

Reported Biological Effects from Radiofrequency Radiation at Low-Intensity Exposure

(Cell Tower, Wi-Fi, Wireless Laptop and 'Smart' Meter RF Intensities)

Power Density (Microwatts/centimeter2 - uW/cm2)	Reference
As low as (10 ⁻¹³) or 100 femtowatts/cm2	Belyaev, 1997
5 picowatts/cm2 (10 ⁻¹²)	Grundler, 1992
0.1 nanowatt/cm2 (10 ⁻¹⁰) or 100 picowatts/cm2	Belyaev, 1997
0.00034 uW/cm2	Behari, 2006
0.0005 uW/cm2	Vellizarov, 1999
0.0006 - 0.0128 uW/cm2	Oberfeld, 2004
0.003 - 0.02 uW/cm2	Heinrich, 2010
0.003 to 0.05 uW/cm2	Thomas, 2010
0.005 uW/cm2	Mohler, 2010
0.005 - 0.04 uW/cm2	Thomas, 2008
0.006 - 0.01 uW/cm2	Buchner, 2012
0.01 - 0.11 uW/cm2	Navarro, 2003

Stress proteins, HSP, disrupted immune function	Brain tumors and blood-brain barrier
Reproduction/fertility effects	Sleep, neuron firing rate, EEG, memory, learning, behavior
Oxidative damage/ROS/DNA damage/DNA repair failure	Cancer (other than brain), cell proliferation
Disrupted calcium metabolism	Cardiac, heart muscle, blood-pressure, vascular effects

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0.01 - 0.05 uW/cm ²	Adults (18-91 yrs) with short-term exposure to GSM cell phone radiation reported headache, neurological problems, sleep and concentration problems. Hutter, 2006
0.005 - 0.04 uW/cm ²	Adults exposed to short-term cell phone radiation reported headaches, concentration difficulties (differences not significant, but elevated) Thomas, 2008
0.015 - 0.21 uW/cm ²	Adults exposed to short-term GSM 900 radiation reported changes in mental state (e.g., calmness) but limitations of study on language descriptors prevented refined word choices (stupified, zoned-out) Augner, 2009
0.05 - 0.1 uW/cm ²	RFR linked to adverse neurological, cardio symptoms and cancer risk Khurana, 2010
0.05 - 0.1 uW/cm ²	RFR related to headache, concentration and sleeping problems, fatigue Kundi, 2009
0.07 - 0.1 uW/cm ²	Sperm head abnormalities in mice exposed for 6-months to base station level RF/MW. Sperm head abnormalities occurred in 39% to 46% exposed mice (only 2% in controls) abnormalities was also found to be dose dependent. The implications of the pin-head and banana-shaped sperm head. The occurrence of sperm head observed increase occurrence of sperm head abnormalities on the reproductive health of humans living in close proximity to GSM base stations were discussed." Otitoloju, 2010
0.38 uW/cm ²	RFR affected calcium metabolism in heart cells Schwartz, 1990
0.8 - 10 uW/cm ²	RFR caused emotional behavior changes, free-radical damage by super-weak MWs Akoev, 2002
0.13 uW/cm ²	RFR from 3G cell towers decreased cognition, well-being Zwamborn, 2003
0.16 uW/cm ²	Motor function, memory and attention of school children affected (Latvia) Kolodynski, 1996
0.168 - 1.053 uW/cm ²	Irreversible infertility in mice after 5 generations of exposure to RFR from an 'antenna park' Magras & Zenos, 1997
0.2 - 8 uW/cm ²	RFR caused a two-fold increase in leukemia in children Hocking, 1996
0.2 - 8 uW/cm ²	RFR decreased survival in children with leukemia Hocking, 2000
0.21 - 1.28 uW/cm ²	Adolescents and adults exposed only 45 min to UMTS cell phone radiation reported increases In headaches. Riddervold, 2008

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0.5 uW/cm2	Significant degeneration of seminiferous epithelium in mice at 2.45 GHz, 30-40 min. Saunders, 1981
0.5 - 1.0 uW/cm2	Wi-Fi level laptop exposure for 4-hr resulted in decrease in sperm viability, DNA fragmentation with sperm samples placed in petri dishes under a laptop connected via WI-FI to the internet. Avendano, 2012
1.0 uW/cm2	RFR induced pathological leakage of the blood-brain barrier Persson, 1997
1.0 uW/cm2	RFR caused significant effect on immune function in mice Fesenko, 1999
1.0 uW/cm2	RFR affected function of the immune system Novoselova, 1999
1.0 uW/cm2	Short-term (50 min) exposure in electrosensitive patients, caused loss of well-being after GSM and especially UMTS cell phone radiation exposure Elititi, 2007
1.3 - 5.7 uW/cm2	RFR associated with a doubling of leukemia in adults Dolk, 1997
1.25 uW/cm2	RFR exposure affected kidney development in rats (in-utero exposure) Pyrrasopoulou, 2004
1.5 uW/cm2	RFR reduced memory function in rats Nittby, 2007
2 uW/cm2	RFR induced double-strand DNA damage in rat brain cells Kesari, 2008
2.5 uW/cm2	RFR affected calcium concentrations in heart muscle cells Wolke, 1996
2 - 4 uW/cm2	Altered cell membranes; acetylcholine-induced ion channel disruption D'Inzeo, 1988
4 uW/cm2	RFR caused changes in hippocampus (brain memory and learning) Tattersall, 2001
4 - 15 uW/cm2	Memory impairment, slowed motor skills and retarded learning in children Chiang, 1989
5 uW/cm2	RFR caused drop in NK lymphocytes (immune function decreased) Boscolo, 2001
5.25 uW/cm2	20 minutes of RFR at cell tower frequencies induced cell stress response Kwee, 2001
5 - 10 uW/cm2	RFR caused impaired nervous system activity Dumansky, 1974
6 uW/cm2	RFR induced DNA damage in cells Phillips, 1998

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8.75 uW/cm ²	RFR at 900 MHz for 2-12 hours caused DNA breaks in leukemia cells Marinelli, 2004
10 uW/cm ²	Changes in behavior (avoidance) after 0.5 hour exposure to pulsed RFR Navakatikian, 1994
10 - 100 uW/cm ²	Increased risk in radar operators of cancer; very short latency period; dose response to exposure level of RFR reported. Richter, 2000
12.5 uW/cm ²	RFR caused calcium efflux in cells - can affect many critical cell functions Dutta, 1989
13.5 uW/cm ²	RFR affected human lymphocytes - induced stress response in cells Sarimov, 2004
20 uW/cm ²	Increase in serum cortisol (a stress hormone) Mann, 1998
28.2 uW/cm ²	RFR increased free radical production in rat cells Yurekli, 2006
37.5 uW/cm ²	Immune system effects - elevation of PFC count (antibody producing cells) Veyret, 1991
45 uW/cm ²	Pulsed RFR affected serum testosterone levels in mice Forgacs, 2006
50 uW/cm ²	Cell phone RFR caused a pathological leakage of the blood-brain barrier in 1 hour Salford, 2003
50 uW/cm ²	An 18% reduction in REM sleep (important to memory and learning functions) Mann, 1996
60 uW/cm ²	RFR caused structural changes in cells of mouse embryos Somozy, 1991
60 uW/cm ²	Pulsed RFR affected immune function in white blood cells Stankiewicz, 2006
60 uW/cm ²	Cortex of the brain was activated by 15 minutes of 902 MHz cell phone Lebedeva, 2000
65 uW/cm ²	RFR affected genes related to cancer Ivaschuk, 1999
92.5 uW/cm ²	RFR caused genetic changes in human white blood cells Belyaev, 2005
100 uW/cm ²	Changes in immune function Elekes, 1996
100 uW/cm ²	A 24.3% drop in testosterone after 6 hours of CW RFR exposure Navakatikian, 1994
120 uW/cm ²	A pathological leakage in the blood-brain barrier with 915 MHz cell RF Salford, 1994

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500 uW/cm2	Intestinal epithelial cells exposed to 2.45 GHz pulsed at 16 Hz showed changes in intercellular calcium.	Somozy, 1993
500 uW/cm2	A 24.6% drop in testosterone and 23.2% drop in insulin after 12 hrs of pulsed RFR exposure.	Navakatikian, 1994
STANDARDS		
530 - 600 uW/cm2	Limit for uncontrolled public exposure to 800-900 MHz	ANSI/IEEE and FCC
1000 uW/cm2	PCS STANDARD for public exposure (as of September 1,1997)	FCC, 1996
5000 uW/cm2	PCS STANDARD for occupational exposure (as of September 1, 1997)	FCC, 1996
BACKGROUND LEVELS		
0.003 uW/cm2	Background RF levels in US cities and suburbs in the 1990s	Mantiply, 1997
0.05 uW/cm2	Median ambient power density in cities in Sweden (30-2000 MHz)	Hamnierijs, 2000
0.1 - 10 uW/cm2	Ambient power density within 100-200' of cell site in US (data from 2000)	Sage, 2000

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SAR (Watts/Kilogram)	Reference
0.000064 - 0.000078 W/Kg	Well-being and cognitive function affected in humans exposed to GSM-UMTS cell phone frequencies; RF levels similar near cell sites TNO Physics and
0.00015 - 0.003 W/Kg	Calcium ion movement in isolated frog heart tissue is increased 18% (P<.01) and by 21% (P<.05) by weak RF field modulated at 16 Hz Schwartz, 1990
0.000021 - 0.0021 W/Kg	Changes in cell cycle; cell proliferation (960 MHz GSM mobile phone) Kwee, 1997
0.0003 - 0.06 W/Kg	Neurobehavioral disorders in offspring of pregnant mice exposed in utero to cell phones - dose-response impaired glutamatergic synaptic transmission onto layer V pyramidal neurons of the prefrontal cortex. Hyperactivity and impaired memory function in offspring. Altered brain development. Aldad, 2012
0.0016 - 0.0044 W/Kg	Very low power 700 MHz CW affects excitability of hippocampus tissue, consistent with reported behavioral changes. Tattersall, 2001
0.0021 W/Kg	Heat shock protein HSP 70 is activated by very low intensity microwave exposure in human epithelial amnion cells Kwee, 2001
0.0024 - 0.024 W/Kg	Digital cell phone RFR at very low intensities causes DNA damage in human cells; both DNA damage and impairment of DNA is reported Phillips, 1998
0.0027 W/Kg	Changes in active avoidance conditioned behavioral effect is seen after one-half hour of pulsed radiofrequency radiation Navakatikian, 1994
0.0035 W/Kg	900 MHz cell phone signal induces DNA breaks and early activation of p53 gene; short exposure of 2-12 hours leads cells to acquire greater survival chance - linked to tumor aggressiveness. Marinelli, 2004
0.0095 W/Kg	MW modulated at 7 Hz produces more errors in short-term memory function on complex tasks (can affect cognitive processes such as attention and memory) Lass, 2002
0.001 W/Kg	750 MHz continuous wave (CW) RFR exposure caused increase in heat shock protein (stress proteins). Equivalent to what would be induced by 3 degree C. heating of tissue (but no heating occurred) De Pomerai, 2000
0.001 W/Kg	Statistically significant change in intracellular calcium concentration in heart muscle cells exposed to RFR (900 MHz/50 Hz modulation) Wolke, 1996

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0.0021 W/Kg	A significant change in cell proliferation not attributable to thermal heating. RFR induces non-thermal stress proteins (960 MHz GSM) Velizarov, 1999
0.004 - 0.008 W/Kg	915 MHz cell phone RFR caused pathological leakage of blood-brain barrier. Worst at lower SAR levels and worse with CW compared to Frequency of pathological changes was 35% in rats exposed to pulsed radiation at 50% to continuous wave RFR. Effects observed at a specific absorption (SA) of > 1.5 joules/Kg in human tissues Persson, 1997
0.0059 W/Kg	Cell phone RFR induces glioma (brain cancer) cells to significantly increase thymidine uptake, which may be indication of more cell division Staggs, 1997
0.014 W/Kg	Sperm damage from oxidative stress and lowered melatonin levels resulted from 2-hr per day/45 days exposure to 10 GHz. Kumar, 2012
0.015 W/Kg	Immune system effects - elevation of PFC count (antibody-producing cells) Veyret, 1991
0.02 W/Kg	A single, 2-hr exposure to GSM cell phone radiation results in serious neuron damage (brain cell damage) and death in cortex, hippocampus, and basal ganglia of brain- even 50+ days later blood-brain barrier is still leaking albumin (P<.002) following only one cell phone exposure Salford, 2003
0.026 W/Kg	Activity of c-jun (oncogene or cancer gene) was altered in cells after 20 minutes exposure to cell phone digital TDMA signal Ivaschuk, 1997
0.0317 W/Kg	Decrease in eating and drinking behavior Ray, 1990
0.037 W/Kg	Hyperactivity caused by nitric oxide synthase inhibitor is countered by exposure to ultra-wide band pulses (600/sec) for 30 min Seaman, 1999
0.037 - 0.040 W/Kg	A 1-hr cell phone exposure causes chromatin condensation; impaired DNA repair mechanisms; last 3 days (longer than stress response) the effect reaches saturation in only one hour of exposure; electro- sensitive (ES) people have different response in formation of DNA repair foci, compared to healthy individuals; effects depend on carrier frequency (915 MHz = 0.037 W/Kg but 1947 MHz = 0.040 W/Kg) Belyaev, 2008
0.05 W/Kg	Significant increase in firing rate of neurons (350%) with pulsed 900 MHz cell phone radiation exposure (but not with CW) in avian brain cells Beason, 2002

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0.09 W/Kg	900 MHz study of mice for 7 days, 12-hr per day (whole-body) resulted in significant effect on mitochondria and genome stability Aitken, 2005
0.091 W/Kg	Wireless internet 2400 MHz, 24-hrs per day/20 weeks increased DNA damage and reduced DNA repair; levels below 802.11 g Authors say "findings raise questions about safety of radiofrequency exposure from Wi-Fi internet access devices for growing organisms of reproductive age, with a potential effect on fertility and integrity of germ cells" (male germ cells are the reproductive cells=sperm) Atasoy, 2012
0.11 W/Kg	Increased cell death (apoptosis) and DNA fragmentation at 2.45 GHz for 35 days exposure (chronic exposure study) Kesari, 2010
0.121 W/Kg	Cardiovascular system shows significant decrease in arterial blood pressure (hypotension) after exposure to ultra-wide band pulses Lu, 1999
0.13 - 1.4 W/Kg	Lymphoma cancer rate doubled with two 1/2-hr exposures per day of cell phone radiation for 18 months (pulsed 900 MHz cell signal) Repacholi, 1997
0.14 W/Kg	Elevation of immune response to RFR exposure Elekes, 1996
0.141 W/Kg	Structural changes in testes - smaller diameter of seminiferous Dasdag, 1999
0.15 - 0.4 W/Kg	Statistically significant increase in malignant tumors in rats chronically exposed to RFR Chou, 1992
0.26 W/Kg	Harmful effects to the eye/certain drugs sensitize the eye to RFR Kues, 1992
0.28 - 1.33 W/Kg	Significant increase in reported headaches with increasing use of hand-held cell phone use (maximum tested was 60 min per day) Chia, 2000
0.3 - 0.44 W/Kg	Cell phone use results in changes in cognitive thinking/mental tasks related to memory retrieval Krause, 2000
0.3 - 0.44 W/Kg	Attention function of brain and brain responses are speeded up Preece, 1999
0.3 - 0.46 W/Kg	Cell phone RFR doubles pathological leakage of blood-brain barrier permeability at two days (P=.002) and triples permeability at four days (P=.001) at 1800 MHz GSM cell phone radiation Schirmacher, 2000
0.43 W/Kg	Significant decrease in sperm mobility; drop in sperm concentration; and decrease in seminiferous tubules at 800 MHz, 8-hr/day, 12 weeks, with mobile phone radiation level on STANDBY ONLY (in rabbits) Salama, 2008

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0.5 W/Kg	900 MHz pulsed RF affects firing rate of neurons (Lymnea stagnalis) but continuous wave had no effect Bolshakov, 1992
0.58 - 0.75 W/Kg	Decrease in brain tumors after chronic exposure to RFR at 836 MHz Adey, 1999
0.6 - 0.9 W/Kg	Mouse embryos develop fragile cranial bones from in utero 900 MHz The authors say "(O)ur results clearly show that even modest exposure (e.g., 6 min daily for 21 days)" is sufficient to interfere with the normal mouse developmental process" Fragopoulou, 2009
0.6 and 1.2 W/Kg	Increase in DNA single and double-strand DNA breaks in rat brain cells with exposure to 2450 MHz RFR Lai & Singh, 1996
0.795 W/Kg	GSM 900 MHz, 217 Hz significantly decreases ovarian development and size of ovaries, due to DNA damage and premature cell death of nurse cells and follicles in ovaries (that nourish egg cells) Panagopoulous, 2012
0.87 W/Kg	Altered human mental performance after exposure to GSM cell phone radiation (900 MHz TDMA digital cell phone signal) Hamblin, 2004
0.87 W/Kg	Change in human brainwaves; decrease in EEG potential and statistically significant change in alpha (8-13 Hz) and beta (13-22 Hz) brainwave activity in humans at 900 MHz; exposures 6/min per day for 21 days (chronic exposure) D'Costa, 2003
0.9 W/Kg	Decreased sperm count and more sperm cell death (apoptosis) after 35 days exposure, 2-hr per day Kesari, 2012
< 1.0 W/Kg	Rats exposed to mobile phone radiation on STANDBY ONLY for 11-hr 45-min plus 15-min TRANSMIT mode; 2 times per day for 21 days showed decreased number of ovarian follicles in pups born to these pregnant rats. The authors conclude "the decreased number of follicles in pups exposed to mobile phone microwaves suggest that intrauterine exposure has toxic effects on ovaries." Gul, 2009
0.4 - 1.0 W/Kg	One 6-hr exposure to 1800 MHz cell phone radiation in human sperm cells caused a significant dose response and reduced sperm motility and viability; reactive oxygen species levels were significantly increased after exposure to 1.0 W/Kg; study confirms detrimental effects of RF/MW to human sperm. The authors conclude "(T)hese findings have clear implications for the safety of extensive mobile phone use by males of reproductive age, potentially affecting both their fertility and the health and wellbeing of their offspring." De Iulii, 2009
1.0 W/Kg	Human semen degraded by exposure to cell phone frequency RF increased free-radical damage. De Iulii, 2009

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1.0 W/Kg	Motility, sperm count, sperm morphology, and viability reduced in active cell phone users (human males) in dose-dependent manner. Agarwal, 2008
1.0 W/Kg	GSM cell phone use modulates brain wave oscillations and sleep EEG Huber, 2002
1.0 W/Kg	Cell phone RFR during waking hours affects brain wave activity. (EEG patterns) during subsequent sleep Achermann, 2000
1.0 W/Kg	Cell phone use causes nitric oxide (NO) nasal vasodilation (swelling inside nasal passage) on side of head phone use Paredi, 2001
1.0 W/Kg	Increase in headache, fatigue and heating behind ear in cell phone users Sandstrom, 2001
1.0 W/Kg	Significant increase in concentration difficulties using 1800 MHz cell phone compared to 900 MHz cell phone Santini, 2001
1.0 W/Kg	Sleep patterns and brain wave activity are changed with 900 MHz cell phone radiation exposure during sleep Borbely, 1999
1.4 W/Kg	GSM cell phone exposure induced heat shock protein HSP 70 by 360% (stress response) and phosphorylation of ELK-1 by 390% Weisbrot, 2003
1.46 W/Kg	850 MHz cell phone radiation decreases sperm motility, viability is significantly decreased; increased oxidative damage (free-radicals) significantly decreased; increased oxidative damage (free-radicals) Agarwal, 2009
1.48 W/Kg	A significant decrease in protein kinase C activity at 112 MHz with 2-hr per day for 35 days; hippocampus is site, consistent with reports that RFR negatively affects learning and memory functions Paulraj, 2004
1.0 - 2.0 W/Kg	Significant elevation in micronuclei in peripheral blood cells at 2450 MHz (8 treatments of 2-hr each) Trosic, 2002
1.5 W/Kg	GSM cell phone exposure affected gene expression levels in tumor suppressor p53-deficient embryonic stem cells; and significantly increased HSP 70 heat shock protein production Czyz, 2004
1.8 W/Kg	Whole-body exposure to RF cell phone radiation of 900-1800 MHz 1 cm from head of rats caused high incidence of sperm cell death; deformation of sperm cells; prominent clumping together of sperm cells into "grass bundle shapes" that are unable to separate/swim. Sperm cells unable to swim and fertilize in normal manner. Yan, 2007

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2.0 W/Kg	GSM cell phone exposure of 1-hr activated heat shock protein HSP 27 (stress response) and P38 MAPK (mutagen-activated protein kinase) that authors say facilitates brain cancer and increased blood-brain barrier permeability, allowing toxins to cross BBB into brain Leszczynski, 2002
2 W/Kg	900 MHz cell phone exposure caused brain cell oxidative damage by increasing levels of NO, MDA, XO and ADA in brain cells; caused statistically significant increase in 'dark neurons' or damaged brain cells in cortex, hippocampus and basal ganglia with a 1-hr exposure for 7 consecutive days Ilhan, 2004
2.6 W/Kg	900 MHz cell phone exposure for 1-hr significantly altered protein expression levels in 38 proteins following irradiation; activates P38 MAP kinase stress signalling pathway and leads to changes in cell size and shape (shrinking and rounding up) and to activation of HSP 27, a stress protein (heat shock protein) Leszczynski, 2004
2.0 - 3.0 W/Kg	RFR accelerated development of both skin and breast tumors Szmigielski, 1982
2 W/Kg	Pulse-modulated RFR and MF affect brain physiology (sleep study) Schmidt, 2012

STANDARDS	
0.08 W/Kg	IEEE Standard uncontrolled public environment (whole body) IEEE
0.4 W/Kg	IEEE Standard controlled occupational environment (whole body) IEEE
1.6 W/Kg	FCC (IEEE) SAR limit for 1 gram of tissue in a partial body exposure FCC, 1996
2 W/Kg	ICNIRP SAR limit for 10 grams of tissue ICNIRP, 1996

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