# A Ferromagnetic Transduction Mechanism for Radio Frequency Bioeffects

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## 1. Introduction

There is currently a scientific controversy dealing with a growing body of evidence both supporting and refuting possible harmful health effects due to radio frequency (RF) radiation exposure from cellular telephones and transmitter towers. The question of transduction mechanism, i.e. how these relatively weak magnetic electromagnetic emissions can be transduced by the human body, is arguably one of the most important. One theoretically sound mechanism is ferromagnetic transduction, i.e. the transduction of weak electromagnetic fields by endogenous biogenic magnetite ($Fe_3O_4$) and maghemite ($\gamma Fe_3O_3$ ) present in the human brain. Both of these materials are ferrimagnetic and transduction can be accomplished either by mechanical forces [1,2] or ferromagnetic resonance [3].
Magnetic and electron microscopic analysis of magnetic extracts from human brain tissue by our group [4] and Kirschvink`s group [5] have revealed that biogenic magnetite in human brain tissue occurs in clusters - probably within specific cells - and is similar to that produced by the magnetotactic bacterium *M.magnetotacticum.* Moreover the recent discovery and characterization of mechanosensitive ion channels in *M.magnetotacticum* make it an excellent system for examining these models [6].

## 2. Theory

The two primary mechanisms by which electromagnetic fields generated by cell phones can interact with biogenic magnetite in the human brain are through ferromagnetic resonance and mechanical ferromagnetic transduction. The theory of ferromagnetic resonance is described by Kirschvink [3]. It is primarily a consequence of the resonance of the magnetization vectors of an ensemble of particles which may be present in the human brain tissue. The resonance of the magnetization excites phonons in the crystal lattice, causing acoustical vibrations which deposit energy in the tissue surround the particles. Resonance in the particles is dependent upon particle size, shape, orientation and the frequency of the applied field. Kirschvink has shown theoretically that RF emissions from cell phones fulfil these conditions in certain circumstances.
Mechanical ferromagnetic transduction of cell phone emissions by biogenic magnetite depends largely on the presence of magnetically blocked particles of magnetite and/or maghemite. Particles are magnetically blocked when they are of sufficient volume to possess a stable magnetization vector. This depends on the magnetic energy of the particle overcoming thermal agitation which acts to flip the magnetization vector in single magnetic domain particles very rapidly between parallel and antiparallel easy axes of magnetization. This process is governed by the relaxation time equation:

$$\tau = \frac{1}{f}\exp\left(\frac{vM_sH_a}{2kT}\right)$$

where $\tau$ is the relaxation time (amount of time the particle's magnetization vector remains stable) $f$ is the frequency factor, v is the grain volume, $M_s$ is the spontaneous magnetization, $H_a$ is the anisotropy field, k is Boltzmann's constant and T is temperature in degrees Kelvin (kT represents the thermal energy at temperature T). Using this formula it is possible to determine the size range at which particles will be magnetically blocked.
Such particles have been observed in TEM examinations of magnetic extracts from human brain tissue including the meninges (the tissue closest to the EM field source) [4,5] and their presence has been demonstrated by magnetic analysis of brain tissue [5,7].
The importance of the presence of blocked, biogenic magnetite in brain tissue is that these particles can mechanically transduce magnetic fields when the applied field is at an angle to the particle's magnetization vector. In this case, the particle will experience a torque according to the equation:

$$\tau = \mu\mathbf{B}\sin\theta$$

In this case, $\tau$ is the torque produced, $\mu$ is the magnetic moment of the particle, **B** is the flux density vector of the applied field and $\theta$ is the angle between the applied field vector and the particle's magnetization vector. In the presence of a pulsed or alternating magnetic field, particles in contact with mechanosensitive ion channels in the brain may cause deformation of the cell membrane, activating these ion channels. Disruption of the normal functioning of the ion channels could lead to physiological consequences such as osmotic shock or artificially induced neuronal discharges. In the case of cell phones, the magnetic field pulses could result from low frequency battery current bursts which transmit to the base station when the user is not speaking.
Though both of these theories represent physically plausible and testable mechanisms for producing bioeffects from cell phones, neither has been examined experimentally up to now.
As stated earlier, magnetotactic bacteria contain magnetite

which is morphologically similar to that found in the human brain. They have also been shown to have mechanosensitive ion channels similar to those found in humans [6]. This makes it an ideal model system for examining these effects and the work described here will examine the ferromagnetic hypotheses using the magenetotactic bacterium *M.magnetotacticum.*

### 3. Experimental Design

Motile gram-negative cultures of *M.magnetotacticum* are divided into control and experimental groups. Experimental groups are exposed to RF emissions from commercially available cellular phones using standardized CD test recordings and specially designed exposure chambers with controlled dosimetry (supplied by Dr. N. Kuster). Experiments are also conducted on phones which are altered to transmit at maximum power. Light, temperature, atmospheric and culture medium conditions are controlled and kept constant for both experimental and control cultures in a $CO_2$ incubator. Chambers are constructed to minimize any interference of the transmitted RF signal. Background static and ELF magnetic fields are measured in the incubator before and after the experiments using Alphalabs Gaussmeter.

Exposure of the cultures to RF follow three RF emission protocols (a-c) from the phones and RF device in order to determine dose-response levels of effects: (a) One time (b) two (c) three times per day standard CD transmission for 0.5 hours each time.

Cell motility and cell mortality rates of experimental and control are monitored by light microscopy (living bacteria swim along magnetic flux lines) and staining methods, with mortality rates analysed in blinded fashion.

### 4. Results and Conclusions

This experimental design should allow us to evaluate the potential effects of mobile phone emissions on a cellular level using a model organism. Preliminary results of these experiments and theoretical analysis will be presented.

### 5. References


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