Still other independent researchers reported that "hot spots" are formed inside models of human heads with radius of from 0.1 to 8.0 cm for frequencies between 300 and 1,200 MHz.[66,67] The range of sizes includes almost all human heads. It is clear that what was first observed as a danger to those with smaller cranial structure, and most notably including children, has been extended by additional scientific studies to include nearly all humans. Of course, the most dramatic "hot spot" peaks are within the smaller heads.

D. T. Borup and O. P. Gandhi[68] have published SAR distributions from a computer analysis of the human head. They found that for a plane-wave arriving from the front of the head, distinct energy absorption "hot spots" are shown. This is interesting, since the computer analysis confirms that even plane-wave induced radiation absorption results in interior energy absorption "hot spots." In this instance the observed "hot spots" amount to an energy absorption (SAR) of 0.6 mW/g for an incident power density of 1 mW/cm^2. At portable cellular telephone power densities, 10-20 mW/cm^2, the SAR would be 6-12 mW/g—enough to cause substantial temperature rises.

In the near-field, that same incident power density would result in a much higher SAR due to a number of

[66] *H. N. Kritikos and H. P. Schwan, "The Distribution of Heating Potential Inside Lossy Spheres," IEEE Transactions on Biomedical Engineering BME —22, no. 6, (November 1975):457-63.*

[67] *G. H. Wong, et al. "Probing Electromagnetic Fields in Lossy Spheres and Cylinders," IEEE Transactions on Microwave Theory and Techniques MTT —32, no. 8 (August 1984):824-28.*

[68] *D. T. Borup and O. P. Gandhi, "Calculation of High-Resolution SAR Distributions in Biological Bodies Using the FFT Algorithm and Conjugate Gradient Method," IEEE Transactions on Microwave Theory and Techniques MTT—33, no. 5, (May 1985):417-19.*

enhancement factors including the near—zone "matching" effect discussed earlier.

The cellular telephone manufacturers have maintained, until recently, that any radiofrequency energy absorption would be primarily superficial and lead to a sensation of heating before excessive or dangerous levels were reached. Of course, that position cannot be supported in view of the many research findings that show that most of the energy radiated from the phones ends up as absorbed energy in a "hot spot" within the user's brain. Our earlier review of radiation absorption and heat sensation has shown the industry claims to be quite absurd.

In 1955, researchers investigated this very topic and concluded that if the power level was sufficient to produce a "feeling of warmth on the skin, the deep temperatures, which are higher than the superficial ones, will be elevated to a point that may bring about tissue destruction.[69] In those types of experiments the temperature rise in brain tissue is much higher than that of the skin and fat layers.

4

Researchers have also investigated the effects of nearby radiation reflectors. Energy-reflecting surfaces or materials can be thought of in the same way as one would think of a mirror acting on visible light. The same is true with radiofrequency radiation except that the reflecting surface might be a metallic conductor or wire mesh rather

[69] H. P. Schwan and G. M. Piersol, "The Absorption of Electromagnetic Energy in Body Tissues," International Review of Physical Medicin and Rehabilitation, June 1955, pp. 424-48.

than a mirror. In terms of radiation absorption within a person's head, it's somewhat like operating two portable cellular telephones or a single phone at a much higher power setting.

Gandhi has reported experimental research that was performed to confirm the radiation absorption enhancement that occurs when subjects are close to reflecting surfaces.[70] According to theory, as the ratio of the body diameter (such as the diameter of the head) to wavelength is reduced the enhancement factor increases and as the distance from the reflecting surface to the absorbing object decreases the enhancement factor also increases.

Therefore, we would expect that operation of a portable cellular telephone in close proximity to energy-reflecting surfaces, such as automobiles or metal structures, would result in enhanced energy absorption within the head and brain of a user. A secondary effect is that as the signal received by the "cell site" is weakened, the portable will receive coded instructions to increase its radiated power level. This provides even more radiation to be absorbed within the user's head. Gandhi reported a measured energy absorption enhancement factor of as much as 27 in close proximity to corner shaped reflectors and about 4.7 for flat reflectors. The first of these numbers, twenty—seven times greater absorption, is truly astounding. But when we consider that more than 50 percent of the energy radiated by portable cellular telephones is absorbed within the user's head without the presence of a reflector, it becomes clear

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[70] *O. P. Gandhi, et al., "Deposition of Electromagnetic Energy in Animals and in Models of Man with and without Grounding and Reflector Effects," Radio Science November—December 1977, pp. 39-47.*

that the enhancement by a factor of 27 is an upper limit that would not be reached.

The other condition, that of enhanced absorption in (close proximity to a flat reflector, is reported to provide a 4.7 —fold increase in absorption. Again, since more than 50 percent of radiated energy is already absorbed by the user, the 4.7—fold increase represents the potential for t enhanced absorption and should be viewed as an indication of what actually happens as one operates a portable phone close to reflectors. That is, of the energy which is actually radiated, and not initially absorbed by the head and brain of a user, much will be reflected by the metallic surfaces and deposited into the user's head. This certainly doesn't leave much energy to be radiated for communications purposes.

This work by Gandhi highlights consideration of yet another absorption "hot spot" mechanism. Although this is not a "hot spot" in the strict sense of others that have already been discussed, it remains a "hot spot" issue related to where a user operates the phone and how that user might move about during operation.

For example, a portable telephone user may initiate a call while standing on a city sidewalk with no reflecting surfaces nearby, in which case the absorbed radiation, although excessive and dangerous, would not be enhanced by reflecting surfaces. Then, during that phone call a truck or bus or even an automobile may drive up and stop alongside the caller, in which case the reflection mechanism occurs and the enhanced absorption takes place. More insidious is the enhancement that may occur in the presence of reflecting surfaces that cannot be seen. Examples would include the metal framing of buildings, metal office furniture, and even the reflections from steel and cast iron bathtubs.

Gandhi also states that

in view of these observations and also since the hot spots may shift rather readily upon placement of other targets in close proximity, the entire region may be considered as one that is potentially capable of creating large enhancements. Furthermore, the reflecting surfaces need neither be good conductors nor solid in construction to cause enhancements.

When these researchers note that "hot spots" may shift readily due to placement of conductive reflectors in close proximity to the entire region this paints the clear picture that as a portable telephone operator moves about, for example by moving his or her head within an automobile, the absorption "hot spots" within the head will also shift.

Gandhi's observation that it is not necessary for reflectors to be good conductors or solid surfaces to cause the enhancements is also very informative. He points out that insulating surfaces, such as, for example, glass with embedded conducting rods, can act as solid reflecting surfaces. Consider, for example metallic screening in screen windows, metallic window shades, or the thin wires in automobile windows that are used for window defogging or for automobile radio antennas. It would be a fairly safe conclusion that the cellular telephone industry has failed to warn users about the enhanced radiation absorption related to operating a portable cellular telephone: (1) while in an automobile or bus, (2) in or near metal-framed buildings, (3) in close proximity to metal window screens or metal window shades, (4) close to metallic office furniture, (5) near large metal objects, (6) while wearing metal-framed eyeglasses, or (7) near any other type of radiofrequency radiation reflecting objects.

In a 1980 report on energy absorption, researchers determined that average SAR may only be employed for plane wave exposure.[71] In the near-field absorption enhancements completely negate any meaning of the term average SAR exposure. Also, as reported earlier by others, those researchers believe that some biological effects that occur at power density levels of less than 0.5 mW/cm^2 can be attributed to "hot spots" which produce thermal effects in localized areas of tissue. They also explain that

> ***because of the complications associated with defining, calculating, or measuring the near-field radiation, problems that are associated with near-field irradiation of biological models have not been solved.***

Let's rephrase that last statement. Since the problems associated with near—zone radiation exposure are difficult, they have not been solved.

R. G. Olsen and T. A. Griner[72] also provide a communication related to their earlier, 1980, research. They identify in the update communication that

> ***Results of those experiments showed a distinctive internal 'hot spot' of microwave absorption in the head of the model.***

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[71] M. F. Iskander, "Irradiation of Prolate Spheroidal Models of Humans in the Near Field of a Short Electric Dipole," IEEE Transactions on Microwave Theory and Techniques MTT—28, no. 7 (July 1980)801-7.
[72] R. G. Olsen, T. A. Griner, Bioelectromagnetics 3, no. 3, 1 1982):385-90. .

The "hot spot" information was not released with the original published research.

It should be remembered that the earlier research to which this correction refers was a plane—wave (far-zone) radiofrequency radiation exposure of a homogeneous material, and yet it produced a "hot spot" within the head.

6

R. J. Spiegel[73] considered the existence of "hot spot" absorption in relation to the existence of nonuniform electric fields in the near-zone of antennas. Other researchers had already investigated and verified very large nonuniformities of the electric fields near the antennas. Spiegel reported that damaging biological effects may be observed at temperatures above 41.6°C and that the severity of effects can be expected to be greater in organs such as the brain. He stated in 1982 that

> ***there is virtually no quantitative information in regard to the heating patterns in a human subjected to near-zone antenna fields. For ethical reasons this information cannot be acquired using actual human subjects.***

Why is this report of significance? Remember that by 1982 the cellular telephone industry had developed within its research and engineering laboratories the first generation of portable telephones. At the same time, the

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[73] *R. J. Spiegel, "The Thermal Response of a Human in the Near-Zone of a Resonant Thin-Wire Antenna," IEEE Transactions on Microwave Theory and Techniques MTT—30, no. 2 (February 1982):177-85.*

research community had warned the manufacturers that: (1) the work related to safety had not been performed; (2) the overwhelming indications are of a hazard to nearzone exposure; (3) many types of "hot spot"—generating mechanisms compound the effects of even low-level radio-frequency radiation exposures; and (4) humans cannot be eased for the potentially deadly experiments to determine safety/hazard levels.

A short time thereafter researchers proved, once again, that focusing radiofrequency energy is effective for providing deep penetration and "hot spot" absorption.[74] The focusing effect was so pronounced that those researchers considered applications of radiofrequency energy for hyperthermia by utilizing absorption "hot spots" for tissue heating and reported that focused deep penetration depths of as much as 6 cm were obtained. The researchers pointed out that by focusing the energy into a "hot spot" the amount of power required from an energy source is reduced by a factor of more than 20. Conversely this means that an energy-radiating element, such as an antenna, can provide greatly enhanced and focused energy deposition. Because of nonuniform absorption, localized "hot spots" may arise without any significant increase of the overall temperature. Small regions of the tissue may reach damaging temperatures while the total body doesn't exhibit an increase. This supports the earlier finding that reported significant internal "hot spots" at very low radiation levels.

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[74] *H. Ling, et al., "Frequency Optimization of Focused Microwave Hyperthermia Applicators," Proceedings of the IEEE 72 no. 2 (Februairy 1984):224-25.*

Spiegel recites some of the concerns related to localized "hot spots" that exist even when the overall temperature rise is inconsequential. They include

> ***localized temperatures above 41.6°C cause protein denaturation, increased permeability of cell membranes, or the liberation of toxins in the location where the hot-spot exists. The severity of the resultant physiologic effect produced by localized temperature increases can be expected to be worsened in critical organs, such as the brain.***[75]

Spiegel recognized the particular susceptibility for damage to the human brain and the complex functions that the brain performs and was concerned with the local "hot spot" absorption effects. He was also cognizant of the nonuniform focusing effects of near-zone exposure to radiating antennas and reported that "localized SAR distributions produced by the antennas are much different than those generated by plane-wave fields.

7

A technique commonly employed to disguise the seriousness of the nonuniform energy absorption in biological tissue is to present data in terms of average whole body terms. In that way, no issue can be raised concerning possible local high—energy density absorption. As an extension of the averaging techniques and homogeneous

[75] R. J. Spiegel, "A Review of Numerical Models for Predicting the Energy Deposition and Resultant Thermal Response of Humans Exposed to Electromagnetic Fields," IEEE Transactions on Microwave Theory and Techniques MTT—32, no. 8 (August 1984):730-46.

modelling, which is nonrepresentative of human structures, researchers have employed materials which represent "average tissue characteristics." That is, they take an average of the electrical properties of materials such as fat, muscle, bone, brain tissue, and skin to arrive at some agglomeration that represents nothing that can be identified as a biological tissue.

Then, using this nonrepresentative material as a ho-. mogeneous gel-like mass that is poured into a human skull, or some material that "represents" a human skull, the researchers perform their tests.

Fortunately, not all researchers employ such nonrepresentative structures, and we have already reviewed reports related to the inaccuracies that they can produce liven more fortunately, the simplified, nonrepresentative structures do not mask the most significant absorption effects.

In a publication by I. Chatterjee, et al., they elected to utilize a nonrepresentative "tissue cocktail" mixture that Guy developed some years earlier.76 It has become known as "2/3 muscle" tissue. That is, the energy-absorbing characteristics of the material are supposed to be approximately two-thirds that of muscle. A mannequin filled with the mixture corresponding to the electrical characteristics of two-thirds muscle properties is used by those researchers to draw conclusions on absorption characteristics.

The homogeneous phantom was irradiated at 800 MHz, and the experimental measurements confirmed the existence of a "hot spot" in the temporal lobe region that

76 I. Chatterjee, et al., "Quantification of Electromagnetic Absorption in Humans from Body-Mounted Communication Transceivers," IEEE Transactions on Vehicular Technology VT—34, no. 2 (May 1985):55-62.

had been observed some years earlier by industry experimenters. Another energy absorption "hot spot" that those researchers found includes the region where an eye would be located, but we should keep in mind that this homogeneous single—material model has no distinct structures or humanlike organs.

In spite of the shortcomings of the model, the researchers were still reporting "hot spots" and radiation absorption in excess of 2 mW/g. Since the radiating antenna was disposed at the front of this experimental model we would anticipate that other "hot spot" generating mechanisms would come into play and cause higher absorption if the experiments were conducted with the antenna at the side of the head and behind the ear of a more representative human head structure. It may be worth noting that the form in which the "tissue cocktail" was poured was a fiberglass mannequin. Not quite the same as a subcutaneous fat layer over bone of a skull.

An unrelated series of near-zone exposure experiments using a whole-body homogeneous model yielded data showing distinct "hot spot" energy absorption.[77] Most of the energy was deposited in the part of the "body" nearest to the antenna, with near-field enhancements of from 30 to 250 being reported. It is puzzling that the researchers chose to place the radiating antenna at the back of the model—approximately at the height of the shoulder blades for a human. However, that odd placement for the antenna still yielded data showing that most of the energy is deposited in the head and neck.

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[77] *S. S. Stuchly, et al., "Energy Deposition in a Model of Man: Frequency Effects," IEEE Transactions on Biomedical Engineering BME—33, no. 7 (July 1986):702-11.*

Even with the unrealistic placement of the radiating antenna, the researchers have found significantly enhanced energy absorption in the head of the human model. As a result of their experiments they have determined that whole-body average SAR is not a proper dosi-metric measure. In other words, they believe that it is improper to take a localized very high exposure and average it over the total body surface in an attempt to meet the IEEE/ANSI standards. They have instead acknowledged that high energy absorption in a small localized area must be treated as a completely different circumstance from plane-wave exposures.

They also point out, and their data support the position, that most of the radiofrequency energy absorption takes place within the human model at locations very close to the antenna. Again, there is nothing surprising in the findings, as they are in concert with the earlier reports of many other scientists. One revealing distinction of this data is an energy absorption "hot spot" located in the model at a position next to the antenna feed-point. Recall that others have earlier found the same type of "hot spot" and associated the increased energy deposition with higher radiation at that point on the antenna.

High SARs in such tissues as brain or other vital organs are likely to be more critical in producing biological effects which may be potentially hazardous. For antennas located close to the body, the high values of the peak SAR on the body surface, compared to the whole body average SAR, result in exceeding ANSI condition of 8 W/kg in one gram of tissue even for transmitters with relatively low RF output power.[78]

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[78] *S. S. Stuchly, et al., "Energy Deposition in a Model of Man: Frequency Effects," IEEE Transactions on Biomedical Engineering BME-33, no. 7 (July 1986):702-711.*

8

During 1991 P. J. Dimbylow and O. P. Gandhi calculated SARs in heterogeneous models over a frequency range covering 600 MHz to 3 GHz with a view toward focusing, resonance, and enhanced energy absorption. Their concerns Were with radiofrequency energy deposition in the human head, particularly the eyes and brain. Although a broad range of graphical data representing the results of the experiments is included, some graphical data at 800 MHz for the adult human head is notably missing. It is intriguing that a blank space exists where the data would have been placed.

From the graphical and tabular data presented, the researchers reconfirm that exposure to radiation in the 800 MHz range leads to nonuniform absorption. For a radiation source located in front of the model the researchers note energy absorption "hot spots" in the eyes and at the center of the brain in the adult human head model. At the same frequency and also for frontal exposure, a model of a smaller head representing a child yields a much higher energy absorption "hot spot" in the brain center in addition to the "hot spots" at the eyes.

For radiation exposure coming from the side of the head only the graphical depiction of the child size head is shown. That graph illustrates significant "hot spot" absorption predominantly at one side of the head and at one eye. Coincidentally, the missing graphical data corresponds to experiments performed with the radiation incident at the side of the adult head model and at 800 MHz. These data would correspond to the type of exposure and absorption we would expect from a cellular phone.

The researchers provide tabulated data for the full range of frequencies covering 600-3,000 MHz. However, the data do not document the absorption peaks but, rather, only averaged values. Some indication of the peaks may be learned by looking to the highest averages listed for each of the exposures.

Even without employing any enhancement mechanisms the researchers have shown that relatively low level radiation, at 1 mW/cm^2, will result in significant energy absorption levels in the human brain.

For a child's head, irradiated from the front with 800 MHz energy, a maximum average energy absorption of 1.23mW/g is listed. For frontal exposure with the adult human model at 800 MHz a maximum average energy absorption of 0.9mW/g is given. For side exposure at 800 MHz to the head of a child the maximum average absorption level is given as 0.8mW/g. Similarly for the adult model the maximum average is given as 0.6mW/g. Keep in mind that all of the "maximums" are, in fact, averaged over one gram of tissue. That is, averaged over a cube of tissue about 0.4 inches on each side. The opportunity for significantly higher energy absorption "hot spots" within such a large volume is most probable. Recall that within a 1 cm cube of tissue there are billions of molecules and bonding links, some of which may be particularly susceptible to high energy absorption.[79]

More significant than the averaging technique the researchers employ, is the fact that these calculations have been performed by simulating plane-wave exposure.

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[79] *P. J. Dimbylow and O. P. Gandhi, "Finite-Difference Time-Domain Calculations of SAR in a Realistic Heterogeneous Model of the Head for Plane-Wave Exposure from 600 MHz to 3 GHz," Physics in Medicine and Biology 36, no. 8 (1991):1075-89.*

Recall that plane-wave radiation assumes the energy radiating element is very far from the human. The result is that the energy arrives at the human as a uniform "wave" of energy without variations in intensity. Since these researchers did not employ real exposure conditions, their results do not incorporate any of the known enhancement mechanisms.

When we relate these findings to the power density levels known to exist as a result of using portable cellular telephones, approximately 10-20mW/cm^2, it is evident that energy absorption levels of 10-20mW/g can be expected at some localized regions in the brain of an operator of the portable telephone. That's also without factoring in any of the absorption "hot spot" mechanisms or nonuniform radiation mechanisms. The potential for highly focused lethal levels of energy deposition is well defined—and documented earlier by Lin.

Consider now, for example, the low-level radiofrequency radiation exposures, without factoring in the effects of reflectors, head curvature, nonuniformities of absorption, nonuniformities of antenna radiation, different tissue interfaces, temperature compensation mechanisms, metal-framed eyeglasses, internal skull ridges, brain size, or any of the other enhancement mechanisms

Then begin to factor in the effect of each of the possible enhancement mechanisms that have already been identified. It doesn't take long before we're ready to conclude that even at low radiation exposure levels these I other mechanisms may provide for local "hot spots" that are truly extraordinary in magnitude and undoubtedly destructive to human tissue, in particular highly sensitive brain tissue. Recall that Lin had already reported in a separate paper a single "hot spot" formation mechanism that provides for local enhancement by a factor of

1500. What should we conclude the total enhancement factor will be when some of these other absorption enhancement mechanisms also come into play?