Human Dielectric Equivalent Model

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Introduction

Problem Statement

Honeywell needs a way to test new RF electronics on a model that simulates the dielectric properties of the human body. Information security is a big concern which is why the transmitted information needs to travel through the body instead of being openly transmitted. The Client is looking to expand beyond the limited scope of possible human testing through the use of a physical equivalent. Honeywell has not yet chosen a specific frequency range, so the model would have to be accurate over a large range of frequencies or specific models would have to be used for specific frequencies.

Purpose

The purpose of this document is to outline the technical project plan to design a physical dielectric equivalent to the human body to be used by Honeywell to run tests on signal degradation through the human body.

Goals

Our goal is to design a model that is at least 75% accurate in simulating the human body's dielectric properties at 3 to 100 kHz and 10 to 20 MHz ranges.

Design Description

Physical Model

Functional Requirements

- The model will simulate the human body dielectrics with a 75% or greater accuracy
- Signal input contacts will be firmly connected to the model.
- The model will simulate frequencies in the 3 to 100 kHz and 10 to 20 MHz ranges. Multiple models may be used if one model cannot handle the full frequency range.
- The model must be accurate through the arms and torso.
- The model must be able to withstand multiple tests.
- Only low power signals will be used (power < 1 Watt).

Non-Functional Requirements

- The model should last at least 2 weeks.
- The model can withstand hot/cold beyond human comfort zones.
- The model will have a price point under $1000.
- The model has to be the same general shape as a human. The model doesn't have to include hair, skin color, or any other superficial detail.
- The model will need little to no maintenance during its lifetime.

Computer Simulation

The computer model being used is the Zubal Phantom developed by George Zubal at Yale University. The available data is binary format with 87 different tissues identified. The data is organized as 498 grayscale slices with each byte of data representing a tissue. The simulations will be ran using HFSS because it is software available to the design team and Honeywell. In order to import the data into HFSS it needs to be converted into a compatible format. The data is in a voxelized form and needs to be in a volume mesh form. In order to keep the tissue id's consistent with the original data the plan is to segment the data by tissue type then converted to a volume mesh then merge the data back together in a compatible format. Currently the data is being segmented using image software and Java. After the data is segmented and verified against the original data, the data will be converted into a compatible format. The Computational Geometry Algorithms Library built in C++ will be used to make the corresponding volume meshes. The electromagnetic properties for each tissue type is made available by ITIS on their website, http://www.itis.ethz.ch/, for the frequency range of 3 kHz to 100 kHz. For the remaining frequency ranges the data is made available by the FCC on their website.

Deliverables

The Client has tasked our group with creating a physical model that closely simulates the human body's dielectric characteristics. The Client has specifically asked for a model or models with dielectric equivalency in the 3 kHz to 100 kHz, 10 MHz to 20 MHz, and 150 MHz to 600MHz bands that can sustain hot and cold temperatures unsafe for humans. The models will be used to test electronics that use the body as their transmission path to decrease the chance of having the transmitted information intercepted. The ideal transmission path is from one hand, up the arm, through the torso, and down the other arm to the other hand. Software models like the VHP model shown in Figure 1 will be used to verify results.

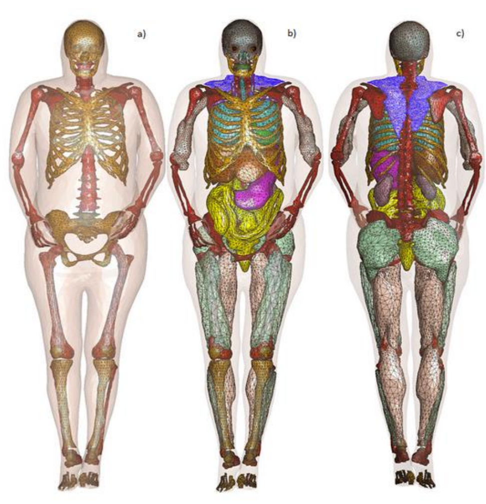


Figure 1: Example computer generated models

The torso will be equipped with a test circuit to verify that the torso is in working condition since the working life is not very long. The test circuit will be capable of generating/detecting a low power signal in each of the required frequency ranges to ensure that the torso model has not broken down. Measurements will be taken for frequency, the phase delay, temperature, and compare input magnitude to output magnitude.

The torso shell will consist of a semi-rigid outer shell like the one shown in Figure 2 below. Contacts will be added to end of each wrist to ensure solid transmission points. The material inside the shell will consist of a gelatinous saline solution.

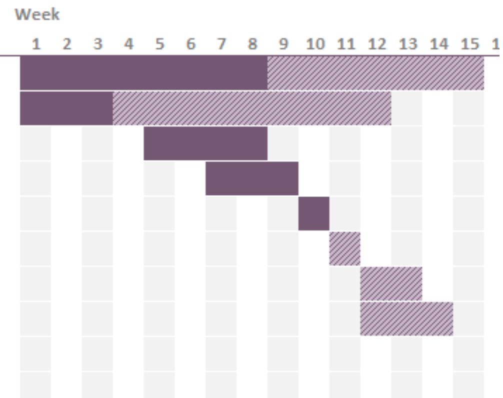
Figure 2: An inflatable torso shell is shown above that will be used to hold the gelatinous saline solution.

Timeline

First Semester:

Human Dielectric Spring 2015

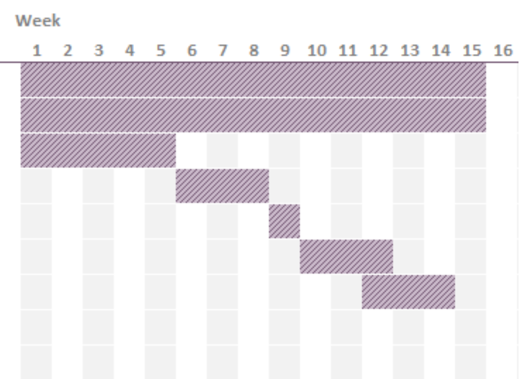
ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Research	1	15	1	15	55%
Computer model	1	12	1	12	30%
"Tissue Samples"	5	4	5	4	100%
Test "Tissues"	7	3.5	7	3.5	100%
Circuit Design	10	1	10	1	20%
Construct Torso Model	11	1	11	1	0%
Test Torso Model	12	2	12	2	0%
Spring Presentation	12	3	12	3	0%



Second Semester:

Human Dielectric Fall 2015

ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Research	1	15	1	15	0%
Computer Simulation	1	15	1	15	0%
"Tissue Samples"	1	5	1	5	0%
Test "Tissues"	6	3	6	3	0%
Construct Torso Model	9	1	9	1	0%
Test Torso Model	10	3	10	3	0%
Fall Presentation	12	3	12	3	0%



Risks/Challenges

- **Budget**
  - Our client has given us a $500 budget to work with. We also have an additional $500 from our department at our disposal. This combined budget of $1000 will pose a problem when trying to purchase a license for software. The software licenses we have looked at are upwards of $3000. Clearly this is outside our budget. Since our department already has licenses for certain software, we will be limited to programs for which the license has been purchased.

- **Accuracy of model/software simulation**
  - The accuracy of our model is very important to the success of our project. Obviously the more accurate our model is the better but we could run into limitations that force us to reach a point of limiting returns. We could also run into the problem that the materials we chose only have a certain maximum accuracy.
  - Software that is capable of running our desired simulations is expensive and not in the budget of our project. Also, some software that is available for research may not be available for commercial use.
  - Without prior experience processing image data, segmentation of image data can be a lengthy process. A concern is poor segmentation resulting in bad simulation results.

- **Materials**
  - Our model will have to use materials that are durable and inexpensive but yet still exhibit the properties of the human dielectric. The most cost effective material given our budget would be some sort of gelatin mixture. By mixing in salt with the gelatin we can obtain a good baseline to start with. The problem with a gelatin based mixture is the shelf life. From our studies the gelatin only has about a two to three week shelf life before it begins to mold. This can be counteracted with some sort of antibacterial agent mixed in with the gelatin. We have not studied how this antibacterial agent would affect the dielectric properties of the gelatin.
  - In order to help preserve the shelf life of our model we need a fridge big enough to hold our model. The fridge we found and are allowed to use is constantly being utilized by the university's food department. This creates a problem because the fridge could run out of space thus forcing our model to be moved out of the fridge. Also since there will

be a lot of traffic in and out of the fridge our model could be damaged or tampered with when items are moved in and out of the fridge.

- **Lab Availability**
    - Gaining access to the labs we need in order to test our materials could prove to be a problem. In order to test our model for frequency ranges of 25 MHz and up we need access to a network analyzer. Since we have access to only a few network analyzers, this proves to be a challenge. Also since these network analyzers are very expensive machines, we need someone familiar with the operation and handling of the analyzer to supervise us. That way we don't damage the machine or get incorrect readings.

References

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