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Research Article

SPECIFIC ABSORPTION RATE DUE TO VARIATION IN FREQUENCY ON HUMAN BODY TISSUES NEAR RADIO BROADCASTING ANTENNA

ARVIND KUMAR[1]*, VIJAY KUMAR[1], PATHAK PP[2]

[1]Department of Physics, Graphic Era University, Dehradun, Uttarakhand, India. [2]Department of Physics, Gurukula Kangri University, Haridwar, Uttarakhand, India. Email: arvindsn0@gmail.com.

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ABSTRACT

Objective: Theoretical studies are made for the specific absorption rate (SAR) in consequences of induced electric fields due to radio broadcasting tower at 100 m distance.

Methods: The penetrated electric fields and SAR inside human body tissues are calculated for different frequencies. A comparison is made with the international safety guidelines given by World Health Organization and International Commission on Non-ionizing Radiation Protection.

Results: The penetrated electric field and SAR by some tissues at frequencies 1377, 1404, 1485, 1512, and 1530 kHz of electromagnetic waves are computed.

Conclusion: According to permissible limit the frequencies 1377, 1404, 1485, 1512 and 1530 kHz of 20 kW EM radiations at 100 m distance are safe for tissues bladder, blood vessel, brain white matter, fat, heart, lung outer and mucous membrane at depths 0.1, 0.2 and 0.3 mm respectively. And this radiation is harmful for blood, body fluid, cerebella spinal fluid, eye sclera, gall bladder, gall bladder bile, gland, lung inner, lymph, mucous membrane, pancreas, stomach, testis and vitreous humor tissues at depths 0.1, 0.2 and 0.3 mm, respectively.

Keywords: Induced electric field, Specific absorption rate, Thermoregulatory mechanism and broadcasting antenna.

INTRODUCTION

The modern technology becomes beneficial for the modern society through their various applications in the field of transportation and telecommunication systems, scientific, medical and industrial equipment, radar devices, radio, television and mobile telephone etc. [1]. These advancements have always been associated with risks and hazards [2]. All the above technologies involve our exposure to electromagnetic fields (EMF). The exposure to EMF has biological effects on human cells that may change cellular processes, which would in turn lead to adverse health consequences. These consequences of EMF have been increasing due to lack of knowledge among us. In this manuscript, we have discussed health risk on human body tissues due to EM exposure from radio broadcasting antennas.

EMF and bio-effects

Exposure to EMF has increased worldwide since the 1990. An epidemiologic study Wertheimer and Leeper [3] first showed that exposure to low-frequency EMF increased childhood leukemia. The rapid increase in use of mobile phones since the late 1990 has increased exposure of human brains to EM waves (EMWs), with a consequent concern regarding the occurrence of brain tumors. Studies of the biological effects of non-ionized EMWs show stimulation by low-frequency EMF <100 kHz and a thermal effect of high-frequency EMF (>100 kHz) [4].

Studies of public exposure to radio frequency radiation (RFR) have focused on two common radio frequency (RF) field sources; radio and TV transmitters and mobile phone use. Populations residing near telecommunications and broadcasting installations tend to have the highest non-occupational RF exposures [5]. An association between proximity of residences to TV towers and increased incidence of childhood leukemia was found in an Australian study conducted by Hocking *et al*. [6]. The researchers study the leukemia incidence among people living close to TV towers (exposed group) and compared this to the incidence among those living farther out from the towers (unexposed or control group). The Hocking study concluded that there was a 95% increase in childhood leukemia associated with proximity to TV towers. No such association was found between RFR emitted by the TV towers and adult leukemia.

McKenzie *et al*. [7] repeated the Hocking study, using more accurate estimates of RFR at the same area and the same period. They found increased childhood leukemia in one area near the TV antennas, but not in other similar areas near the same TV antennas. They found no significant correlation between RF exposure and the rate of childhood leukemia. They also found that much of the "excess childhood leukemia" reported by the Hocking study occurred before high-power 24 hrs TV broadcasting had started.

In Italy, Michelozzi *et al*. and Michelozzi *et al*. [8,9] conducted a small area study to investigate a cluster of leukemia near a high-power radio-transmitter in a peripheral area of Rome. The leukemia mortality within 3.5 km (5863 inhabitants) was higher than expected. The excess was due to a significantly higher mortality among men (seven cases were observed). Furthermore, the results were showed a significant decline in risk with distance from the transmitter, only among men, but no association for women and a non-significant decrease in risk for both sexes combined. For childhood leukemia, based on eight cases, there was a significant trend of risk decreasing with distance. Burch *et al*., [5] study demonstrated the feasibility of using global positioning system and geographic information system technologies to improve RF exposure assessment and reduce exposure misclassification. They were found that proximity, elevation, line of sight, alternate sources and temporal variability each contributed to RF exposure and should be evaluated in future investigations of the potential health effects of RF broadcasting in human populations.

Adair *et al*. [10] exposed two different groups of volunteers to 2450 MHz continues wave (CW) (two females, five males) and pulse wave (PW) (65 seconds pulse width, 104 pps; three females, three males)

RF fields. They were measured thermo-physiological responses of heat production and heat loss under a standardized protocol (30 minutes baseline, 45 minutes RF or sham exposure, 10 minutes baseline) and conducted in three ambient temperatures (24, 28, and 31°C). At each temperature average power density studied was 0, 27, and 35 mW/ cm^2 (SAR=0, 5.94 and 7.7 W/kg). Mean data for each group showed minimal changes in core temperature and metabolic heat production for all test conditions and no reliable differences between CW and PW exposure. Local skin temperatures showed similar trends for CW and PW exposure that were power density-dependent; only the skin temperature of the upper back (facing the antenna) showed a reliably greater increase during PW exposure than during CW exposure. Local sweat rate and skin blood flow were both temperature and power density dependent and showed greater variability than other measures between CW and PW exposures; this variability was attributable primarily to the characteristics of the two subject groups.

Microwaves are EMWs with wavelengths ranging from as long as 1 m to as short as 1 mm. Microwaves also have other subtle effects, but the heating effect is the best understood. In one study male albino mice were fed with the fixed amount of food exposed to the microwave radiation for 10 minutes at 320°C. In this study, it was observed that the level of cholesterol showed that significant increase in experimental and sham group as compared to the control group but the increase in sham is comparatively lesser than experimental and simultaneously the level of testosterone showed the significant decline in the same pattern. The decline in testosterone may be because of increased amount of cholesterol as cholesterol is known to be a precursor in androgen synthesis in the testis; its enhanced level can be co-related with the inhibition of synthesis of testosterone leading to infertility [11].

Sarumathy *et al.* [12] determine the efficacy and safety of oral glutamine in the treatment of radiation-induced oral mucositis in patients with head and neck cancer. The study groups were compared for the oral mucositis development using the World Health Organization scale. The adverse events due to radiation or glutamine treatment were also assessed. Glutamine significantly delayed the onset of oral mucositis and reduced the incidence and severity of grade three mucositis.

Table 1: Penetrated electric fields inside human body tissues at a depth of 0.1 mm from skin, located at 100 m distance from 20 kW broadcasting antenna

Tissue of human body	Penetrated electric field (E_z) in (V/m) at depth 0.1 mm at frequencies (kHz)				
	1377	1404	1485	1512	1530
Bladder	13.4130	13.4138	13.4137	13.4136	13.4136
Blood	13.4113	13.4126	13.4125	13.4124	13.4124
Blood vessel	13.4126	13.4135	13.4134	13.4133	13.4133
Body fluid	13.4095	13.4114	13.4113	13.4111	13.4111
Brain white matter	13.4139	13.4144	13.4143	13.4142	13.4142
Cerebella spinal fluid	13.4086	13.4108	13.4107	13.4105	13.4105
Eye sclera	13.4118	13.4129	13.4129	13.4127	13.4127
Fat	13.4145	13.4148	13.4148	13.4146	13.4146
Gall bladder	13.4108	13.4123	13.4122	13.4121	13.4120
Gall bladder bile	13.4097	13.4115	13.4115	13.4113	13.4113
Gland	13.4118	13.4129	13.4129	13.4127	13.4127
Heart	13.4129	13.4137	13.4136	13.4135	13.4135
Lung outer	13.4127	13.4136	13.4135	13.4134	13.4134
Lung inner	13.4137	13.4142	13.4142	13.4141	13.4141
Lymph	13.4118	13.4129	13.4129	13.4127	13.4127
Mucous membrane	13.4134	13.4140	13.4140	13.4138	13.4138
Muscle	13.4122	13.4132	13.4131	13.4130	13.4130
Pancreas	13.4118	13.4129	13.4129	13.4127	13.4127
Stomach	13.4119	13.4130	13.4130	13.4128	13.4128
Testis	13.4120	13.4131	13.4130	13.4129	13.4129
Vitreous humor	13.4095	13.4114	13.4113	13.4111	13.4111

METHODS

The proposed approach is to predict the induced electric field around all India radio tower, penetrated electric field inside the body and SAR of the tissues of the human body. The power of the broadcasting antenna, which radiate the EM energy at different frequencies is taken as 20 kW. The EMW emitted from broadcasting antenna is incident on the human body. The wave produced by a dipole antenna has a cylindrical wave front. The incident electric field E_{rms} around the radio broadcasting tower of power P is given by [13],

Table 2: Penetrated electric fields inside human body tissues at a depth of 0.2 mm from skin, located at 100 m distance from 20 kW broadcasting antenna

Tissue of human body	Penetrated electric field (E_z) in (V/m) at depth 0.2 mm at frequencies (kHz)				
	1377	1404	1485	1512	1530
Bladder	13.4111	13.4110	13.4109	13.4108	13.4107
Blood	13.4088	13.4086	13.4085	13.4083	13.4083
Blood vessel	13.4105	13.4104	13.4103	13.4102	13.4102
Body fluid	13.4064	13.4062	13.4061	13.4058	13.4058
Brain white matter	13.4123	13.4122	13.4121	13.4120	13.4120
Cerebella spinal fluid	13.4052	13.4050	13.4049	13.4046	13.4046
Eye sclera	13.4095	13.4093	13.4092	13.4090	13.4090
Fat	13.4131	13.4130	13.4130	13.4128	13.4128
Gall bladder	13.4081	13.4080	13.4079	13.4077	13.4076
Gall bladder bile	13.4067	13.4065	13.4064	13.4061	13.4061
Gland	13.4094	13.4093	13.4092	13.4090	13.4090
Heart	13.4109	13.4108	13.4107	13.4105	13.4105
Lung outer	13.4107	13.4106	13.4105	13.4103	13.4103
Lung inner	13.4120	13.4119	13.4119	13.4117	13.4117
Lymph	13.4094	13.4093	13.4092	13.4090	13.4090
Mucous membrane	13.4116	13.4114	13.4114	13.4112	13.4112
Muscle	13.4099	13.4098	13.4097	13.4095	13.4095
Pancreas	13.4094	13.4093	13.4092	13.4090	13.4090
Stomach	13.4096	13.4095	13.4094	13.4092	13.4091
Testis	13.4098	13.4096	13.4095	13.4093	13.4093
Vitreous humor	13.4064	13.4062	13.4061	13.4058	13.4058

Table 3: Penetrated electric fields inside human body tissues at a depth of 0.3 mm from skin, located at 100 m distance from 20 kW broadcasting antenna

Tissue of human body	Penetrated electric field (E_z) in (V/m) at depth 0.3 mm at frequencies (kHz)				
	1377	1404	1485	1512	1530
Bladder	13.4083	13.4083	13.4081	13.4079	13.4078
Blood	13.4049	13.4048	13.4045	13.4042	13.4041
Blood vessel	13.4075	13.4074	13.4072	13.4070	13.4069
Body fluid	13.4013	13.4012	13.4009	13.4005	13.4004
Brain white matter	13.4101	13.4101	13.4099	13.4098	13.4097
Cerebella spinal fluid	13.3995	13.3994	13.3990	13.3987	13.3985
Eye sclera	13.4059	13.4058	13.4055	13.4053	13.4051
Fat	13.4113	13.4113	13.4112	13.4110	13.4109
Gall bladder	13.4039	13.4038	13.4035	13.4033	13.4031
Gall bladder bile	13.4017	13.4016	13.4013	13.4010	13.4008
Gland	13.4058	13.4058	13.4055	13.4053	13.4051
Heart	13.4080	13.4080	13.4077	13.4075	13.4074
Lung outer	13.4077	13.4077	13.4075	13.4073	13.4071
Lung inner	13.4097	13.4097	13.4095	13.4093	13.4092
Lymph	13.4058	13.4058	13.4055	13.4053	13.4051
Mucous membrane	13.4090	13.4090	13.4088	13.4086	13.4084
Muscle	13.4066	13.4065	13.4062	13.4060	13.4059
Pancreas	13.4058	13.4058	13.4055	13.4053	13.4051
Stomach	13.4061	13.4060	13.4058	13.4055	13.4054
Testis	13.4063	13.4063	13.4060	13.4058	13.4056
Vitreous humor	13.4013	13.4012	13.4009	13.4005	13.4004

$$E_{rms} = \frac{\sqrt{90P}}{r} = 9.487\frac{\sqrt{P}}{r} \quad (1)$$

There (r) is the distance of the human body from the transmitter antenna. When a human body is exposed to the EM wave of this electric field, it penetrates into the body. It results into inside or induced electric field E_z at a given depth z given as [14],

$$E_z = E_{rms}\exp\left(\frac{-Z}{\delta}\right) \quad (2)$$

where (δ) is skin depth, which is the distance over which the field decreases to 0.368 of its value just inside the boundary. The value of skin depth for body tissues are taken from the parametric model [15].

Specific absorption rate (SAR)

The SAR is defined as the time derivative of the incremental energy (dW) absorbed by or dissipated in an incremental mass (dm) contained in a volume element (dV) of a given density (ρ). It can be defined as,

$$SAR = \frac{d}{dt}\left(\frac{dW}{dm}\right) \quad (3)$$

$$SAR = \frac{d}{dt}\left(\frac{dW}{\rho dV}\right)$$

By using Poyinting's vector theorem for sinusoidal EMF, we get

$$SAR = \frac{\sigma E_z^2}{\rho} \quad (4)$$

Table 4: SAR in W/kg inside different human tissues at a depth of 0.1 mm from skin of a human body located at 100 m distance from 20 kW broadcasting antenna

Tissue of human body	SAR in (W/kg) at depth 0.1 mm inside human body at frequencies (kHz)				
	1377	1404	1485	1512	1530
Bladder	0.042027	0.042079	0.0422175	0.0422651	0.0422948
Blood	0.147453	0.147985	0.148966	0.1499120	0.150222
Blood vessel	0.056768	0.0567915	0.056822	0.0568524	0.056862
Body fluid	0.267214	0.2673068	0.267303	0.2672964	0.267296
Brain white matter	0.018379	0.0184272	0.0185171	0.0180859	0.018634
Cerebella spinal fluid	0.356025	0.3561400	0.356135	0.3563039	0.356302
Eye sclera	0.113775	0.114143	0.114820	0.1154695	0.115680
Fat	0.0049365	0.004939	0.004943	0.0049477	0.004949
Gall bladder	0.1571988	0.157232	0.157233	0.1572313	0.157230
Gall bladder bile	0.249275	0.249343	0.249340	0.24933416	0.249333
Gland	0.106830	0.107067	0.107489	0.1079020	0.108033
Heart	0.0615019	0.061772	0.062284	0.0627755	0.0629361
Lung outer	0.0598305	0.059995	0.060300	0.0605954	0.0606912
Lung inner	0.1003729	0.100802	0.101646	0.1024821	0.1026518
Lymph	0.107857	0.1080968	0.108526	0.1089395	0.1090724
Mucous membrane	0.0418469	0.0420687	0.042494	0.0429068	0.0430399
Muscle	0.0899812	0.0902124	0.0906281	0.0910185	0.0911451
Pancreas	0.1078572	0.1080968	0.1085267	0.1089395	0.1090724
Stomach	0.1039916	0.1042860	0.104833	0.105374	0.1055524
Testis	0.1042170	0.1046622	0.105493	0.106290	0.1065495
Vitreous humor	0.2672143	0.2673068	0.2673039	0.267297	0.2672961

SAR: Specific absorption rate

Table 5: SAR in W/kg inside different human tissues at a depth of 0.2 mm from skin of a human body located at 100 m distance from 20 kW broadcasting antenna

Tissue of human body	SAR in (W/kg) at the depth 0.2 mm, inside human body tissues at frequencies (kHz)				
	1377	1404	1485	1512	1530
Bladder	0.042015	0.0420617	0.042157	0.042247	0.042276
Blood	0.1473980	0.1478983	0.148877	0.149820	0.150130
Blood vessel	0.0567511	0.0567656	0.056796	0.056825	0.056836
Body fluid	0.267090	0.2671012	0.267095	0.267084	0.267083
Brain white matter	0.0183748	0.0184211	0.018511	0.018079	0.018628
Cerebella spinal fluid	0.355844	0.355834	0.355825	0.355989	0.355986
Eye sclera	0.113735	0.114082	0.114757	0.115405	0.115616
Fat	0.004935	0.004937	0.004942	0.004946	0.004947
Gall bladder	0.157136	0.1571324	0.157131	0.157128	0.157127
Gall bladder bile	0.249162	0.249156	0.249151	0.249142	0.249140
Gland	0.106792	0.107009	0.107430	0.107841	0.107973
Heart	0.0614836	0.061746	0.062256	0.062747	0.062908
Lung outer	0.0598124	0.059968	0.060272	0.060567	0.060663
Lung inner	0.1003474	0.100767	0.101610	0.102445	0.102715
Lymph	0.1078193	0.108038	0.108467	0.108878	0.109011
Mucous membrane	0.0418355	0.042052	0.042477	0.042890	0.043023
Muscle	0.0899512	0.090166	0.090581	0.090971	0.091097
Pancreas	0.1078193	0.108038	0.108467	0.108878	0.109011
Stomach	0.1039557	0.104230	0.104777	0.105317	0.105494
Testis	0.1041818	0.104608	0.105438	0.106233	0.106492
Vitreous humor	0.267090	0.267101	0.267095	0.267085	0.267083

SAR: Specific absorption rate

Table 6: SAR in W/kg inside different human tissues at a depth of 0.3 mm from skin of a human body located at 100 m distance from 20 kW broadcasting antenna

Tissue of human body	SAR in (W/kg) at the depth 0.3 mm inside the human body tissues at frequencies (kHz)				
	1377	1404	1485	1512	1530
Bladder	0.0419981	0.042044	0.042139	0.042229	0.042258
Blood	0.147318	0.147813	0.148788	0.149729	0.150036
Blood vessel	0.0567253	0.05674	0.056769	0.056799	0.056808
Body fluid	0.2668864	0.266899	0.266887	0.266872	0.266867
Brain white matter	0.0183688	0.018415	0.018504	0.018073	0.018621
Cerebella spinal fluid	0.355541	0.355534	0.355515	0.355675	0.355665
Eye sclera	0.113674	0.114022	0.114695	0.115341	0.115550
Fat	0.0049341	0.004936	0.004940	0.004945	0.004946
Gall bladder	0.1570364	0.157034	0.157029	0.157085	0.157021
Gall bladder bile	0.2489774	0.248973	0.248961	0.248950	0.248944
Gland	0.1067350	0.106952	0.107371	0.107782	0.107911
Heart	0.061457	0.061720	0.062229	0.062719	0.062879
Lung outer	0.0597858	0.059942	0.060245	0.060540	0.060634
Lung inner	0.1003127	0.100734	0.101575	0.102409	0.102677
Lymph	0.1077613	0.1007981	0.108407	0.108818	0.108949
Mucous membrane	0.041819	0.042037	0.042461	0.042873	0.043005
Muscle	0.0899061	0.090122	0.090535	0.090924	0.091048
Pancreas	0.1077613	0.107981	0.108407	0.108818	0.108949
Stomach	0.1039011	0.104177	0.104721	0.105260	0.105435
Testis	0.1041284	0.104555	0.105383	0.106177	0.106434
Vitreous humor	0.2668864	0.266899	0.266887	0.266874	0.266867

SAR: Specific absorption rate

Where σ the conductivity of the biological materials and (E_z) is a field inside that material. This relation represents the rate at which the EM energy is converted into heat through well-established interaction mechanisms. It provides a valid quantitative measure of all interaction mechanisms that are dependent on the intensity of the internal electric field [16]. The amount of heating produced in a living organism depends primarily on the intensity of the radiation once it has penetrated inside the body.

RESULTS AND DISCUSSION

The induced electric field and SAR of the tissues due to radiation at frequencies 1377, 1404, 1484, 1512, 1530 kHz at radiated power 20 kW are taking for this study. The radiation produces an electric blanket around the people. These incident electric fields penetrate inside the human body. The incident electric fields around the broadcasting tower are calculated by Eq. (1). This electric field penetrates inside the human body and penetrated electric fields inside the tissues are calculated by Eq. (2). The calculated values of penetrated electric field at depths 0.1, 0.2 and 0.3 mm inside human body located at the distance 100 m from the broadcasting antenna radiating at frequencies of 1377, 1404, 1484, 1512 and 1530 kHz with power of 20 kW are represented in Tables 1-3 respectively. Calculated SAR values at same depths due to these transmitters are given in Tables 4-6.

According to permissible limit [13] the frequencies 1377, 1404, 1485, 1512 and 1530 kHz of 20 kW EM radiation at 100 m distance are safe for tissues bladder, blood vessel, brain white matter, fat, heart, lung outer and mucous membrane at depths 0.1, 0.2 and 0.3 mm respectively. And this radiation is harmful for blood, body fluid, cerebella spinal fluid, eye sclera, gall bladder, gall bladder bile, gland, lung inner, lymph, mucous membrane, pancreas, stomach, testis and vitreous humor tissues at depths 0.1, 0.2 and 0.3 mm respectively. These calculations are made only 100 m distance from the broadcasting tower.

CONCLUSION

The above calculations and analysis represents that, the values of SAR for the frequency 1377, 1404, 1485, 1512 and 1530 kHz of wavelengths within 217 m, 213 m, 201 m, 198 m, and 196 m respectively, of 20 kW EM radiation at 100 m distance are harmful for body tissues from the broadcasting antenna. This study is done only for some selected tissues. Thus, if study is done for some more tissues of the body, it may be possible that the health of the tissues will become more negative. Thus it is suggested that peoples and workers should keep away from these broadcasting antennas emitted frequencies of 1377, 1404, 1485, 1512 and 1530 kHz radiation or we can say that these types of radio broadcasting tower should located away from the populated area.

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