On the difference between Man-made and Natural Electromagnetic Fields/Radiation, in regard to Biological Activity

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Summary

It is explained why the weak low-frequency (LF) electromagnetic fields (EMF) from high-voltage lines and domestic appliances and the radio-frequency (RF) EMF/radiation from wireless communication can induce biological effects in our body while the much stronger natural electromagnetic radiation (EMR), such as from the sun, cannot do so. As far as physics is concerned there are two reasons:

1. The man-made LF EMF and RF EMF/radiation yield macroscopic field strengths, while the field strength of the natural EMR is equal to zero at all frequencies, and
2. The man-made LF magnetic fields and RF EMF penetrate into our body and the RF EMF are largely absorbed there, while most of the natural EMR from the sun does not penetrate through our skin.

The man-made EMF thus induce currents, resonant interactions and interferences – involving charged and polar particles and surfaces and magnetic particles - in our body. These interactions and the absorption can lead to harmful biological processes and to interference with the biological processes already going on.

The natural EMR, although having a much higher intensity, does not have any effect inside. Most of it does not penetrate our skin and the part that penetrates has field strengths equal to zero and therefore does not exert any force.

Quote (p.6): Saying that the RF radiation from wireless communication cannot do any harm because the individual photon energies are not large enough is the same as saying that a tsunami cannot cause any harm because the individual water molecules don't have enough energy.

1. Introduction

In two papers[1,2] polarization was claimed to make the key difference between man-made and natural electromagnetic fields/radiation, in regard to biological activity. This claim is not correct. After the first paper in 2015 I gave my comments in private. After the second paper in 2017 and a further report with again the emphasis on polarization I wrote a note to prevent further spreading of this incorrect information and to explain why this is incorrect

[1] http://www.nature.com/articles/srep14914
[2] https://www.diagnose-funk.org/publikationen/artikel/detail&newsid=1170

and what really makes the difference. Now one year later I made this improved and extended version in which I also discuss two other incorrect arguments which are frequently used in an attempt to convince ignorent readers that the EMF/radiation from wireless communication cannot be harmful for humans.

First I will clarify what is meant here by Man-made and Natural Electromagnetic Fields (EMF) and Electromagnetic Radiation (EMR) .

Man-made refers to the EMF made by high-power lines and electric appliancies on the low frequency (LF) side and by antennas for wireless communication on the radio-frequency (RF) side.

Natural mainly refers to EMR from the sun, but light from lamps, flames and infrared sources also belong to this category.

There are also natural EMF, the main ones beiing the static electric field between the ionosphere and the earth, the static magnetic field from the earth and the Schumann resonance EMF, with higher harmonics, resulting from lightning. On a microscopic scale natural EMF are very common. Our body is full of it, think of EEG's and ECG's. These natural EMF are most important for life, but they are not important for the present discussion.

To make my points clear it will suffice to confine myself in the following to the natural EMR from the sun and the man-made EMF from power lines and electric appliances and from antennas for RF wireless communication. The reason why I use the name EMR for the sun and EMF for power lines and antennas will become clear furtheron.

The microscopic natural EMF inside our body can and will be disturbed by the man-made EMF which penetrate into our body. These can by induced currents, resonant interactions, interferences and absorption lead to harmful biological processes and harmful interference with biological processes already going on. In the following I confine myself to the physics part.

2. Natural electromagnetic radiation (EMR)

The EMR from the sun comes to us in the form of photons. These have an extremely wide distribution of energies. On one side there are high-energy X-ray photons, on the other side photons at the ultra-long radio wavelengths and in between UV, visible and infrared photons. The maximum of the sun's energy output in the form of photons is in the visible light range. Throughout evolution our eyes (and we) have evolved to that. Except for some deep UV we are protected against the more energetic photons by the earth's atmosphere.

Each photon can be regarded as an electromagnetic EM wave. It propagates with the speed of light and is characterized by electric and magnetic field vectors perpendicular to the propagation direction. These two field vectors are mutually perpendicular. EM waves are generally characterized by two quantities, frequency and wavelength. For photons the product of wavelength and frequency is equal to the speed of light and the photon energy is proportional to its frequency. So, the extremely wide distribution of energies of photons

from the sun implies extremely wide distributions of frequencies and wavelengths. Furthermore, photons are polarized, the polarization direction is the direction of the electric field vector.

Often waves add up but for photons from the sun this does not happen. Photons from the sun are mutually independent. They have different frequencies, different polarizations, different phases and don't come to us along the same paths. The energy deposited by them on earth can be appreciable. In the middle of a sunny day in the summer it can be over[3] 1000 W/m^2. However, because of their independence there is no constructive nor destructive interference between them. So their energy is deposited on earth, but because of the absence of constructive interference there is no build up of a macroscopic electric field at any frequency. This last point is the essence why we can tolerate sunlight with an energy deposition on the earth's surface of 100 times the ICNIRP norm (10 W/m^2) for UMTS radiation. There is a lot of energy which on our skin - apart from sunburn and possibly melanoma after long time exposure to deep UV - is partly reflected and partly absorbed and converted to heat, with some benificial effects in addition (such as formation of vitamin D), but there is no macroscopic electric field at any frequency. Furthermore, as said, the sun's radiation (light) does not penetrate through our skin.

3. Man-made electromagnetic fields (EMF) / radiation (EMR)

When an oscillating current flows through an antenna one gets a macroscopic EMF around it which oscillates at the same frequency. Close to the antenna, in the so called near field[4], this EMF is quite complicated, the strengths of the electric and magnetic field components have no fixed well defined ratio, which is a prerequisite[5] for calling it EMR. In the near field there is around the antenna therefore no EMR and there are no photons. The near field extends to about one wavelength from the antenne. The consequences are interesting.

A high-voltage power line can be regarded as an antenna. In Europe 50 Hz alternating current (AC) is used and the corresponding wavelength is 6000 km. The near field thus extends up to 6000 km beyond the power line. On such a power line one can put a high voltage without drawing a current[6]. One then gets an electric field which radially extends from the power line, while the magnetic field is zero. Once a current flows through the power line one gets a magnetic field which is proportional to the current, while the electric field remains the same. So it is clear that the electric and magnetic field components are independent and that there is therefore no EMR and there are no photons.

In the radiofrequency range used for wireless communication the carrier frequencies range from below 1 GHz to above 2 GHz and the corresponding wavelengths from above 30 cm to

[3] https://en.wikipedia.org/wiki/Sunlight
[4] https://en.wikipedia.org/wiki/Near_and_far_field
[5] https://en.wikipedia.org/wiki/Electromagnetic_radiation
[6] For simplicity I neglect the small blind current needed to sustain the AC high voltage on the power line.

below 15 cm.

The implication is that when we hold a smartphone next to our ear or have a laptop on our lap, our head or some of our more sensitive parts are in the near field. Thus we are not subjected to EMR but to an EMF with independent electric and magnetic field components. To come back to the statement that polarization makes the key difference one can question here: polarization of what? Not of photons, because there are no photons in the near field.

Beyond about 2x the afore mentioned 15 to 30 cm we are in the far field[4] in which there is a fixed relation between the electric and magnetic field components. In between there is a transition region. In the far field the EMF is also EMR. This EMR is very different from the EMR from the sun. As said, the EMR from the sun consists of mutually independent photons with different frequencies, different polarizations and different phases. There is therefore no constructive nor destructive interference between them. In contrast, the EMF/EMR in the far field of an antenna has only one basic frequency, the carrier frequency, and because of the way this radiation is produced, by an oscillating current through an antenna, all photons have the same phase and the same polarization. Because of these three properties, one frequency, the same phase and the same polarization, there is constructive interference and the photon contributions add up. This results in an EMF with electric and magnetic field strengths dependent on the current through and the voltage over the antenna and, in this far field, the fixed ratio between these two field strengths which is characteristic for EMR.

Finally, at the frequencies used for wireless communication, the EMF penetrates into our body, while the EMR from the sun has no EMF and does not pass our skin.

4. Classical EMF, the basis for model calculations

Let us now suppose we want to make model calculations of the effect of man-made EMF on biological material. We then have to know the electric and magnetic field strengths throughout that material as a function of time. The first step will then be to calculate the field distributions in the absence of the biological material, This is done in principle from Maxwell's equations[5,7], which among other things describe how electric and magnetic fields are generated by charges, currents and changes of each other. In all cases considered, LF, near-field RF and far-field RF, one then gets the distribution throughout space and time of these electric and magnetic field components. This is called a classical electromagnetic field. Maxwell's equations were derived well before the year 1900, some decennia before one knew that photons existed. That the far field RF EMF can be described as being build up of individual photons is unimportant. What I mean is that the photon energies are so small that as separate photons they don't have any biological effect. It is just their combined effect which results in a macroscopic EMF with appreciable strength.

5. EMF versus EMR, the key difference(s)

[7] https://en.wikipedia.org/wiki/Maxwell's_equations

So, what is left of the argument that polarization would make the main difference between Man-made and Natural EMF? The answer is: nothing in the near field. In the far field it is one of the three essential factors when the far field is described as being build up of photons. Man-made EMF, as produced by high-voltage power lines and antennas for wireless communication, can be regarded as classical EMF. In the LF and near-field RF range there are no photons and there is no EMR. In the far-field RF range the names EMF and EMR can both be used, with the restriction that this is an EMR with only one frequency and with moreover constructive interference in such a way that this EMR is an EMF.

The indication EMF is complete, it tells that there are electric and magnetic field vectors with magnitudes that can be calculated from Maxwell's equations. The indication EMR is in this case applicable only in the far-field RF range and is not complete. The word polarization does not give additional information, it only indicates the direction of the electric field vector. This electric field vector has in addition a magnitude and gives more information.

External natural EMF are mainly those mentioned in the beginning, the static electric field between the ionosphere and the earth, the static magnetic field from the earth and the Schumann resonance frequency EMF with higher frequency harmonics. But, as said, these are not important for the present discussion. And the macroscopic EMF from the radiation coming to us from the sun? Well, as I have explained, that is zero for all frequencies.

To conclude, the main difference between man-made and natural EMF is that the man-made EMF referred to here are made with appreciable strength and that the natural EMF resulting from the photons from the sun (or lamps, or flames) is zero at all frequencies. EMR is the appropriate name for the suns photons, their contributions don't add up to yield a macroscopic EMF. EMF is the most appropriate name for all the fields made by power lines, electrical appliances and RF antennas.

In addition to this difference there is another difference, namely that most of the natural radiation from the sun does not penetrate through our skin, while the EMF from wireless communication easily penetrates through our skin and is largely absorbed in our body. Furthermore, the lower frequency EMF from high-voltage lines induces voltage differences, currents and magnetic fields in our body.

6. Ionizing versus non-ionizing radiation

In discussions and popular non-scientific literature a comparison is often made between ionizing radiation such as X-rays and non-ionizing radiation such as from wireless communication. A frequently used argument is that ionizing radiation is harmful because the individual photons have enough energy to ionize molecules and to break molecular bonds in our body, while the RF photons of wireless communication are not energetic enough to do so. The correct counter argument is that in the near field of an antenna there are no RF photons at all, but instead a complicated EMF with field strengths which are completely independent of the RF photon energy. This is also true in the far field although the EMF can also be described there as being build up of billions times billions photons. To be more

precise, for a EM radiation intensity of 1 mW/m^2 coming from an antenna and composed of 1 GHz photons, the number of photons passing this surface of one square meter per second is equal to $1,5 \times 10^{21}$. For each square cm this is $1,5 \times 10^{17}$. In their interaction with biological material these gigantic numbers of photons don't act individually, but as an EMF.

Saying that the RF radiation from wireless communication cannot do any harm because the individual photon energies are not large enough is the same as saying that a tsunami cannot cause any harm because the individual water molecules don't have enough energy.

Furthermore, the word non-ionizing does not give information about whether something is harmful or not. Most harmful environmental interactions with our body are non-ionizing.

7. Additional remarks.

The above is meant to be tutorial and describes only basic concepts. The actual man-made EMF for wireless communication are more complicated because the data information, including beacon signals, is superposed on the carrier frequency signals.

It is known from experiment that these pulsed RF signals are responsible for most of the harmful biological effects and are responsible for a lowering of some of the threshold intensities at which these effects occur, as compared to non-pulsed signals.

In many places there is not one antenna but there are more. Each gives its own EMF. These EMF add up and result in a more complicated sum EMF. When different antennas work at different frequencies one gets an EMF with these frequencies and with sum and difference frequencies. In some cases different (two) polarization directions are used as well. The end result is always an EMF, although possibly a complicated one.

Another difference between the EMR from the sun and the EMF from RF wireless communication is that the central frequency of the sun's radiation lies a factor of about a million above the RF frequencies used for wireless communication. At the visible frequencies photons don't penetrate into our body, at the RF frequencies the field does and is largely absorbed there, possibly doing harm. The 1000 W/m^2 radiation from the sun on our body on a sunny day does not induce any EMF in our body, while the common 0,001 to 0,1 W/m^2 EMF from wireless communications correspond to electric fields with strenghts from 0,6 to 6 V/m. These penetrate into our body and exert a force on charged (ions), polar (such as water) particles and surfaces (e.g. cell membranes) and on magnetic (magnetite) particles proportional to these field strengths.

From the preceding explanation it follows that it is perfecty safe to use sun glasses with polarization filters (polaroid for example). One then gets polarized light entering into our eyes, but the photons in it are still independent, with different frequencies and phases, implying that the resulting EMF is zero at all frequencies. Light reflected from a water surface under Brewster angle can also be polarized and that is also safe, for the same reason.

Finally, I did not use any formulae in this note. These, with explanations and definitions, can all be found in the Wikipedia articles referred to.

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