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Human Exposure Assessment in the Near-Field of Antennas Used by Mobile Phone Devices

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Abstract

Nowadays mobile communication is one of the most rapidly developing telecommunication systems. In every country, millions of users employ this type of mobile communication. It is the only radiation producing consumer product that people intentionally place against their head for extended time periods. There is irrefutable evidence that mobile phone radiation affects biological mechanisms in the body. This radiation penetrates the head and increases the brain temperature (thermal level) of the user while the phone is in use, also affects protective biological mechanisms in the body. Since the large amount of general population is using the mobile phones, there is a need to determine the level of radiation in respect to the exposure standards (SAR). The purpose of this paper is to calculate the radiation power density of mobile phone, minimum safety distance and find out how mobile phone radiation decreases over short and long distances.

Keywords: Mobile phone radiation, GSM exposure limits, Health risks

Introduction

Scientists have known for a long time about the ability of electromagnetic radiation to cause heating, which can lead to severe health effects on the body such as cancer, hyperthermia, neural and behavior effects ofpeople exposed to GSM fields are being studied (Pllana, 2007). These effects are known as thermal effects (Van Leeuwen, 1999).Many scientific reports have indicated that the health risks associated with electromagnetic radiation are much higher than initially understood (NRPB, 2004). New reports continue to be published several times a year, suggesting that there might be health risks from mobile phones electromagnetic radiation.Radio-frequency energy can rapidly heat biological tissue and cause damage (Muscat, 2006).

A mobile phone is designed to transmit radio waves in all directions because base stations could be in any direction with respect to phone users. This means that a proportion of the radio waves they produce are directed towards the user's body.The electromagnetic fields from a mobile phone depend upon the design of the mobile phone and its antenna, how it operates, as well as how it is held and used (Kraus, 2002). In fact, it is necessary to calculate how much radio frequency energy from the phone can penetrate the brain, depending on how close the mobile phone antenna is to the head (Freude, 1998). More than sixty percent of energy emitted by a mobile phone is absorbed by hand and head of user. The energy absorbed, apparently, can cause biological effects (Len, 2004).Mobile phones emit low levels of radio frequency energy in the microwave range while being used. Radiation can damage human tissue if it is exposed to high levels of radio frequency radiation, according to the FCC (Neawedde, 2006). Radio frequency radiation has the ability to heat human tissue, much like the way microwave ovens heat food (Van Leeuwen, 1999). Damage to tissue can be caused by exposure to radio frequency radiation because the body is not equipped to dissipate excessive amounts of heat. The eyes are particularly vulnerable due to the lack of blood flow in that area (Schachter, 2005). However, it is not known to what extent or through what mechanism, lower levels of radio frequency might cause adverse health effects as well.Laboratory tests on mice have shown that radiation from mobile phones can have an adverse effect on their overall health (Repacholi, 2001). It is still not clear whether those findings can be applied directly to humans.Children could be more at risk from the radio waves emitted by mobile phones. This is because their brains are still developing and their skulls are thinner, making it easier for the radio waves to penetrate them (Christensen, 2005). Also if they start using mobiles at a young age, their cumulative lifetime use will be higher than adults.

Radio Frequency Radiation

Mobile phones and base stations emit radio frequency radiation. National operators of mobile communication use systems of GSM900 standard, range of operating frequencies of base station 935-960 MHz (down link), and for mobile phones 890-915 MHz (up link), GSM1800 standard, 1805-1830 MHz (down link), and 1710-1785 MHz (up link), correspondingly.In both cases levels of exposure generally reduce with increasing distance from the source. For mobile phones, exposures will be principally to the side of the head for hand-held use, or to the parts of the body closest to the phone during hands-free use. For base station emissions, exposures of the general population will be to the whole body (TIA/EIA Interim Standard 95, 1999, TAI/EIA-553, 1999).

Base stations communicate with mobile phones within a defined area or "cell". When considering possible hazards from exposure to wireless transmitters, several considerations must be taken into account. The first consideration is frequency because exposure guidelines vary with frequency. A second consideration is the power output of the transmitter, and the third is the distance from the body (Foster, 2007). Hand-held units (either mobile phones or other communications handsets) operate at comparatively low power levels but they are used very close to the head. Base stations operate at higher power levels, but their transmitting antennas are located some distance from their users. The power of a mobile phone automatically adjusts depending on how close/far the user is from the closest base station. Another interesting fact is related to the antennas of mobile phones.

The radio waves that carry the encoded signal are made up of electromagnetic radiation propagated by the antenna. The function of an antenna in any radio transmitter is to launch the radio waves into space; in the case of mobile phones, these waves are picked up by a receiver in the base station tower. When talking on a mobile phone, most users place the phone against the head. In this position, there is a good chance that most of the radiation will be absorbed by human tissue (Fulitz, 1998).In this paper I have presented results of calculationsof electromagnetic power density and its exposure assessment is done.

Calculations of the Power Density

What is being debated in the scientific is just how much radiation is considered unsafe, and if there are any potential long-term effects of mobile phone radiation exposure. Electromagnetic waves radiate from mobile antenna will spread uniformly in all directions; therefore the wave front is spherical. The power density is inversely proportional to the square of the distance from the mobile antenna. This is the inverse-square law, which applies universally to all forms of radiation in free space, and establishes that the power will diminish as a function of the inverse of the square of the distance (Kraus, 2002). Stating this mathematically, we have:

$$P_d=P_tG_t/(4\pi R^2) \quad \ldots\ldots\ldots\ldots \quad (1)$$

Where,P_d is the power density in mW/cm^2 at a distance R from the mobile's antenna in cm, P_t is the transmitted power of the mobile in mW, and G_t is the transmitter antenna gain. The minimum safety distance (where the power density is equal to 0.4 mW/cm^2) can be calculated as follows:

$$R_s^2 = (P_tG_t/4\pi P_d)$$

$$R_s = (P_tG_t/4\pi \times 0.4)^{1/2}$$

$$R_s=(P_tG_t/5.02655)^{1/2} \quad \ldots\ldots\ldots \quad (2)$$

Where R_s is the minimum safety distance from the mobile phone in cm.

In mobile communication, the user's head is in the reactive near-field region, which is the near-field region immediately surrounding the antenna, wherein the reactive field predominates (Balzano,1981). For a very short antenna, the outer boundary of this region is commonly taken to exist at a distance R_1 from the antenna surface (Kraus, 2002):

$$R_1 = (\lambda/2\pi) \;\ldots\ldots\; (3)$$

The transmitted frequency from the mobile equipment is around (900 MHz), which means that R_1 is equal to 5.3 cm.

The radio waves that are directed towards the head of the user penetrate into the body tissues for a few cm and tend to be absorbed. In order to have more accurate results power densityis calculated at considerable distances from radiatingantenna using Matlab software. The flowchart of the programused is shown in the figure (1).Table (1) gives the calculated power density of the mobile phone with respect to distance from the mobile's antenna for different transmitting power using equation (1), and figure (2) illustrates these results. Table (2) gives, by how much the radiation was reduced from power density P_R to power density P_{R+1}, where $R = 1, 2, 3,\ldots\ldots$ cm.Table (3) gives the minimum safety distances from the mobile antenna for different mobile transmitted power, when power density is equal to the Specific Absorption Rate (SAR) and equal to 0.4 mW/cm^2, using equation (2). The results are illustrated in figure (3).

The danger of mobile phone radiation is that it could have long-term effects. Figure (4) is a computer graphic showing the penetration of electromagnetic waves in the human head (Siwiak, 1993).The penetration of electromagnetic waves is far greater in the head of a 10 year old child than in the head of an adult, and much greater in the head of a 5 year old child than in the head of 10 year old one. The reason is that at an early age bones are much lighter, and so children are at the greatest risk of penetration from electromagnetic waves.

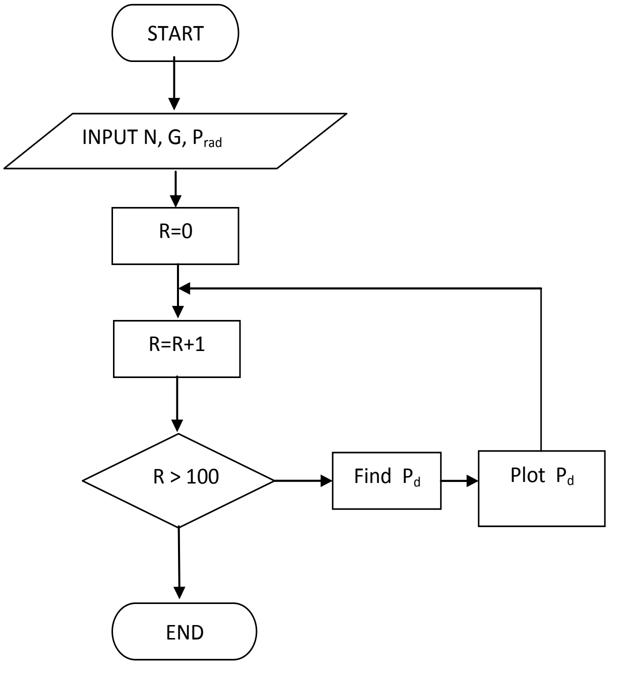

Figure (1): The flowchart of the power density calculation.

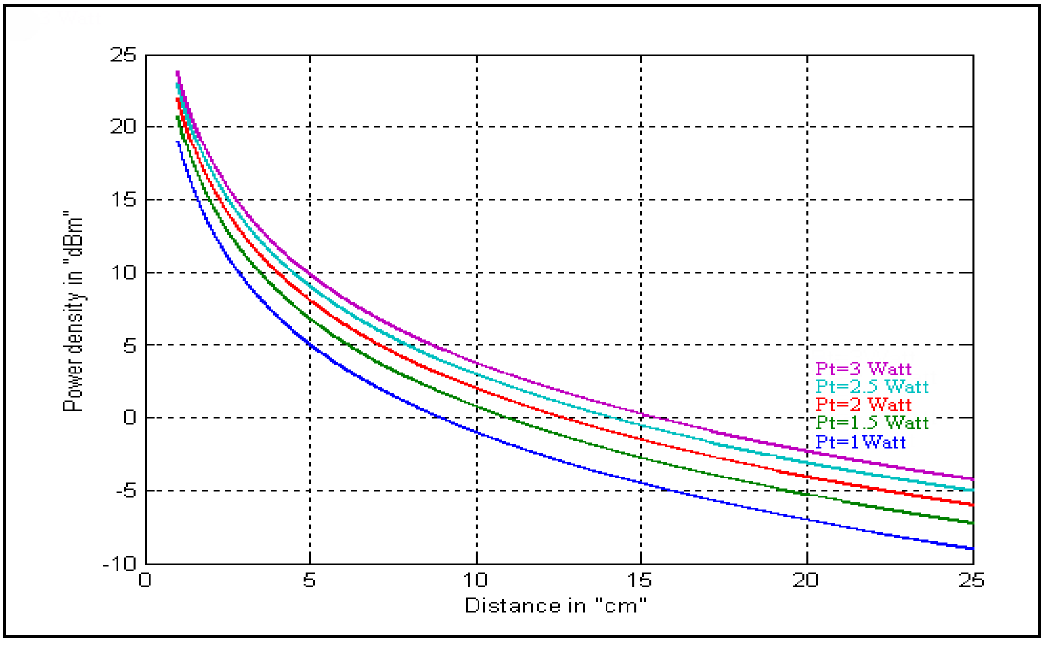

Figure (2): Power density of each mobile phone.

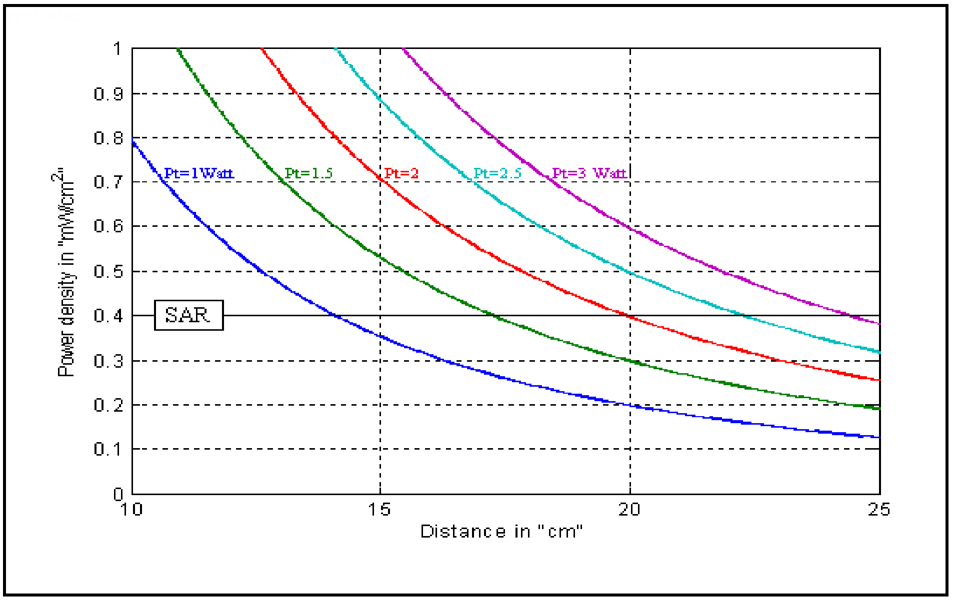

Figure (3): Minimum safety distances from the mobile phone antenna.

Table (1): Power densities of mobile phones with respect to distances and transmitted power.

Distance R in cm	P_t = 1 W		P_t = 1.5 W		P_t = 2 W		P_t = 2.5 W		P_t = 3 W	
	Power density in									
	mW/cm^2	dBm	mW/cm^2	dBm	mW/cm^2	dBm	mW/cm^2	dBm	mW/cm^2	dBm
1	79.578	19.008	119.366	20.77	159.155	22.018	198.944	22.987	238.732	23.779
2	19.894	12.987	29.842	14.751	39.789	15.998	49.736	16.967	59.683	17.758
3	8.842	9.465	13.263	11.226	17.684	12.476	22.105	13.445	26.526	14.237
4	4.974	6.967	7.460	8.727	9.947	9.977	12.434	10.946	14.921	11.738
5	3.183	5.028	4.775	6.789	6.366	8.039	7.958	9.008	9.549	9.799
6	2.211	3.446	3.316	5.206	4.421	6.455	5.526	7.424	6.632	8.216
7	1.624	2.106	2.436	3.867	3.248	5.116	4.060	6.085	4.872	6.877
8	1.243	0.945	1.865	2.707	2.487	3.957	3.109	4.926	3.730	5.717
9	0.982	-0.079	1.474	1.685	1.965	2.934	2.456	3.902	2.947	4.694
10	0.796	-0.991	1.194	0.770	1.592	2.019	1.989	2.986	2.387	3.778
11	0.658	-1.818	0.987	-0.057	1.315	1.189	1.644	2.159	1.973	2.951
12	0.553	-2.573	0.829	-0.814	1.105	0.434	1.382	1.405	1.658	2.196
13	0.471	-3.269	0.706	-1.512	0.942	-0.259	1.177	0.708	1.413	1.501
14	0.406	-3.915	0.609	-2.154	0.812	-0.904	1.015	0.0647	1.218	0.856
15	0.354	-4.510	0.531	-2.749	0.707	-1.506	0.884	-0.535	1.061	0.257
16	0.311	-5.072	0.466	-3.316	0.622	-2.062	0.777	-1.096	0.933	-0.301
17	0.275	-5.607	0.413	-3.841	0.551	-2.589	0.688	-1.624	0.826	-0.830
18	0.246	-6.091	0.368	-4.341	0.491	-3.089	0.614	-2.118	0.737	-1.325
19	0.220	-6.576	0.331	-4.802	0.441	-3.556	0.551	-2.589	0.661	-1.798
20	0.199	-7.012	0.298	-5.258	0.398	-4.001	0.497	-3.036	0.597	-2.240
21	0.180	-7.447	0.271	-5.670	0.361	-4.425	0.451	-3.458	0.541	-2.668
22	0.164	-7.852	0.247	-6.073	0.329	-4.828	0.411	-3.862	0.493	-3.072
23	0.150	-8.239	0.226	-6.459	0.301	-5.214	0.376	-4.248	0.451	-3.458
24	0.138	-8.601	0.207	-6.840	0.276	-5.591	0.345	-4.622	0.415	-3.819
25	0.127	-8.962	0.191	-7.190	0.255	-5.935	0.318	-4.976	0.382	-4.179

Table (2): The amount of power density of mobile phones reduced for any P_t.

R cm	P_d mW/ cm^2	P_R/P_{R+1} times reduce	R cm	P_d mW/ cm^2	P_R/P_{R+1} times reduce	R cm	P_d mW/ cm^2	P_R/P_{R+1} times reduce	R cm	P_d mW/ cm^2	P_R/P_{R+1} times reduce
1	79.577	100.0	9	0.9824	1.266	17	0.2754	1.129	25	0.1273	1.085
2	19.894	4.000	10	0.7958	1.235	18	0.2456	1.121	26	0.1177	1.082
3	8.8419	2.250	11	0.6577	1.210	19	0.2204	1.114	27	0.1092	1.078
4	4.9736	1.778	12	0.5526	1.190	20	0.1989	1.108	28	0.1015	1.075
5	3.1831	1.562	13	0.4709	1.174	21	0.1808	1.102	29	0.0946	1.073
6	2.2105	1.440	14	0.4060	1.160	22	0.1644	1.097	30	0.0884	1.070
7	1.6240	1.361	15	0.3537	1.148	23	0.1504	1.093	31	0.0828	1.068
8	1.2434	1.306	16	0.3108	1.138	24	0.1382	1.089			

Table (3): Minimum safety distances from the mobile phone antenna.

P_t in Watt	Minimum safety distance in cm (when P_d = 0.4 mW/cm^2)
1.0	14.105 cm
1.5	17.275 cm
2.0	19.947 cm
2.5	22.302 cm
3.0	24.430 cm

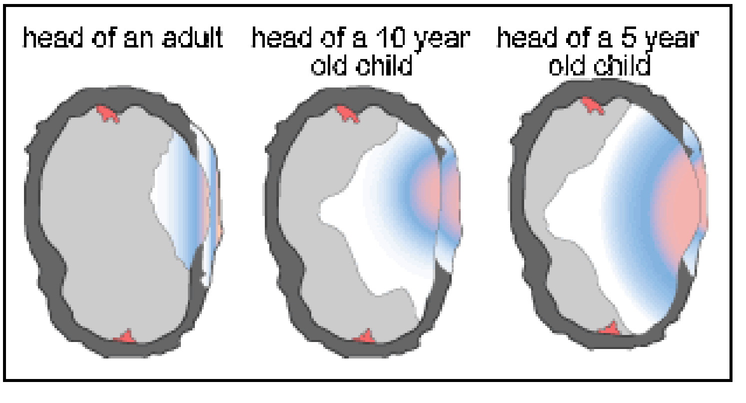

Figure (4): A computerized model of the head at various stages of development [17].

Calculation of the Minimum Safety Distance from the Base Station

The power from antennas used with base stations is radiated in conical fan-shaped beams, which are essentially directed towards the horizon with a slight downward tilt, as illustrated in the figure (5). This is causes radio wave strengths, below the antennas and at the base of masts, to be much lower than directly in front of the antennas at a similar distance. The beams from the antennas spread out as distance increases and tend to reach ground level at distances in the range (30-300 m) from the antennas base. The radio wave levels at these distances are much less than those directly in front of the antennas and can easily be calculated(Saeid, 2011).

For calculating the minimum safety distance from the base station antenna, the transmitted power must be known. Assume the numbers of transmitters are four and the transmitted power is 50 W each, then the maximum power of the antenna is (Saeid, 2008):

P_{max} = 200 = 10 log (200/10^{-3}) = 53 dB_m

There are losses in the combiners between the transmitters about 6 dB, and losses in connection cables about 3 dB, then,

Total losses = 6 dB + 3 dB = 9 dB
Maximum input power to the antenna = 53 – 9 = 44 dB_m

The antenna gain is about 16 dB, and then the Effective Isotropic Radiated Power (EIRP) in the direction of main lobe is:
EIRP = 44 + 16 = 60 dB_m = 1000 Watt

In the other directions the EIRP is 20 dB_m less than main lobe (Kraus, 1988), then:

EIRP = 60 – 20 = 40 dB_m = 10 Watt, (outside the main lobe).

The minimum safety distance from the base station antenna is:

$$D = [EIRP/(4\pi P_d)]^{1/2} \quad \text{........} \quad (4)$$

Assume that the maximum safety power density (P_d) is 0.4 mW/ cm^2, then:

$$D_{min.} = [1000/ (4\pi \times 0.4)]^{1/2} = 446 \text{ cm.}$$

Figure (6) shows the relation between the power density of the base station and the distance for the main lobe.

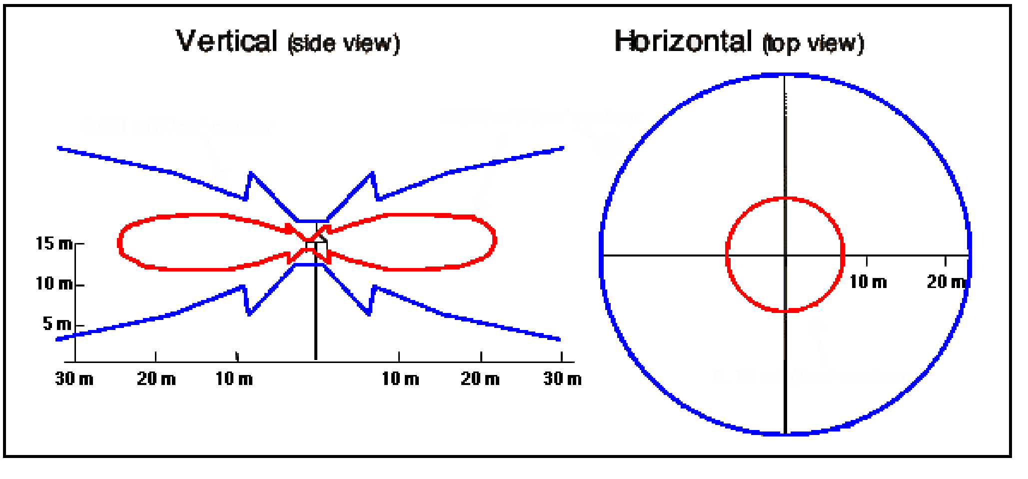

Figure (5): Base station antenna radiation.

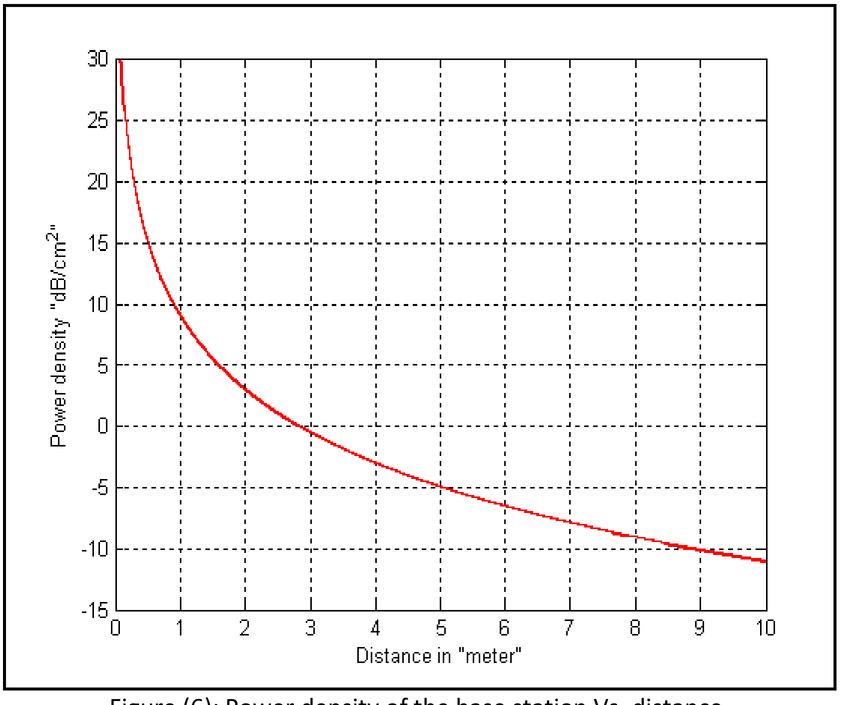

Figure (6): Power density of the base station Vs. distance.

Recommendations

Based on the results of the previous sections one can see that the mobile phone radiation has an effect on human body. To avoid the potential hazards of the mobile phone radiation, the following ways are recommended to reduce the risk:

- Use a hands-free headset.
- Use a phone that places the antenna as far away from you as possible.
- Extend the antenna during use.
- Limit calls inside buildings.
- Use the phone in open spaces as often as possible.
- Children should be advised only to use mobile phones in emergencies.
- Don't use mobile phone in an area with weak reception, for example, in a closed area such as a car and an elevator. In these areas the mobile phone radiates much more powerfully than in an area with strong reception to substitute for weak power reception.

Conclusion

After taking a look at the results above one could notice that over short distances radiation decreases more rapidly, and over long distances it decreases quite slowly. Also radiation is depending on the transmitting power of the mobile phone as shown in table (1), and table (2). Even a small distance between the mobile phone and body reduces exposure significantly. The safety distances from mobile phone antennas given in table (3). The results show that, exposure depends upon the transmitting power of the mobile phone. For example it is about 14.1 cm if the transmitting power is only 1 Watt, and it increases to 24.43 cm if the transmitting power is 3 Watts. The exposure is smaller if you, for example, keep the phone in a separate hand bag instead of keeping it in your pocket. Also, after looking at the results, one could safely say that using a mobile phone in a public place is not similar to secondhand smoke and is actually pretty safe for those around you (but not yourself). The greatest risk is to mobile phone users because the user's head is in the reactive near-field region of the mobile's antenna, and with a high exposure to the head, there is greater risk to brain tissue and brain processes. Since the magnetic field of a short antenna is closer to the brain than that of an old mobile phone, the short antenna is more dangerous. The newer models of mobile phones fool many people; into thinking that they are safer than the old ones. However it is completely the opposite.

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Author Biography

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