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Health Precautions Science

Distance and the Inverse Square Law

The **inverse square law** states that the magnitude of one's exposure drops dramatically, proportionally to the square of one's distance from the source.
See also: **Standards** | **Effects By Power Level** | **SAR**

The following tables tell you the approximate distances required to reach the **Salzburg Precautionary Limit of 2001 and 2002**. The purpose of the calculations below is to demonstrate that the inverse square law (defined at right) is not as helpful as you may think, when the level at which health effects occur is far below the transmit power of the devices (and international standards).

> The **inverse square law** states that the magnitude of one's exposure drops dramatically, proportionally to the square of one's distance from the source.
>
> **Conversely,** the magnitude of one's exposure also increases dramatically with proximity.

After performing the calculations, one realizes that having a cordless phone station using DECT non-stop radiation, or a Wi-Fi router in the same room provides similar (or greater) power densities to living near a cell tower. Sleeping with an alarm clock within one foot of your head is like having one's personal electricity tower. There are studies showing that both cell towers (e.g., see studies by Robert Santini) and cordless phones (e.g., see studies by Leonnart Hardell) can be a potential health risk. **Effects** have been reported at very low levels.

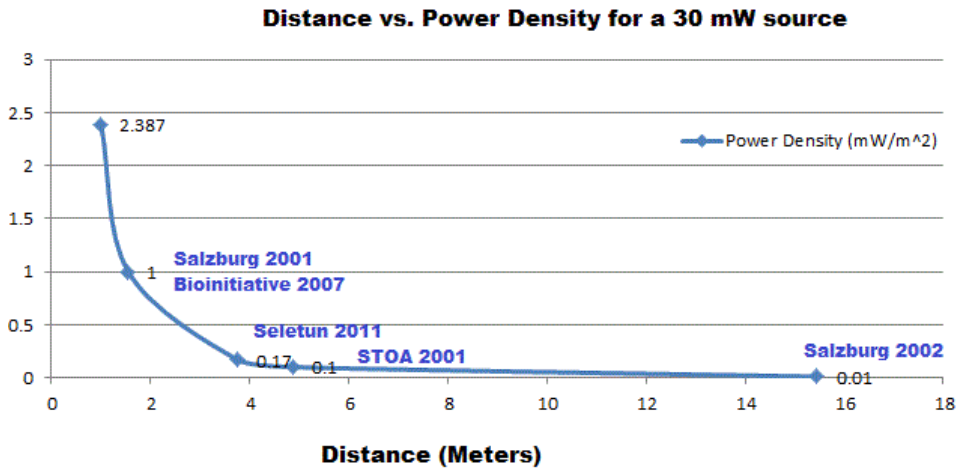
Below, find the comparisons between:

- **Wi-Fi devices, Cordless Phones, and Mobile phones** and **Smart Meters**, **Cell Towers**, and **Radio Towers**
- **Alarm Clock** and **Power Lines**

Note that the measurements below assume radiation in direct line of sight. Wood and dry wall do very little to block wireless signals. Windows with low-E coating or low-E films, concrete, and brick, may provide higher levels of attenuation, and are not factored into the calculations below.

1. Wi-Fi Router (microwave exposure) with transmit power (30mW)





Method of Calculation: We can approximate the average power density using the equation $P*G/4\Pi r^2$, where $4\Pi r^2$ is the surface area of a sphere and G is the antenna gain. For approximate purposes, the numbers calculated below assume an isotropic antenna with uniform intensity.

Distance	Approx. Power Density**	Notes
30cm	**26.5mW/m^2**	Calculation: 30/4Π(0.3*0.3) =~26.5
1m	**2.387 mW/m^2**	Calculation: 30/4Π =~2.387
1.55m	**1 mW/m^2**	Salzburg Precautionary Limit (2001) BioInitiative Recommendation — (2007)
3.7m	**170 microW/m^2**	Seletun Scientific Panel (2011)
5m	**100 microW/m^2**	STOA (2001)
15.5m	**10 microW/m^2**	New Salzburg Precautionary Outdoor (2002)

**Note that directional antennae are not factored in here, which could underestimate the power in certain directions and overestimate the power in other directions. For directional antennae, we must factor in gain to calculate the maximum required distance. The distances in this section may need to be additionally adjusted by multiplying the distances by the square root of the gain. This multiplication factor might vary anywhere from 1.3 to 7, depending upon the antenna's gain.

The following **presentation** by Graham Philips shows that a Wi-Fi enabled laptop at 50 cm can provide more radiation than a mobile phone mast (cell tower) at 100 meters (See slide 13).

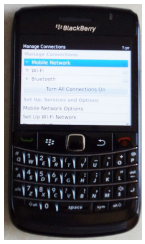
Recommended Distances for Wireless Devices

The following table shows the minimal distances required to satisfy the Salzburg 2001 Limit and 2002 Outdoor Limit based upon the assumption of an isotropic antenna. According to the Table of Effects mentioned above, some effects are still seen at the Salzburg(2001) limit. Hence, the Salzburg(2002) limit is preferrable, or somewhere in between. To calculate these numbers yourself given the transmit power of a wireless product, refer to the **Formulas** page.

****Note:** Since the antenna may be directional rather than isotropic, the distances below may be higher depending upon the direction and the antenna gain. In some directions, the distances required could be anywhere from 1.3 to 7 times higher depending upon the antenna's gain.

These are only general guidelines. Different wireless routers will vary in strength. Some wireless routers allow you to reduce the transmitting power, and even schedule the hours during which Wi-Fi will be turned on.

Device	Duration Transmit Power	Salzburg (2001)**	Salzburg (2002)**	Comments
 Wi-Fi Routers (Lower Power)	Continual from router or access point, even when not in use 30 mW (~15dBm)	**1.55m**	**15.5m**	Note that Wi-Fi enabled computers may be similar in strength to 15 dBm. If possible, choose a Wi-Fi router with configurable strength and scheduling ability. For example, one particular model provides 10

Wi-Fi Routers (Exterior AP) Wi-Fi Routers (High Power)	63 mW (~18dBm) 500 mW (~27dBm)	**2.24m** **6.3m**	**22.4m** **63m**	levels of power, allowing one to drastically reduce the strength. Wi-Fi routers and Digital Cordless Systems are allowed up to a transmit power as high as 1W (requiring 9m/90m recommendations for Salzburg (2001) and (2002) respectively.
Cordless Phone System **(Earlier Analog)**	Standby from base station, when not in use ~1mW	**0.3m**	**3m**	Note that very early cordless phones were by comparison only ~1mW, but now the FCC allows a higher transmitter power of 1W. See **reference**.
Cordless Phone System **(Modern Digital)** 	Continual from base station, even when not in use Peak: ~250mW Mean: ~10mW	**4.5m**	**45m**	While the average output power is ~10mW, it is in the form of 100 bursts per second of **250 mW** power, each for ~0.4 ms, according to **HPA on Cordless Phones**. Hence, its peak output power is comparable to a mobile phone. The pulsing on/off signals are believed to be dangerous.
Mobile Phone  	**Settings** determine duration of exposure ~125mW (power class 4) ~250 mW (power class 3) 600mW Adaptive power	**3.2m** **4.5m** **6.9m**	**32m** **45m** **69m**	To reduce the duration of exposure, turn off data services like **"Mobile Data" and "Wi-Fi"** except when needed, turn off Background Data, or increase **auto-sync intervals**, and avoid use where signal reception is weak. Although speaker mode or a wired headset at 1 meter's distance greatly reduces the power density, it may not be enough to achieve the precautionary limit. By adaptive power control, a cell phone may adjust to a lower power level based on proximity to the nearest base station.

See **Wikipedia site on relative strengths of wireless transmissions**.

2a. Smart Meter (at 1 W, or 2.5 W after factoring in gain)



Distance	Approximate power density assuming 4 dBi gain	Notes
1m	**199 mW/m^2**	1000mW*10^0.4/(4Π(1m)^2)=199 mW/m^2
3m	**22 mW/m^2**	
14m	**1 mW/m^2**	<== Salzburg Precautionary Limit (2001)
44m	**100 µW/m^2**	<== EU STOA 2001

140m	**10 μW/m^2**	<== New Salzburg Precautionary Outdoor (2002)

Method of Calculation: The power density is estimated using the equation **P*G/4Πr^2**, where G is the gain from the directional antenna (4 dBi translates to 10^(4/10)=2.5) and 4Πr^2 is the surface area of a sphere.

See an **actual smart meter measurement** from Stop Smart Meters!. Note that the meter used in this video uses μW/cm^2. To convert from μW/cm^{2}to mW/m^2, multiply by 10. Thus, 8 to 40 μW/cm^2 converts to 80 to 400 mW/m^2. For more information on smart meters, see **What is a Smart Meter?**.

2b. Cell Tower/Mobile Phone Mast (10 W)



Distance	Approximate power density assuming 17 dB gain	Notes
100m	**4 mW/m^2**	10000mW/(4Π(100m)^2)*10^(17/10)=0.08*50=4 mW/m^2
200m	**1 mW/m^2**	<== Salzburg Precautionary Limit (2001)
630m	**100 μW/m^2**	<== EU STOA 2001
2 km	**10 μW/m^2**	<== New Salzburg Precautionary Outdoor (2002)

Method of Calculation: The power density can be estimated using the equation **P*G/4Πr^2**, where G is the gain from the directional antenna and 4Πr^2 is the surface area of a sphere. In practice, the cell tower radiation is not usually isotropic but is **directional with main lobe and side lobes**. Note that a directional antenna focuses the power in certain directions, resulting in higher required distances. If we assume a directional antenna with gain of 17 dB = 50, then the distances required in certain directions could require a multiplication factor of sqrt(50)=7. For more information, see **Report on Cell Tower Radiation** submitted to Secretary, DOT, Delhi, Prepared by Prof. Girish Kumar, IIT.

Recommended Distances for Wireless Towers

Note: Many surveys find cancer or other health effects within 300-400 meters.

Transmitter	Transmit Power assume 17dB gain	Salzburg (2001)*	Salzburg (2002)*
Very Weak Transmitter	1 W	**63m**	**630m**
Weak Cell Tower	10 W	**200m**	**2 km**
Strong Cell Tower	50 W	**446m**	**4.46 km**
Stronger Cell Tower	100 W	**630m**	**6.3 km**

- **Note**: If there are more transmitters, the power output can be higher. For example, the HPA UK website suggests that ten 10W transmitters could result in a power output from 10 to 100 W.
- **Note***: The calculations above assume a 17 dB gain (a factor of 10^1.7=50) as suggested by Professor Kumar. To accommodate this, the distance is multipled by a factor of approximately sqrt(50)=7, as compared to an isotropic antenna model.

3. Radio Tower

Note: Vatican radio tower study found cancer risk within a 5.5 mile radius = **8.85 km**. The radio tower is said to include a 500 kW transmitter for the Far East and Latin America.

Radio Tower	Transmit Power	Salzburg	Salzburg

		(2001)	(2002)
Radio Tower	6 kW	**690m**	**6900m**
Radio Tower	20 kW	**1.26 km**	**12.6 km**
Strong Radio Tower	100 kW	**2.82 km**	**28.2 km**
Stronger Radio Tower	500 kW	**6.3 km**	**63 km**
Very Strong Radio Tower	1000 kW	**8.9 km**	**89.2 km**

Method of Calculation: We can approximate the power density using the equation $P*G/4\Pi r^2$, where $4\Pi r^2$ is the surface area of a sphere and G is the antenna gain. Below we will assume an omnidirectional isotropic antenna with G=1.

4. Alarm Clock (Power Line Exposure)

Note that power line (AC) magnetic fields drop much more quickly down to levels thought to be safe.



Distance	Approximate magnetic field	Notes
3 in.	**29.2 mG**	Measured by Bell 4180 gaussmeter
6 in.	**7.5 mG**	
9 in.	**3.1 mG**	Childhood Cancer epidemiology studies
12 in.	**1.6 mG**	Infertility study. Ideally < 1mG
16 in.	**0.8 mG**	Better
19 in.	**0.5 mG**	Even better

- **Comment**: The reduction typically occurs rapidly with a meter of distance. Meanwhile, the wireless power density reduction of 100,000+ times needed to satisfy the recommended safety limits, requires many meters.

5. Power Lines

Power Line Source	Approximate Distance to reach 2mG
Alarm clock(above)	**Between 9 and 12 inches**
11 kV lines	**~25m**
66 kV lines	**~50m**
Strongest 400 kV lines	**~150m**

These approximations are taken from "Buying an "EMF Safe" Property - 2. Powerlines and pylons" from Powerwatch UK and the PowerWatch Handbook, p.43. However, it is stressed that one should **measure** the magnetic field to be sure. Even in the absence of power lines, there are other factors that can also influence the power line magnetic field.

Furthermore, note that ideally, the target level should be < 1 mG, with an even stricter guideline of < 0.2 mG for sleeping quarters. See the **Power line Fact Sheet** and the **SBM 2008 standard for power lines** which recommend levels < 1 mG.

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