



Can Earth's ULF Magnetic Micropulsations Induce Brain's Spurious Activities?

Altair Souza de Assis¹, Claudio Elias da Silva², Charles Cury³

¹Universidade Federal Fluminense, Niteroi, RJ, Brasil,

²State University of Rio de Janeiro, Rio de Janeiro, RJ, Brazil

³Neurologic Clinic Charles Cury, Niteroi, RJ, Brasil

Email: altairsouzadeassis@gmail.com, claudio.elias13@gmail.com, contabilidadecharlescury@gmail.com

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Abstract

We present in this paper some preliminary studies on how the Earth's ULF—Ultra Low Frequency magnetic micropulsations might interact with the human brain's activities. Magnetic micropulsations are magnetospheric plasma wave eigenmodes that are generated at the Earth's magnetosphere and, via magnetospheric-ionospheric coupling, induce ionospheric currents, and this ionospheric current pattern creates surface geomagnetic perturbations which in turn induce the Earth's surface electrical currents easily detected by ground based magnetometers. These wave modes are basically of Alfvén type, and can be generated or enhanced, for instance, by magnetic storms, situation where they are more intense and, in principle, may be felt by a more magnetic sensitive human brain. Here, we also show how the modes are generated and present their basic physical properties. Finally, we compare the magnetic field level at the brain with the micro pulsation magnetic intensity.

Subject Areas

Neurology, Space Weather, Biomagnetism

Keywords

Sun-Earth Interaction, Space Weather Forecast, Alfvén Waves, Ultra Low Frequency Geomagnetic Micropulsations, Brain's Magnetic Field, SQUID, Crime, Depression, Suicide

1. Introduction

The human brain is the most complex organized structure known to exist, even considering very simple alive beings, the highly complex structure is also ob-

served. According to estimates, the human brain may contain around 100 billion neurons. The number of neuron connections is not well known, estimates say that each neuron can be connected around/more than 10,000 other neurons. However, the Purkinje neurons in the cerebellum can have even more communication channels, estimates may go up to 200,000 dendritic connections, where each neuron passes its signals to each other via thousand of trillions synaptic connections. The spatiotemporal dynamics of cortical signal processing is of paramount importance to brain's dynamics modeling.

With the advent of the superconducting quantum interference devices—Squids, it is now possible to obtain a magnetoencephalography [MEG] recording of the brain. This technological achievement permits us to investigate the signal with more recording spatial accuracy, exceeding the ones delivered by the EEG—electroencephalography, the structure of the brain's magnetic field induced by brain's activities due to emotion, language, esthetics pleasure or other relevant brain's activities. When information is being processed, small currents flow in the neural system and produce a weak magnetic field that can be detected noninvasively by the SQUID magnetometer. The study of the magnetic field emanating from organs of the human body is referred to as biomagnetism.

MEG is closely related to the EEG—Electroencephalography, since both methods measure signals, with time resolution in the millisecond range, generated by the same synchronized neuronal activity in the brain.

Neuromagnetic signals are typically in the range of 50 fT to 500 fT, where fT reads to femto Tesla [10 to minus 15 Tesla]. These fields are in the range of 10 to the power of 9 up to 10 to the power of 8 Earth's background magnetic field, the Earth's magnetic field is about 0.5 gauss. On the earth's surface, actually, the field varies more in intensity than in direction, ranging from 25 nT up to 42,000 nT on the equator, and up to 60,000 nT at the magnetic poles, where nT reads for nanoTesla [10 to the power of minus 9 Tesla].

Magnetic field strength is a measure of the intensity of a magnetic field, given in Teslas (T), the standard international unit. One Tesla is equal to one Weber per square meter, where one Weber is equivalent per second required to induce an electromotive force of one volt. Another way to define a Tesla is that a magnetic field of 1 Tesla must exert force of 1 Newton on a wire of length 1 meter carrying 1 ampere of current. This is a lot of force for a magnetic field to exert, as a Newton is the force necessary to accelerate a 1 kg weight at one meter per second squared.

The neuromagnetic signals are so tiny magnetic field generated in the human brains that can be only detected by the SQUID device, due to its quantum sensitivity. The SQUID is basically a superconducting ring, interrupted by one or two Josephson junctions [1].

2. The Human Brain—Geomagnetic Field Interaction

In order to access the effect of the Earth magnetic field, under quiet or stormy conditions, on the human brain dynamics, it is of paramount importance to un-

derstand the space weather conditions [space weather forecast], very briefly presented later.

2.1. Earth's Magnetic Field and Alfvén Waves

The Earth is a giant magnet, the magnetic field associated with this magnet is considered to originate from the motion of electrically conducting molten fluid swirling deep inside the core of the planet. In addition to sources in the Earth's core the magnetic field observable at the surface has sources in the crust and in the ionosphere and magnetosphere. At the Earth's surface the geomagnetic field can be approximated by a dipole placed at the planet centre and tilted to the axis of rotation by about 12 degree angle. However, significant deviations from a dipole field exist, mainly at higher altitudes in magnetosphere. In space, these magnetic field lines deflect the continuous streams of energetic particles and radiation that comprises the sun's solar wind, and thereby carve out a "magnetosphere" in which the Earth remains embedded as it orbits the sun. The lines of force of the magnetic field extend not only to the surface of the Earth, but also continue deep into space, it is called magnetospheric tail. It has only been possible to accurately determine the small but persistent field generated outside the Earth, largely by the magnetospheric ring current, strongly influenced by magnetic storms [2] [3].

Below, in **Figure 1**, it is shown the Earth's magnetic field without/with sun's solar wind interaction.

The first systematic and scientific study of the earth's magnetic field was conducted by William Gilbert, who published his finding in *De Magnete* in 1600 (**Figure 2**). The fact that the magnetic field is not absolutely steady, but is continually changing and may experience violent changes was noted by several scientists. The connection between the magnetic storms and the aurora was suggested by Halley in 1716 and later, in the same century, Celsius and his students Hiorter made similar discoveries. In 1838, Gauss recognized that the

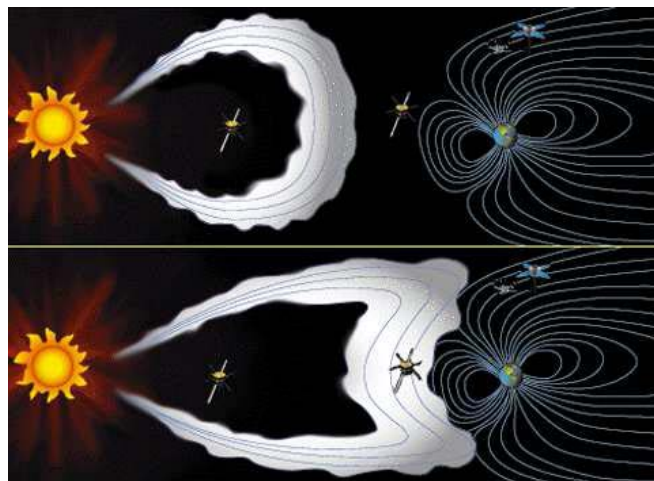


Figure 1. Interaction of the magnetosphere with an expanding magnetic cloud—NASA's scheme.

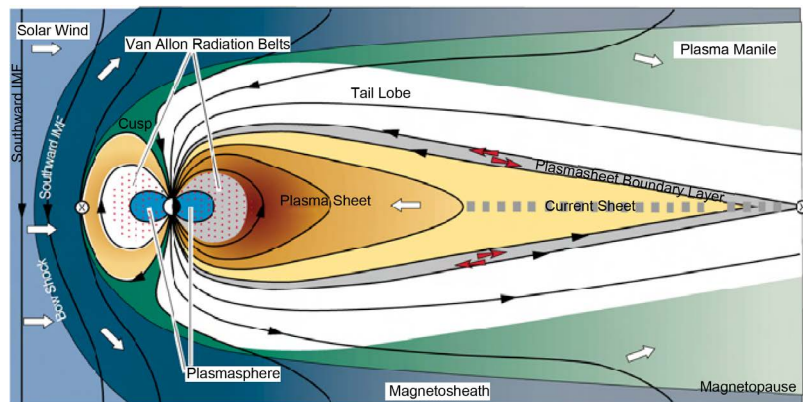


Figure 2. A schematic view of Earth's magnetosphere [After Magnus Wik] [4].

magnetic field measured on the surface of the Earth does not originate entirely within the Earth, but part of it may be of external origin due to currents flowing somewhere above the surface [2].

Going further, modeling the solar and Earth's magnetospheric wave plasma dynamics, in 1942, Hannes Alfvén has shown, using Maxwell's equations in a magnetized solar plasma, the existence of magnetohydrodynamic waves [also called Alfvén waves, hydromagnetic waves or simply MHD waves]. These wave modes have shown to be ubiquitous and ever present phenomena in space environment, such as planetary ionospheres and magnetospheres, solar atmosphere, solar wind, pulsar magnetospheres, extragalactic jets, and so on. Basically, the Alfvén wave propagates due to a disturbing, that might be a shear in the ambient magnetic field, created by any current source, in a magnetized background plasma [5].

The Alfvén waves, present throughout Earth's space environment, mainly at the magnetosphere, occur in various plasma regimes in the frequency range from just around 1 mHz to the local proton gyro frequency ≥ 1 Hz. In this range of frequency, the ULF—Ultra Low Frequency band magnetic signals are commonly called of geomagnetic pulsations, as these arise due to the sinusoidal low frequency oscillations of the Earth's magnetic field. The geomagnetic pulsations are classified by the period and characteristic features [continuous or irregular] as Pc 1 to 5 and Pi 1 and 2. The observation of micropulsations has a long history owing to their detectability on the ground with simple magnetometers [6].

The classification of magnetospheric electromagnetic signals is given below:

Radiofrequency: SHF 3 - 30 GHz/UHF 0.3 - 3 GHz/VHF 30 - 300 MHz/HF 3 - 30 MHz/MF 0.3 - 3.0 MHz/LF 30 - 300 kHz/VLF 3 - 30 kHz/ELF 3 - 300 Hz.

ULF (ultra-low-frequency) Geomagnetic Variations: For signals with frequency of the order of/smaller than 3 Hz, we classify them as Pc1 0.2 sec - 5.0 sec/Pc2 5 sec - 10 sec, Pc3 10 sec - 45 sec/Pc4 45 sec - 150 sec/Pc5 150 sec - 600 sec/Pi 1 1 sec - 40 sec, Pi2 40 sec - 150 sec. The periods for Sc- and si are of the order 300 s.

The continuous [Pc] oscillations are thought to be generated at the surface of the magnetosphere, or within the magnetosphere, and to be propagated in a hydromagnetic mode—Alfvénic mode, as a toroidal oscillation of the whole geomagnetic field lines between conjugate points, as shown in Figure 3, it is clear

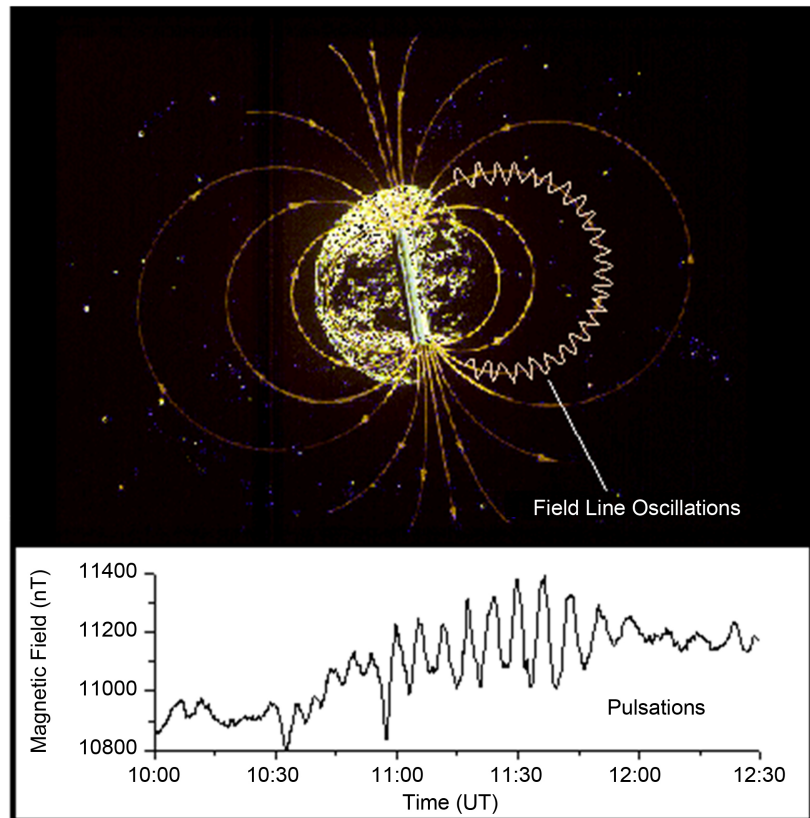


Figure 3. A schematic view of Earth's magnetosphere magnetic field line oscillations. Source: Natural Resources of Canada, <https://www.nrcan.gc.ca/>.

that it can be detected and felt by human brain at north hemisphere, south hemisphere, and at the equator region.

2.2. Space Weather and Earth's Magnetic Micro Pulsations

The ULF magnetic micropulsation and the background Earth's magnetic field are strongly influenced by the space weather conditions, mainly by the Solar and Geomagnetic Activity (S-GMA) [2].

The US National Space Weather Program defines space weather as the condition of the sun and in the solar wind, magnetosphere, ionosphere, and thermosphere system that can influence the performance and reability of space-borne and ground-based technological systems and can endanger human life or health. It further observes that adverse conditions in the space environment can disrupt satellite operations, communications, navigation, and electrical power distribution grids and lead to a variety of socioeconomic losses. The systems more affected by the space weather changes are the satellites, rockets, planes, electrical power stations, oil ducts, Global Positioning System—GPS, and Radio/TV systems, read further, for instance; Time, February 14, 2000

<https://wattsupwiththat.com/2019/05/13/three-solar-storms-headed-for-earth/>.

The main space changes in the Earth's space environment, as magnetic storms and sub storms, are related to solar flares, coronal mass ejections, and magnetic

clouds, inversion of the solar magnetic field and magnetic reconnections of the earth's magnetosphere magnetic field. These events can cause recurrent storms, but also sporadic geomagnetic storms. Recurrent storms are weaker and typically present gradual onsets, while sporadic geomagnetic storms are usually preceded by a sudden commencement, their intensities are larger and, though having a non random behavior, they tend to occur more frequently near solar maximum. There is a very reasonable correlation between the solar activity and magnetic storm as shown below in **Figure 3**.

2.3. Storming Space Weather

Space storms are dangerous and tricky to track down. As the solar wind blows against the Earth's geomagnetic field around our globe it causes magnetospheric and ionospheric currents which circulating back and forth, create strong primary electromagnetic field, and because Earth is a conductor [although a pretty poor one] it creates a secondary field, too. When varying rapidly these fields create Geomagnetically Induced Currents—GICs in earthed good conductors like a power system or pipelines, and these effects are enhanced during space storming conditions. Most of scientists agree that a storm is caused by the sun spewing out a million Kilometer—long blob of plasma, a coronal mass ejection—CME. The CMEs merge with the solar wind, the stream of ionized gas that is constantly flowing off the sun, and form disturbances in the speed, density and magnetic field of the normally smooth wind. If a CME hits Earth, we have a storm at hand [4]. However, it is also considered as causing intense magnetic storms the Interplanetary Magnetic Field—IMF, southward component, associated to duskward electric fields [7] [8].

Every 11 years, the sun's activity rises to a violent peak [solar maximum]. During this interval, called the solar maximum, the sun showers the earth with highly energetic particles and radiation. A blast from the sun can shower jet passengers with as much radiation as they get from several chest X-rays. During the solar maximum, space weather becomes stormy and more hydro magnetic activities are present in the earth's space environment causing stronger geomagnetic activities up and down to earth such as magnetic micro pulsations, auroras and enhancement of GICs.

Background geomagnetic field at quiet and stormy days are shown in **Figure 4** and **Figure 5**.

3. Interaction Brain—Earth's Geomagnetic Field

In order to describe, even in a very speculative preliminary pale way, how the ULF magnetic micro pulsations might affect human synapses and, therefore, induce anomalous functioning of human brain, it is necessary to describe how the information flows in brain, what will be done next briefly.

The brain has been called by some scientists as the most complex system in the universe; it is so complex that we can easily say that we are so far from understanding its functioning structure as we are far from the most distant galaxy

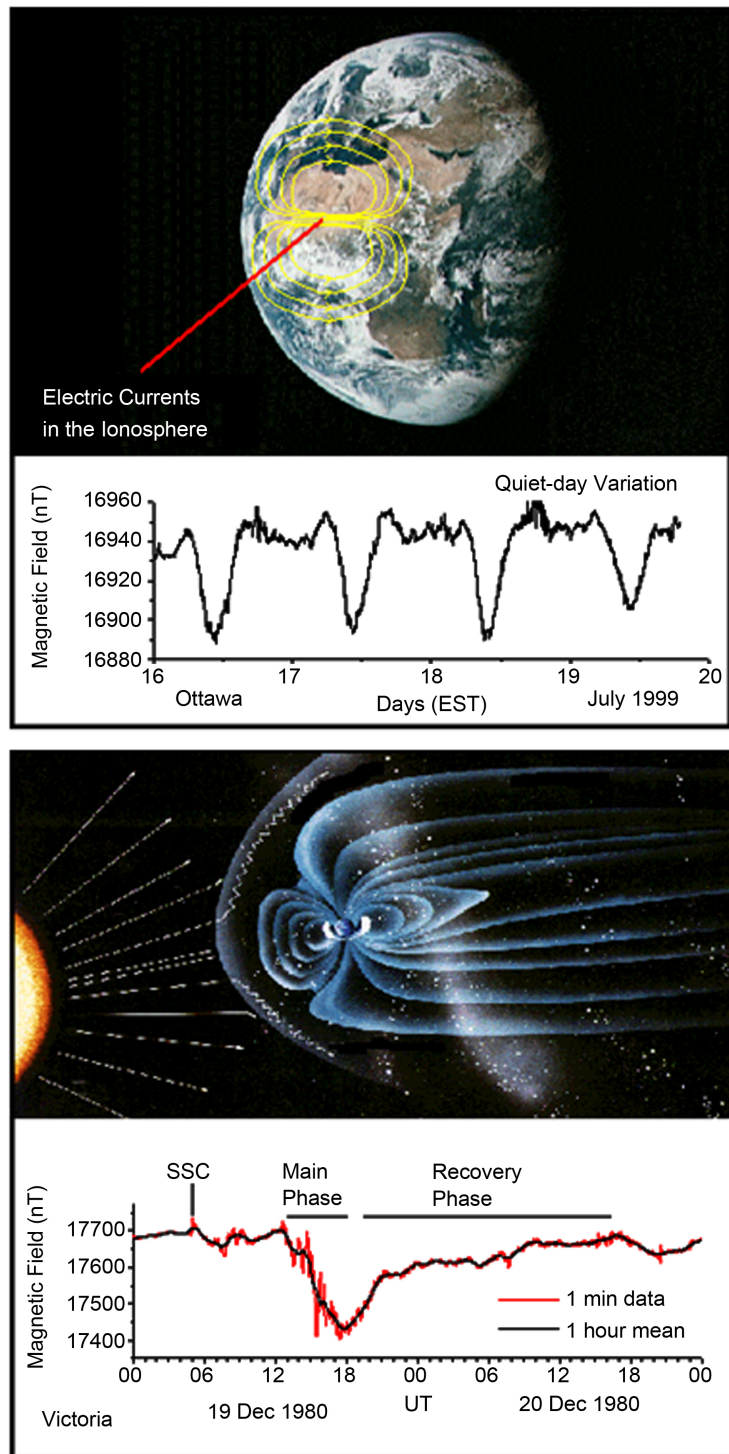


Figure 4. A schematic view of Earth's magnetic field at quiet and stormy conditions. Source: Natural Resources of Canada: <http://www.nrcan.gc.ca/>.

in the universe. The brain has two types of tissue; namely, grey matter and white matter. It communicates with body via nerves and has different identifiable parts, which probably performs different functions. In ascending order of complexity, the levels of brain's analysis are: molecular, cellular, systems, behavioral,

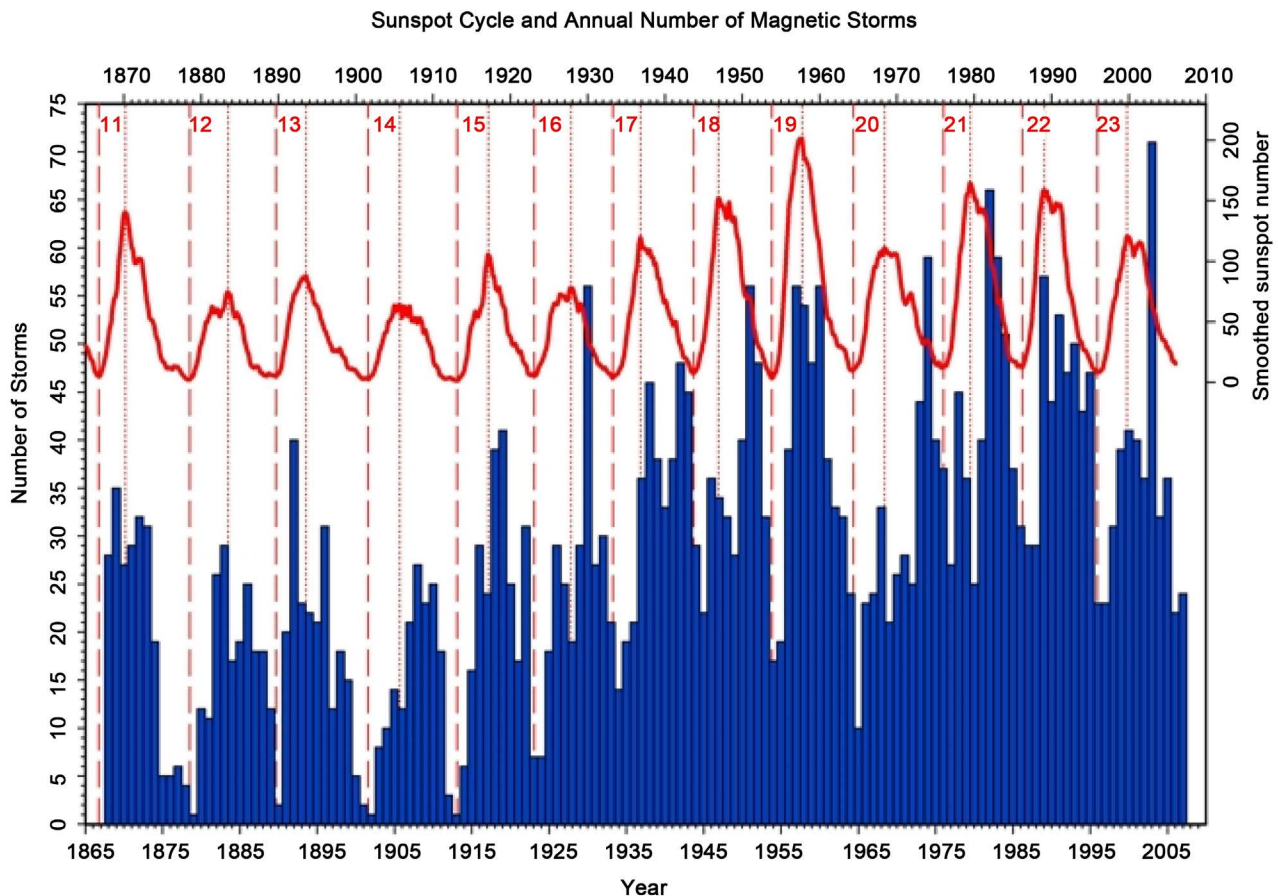


Figure 5. Sunspot Cycle and Annual Number of Magnetic Storms. “Based upon [The earth’s magnetic field—an overview], with the permission of the British Geological Survey”.

and cognitive.

Some major disorders of the nervous system are the Alzheimer’s disease, stroke, cerebral palsy, epilepsy, multiple sclerosis, Parkinson’s disease, spinal paralysis and depression. Americans are hospitalized with neurological and mental disorders than any other major disease, including heart disease and cancer. The economic costs of brain dysfunction are enormous, but they pale in comparison with the staggering emotional toll on victims and their families. The prevention and treatment of brain disorders require an understanding of normal brain function, and, of course, this requires understanding the background where it is immersed [9].

Depression is an effective disorder characterized by prolonged, severe impairment of mood; may include anxiety, sleep disturbance, and other physiological disturbances. The long term depression is a long lasting decrement of the effectiveness of synaptic transmission that follows certain types of conditioning stimulation. An episode of depression can occur suddenly, often without obvious external cause, and if left untreated, it usually lasts 4 - 12 months [9] [10] [11].

In order to model how the geomagnetic field might interact with the human

brain inducing modifications in the synapses, we have to consider that the nerve cells differ from other cells in the body because of their ability to communicate rapidly with one another, sometimes over great distances and with great precision. The rapid and precise communication is made possible by two signaling mechanisms: axonal conduction and synaptic transmission.

Synapse is a specialized zone of contact between neurons; the synaptic transmission can be electrical or chemical. Potentials of mili Volts—mV and currents of the order hundred nano Amperes—nA are present in pre synaptic and post synaptic processes, for duration of some/one order below mili seconds. The chemical transmission involves transmitter release and receptor activation triggered by an action potential arriving at the terminal of a pre synaptic axon, so the neurotransmitter is realized. The released neurotransmitter substance then diffuse across the synaptic cleft and bind to specific receptors cause ion channels to open or close, thereby, changing the membrane conductance and depolarizing the cell. Whereas transmission at electrical synaptic transmission is virtually instantaneous, chemical synaptic transmission involves a delay action potential in the pre synaptic and post synaptic cells.

It is well known by the neurologists that even though the release of synaptic transmitter appears smoothly graded, it is actually quantized in structure. Each quantum of transmitter produces a post synaptic potential of fixed size, called unit synaptic potential. Transmitter is released in quanta in a random manner, and the fate of each quantum of transmitter in response to an action potential has only two possible outcomes: the transmitter is or is not released therefore this process resembles a binomial or Bernoulli trial. It means that the probability of a quantum being released by an action potential is independent of the probability of other quanta being released by that action potential. The amount of transmitter in each quantum varies slightly and in a random fashion.

Interaction Brain Magnetic Field

The electrical conductivity of the skull is low compared with that of the brain tissue, the currents which give rise to MEG signals are mainly confined to the intracranial space. Its magnetic permeability is very close to that of vacuum, then the head does not deform the magnetic field distribution too much, and so we are not also well shielded from external magnetic fields in our daily life. Therefore the geomagnetic field, under time varying various regimes, as on sub storm and storm conditions, can leak to our skulls and reach our brain's white/grey areas, thus possibly interacting with our synaptic potentials/currents inducing spurious charge transport which in turn can be felt by a more sensitive brain system. Time varying background magnetic field can be generated, for instance, upon arrival of ULF magnetic micropulsations or due to magnetic storms and sub-storms. For sure, we are already adapted to our daily [depending, of course, on our local altitude, latitude, and longitude—considering a toroidal coordinates system] background geomagnetic field, but changes in one of those coordinates

induce changes at the brain's background magnetic field, and, speculating, it might well be the very cause of the brain's adjusting asymmetry on flying to different parts of the globe.

Our brain interact with weak magnetic fields much more often than with strong ones, but the problem is not much related to its intensity, but indeed the frequency, in general, is the one that plays the important role. It is well known that our body generates magnetic fields at the frequency band ranging from 0.01 Hz up to 100 Hz and magnetic fields ranging from 10^{-8} Tesla to 10^{-9} Tesla [1]. Since the brain's working system is highly nonlinear and unknown system, more does not means more effectiveness, and also small changes at the initial conditions can induce dramatic changes on final states, this has also proven true for hearth's dynamics.

In **Figure 6** (after Matti *et al.* [1]), below, we show how the Earth's ULF magnetic micropulsations might interact (or micro interact) with human body, and specifically with the human brain, where the yellow color shows the frequency interaction region for both. Considering hypothetically that the mechanism of the response of the brain on external weak magnetic fields is mainly based on resonances, it would be quite reasonable to assume that the local geomagnetic field with similar frequency of local oscillations might induce measurable bio effects [1] [2] [3] [12] [13] [14] [15].

In this picture (**Figure 6**), it is shown the peak amplitudes (the arrows) and the spectral densities of the magnetic field due to typical biomagnetic sources and noise sources. The vertical axis (y) shows the magnetic field spectral density in units of femto Tesla (fT) per square root of Hertz (Hz) and the horizontal axis (x) is the frequency in Hz.

The α rhythm, for instance, at the 10 Hz frequency range might interact with the geomagnetic Earth's magnetic field under ac regimes. Furthermore, biological magnetic noise might be amplified at the frequency range of 0.01 Hz up to 1 Hz. The continuous Pc5 ULF micropulsation, and the irregular micro pulsations

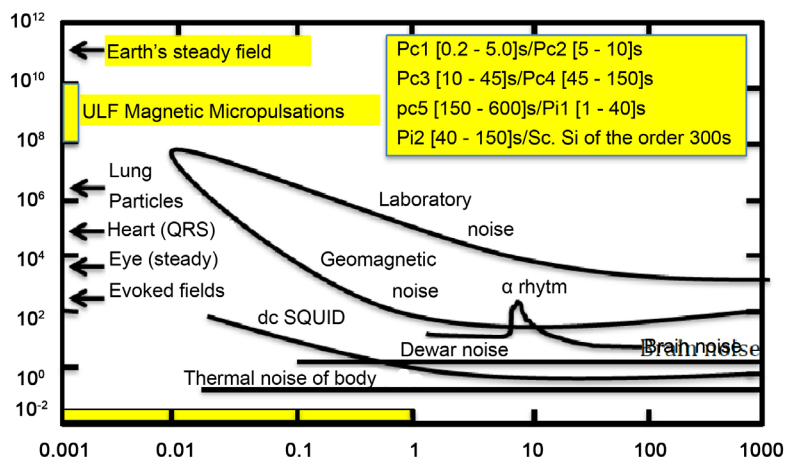


Figure 6. Peak amplitude (arrows) and spectral densities of fields due to typical biomagnetic and noise sources.

Sc and si might be the good candidates to fuel brain's magnetic resonances. Note that from the above picture, we can infer that the Schulmann frequencies might be considered in this type of study [12] [13] [14].

Magnetic storms not only affect the performance of equipments, disturb radio communications, blackout radars, and disrupt navigation systems as the GPS, but can also endanger living organisms; it can change the blood flow, especially in capillaries, affect blood pressure, and boost adrenalin. The brain is clearly its major target due to the complex tiny blood pipes circuits, and the current pattern induced by the electrical and chemical synapses, already described above. Under stormy space weather conditions the geomagnetic micro pulsations are more active and therefore more interaction might occurs, indeed, there are reports correlating space weather conditions with changes of social behavior in susceptible individuals, such as inducing psychotic depression consistent with a threshold event affecting predisposed individuals [11] [14] [15].

Also, there exist medical statistics showing that most of all background magnetic micro variations, caused by geomagnetic disturbances, are accompanied by an abnormally high incidence of heart attacks, and blood-strokes. The low and extremely low frequency electromagnetic fields can destabilize the heartbeat, leading to a sudden death or infarction. Medical experts have finally understood why heart attacks take a heavy toll before a magnetic storm, and this is because micro variations begin 24 hours before the storm. Response induced by magnetic storms can be divided into two phases: hyper function with a maximum of adaptation capabilities of an organism (several hours) and depression (several days). Such response is characteristic only for magnetic storm, for the remaining stress-factors (such as change of atmospheric pressure, weather conditions, family disorders) the phase of depression is sharply reduced (no more day). It seems that the intensity of a response to geomagnetic disturbance depends not on a type of disease, but on coordination of systems of an organism activity. The people with poorly connected matrixes of internal correlations endure magnetic storms most heavily, as their organism is strongly trimmed out during the phase of depression. Ultra Low Frequency magnetic micro pulsations can also create brain's relevant geomagnetic disturbances due to its slow ac nature [16] [17].

Space medical doctors probed cosmonauts during landing and flights of various duration, when they were exposed to geomagnetic disturbances, and then studied the same parameters in a neutral situation. The influence of a magnetic storm on cosmonauts, in general, manifested as a change of pulse and blood pressure, vegetative disorders, reduction of heartbeat rate variability and the power of respiratory undulations, and in a more irregular heartbeat pattern. Reactions varied depending on the duration of the flights and an ability of cosmonauts to adapt them to the new environment. They have considered that the response of a complicated system as the human organism to external factors largely depends on its condition. Therefore, a magnetic storm and so ULF magnetic micropulsations are not, in principle, dangerous for healthy people, the

response of an organism on a ac magnetic field is identical to an overwhelming majority of people, despite of difference in the age, diseases and subjective sensations [2] [3] [12] [13] [14] [15] [17].

However, it should be considered that there are risk groups with unstable biological status; these include people suffering from general brain disorders or hypertension, or also children whose adaptation system is in process of formation. New born babies might be particularly at risk [2] [17].

Further epidemiological studies must be considered, but not simply looking into the storms, but also forecasting steady micro variations of the geomagnetic magnetic field, correlating then magnetic micro pulsations and magnetic storm patterns to health problems in human beings. One should map further, for instance, pulse, temperature, pressure, ECG, magnetograms and ultrasound [1] [18] [19].

4. Conclusion

It is very clear that the functioning assessment of the human brain is still full of surprises and beauties that Yahweh has permitted us to observe and deeply and humbly enjoy. Some best minds on biophysics have been divided on the question related to how to model the physical part of the functioning of the human brain that impacts directly and dramatically emotions, decisions, and body metabolism. There is also the highly complex issue of the possible quantum effects on consciousness that is not yet conclusively shown. Mark Tegmark from Princeton said “There is nothing fundamentally quantum mechanical about the cognitive process in the brain”. It seems that the coherent time does not permit it [19]. All these discussions make the subject involved in an overwhelming atmosphere of beauty and mystery, and it is far to be completely accessed by our common minds, but what is true is that it is necessary to make a much deeper and more rigor epidemiological assessment on how the general electromagnetic fields: non ionizing readiation [mobiles, remote controls, computers, medical/industrial electric equipments, city wire network, etc.], time variable geomagnetic field induced by ULF magnetic micropulsions and/or magnetic storms/substorms might affect the brain’s synaptic dynamics, inducing possible “damage” on the brain information network, flow dynamics, such as inducing suicide thoughts, depression and related issues. Of course, in general, the brain studies, which should be accessed with much responsibility and respect to the screened person, can aloud one to access more sophisticated areas say in business and learning such as the neurobusiness, in particular; neuromarketing and behavioural science, and further neurolearning in general. Those areas which require from the researchers a great degree of moral and ethical behavior, profit from technologies such as brain scanning, which measures neural activities, and physiological tracking.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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