

# Power Line Panic and Mobile Mania

*What is the physics that underlies any possible linkage between mobile phones,  
power lines, and cancer?*

S.T. LAKSHMIKUMAR

**H**eadlines in the news periodically highlight the “latest” investigation into the link between cancer and either use of mobile (cell) phones or residing near power lines. Some reports claim that there is statistically significant evidence for such linkages yet others deny this. However, both typically include a disclaimer that “scientists claim that there is no physical basis for such a linkage.” The purpose of this piece is neither to investigate the large amount of data that has been generated nor to persuade the public health authorities on the utility (or otherwise) of such investigations. It is to bring out as clearly as possible what scientists mean when they say “there is no physical basis for such a linkage.” The strength of this argument may enable

individuals to be less worried about this “panic and mania.”

What is the physics underlying the operation of both power lines and cell phones? Quantum mechanics. How well is this theory established? If this theory were used to calculate the diameter of Earth using paper and pen, one would get a value that agrees with the measured value within the thickness of a human hair. There is really no “experimental” reason to doubt quantum mechanics. It can be called the crown jewel of all science.

What is the relevant idea of quantum mechanics we need to understand power lines and cell phones? The first idea is that all electromagnetic radiation consists of small particles called photons. The energy of a photon is determined by a formula called Planck’s law: the energy of the photon increases as the frequency increases. Now consider a photon of yellow light. This has a frequency of some  $5 \times 10^{14}$  Hz. The energy of such a photon is approximately 2 electron volts (eV; obtained by multiplying the frequency by  $4.13 \times 10^{-15}$ ). If there is an increase in the power, only the number of photons increase, not its energy. Thus, a standard yellow sodium lamp with higher power rating provides more light with more photons, but each photon still has exactly the same amount of energy. A typical cell phone uses a frequency of  $1 \times 10^9$  Hz. The frequency used in a household microwave oven is  $2.45 \times 10^{12}$  Hz. Therefore the energy of photons in these sources will be lower than that of yellow light by a factor of a thousand for the microwave oven and a million for the cell phone. The frequencies of a standard 60 Hz power line will be further lower by a factor of one million. Roughly one million photons in a power line together have the same energy as a single photon in a microwave oven, and a thousand microwave photons have the energy equal to one photon of visible light. A photon in an X-ray machine has a frequency of  $3 \times 10^{17}$ , or energy a thousand times larger than the photon of visible light.

The next important quantum concept is the way in which a photon can interact with atoms or molecules. Only electrons in molecules or atoms can absorb the energy in a given photon. The nucleus of atoms cannot absorb any but the most energetic photons called gamma rays, which are not relevant here. If the energy in the photon is 1–3 eV, the electron can break bonds between atoms in the molecule if it is absorbed. This is obviously a source for disruption of the biological processes in the cells and can perhaps lead to lasting damage—

---

*S. T. Lakshmikummar is a scientist at National Physical Laboratory, India, with a doctorate from the Indian Institute of Science and thirty-five years of research experience in materials science. He has a passionate interest in communicating science to young students and the general public.*

maybe even cancer. However, only ultraviolet photons (which have higher energy than visible photons) have the required energy to break this bond, which explains the link between excess UV exposure due to sunbathing and skin cancer. A beneficial example is the formation of vitamin D due to exposure to sunlight. Visible light cannot cause this since it is reflected by the skin.

What happens with photons of higher energies, for example an X-ray photon? Now the atom as it dissociates from its molecule has enough kinetic energy to knock out other atoms from other molecules, very much like a cannon ball. Thus for every X-ray photon, many biological molecules are damaged.

Despite the fact that most X-rays penetrate the body without any effect (this is the reason bones become visible; the flesh hardly absorbs any X-rays), even the few that get absorbed can cause damage. If only a few molecules are damaged, the body can repair itself. The conversion of an ordinary cellular activity into cancerous activity is the result of this damage, hence, the strict low limits to permitted exposure.

What if the energy is low? Can an atom absorb two photons, each contributing half the energy? This is certainly possible, but there is a problem. The process of absorption of a photon by an atom typically takes about a nanosecond or less, so the two photons must be absorbed by the same atom in this short time. Since the photons and the atom are both very small and this event takes place in such a brief period of time, it is extremely rare. In a laboratory this double absorption is induced with lasers. In a laser, the photons emerge after fixed

intervals of time and travel in the same direction. Even with this advantage, only about one in a million photons in the laser contributes to such processes. Neither the cell phone nor the power line is a source of laser radiation, thus their photons will all be moving independently of one another. Also, about a thousand microwave photons have to get onto the same atom instead of merely two or three. Obviously there is no chance for these very small energy photons to cause damage to molecules by exciting the atom and causing molecular dissociation and damage.

What are the other ways in which low-energy photons can interact with matter? In the case of infrared photons, those with typically 0.1 to 1 eV energy, the result of absorption is the stretching or bending of molecules. The energy is shared by all the atoms in the molecule and the molecules vibrate as if the atoms were linked together with springs. This vibration causes heating. A typical sun lamp in action for heat therapy or relaxation of sore muscles uses these photons. Special thermal treatments for treating cancer that heat the tissue by about  $8^\circ\text{C}$



have been demonstrated to improve the performance of other cancer therapies in some types of cancers. The first point to note is that this level of tissue heating is not disruptive to normal cell activity. So generally speaking, even infrared photons cannot cause molecular damage the way UV radiation can. As before, multiple photon absorption is not possible.



When we consider absorption of photons of lower energy such as microwaves, the physical consequence cannot be vibration or bending since this requires much higher energy. The molecules, however, can rotate. This rotation increases the energy, which is equivalent to an increase in temperature. The microwave oven works at a frequency specifically chosen for

absorption by water molecules in the liquid state when the water molecules can rotate. Popcorn pops because the free water molecules in the kernel heat and become steam that explodes the corn. The dish does not get heated by the microwaves because it doesn't contain any liquid (free-to-rotate) molecules of water. The dish only gets heated by contact with the hot water inside. The primary requirement for rotation of a molecule is small size. Most molecules in the human body are polymers and so cannot rotate. Only water or other smaller molecules can absorb microwave photons and then heat up. Even when absorption is possible, this cannot easily result in heating by several degrees unless power levels are very high. A typical microwave oven operates at 500–1000 watts. Extrapolating from the example of popcorn and microwave cooking to claim that molecules' and atoms' absorption of photons of smaller energy will cause heating that will induce some cancers is quite misguided.

Finally we come to the case of the photons of the cell phone, which have even lower energy. These cannot cause even molecular rotation, and their absorption results in physical motion, or translation of the individual molecules. Naturally, the amount of energy that can be transferred to any molecule is very small, and the increase in its velocity and hence heating is therefore extremely small. Once again, large biopolymers heat much more slowly. The easiest way to recognize this extremely poor interaction between very low-energy photons associated with the radio frequency (RF) in cell phones and molecules is to remember that the small amount of power being transmit-

## Viral Video Cell-Phone Scare

In June 2009 a new urban legend was born—that the power generated by cell phones can cook popcorn. A series of videos on YouTube appeared to show four users popping a table full of corn kernels simply by pointing their ringing phones at them. The implication for the casual observer was clear: if cell phones emit enough radiation to pop corn, imagine what they are doing to your brain!

The execution was new, but the scare was not. The media has been reporting for years on alleged links between cell-phone usage and brain tumors, and alarmist headlines continue to excite the public regardless of the facts. As far back as 2000, spoof videos were being created of eggs being cooked by cell-phone power. The creator of the first of these, electron-

ics expert Charlie Ivermee, created his video to poke fun at media scare stories but was surprised when it was taken seriously. As an early viral, which in those days were mostly circulated by e-mail, it accidentally exploited a powerful stimulus: fear. Despite the creator's satirical intention, he had underestimated the public's willingness to demonize new technology and find cancer around every corner.

Fast forward to 2008 when YouTube videos imply that cell phones emit enough radiation to cook popcorn. The viewer is left to assume that it's true, although a moment's thought about the temperature needed to pop a kernel of corn—150 degrees Fahrenheit—might give even the average YouTube viewer

pause. If your cell phone reached that temperature, you'd very probably notice. It's not hot enough to melt plastic, but it's hot enough to burn skin.

So who would benefit from pandering to public concerns about health and cancer? Satirists, certainly, who are then free to expose their mockery of scaremongering. But the brains behind the popcorn video had another motive: profit. Cardio Systems describe themselves as "an established world leader in the field of wireless Bluetooth communications." In other words, they make the wireless headsets that help you avoid putting your mobile phone to your ear. Useful for hands-free chatting while driving, but perhaps a horrible fiery death in a car wreck wasn't considered appropriate material

ted by the phone is traveling several kilometers to the tower. Also, the cell phone has to transmit this very little power in all directions. The small power in the direction of the tower passes through several walls and other obstructions, even people, without impeding the communication. This explains the usual statement that the power levels in these situations are well below the limits set for exposure to RF sources. As for the typical 50–60 Hz power lines, the photon energies are too low for any meaningful interaction with atoms.

**The presence of power lines can spoil the view, can lower market value, or even psychologically irritate one, but there is simply no reason to worry about cancers of any variety from their presence.**

Another possibility mentioned is formation of hot spots. A magnifying lens can focus sunlight and start a fire. The key issue here is the relation between the structure of a magnifying glass and the photons that it can focus. A magnifying-glass surface is polished to approximately the wavelength of photons. The shape of the lens and uniformity of the refractive index of glass over dimensions much larger than the wavelength are also

necessary for focusing. The wavelength of radio frequency from a cell phone is about 30cm. It is not reasonable to expect a medium such as a human body to act as a focusing lens for waves of such dimensions emanating from a point source. The diverging rays from the mobile phone have to somehow be converted into a convergent beam. Even then the powers involved are too small for any meaningful number of photons to converge and then heat the localized region to trigger cancer formation. The wavelength of a photon in a microwave oven is approximately 0.1mm. The metallic walls of the oven reflect the photons into the oven space. Parabolic reflectors for focusing RF would have to consider the wavelength. The radiotelescope dish antennas focus RF; small mobile phones do not. In the case of power lines, the frequencies—and hence the energies—are smaller while the wavelengths are correspondingly longer, which makes worry about these photons unrealistic.

Unless one is willing to discard the concept of photons, Planck's law, and the interaction between photons and atoms—and thus the entire body of quantum physics—it is simply not possible for the photons associated with either a power line or a cell phone to cause cancer. Mobile phones have caused major problems, especially auto accidents from distracted driving, but one thing that need not be feared is the possibility of the “radio waves” causing cancer. The presence of power lines can spoil the view, can lower market value, or even psychologically irritate one, but there is simply no reason to worry about cancers of any variety from their presence. □



for a viral video. The creative team at Cardo who created the popcorn videos exploited existing concerns about cell-phone radiation and made them legend. The “anonymous” videos were viewed nearly 10 million times in just two weeks before Cardo stepped forward to take credit, although not, initially, to debunk the pseudoscience. Cardo claims that traffic to its Web site doubled in the days the videos were active, and although no figures have been supplied to show an increase in headset sales, it would be unusual for such a viral hit to have no commercial impact.

For those wondering, the secret of the video is mundane. Popped kernels were dropped onto the table as the phones rang, and the unpopped kernels were simply edited out. It is a simple trick that

any media student could achieve in a few hours, but Cardo created an urban myth so instantly popular it attracted international media and a place of honor at the urban legend Web site Snopes.com.

Cardo seemed unconcerned about potential accusations of scaremongering; at the time it claimed openly that its headsets reduce the amount of RF power going to users' ears but did not explain why that's a benefit. The popcorn video viewers may have their own motives for purchasing a headset, but if reducing cancer risk is one of them they should perhaps consider themselves misled.

—Tracy King

*Tracy King is a skeptical writer and marketing consultant in London, England.*

