effects on Mammals

Many studies have shown that mammals are sensitive to changes in electromagnetic radiation. A wide variety of animals have been studied ⁷, including mice, rats (multiple strains)¹², rabbits and non-human primates ¹³. Many of these early studies were undertaken in response to the development of the United States space program.

A particularly intriguing topic is the neurophysiological effect of electromagnetic fields, including observations in the VLF and extremely low frequency (ELF) ranges, in which the Schumann Resonances occur. For example, freshly isolated chick and cat cerebral tissues exposed to sinusoidal electric fields at 1, 16, and 32 or 75 Hz, with electric gradients in air of 5, 10, 56, and 100 V/m, exhibit a general trend toward a reduction in the release of preincubated $^{45}\text{Ca}^{2+}$ ¹⁴. Both frequency and amplitude sensitivities were observed. These findings are potentially relevant to the human response to the Schumann Resonances. The Schumann Resonance frequencies start at 7.8 Hz and progress by increments that describe the overtone series at about 13.7, 19.6, 25.5, 31.4, 37.3, and 43.2 Hz. The first five modes agree with the frequency range of the first four electroencephalogram (EEG) bands with the primary EEG frequency bands being Delta, 0.5 to 4 Hz, Theta, 4-8 Hz, Alpha, 8-13 Hz and 13 to 30 Hz.

Interestingly, the band at 7.8 Hz is observed with subjects in a state of relaxation and that at 13.7 Hz with subjects in a state of concentration. Based upon these observations, we need to explore more deeply how a suppression of the Schumann Resonances affects these two EEG states in humans.

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

Observations relating physiological responses to weakly energetic phenomenon are intriguing, but they become even more so in view of NASA's human exploration plans. In this context the Schumann Resonances take center stage. While the orbit of the ISS is low enough that it is still influenced by the Schumann Resonances, the moon is clearly far beyond their influence. *What about the Apollo era astronauts?* They certainly experienced a lack of Schumann Resonances while on the moon. But, given the short duration of these missions and other factors, effects would have been difficult to discern. Now, since NASA is on the brink of returning astronauts to the moon for much longer duration missions, the question "*What happens to human physiology beyond the reach of the Schumann Resonances?*" becomes relevant. In preparation for NASA's new moon missions, investigations of the Schumann Resonances and human physiology, *via* earth-based studies, is especially warranted and timely.

An Opportunity to Study Human and Model Organism in the Absence of the Schumann Resonance: *The "Berlin Magnetically Shielded Room"*

The Schumann Resonances are present everywhere on earth, and they are difficult to shield. For that reason, it is very challenging to conduct experiments of any kind that are *not* subject to the Schumann Resonances. Any experimentally imposed electromagnetic field exposures are invariably superimposed onto Schumann Resonances plus other background electromagnetic fields that can vary substantially as a function of time and from one location to another. "Clean" experiments are extremely 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 Japan¹⁵ and in Germany¹⁶, so that experiments on both biological systems and physical systems can be conducted in the near-complete absence of ambient electromagnetic fields, including the Schumann Resonances. *The Berlin Magnetically Shielded Room* (BMSR), located at the Physikalisch-Technische Bundesanstalt (Federal Metrology Institute of Germany) is one such facility¹⁷. The core of the BMSR is a cube-shaped structure consisting of 8 shells that provide state-of-the-art electromagnetic shielding. The outer shell consists of a seamless layer of aluminum, which acts as an eddy current shield. The remaining seven shells consist of double-layered high-permeable mu-metal sheets (μ -metal, a soft ferromagnetic nickel-iron alloy with very high permeability) with non-magnetic spacings. Considering all 8 layers, the walls of the BMSR core are more than 1 meter thick. The inside

space measures 2.25 m x 2.25 m x 2.25 m, and is designed to accommodate human studies.

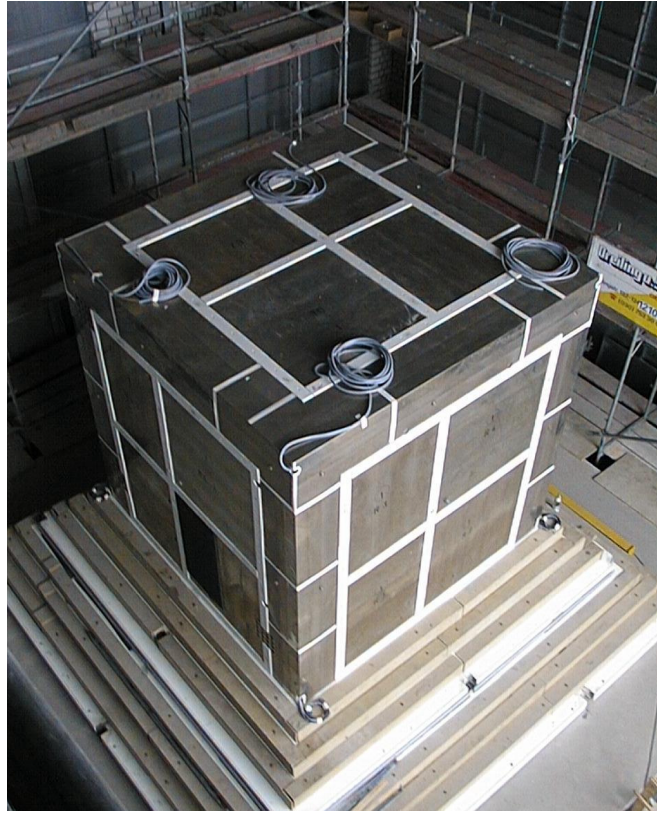


Fig. 2. The Berlin Magnetically Shielded Room is a specialized facility designed for magnetic and bio-magnetic studies. The space inside the rigorously shielded room measures 2.25 m x 2.25 m x 2.25 m and is designed to accommodate human studies, with accessory rooms to support monitoring of human study participants.

An important additional feature of the shielding performance of the BMSR is an orthogonal set of large coils outside of the 8-layered core structure. These coils compensate for Earth's steady magnetic field, but also allow for active shielding.

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

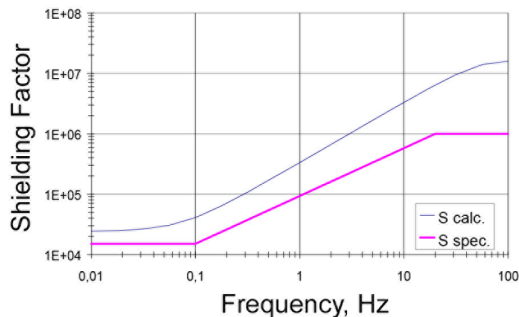


Fig. 3. Performance of the Berlin Magnetically Shielded Room

Once constructed, the performance of the *Berlin Magnetically Shielded Room* (BMSR) (blue line) exceeded its target performance 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 electromagnetic field strength to the low femto Tesla range. This is the best performance of any electromagnetic shielding facility currently available today.

Recommended Studies in Rodents at the Berlin Magnetically Shielded Room (BMSR)

- a. The authors of this white paper recommend that a heart rate variability (HRV) study in rodents be conducted at the BMSR, with shielded and un-shielded conditions to be the primary independent variable. Such a study will help to establish a convenient animal experimental system for examining autonomic nervous system physiology in relation to weak electromagnetic fields that can be transferred to the moon, when Space Biology experiments at that location become available. A rodent model will be complimentary to humans on the moon. Follow-on rodent studies will be planned based on these results.

Recommended Studies in Humans at the Berlin Magnetically Shielded Room (BMSR)

- a. The authors of this white paper recommend that a heart rate variability (HRV) study be conducted in humans, at the BMSR.
- b. We propose EEG studies on healthy human subjects to be conducted simultaneously inside and outside the BMSR, each test with its own control for states of relaxation and states of concentration.
- c. We will also explore how the Schumann Resonances impact the circadian rhythms of subjects inside and outside of the BMSR by measuring the melatonin secretion of the subjects and its variation during the day. We will perform strict clinical and biological observations to detect symptoms of sleep/vigilance/mood/appetite disturbances.

Summary

Substantial evidence supports the notion that the human autonomic nervous system (ANS) responds to changes in solar and geomagnetic activity, affecting human health and human performance. In some countries magnetic field disturbances are already included in public weather forecast reports to account for human susceptibility to large variations in the magnetic field. For NASA, the absence of the Schumann Resonances (SR) field in spaceflight beyond low Earth orbit may pose a risk to astronauts, especially during long duration missions. Exploration of the coupling between the Schumann Resonances and physiology is possible in the unique environment of spaceflight beyond low Earth orbit (where SR can be artificially added), as well as in ground-based magnetically shielded facilities, such as the Berlin Magnetically Shielded Room, where the ambient terrestrial SR can be shielded. The extent of the effect of variation in SR amplitude and frequency on human physiology and performance can be studied and characterized using physiological measurements such as the Heart Rate Variability and by conducting sleep studies.

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