WiFi in the Home

This document is a summary of what I've learned during a few weeks of trying to decode the conflicting information about the health effects of WiFi, or wireless computer networking in the home. It was spurred by my frustration at the polarities of information, from techies pooh-poohing all questions of health from WiFi or cell phones, to alarmist voices that seemed unable to distinguish cell phones from WiFi, or to realistically address the current state of the science investigating health effects (ie how much certainty there is at this point, how many studies have been replicated, and similar standard steps in the maturation of a new line of scientific inquiry). Nowhere, it seemed, was there a source of information that looked at both poles and made an honest attempt to cross-check the assumptions being made and to assess, with an open mind, the real situation. With the help of a few golden needles in the haystack of chatter, here is such an attempt.

From the start, it will be helpful to bear in mind that the radio transmissions from cell phones are six to twenty times more powerful than WiFi signals, and that increasing distance from the WiFi base station decreases exposure levels dramatically. As the British Health Protection Authority states, WiFi equipment creates only a fraction of the signal people normally get from cell phones: "When we have conducted measurements in schools, typical exposures from WiFi are around 20 millionths of the international guideline levels of exposure to radiation. As a comparison, a child on a mobile phone receives up to 50 per cent of guideline levels." The HPA has similarly equated 20 minutes of cell phone use with a year of WiFi exposure. *(Note: A convincing analysis of the HPA numbers suggests that the difference is not quite so great, concluding that the WiFi exposure is actually one ten-thousandth of the guidelines, and cell phone exposure closer to 1/200th, still a 50-fold difference, equating 20 minutes on a cell phone with 16 hours in a WiFi classroom—here assuming that at least one computer is triggering the base station to be active at all times. In home settings, when the base station is active only a small proportion of the time, the WiFi equivalent would be much more, more like 300 hours.)* Still, these low levels may have biological effects. However, even the extremely precautionary standards proposed by the BioInitiative project lead them to state that "this target level does not preclude further rollout of WiFi technologies," though they do encourage wired alternatives, especially in schools where many computers are in use.

Since this began as a personal question, some details herein relate to my specific circumstances: the FM radio received levels are for Santa Fe and Albuquerque, NM, and the calculated radiated energy at various distances from a WiFi base station use the Apple Airport Extreme as the source, which is on the high end of signal strength among home and coffee-shop base stations (see page 8 for more details), so the received levels reported here at any given distance are likely to be higher than most people experience.

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Basics: Measuring Electromagnetic Effects

WiFi, using an Airport base station or similar wireless hub unit, sends out high-frequency radio waves that create Electrical Fields (measured in voltage over a distance) and sends electrical energy out in a sphere (measured in density of electrical energy received in an area). Both decrease with distance, as the energy spreads in a spherical pattern and is diffused across larger areas.

EF (electrical field) exposure:
Electrical fields are measured in V/m (difference in voltage of across a meter).

2X distance=1/2 EF
10X distance= 1/10 EF

Inverse but linear, dealing just with a loss of EF intensity across a distance

Electrical Power Flux Density (PFD) exposure:
Watts are a unit of power: 1 watt equals 1 joule of energy per second, with PFD measured in Watts per square meter, W/m^2. (or, as levels decrease as in our situations, in mW/cm^2 (milliWatts, or one-thousandth of a Watt) or uW/cm^2 (microwatts, or one-millionth of a Watt)

2x distance = 1/4 power
10x distance = 1/100th power

Inverse square, because we're dealing with energy per area

At higher frequencies (shorter wavelengths), the electromagnetic energy is more commonly assessed as PFD, calculated as watts/square meter (or milliwatts/microwatts per square centimeter), rather than as an EF. This is because EF is most relevant to physiological effects when within a wavelength or few of source, and power density is more relevant in the far-field, since PFD (W/m2) are really meant to assess thermal (heating) effects. Some precautionary experts consider EF (V/m) to still be more useful for radio frequency energy when considering non-thermal effects. Therefore, this paper calculates WiFi exposures using both EF and PFD measurements.

Can do cross-calculations between the two, and some safety standards use one or both.
http://www.compeng.com.au/emc_conversion_tables.asp

Sources of Electromagnetic influence in the home

Household EF (electrical fields)
Created by the A/C current running through wires in our walls, 60Hz (very low frequency, so that means VERY long wavelengths—on the scale of 5 thousand kilometers per wave!)

Create Electrical Fields at 5-10 V/m (some places in house as low as 1 V/m)
A few estimates say house EFs can be higher, up to 10-50 V/m
Near small appliance: 20-200 V/m—near a laptop can be 5 V/m@1 foot, 18 V/m @6 inches

At these frequencies and wavelengths, official standards tend toward 600 V/m as the safe threshold. Some countries and agencies don't even set an official safety limit, and some set it at 10,000 V/m; the reason, I think, is that the wavelengths are so long that our bodies aren't big enough to feel the electrical differential over the scale we experience the energy at. At these scales, more concern is placed on *magnetic* fields created by the electricity, measured in Gauss and Teslas. But this does not concern us with WiFi, with its much shorter wavelengths.

Radio signals
FM Radio and TV signals are in the 88-200 MHz range (88-200 million Hz).
AM Radio uses the 550-1610 kHz range (550,000Hz to 1.6 million Hz)

What is the level of the radio signal when we receive it?
Can be as high as .7 V/m (in areas near the biggest station in Albuquerque)
In Albuquerque there are several stations that people receive at .1-.2 V/m
In Santa Fe, by and large, we receive our stations at levels of .01-.05 V/m

FM and TV frequency waves have wavelengths of just about the size that our bodies can act as antennae (5-10 feet); therefore, these signals have the greatest effect on our bodies, and the official safety levels are lower than those for either A/C or WiFi frequencies/wavelengths. ("official" safety standards: 600 V/m for lower frequencies, roughly 25 V/m for radio frequencies, and 61 V/m for WiFi frequencies).

Cell Phones
Cell phones use frequencies of 824-894 MHz, and run at powers of .6 Watts to 2 Watts (newer ones are generally lower power, because of improved digital signal processing so they can work well with less signal strength). Wavelength at this frequency is around a foot.

Since they're used against our heads, the power density we receive in our bodies, especially our heads, is very high, at least compared to WiFi. As we'll see below, there are many studies that suggest cellphone-scale power can cause a range of physical effects (though by and large the science is coming up with roughly equal positive and negative results so far).

Airport uses much less power, so even at close range is roughly 10x less powerful than a cell phone, and as distance increases, exposures drop quickly.

WiFi Airport base station
WiFi uses higher frequency signals (2.4 GHz, which is 2400 MHz, and 5.8 GHz). Higher frequency means shorter wavelengths, much shorter (a few inches), so that they are not in a scale that creates significant Electrical Fields. At this scale, more attention is paid to the Power density exposures (W/m^2, though here so small that we measure in microWatts/cm^2; microWatts are one millionth of a Watt)

Power output f the Airport is .1W (100 mW); my computer's side of the connection generates .035W (35 mW). Many older base stations, including the rounded Airport Base

Station, also use .035W.

Cell phones used to be 2W (20 times more than .1W); mostly now are 600 mW (.6W, 6 times more powerful than Airport, 10-100x more powerful than exposure at common distances from Airport)

A 100 mW Airport WiFi base station (Airport Extreme, early 2008) creates Electrical Fields and power densities as follows:
(electrical power density in parentheses)

Important note: these propagation figures are based on simple mathematical spreading of the signal over increasing space. They assume an ideal, perfectly open setting; **any walls, furniture, etc, will reduce these figures dramatically**. Indeed, in my particular case, there is little or no signal at distances beyond 15-20m, though the Airport is rated to be able to deliver a signal for up to 50m.

At 1 foot: 5.22 V/m (7.2 uW/cm^2—microWatts per square cm)
At 1 meter: 1.74 V/m (.8 uW/cm^2)
At 2 meters: .87 V/m (.2 uW/cm^2)
At 3 meters: .58 V/m (.09 uW/cm^2)
At 4 meters: .44 V/m (.05 uW/cm^2)
At 9 meters: .19 V/m (.01 uW/cm^2)
At 10 meters: .17 V/m (.008 uW/cm^2)
At 20 meters: .08 V/m (.0015 uW/cm^2)
At 30 meters: .06 V/m (.001 uW/cm^2)

"Safe" levels

(for frequencies used by WiFi)

The BioInitiative Report
http://bioinitiative.org/report/index.htm
Most comprehensive precautionary report, over 600 pages, mostly spent summarizing research. Their final recommendation is that the EF not exceed:

.614 V/m outdoors (.1 uW/cm^2) We'll call this the **precautionary** standard
.19 V/m indoors (.01 uW/cm^2)
It's not clear why a difference--no other standards make this differentiation.
We'll call this the **very precautionary** standard

The BioInitiative "precautionary" recommendations match those that emerged from the Salzburg International Conference on Cell Phone Tower Siting in 2000.

Official gov't/electrical industry safety thresholds (for the frequencies used by WiFi)

61 V/m: Canada, Sweden, International Commission on Non-ionizing Radiation Protection (ICNIRC), IEEE (electrical engineers)
= 1mW/cm2 (1000 uW/cm2)

Other similar standards, different units/circumstances:
Sweden: .08 W/kg
UK: 194 V/m, 100 W/m2 (10 mW/cm^2)
US: no V/m limit, 30 W/m2 (3 mW/cm^2), cell phone .08 W/kg (whole body), 1.6 W/kg (partial body)
ICNIRP: 2 W/kg (head and trunk), 4 W/kg (limbs), .08 W/kg (whole body)
IEEE: 1mW/cm^2 (=1000 uW/cm2)

So the *precautionary limit is 1/100th of what the "official" bodies suggest* (.6 V/m rather than 60V/m) for Electric Fields, and about 1/10,000th of what they suggest for electrical energy power exposure (.1 uW/cm2 rather than 1000uW/cm2)

The indoor "very precautionary" limit is 1/1000th of what the official bodies say is safe for EFs and 1/100,000th for energy power density exposure.

Non-thermal concerns

The difference between the standards is largely because the "official" standards are only trying to prevent "thermal" effects (EF or power that subtly heats liquid in cells, causing damage), while the "precautionary" limits aim to protect from non-thermal effects, the nature of which are not clearly understood or definitively proven, but seem increasingly likely to be occurring. In both cases, the standards suggested add a hundred- or thousand-fold safety buffer to the radiation level they deem safe (i.e., standard limits are significantly lower than levels that cause thermal effects, and precautionary limits are significantly lower than levels that may cause non-thermal effects).

I've summarized the good, detailed information on recent research into non-thermal effects found in the BioInitiative Report in my notes elsewhere, but the bottom line is that, at least according to the BioInitiative Report,any non-thermal effects have so far been seen in studies using far higher energy levels than the Airport is capable of emitting (in the range of hundreds to thousands of times higher EFs and thousands to hundreds of thousands of times higher power densities).

In all areas of study (effects on gene expression, micronucleus, DNA, chromosome, immune system, cognitive/neurology), there is close to an even split between studies that find effects at low (non-thermal) levels and studies that find no effect. Few studies on either side have been successfully replicated. But even considering just the studies that DO find an effect, virtually all use doses at or above the dose of a cell phone against one's head.

Tissue and cellular damage due to cell phone radiation is often assessed using yet another measurement standard: the Specific Absorption Rate (SAR), measured in Watts per kilogram of tissue. Cell phones generally create SARs of .35 to 1.5 W/kg, and the "official" safety threshold is 1.6 W/kg. The general range of exposure levels used in these studies is from .6 W/kg to 5 W/kg (though some studies used as much as 5-10 W/kg, and even some of these found no effect). As we've noted above, cell phones operate at .6 to 2 Watts, and Airport operates at .1 Watt. Thus, even if an Airport were held to one's head, SAR is unlikely to exceed .1 W/kg, and is more apt to be .05 W/kg or less; of course, at a few feet distant, SARs would be virtually nill.

Switching to the Power Flux Density (W/cm^2) standard we are using for WiFi, several studies find evidence of possible effects at 1-30 mW/cm^2 (one mW, milliwatt, is 1000 microWatts, uW—immediately next to an Aiport, the PFD is 7 uW/cm^2, or .007 mW/cm^2).

Cell nucleus effects were seen in plants at 40-170 V/m (an Airport at 1 foot emits 5 V/m).

The lowest levels used in studies that showed possible effects were 1 uW/cm^2 (about like an Airport at 3 feet) and .09W/kg (holding Airport against your skin); these are extreme outliers among studies, with virtually all other studies (both positive and negative results) using at 5-100 times more power.

Studies of cellular change at non-thermal doses raise definite concerns about cell phone

exposures (especially prolonged, regular use), but are not yet providing any evidence for concern about the much lower exposures from WiFi. Unfortunately, it is common to see blanket statements suggesting that there is clear evidence of harm in studies at powers "commonly used for wireless communication", without making the distinction between a cell phone against your head and a base station's lower power and much greater distance.

Even mixed research results are a valid reason to take precautions when exposures are in the ranges with repeated indications of harmful effects: 1 mW/cm2, 1W/kg, and possibly 10-50 V/m. Airport operates at levels much lower in all these scales (tens to thousands times lower).

The BioInitiative team does not state the reason that they set their standards so much lower than even the non-thermal research so far might suggest (10,000 times lower as measured in W/cm2, twenty to a hundred times lower as measured in V/m). Perhaps it's just solid precaution, or precautionary response to the most extreme, and unconfirmed, research. As noted above, their proposal matches the one made after a 2000 Salzburg conference to address the issue.

It's worth noting that, in fact, the "standard" safety limits—designed as conservative protection against thermal effects—are not that out of line with even this leading edge "non-thermal effects" research. Most studies finding effects do so at 5-30 mW/cm2, with some as low as 1 mW/cm2, which is the accepted limit for exposure at WiFi frequencies. This is certainly pushing the limit dangerously close to the observed effects level (there is usually some conservative buffer built in). Likewise, the 61 V/m limit is slightly out of synch with some observed effects at 10-50 V/m; a reduction to 6 V/m or less could be a very reasonable step, and the BioInitiative team chose to take it one order of magnitude lower, to .6 V/m.

How Airport compares to existing EF and both safety standards

Once again, remember that in almost all real-world situations, these descriptions of exposure levels at a given distance are over-estimates of the effect, for two main reasons:

First, the distances are based on a perfect, ideal transmission setting (open air with no obstructions). Furniture, other electrical fields, and especially walls will reduce the EF and PFD dramatically, so that virtually all of these figures (especially at over 6 feet) will likely be much lower. Walls can reduce signal strength by 20%; glass and solid doors can reduce signal strength by 30-60% (from Netgear website). For example, see the second section below: the "very precautionary" limit is shown to be reached at 27 feet. In any household situation, it is nearly certain that this safety threshold will be much closer, perhaps as little as 10 or 15 feet if walls are involved. In short, you'd either decrease the distance that is noted for a given threshold, or know that the description of the effect would actually be less than noted at a given distance.

Second, the health standards are based on a continuous exposure over a period of time, while in most cases, use of a WiFi connection will reach the levels we speak of below only in short bursts as data is actually being transferred to or from a website (ie, while a page is loading). An exception may be watching streaming video, during which the transmissions will be closer to continuous; in this situation, the figures below are likely more accurate, if there are no walls or other obstructions.

Electrical Fields (EF) from Airport are:

- 1 foot away (5.2 V/m): half the EF of the lowest EF researchers suggest can cause non thermal effects
- 1 foot away (5.2 V/m): less than 1/10th of "official" safety level
- 3 feet away (1.7 V/m): less than 1/30th of "official" safety level
- 8 feet away (.6 V/m): at the "precautionary" safety level
- 9 feet away (.58 V/m): less than 1/100th of "official" safety level
- 27 feet away (.19 V/m): at the "very precautionary" safety level
- 100 feet away (if the signal reaches): about like a solid radio signal (.05 V/m)

Electrical energy Power Flux Density (PFD) per unit area from Airport is:

- 1 foot away (7.2 uW/cm^2), less than 1/100th of energy at the low end of range used by most researchers studying non-thermal effects
- 1 foot away (7.2 uW/cm^2), 1/100th of "official" safety level
- 3 feet away (.8 uW/cm^2), less than lowest energy used in research that has shown possibility of non-thermal effects
- 3 feet away (.8 uW/cm^2), less than 1/1000th of "official" safety level
- 8 feet away (.1 uW/cm^2), equal to "precautionary" safety level
- 9 feet away (.09 uW/cm^2), less than 1/10,000th of "official" safety level
- 27 feet away (.0015 uW/cm^2), equal to the "very precautionary" safety level
- 100 feet away, if signal reaches (.001 uW/cm^2): 1/100th of precautionary level and 1/10th of very precautionary level

One more important additional consideration: The computer that is accessing a WiFi network also sends out short bursts of radio waves at the same frequency as the base station.

It will generally operate at a lower power, .035 Watts. This is just over a third the power of the Airport (.1 Watts). So all the distance thresholds above for the base station would be roughly a third as far for EF thresholds and one-ninth as far for energy density. For

example, you'd meet the "precautionary" PFD safety level at about a foot away from computer, rather than 8 feet away from Airport base station; even direct contact with the computer leaves you under the "official" safety threshold.

Also, both the Airport base station and the receiving computer send full-strength radio signals only when actively communicating with each other (for most users, when loading a web page or sending or receiving email).

Finally, *if you are not using an Airport Extreme, your base station may well create EFs and PFDs of a different level than those reported here, most likely lower.* As noted above, these figures are based on the Airport's power output of .1W (100mW). This is equal to the upper legal limit for wireless routers sold in the European Union. Many base stations have lower outputs than this, down to .035W (35mW). For example, current Linksys routers (n standard) radiate at .05W. Some may be more, and it would not be surprising to see ever higher-power units created, in an attempt to provide reliable signals through more walls. If your unit is higher power, then the exposures noted here will be higher (if 200mW, then EFs at a given distance would be twice as high; conversely, to match a "safe" EF, you'd have to be twice as far from the base station). Likewise, additional antennae or power booster meant to boost the signal strength will also generate equivalent EFs and PFDs at greater distances.

Airport EFs in relation to EFs created by the computer and household electrical circuits

I am not sure that these comparisons are relevant, as the EFs from AC and DC powered circuits are generated at vastly different frequencies, which interact with our bodies differently.

An initial query into EFs generated by laptops, not confirmed, suggests a laptop's EF is 3-13 V/m, likely higher than the field generated by its on-board lower power WiFi broadcasts (.035W, generating an EF of 1.7 V/m at one foot). Given the different wavelengths generating the voltages, it is quite possible that the 3-13 V/m field may be less of a physiological concern than the 1-2 V/m field from the Wifi radio transmissions.

Airport base station Electrical Field compared to existing EF in house:

- 1 foot from Airport base, EF is 6 V/m, the same as the lowest the house is likely to average (5-10 V/m)
- Airport emits a tenth to a hundredth the EF of typical small appliance (2 V/m at three feet, compared to 20-200 V/m)
- 3 feet from Airport base, EF is less than existing household EF (2 V/m, compared to 5-10)
- 6 feet or more from Airport base, EF is less than the likely lowest spot in a household EF (under 1 V/m); that is, from 6 feet on out, the Airport's impact on the EF you are exposed to is less than the house electrical system; this is likely the case from 1 foot out unless the house EF is very low by national standards.

To learn more

Information

http://bioinitiative.org/
Best source for the careful/precautionary/alarmist perspective. They produced a great 600 page research summary that provides clear information on hundreds of studies. While they end up proposing a very stringent safety threshold, the body of the report is completely balanced: research sections include studies that both found an effect and did not find an effect and they note whether the results have been duplicated and alternative causation explored. (Hint: virtually no lines of research have yet completed the standard process of scientific scrutiny and confirmation) Long sections of the report address a range of electromagnetic effects independently of each other: gene expression, DNA damage, micronucleus changes, chromosome effects, immune system, cognitive/neurological effects.

http://www.salzburg.gv.at/themen/gs/gesundheit/umweltmedizin/elektrosmog/celltower_e.htm
Tiny URL: http://tinyurl.com/3oqpgq
Salzburg Confernce, 2000, first proposal of precautionary .1 uW/cm2 standard.
http://www.salzburg.gv.at/Proceedings_(33)_Conversion_of_Units.pdf
Chart of current standards in several countries, and as proposed by precautionary researchers

http://www.powerwatch.org.uk/
A UK organization that also compiles research data, including recent studies, presented fairly objectively, though not quite as much so as the BioInitiative summaries.

http://www.wlana.org/learn/health.htm
Wireless LAN Association

http://www.v-soft.com/ZipSignal/zip_answer.asp
Find out how powerful radio signals are in your zip code

http://www.who.int/peh-emf/en/
World Health Organization; links to IEEE and country standards

http://www.hpa.org.uk/webw/HPAweb&Page&HPAwebAutoListName/Page/1199451940308?p=1199451940308
Tiny URL: http://tinyurl.com/6yakqp
UK Health Protection Agency WiFi section

Math help

http://www.compeng.com.au/emc_conversion_tables.asp
Calculator to convert energy power density to EF, etc.

http://www.unitconversion.org/index.html
This site is awesome; can convert almost any units…..many sub-pages for each discipline

http://www.translatorscafe.com/cafe/units-converter/frequency-wavelength/
See how frequency relates to wavelength, and more

http://www.rfcafe.com/references/electrical/electric_fields.htm
Chart showing how power (watts) relates to EF generation (scroll down)

Final musings

While this process has helped me to feel comfortable that current WiFi technology can be used in the home while maintaining a large "uncertainty" buffer compared to levels that may trigger non-thermal harm to humans, I still wonder how electromagnetic fields affect our tiny brethren (like insects), as well as plants, and whether our electromagnetic blanket is in any way a barrier to human communion with subtler realms of the spirit. It appears WiFi does not increase the overall household or regional EF totals, so I suppose I might rest easy…….yet……I notice our culture getting ever more off-kilter and out of touch during the decades of increasing radio and electricity installation world-wide……. I would hope that even as we become more globally connected via electronic medias, we will remember to go outside, touch the places where we live, and create times to listen for deeper guidance.

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