EFFECT OF ELECTROMAGNETIC RADIATION ON BIO-OBJECTS

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ABSTRACT:

The thermal-effect of electromagnetic field on bio-objects is directly related to the incident field strength. Energy transfer may take place when the said wave strikes a human body.

In this paper authors theoretically studied.

- The energy supplied to the semi-permeable membrane surrounding the cell in human body.
- The increase in temperature due to energy absorbed.
- The change in the ratios of concentrations of Na+, K+ ions in and out side of the cell
- The changes in potential difference between the two sides of the membrane and action/rest potential.
- The rise in temperature in human eye.

INTRODUCTION:

Some parts of the human body inside the skin are conductor. But human body contains water and other materials. This part may be considered as imperfect dielectric. So the currents flow may be of two types: conduction current and displacement current. These two currents transform Electromagnetic energy into heat .The heat absorption process is a quicker process in comparison to heat dissipation system. The time required for dissipating a particular amount of heat is almost six times than the time required for absorption by the same tissue. The power absorbed by the tissue pre unit mass, per unit time due to reception of Electromagnetic energy is called specific absorption rate or SAR. The heat generated due to absorption of Electromagnetic energy is proportional to the water content of the tissue. Thick and fatty tissues allow Electromagnetic waves to penetrate into those more than thin tissues. The lens of the eye is transparent. Through the lens Electromagnetic energy may penetrate in to head .The skull is almost spherical. So inside skull multiple reflections of Electromagnetic waves take place. Hence standing waves are generated and a few hot spots may be developed. On withdrawal of the field the influence of occurrence disappears for the other parts of the human body but for eye this effect is irreversible .The absorption of energy is nonlinear through the whole body. This becomes a maximum when the height of the human body is parallel to the electrical field and $2/5^{th}$ of the incident wavelength.

The mode of propagation of any information through nerve fiber is electrical. The absorption of heat by nerve fiber or axon takes place on interaction with Electromagnetic waves. So there may be unwanted and undesired generation of action or rest potential or a trend towards that. A biological membrane is a super molecular system. Membranes are semi-permeable in nature. Most of the cells including nerves contain more potassium ions (K+) than sodium ions (Na+). Out side the cells the pictures is just reverse. The sequences of operation are as under:

- The electric field (E) supplies energy to the membrane.
- The membrane absorbs a part of the energy.
- That absorbed energy causes increase in temperature.
- The increase in temperature causes change in the ratios of Na+ and K+ ions concentration in and out side the cells.
- So the potential difference the two sides of the membrane changes.

FIELD DISTRIBUTION INSIDE HUMAN BODY:

A human body has been sub divided into several small cubes. The sides of the cubs are 1 cm. Then

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Finite Difference Time Domain method has been incorporated taking a human body as a heterogeneous combination of conductors and imperfect dielectric. Skin, fat, muscle, blood, bone have different conductivities and dielectric constants. Any electromagnetic field interacting any bio-object may be distributed inside. Four graphs at different frequencies have been shown in Fig1, Fig2, Fig3, and Fig4.

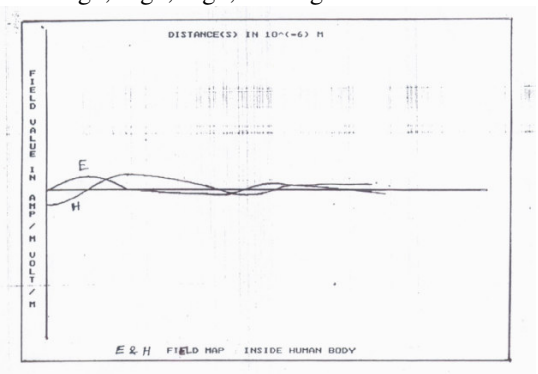

Fig. 1 Frequency 900 MHz, skin, fat, muscle, blood, bone –E=90 V/M, H=0.24 AMP/M

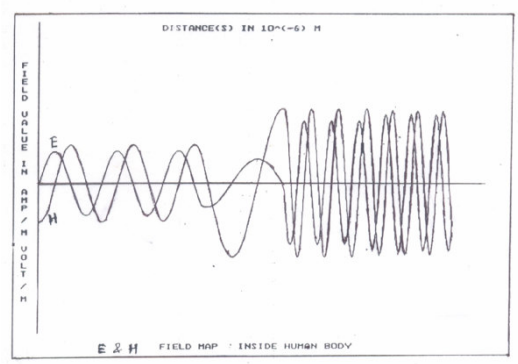

Fig.2 Frequency=6GHz, skin, fat muscle, blood bone. E=232.38 V/M, H= 0.619 AMP/M

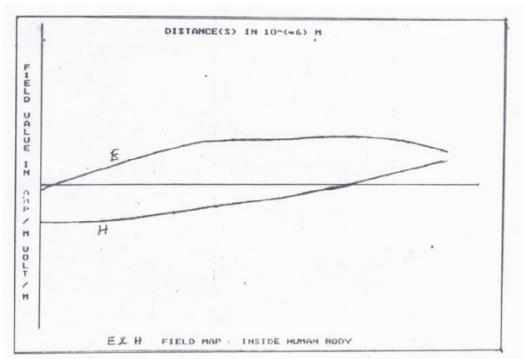

Fig. 3 frequency=64MHz, skin, fat, muscle, blood, bone.

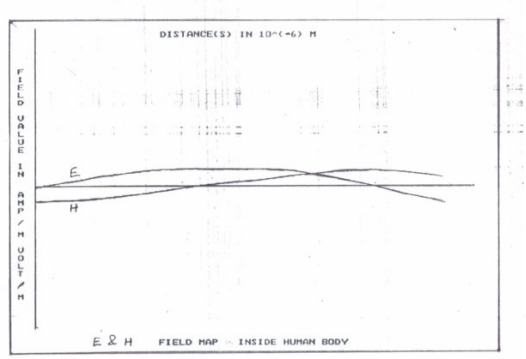

Fig. 4 Frequency=27MHz, skin, fat, muscle, blood, bone.

CALCULATION OF SPECIFIC ABSORPTION RATE:

Equations for specific absorption rate (SAR):

Below 100 Hz [1]	$\varepsilon = \sqrt{[(25*10*10^7/\omega*\varepsilon_0)^2 + 1]} / 100$ $SAR = 1/2 * \varepsilon E^2$
100KHz to 25 MHz [2]	$I = 0.108\ h^2 * E * f / A$ $SAR = (0.108\ h^2 * E * f)^2 * 10^2 / (\sigma * \rho * A^2)$ $SAR_{average} = (0.108\ h^2 * E * f)^2 * h * 10^{-2} / (70*A*\sigma)$
25MHz to 50MHz [3]	$I = 11\ (f / f_r) * E * \sin[(\pi/2) * (f/f_r)]$ $SAR = [11 * (f / f_r) * \sin(\pi/2) * (f/f_r)\ E]^2 * 10^2 / (A^2 * \sigma * \rho)$ $SAR_{average} = [11 * (f / f_r) * \sin(\pi/2) * (f / f_r)\ E]^2 * h * 10^{-2} / (70 * A * \sigma)$
50MHz to 100MHz [3]	$I = 1000 * f^2$ $SAR = \sigma [E_x^2 + E_y^2 + E_z^2] / 2\rho = \sigma * E_{rms}^2 / \rho$
Below 20GHz [4]	$\varepsilon_r = \varepsilon_\infty + (\varepsilon_r - \varepsilon_\infty) / (1 + j\omega\tau) + \sigma / (j\omega\varepsilon_0)$ $P = \omega \varepsilon_0 \varepsilon'' E^2$

Where

I = Current passing through the horizontal section of the human body, ε' =Relative permittivity of the material, ε'' = Out of phase loss= $\sigma/\varepsilon_0\omega$, σ = Conductivity of the material., E = Incident electric field in V/meter , h = Height of human body in meter , f = frequency of the incident wave in MHz, f_r= Resonant frequency in MHz , ε_0= Permittivity of the free space , ε_s= Static permittivity at $\omega \rightarrow 0$, ε_∞= Permittivity at $\omega \rightarrow \infty$, $\tau = 1/\omega_r$, ω_r= Angular frequency , P = power

EFFECT OF SAR ON MEMBRANE POTENTIAL:

$$SAR = C\,(dT / dt) \qquad [5]$$

$dT = T_f - T_i$ =Change in temperature , T_i =Initial temperature of the tissue , T_f =Final temperature of the tissue , C = Specific heat of the human tissue , dt = Time duration

The rise in temperature causes change in action/resting potential which is expressed by using the following formula:

$$\Delta\psi = (R\,T / Z\,F) * \ln (C_1 / C_2)$$

Where

F = Faraday coefficient, Z = Valancy of the ion, C_1 and C_2 = Concentration of ions in and out side of the cell

EFFECT OF SAR ON EYE:

The temperature increases in human eye due to electromagnetic wave interaction may be calculated using the following formulae:

$$C * \rho\,(dT / dt) = K\,\nabla^2\,T + \rho\,(SAR) - B\,T$$

$$H * (T_s - T_e) = -K\,(\partial T / \partial n)$$

Where

T = Temperature increase of the tissue, K = Thermal conductivity of the tissue, C = Heat capacity of the tissue, B = Coefficient associated with the blood flow, H = Convection coefficient, T_s= Temperature of the skin surface, T_e= Temperature of the air

RESULTS:

The authors have considers the standard limiting values of the Electric fields at different frequencies. At every case the SAR, rise in temperature, change in action or resting potential have been calculated. For this software have been developed by the authors. The results are shown in Table-I.

Table- I

Frequency	ε	Time (sec)	SAR (w/Kg)	T_f (°C)	C_1 / C_2	E (V)
50Hz	0.186422	1	0.034684	35.846836	9.253986	0.059000000357628
80Hz	0.116775	1	0.021726	35.717258	9.262632	0.0590000004082918
90Hz	0.103901	1	0.019331	35.693306	9.264233	0.059000000357628
100Hz	0.094547	1	0.017591	35.675903	9.265395	0.058999996632338
10MHz	0.412222	1	0.103413	36.534130	9.20837	0.0589999996632338
10MHz	0.412222	8	0.103413	43.773041	8.752853	0.05000000357628
20MHz	0.414444	1	0.413652	39.636520	9.007729	0.05900000357628
20MHz	0.414444	8	0.413652	68.52163	7.476455	0.059000004082918
25MHz	0.414444	1	0.032048	35.820477	9.255744	0.059000000357628

25MHz	0.414444	8	0.032048	38.063828	9.108392	0.058999996632338
30MHz	0.418889	1	0.066450	36.164497	9.232854	0.059000000357628
30MHz	0.418889	8	0.066450	40.815987	8.933619	0.05899996632338
40MHz	0.418889	1	0.209978	37.599785	9.138504	0.059000004082918
40MHz	0.418889	8	0.20978	52.298279	8.269101	0.05899996632338
50Mhz	0.420000	1	0.512530	40.625298	8.945521	0.059000000357628
50MHz	0.420000	8	0.512530	76.502373	7.143672	0.059000000357628
99MHz	0.420000	1	0.078141	36.281410	9.222100	0.059000000357628
99MHz	0.420000	8	0.078141	41.751274	8.875675	0.058999996632338
100MHz	0.420000	15	0.078141	47.221138	8.550759	0.059000000357628

The eye has different parts. Using the equation mentioned before the temperatures at different positions have been calculated. For this software have been developed by the authors. Table-II shows the rise in temperature at different frequencies at different spots of human eye.

Table - II

Frequency	Distance (μm)	Temperature Increased in Different Parts Of Human body			
		Cornea	Aqueous Humor	Vitreous Humor	Lens
27MHz	1	0.06334922799856	0.015759546	0.053249604195	0.01344280700234
	2	0.03167461399928	0.007879773040	0.02662480209	0.00672140350117
	3	0.02111640933	0.00525318202715	0.01774986806	0.004480935667
	4	0.015837306	0.00393988652036	0.013312401048	0.00360701
50MHz	1	0.128594716169	0.02319335142696	0.078367535274	0.01978380248
	2	0.06429735	0.0155596675	0.03918376763	0.0098910124
	3	0.042864905389	0.00773111714	0.02612251175805	0.006594
	4	0.032148679	0.05798337856	0.0195918838	0.0049459

CONCLUSION:

The results obtained have shown only theoretical values. So there must be some practical tests to verify the results. But the results will help to predict the entire situation that is the ill effects, if any, of electromagnetic fields on human body.

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