with near-zone exposures. Only a few months later the industry researchers confirmed that position in a published paper that states:

One can reasonably presume that most human exposures of any concern are and will be in the near field of electromagnetic sources. Yet the study of the near field has been substantially neglected.

By that point in time industry research and engineering teams had been investigating portable cellular telephones for quite a few years. Even without the evolution of the portable cellular telephone, many manufacturers had been providing portable radios for commercial use for many years. Keeping this in mind, it becomes alarming to find the industry researchers admitting that

dipole antennas, although extensively used in portable and mobile communications, have not been carefully investigated in the near field.156

It was only two years later, during 1983, that the portable cellular telephone became commercially available, yet industry researchers admitted that they had not done the necessary investigation of the effects from energy radiation antennas placed next to the human head. At about the time that the revelations about the lack of research in the near-zone of antennas were made known, other researchers performed experiments with scaled-down miniature salt-water-filled spheroidal phantom models to determine near-zone exposure and energy

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156 Balzano, et al., "The Near Field of Dipole Antennas, Part II: Experimental Results," IEEE Transactions on Vehicular Technology VT-30, no. 4 (November 1981):175-81.

absorption for humans.157 It seems that not only was meaningful near-zone research an unfulfilled need, but that which was performed took on some rather strange characteristics. It's difficult to imagine the intricate features of the human head and brain being simulated by a salt-water-filled ball.

Although the concept of using scaled—down salt-water—filled plastic spheroids to represent humans is inapplicable for any comparative purposes, the experiments do provide some data that is valuable. For one, it revealed that in the near-zone the electric and magnetic field intensities increase at a faster rate than the far-zone rate of increase predicts.

Earlier research, performed at about 1980, has provided an interesting view of the type of laboratory models that were used in some experiments to determine energy absorption and safe exposure levels for humans. In this instance, the experimental model only vaguely represents any recognizable form and is wholly comprised of a mixture of salt water and plastic powders to simulate muscle tissue. No bone, fat, or skin layers were included as are so important for any energy absorption experiments.

However, even that crude model of a rhesus monkey provided energy absorption data that was almost three times higher than the researchers expected. They commented that

> ***it is surprising that the average SAR of the rhesus model. . . is nearly three times the expected value***

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157 M. F. Iskander, et al., "Mcasurements of the RF Power Absorption in Spheroidal Human and Animal Phantoms Exposed to the Near Field of a Dipole Source," IEEE Transactions on Biomedical Engineering BME—28, no. 3 (March 1.981):258-64.

based on the empirical formula found in the dosimetry handbook of Durney and co-workers [1978].

The handbook, to which they refer, is a product of the USAF School of Aerospace Medicine at Brooks Air Force Base, Texas.[158]

The researchers at that particular air force base figure prominently in other questionable research reports, as We shall review shortly. For the present it is interesting to note that the U.S. military, which has a history of presenting research data to "dispel fear and improve morale of personnel," has provided the handbook of radiofrequency radiation absorption. Researchers have frequently determined that the findings in the handbook understate the actual absorption of radiation that laboratory experiments conclude. They also wrote:

The strong absorption caused the average SAR of the rhesus model to exceed the theoretical predictions by a factor of 2.67. The disparity between experimental and theoretical results cannot be completely explained . . .
Certain combinations of fat and skin thicknesses produce resonances such that . . . [absorption efficiencies] may be on the order of 70% to 100% . . .
(see footnote 157).

The resonances refer to optimal conditions for the absorption of energy—the "matching" effect. That is, 70 percent to 100 percent of the energy may be absorbed. Not only are the various thicknesses of the tissue layers

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[158] C. H. Durney, et al., Radiofrequency Radiation Dosimetry Handbook, Rep. SAM-TR-78-22, 1978, USAF School of Aerospace Medicine, Brooks Air Force Base, Texas, 1978.

important, but so, too, is the distance at which the radiation source, the antenna, is held during operation. In the region of a few centimeters from the human head, approximately 0.5-7 cm, there will be energy absorption resonances that allow for a very large portion of the energy radiated by the portable antenna to be deposited into the user's head, instead of radiated to the atmosphere.

Also, the high levels of stored energy will couple efficiently into the head and brain in addition to the 70-100 percent of the radiated energy. It's like a double dose of energy deposition. The first, radiated energy deposition, the industry reluctantly talks about because bioeffects researchers are familiar with the concept. The second source, energy stored in the near-zone fields close to the antenna, the industry never speaks of because very few, except antenna engineers and electromagnetics researchers, are aware of its existence. Under some circumstances the stored energy is 10 to 100 times greater than the radiated energy. It depends to a great extent on the configuration of the antenna. Knowledge that this great amount of stored energy may be "eff1ciently" coupled into the head and brain of a user should be enough to keep all but the most daring from using portable cellular telephones.

R. G. Olsen, et al., documented energy absorption in a full-sized human model. The absorption is again about three times higher than that which was predicted by the air force's dosimetry handbook. As with the previous experimental setup, the researchers employed a simplistic homogeneous mold of "muscle tissue equivalent" comprised of salt-water and plastic powders.[159] And as with

[159] *R. G. Olsen, "Far ficld Dosimetric Measurements in a Full-Sized Man Model at 2.0 GHz," Bioelectromagnetics 3, no. 4 (1982): 433-41.*

the previous experimental results the findings would have been higher by a factor of 3 to 5 if the researchers had constructed a multilayered model for the experiments.

While some researchers have employed scaled models of humans to measure radiofrequency energy absorption, others have lectured on the serious shortcomings of such methods. The fundamental problem is that the radiation exposure and energy absorption in humans has no connection to that which is observed in miniature models. A. Kraszewski, et al., agree and have stated that

> ***The main limitations of this technique are a limited spatial resolution due to the small size of the models and a difficulty in incorporating the anatomical structure into such a small model.160***

Of course, when a scaled-down model of a human that has no features such as skin, fat, bone, brain tissue, or nonuniformities is used to determine energy deposition within humans one wonders how the experimental results might be presented. Certainly there can be no correlation between the energy absorption in the model and that which is found at small "hot spot" areas in the living human brain.

These researchers confirm that scaled models used for thermographic measurements of SAR do not allow for resolution of anatomical features. Significant differences between calculated absorption and that measured in the sealed models indicates that the scaled models underestimate the energy absorption in some areas by as much as ten times.

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160 A. Kraszewski, et al., "Specif1c Absorption Rate Distribution in a Full-Scale Model of Man at 350 MHz," IEEE Transactions on

Reports of researchers using printed circuit board antennas for hyperthermia therapy highlight an important point about using energy—radiating structures close to the human head. The researchers observed that the radiating element could be "matched" to their phantom model when the distance separating the two was less than 1 cm.[161] The term *matched* refers to optimal conditions, or best conditions, for transferring radiofrequency energy to the body in close proximity to the radiating antenna. When the radiating antenna is "matched" to the load, for instance the human head and brain, maximum energy absorption will occur. Those researchers have reconfirmed the experimental findings of others that indicate that in the near-zone absorption is enhanced by the improved "match" between the antenna and absorbing body. The "matching" effect is another enhancement mode that must be, or should have been, considered in research related to safety of portable transmitting devices such as portable telephones.

Once again, as with others in the past, those researchers reported that radiation in the near-zone is highly nonuniform. That is, in the near-zone there are regions of very high radiation and regions of very low radiation, regions of very high energy density and regions of lesser energy density. The near-zone peaks and dips average out in the far—zone to yield the uniform level of radiation.

Microwave Theory and Techniques, MTT—32, no. 8 (August 1984):779-83.

[161] *I. J. Bahl, et al., "Microstrip Loop Radiators for Medical Applications," IEEE Transactions on Microwave Theory and Techniques MTT—30, no. 7 (July 1982):1090-93.*

Two years later, during 1984, another group of independent university researchers again acknowledged that characterization of fields very close to radiating elements had not been completed and that much work remained to be done.[162] However, by that time it was too late. The genie was already out of the bottle; portable cellular telephones were available in the marketplace.

5

H S. Stuchly, et al., performed a series of near-zone exposure experiments by using a whole-body homogeneous model of a human. Not surprisingly they measured and reported the presence of "hot spot" energy absorption. Most of the energy was deposited in the part of the "body" nearest to the antenna, with near-zone enhancements of from 30 to 250 times greater than the average for the whole body.[163] It is puzzling that the researchers chose to place the radiating antenna at the center of the back of the model. But even that odd placement for the antenna yields data showing that most of the energy is deposited in the head and neck.

It just doesn't seem to make any sense that a human operator would place a transmitting portable radio or portable cellular telephone at the center of his back. However, even with the unrealistic placement of the radiating

[162] *D. T. Borup and O. P. Gandhi, "Fast-Fourier-Transform Method for Calculation of SAR Distributions in Finely Discretized Inhomogeneous Models of Biological Bodies," IEEE Transactions on Microwave Theory and Techniques 32, no. 4 (April 1984):355-60.*

[163] *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.*

antenna, the researchers have found significantly enhanced energy absorption in the head of the human model. As a result of their experiments they determined that whole-body average SAR is not a proper dosimetric 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, instead, acknowledge that high energy absorption in a small localized area must be treated as a completely different circumstance from plane-wave exposures.

Another contribution to the portfolio of "nonrepresentative" research findings provides data for energy absorption within a laboratory model. However, the model is irradiated by placing the transmit antenna at the chest area of the model.164 This work was performed by the same research team that gave us data for an antenna placed at the back of a human model. An improvement over those earlier experiments is that the model currently used includes discrete materials to simulate organs such as lungs and brain.

But the researchers employ a type of "tissue cocktail," representing no known living tissue, to fill the model. It's the same type of all-purpose simulated tissue mixture that other researchers have been using instead of providing accurate simulating materials. The mixture has a combination of the electrical properties of many tissue types but none of the real properties of any actual human tissue. As mentioned, the evaluation of near-field exposure employed an antenna placed in front of the

164 M. Stuchly, et al., "Exposure of Man in the Near-Field of a Resonant Dipole: Comparison between Theory and Measurements," IEEE Transactions on Microwave Theory and Techniques MTT—34, no. 1 (January 1986):26-31.

model at the chest area. The researchers report that SARs approximately two to five times higher than for homogeneous models were found, which certainly conforms with the data that has been reported for many years prior to this study. That is, multilayered, heterogeneous models will more accurately represent real humans.

The researchers then make a truly unconnected leap in concluding that

the antennas and their orientation can be considered as representative of the operation of portable (hand-held) transmitters. [165]

Clearly these experiments were not designed to represent any actual radiation exposures. What the experimental findings do provide is a repetitive confirmation that simplified homogeneous models are underestimating the actual energy absorption by significant amounts; a factor of 5 was documented from this research team alone.

This research paper also serves to provide notice of the apparent "hand-in-glove" cooperation between governments and the industry, as the principal researcher was employed by the Bureau of Radiation and Medical Devices, Health and Welfare Canada, and the funding came from the U.S. Environmental Protection Agency. Another of the researchers was with the U.S. FDA and is now employed by Motorola.

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[165] M. Stuchly, et al., "RF Energy Deposition in a Heterogeneous Model of Man: Near-Field Exposures," IEEE Transactions on Biomedical Engineering BME-34, no. 12 (December 1987):944-49.

Another industry research report proposes to provide information related to the "unexplored" area of heating of simulated tissue.[166] It's A curious that the researchers should describe the technical area as unexplored, even at that time, particularly in view of the full body of prior research, only some of which has been described here. In any event, the report on the heating effects to persons who operate portable radios indicates that radiation exposures might exceed a power density of 10 mW/cm^2. The measurement technique employed, thermal measurements taken by inserting a probe after exposure to radiofrequency energy, has been considered poor by others.

Since their measurement method is time-consuming it typically understates the maximum heating and, therefore, understates the maximum energy absorption. In addition, the experiments were performed with models employing a homogeneous gel-like substance to simulate the human brain. The industry researchers state:

> ***At the end of the exposure, the thermal probe was immediately reinserted in the dummy and the temperature increase recorded.***[166]

The researchers reported that they observed and documented an energy absorption "hot spot" associated with high electric fields at the tip of the antenna. But if the published research is any indication, they never pursued any further investigation of the "hot spot" absorption.

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[166] Q. Balzano, et al., "Heating of Biological Tissue in the Induction Field of VHF Portable Radio Transmitters", IEEE Transactions on Vehicular Technology 27, no. 2 (May 1978):51-56.

Researchers have found during this period that the SAR in man models exposed to cellular telephone mobile antennas does not meet the IEEE/ANSI standard. That's not surprising, since other, earlier, researchers have consistently reported that transmitting antennas could not be operated close to the human body—the human head—without violating the safe exposure limits. That is why the industry has argued, and was successful in obtaining, a categorical exemption for their products.

During 1986 a team of university researchers performed a series of radiofrequency energy exposure experiments to determine the SARs in human models exposed to radiating antennas that were mounted on the roof—top and trunk lid of an automobile.[167,168] As in the past they employed the fiber—glass mannequins filled with the "tissue cocktail" material.

It has previously been described that this pseudo-tissue material is of no practical value in determining accurate radiation absorptions. The researchers recognize this shortcoming by stating that

> ***though it has been demonstrated by other researchers that homogeneous whole-body phantom models with an electrical conductivity 2/3 that of muscle will provide the most realistic condition for determining whole body average SAR, this is not valid for local partial body exposures nor is it valid for***

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[167] *A. W. Guy and C. K. Chou, "Specif1c Absorption Rates of Energy in Man Models Exposed to Cellular UHF Mobile-Antenna Fields," IEEE Transactions on Microwave Theory and Techniques MTT—34, no. 6 (June 1986):671-80.*

[168] *A. W. Guy, "Dosimetry Associated with Exposure to Non-Ionizing Radiation: Very Low Frequency to Microwaves," Radio Physics 53, no. 6 (December 1987):569-84.*

determining SAR distribution within the model (see footnote 167).

Let's consider what these researchers have said. First, they have said that other researchers have validated the model that is being used. That is not true. Although the nonrepresentative mixture has been used by others and those other researchers have published experimental findings, there is nothing that indicates that the practice of using the "tissue cocktail" gives meaningful results or has been validated.

Second, by the researchers' own admission the homogeneous model mannequins: (1) will provide no information related to specific absorption in particular organs; (2) will provide no information related to energy absorption distributions within any organs, such as the brain; and (3) are not suitable for determining partial body exposures such as the amount of energy absorbed within the head.

Further, these researchers have documented other shortcomings of the mannequins as:

No attempt was made to simulate skin, fat, bone, or internal organs. (see footnote 167).

In summary, what they have provided is some gelatinous mass of material shaped in the form of various-sized humans (man, woman, child), which they have exposed to radiofrequency energy. Even with the gross misrepresentation, with respect to any living being, the results of this research are not encouraging.

Exposures were made with the mannequins positioned at various locations around the automobile. In one instance, the adult male—size mannequin was exposed while positioned directly in front of the antenna, which places the antenna immediately in front of its stomach. A standing smaller adult-size mannequin, having surface contours similar to those of a woman, was also similarly positioned and exposed to the radiation. The child-size mannequin was positioned as kneeling in the rear seat of the auto approximately two to three feet from the antenna.

As if the nonrepresentative materials weren't sufficient to skew the data, the researchers used thermographic methods for determining the energy absorption. This technique has been evaluated earlier and found to be unsuitable. The long set-up and measurement time makes accurate measurements unlikely, as the temperatures in the mannequins change during the set-up. This results in serious understatement of the maximum energy absorption locations. The researchers alluded to the shortcomings by stating that

> ***The thermographic method used in the past was first used for determination of the SAR in the foam woman and child models exposed to the roof-mounted antennas. For later thermographic work with the trunk-mounted antenna, however, an improved thermographic technique was employed with digital recording and interactive-computer analysis. (see footnote 167).***

In spite of the "improvements" it was still necessary to physically disassemble each mannequin every time a thermal scan was to be taken.

The experimenters concluded that

> ***the maximum power densities and SARs for the worst-case exposure conditions tested with this input power to the antenna does not satisfy the ANSI***

primary exposure criteria; however, it does satisfy the 7-W and 8-W/kg exclusion clauses. (see footnote 167).

What these researchers are stating is that the experimental results do not fall within the constraints of the overall safe radiation exposure limits of the IEEE/ANSI standards; but since any portable transmitting antennas radiating less than seven 7 watts are exempt, the antennas meet the standard by virtue of that exemption.

They continue with their own description of the shortcomings of their models with statements such as:

The models used in this research were simple, homogeneous figures, but there are no technical restrictions in fabricating more advanced and realistic designs... (see footnote 167).

That particular research publication provides a very clear indication of how prominent researchers can produce experimental results, which do not represent energy absorptions in any living creature, and by making their own bold self-proclamations of validity try to elevate a very suspect set of experiments to the level of acceptable science. Further, and perhaps most dangerous, they try to extend the limited value of the findings to statements regarding radiofrequency energy exposures and radiation absorptions in general.

7

Average and maximum (peak) SAR may vary over several orders of magnitude for a given exposure level. That is, the peaks of the SAR at certain spots may be hundreds or thousands of times greater than the average SAR over the whole of the tissue. For example, a human brain exposed to radiofrequency energy will have a susceptibility to absorb great amounts of energy at certain spots that may be hundreds and thousands of times more than for the rest of the brain. Quantifying near-zone exposure remains difficult, although progress is continually being made in this area. Every time a research experiment identifies a new "hot spot" location, or a new mechanism for depositing energy in a non-uniform manner the total picture becomes more clear.

During 1987 university researchers concluded that

> ***the actual SAR patterns in exposed subjects in bio-logical systems have such great variability that it is impossible to establish any meaningful relationship between SAR distributions and safe exposure standards.***[169]

That conclusion brings our attention to the fact that the industry and independent researchers are both experimenting with simulated human heads and brains. In most cases the simulated structures have none of the features of actual human heads. We have already learned to be wary of researchers voicing opinions based on experiments conducted with simplified models and experiments conducted with radiating antennas located at misleading positions. Now they have told us that, since the structure and features of the human head change so much from one individual to the next, the variability with

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[169] *A. W. Guy, "Dosimetry Associated with Exposure to Non-Ionizing Radiation: Very Low Frequency to Microwaves," Radio Physics 53, no. 6 (December 1987):569-84.*