Human Dielectric Equivalent
Design Document

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Introduction

Project Definition
The idea is to create a physical model that mimics the human body's dielectric properties to use for running tests involving EM wave propagations. We will use already available voxel based computational human phantoms to simulate the effects of different frequencies. We will use the results of these simulations and research results to construct the physical model that has similar properties.

Project Goals:
By the end of the spring 2015 semester we intend to have the following goals completed.

- Have a working computer model of the human body. This will entail converting the Zubal computational human phantom obtained from Yale University into a format that can be read by ANSYS HFSS software.
- Construct a model from which a mold can be created. This model is only a physical model.
- Construct a mold from which we can create the physical dielectric model.
- Have a homogenous physical conductivity model of the human torso. This model will be used to show feasibility of the physical construction material and relative accuracy we can expect to obtain.

By the end of the fall 2015 semester we intend to have the following goals completed.

- Have a physical human dielectric model that is accurate to within 75%.
- Verify and validate the physical model using the results from software simulation.

Deliverables
A physical model that mimics the Human body's dielectric properties with greater than or equal to 75% accuracy. This model will also include terminals that act as a means of transmission into and through the model. Additionally, this model must be able to achieve a minimum of a two week shelf life and be able to withstand multiple test cycles. This project also requires the creation of a software model to verify and validate the physical model's dielectric properties.

System Level Design
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 kHz to 100 kHz and 10 MHz to 20 MHz range. 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 with 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 not need any maintenance during its lifetime.

Functional Decomposition

High Level Block Diagram

Figure 1: high level block diagram

The signal generator will be a low power transmitter provided by the client. The transmitter will connect to a contact in the wrist of the body model. The body model will contain a solution that will allow for transmission of the signal from one wrist to the other, where a signal receiver will be connected.

Computer Simulation

The computer model is a computational human phantom designed for computer analysis and simulations by George Zubal of Yale University. This is a voxelized phantom with differing cubal voxel resolutions. Each voxel has dimensions, placement, and tissue type. The electromagnetic properties needed to run the simulations are being obtained from an online database put together by the IT'IS foundation based in Zurich. The data used to make the phantoms were taken from CT scans and MRIs. The model we will be using has a resolution of 3.6mm. The data was obtained in a raw format and will need to be converted into a format compatible with AnSoft HFSS. The compatible formats are sld, .stp, .igs, .iges, .sat, .stl, .geo, and .sm3 for 3D modeling. As of now .stl is the target format due to simplicity. After we have a compatible format running on HFSS we will load the electromagnetic properties from the online database.

The plan is to use a script to import all the data into the HFSS software. This will be a trial and error process as we have never used HFSS and still learning to use the software. We will then simulate using the different frequency ranges. We will start by doing simulations for the range parameters and then incremental frequencies in between minimum and maximum frequencies in the desired range. The availability of other phantoms to test against these simulations is being researched. The physical model right now only consists of head, torso, and arms. After we have several successful simulations of the full model, the plan is to break the model up into body parts in order to see if there is a significant difference between a full model and a legless model as well as different positions of different body parts. The number of simulations is highly dependent on amount of time a simulation will take. Optimization of the simulation will be pursued.

Testing Procedure

In order to test our physical model for accuracy we will be using a testing apparatus that tests for the dielectric constant. This apparatus is a parallel plate capacitor, which when placed on either side of the test sample and a voltage is applied, calculations can be done to determine the dielectric constant. From the dielectric constant the conductivity of the material can be determined.

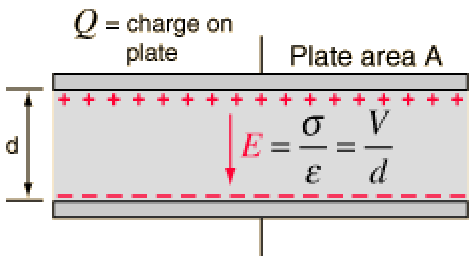

Figure 2: Illustrates the parallel capacitor

We will use the parallel plate capacitor to test smaller samples of materials in order to find out what materials represent the conductivity of tissues in the human body. Once we determine suitable materials those materials will then be implemented into our final model.

To test our final model, a signal will be sent through one arm and a receiver will be placed at the other arm in order to see how much the signal degradation occurred. The signals will be generated and measured using a network analyzer because other means of generation and measurement will not be as accurate. After gathering ample test results, those results will then be compared to our software simulation results. If the results are similar then the physical model will not need to be tweaked, however if the results are significantly different (less than 75% accurate) then the model will need to be tweaked by adding a different composition of materials.

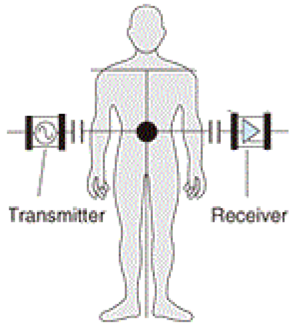

Figure 3: High level testing setup that shows how to test signals passing through the body

Verification and Validation

Verification and validation are both necessary to ensure that a precise and accurate model will be delivered. Our team will conduct various test to verify that the model meets specification. Additionally, we will conduct tests to validate that the model meets the customer needs. We will perform tests identified in the testing procedure on individual components of the model prior to final assembly. Additionally, we will repeat these tests and the complete model testing daily for a period of two weeks. This will ensure consistency and shelf life.

Challenges

This project has several challenges that are currently being addressed. Through the course of the project we have come to the realization that this project is highly related to materials science engineering. Our lack of material science background has proven to be a challenge. We are having to do extensive research to gain an understanding on how to change the dielectric properties of a material. Additionally, we have based most of our design work around the use of gelatin as our base material for the model. This has many benefits, gelatin is cheap, easy to work with, and readily available. However, the gelatin has shown to mold and lose water content when exposed to air for extended periods of time. Additionally, the gelatin does not provide rigidity to the model. We have are actively working to remedy these challenges. We have identified adding “skin” and a “skeletal structure” to the model to as possible solutions to the challenges of using gelatin. However, we have not yet decided on the best method to accomplish this.

Conclusion

The ultimate goal is to use the body as the only transmission path when “wirelessly” transmitting data. The body mold will be used as a test bench for signal transmission through the body. The model test results will show what would happen if the same signal were to be passed through a Human body with greater than or equal to 75% accuracy.

References

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