Human Body Dielectric Equivalent Model

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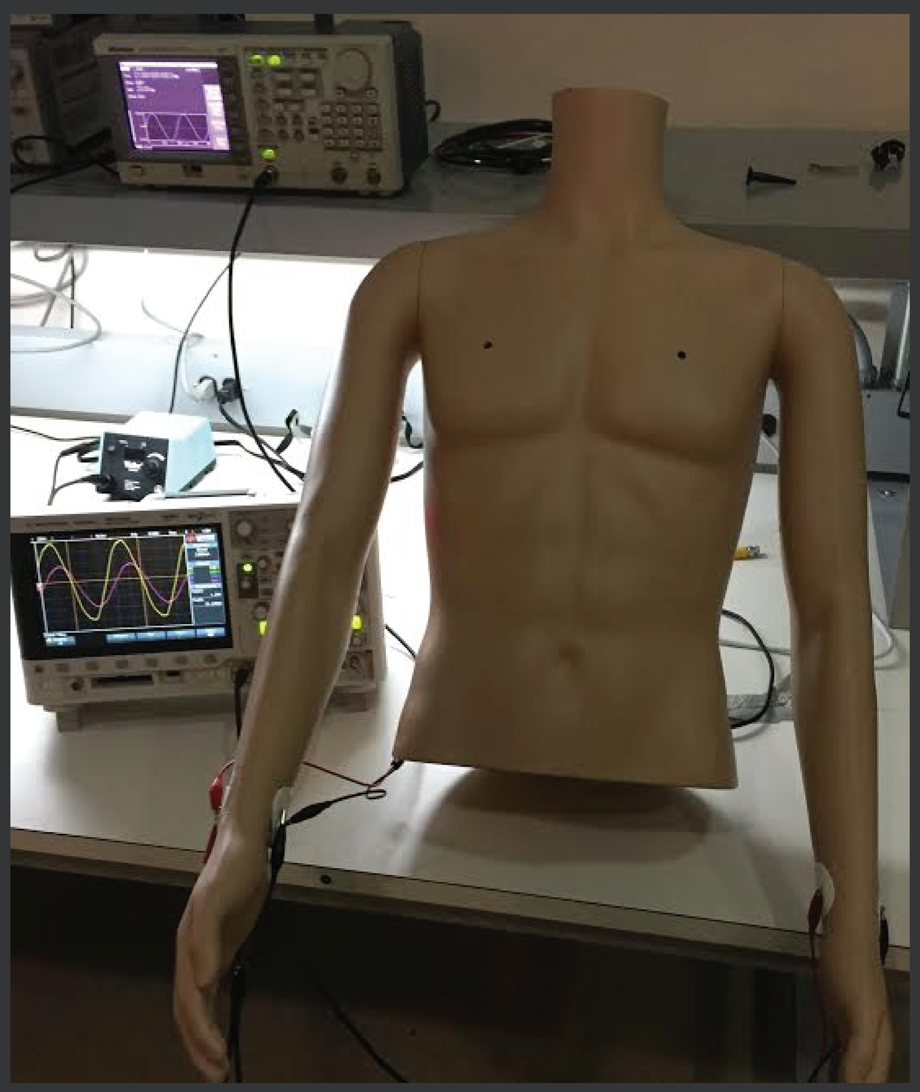
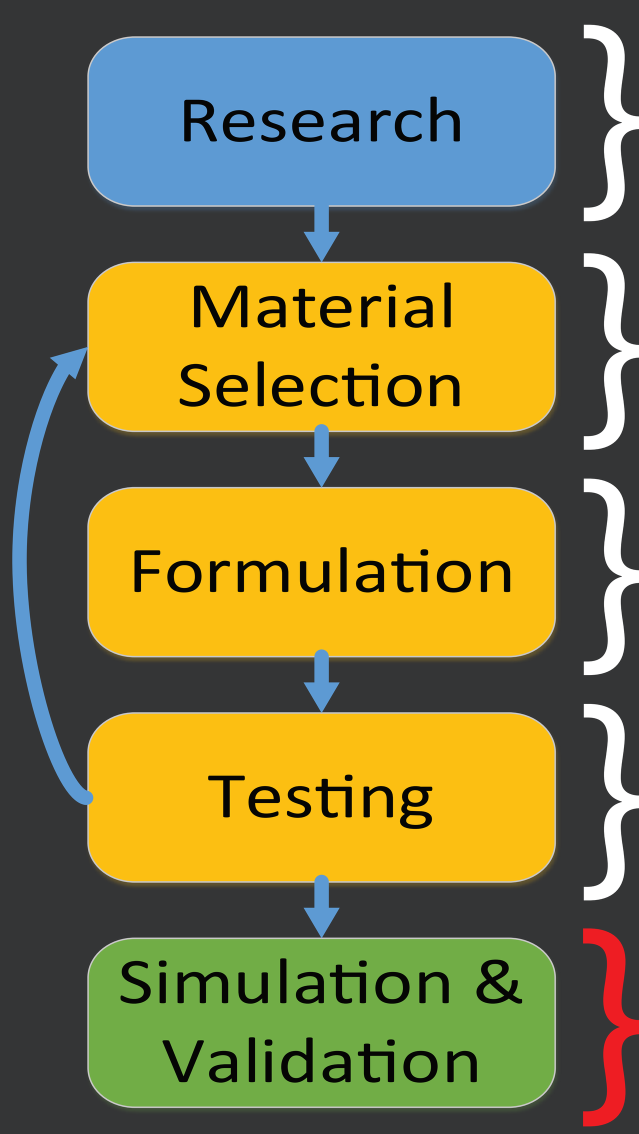
Introduction

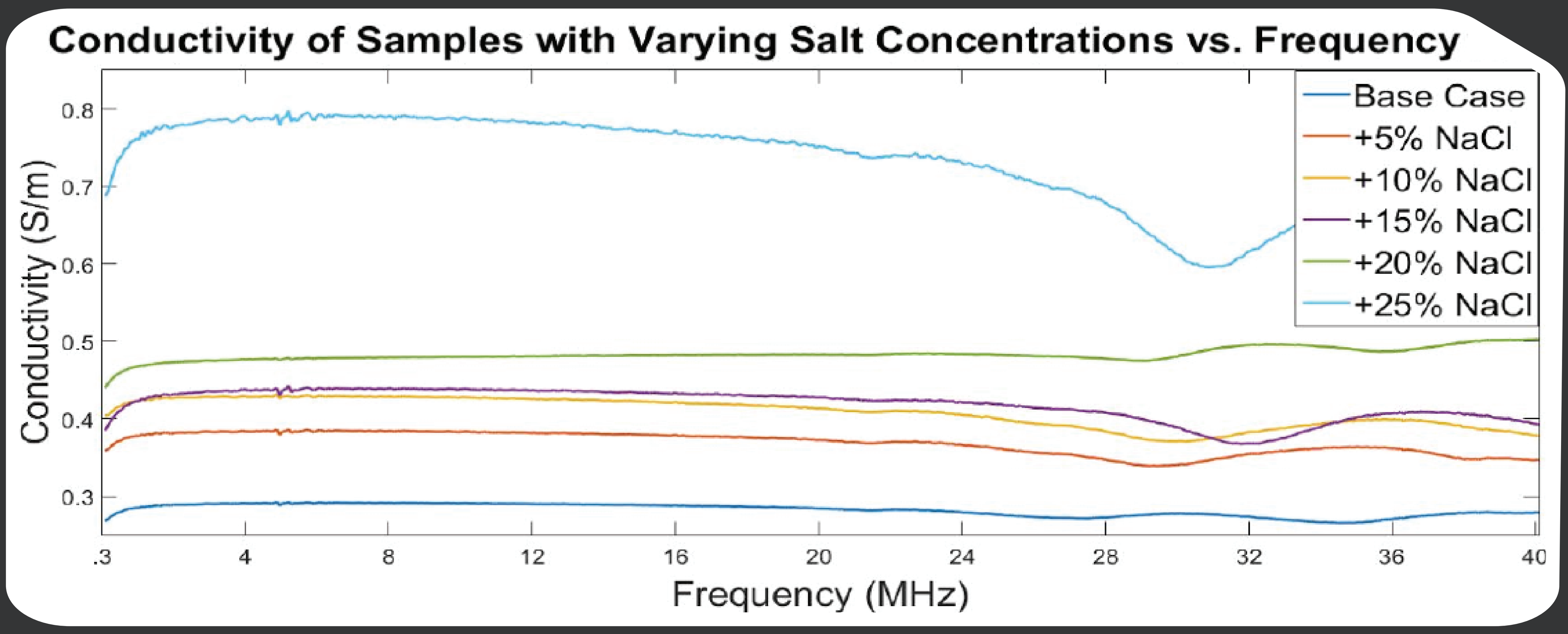
The Human Dielectric Equivalent Model is a project to build a physical phantom that can be used for developing secure human body area networks (BAN's). The bulk of the project was to research material properties and create a formulation that could be used to construct a phantom. The formulation was based on published research and then tuned to meet our design requirements. The tuning was completed using different materials and concentrations for conductivity, signal propagation, physical stability, and longevity. After each iteration of tuning, the product was tested based on the criteria listed above and the formulation was re-visited. Once the material met the specifications, a full torso sized model was created and validated.





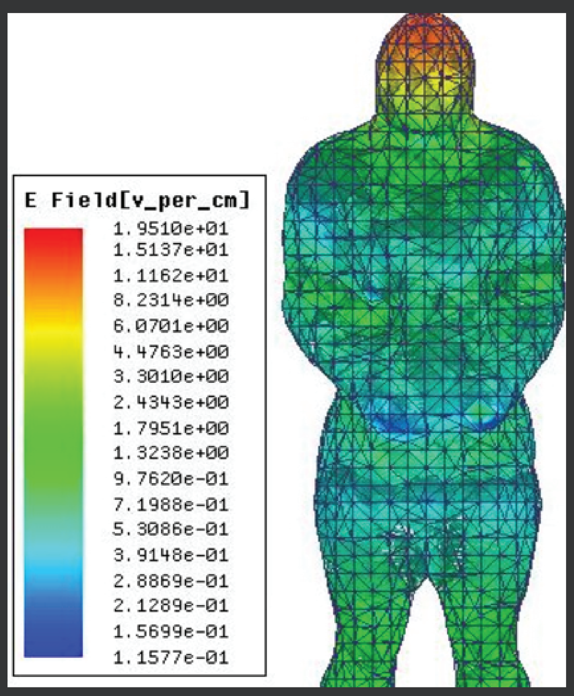
Testing

The network analyzer was used to measure the scattering (S) parameters and Matlab was used to convert the S parameters to complex impedance (Z) and admittance (Y) values in order to find conductvity. The conductivity of the samples was then compared to the target value of 0.46 S/m as shown in the graph below. A trend line was extracted from the data to understand how the salt content affects conductivity. The formulation was then adjusted to hone in on the target value before the next test cycle.



Simulation & Validation

The simulation plan began with converting the Zubal model into a format compatible with High Frequency Structural Simulator (HFSS) and then import the model into the program. After the model was imported, simple verifiable simulations were ran in HFSS. After the simulations were shown to be accurate the human model was assigned the target conductivity of the physical model and the results were used to help validate the accuracy of the physical model. The model consists of 10x10x10mm cubal voxels with a coloring representing the different tissues. Since the physical model was using a homogeneous material the coloring was not used.



The figure shown is an approximate surface reconstruction of the Zubal model performed in MeshLab. The surfaced data was then imported into ANSYSS HFSS to allow for high frequency signal testing. The image shows the E-field distribution when a voltage was applied to the top of the head

Intended User and Uses

Honeywell is currently developing a secure communication system based on body area networks (BAN). Honeywell will utilize the physical phantom to perform preliminary testing for their BAN system. The phantom provides a static human analogue which can be used in a variety of environmental conditions without posing a risk to humans.

Design Requirements

Functional

- Simulate frequencies in the 300 kHz - 40 MHz range
- The phantom will only model the torso
- Accuracy of dielectric properties of at least 75% when compared to a human body
- Multiple means of transmission coupling
- Only low power signals will be used

Non- functional

- The phantom should have a shelf life of 2 weeks
- Withstand temperatures beyond human comfort zones
- The phantom will be maintenance free during its lifetime

Research

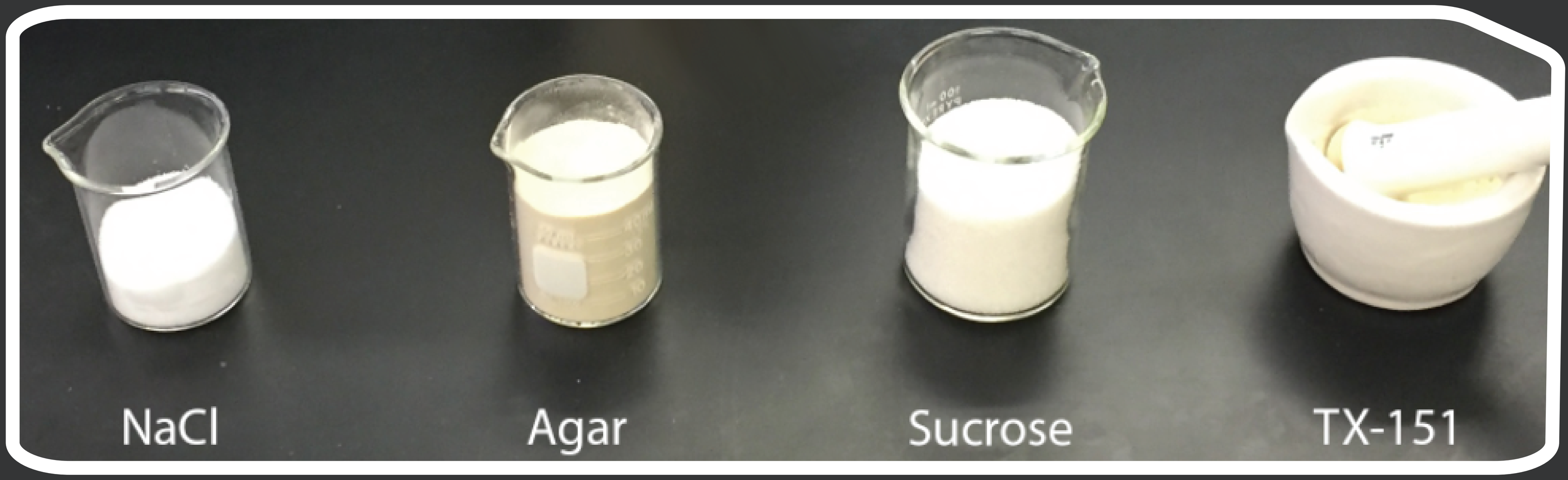
Research was focused on three main areas: properties of body tissues, phantom types, and phantom materials and construction. The body tissues had to be identified by electrical properties in order to understand how they affect signal propagation. The main tissues of interest were the skin, muscle, bone, blood, fat, and body fluid. There are multiple phantom types used in various industries, each with its own pros and cons. Non-resin based phantoms were identified as the best choice due to cost, accessibility, moldability, and testability. The phantom contruction provided its own set of challenges as the model had to take on the shape of a torso. The phantom materials are discussed in detail below.

Material Selection

De-ionized water was used as the base material to accurately represent water content in the body while allowing for greater control of unknown contaminates.

The permittivity and conductivity of the material had to be controlled in order to create an accurate phantom. Sucrose was utilized as an effective means of lowering the permittivity of the materials. For conductivity control, sodium chloride was chosen for its properties, accessibility, and ease of use.

Agar (a plant based gelatin) provided the desired solidity and held up well in the saline environment. TX-151 (petroleum based gelling agent) was also incorporated to increase the malleability and strength of the Phantom.



Formulation

The formulation process consisted of three main phases: a gelatin formulation, a physiological saline formulation , and an agar formulation. For all of the phantoms, an iterative process was followed in which the concentrations of sodium chloride were altered in order to control the conductivity of the material. Ultimately it was determined that an agar based phantom was best due to promising electrical characteristics, repeatability, physical stability, and longevity.