# A Closer Look at Witricity

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## Introduction

In 2007, MIT published the results of an experiment employing "tightly coupled magnetic resonances" to transmit useable amounts of electrical power across room-sized distances with reasonable efficiency[1]. A photo was released showing the system, sometimes called "magnetic resonance" or "Witricity", powering a lightbulb as the researchers posed between the two coils. Soon after the paper was published, articles appeared touting the "discovery" of this "new physics", and espousing a vision of a world in which all electronic devices are conveniently and safely powered without wires.

**Figure 1**

*Participants in MIT's experiment pose while power transmits through the intervening space*

However, upon closer examination, it is revealed that "Witricity" is not new physics. It is, in fact, physics discovered more that 150 years ago and routinely put in use today. More importantly, it has never been safe, and it is not safe now, even for low power levels. At best, Witricity can be described as only a particular example of a science that has been known for 150 years. Various reports have erroneously claimed that the fields produced are strictly magnetic -- that there is little or no electric field. However, it is shown that both the electric and magnetic fields produced by the experiment far exceed regulatory safety guidelines.

Further the claim has been made that magnetic fields are safe, and this wrong in two ways. Firstly, safety guidelines are published for magnetic fields, which certainly implies that they are not strictly safe. And secondly, as any undergraduate physics student can tell you, changing magnetic fields produce electric fields.

The method is examined in detail starting with the derivation of expressions for the fields generated by the coils. The fields are plotted and compared to regulatory safety guidelines to assess safety.

## History

In basic terms, MIT's method amounts to two coils separated by a distance. An alternating current in the "primary" coil induces an alternating voltage in the "secondary" coil. This effect is called magnetic induction and was discovered by Michael Faraday in 1831[2]. It is the same principle that has been used in power transformers for more than 100 years. This is not new physics by any stretch of the imagination.

MIT's idea to use resonant coils increases the efficiency, but is also nothing new. In fact, equations used to describe the energy transfer between two resonant coils was put in practice in the earliest radios in the 1920's and can be found in textbooks dating back more than 60 years[3]. Years before the MIT paper, it is a fact that nearly every company attempting to commercialize wireless inductive power has employed resonance to improve efficiency.

So what is new about MIT's Witricity? It appears that the only thing new about Witricity is that it is claimed to be safe when the distances are increased to room-sized scale, and the power level is increased to tens of Watts. Up until 2007, no one dared to make that claim, and as is shown below, there is good reason.

## Efficiency of Room-Scale Inductive Power Transfer

MIT has shown that relatively large amounts of power (about 100W) can be transferred across room-scale distances with "reasonable" efficiency. In their experiment, they achieved an efficiency of about 40%. It is fair to say that this is good efficiency for the wireless transfer of power across room-scale distances. However, 40% is poor efficiency compared to the use of wires, or compared to industry-accepted standards. It is important to note that this figure does not include the efficiency of the driver and receiver electronics—it accounts only for the wireless power transfer itself. The Environmental Protection Agency's (EPA's) Energy Star program provides an example of a published standard for the energy requirements of electronic equipment, and their logo can be found on computer monitors and AC adapters. An AC adapter, for example, must have better than 87% efficiency to comply with Energy Star requirements [4]. These requirements are periodically tightened to reflect the latest improvements in power supply technology.

Energy Star and other bodies intended to regulate the energy efficiency of electronic devices are becoming more and more important for managing today's energy problems. At one time in the not-so-distant past, the power consumed by consumer electronic goods was not significant. Still today, the energy consumed by a single device such as a cell phone is small, and may seem at first to be inconsequential. But the sheer number of devices – billions of devices in use around the world – multiplies the importance of energy efficiency even when talking about milliwatts of wasted power. This means that the energy efficiency for electronics will continue to be more and more important in our world.

Witricity's performance at 40% is unacceptably below the 87% expectation for today's power supplies. It is important to keep in mind that Witricity's efficiency is not expected to improve significantly. If anything it is expected to get much worse. There are a number of reasons for this. Firstly, the efficiency reported in their 2007 paper does not include the efficiency of the electronics required for the driver and for the receiver to make it into a practical product. Furthermore, the coils that MIT used are not practical for use with, for example, a cell phone. The coils used for a cell phone will have to be much smaller, and that will necessarily decrease their efficiency. Because it can be said that there is nothing more to learn about electromagnetism that wasn't thoroughly described 100 years ago, it is fair to say that we should not expect any breakthroughs to alter the current reality of Witricity's poor efficiency.

So as you can see, Witricity, although it may have at first seemed promising, faces some rather severe limitations when it comes to energy efficiency. This alone may render the technology a non-starter, but there is another concern that is far more disturbing - safety.

## The Safety of Room-Scale Inductive Power Transfer

MIT has shown that relatively large amounts of power (about 100W) can be transferred across room-scale distances using Witricity. Is this proposition safe? They claim it is.

Fortunately, the tools required to answer the question of safety are well developed. In fact, they were developed over 100 years ago with Maxwell's equations in the early days of the field of electromagnetism[5]. The analysis herein starts with a physical model of the system and an associated electrical model. Once the currents in the coils are determined with the electrical model, Maxwell's equations are applied to derive the magnitude of the electromagnetic fields generated. These fields can then be compared to governmental safety standards for exposure to electromagnetic fields to determine the safety of the system.

The full analysis is given below for readers interested in the details and/or those who wish to confirm that the analysis is valid. However, a full understanding of the analysis is not necessary to appreciate the conclusion. For those readers not interested or not versed in electromagnetic theory, it is recommended to skip this portion of the paper to the section headed: **Simulation of the MIT experiment**.

## Derivation of the Electromagnetic Fields Produced by Resonant Coils

Figure 1 shows the system of interest, defining the source and device coil radii $R_S$ and $R_D$ respectively, and the coil separation $z = d$. The planar coils are assumed parallel and aligned coaxially. Each coil is resonated by an ideal, infinitesimal capacitor so that the frequency of operation is arbitrary and electric fields due to spatial charge distribution are negligible.

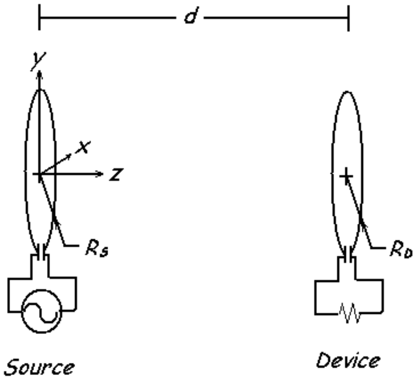

**Figure 2**

The MIT paper of 2007 introducing Witricity[1] made use of coupled mode theory to describe the system. This approach is not normally that taken by electrical engineers. This may have had the inadvertent effect of implying that something new was happening in the system. However, this is not the case, and the same results are obtained using standard circuit analysis techniques normally taught in first-semester circuits courses for electrical engineers. Nevertheless, coupled mode theory is used here to take advantage of MIT's results for the sake of brevity.

## Coil Currents

By MIT's definition, the parameters $a_S$ and $a_D$ are the amplitudes of the source and device coils normalized such hat $|a_S|^2$ and $|a_D|^2$ are the energies of the resonant source coil and the resonant device coil respectively. According to coupled-mode theory

$$\frac{a_D}{a_S} = \frac{i\kappa}{\Gamma_\mathrm{D} + \Gamma_\mathrm{w}} \tag{1}$$

where the imaginary number $i$ indicates a 90° phase difference between source coil and device coil in the usual phasor sense, $\Gamma_\mathrm{D}$ and $\Gamma_\mathrm{w}$ are the device and load decay rates respectively, and $\kappa$ is the coupling coefficient given by[1]

$$\kappa = \frac{\omega M}{2\sqrt{L_S L_D}} \tag{2}$$

where $\omega$ is the frequency, $M$ is the mutual inductance, and $L_S$ and $L_D$ are the source coil and device coil inductances respectively. Note that the conventions as defined herein result in a negative mutual inductance $M$, giving rise to a lagging phase in the device coil. The ratio of device to source energies is

$$\frac{|a_D|^2}{|a_S|^2} = \frac{\kappa^2}{(\Gamma_\mathrm{D} + \Gamma_\mathrm{w})^2} \tag{3}$$

The parameters are normalized such that power is expressed as $P = 2|a|^2\Gamma$, so equation (3) leads to

$$P_D = 2|a_D|^2(\Gamma_\mathrm{D} + \Gamma_\mathrm{w}) = 2|a_S|^2 \frac{\kappa^2}{(\Gamma_\mathrm{D} + \Gamma_\mathrm{w})} \tag{4}$$

where $P_D$ is the total power received at the device side including both dissipation in the coil losses (the $\Gamma_\mathrm{D}$ term) and dissipation in the load (the $\Gamma_\mathrm{W}$ term). The separation of equation (4) follows from the substitution of (2) as

$$P_D = 2|a_D|^2(\Gamma_\mathrm{D} + \Gamma_\mathrm{w}) \tag{5}$$

and

$$P_D = |a_S|^2 \frac{\omega^2 M^2}{2L_S L_D(\Gamma_\mathrm{D} + \Gamma_\mathrm{w})} \tag{6}$$

Equations (5) and (6) relate the power transferred to the energy in the coils. By the substitution of the relation $|a|^2 = LI^2$ where $L$ is the inductance and $I$ is the RMS current in the coil, and with the loaded Q of the receiver coil defined as $Q_L \equiv \frac{\omega}{2(\Gamma_\mathrm{D}+\Gamma_\mathrm{w})}$, the current of each coil is thus

$$I_D = \sqrt{\frac{Q_L P_D}{\omega L_D}} \tag{7}$$

and

$$I_S = \sqrt{\frac{P_D L_D}{\omega Q_L M^2}} \tag{8}$$

The expressions stated in this form give the coil currents simply in terms of system parameters: inductance, mutual inductance, power level, and Q.

The fields generated by a coil arise from its current $I$ and are proportional to the number of turns N. However, for a given geometry and stored energy the product NI is constant by the following argument. With the inductance of a coil of a given geometry proportional to $N^2$ , it follows that the stored energy $|a|^2 = LI^2 = (N^2 L_0)\left(\frac{I_0}{N}\right)^2$ where $L_0$ is the inductance of a single-turn loop, and $I_0$ is the current in the single-turn loop. As such, the magnetic field produced is proportional to $NI = N\left(\frac{I_0}{N}\right) = I_0$, independent of the number of turns N. Without loss of generality, therefore, the analysis assumes the circular loops are constructed as a single turn of wire.

### Analytical Expressions for the Resultant Fields

The magnetic vector potential is used to determine the electromagnetic fields produced by the system everywhere in space. The general time-harmonic magnetic vector potential arising from a current distribution in free space is given as[2]

$$\boldsymbol{A}(\boldsymbol{x}) = \frac{\mu}{4\pi}\int \boldsymbol{J}(\boldsymbol{x}')\frac{e^{ik|\boldsymbol{x}-\boldsymbol{x}'|}}{|\boldsymbol{x}-\boldsymbol{x}'|}d^3\boldsymbol{x}' \tag{9}$$

The fields produced by the system can be considered a superposition of the fields produced by each of the coils individually. Therefore, $\boldsymbol{J}(\boldsymbol{x}')$ is taken to represent a single filamentary circular current loop of unit amplitude. The current is taken to be uniform around the loop, which is assumed a good approximation for a single-turn loop resonated with an ideal capacitor provided the wavelength $\lambda \gg R$. In cylindrical coordinates

$$\boldsymbol{A}(\rho, z, \phi) = \frac{\mu R}{4\pi}\int_0^{2\pi}\left[-sin(\phi-\phi')\hat{a}_\rho + cos(\phi-\phi')\hat{a}_\phi\right]\frac{e^{ik\mathscr{r}}}{\mathscr{r}}d\phi' \tag{10}$$

Where $k$ is the wavenumber $k = {}^{\omega}/_{c}$, and $\mathscr{r}$ is given by

$$\mathscr{r} = (R^2 - 2\rho R cos(\phi') + \rho^2 + z^2)^{\frac{1}{2}} \tag{11}$$

Noting that the $\hat{a}_\rho$ component vanishes over the limits of the definite integral, and recognizing the symmetry in $\phi$, $\boldsymbol{A}$ is directed in the $\hat{a}_\phi$ direction as

$$\boldsymbol{A}(\rho, z) = \frac{\mu R}{4\pi}\int_0^{2\pi}\frac{e^{ik\mathscr{r}}}{\mathscr{r}}cos(\phi')d\phi'\,\hat{a}_\phi \tag{12}$$

Assuming there is no charge build-up in the device or in the surrounding space, the electric field follows immediately as

$$\boldsymbol{E} = -\frac{\partial\boldsymbol{A}}{\partial t} = -\frac{i\omega\mu R}{4\pi}\int_0^{2\pi}\frac{e^{ik\mathscr{r}}}{\mathscr{r}}cos(\phi')d\phi'\,\hat{a}_\phi \tag{13}$$

The magnetic field is given as the curl of $\boldsymbol{A}$. Thus in cylindrical coordinates

$$\boldsymbol{H} = \boldsymbol{\nabla} \times \boldsymbol{A} = -\frac{1}{\mu}\frac{\partial A_\phi}{\partial z}\hat{a}_\rho + \frac{1}{\rho\mu}\frac{\partial}{\partial \rho}\left(\rho A_\phi\right)\hat{a}_z \tag{14}$$

The $\rho$-directed magnetic field follows by taking $-\frac{1}{\mu}\frac{\partial A_\phi}{\partial z}$ under the integral of $A_\phi$ yielding

$$\begin{aligned} H_\rho &= -\frac{R}{4\pi}\int_0^{2\pi}\left[\frac{r\frac{\partial}{\partial z}e^{ikr} - e^{ikr}\frac{\partial}{\partial z}r}{r^2}\right]cos(\phi')d\phi' \\ &= \frac{R}{4\pi}\int_0^{2\pi}\left[\frac{z(1-ikr)e^{ikr}}{r^3}\right]cos(\phi')d\phi' \end{aligned} \tag{15}$$

Similarly, the $z$-directed magnetic field follows by taking $\frac{1}{\rho\mu}\frac{\partial}{\partial\rho}\left(\rho A_\phi\right)$ under the integral of $A_\phi$. Applying the differentiation gives

$$\begin{aligned} H_z &= -\frac{R}{4\pi\rho}\int_0^{2\pi}\frac{\partial}{\partial\rho}\frac{\rho e^{ikr}}{r}cos(\phi')d\phi'\,\hat{a}_\phi \\ &= -\frac{R}{4\pi\rho}\int_0^{2\pi}\frac{r\frac{\partial}{\partial\rho}\rho e^{ikr} - \rho e^{ikr}\frac{\partial}{\partial\rho}r}{r^2}cos(\phi')d\phi' \end{aligned} \tag{16}$$

Which reduces to[3]

$$H_z = \frac{R}{4\pi}\int_0^{2\pi}\frac{R - \rho cos(\phi')}{r^3}(1 - ikr)e^{ikr}d\phi' \tag{17}$$

In the quasistatic limit $(ikr \ll 1)$, the field equations for a single filamentary current loop simplify to

$$\begin{aligned} E_\phi(R,z,\rho) &= -\frac{i\omega\mu R}{4\pi}\int_0^{2\pi}\frac{cos(\phi')}{r}d\phi' \\ H_\rho(R,z,\rho) &= \frac{R}{4\pi}\int_0^{2\pi}\frac{zcos(\phi')}{r^3}d\phi' \\ H_z(R,z,\rho) &= \frac{R}{4\pi}\int_0^{2\pi}\frac{R - \rho cos(\phi')}{r^3}d\phi' \end{aligned} \tag{18}$$

where the dependence on the radius R is shown explicitly.

The magnetic fields of the combined system are taken as the superposition of the fields from each of two coils separated by distance $d$ and in which the phase of the device coil lags that of the source coil by 90°.

$$\begin{aligned} \boldsymbol{H}(z,\rho) &= \boldsymbol{H_S}(z,\rho) + \boldsymbol{H_D}(z,\rho) \\ &= I_S\boldsymbol{H}(R_S,z,\rho) - iI_D\boldsymbol{H}(R_D,z-d,\rho) \\ &= \Big(I_S H_\rho(R_S,z,\rho) - iI_D H_\rho(R_D,z-d,\rho)\Big)\hat{a}_\rho \\ &\quad + \left(I_S H_z(R_S,z,\rho) - iI_D H_z(R_D,z-d,\rho)\right)\hat{a}_z \end{aligned} \tag{19}$$

With the definition

$$\mathcal{E}_{\phi}(R,z,\rho) \equiv \frac{\mu R}{4\pi}\int_{0}^{2\pi}\frac{cos(\phi')}{\mathcal{r}}d\phi' \tag{20}$$

The electric field of the coaxially-aligned, two-coil system $E_{T\phi}$ is similarly

$$\begin{aligned} E_{\phi T}(z,\rho) &= I_S E(R_S,z,\rho) - iI_D E(R_D,z-d,\rho) \\ &= I_S\left(-i\omega\mathcal{E}_{\phi}(R_S,z,\rho)\right) - iI_D\left(-i\omega\mathcal{E}_{\phi}(R_D,z-d,\rho)\right) \\ &= -\omega I_D\mathcal{E}_{\phi}(R_D,z-d,\rho) - i\omega I_S\mathcal{E}_{\phi}(R_S,z,\rho) \end{aligned} \tag{21}$$

The Poynting vector, indicating the magnitude and direction of energy flow, is given by

$$\begin{aligned} \boldsymbol{S}(z,\rho) = \ &\mathcal{R}\{\boldsymbol{E}\times\boldsymbol{H}^{*}\} \\ &= \left[-\omega I_D\mathcal{E}_{\phi}(R_D,z-d,\rho) - i\omega I_S\mathcal{E}_{\phi}(R_S,z,\rho)\right]\hat{a}_{\phi} \\ &\times\Big[\left(I_S H_{\rho}(R_S,z,\rho) + iI_D H_{\rho}(R_D,z-d,\rho)\right)\hat{a}_{\rho} \\ &+\left(I_S H_z(R_S,z,\rho) + iI_D H_z(R_D,z-d,\rho)\right)\hat{a}_z\Big] \end{aligned} \tag{22}$$

So that

$$\begin{aligned} \boldsymbol{S}(z,\rho) = \omega I_S I_D\big[&\mathcal{E}_{\phi}(R_D,z-d,\rho)H_{\rho}(R_S,z,\rho) \\ &-\mathcal{E}_{\phi}(R_S,z,\rho)H_{\rho}(R_D,z-d,\rho)\big]\hat{a}_z \\ &+\omega I_S I_D\big[-\mathcal{E}_{\phi}(R_D,z-d,\rho)H_z(R_S,z,\rho) \\ &+\mathcal{E}_{\phi}(R_S,z,\rho)H_z(R_D,z-d,\rho)\big]\hat{a}_r \end{aligned} \tag{23}$$

It is interesting to note the characteristics of the factor $\omega I_S I_D$ that multiplies each component of $\boldsymbol{S}$. By substituting (7) and (8) it can be seen that

$$\omega I_S I_D = \omega\sqrt{\frac{P_D L_D}{\omega Q_L M^2}}\sqrt{\frac{Q_L P_D}{\omega L_D}} = \frac{P_D}{|M|} \tag{24}$$

Remarkably, the geometry of the coils alone defines the vector power density field $\boldsymbol{S}$ up to a multiplicative term, and the multiplicative term depends only on the amount of power transferred $P_D$. Most notably, the power density is not dependent on the degree of resonance, $Q_L$ ,and is identical to the non-resonant case for a given power $P_D$.

### Simulation of the MIT Experiment

The expressions predicting the resultant fields are used to numerically simulate the MIT experiment to determine the strength of the fields present for the participants. This analysis assumes a circular filamentary loop for both the Source and Device coils, which is different than the helical coils used in the MIT experiment. Even so, a simple geometrical argument shows that the fields predicted by the filamentary loops are substantially similar to those expected from helical loops for regions further away than about one loop diameter.

In the case of the MIT experiment, the source coil and device coil are the same size $R_S = R_D = R$ and the degree of resonance is close to a special value $Q_L = {}^{L}/_{|M|}$ = 943.14 such that $I_S = I_D = I$. Thus, Let $R_S = R_D =$ 0.3m, $b_S = b_D =$ 0.003m, $d =$ 2m, $f = {}^{\omega}/_{2\pi}$ = 10 MHz, and $P_D =$ 105 Watts. A formula for the inductance of a circular loop attributed to Grover[6] yields $L = 1.766\ \mu H$ for this case. An approximate formula for the mutual inductance of two coaxial loops (Cohen[4] ) gives $|M| = 1.87\ nH$. Consequently, from (7) and (8), $I = 29.87 A_{RMS}$ and from (14), $Q_L =$ 943.14. The diameter, the power delivered, and the Q assumed generate fields that likely correspond closely to those present in the MIT experiment of 2007[1].

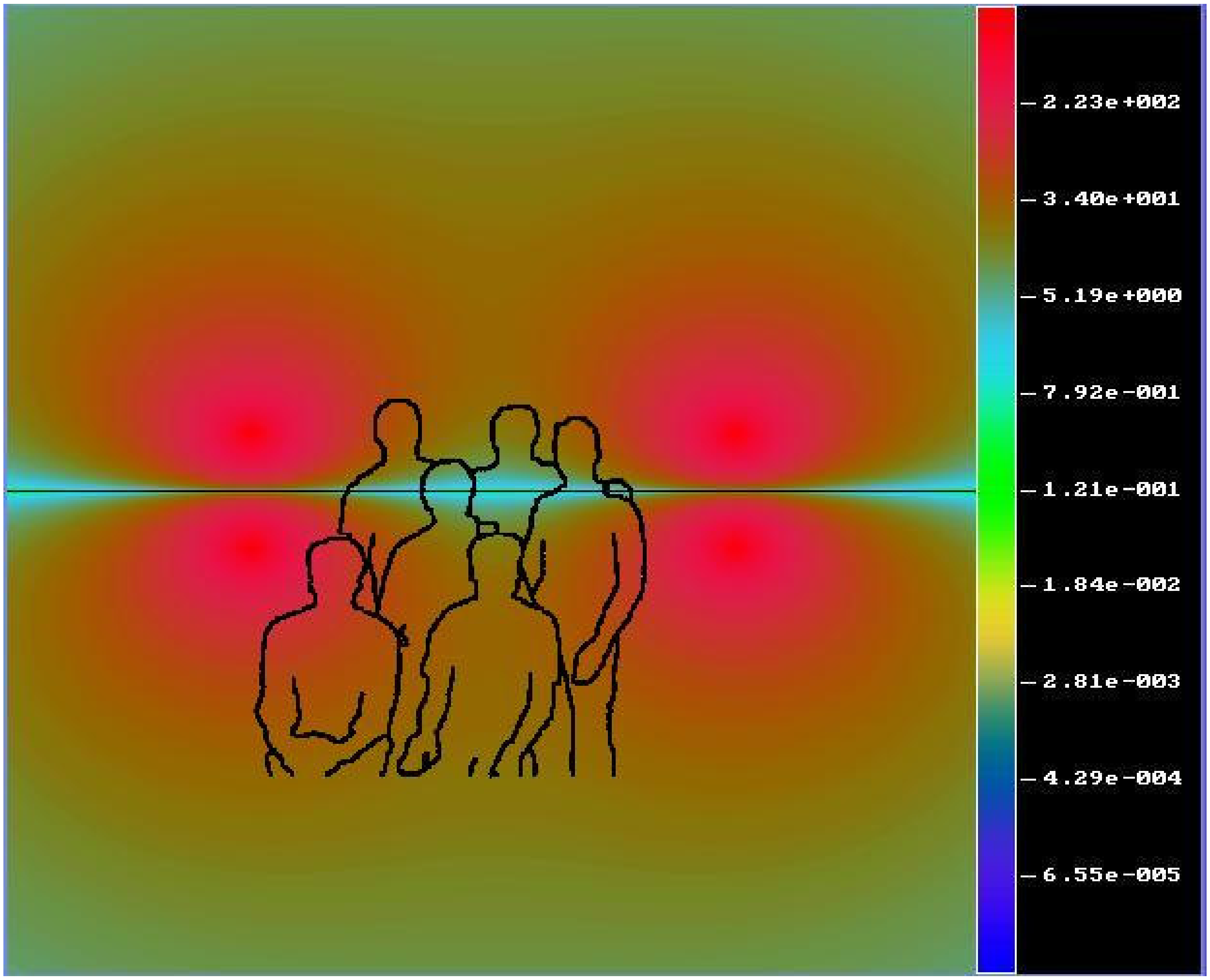

**Figure 3**

*Calculated Electric Field of the MIT Apparatus (in Volts/meter)*

The resulting fields are shown in Figure 3, and 4. These figures represent scalar magnitudes of the fields in the plane y=0, which takes a cross section through each coil thereby revealing a pair of points. The pair of points on the left is the source coil, while the pair of points on the right is the device coil.

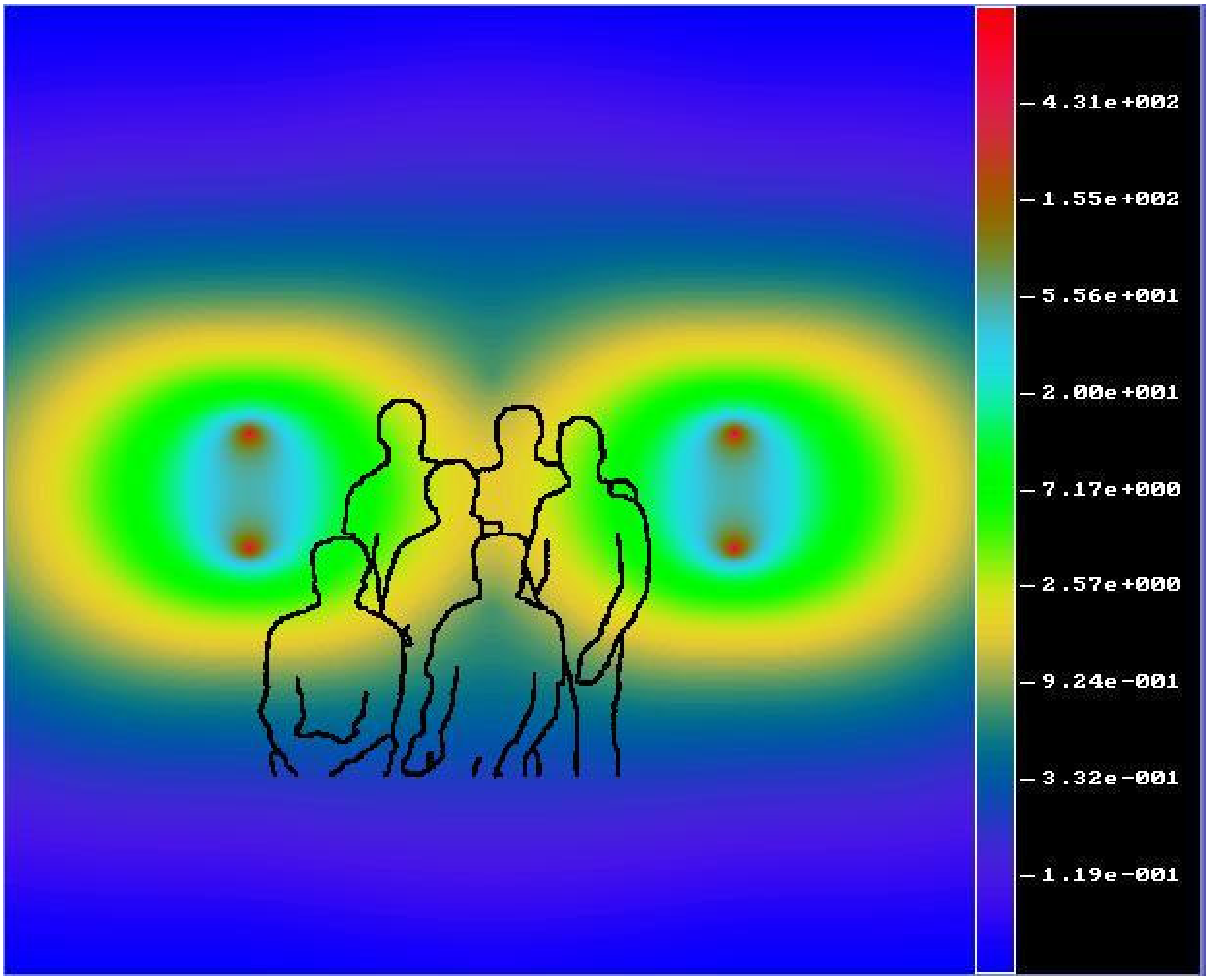

**Figure 4**

*Calculated Magnetic Field of the MIT Apparatus (in Amps/meter)*

It is important to note a surprising phenomenon indicated by the above example. The magnitude of the fields near the Device coil is on the order of the fields near the Source coil. This is not necessarily intuitively obvious, and has important implications for safety. Because the Device coil is likely close to a human – such as embedded in a cell phone or laptop computer – it is unfortunate that the fields surrounding the coil may be as large as the fields surrounding the transmitter. This implies that there is no way to “hide-away” the problem because the Device coil must be located with the device, and therefore is likely at times close to a human.

Now that the fields have been calculated, we have the necessary information to determine safety based on regulatory safety guidelines.

**Safety Standards for Electromagnetic Fields**

Two leading organizations set the guidelines upon which health and safety exposure limits for electromagnetic radiation are set by countries around the world. They are the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the Institute of Electrical and Electronics Engineers (IEEE). Their guidelines are based on reviews of published scientific research on the possible biological effects of exposure to electromagnetic fields. Presently the European Union, the World Health Organization, and numerous other countries have adopted ICNIRP-based limits whereas the United States, Canada, Korea, and Taiwan have adopted limits based on the IEEE guidelines. These recommendations describe the maximum allowable electric field strengths present within various tissues. Because of the difficulties in measuring field strengths within tissues, the recommendations also include published Maximum Permissible Exposure (MPE) limits to guarantee that unsafe fields do not exist within tissue[7][8].

The safety limits set by the two leading organizations, the ICNIRP, and the IEEE, are different reflecting some amount of uncertainty in the effects of electromagnetic fields on biological tissues. These limits are superimposed on the fields calculation to indicate regions of safety as defined by the two organizations. In the case of both the electric and magnetic field guidelines, the ICNIRP has the higher standard of safety. Figure 5 shows the magnetic field strength with the ICNIRP and IEEE limits superimposed. The horizontal lines at the top and bottom represent the safety zone for the ICNIRP standard. Anyone within those lines is being exposed to fields in excess of the maximum allowed exposure limits as set by ICNIRP.

As can be seen from the image, all of the participants in the MIT photo were being exposed to fields far in excess of allowable limits according to the ICNIRP.

The figure-eight-shaped contour delineates the safety zone as defined by the IEEE. All but one of the participants in the MIT photo were being exposed to fields substantially in excess of the maximum permissible exposure guidelines for magnetic field strength as set by the IEEE.

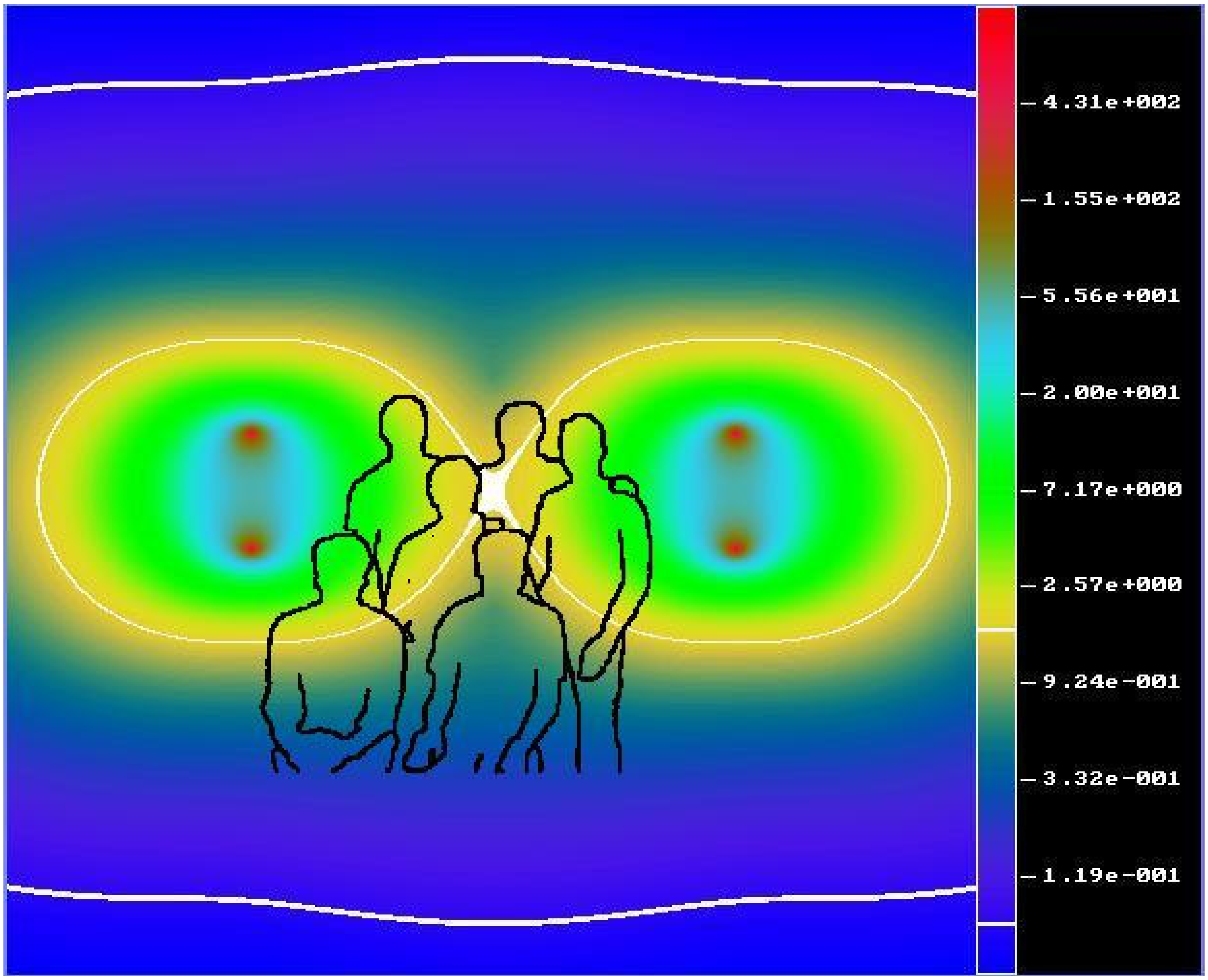

**Figure 5**

Figure 6 below shows the safety zones for the electric field. There are eight ovals in the image. The four largest ovals represent the safety zone as set by the ICNIRP. Any living tissue within the oval contours is subject to fields in excess of the safety limits set by the ICNIRP. Again, all but one member of the MIT team were being exposed to electric fields significantly in excess of the maximum permissible fields as set by the ICNIRP.

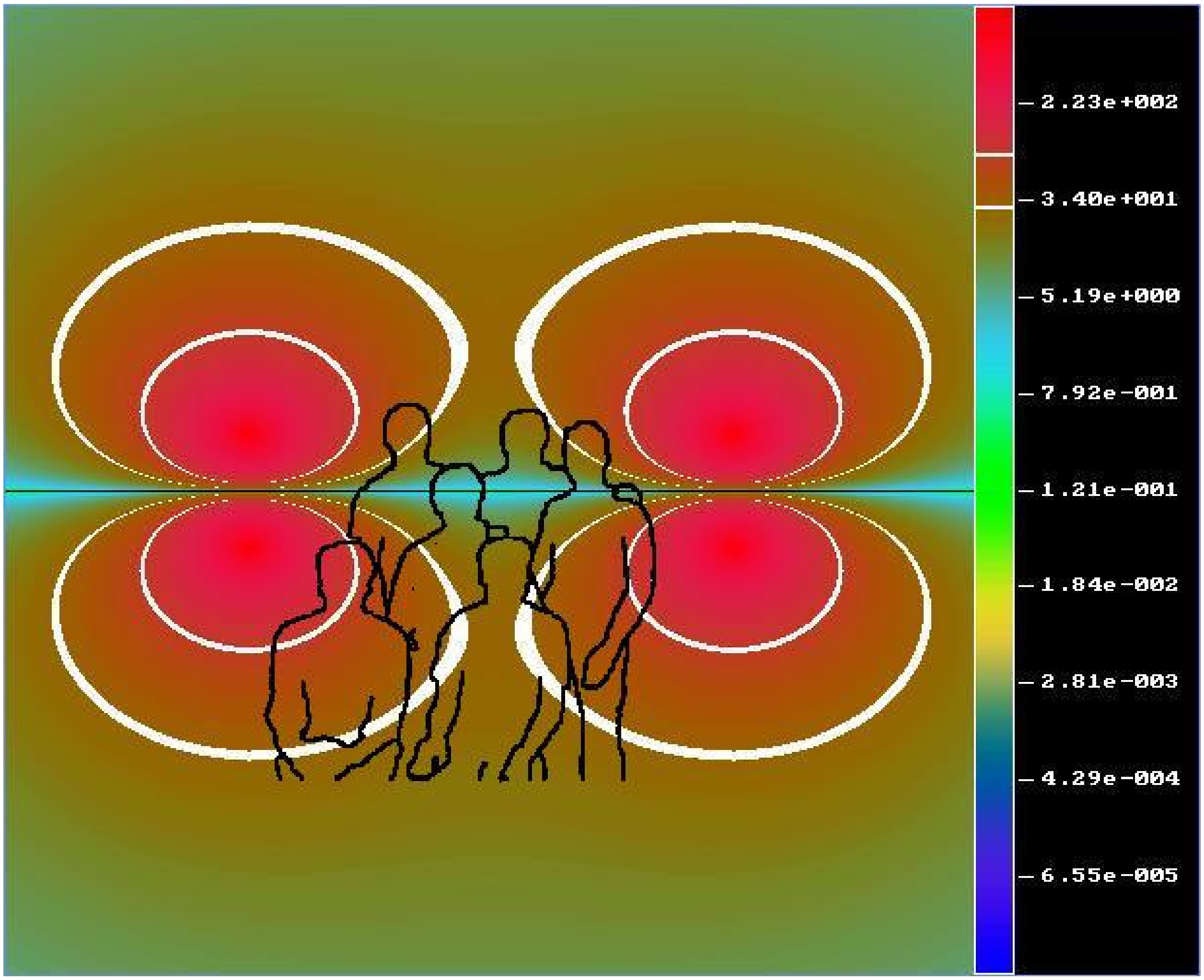

**Figure 6**

The IEEE safety zone is represented by the four smaller ovals. Any tissue within these areas has been determined to be unsafe by the IEEE. At least two members of the MIT were exposed to fields significantly in excess of those deemed to be safe by the IEEE.

## Conclusions

In 2007, MIT published a paper detailing the transfer of about 100W across room-sized distance with about 40% efficiency. This approach was soon branded as Witricity, and was picked up by the popular media as new physics to wirelessly power our future. Those who understood the paper knew that the physics involved, electromagnetism, was discovered 150 years ago, and resonant coupling, in fact, can be found in dusty textbooks from 65 years ago. The only thing new about Witricity was that it scaled-up the distance and power of the electromagnetic fields while being claimed to be efficient and safe. However, these claims do not hold up to close inspection.

An efficiency of 40% may seem surprisingly good for waves transmitted on one side of the room and received at another, however, it is unacceptable by today's standards for power. Today we are faced with dwindling energy resources and are concerned about every Watt we consume. What's more, we can expect practical products based on Witricity to have far lower efficiency when the coil size is reduced and the necessary electronics are included. This is something that any radio frequency (RF) engineer could tell you, because, after all, Witricity is just electromagnetism – the domain of the RF engineer.

Safety is the largest concern with Witricity. Although Witricity has been claimed in the media to be "just magnetism, which is safe", the fact is magnetism isn't simply "safe", and Witricity is not simply magnetism. Witricity is based on electromagnetism and generates electric and magnetic fields – both of which are subject to safety regulations. Organizations such as the IEEE and the ICNIRP make safety recommendations for electric and magnetic fields. We see here that, according to their guidelines, the MIT experiment subjected the participants to harmful levels of electromagnetic radiation.

Unfortunately, this technique has the surprising and unwanted effect that significant fields are generated by the *receiver*. This provides a very large challenge for Witricity engineers trying to make products that are safe in a consumer's pocket.

**References**

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**Mitch Randall** received his bachelors of science degree in electrical engineering in 1984 from Iowa State University. In 1989 he received his masters degree in electrical engineering from the University of Colorado, Boulder. In 2001 he received his masters degree in physics also from the University of Colorado. Randall spent 13 years as an engineer at the National Center for Atmospheric Research developing various scientific remote sensing instruments such as the DOW storm chasing radar trucks seen on TV. His invention and architecture of a conductive wire-free power technology led to the founding of WildCharge, Inc. and made TIME magazine's "One of the best inventions of 2007".