Influence of Combined Alternating and Static Electromagnetic Fields on Cell Plasma Membrane

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INTRODUCTION
Exposure to electromagnetic fields is a research area that has generated conflicting results and thus uncertainty regarding possible adverse health effects. Accurate modelling and experimentation increases our understanding of the process. This study has investigated the effect on charged particles due to three possibilities of alternating and static electromagnetic fields: (i) Alternating electric field and static magnetic field. (ii) Alternating magnetic field and static magnetic field. (iii) Alternating electric field and alternating and static magnetic field. We show the numerical results and then the behavior of the particle due to these fields with different initial conditions. External field deploy a periodic force on each free ion which can pass across plasma membrane. Due to this force ion is displaced distance \( r \) from its initial position. The force, \( F \), on a particle due to \( E \) electric field and \( B \) magnetic field, in the vicinity of a cells plasma membrane is given by

\[
F = m \nu \sin \theta \omega t + m \nu \cos \theta \omega t = \psi q (E + \nu B),
\]

where \( v \) is the drag coefficient, \( \psi \) is the particle valence, \( q \) is the electric charge of the particle of mass \( m \) and \( \nu \) denotes the velocity of the particle at time \( t \). The drag coefficient shows the drag or resistance of a particle in a moving fluid. This depends on the particle size, shape as well as the fluid viscosity. We choose \( E \) and \( B \), arbitrarily to be at 90° such as alternating \( E = (E_x, 0, 0) \), static \( B = (0, B_{oy}, B_{oz}) \), and alternating \( B = (0, 0, B_{1z}) \). Here \( E \) and \( B \) varies sinusoidally with time as \( E(t) = E_1 \sin k y \cos k x \sin \omega t \), and \( B(t) = B_1 \cos k x \cos k y \cos \omega t \) where \( k = \omega / c \sqrt{2} \), angular frequency \( \omega = 2 \pi f \), \( f \) frequency and \( c \) is speed of light. Zero drag is considered here as in [1].

(a) Alternating Electric Field and Static Magnetic Field
The force due to alternating electric field and static magnetic field considering non linear model is given by replacing \( ky \) by \( y \), \( kx \) by \( x \) and \( \omega t \) by \( t \)

\[
\begin{align*}
x'' + \dot{\nu} x' + \omega_n^2 x &= \beta_1 \sin y \cos x \sin t + \omega_{oz} y' - \omega_{oy} z', \\
y'' + \dot{\nu} y' + \omega_n^2 y &= -\omega_{oz} x', \\
z'' + \dot{\nu} z' + \omega_n^2 z &= \omega_{oy} x'.
\end{align*}
\]

Considering dimensionless quantities \( \dot{\nu} = v/f \) where \( \omega_{oy} = \psi q B_{oy}/mw \) and \( \omega_{oz} = \psi q B_{oz}/mw \), \( \beta_1 = \psi q E_1/m\beta_0 \) and \( \beta_0 = \psi q E_0/m \). Here \( \omega_{oy} = \omega_0 \cos \theta \), \( \omega_{oz} = \omega_0 \sin \theta \) and \( \omega_0 = \psi q B_0/mw \). Since self oscillating frequency is too small we considered it as a constant and \( \omega_3 = cont./\omega \). Thus the linear model for alternating electric field and static magnetic field replacing sin \( y \) by \( y \) and cos \( x \) by 1 is given by

\[
\begin{align*}
x'' + \dot{\nu} x' + \omega_n^2 x &= \beta_1 y \sin t + \omega_{oz} y' - \omega_{oy} z', \\
y'' + \dot{\nu} y' + \omega_n^2 y &= -\omega_{oz} x', \\
z'' + \dot{\nu} z' + \omega_n^2 z &= \omega_{oy} x'.
\end{align*}
\]
Figure 1: Non-Linear Models: The particle displacement in a non-linear model is given by.

(b) Alternating Magnetic Field and Static Magnetic Field

Non-linear model is given by

\[ x'' + \hat{v}x' + \omega_3^2 x = (\omega_{oz} + \omega_1 \cos x \cos y \cos t)y' - \omega_{oy} z', \]
\[ y'' + \hat{v}y' + \omega_3^2 y = - (\omega_{oz} + \omega_1 \cos x \cos y \cos t)x', \]
\[ z'' + \hat{v}z' + \omega_3^2 z = \omega_{oy} x'. \]  

(3)

where \( \omega_1 = \psi q B_1 / m \omega \). Linear model is given by considering \( \cos x = \cos y = 1 \),

\[ x'' + \hat{v}x' + \omega_3^2 x = (\omega_{oz} + \omega_1 \cos t)y' - \omega_{oy} z', \]
\[ y'' + \hat{v}y' + \omega_3^2 y = - (\omega_{oz} + \omega_1 \cos t)x', \]
\[ z'' + \hat{v}z' + \omega_3^2 z = \omega_{oy} x'. \]  

(4)

(c) Alternating Electric Field and Alternating and Static Magnetic Field

Non-linear model is given by

\[ x'' + \hat{v}x' + \omega_3^2 x = (-\omega_1/2) \cos x \sin y \sin t + (\omega_{oz} + \omega_1 \cos x \cos y \cos t)y' - \omega_{oy} z', \]
\[ y'' + \hat{v}y' + \omega_3^2 y = (\omega_1/2) \sin x \cos y \sin t - (\omega_{oz} + \omega_1 \cos x \cos y \cos t)x', \]
\[ z'' + \hat{v}z' + \omega_3^2 z = \omega_{oy} x'. \]  

(5)

Thus the linear model is given by

\[ x'' + \hat{v}x' + \omega_3^2 x = (-\omega_1/2) y \sin t + (\omega_{oz} + \omega_1 \cos t)y' - \omega_{oy} z', \]
\[ y'' + \hat{v}y' + \omega_3^2 y = (\omega_1/2) x \sin t - (\omega_{oz} + \omega_1 \cos t)x', \]
\[ z'' + \hat{v}z' + \omega_3^2 z = \omega_{oy} x'. \]  

(6)

RESULTS & CONCLUSIONS

The resonant arises at \( \omega_0 = 1 \), hence external field frequency = cyclotron frequency. When alternating and static magnetic fields are parallel to each other and alternating electric field is perpendicular to the magnetic field, the maximum displacement occurs. Alternating electric field influences more than alternating magnetic field to the displacement.

REFERENCES