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To: Dr. Gary Brown , ETS
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From: Bill P. Curry, Ph.D.
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Subject: Wireless LAN’s in the school room

As you requested, I have investigated the microwave radiation environment imposed on children by their being in classrooms equipped with computers that use Wireless Local Area Networks (WLAN’s). Most of the computers probably use the Lucent WaveLAN technology. I am sure of this fact in regard to the Apple iMac, but I don’t know what other computers you are considering. I also don’t know whether the Aironet (CISCO) system differs significantly from Lucent’s system.

From the information that you sent me, my first concern arises from the proximity of the child user to his/her computer that is equipped with a WLAN. In order to compute the radiation density that is incident on a child from any RF radiation source, I use the following equation that is based on equations stated in the official FCC compliance document OET bulletin-65.

$$\rho = 250000\, \frac{P\,10^{0.1\,g}}{\pi}\, \frac{1}{\left(30.48\,\sqrt{\left[h - H\right]^{2} + x^{2}}\right)^{2}}$$

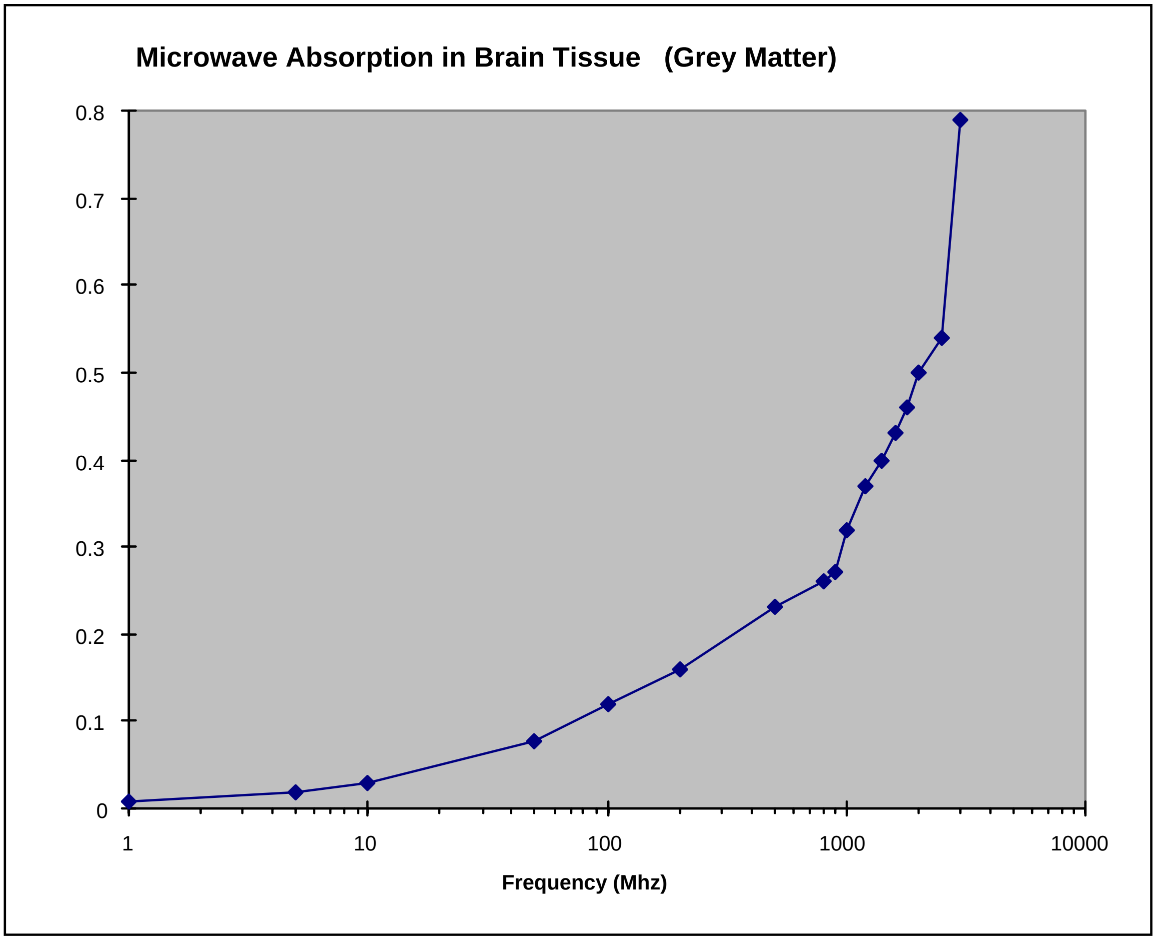
In this equation ρ is the radiation power density expressed in microwatts per square centimeter, g is the gain of the antenna, expressed in decibels referenced to isotropic emission (dBi), h is the vertical height of the source, H is the vertical height of the child (or some part of the child) that is of greatest concern, P is the power put into the antenna (expressed in watts) and x is the horizontal distance of the child from the source. All these distances are to be expressed in feet. This equation is general enough to be used for both the individual computer WLAN’s and the base stations. Here is how to use this equation. If the antenna radiation pattern is available for the antenna under question (this means a polar plot of the antenna gain versus angle measured from the direction of maximum gain), one can read the gain off the graph of the antenna radiation pattern for a particular angle, then calculate the corresponding horizontal distance.

$$x = \cot\left(\alpha \frac{\pi}{180}\right)\left(h - H\right)$$

where α is the same angle used to calculate the antenna gain. Then one inserts this equation into the radiation density equation to calculate the radiation density at the desired position. Thus, this equation is very useful if you know the antenna radiation pattern.

Lacking the actual antenna radiation pattern, for a child sitting at a desk and operating a computer that has a WLAN, we might as well assume that the worst case is when the highest gain direction is aimed straight toward some part of the child. This would mean that h - H = 0 and x is the distance to the closest part of the child. The iMac Airporter (which uses the Lucent WaveLAN) is a nearly isotropic source (i.e., it radiates almost equally in all directions). Having a gain of 3 dBi, the effective isotropic radiated power (EIRP) of the Airporter in the direction of maximum gain is twice the actual power of 30.0 milliwatts or 60.0 milliwatts in the direction of maximum gain. If some part of the child's anatomy is x = 1.50 feet from the computer, the above equation would give a radiation density incident on that part of the child's anatomy of 2.28 microwatts per square centimeter. Because the presence of the desk, the floor, and other structures allows some degree of intensification of the incident radiation by reflection from electrically lossy surfaces, the FCC document includes an empirical multiplication factor of 1.60 times the incident field strength. For power density calculations, this factor is squared, so we must multiply the above results by a factor 2.56, getting radiation power density = 5.83 µW/cm^2. This is the power density that would be incident on the child from only the direction of maximum gain. At the direction of minimum gain (the half beam width of the antenna) the power density will be a factor of two lower, so the average power density on the portion of the child's anatomy that is closest to the WLAN is (5.83 + 2.92)/2 = 3.75 µW/cm^2. Since the half beamwidth of the WLAN antenna is probably about 90 degrees. The total radiation density impinging on the child is about p/2 times the above figure or nearly 6 µW/cm^2.

I certainly consider this an excessive radiation amount, especially at the WLAN frequency of 2.45 Ghz. It is no coincidence that this frequency is near that of microwave ovens. The absorption of microwave radiation by human tissues is dominated by the absorption of water, since the tissues are about 40% water. Dr. Camelia Gabriel of London University has measured the dielectric constant (also called permittivity) and electrical conductivity through a large frequency range for 30 different types of tissues taken from animals and from human cadavers for Brooks Air Force Base. I have a large Air Force report (AL/OE-TR-1996-0037) that documents her results. From these data, I have computed the absorption coefficient for grey matter (a type of human brain tissue). The results are shown in the graph on the next page:



This graph shows why I am concerned about the drive of the "wireless revolution" toward ever higher frequency. I understand why they have to go to higher frequency. It is because of two factors: 1) nearly all the lower frequency bands have already been allocated by the FCC for specific types of radio transmissions and 2) transmission of ever more information content on any given channel requires higher and higher bandwidth. The required bandwidth can only be obtained by using ever higher frequencies. Unfortunately, engineers who design these systems rarely consider the effects on health, beyond protection against heating of tissues.

At this point, I have considered only the effect on the child of the child's computer with WLAN. The Lucent WaveLAN prevents interference between up to 8 computers associated with any one base station by preventing any computer from firing its WLAN when any other computer is already engaged with the base station. If there are more students than 8 in the classroom, there will have to be additional base stations, because the WaveLAN can only handle eight satellite computers at a time. (I assume there is a similar restriction for the Aironet, but I don't know details for that system.) If you assume there are 30 students in the classroom, then there will have to be either 5 base stations with 6 computers associated with each base station or else 3 base stations with 8 computers associated with each base station and one other base station with 6 computers associated with that base station. In order to have all WLAN's not interfere with each other, the operating frequencies will have to be slightly different for each base station and the computer WLAN's associated with each base station. This solves the interference problem. The child's tissues, however, are sensitive to a broad range of frequencies. Preventing electronic interference between the WLAN's will not protect the child from being irradiated by the computer WLAN's associated with different base stations. Presumably, a given child can be irradiated simultaneously by any one computer associated with each different base station. Let us assume that the child is simultaneously irradiated by his/her own computer WLAN and by that of one computer in the adjacent cell of base station plus satellite computer WLAN's. Assume, further that the first child and the computer of the child associated with the second base station are 3 feet apart. The radiation density from the computer associated with the adjacent base station can add (for the worst case irradiation direction) to the existing radiation density at the first child's location about 0.94 µW/cm^2. Clearly, this is a worst case scenario, because the configuration of the classroom may be planned to try to minimize these impacts. However, I have completely neglected all the other base stations and their associated WLAN's. Remember that the chances are good that one WLAN associated with each base station may be firing simultaneously - unless the base stations incorporate some provision for preventing this.

Can the base station radiation impinge on the child also? This depends on the characteristics of the base station antennas and whether they are mounted so as to project beams over the heads of the students to the transmitting devices that are outside the school room. Clearly, there will be some radiation from the base stations to their associated computer LAN's and this radiation will add to the radiation burden that the child experiences. With all this mind, I think one can conservatively say that any one child will receive a radiation dose commensurate with a radiation density of at least 6 - 8 µW/cm^2, perhaps even more. Presumably, this will continue for the duration the child is in the classroom where the computers are being used, every school day. I think this is likely to be a serious health hazard.

Most bioelectromagnetic experimenters have correlated their results with radiation dose level expressed in watts of power absorbed per kilogram of body tissue. These radiation dose quantities are called specific absorption rates (SAR). It is very difficult to convert from radiation density to SAR, because one has to be able to measure or calculate the electric field inside tissues. Nevertheless, some experimenters have expressed their results in one type of quantity, and some in the other type of quantity. By reading the bioelectromagnetic literature, you will find that significant biological effects that are sometimes associated with adverse health effects have been found at radiation levels (either radiation density or SAR values) hundreds or thousands of times less than the FCC considers "safe" on the basis of radiation limits intended to prevent heating of tissues.

The latest information from L. G. Salford, et al. (1997) in Sweden (neurosurgeon at Lund University) shows that the blood brain barrier can open at a radiation dose as low as 0.0004 W/kg. This is 4,000 times lower than the 1.6 W/kg "safe level" usually associated with frequencies lower than those of the WLAN. The FCC guidelines include upward adjustment of the “safe” level with increasing frequency. I think the “safe” levels should be adjusted downward with increasing frequency, instead, on the basis of increased brain absorption coefficient with frequency! Also, Jerry Phillips, et al. (1998) found DNA breakage in human white blood cells at SAR values of 0.0024 w/kg at frequencies in the range 800-900 Mhz following on previous work by Henry Lai and Narendra P. Singh that found DNA breakage in rat brains resulting from irradiation at 2.5 Ghz to an SAR level (1.2 W/kg) near the FCC “safe” limit. DNA breakage is a possible precursor to cancer. W. Ross Adey has warned that children are especially vulnerable to the assaults of RF radiation, because their brains are developing and their hormonal balance is changing. T. A. Litovitz, et. al (1993) found that a vital enzyme’s function (ornithine decarboxylate, which is essential for cell growth and DNA synthesis) is affected by microwave radiation modulated at audio frequencies. Excessive activity of this enzyme is associated with cancer.

About the author:

The author of this memo is a retired physicist who used to be a staff scientist at Argonne National Laboratory near Chicago (1987-1994). He has two BA and MS degrees in Physics and a Ph.D. in Electrical Engineering. At Argonne, the author participated in programs involving light scattering and absorption and the physics of charged particle beams. In the latter, he developed techniques to measure the aberrations in particle beams and he carried out computational studies of high current ion beams. Over a 40 year career as a physicist, the author has spent about 30 years specializing in some aspect of electromagnetics or another. For his Ph.D. dissertation, the author developed a computational technique to obtain the distribution of sizes of particles from laser scattering measurements on an ensemble of particles of many different sizes. He also headed a team that obtained a patent (for Air Force) on a method to measure particle sizes and densities simultaneously at multiple locations across the cross section of a particle laden flow.

Among the author’s employers have been operating contractors of the Arnold Engineering Development Center (a large Air Force research and development center in Tennessee) in two different periods (1960-1966 and 1976-1986). He has also been a staff scientist at Lawrence Livermore National Laboratory in California (1968-1973) and by two private companies in California (Physics International Co. 1966-1968 and STD Research Corp. 1973-1976). He has also taught part time at two colleges (California State College 1968-1970 and College of Dupage in Illinois 1996-1998). Since leaving Argonne in 1994, the author has consulted for four commercial organizations on the physics of smoke detectors, electron optical aspects of x-ray tube design (two different companies), and the design of electrodes for gas chromatography.

The author has published about 80 reports, meeting papers, and refereed journal articles (9 journal articles). Journals in which he has published include Physical Review, Journal of Chemical Physics, Physical Review Letters, Applied Physics Letters, and Applied Optics. He has also presented papers in several international conferences that resulted in publication in the proceedings of the conference. He is listed in both American Men and Women of Science and Who’s Who in Science and Engineering.

Since 1998, the author has been concerned about health implications of the "wireless revolution." He has attended two professional meetings about dealing with this topic and read many published papers in the area of bioelectromagnetics. He is a cofounder of the EMR Network, a national group of citizens and professionals who are trying to educate the public about potential hazards of excessive RF and microwave radiation and are pushing for more research in the most pertinent areas of health impact. He has testified in hearings in 3 states regarding cell phone base station antenna citing, and he has made presentations in several forums on this subject.

I hope this memo is useful to you.

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