Chapter 2

Analysis of Biological Effect of AC–DC Electromagnetic Fields using the Lorenz Model

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ABSTRACT

Electromagnetic fields (EMF) are essential to various applications directly involving humans. Fears about the biological effect of exposure to electromagnetic fields drive enormous research into this area. This research generates conflicting results, and consequently, uncertainty regarding possible health effects. This chapter studies a nonlinear Lorenz model describing interactions among charged particles and combined alternating (AC: alternating current) and static (DC: direct current) electromagnetic fields, for various combinations of frequencies, field strengths and relative angle (θ) between the AC and DC magnetic fields. We investigate the effect on charged particles of three possible combinations of alternating and static electromagnetic fields: (i) AC electric field and DC magnetic field (ii) AC magnetic field and DC magnetic field (iii) AC electric field and AC and DC magnetic field. Then the behavior of the particle in these fields with different initial conditions and strong directional effects is observed when the angle between AC and DC magnetic fields is varied. The results show that the cyclotron resonance frequency is affected by charged particles' initial position and initial velocity. Further, we observe strong effects of electric and magnetic fields on a charged particle in a biological cell with initial position and initial velocity.

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INTRODUCTION

Electromagnetic radiation can be either ionizing (ultraviolet, X-ray and gamma rays) or non-ionizing radiation (microwave, radio waves, infrared, visible light and near ultraviolet), according to the frequency or wavelength of the radiation. Generally, either excitation or ionization can take place when radiation is absorbed by tissue. Ionization arises once radiation transports adequate energy to eliminate an electron from an atom or molecule. Excitation arises when radiation excites the motion of the atoms or molecules, or when it excites an electron from an engaged orbital into a higher-energy orbital. Electromagnetic radiation which does not hold enough energy to ionize atoms or molecules is called non-ionizing radiation.

Amplitude modulated radiofrequency fields were used in early experimental work. The amplitude modulation has been recognised as a significant factor in generating biological effects. Hence, later on electric and magnetic fields were used in experiments. Theoretical models that clarify the interaction between low frequency magnetic fields and biological tissue are crucial. Several experiments indicate an enhancement of the biological effect of certain resonance frequencies (Liboff, 1987; Liboff, Rozek, Sherman, McLeod, & Smith, 1987; McLeod, Smith, Cooksey, & Liboff, 1987; Smith, McLeod, Liboff, & Cooksey, 1987). The resonance frequencies may possibly be linked to the magnitude of the local geomagnetic field (Blackman, Benane, Rabinowitz, House, & Joines, 1985; Blackman, Kinney, House, & Joines, 1989). Further, amplitude windows were found, suggesting that stronger magnetic fields do not constantly involve rigorous biological consequence (Blackman et al., 1989).

In this chapter, we analyze the biological effects of non-ionizing radiation, in particular the behavior of charged particles exposed to alternating and static electromagnetic fields in a biological cell. Investigating the biological effects of electromagnetic fields covers a broad range of disciplines: basic biology, fundamental physics and biophysics, fundamental chemistry, biochemistry and electrical engineering (Barnes, 2006). According to the AC electric and magnetic signal, the model can be linear or non-linear. Both linear and non-linear models are considered in our analysis. A previous study (Thompson et al., 1995) of a nonlinear Lorenz model describing interaction between charged particles and combined AC and DC magnetic fields investigated the different combinations of field strengths, frequencies and relative angles between AC and DC magnetic fields in a vacuum. In this chapter, we investigate the effects on charged particles in a biological cell due to three possible combinations of alternating and static electromagnetic fields. The intention of this analysis is to clarify some of the basic characteristics in terms of the simplest possible model, which includes at least the crucial elements of the interaction of charged particles exposed to all combinations of AC and DC electromagnetic fields. See Figure 1.

ELECTRIC & MAGNETIC FIELDS

Electric and magnetic fields are interrelated. Electric fields are formed by voltage and measured in volts per meter (V/m) or newton per coulomb (N/C). Magnetic fields are induced by alternating current and measured using the derived quantity magnetic flux density (B) in webers per square meter (Wb/m^2), tesla (T) or gauss (G) where 1 μT = 10 mG. Magnetic fields only present when the appliance is turned on while electric fields can exist without any current flow (Habash, 2004). Electric fields proceed on static and moving ions, while magnetic fields only act on moving ions. Magnetic fields penetrate biological bodies without attenuation, even though electric fields are usually highly filtered from the cell interior. The speed and direction of the ion's motion are affected by electric force, as electric force is in the direction of the electric field. However, magnetic