

Original Research Paper

Change in Temperature of Skin, Blood, Muscle and Bone Tissues Due to Mobile Phone Radiations at Frequencies 800, 900, 1800 and 2450 MHz

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Abstract: The mathematical calculation of change in temperature of skin, blood, muscle and bone tissues of human being working at the frequency of 800, 900, 1800 and 2450 MHz is done in this manuscript. The power of the antenna of mobile phone is of 2 W. The calculation is made at the various depths, by taking the different distances of human body from the mobile phone. The depth of penetration is ranging from 0.1 to 0.5 mm inside the body tissues. The thermoregulation system of the body can maintain the body temperature but at some extent. Variation of change in temperature due to the exposure of 15, 30, 45 and 60 min in selected tissues is also analysed.

Keywords: Temperature Change, Induced Electric Field, Thermoregulatory Mechanism, Mobile Phone Handset and Electromagnetic Waves

Introduction

Electromagnetic fields are all around due to mobile phone and mobile phone tower radiations keep our heart beating, brain thinking and muscles moving they are even within our bodies. During speaking, human being absorb some electromagnetic energy when it is exposed to it. This interaction of electromagnetic energy with the body can cause both thermal and non-thermal effects (Kumar *et al.*, 2008).

Depending on the frequency of electromagnetic radiation, the human body interacts with such a field via induced currents and thermal effects. The field generated within the body, so called thermal field is determined by the amount by which a body is influenced by electromagnetic fields (Gandhi and Mohammad, 2008).

The absorbed mobile phone radiations produced molecular vibration and convert the energy into heat. When the rate of energy absorption is high it produces heating effects in the living tissues (Ozen *et al.*, 2009). The biological effects of radiofrequency energy depend on the rate at which power is absorbed (Osepchuk and Petersen, 2003). If the organism cannot dissipate this heat energy as fast as then the internal temperature of the body will rise. Thus the thermal interaction may cause tissue heating by deposition of power from ionic conductivity of the tissue as well as losses associated with motion of the molecules caused by time vibration of electromagnetic field (Furse *et al.*, 2009). Exposure to

very high radiofrequency power densities can result increase in temperature heat human body tissues. During the expose of high radio frequency levels tissue damage will occur. Under certain conditions exposure to At power density levels of 1 to 10 mW/cm² the radio frequency energy can result in heating of body, testis and eyes are to particularly known to heating by radio frequency energy because available of blood flow to dissipate the excessive heat energy. Such change in sperm mobility effects causes the temporary sterility after the exposure testis to high radio frequency radiation level. Most of the experimental investigations rabbits and mice have been employed for biological effects of radio frequency exposure (James, 2003; Karunathna and Dayawansa, 2006).

One well-understood the effect of mobile phone wave is dielectric heating in which the living tissues of human being are heated by the rotations of polar molecules. Mobile phone radiation penetrates in tissues to a distance proportional to their power density. That is why it is dangerous to live close to high power mobile phone tower for a long time.

Method and Calculation

When human body is exposed to the *EM* wave of electric field E_{rms} , it penetrates into the body. It results into inside or induced field E_i at a given depth Z given by Equation 1:

$$E_i = E_{rms} e^{(-z/\delta)} \quad (1)$$

where, δ is skin depth.

As we want to access the effect of mobile phone tower whose power is the only parameter we know, we have to relate the electric field (more generally E_{rms}) to the power of transmission Equation 2:

$$\begin{aligned} E_{rms} &= 10.946 / r \text{ (for handset) and} \\ E_{rms} &= 34.641 / r \text{ (for tower)} \end{aligned} \quad (2)$$

where, r is the radius of spherical wave front around mobile phone handset and their tower.

The Specific Absorption Rate (SAR) can be defined as Equation 3:

$$SAR = \frac{\sigma E_i^2}{\rho} \quad (3)$$

where, E_i is the field inside that material, σ is the conductivity of the biological material, ρ is the density of bio material Equation 4:

$$C \times \Delta T = SAR(\Delta t) \quad (4)$$

where, Δt is time in seconds, C is specific heat of bio-material.

The dielectric properties of the body tissues are taken from Gabriel *et al.* (1996a; 1996b; 1996c) for the calculation of change in temperature of different tissues. The change in temperature 15, 30, 45 and 60 min for mobile phone in consequence of specific absorption rate is given in the following tables respectively. The depth inside the tissues is taken 0.1, 0.2, 0.3, 0.4 and 0.5 mm for the calculation of change in temperature at different distances from the mobile phone working at the

frequencies of 800, 900, 1800 and 2450 MHz. The power of mobile phone is taken as 2 W.

Standard Values

- $z = 0.1, 0.2, 0.3, 0.4$ and 0.5 mm
- At 800 MHz, $\sigma = 0.80864 \text{ W K}^{-1} \text{ m}^{-1}$, skin depth $\delta = 45.59$ mm
- At 900 MHz, $\sigma = 0.84465 \text{ W K}^{-1} \text{ m}^{-1}$, of skin depth $\delta = 43.352$ mm
- At 1800 MHz, $\sigma = 1.232 \text{ W K}^{-1} \text{ m}^{-1}$, skin depth $\delta = 28.808$ mm
- At 2450 MHz, $\sigma = 1.5919 \text{ W K}^{-1} \text{ m}^{-1}$, skin depth $\delta = 28.808$ mm

The value of density ρ for skin = 1070 kg m^{-3} , for blood = 1060 kg m^{-3} , for muscles = 1050 kg m^{-3} , for bone = 1520 kg m^{-3}

Specific heat C for skin = $3662 \text{ J K}^{-1} \text{ kg}^{-1}$, blood = $4186 \text{ J K}^{-1} \text{ kg}^{-1}$, muscles = $3639 \text{ J K}^{-1} \text{ kg}^{-1}$ and bone = $1590 \text{ J K}^{-1} \text{ kg}^{-1}$.

Results and Discussion

In most of the countries in the world 800, 900, 1800 and 2450 MHz frequency of electromagnetic waves are used for communication. In this chapter, we discuss about four frequencies of mobile phone waves. Calculation of change in temperature for skin, blood, muscles and bones at different depth and different distances are made. The penetrated electromagnetic wave absorbed inside the human body tissues and deposited in the form of extra energy. This energy increases the temperature of tissues which are previously at thermostatic state.

When a mobile phone handset move from 15 to 1 cm distance towards person, then the temperature of tissue increases. The results are represented by Table 17 and Fig. 1.

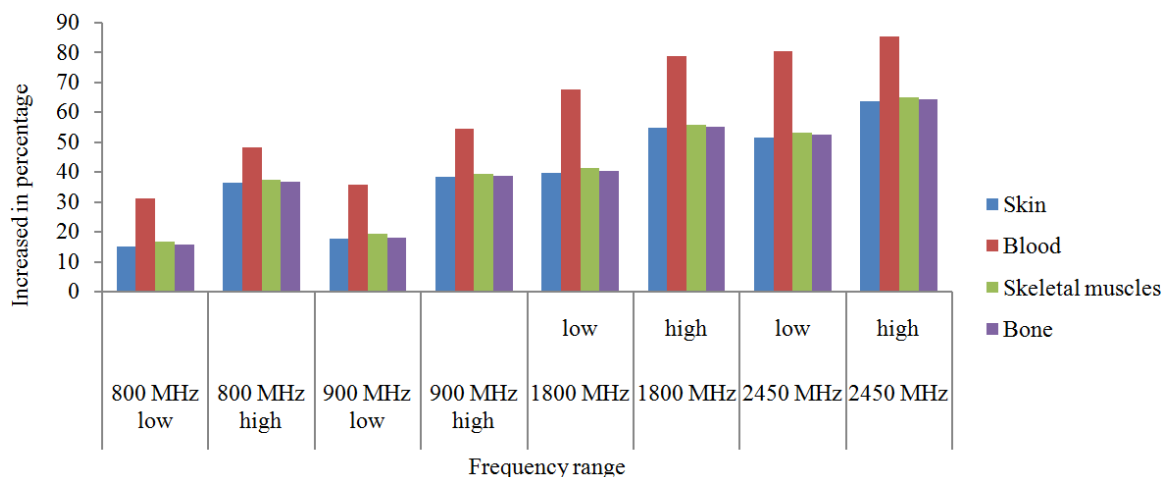


Fig. 1. Represents the increased percentage of skin, blood, muscles and bone tissues

Conclusion

Four frequencies of mobile phone waves namely 800, 900, 1800 and 2450 MHz for the calculation of change in temperature for skin, blood, muscles and bones at different depth and different distances are made.

When we move towards from 15 cm to 1 cm distance from mobile phone temperature of tissues increases. It is observed from the Table 1 to 16 at 800 MHz, temperature of skin increases from 15.16 to 36.36%, temperature of blood increases from 31.10 to 48.32%, for muscles from 16.68 to 37.51%, for bone 15.63 to 36.72%.

At frequency 900 MHz, temperature of skin increases from 17.71 to 38.29%, temperature of blood increases from 35.66 to 54.40%, for muscles from 19.26 to 39.47%, for bone 18.21% to 38.68%.

At frequency 1800 MHz, temperature of skin increases from 39.61 to 54.72%, temperature of blood increases from 67.74 to 78.81%, for muscles from 41.25 to 55.95%, for bone 40.33 to 55.25%.

At frequency 2450 MHz, temperature of skin increases from 51.66 to 63.78%, temperature of blood increases from 80.34 to 85.27%, for muscles from 53.36 to 65.07%, for bone 52.54 to 64.45%.

Table 1. Change in temperature (degree C/15 min) at different depth and 1 cm apart from the mobile phone at 800, 900, 1800 and 2450 MHz

Change in temperature in 15 min, 1 cm distance from mobile phone at different depth						
Frequency	Tissue name	0.1 mm	0.2 mm	0.3 mm	0.4 mm	0.5 mm
800 MHz	Skin	1.868408	1.793178	1.720932	1.651645	1.58513
	Blood	3.311267	3.028225	2.748348	2.503819	2.281137
	Muscles	2.132611	2.037499	1.946575	1.859736	1.776734
	Bone	0.213770	0.204871	0.196346	0.188181	0.180350
900 MHz	Skin	1.936788	1.844612	1.756893	1.673333	1.593715
	Blood	3.347286	2.997729	2.684838	2.404501	2.153485
	Muscles	2.192846	2.078569	1.970315	1.867689	1.770394
	Bone	0.230970	0.219644	0.208883	0.198648	0.188906
1800 MHz	Skin	2.614534	2.304714	2.031655	1.790894	1.578688
	Blood	3.742566	2.820563	2.125670	1.602042	1.207349
	Muscles	2.880228	2.521550	2.207692	1.932750	1.692128
	Bone	0.409922	0.360271	0.316641	0.278283	0.244580
2450 MHz	Skin	3.191233	2.663020	2.219818	1.850446	1.542481
	Blood	4.112398	2.740496	1.824355	1.214457	0.808453
	Muscles	3.520391	2.911515	2.405322	1.987183	1.641702
	Bone	0.554028	0.460126	0.381820	0.316836	0.262910

Table 2. Change in temperature (degree C/30 min) at different depth and 1 cm apart from the mobile phone at 800, 900, 1800 and 2450 MHz

Change in temperature in 30 min, 1 cm distance from mobile phone at different depth						
Frequency	Tissue name	0.1 mm	0.2 mm	0.3 mm	0.4 mm	0.5 mm
800 MHz	Skin	3.736815	3.586356	3.441864	3.303290	3.170260
	Blood	6.622534	6.056450	5.496695	5.007638	4.562273
	Muscles	4.265221	4.074998	3.893150	3.719472	3.553467
	Bone	0.427539	0.409742	0.392691	0.376361	0.360701
900 MHz	Skin	3.873576	3.689224	3.513787	3.346665	3.187431
	Blood	6.694572	5.995458	5.369676	4.809001	4.306971
	Muscles	4.385692	4.157138	3.940629	3.735377	3.540789
	Bone	0.461940	0.439288	0.417765	0.397297	0.377812
1800 MHz	Skin	5.229069	4.609428	4.063310	3.581788	3.157375
	Blood	7.485132	5.641125	4.251339	3.204083	2.414699
	Muscles	5.760456	5.043100	4.415384	3.865500	3.384255
	Bone	0.819844	0.720543	0.633283	0.556566	0.489160
2450 MHz	Skin	6.382466	5.326039	4.439636	3.700893	3.084961
	Blood	8.224796	5.480991	3.648711	2.428913	1.616907
	Muscles	7.040782	5.823030	4.810644	3.974366	3.283404
	Bone	1.108056	0.920252	0.763639	0.633672	0.525820

Table 3. Change in temperature (degree C/45 min) at different depth and 1 cm apart from the mobile phone at 800, 900, 1800 and 2450 MHz

Change in temperature in 45 min, 1 cm distance from mobile phone at different depth						
Frequency	Tissue name	0.1 mm	0.2 mm	0.3 mm	0.4 mm	0.5 mm
800 MHz	Skin	5.605223	5.379534	5.162795	4.954935	4.755390
	Blood	9.933801	9.084674	8.245043	7.511457	6.843410
	Muscles	6.397832	6.112497	5.839725	5.579208	5.330201
	Bone	0.641309	0.614614	0.589037	0.564542	0.541051
900 MHz	Skin	5.810364	5.533836	5.270680	5.019998	4.781146
	Blood	10.04186	8.993187	8.054514	7.213502	6.460456
	Muscles	6.578538	6.235707	5.910944	5.603066	5.311183
	Bone	0.692909	0.658932	0.626648	0.595945	0.566718
1800 MHz	Skin	7.843603	6.914141	6.094964	5.372683	4.736063
	Blood	11.22770	8.461688	6.377009	4.806125	3.622048
	Muscles	8.640684	7.564651	6.623075	5.798249	5.076383
	Bone	1.229766	1.080814	0.949924	0.834848	0.733740
2450 MHz	Skin	9.573699	7.989059	6.659454	5.551339	4.627442
	Blood	12.33719	8.221487	5.473066	3.643370	2.425360
	Muscles	10.56117	8.734545	7.215966	5.961548	4.925106
	Bone	1.662083	1.380379	1.145459	0.950508	0.788730

Table 4. Change in temperature (degree C/60 min) at different depth and 1 cm apart from the mobile phone at 800, 900, 1800 and 2450 MHz

Change in temperature in 60 min, 1 cm distance from mobile phone at different depth						
Frequency	Tissue name	0.1 mm	0.2 mm	0.3 mm	0.4 mm	0.5 mm
800 MHz	Skin	7.473631	7.172712	6.883727	6.606581	6.340519
	Blood	13.24507	12.1129	10.99339	10.01528	9.124547
	Muscles	8.530443	8.149996	7.786299	7.438943	7.106934
	Bone	0.855078	0.819485	0.785382	0.752723	0.721402
900 MHz	Skin	7.747152	7.378449	7.027573	6.693331	6.374861
	Blood	13.38914	11.99092	10.73935	9.618003	8.613942
	Muscles	8.771384	8.314277	7.881258	7.470754	7.081578
	Bone	0.923879	0.878575	0.835531	0.794594	0.755624
1800 MHz	Skin	10.45814	9.218855	8.126619	7.163577	6.314750
	Blood	14.97026	11.28225	8.502679	6.408167	4.829397
	Muscles	11.52091	10.08620	8.830767	7.730999	6.768511
	Bone	1.639688	1.441085	1.266565	1.113131	0.978319
2450 MHz	Skin	12.76493	10.65208	8.879272	7.401786	6.169923
	Blood	16.44959	10.96198	7.297421	4.857827	3.233813
	Muscles	14.08156	11.64606	9.621288	7.948731	6.566809
	Bone	2.216111	1.840505	1.527278	1.267344	1.051640

Table 5. Change in temperature (degree C/15 min) at different depth and 5 cm apart from the mobile phone at 800, 900, 1800 and 2450 MHz

Change in temperature in 15 min, 5 cm distance from mobile phone at different depth						
Frequency	Tissue name	0.1 mm	0.2 mm	0.3 mm	0.4 mm	0.5 mm
800 MHz	Skin	0.074732	0.071724	0.068832	0.066064	0.063405
	Blood	0.132433	0.120664	0.109915	0.100142	0.091243
	Muscles	0.085300	0.081491	0.077854	0.074382	0.071069
	Bone	0.008550	0.008194	0.007853	0.007527	0.007214
900 MHz	Skin	0.077472	0.073782	0.070272	0.066484	0.063745
	Blood	0.140567	0.119894	0.107384	0.095530	0.086133
	Muscles	0.087714	0.083133	0.078808	0.074204	0.070807
	Bone	0.009238	0.008785	0.008354	0.007893	0.007555
1800 MHz	Skin	0.104573	0.092183	0.081263	0.071636	0.063144
	Blood	0.149677	0.112803	0.085020	0.064082	0.048292
	Muscles	0.115193	0.100856	0.088296	0.077306	0.067675
	Bone	0.016395	0.014409	0.012665	0.011131	0.009782
2450 MHz	Skin	0.127782	0.106514	0.088793	0.074010	0.061696
	Blood	0.164665	0.109605	0.072972	0.048566	0.032336
	Muscles	0.140954	0.116450	0.096206	0.079481	0.065660
	Bone	0.022183	0.018404	0.015271	0.012672	0.010516

Table 6. Change in temperature (degree C/30 min) at different depth and 5 cm apart from the mobile phone at 800, 900, 1800 and 2450 MHz

Change in temperature in 30 min, 5 cm distance from mobile phone at different depth						
Frequency	Tissue name	0.1 mm	0.2 mm	0.3 mm	0.4 mm	0.5 mm
800 MHz	Skin	0.149464	0.143449	0.137664	0.132129	0.126810
	Blood	0.264866	0.241328	0.219831	0.200283	0.182487
	Muscles	0.170601	0.162981	0.155708	0.148764	0.142139
	Bone	0.017100	0.016388	0.015706	0.015054	0.014427
900 MHz	Skin	0.154943	0.147563	0.140543	0.132968	0.127489
	Blood	0.281134	0.239789	0.214769	0.191061	0.172266
	Muscles	0.175428	0.166266	0.157616	0.148408	0.141614
	Bone	0.018477	0.017571	0.016709	0.015785	0.015111
1800 MHz	Skin	0.209147	0.184366	0.162525	0.143272	0.126289
	Blood	0.299355	0.225607	0.170039	0.128163	0.096584
	Muscles	0.230387	0.201711	0.176592	0.154613	0.135350
	Bone	0.032791	0.028819	0.025330	0.022261	0.019565
2450 MHz	Skin	0.255564	0.213028	0.177585	0.148020	0.123391
	Blood	0.329331	0.219210	0.145943	0.097132	0.064673
	Muscles	0.281909	0.232901	0.192412	0.158962	0.131321
	Bone	0.044366	0.036808	0.030543	0.025344	0.021032

Table 7. Change in temperature (degree C/45 min) at different depth and 5 cm apart from the mobile phone at 800, 900, 1800 and 2450 MHz

Change in temperature in 45 min, 5 cm distance from mobile phone at different depth						
Frequency	Tissue name	0.1 mm	0.2 mm	0.3 mm	0.4 mm	0.5 mm
800 MHz	Skin	0.224196	0.215173	0.206496	0.198193	0.190216
	Blood	0.397299	0.361992	0.329746	0.300425	0.273730
	Muscles	0.255901	0.244472	0.233562	0.223146	0.213208
	Bone	0.025650	0.024582	0.023560	0.022581	0.021641
900 MHz	Skin	0.232415	0.221345	0.210815	0.199451	0.191234
	Blood	0.421701	0.359683	0.322153	0.286591	0.258400
	Muscles	0.263141	0.249399	0.236424	0.222612	0.212421
	Bone	0.027715	0.026356	0.025063	0.023678	0.022666
1800 MHz	Skin	0.313720	0.276548	0.243788	0.214907	0.189433
	Blood	0.449032	0.338410	0.255059	0.192245	0.144877
	Muscles	0.345580	0.302567	0.264887	0.231919	0.203024
	Bone	0.049186	0.043228	0.037995	0.033392	0.029347
2450 MHz	Skin	0.383347	0.319541	0.266378	0.222030	0.185087
	Blood	0.493996	0.328814	0.218915	0.145699	0.097009
	Muscles	0.422863	0.349351	0.288618	0.238443	0.196981
	Bone	0.066549	0.055211	0.045814	0.038015	0.031547

Table 8. Change in temperature (degree C/60 min) at different depth and 5 cm apart from the mobile phone at 800, 900, 1800 and 2450 MHz

Change in temperature in 60 min, 5 cm distance from mobile phone at different depth						
Frequency	Tissue name	0.1 mm	0.2 mm	0.3 mm	0.4 mm	0.5 mm
800 MHz	Skin	0.298928	0.286898	0.275328	0.264258	0.253621
	Blood	0.529732	0.482656	0.439662	0.400567	0.364974
	Muscles	0.341202	0.325962	0.311415	0.297528	0.284277
	Bone	0.034201	0.032776	0.031413	0.030108	0.028855
900 MHz	Skin	0.309886	0.295127	0.281086	0.265935	0.254979
	Blood	0.562268	0.479578	0.429537	0.382122	0.344533
	Muscles	0.350855	0.332533	0.315232	0.296816	0.283228
	Bone	0.036953	0.035141	0.033417	0.031570	0.030222
1800 MHz	Skin	0.418293	0.368731	0.325050	0.286543	0.252577
	Blood	0.598710	0.451213	0.340079	0.256327	0.193169
	Muscles	0.460774	0.403423	0.353183	0.309225	0.270699
	Bone	0.065581	0.057637	0.050660	0.044522	0.039130
2450 MHz	Skin	0.511129	0.426055	0.355171	0.296040	0.246783
	Blood	0.658662	0.438419	0.291887	0.194265	0.129346
	Muscles	0.563818	0.465801	0.384823	0.317924	0.262641
	Bone	0.088732	0.073615	0.061085	0.050687	0.042063

Table 9. Change in temperature (degree C/15 min) at different depth and 10 cm apart from the mobile phone at 800, 900, 1800 and 2450 MHz

Change in temperature in 15 min, 10 cm distance from mobile phone at different depth						
Frequency	Tissue name	0.1 mm	0.2 mm	0.3 mm	0.4 mm	0.5 mm
800 MHz	Skin	0.018683	0.017931	0.017208	0.016516	0.015851
	Blood	0.033108	0.030171	0.027480	0.025033	0.022810
	Muscles	0.021323	0.020373	0.019463	0.018594	0.017766
	Bone	0.002137	0.002049	0.001963	0.001882	0.001803
900 MHz	Skin	0.019366	0.018445	0.017568	0.016732	0.015936
	Blood	0.035142	0.029971	0.026846	0.024041	0.021531
	Muscles	0.021924	0.020783	0.019700	0.018672	0.017702
	Bone	0.002309	0.002196	0.002088	0.001986	0.001889
1800 MHz	Skin	0.026141	0.023043	0.020316	0.017907	0.015784
	Blood	0.037415	0.028197	0.021255	0.016015	0.012069
	Muscles	0.028793	0.025211	0.022074	0.019324	0.016917
	Bone	0.004098	0.003602	0.003166	0.002782	0.002445
2450 MHz	Skin	0.031942	0.026628	0.022196	0.018500	0.015424
	Blood	0.041162	0.027401	0.018237	0.012142	0.008082
	Muscles	0.034952	0.029109	0.024046	0.019868	0.016415
	Bone	0.005545	0.004611	0.003817	0.003168	0.002629

Table 10. Change in temperature (degree C/30 min) at different depth and 10 cm apart from the mobile phone at 800, 900, 1800 and 2450 MHz

Change in temperature in 30 min, 10 cm distance from mobile phone at different depth						
Frequency	Tissue name	0.1 mm	0.2 mm	0.3 mm	0.4 mm	0.5 mm
800 MHz	Skin	0.037366	0.035862	0.034416	0.033032	0.031703
	Blood	0.066216	0.060343	0.054960	0.050065	0.045621
	Muscles	0.042645	0.040745	0.038927	0.037187	0.035531
	Bone	0.004275	0.004097	0.003926	0.003764	0.003606
900 MHz	Skin	0.038732	0.036891	0.035136	0.033464	0.031872
	Blood	0.070284	0.059941	0.053692	0.048082	0.043061
	Muscles	0.043849	0.041567	0.039400	0.037345	0.035403
	Bone	0.004618	0.004393	0.004177	0.003972	0.003778
1800 MHz	Skin	0.052282	0.046087	0.040631	0.035814	0.031568
	Blood	0.074831	0.056395	0.042510	0.032031	0.024137
	Muscles	0.057585	0.050423	0.044148	0.038649	0.033833
	Bone	0.008196	0.007204	0.006332	0.005565	0.004890
2450 MHz	Skin	0.063885	0.053257	0.044391	0.037000	0.030848
	Blood	0.082324	0.054802	0.036474	0.024283	0.016164
	Muscles	0.069905	0.058219	0.048091	0.039735	0.032830
	Bone	0.011090	0.009221	0.007635	0.006335	0.005257

Table 11. Change in temperature (degree C/45 min) at different depth and 10 cm apart from the mobile phone at 800, 900, 1800 and 2450 MHz

Change in temperature in 45 min, 10 cm distance from mobile phone at different depth						
Frequency	Tissue name	0.1 mm	0.2 mm	0.3 mm	0.4 mm	0.5 mm
800 MHz	Skin	0.056049	0.053793	0.051624	0.049548	0.047554
	Blood	0.099325	0.090514	0.082440	0.075098	0.068431
	Muscles	0.063968	0.061118	0.058390	0.055781	0.053297
	Bone	0.006412	0.006146	0.005889	0.005645	0.005410
900 MHz	Skin	0.058098	0.055336	0.052704	0.050196	0.047808
	Blood	0.105425	0.089912	0.080538	0.072124	0.064592
	Muscles	0.065773	0.062350	0.059100	0.056017	0.053105
	Bone	0.006927	0.006589	0.006265	0.005958	0.005667
1800 MHz	Skin	0.078422	0.069130	0.060947	0.053721	0.047352
	Blood	0.112246	0.084592	0.063765	0.048046	0.036206
	Muscles	0.086378	0.075634	0.066222	0.057973	0.050750
	Bone	0.012294	0.010806	0.009498	0.008347	0.007335
2450 MHz	Skin	0.095827	0.079885	0.066587	0.055500	0.046272
	Blood	0.123485	0.082204	0.054710	0.036425	0.024246
	Muscles	0.104857	0.087328	0.072137	0.059603	0.049245
	Bone	0.016636	0.013832	0.011452	0.009503	0.007886

Table 12. Change in temperature (degree C/60 min) at different depth and 10 cm apart from the mobile phone at 800, 900, 1800 and 2450 MHz

Change in temperature in 60 min, 10 cm distance from mobile phone at different depth						
Frequency	Tissue name	0.1 mm	0.2 mm	0.3 mm	0.4 mm	0.5 mm
800 MHz	Skin	0.074732	0.071724	0.068832	0.066064	0.063405
	Blood	0.132433	0.120686	0.109920	0.100131	0.091241
	Muscles	0.085290	0.081491	0.077854	0.074375	0.071062
	Bone	0.008549	0.008194	0.007852	0.007527	0.007213
900 MHz	Skin	0.077464	0.073782	0.070272	0.066928	0.063745
	Blood	0.140567	0.119882	0.107384	0.096165	0.086123
	Muscles	0.087697	0.083133	0.078800	0.074689	0.070807
	Bone	0.009237	0.008785	0.008353	0.007944	0.007555
1800 MHz	Skin	0.104563	0.092173	0.081263	0.071627	0.063136
	Blood	0.149662	0.112790	0.085020	0.064061	0.048274
	Muscles	0.115171	0.100845	0.088296	0.077297	0.067666
	Bone	0.016392	0.014408	0.012664	0.011129	0.009780
2450 MHz	Skin	0.127769	0.106514	0.088782	0.074000	0.061696
	Blood	0.164647	0.109605	0.072947	0.048566	0.032328
	Muscles	0.139809	0.116437	0.096182	0.079470	0.065660
	Bone	0.022181	0.018442	0.015269	0.012670	0.010514

Table 13. Change in temperature (degree C/15 min) at different depth and 15 cm apart from the mobile phone at 800, 900, 1800 and 2450 MHz

Change in temperature in 15 min, 15 cm distance from mobile phone at different depth						
Frequency	Tissue name	0.1 mm	0.2 mm	0.3 mm	0.4 mm	0.5 mm
800 MHz	Skin	0.008302	0.007969	0.007647	0.007340	0.007044
	Blood	0.014712	0.014518	0.012209	0.011126	0.010137
	Muscles	0.009474	0.009054	0.008648	0.008264	0.007893
	Bone	0.000950	0.000910	0.000872	0.000836	0.000801
900 MHz	Skin	0.008606	0.008196	0.007806	0.007436	0.007081
	Blood	0.015614	0.013318	0.011929	0.010683	0.009567
	Muscles	0.009744	0.009233	0.008753	0.008299	0.007864
	Bone	0.001026	0.000976	0.000928	0.000882	0.000839
1800 MHz	Skin	0.011619	0.010241	0.009028	0.007959	0.007014
	Blood	0.016629	0.012534	0.009443	0.007118	0.005363
	Muscles	0.012798	0.011205	0.009810	0.008587	0.007517
	Bone	0.001821	0.001601	0.001407	0.001237	0.001087
2450 MHz	Skin	0.010987	0.009157	0.007634	0.006363	0.005305
	Blood	0.018292	0.012177	0.008103	0.005395	0.003592
	Muscles	0.015660	0.012933	0.008830	0.008830	0.007293
	Bone	0.008302	0.007969	0.007647	0.007340	0.007044

Table 14. Change in temperature (degree C/30 min) at different depth and 15 cm apart from the mobile phone at 800, 900, 1800 and 2450 MHz

Change in temperature in 30 min, 15 cm distance from mobile phone at different depth						
Frequency	Tissue name	0.1 mm	0.2 mm	0.3 mm	0.4 mm	0.5 mm
800 MHz	Skin	0.016604	0.015937	0.015293	0.014680	0.014087
	Blood	0.029424	0.029036	0.024418	0.022251	0.020274
	Muscles	0.018948	0.018107	0.017296	0.016528	0.015787
	Bone	0.001900	0.001821	0.001744	0.001672	0.001603
900 MHz	Skin	0.017213	0.016391	0.015613	0.014871	0.014161
	Blood	0.031228	0.026635	0.023858	0.021365	0.019134
	Muscles	0.019488	0.018465	0.017506	0.016598	0.015728
	Bone	0.002052	0.001952	0.001856	0.001765	0.001678
1800 MHz	Skin	0.023239	0.020483	0.018056	0.015917	0.014029
	Blood	0.033258	0.025067	0.018885	0.014236	0.010726
	Muscles	0.025596	0.022410	0.019619	0.017173	0.015033
	Bone	0.003643	0.003201	0.002814	0.002473	0.002173
2450 MHz	Skin	0.021974	0.018314	0.015267	0.012727	0.010609
	Blood	0.036584	0.024353	0.016205	0.010790	0.007184
	Muscles	0.031320	0.025866	0.017660	0.017660	0.014587
	Bone	0.004929	0.004088	0.003393	0.002816	0.002336

Table 15. Change in temperature (degree C/45 min) at different depth and 15 cm apart from the mobile phone at 800, 900, 1800 and 2450 MHz

Change in temperature in 45 min, 15 cm distance from mobile phone at different depth						
Frequency	Tissue name	0.1 mm	0.2 mm	0.3 mm	0.4 mm	0.5 mm
800 MHz	Skin	0.024906	0.023906	0.022940	0.022019	0.021131
	Blood	0.044136	0.043553	0.036627	0.033377	0.030411
	Muscles	0.028422	0.027161	0.025944	0.024792	0.023680
	Bone	0.002850	0.002731	0.002617	0.002509	0.002404
900 MHz	Skin	0.025819	0.024587	0.023419	0.022307	0.021242
	Blood	0.046842	0.039953	0.035787	0.032048	0.028701
	Muscles	0.029232	0.027698	0.026259	0.024896	0.023592
	Bone	0.003079	0.002927	0.002784	0.002647	0.002517
1800 MHz	Skin	0.034858	0.030724	0.027085	0.023876	0.021043
	Blood	0.049887	0.037601	0.028328	0.021354	0.016088
	Muscles	0.038394	0.033615	0.029429	0.025760	0.022550
	Bone	0.005464	0.004802	0.004221	0.003710	0.003260
2450 MHz	Skin	0.032961	0.027472	0.022901	0.019090	0.015914
	Blood	0.054876	0.036530	0.024308	0.016185	0.010776
	Muscles	0.046980	0.038800	0.026490	0.026490	0.021880
	Bone	0.024906	0.023906	0.022940	0.022019	0.021131

Table 16. Change in temperature (degree C/60 min) at different depth and 15 cm apart from the mobile phone at 800, 900, 1800 and 2450 MHz

Change in temperature in 60 min, 15 cm distance from mobile phone at different depth						
Frequency	Tissue name	0.1 mm	0.2 mm	0.3 mm	0.4 mm	0.5 mm
800 MHz	Skin	0.033208	0.031874	0.030586	0.022019	0.021131
	Blood	0.058848	0.058071	0.048836	0.033377	0.030411
	Muscles	0.037896	0.036215	0.034592	0.024792	0.023680
	Bone	0.003799	0.003641	0.003489	0.002509	0.002404
900 MHz	Skin	0.034425	0.032782	0.031226	0.022307	0.021242
	Blood	0.062457	0.053270	0.047716	0.032048	0.028701
	Muscles	0.038977	0.036930	0.035012	0.024896	0.023592
	Bone	0.004105	0.003903	0.003712	0.002647	0.002517
1800 MHz	Skin	0.046477	0.040966	0.036113	0.023876	0.021043
	Blood	0.066516	0.050135	0.037771	0.021354	0.016088
	Muscles	0.051192	0.044820	0.039238	0.025760	0.022550
	Bone	0.007285	0.006402	0.005628	0.003710	0.003260
2450 MHz	Skin	0.043948	0.036629	0.030534	0.019090	0.015914
	Blood	0.073168	0.048707	0.032410	0.016185	0.010776
	Muscles	0.062640	0.051733	0.035320	0.026490	0.021880
	Bone	0.009857	0.008177	0.006786	0.004223	0.003504

Table 17. Represents the increased percentage of skin blood, muscles and bone tissue at frequencies of 800, 900, 1800 and 2450 MHz

Name of the tissues	Increased % at frequency 800 MHz (handset)	Increased % at frequency 900 MHz (handset)	Increased % at frequency 1800 MHz (handset)	Increased % at frequency 2450 MHz (handset)
Skin	15.16 to 36.36	17.71 to 38.29	39.61 to 54.72	51.66 to 63.78
Blood	31.10 to 48.32	35.66 to 54.40	67.74 to 78.81	80.34 to 85.27
Skeletal muscles	16.68 to 37.51	19.26 to 39.47	41.25 to 55.95	53.36 to 65.07
Bone	15.63 to 36.72	18.21 to 38.68	40.33 to 55.25	52.54 to 64.45

It concludes from above highest change in temperature in blood is from 80.34 to 85.27% at frequency 2450 MHz and change in temperature of bone is low as compared to other tissues when we move from 15 to 1 cm distance of mobile phone.

It is found that with the mobile phone radiations of above frequencies, the temperature of skin, blood,

muscle and bone tissues slightly increases as the talking time is increased, but there is the highest raise in temperature in blood tissue and the lowest change in temperature in case of bone tissue. The rise in temperature of human body tissues is considerably large and the human body is not able to regulate it through the normal process of thermoregulation. Therefore human

body may face thermal stress resulting into some diseases. When this temperature increases greater to 39°C, it can produce many diseases in tissues and may become harmful for the life of tissues. Increase in temperature of these tissues cause thermal effect, which is harmful for human being.

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Author's Contributions

All authors equally contributed in this work.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues involved.

References

- Furse, C., D.A. Christensen and C.H. Durney, 2009. Basic Introduction to Bioelectromagnetics. 2nd Edn., CRC Press, ISBN-10: 1420055429, pp: 288.
- Gabriel, C., S. Gabriel and E. Corthout, 1996a. The dielectric properties of biological tissues: I. Literature survey. *Phys. Med. Biol.*, 41: 2231-2269. DOI: 10.1088/0031-9155/41/11/001
- Gabriel, S., R.W. Lau and C. Gabriel, 1996b. The dielectric properties of biological tissues: III. Parametric models for the dielectric spectrum of tissues. *Phys. Med. Biol.*, 41: 2271-2293. DOI: 10.1088/0031-9155/41/11/003
- Gabriel, S., R.W. Lau and C. Gabriel, 1996c. The dielectric properties of biological tissues: II. Measurements in the frequency range 10 Hz to 20 GHz. *Phys. Med. Biol.*, 41: 2251-2269. DOI: 10.1088/0031-9155/41/11/002
- Gandhi, F.M. and M.A.S. Mohammad, 2008. Dynamic source routing in adhoc wireless networks. *J. Mobile Commun.*, 2: 39-45.
- James, C.L., 2003. *IEEE Antenas Propagat. Magaz.*, 45: 22-29.
- Karunarithna, M.A. and I.J. Dayawansa, 2006. Energy absorption by the human body from RF and microwave emissions in Sri Lanka. *Sri Lankan J. Phys.*, 7: 35-47. DOI: 10.4038/sljp.v7i0.207
- Kumar, V., R.P. Vats and P.P. Pathak, 2008. Harmful effects of 41 and 202 MHz radiations on some body parts and tissues. *Ind. J. Biochem. Biophys.*, 45: 269- 274. PMID: 18788478
- Osepchuk, J.M. and R.C. Petersen, 2003. Safety standards for exposure to electromagnetic fields. *Bioelectromagnet. Suppl.*, 6: 7-16.
- Ozen, S., S. Helnel and O. Cerezci, 2009. Heat analysis of biological tissue exposed to microwave by using thermal wave model of bio-heat transfer. *J. Mobile Commun.*, 3: 445-449.