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SCHREYER HONORS COLLEGE

DEPARTMENT OF MECHANICAL AND NUCLEAR ENGINEERING

ASSESSING THE EFFECTIVENESS OF TWO SOLUTIONS FOR REDUCING HUMAN EXPOSURE TO ELECTROMAGNETIC RADIATION: A PRELIMINARY STUDY

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Abstract

This thesis examines the problem of reducing human exposure to electromagnetic radiation from domestic surroundings, with a particular emphasis on reducing the impact of such radiation on pregnant mothers. There are many sources of electromagnetic radiation in indoor environments, including computers, cellphones, televisions, refrigerators, microwave ovens, and other household appliances. This thesis begins by surveying the literature describing the potential health risks associated with these radiation sources. The thesis then assesses two existing products – an anti-radiation sticker and anti-radiation maternity gown – using a simple experiment. Finally, the thesis presents an attempt to assess these products using a finite element analysis tool. These three studies provide insights into the advantages, disadvantages, and possible improvements for the above two products. The thesis concludes with a discussion of possible further work to address the open gaps in the designs and configurations of these products.

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Chapter 1: INTRODUCTION

1.1 Thesis Goal

The goal of this thesis is to assess different existing commercial solutions for protecting human beings from the biological impacts of exposure to electromagnetic radiation. The thesis surveys existing scientific research relating electromagnetic radiation to human diseases and discomfort. This survey serves as a warning that the potential health problems induced by electromagnetic radiation may not be negligible. The thesis then examines two existing commercial anti-radiation products. The thesis compares the effectiveness of these two existing solutions, identifies their potential limitations, and suggests possible improvements that could provide better protection from domestic electromagnetic radiation.

1.2 Thesis Motivation

Motivation for this thesis comes from the significant potential impacts of electromagnetic radiation on human biology. Apart from the narrow visible light spectrum, electromagnetic radiation is not directly detectable by sight, taste, or smell, yet it is among the most widespread environmental hazards in industrialized countries today [23]. Electromagnetic radiation exposure is created by many wired and wireless devices designed to improve human quality of life, but with potentially unintended biological and health consequences [24].

Human beings can be viewed as bioelectrical systems, with internal bioelectrical signals playing an important role in the regulation of cardiac and brain functions [13]. This suggests that exposure to electromagnetic radiation has the potential to interact with the basic biological processes in the human body. Some concerned citizens and scientists have expressed the suspicion that prolonged exposure to even relatively mild levels electromagnetic radiation may lead to discomfort and disease [2]. Human beings are typically exposed to two types of man-made electromagnetic radiation in the modern world: one is the extremely low-frequency electromagnetic radiation from electrical and electronic appliances and power lines; the other one is the radio-frequency radiation from wireless devices such as wi-fi, cellphones, antennas, etc. Both of these types of radiation are non-ionizing, meaning that they do not carry enough energy per quantum to completely remove an electron from an atom or molecule. Although non-ionizing radiation does not break off electrons from their orbits around atoms and charge the atoms the way x-rays, CT scans, and other forms of ionizing radiation do, the biological effects on human beings may not be negligible [5]. One main goal of this thesis is to survey some of the peer-reviewed scientific literature pertaining to radiation exposure and the associated biological hazards. Another goal is to evaluate the ability of two specific commercial anti-radiation products to reduce human exposure to background radiation.

1.3 Radiation Protection Solutions Evaluated

Several so-called "anti-radiation" products are commercially available on the market today. This thesis focuses on two specific representative products as benchmarks for evaluation: an "anti-radiation" maternity gown, shown in Figure 1, and an "anti-radiation" sticker, shown in Figure 2. These products are very distinct in size, configuration, and commercially-advertised operational principle: a fact that makes their comparison and contrast interesting and valuable. The following subsections summarize the commercial descriptions of these products, noting that these descriptions are intended for marketing and must therefore be examined with a "grain of salt". The remainder of this thesis describes the studies used for evaluating these products.

1.3.1 Product #1: A Radiation-Shielding Maternity Gown

Figure 1 shows the *Osun Baby-Shield Maternity Camisole*, one of two products assessed in this thesis. The product's commercial description states that it is woven from a so-called "silver fiber blend", i.e., a textile fabric either coated with or containing silver. The manufacturer claims that this particular product is woven from "100% high-tech silver fiber blend", and that it is capable of reducing radio-frequency radiation intensity by 99.99% (60dB) for frequencies in the 500MHz-12GHz range. The manufacturer also claims that the higher the percentage of silver fiber blend, the higher the radio-frequency shielding performance it yields, and that this particular product can ultimately protect unborn babies against "all" radio-frequency radiations. This thesis does not verify the manufacturer's claims regarding the composition of this gown, but a key goal is to quantify the gown's ability to protect its wearer from background electromagnetic radiation.

Figure 1: Osun Baby-Shield Maternity Camisole

1.3.2 Product #2: An Anti-Radiation Sticker

Figure 2 shows the *Aulterra EMF Neutralizer*, the second anti-radiation product assessed in this thesis. The product's commercial advertising claims that it contains a proprietary blend of materials capable of reducing the adverse effects of manmade electromagnetic field exposure on human DNA. As with the radiation-shielding maternity gown, this thesis does not verify the manufacturer's claims regarding the composition of this sticker/product, but a key goal is to quantify the sticker's ability to protect its user from background electromagnetic radiation.

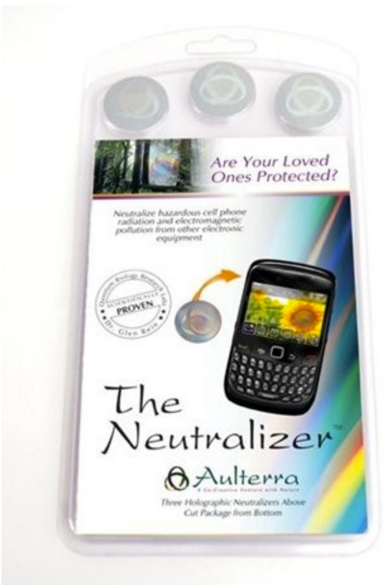

Figure 2: Aulterra EMF Neutralizer

1.3.3 Product Selection Rationale

The two products evaluated in this thesis represent two very different concepts for reducing electromagnetic radiation. The general concept behind the *Osun Baby-Shield Maternity Camisole* is to use anti-radiation materials to almost cover the human body. The main idea behind *Aulterra Neutralizer* is to use a much smaller amount of material to veil a small portion of the radiation sources, such as cellphones, computers or any other electronic equipment, in order to reduce electromagnetic radiation. By assessing and comparing these two existing products, the thesis can at least answer this question: what is the relationship between the amount of surface area covered by anti-radiation materials and their effectiveness in reducing electromagnetic radiation? By analyzing the limitations of the two existing products, the thesis can also offer a hypothesis on how to improve these two existing products.

1.4 Contributions of This Thesis

The thesis assesses two existing anti-radiation products based on their effectiveness in reducing electromagnetic radiation. The thesis provides objective and scientific evidence on how efficiently these two existing products reduce electromagnetic radiation. The thesis concludes with a guideline on how to use anti-radiation material to reduce electromagnetic radiation and what material could be used as anti-radiation material. The thesis also proposes guidelines for improved solutions based on the assessments of the two existing products, which could contribute to new anti-radiation products.

1.5 Thesis Outline

The remainder of this thesis first introduces the possible biological effects that electromagnetic radiation could have on human beings by surveying the scientific literature on this topic. The thesis then presents the assessment of two existing anti-radiation products by testing the materials of the products and simulating the product models in the finite element analysis package Ansys. Based on the analysis of the effectiveness and limitations of those products, the thesis proposes a solution to address the open gaps in the existing products.

Chapter 2: LITERATURE SURVEY

2.1 Effect of Electromagnetic Radiation on Human Health

This chapter surveys the peer-reviewed scientific literature on the effect of electromagnetic radiation on human health. The survey suggests that exposure to low-frequency electromagnetic radiation may be related to the ailments listed below:

- Cancer
    1. Childhood Leukemia [25]
    2. Brain Tumors and Acoustic Neuromas [15]
    3. Breast Cancer [9] [29]
- Changes in the Nervous System and Brain Function [6]
- Effects on Genes [1]
- Effects on Stress Proteins [5]
- Effects on the Immune System [33]
- Effects on Melatonin Production [3]

Of the above effects, three important ones receive additional attention in this literature survey, namely, the possible effects of electromagnetic radiation on *(i)* childhood leukemia, *(ii)* the nervous system, and *(iii)* melatonin production [4] [17] [25]. Surveying these three effects indicates two things: first, electromagnetic radiation may have long-term effects on everyone. Second, children seem to be affected by electromagnetic radiation most easily. The chapter concludes by surveying some of the existing public electromagnetic radiation exposure standards and some of the literature on the adequacy/inadequacy of these standards. This survey and discussion motivates the subsequent examination of different radiation protection solutions.

2.1.1 Effects on Childhood Leukemia

Childhood is a critical period of enormous cell growth [25]. This raises concerns regarding children's safety and exposure to electromagnetic radiation, including exposure to fields from nearby power lines, computers or other electronics at home and school, and TV screens [8].

Leukemia is cancer of the blood and develops in the bone marrow where new blood cells are formed [7]. When a child has leukemia, the bone marrow produces white blood cells that do not mature correctly [32]. These abnormal white blood cells, as the disease advances, battle with the healthy white blood cells that the body needs to fight bacterial, viral and other infections. Red blood cells are also affected by the abnormal white blood cells.

Leukemia is the most common form of cancer found in children, mainly acute lymphocytic leukemia [2]. There is strong evidence suggesting that exposure to electromagnetic radiation causes childhood leukemia. An overview of existing evidence [9] [25] from epidemiological studies shows that there is a continuous increase of risk with increasing levels of average magnetic field exposure.

2.1.2 Effects on Changes in the Nervous System and Brain Function

Exposure to electromagnetic fields has been studied in connection with Alzheimer's disease, motor neuron disease and Parkinson's disease [2]. These diseases all involve the death of specific neurons and may be classified as neurodegenerative diseases. There is evidence that exposure to extremely low-frequency electromagnetic fields can increase levels of amyloid beta, considered a risk factor for Alzheimer's disease [18]. There is also evidence that exposure to extremely low-frequency electromagnetic fields can reduce field melatonin levels which can strongly protect the brain against damage leading to Alzheimer's disease [26]. This leads to the hypothesis that one of the body's main protections against developing Alzheimer's disease, melatonin, is less available to the body when people are exposed to extremely low-frequency field strength.

Sobel et al. [34] reported an association between occupations with electromagnetic field exposure and Alzheimer's disease during the period 1994-1995 using three different clinical case-control series, two from Finland and one from the United States involving 386 Alzheimer's disease patients and 475 controls. The estimated odd ratios (ORs) for men, women, and both combined were 2.9, 3.1, and 3.0. This means that electromagnetic field exposure increased the odds of Alzheimer's by a factor of 2.9, 3.1, and 3.0 for men, women, and both men/women together. The study also found that males with Alzheimer's disease were 4.9 times as likely to have had a high occupational exposure to fields while females were 3.4 times as likely. These results indicate that people who were exposed to high radiation levels on the job have three to five times the normal risk of contracting this harmful disease associated with aging. The risk was also high for carpenters, electricians, electrical and electronic assemblers, and those who use electrically powered tools held close to their bodies.

The nervous system is functionally composed of nerve cells and supporting cells, both of which are very sensitive to environmental disturbances [2]. Disturbances to the nervous system may lead to behavioral changes. On the other hand, alteration in behavior could imply a change in function of the nervous system. One of the most well-studied spontaneous behaviors in bioelectromagnetics research is motor activity. Change in motor activity is regarded as an indication of change in the alertness/state of an animal [22]. Exposure to radio-frequency radiation could also affect controlled and learned behaviors. Wang and Lai [35] investigated spatial long-term memory using a water maze. In the test, rats were trained to learn the location of a submerged platform in a circular water pool. It was found that rats exposed to pulsed 2450 MHz radio-frequency radiation were significantly slower in learning and used a different strategy in locating the position of the platform. Generally speaking, radio-frequency radiation disrupted schedule-controlled behavior in animals such as discrimination, response, learning and avoidance.

2.1.3 Effects on Melatonin Production

Melatonin is a hormone produced by the pineal gland, a small pinecone-shaped gland located deep near the center of the brain [14]. It surges into almost every cell in the human body, destroying radicals and helping cell division to take place with undamaged DNA. Melatonin also assists in regulating the female menstrual cycle and circadian rhythms [2].

Melatonin secretion decreases over one's lifetime, peaking in childhood and gradually lessening after puberty [31]. Melatonin regulates sleep, mood, behavior, and gene expression. It reduces secretion of tumor-promoting hormones. It has the ability to increase cytotoxicity of the immune system's killer lymphocytes, which is essential for the immune system and protects the body from infection and cancer cells. 85% to 90% of pineal melatonin production is at night. Research by multiple laboratories [14] [16] shows melatonin reduction in cells, animals, and humans exposed to extremely low-frequency fields.

2.1.4 Existing Public Exposure Standards

In the United States, the Federal Communications Commission (FCC) enforces limits for both occupational exposures (in the workplace) and public exposures to electromagnetic radiation. The exposure limits are variable according to the frequency (in MHz) and the duration of exposure time (6 minutes for occupational and 30 minutes for public exposures). Figure 3 shows exposure limits for occupational and uncontrolled public access to radio-frequency radiation emitted from AM, FM, television and wireless sources through the air. As an example, 583 microwatts/cm^2 (μW/cm^2) is the public limit for the 875 MHz cell phone wireless frequency and 1000 μW/cm^2 is the limit for PCS frequencies in the 1800 – 1950 MHz range averaged over 30 minutes.

(A) Limits for Occupational/Controlled Exposure

Frequency Range (MHz)	Electric Field Strength (E) (V/m)	Magnetic Field Strength (H) (A/m)	Power Density (S) (mW/cm2)	Averaging Time $[E]^2$ $[H]^2$ or S (minutes)
0.3-3.0	614	1.63	(100)*	6
3.0-30	1842/f	4.89/f	$(900/f_2)$*	6
30-300	61.4	0.163	1.0	6
300-1500			f/300	6
1500-100,000			5	6

(B) FCC Limits for General Population/Uncontrolled Exposure

Frequency Range (MHz)	Electric Field Strength (E) (V/m)	Magnetic Field Strength (H) (A/m)	Power Density (S) (mW/cm2)	Averaging Time $[E]^2$ $[H]^2$ or S (minutes)
0.3-3.0	614	1.63	(100)*	30
3.0-30	824/f	2.19/f	$(180/f_2)$*	30
30-300	27.5	0.073	0.2	30
300-1500	--	--	f/1500	30
1500-100,000	--	--	1.0	30

f = frequency in MHz *Plane-wave equivalent power density

Figure 3: FCC Limits for Maximum Permissible Exposure

Some countries have established new, low-intensity electromagnetic radiation exposure standards that respond to studies reporting health risks that may not be solely associated with radiation-induced heating [20] [27] [28] [30]. These new exposure limits are hundreds or thousands of times lower than those of IEEE and ICNIRP [12] [19] [21]. Figure 4 illustrates this by comparing the radiation limits in the 800MHz-900MHz for several countries. The levels range from 10 μW/cm^2 in Italy and Russia to 4.2 μW/cm^2 in Switzerland. In comparison, the

United States limits such exposures to 580 μW/cm^2, while the United Kingdom and Canada allow up to 5800 μW/cm^2.

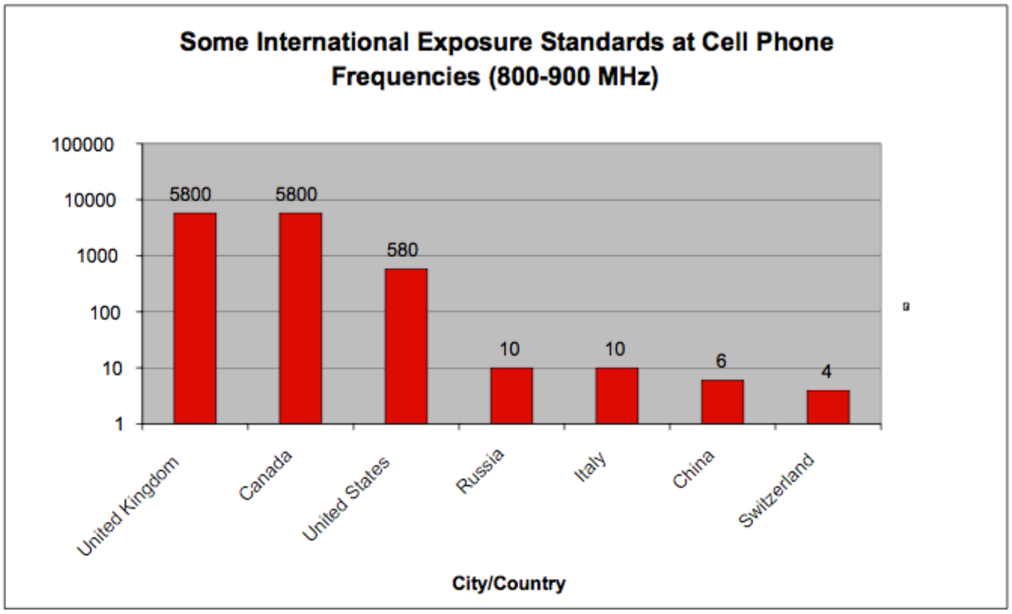

Figure 4: Some International Exposure Standards at Cell Phone Frequencies

2.1.5 Adequacy of Existing Public Exposure Standards

Some international associations have examined the adequacy of the existing public electromagnetic radiation exposure standards. The World Health Organization (WHO), for instance, has examined the current exposure limits. In 2007, the WHO EMF Program released its ELF Health Criteria Monograph [36] [37], cited below:

"Conclusions

Acute biological effects have been established for exposure to ELF electric and magnetic fields in the frequency range up to 100 kHz that may have adverse consequences on health. Therefore, exposure limits are needed. International guidelines exist that have addressed this issue. Compliance with these guidelines provides adequate protection.

Consistent epidemiological evidence suggests that chronic low-intensity ELF magnetic field exposure is associated with an increased risk of childhood leukaemia. However, the evidence for a causal relationship is limited, therefore exposure limits based upon epidemiological evidence are not recommended, but some precautionary measures are warranted."

The WHO Fact Sheet [38] [39] also summarizes some of the Monograph findings [20] but adds further recommendations:

"Much of the scientific research examining long-term risks from ELF magnetic field exposure has focused on childhood leukaemia. In 2002, IARC published a monograph classifying ELF magnetic fields as "possibly carcinogenic to humans. This classification was based on pooled analyses of epidemiological studies demonstrating a consistent pattern of a two-fold increase in childhood leukaemia associated with average exposure to residential power-frequency magnetic field above 0.3 to 0.4 μT. The Task Group concluded that additional studies since then do not alter the status of this classification."

The above reports are important because they specifically emphasize the need for "precautionary measures" above and beyond the electromagnetic radiation exposure standards dictated by law. This motivates the overarching goal of this thesis, namely, assessing the viability of two such "precautionary measures".

Chapter 3: SOLUTION METHOD

This chapter summarizes both the experimental and simulation-based studies at the core of this thesis. The chapter begins by describing experiments performed to assess the viability of the two anti-radiation products (Section 3.1). The chapter then summarizes an attempt to understand the operation of these products via finite element analysis (Section 3.2). Results from these studies are presented in Chapter 4.

3.1 Experimental Assessment of Existing Products

3.1.1 Description of the Tools

Figure 5 shows the Cornet ED85EX meter, the radiation meter used for the experimental work in this thesis. Its advertised technical specializations are listed below:

- *Wide frequency range : 1MHz to 8GHz (useful to 10GHz).*
- *Super Wide dynamic range : 60dB.*
- *High sensitivity : –55dBm to 5 dBm (25mV/m to 14.8V/m).*
- *Peak power density measurement : 1.5uW/m2 to 0.58W/m2.*
- *LCD moving graphic Histogram and Bar display to display signal power level.*
- *Ultra fast color LED 8 segment level display for easy signal levelindication.*
- *Continue wave (AM,FM) and High speed Burst RF(GSM,TDMA,,CDMA, Wi-Fi,WiMAX).*
- *External SMA connector : (50ohms) for external Antenna, attenuator, and filter.*

Figure 5: Cornet ED85EX

3.1.2 Description of Experiments

3.1.2.1 Examination of Silver Fiber Blend

The experimental work in this thesis replaces the human body (or anything that is supposed to be isolated from electromagnetic radiation) by a 7in * 3.5in * 3.5in box. This box serves as a reproducible idealized representation of the space to be protected from radiation. The main purpose of the box is to examine the material of the maternity clothes, the silver fiber blend, more efficiently. The frame of the box is made from wood, shown in Figure 6. Prior to conducting the experiments below, the effectiveness of the box itself as an anti-radiation device was studied experimentally to provide a reference point for subsequent experiments. This examination showed that the wood frame barely affects surrounding background radiation, and is therefore suitable as a starting point for further experimental work. The anti-radiation gown's silver fiber blend was then cut into shapes that best fit the size of the wood frame/box. Five pieces of silver fiber blend were attached to the wood frame covering all the surfaces of the box except one 3.5in * 3.5in side surface. That side was designed to be adjustable: it can be completely closed so that the box could be an approximately closed volume; it can also be opened so that tools could be inserted in if necessarily.

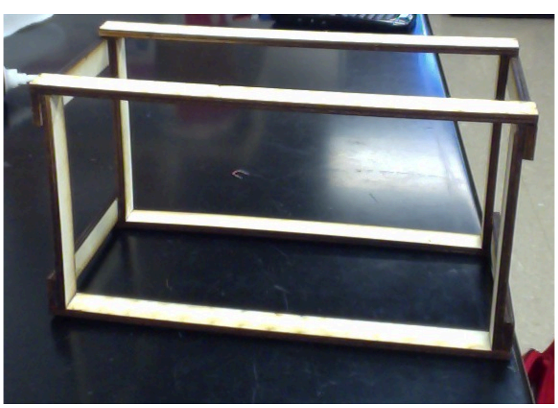

Figure 6: The hand-made box frame

Experiment #1:

The purpose of this set of experiments is to test whether the silver fiber blend can reduce electromagnetic radiation, and if so, by how much. From a quantitative perspective, the goal of this set of experiments is to test whether the electromagnetic radiation power density inside the box is lower than the original power density at the same point in space without the box, and if so, by how much.

In performing these experiments, I used a variety of surrounding electromagnetic radiation environments, such as computer labs, apartments, and classrooms. The power intensity in these environments ranges from -20 dBm to -40 dBm. Since this range of power intensity is relatively low, I also used a microwave oven to help produce high power intensity so that I could examine the effectiveness of the anti-radiation material in both high power intensity and low power intensity. While operating, the microwave oven produces +5 dBm power intensity, the maximum power intensity the Cornet meter can measure. I first measured and recorded the power intensity at one specific point in space, and then placed the box over that target point, and lastly measured the power intensity inside the box.

3.1.2.2 Examination of Anti-radiation Sticker

Experiment #2:

The purpose of this set of experiments is to record the original power intensity at three different points/instants in time. The first point in time is when no phone call is made, so this measurement simply quantifies background electromagnetic field intensity. The second point in time is when a phone call is made to the target cellphone and the target cellphone starts to ring or vibrate but the phone call is not answered. The third point in time is when the phone call is answered with the target cellphone. The cellphones used are the IPhone 4, BlackBerry 9800, and Nokia E72.

This set of experiments requires a surrounding with relatively steady and low power intensity in order to ensure that the increasing power intensity for different successive experiments is caused by cellphone frequency radiation. I set the tip of the Cornet antenna right next to the center of the rear of the cellphone and then I recorded the measurements at the three time points mentioned above. The reason why I chose the center of the rear of the cellphone to be the target spot is to avoid the electromagnetic radiation from the screen affecting the accuracy of my results.

Experiment #3:

The purpose of this set of experiments is to record the power intensity after the anti-radiation sticker/neutralizer is stuck to the center of the rear of the cellphone at the same three time points mentioned in the previous set of experiments. The cellphones used are also the same, namely, the IPhone 4, BlackBerry 9800, and Nokia E72. Again, this set of experiments requires a surrounding with relatively steady and low power intensity.

Detailed procedures are listed below:

- Stick the neutralizer to the center of the rear of the target cellphone
- Set the tip of the antenna set right next to the center of the rear of the cellphone
- Record the readings of the meter at three time points
- Compare this set of results with the previous set of results and analyze the effectiveness of this product.

3.2 Simulation of Possible Solution

To better understand the effectiveness of different anti-radiation solutions, I used the finite element analysis software Ansys to simulate a radiation source next to a simple anti-radiation shield. There are four purposes behind this simulation. First, the simulation makes it relatively easy to examine the effectiveness of reducing electromagnetic radiation at different frequencies. This is important because the silver fiber blend may have different levels of performance as an anti-radiation shield at different amplitudes or different frequencies. By changing the input parameters of radiation sources in simulation, I can control the frequency and amplitude of the created electromagnetic radiation and assess the possible different effectiveness levels at different frequencies or amplitudes. Second, this simulation can help me understand how anti-radiation materials reduce electromagnetic radiation. Specifically, I can use the simulation to understand the actual wave behaviors when electromagnetic waves encounter the boundary between two media created by the anti-radiation material. By solving Maxwell's equations, the Ansys simulation can output the results showing whether the given anti-radiation shield works by reflecting, refracting, or absorbing incoming electromagnetic waves. Understanding how the waves react when encountering a boundary can help the design of anti-radiation products. Third, by changing the input parameters of the anti-radiation material, such as permeability and permittivity, I can examine the effectiveness of different materials in reducing electromagnetic radiation. Fourth, since Experiment #1 could only examine the effectiveness of the silver fiber blend rather than the maternity clothes, I can use Ansys to simulate a human body covered by the anti-radiation gown to test the effectiveness of the geometry of the product and improve the geometric design of anti-radiation products.

In order to meet the four purposes mentioned above, I simulated a sinusoidal current, as a radiation source with controllable frequency and amplitude, next to a metal plate, representing an anti-radiation shield with controllable geometry and properties (specifically, permeability and permittivity). By solving Maxwell's equations, Ansys should be able to output the magnitudes and directions for both the magnetic field intensity and the electric field intensity. Based on those results, I could optimize the product effectiveness by changing the choice of anti-radiation materials and the geometric design of the given product.

Chapter 4: RESULTS

4.1 Results of the Experiments Related to Maternity Clothes

The material of the maternity clothes, the silver fiber blend, reduces background electromagnetic radiation by 14 dBm at least. Based on twenty sets of measurements, the average reduction is 20.2 dBm, the maximum reduction is 29.4 dBm, and the minimum reduction is 14.1 dBm (see Figure 7). There are two comparisons made in Figure 7. The first comparison is made in a "laboratory" setting where the main source of electromagnetic radiation is computer equipment, and electromagnetic field intensity is in the -20dBm to -40dBm range. The second comparison is made in a "dormitory" setting where much higher background radiation levels (+5dBm) are achieved by operating a microwave oven. Note that even if the power intensity is as high as +5.0 dBm, the maximum power intensity the Cornet meter can measure, the silver fiber blend box can still reduce that power intensity to a relatively safe rage, less than -20 dBm. The results also show that the silver fiber blend is not able to reduce all the different electromagnetic radiation to the same level. For example, Figure 7 shows that this material cannot reduce originally high power intensity, +5 dBm, to -30dBm. In fact, the effectiveness of the silver fiber blend appears to be a function of the power intensity of the surrounding radiation. The amount of power intensity that can be reduced is likely to depend on the strength of the background electromagnetic radiation.

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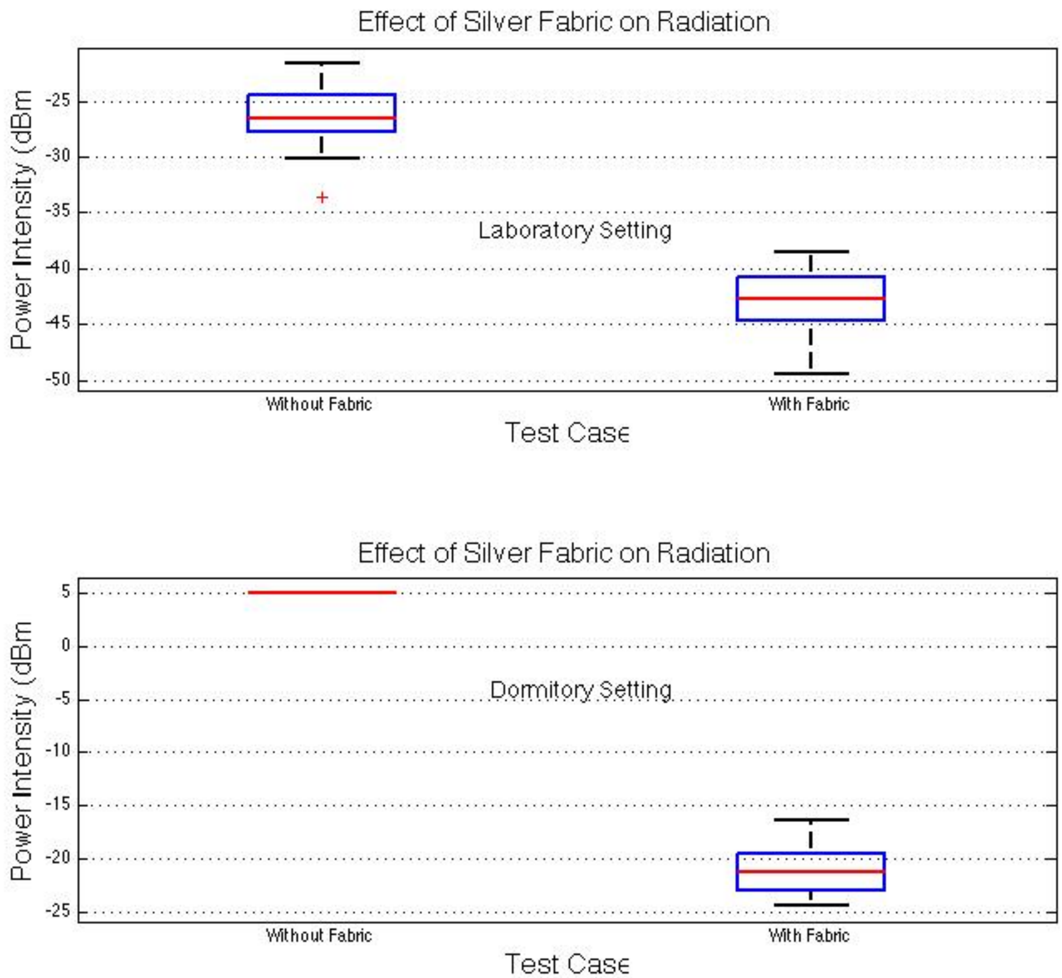

Figure 7: Effect of Silver Fabric on Radiation

4.2 Results of the Experiments Related to Neutralizer

Figure 8, Figure 9, and Figure 10 show the original measurements at three different time points. For the BlackBerry 9800, the average power intensity at step 2, when the cellphone starts to ring or vibrate, is 3.8 dBm; the average power intensity at step 3, after the phone call is answered, is –6.7 dBm. For the IPhone 4, the average power intensity at step 2 is 4.1 dBm; the average power intensity at step 3 is -3.9 dBm. For the Nokia E72, the average power intensity at step 2 is -23.6 dBm; the average power intensity at step 3, after the phone call is picked, is -32.2

dBm. Overall, cellphone frequency radiation greatly increases the power intensity around the cellphone surface. BlackBerry 9800 and IPhone 4 generate much higher power intensities than Nokia E72.

The Neutralizer is extremely ineffective in reducing electromagnetic radiation. After the neutralizer is attached to the center of the rear cellphone surface, another twenty sets of measurements are taken for each cellphone at the exact same spot. However, I did not find any significant changes of the power intensity where the neutralizer is attached.

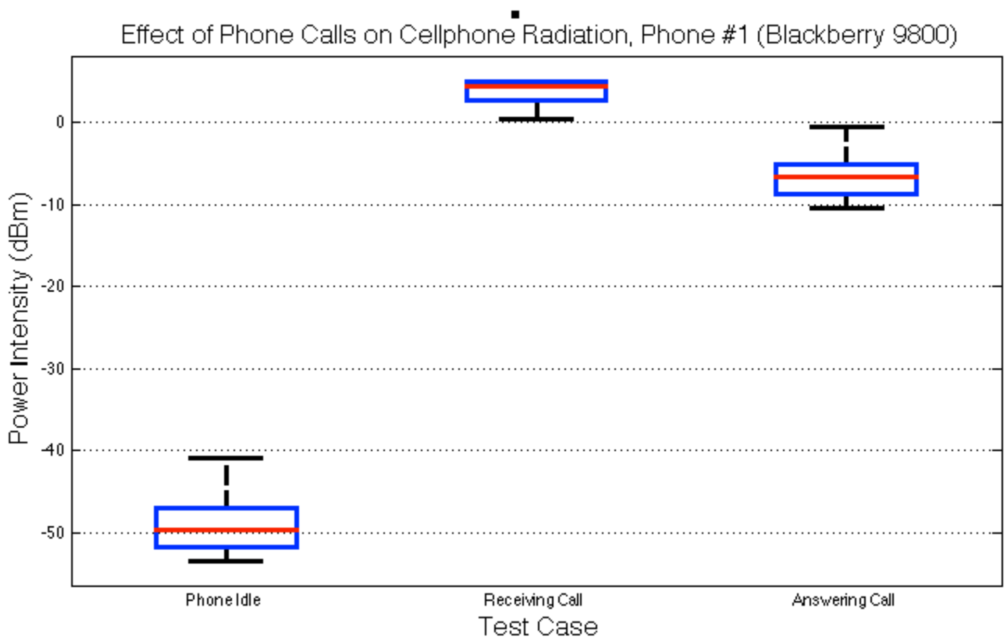

Figure 8: Effect of Phone Calls on Cellphone Radiation, Phone #1 (Blackberry 9800)

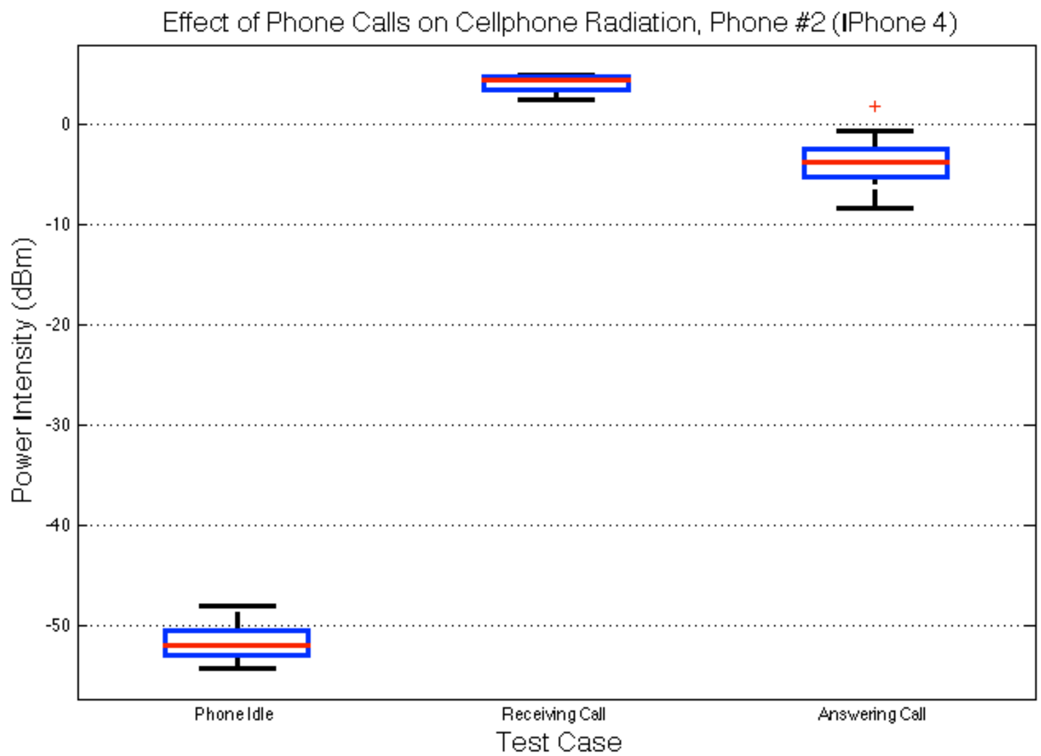

Figure 9: Effect of Phone Calls on Cellphone Radiation, Phone #2 (IPhone 4)

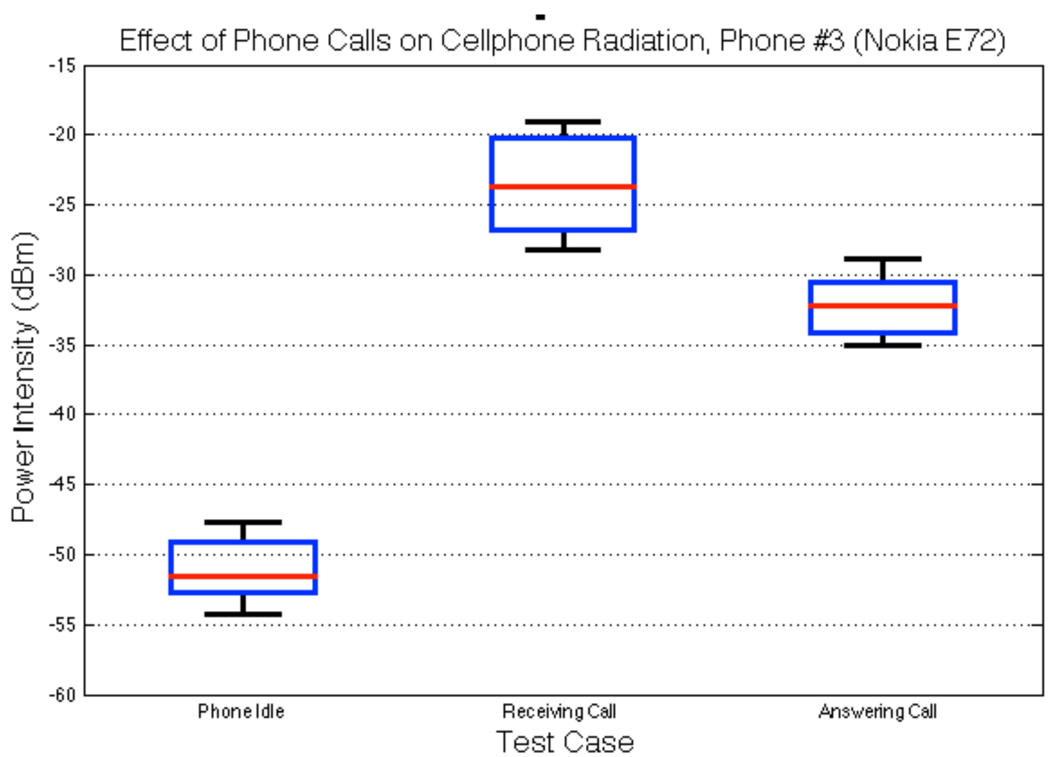

Figure 10: Effect of Phone Calls on Cellphone Radiation, Phone #1 (Nokia E72)

Figure 11 and Figure 12 show the average power intensity at the center-rear cellphone location with and without the neutralizer. There is no obvious decease of power intensity in both time points 2 and 3. For both Figure 11 and Figure 12, the label "1" on the x-axis represents the BlackBerry 9800, "2" represents the IPhone 4, and "3" represents the Nokia E72. Figure 11 shows at the time point when the cellphone starts to ring or vibrate, the average power intensity increases from 3.8 dBm to 3.9 dBm after the neutralizer is attached to BlackBerry 9800, the average power intensity decreases from 4.1 dBm to 4 dBm after the neutralizer is attached to IPhone 4, and the average power intensity decreases from -23.6 dBm to -25.2 dBm after the neutralizer is attached to Nokia E72. Similar results are achieved in step 3, i.e., there is no obvious increase or decrease in radiation after the neutralizer is attached.

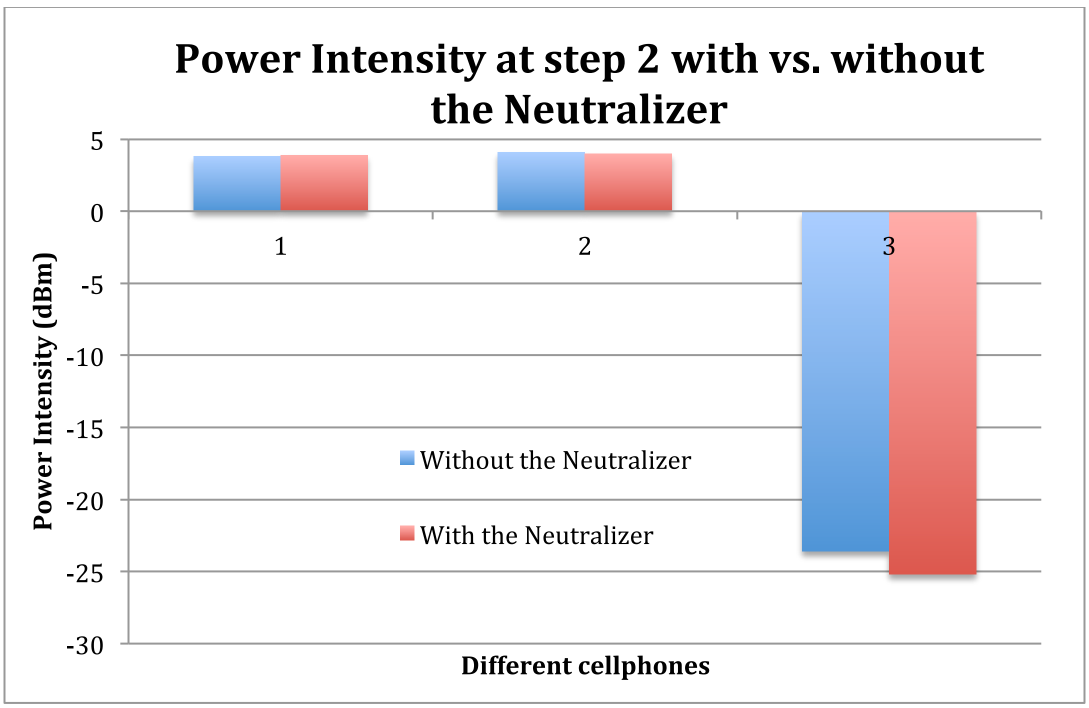

Figure 11: Power intensity at step 2 with and without the neutralizer

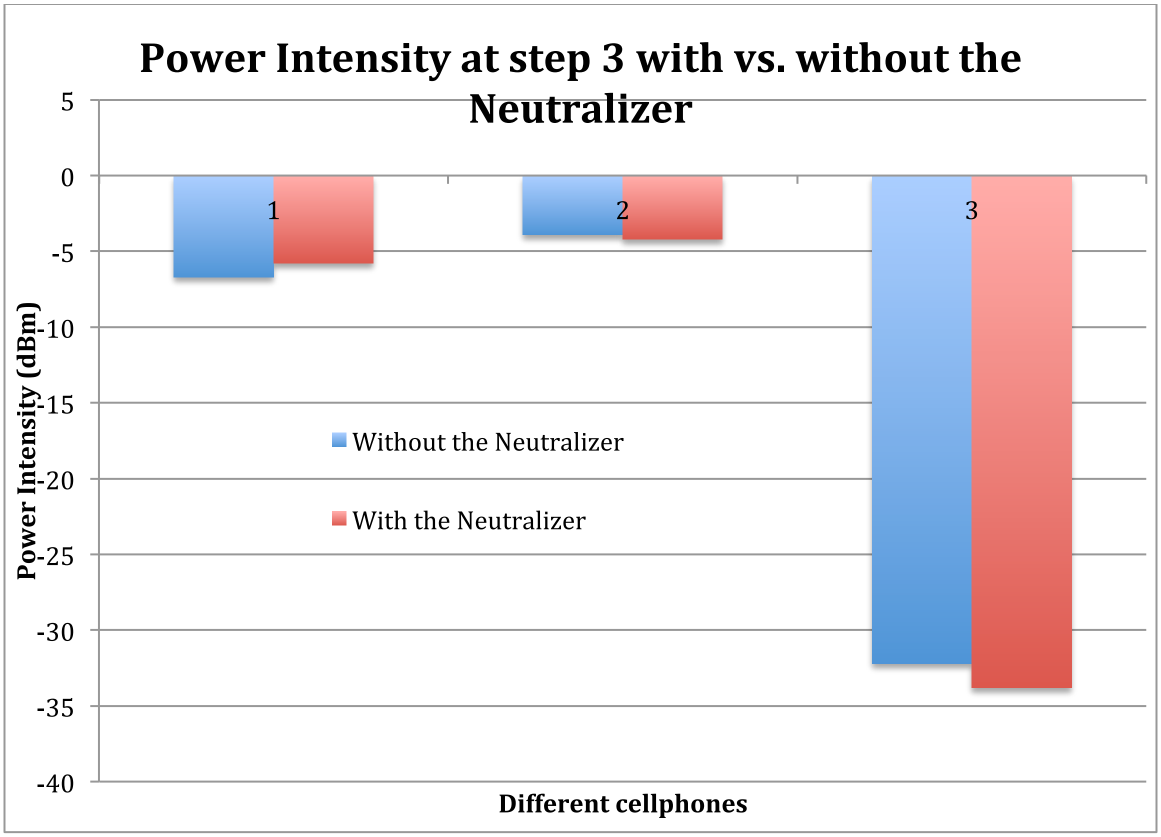

Figure 12: Power intensity at step 3 with and without the neutralizer

4.4 Results of Simulation

Figure 13 and Figure 14 show the simulation results by Ansys. Figure 13 represents the magnetic field intensity for a sinusoidal current in the cylinder on the left, in the presence of the anti-radiation material (i.e., the plate on the right) and the surrounding air (the cube). The magnetic field intensity does not behave as expected. Figure 13 only shows the intensity in the current source, the cylinder, without showing the intensity in the air, the cubic, and in the boundary when encountering the metal layer, the plate. I expected it to show a higher-intensity magnetic field in the surrounding air and the metal plate.

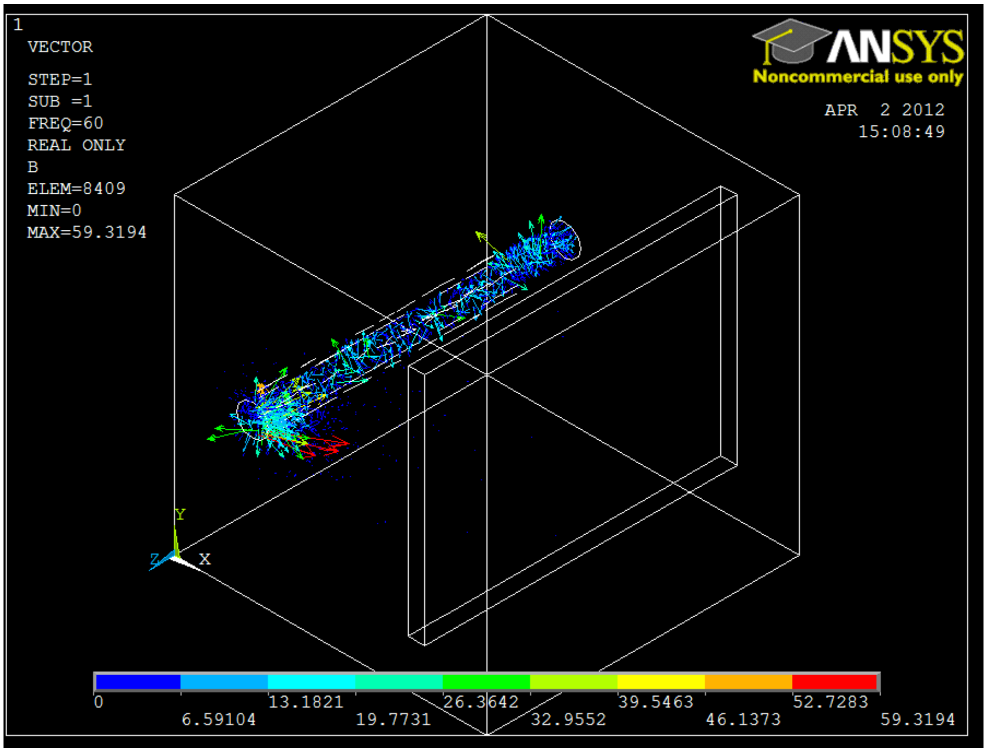

Figure 13: Magnetic field intensity

Figure 14 represents the corresponding electric field intensity computed by Ansys. Given the harmonic current excitation used in this study, I expected an electric field to be created due to the sinusoidal changes in magnetic field intensity. However, Figure 14 does not show an electric field.

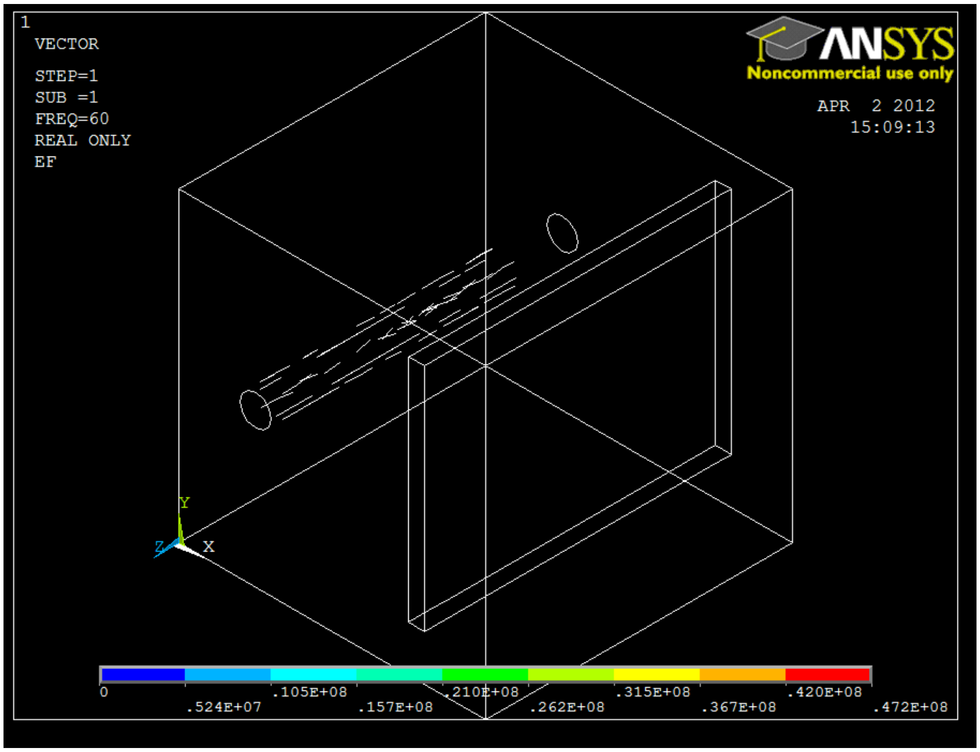

Figure 14: Electric field intensity

4.3 Analysis of the Results

The results match the expectation that the box made by the silver fiber blend does work and the neutralizer does not work in reducing electromagnetic radiation. This is because electromagnetic waves can be reflected, refracted and absorbed if and only if electromagnetic waves encounter a boundary between two media with different electromagnetic properties. When an electromagnetic wave encounters such a boundary between two media, some of the energy the wave conveys can be reflected or absorbed so that the power intensity without the protective media is larger than the power intensity with the media.

The silver fiber blend, covering the entire surface of the hand-made box, actually induces a boundary that can either reflect or absorb the energy of electromagnetic radiation. This is why the power intensity inside the box is reduced, shown in Figure 7. Although the silver fiber blend cannot eliminate all the radiation energy, it is able to reduce high power intensity to relatively low power intensity. However, the effectiveness of the sliver-fiber-blend box cannot imply the effectiveness of the maternity clothes. The critical difference is that the anti-radiation material covers the box totally, in 360 degrees, while the maternity clothes only cover a certain proportion of woman's body. Great amount of energy conveyed by electromagnetic radiation could still travel into the body from the remaining portion of the body and affect this remaining portion of the body. This can be potentially critical if a cellphone is worn under the maternity clothes, a situation where one may conjecture the possibility that the maternity clothes will increase risk to the pregnant mother by reflecting the electromagnetic waves back towards her body. Therefore, the effectiveness of maternity clothes is still uncertain, but the effectiveness of the sliver fiber blend, this one type of anti-radiation material, is confirmed from the results.

The ineffectiveness of the neutralizer is due to the same principle. The neutralizer only covers an area of one-inch diameter circle. The amount of energy the neutralizer can reduce is limited because it can only reflect or absorb the energy traveling through that small area. The results indicate that the ability of reducing electromagnetic radiation is questionable even in that small area. The power intensity barely reduces or even changes in that area compared with the original power intensity, shown in Figure 11 and Figure 12.

Chapter 5: CONCLUSIONS

5.1 Summary of the Thesis

The broad goal of this thesis is to find a method that can prevent human beings from the possible side effects of electromagnetic radiation. More and more scientific research studies suggest that exposure to electromagnetic radiation can be related to some human biological changes, which may further cause some diseases and discomforts. Two main concerns associated with electromagnetic radiation are childhood leukemia and Alzheimer's disease. Electromagnetic radiation threatens the safety of children and pregnant women most, and it could have chronic effects on each single human being. The thesis mainly examines and assesses two existing anti-radiation products, a maternity camisole and a neutralizer sticker. They represent two different concepts for reducing electromagnetic radiation, one covering most the surface area of the target that is to be protected, and one covering a small area of one radiation source.

Several experiments are conducted to examine and assess the effectiveness of the above two existing products. For the maternity camisole, a box is made to test the effectiveness of the material of that maternity camisole, the silver fiber blend. By measuring the power intensity with and without the box, the sliver fiber blend is found to be an applicable anti-radiation material. It indeed can reduce large the amount of energy conveyed by electromagnetic radiation. For the neutralizer sticker, three cellphones are used for examination and assessment. By sticking the back center of the cellphones and measuring the power intensity at that point with and without the neutralizer at three different time points/events, the thesis concludes that the neutralizer cannot reduce the cellphones' electromagnetic radiation effectively. In particular, my results show that the sticker has no discernible impact on radiation power intensity.

5.2 Contributions and Applications

Based on the conclusions made above and the understanding of electromagnetic wave behaviors, here are some suggestions how to choose an anti-radiation product that are truly effective in protecting humans against electromagnetic radiation. First, it appears that anti-radiation stickers, necklaces, or other products that only cover a small part of the human body are less effective at protecting people from exposure to electromagnetic radiation. A better option appears to be choosing products that simply cover a larger area of the human body. Second, anti-radiation products can be made from normal, ordinary and well-known materials that have a reasonable cost. The product booklet for the neutralizer states, "Three micro-thin layers of rare activated earth elements produce our thinnest, most effective Neutralizer ever." Generally speaking, metals can also absorb or reflect the energy conveyed by electromagnetic radiation. This suggests that anti-radiation materials do not have to be made from rare-earth metals, and can be made from more commonly-available materials instead. Third, based on the results of the cellphone experiments, cellphones can produce very high power intensities close to the surfaces of the cellphones, potentially within the dangerous range marked by the Cornet meter. This suggests that when making a phone call, one may want to stay far away from the cellphone by using earphones, and also try to keep the phone call short, and perhaps balance the time spent listening through each ear.

One effort described in this thesis is an attempt to simulate a radiation source and an anti-radiation material in a finite elements package (namely, Ansys). The goal of this effort was to better understand how electromagnetic waves react when encountering a boundary between two media: are the waves most likely to be reflected, refracted, or absorbed? Understanding the behavior of electromagnetic waves for different interfaces between objects/materials/media can greatly help in the design of anti-radiation products that everyone can use. For example, if electromagnetic waves are most likely to be refracted at a specific boundary condition, this boundary condition should not be applied to the design of anti-radiation clothes because refraction could lead to a concentration of electromagnetic radiation inside of the clothes, which may more possibly affect human safety. Unfortunately, this simulation attempt was unsuccessful: Ansys only shows the magnetic field and magnetic field intensity produced by the test scenario, and fails to find a corresponding solution for the electric field and electric field intensity. The root cause of this problem/failure remains unidentified at the time of writing this thesis.

5.3 Possible Improvements

This section concludes the thesis by highlighting the potential benefits of one particular important direction for future work, namely, understanding how to use Ansys correctly for assessing different radiation protection solutions. A successful Ansys solution could greatly help in the design of more effective anti-radiation products in a number of ways. Firstly, anti-radiation materials can be tested at different radiation frequencies different amplitudes in simulation. Ansys makes it particularly easy to adjust the frequency and amplitude of an electromagnetic wave. The purpose of doing this is to examine how effectivelu a certain material could reduce electromagnetic radiation at different frequencies and different amplitudes. For example, some materials might be good at reducing extremely low-frequency electromagnetic radiation while some other materials might be good at reducing radio frequency electromagnetic radiation. By understanding this, one could tailor different products for radiation protection in different environments, or perhaps tailor a mix of solutions to protect against a broad range of radiation scenarios. Secondly, more tests or simulations should be done to understand how an electromagnetic radiation reacts when encountering a boundary condition, i.e., whether it is reflected, refracted, or absorbed. As mentioned above, the geometry of how the anti-radiation materials cover the human body are important. By understanding the wave behaviors, one could start to play with the geometry of anti-radiation clothes to ensure maximum protection. For example, if a material purely reflects all the electromagnetic waves, this material may be the best choice for protecting the human brain. Thirdly, the Ansys model can be improved to include a geometric representation of the human body. The human body is not a cube that can be simply covered from all directions. Understanding the geometry of human body can help in designing anti-radiation garments that ensure maximum protection by, say, reflecting electromagnetic radiation away from the body.

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Fluid Flow and Heat Transfer	Engineering Thermodynamics

Research Experience:

Reducing Electromagnetic Radiation From Computers, University Park, PA *Fall 20 11 - Present*

- Researched human bioeffects and safety under electromagnetic fields and radiation
- Established an experiment to measure EM radiation generated by keyboard, mouse, and screen
- Examined the advantages and limitations of other anti-radiation products by experiments
- Designed and simulated an anti-radiation product by using 2D and 3D harmonic analysis in Ansys

Jar Opener Group Project, University Park, *Spring 2011*

- Assessed customer needs and generated concepts by internal and external research for a jar opener
- Selected concepts that best fit customer needs by concept screening and concept scoring methods
- Conducted a preliminary economic analysis to estimate the financial profitability of this product
- Modeled a 3D demo by Solidworks and Constructed a cardboard prototype and a functional prototype of the design,

Dynamic Simulation Research, University Park, PA *Spring 2010*

- Simulated medical devices, the forceps, in three composites by Ansys
- Input parameters of different materials and collected data in free and blocked situations by Ansys
- Analyzed the data to achieve the optimized mixture of different materials for feasible manufacturing process

Integrated Wind Energy Generation System in-class Project *Spring 2009*

- Measured and analyzed the wind velocity in different conditions: corners, heights, the degree of blades, etc
- Integrated VAWTs architecturally in retrofit applications for reliability, cost, maintenance, efficiency, etc.
- Assembled VAWTs into ideal constructions using Solidworks for motion prediction and built a solid model

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