

Human Dielectric Equivalent Model

Honeywell

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Team

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Overview

- Background
 - Problem Statement
 - Specifications and Requirements
- Approach
 - Research
 - Properties/Equations
 - Materials
 - Simulation
 - Testing
- Results

Problem Statement

- Honeywell needs a physical human body equivalent model for testing electronics
- Three frequency ranges were identified for testing: 3 – 100 kHz, 10 – 20 MHz, and 150 – 600 MHz
- Frequency range was narrowed to 300 kHz - 40 MHz

Functional Requirements

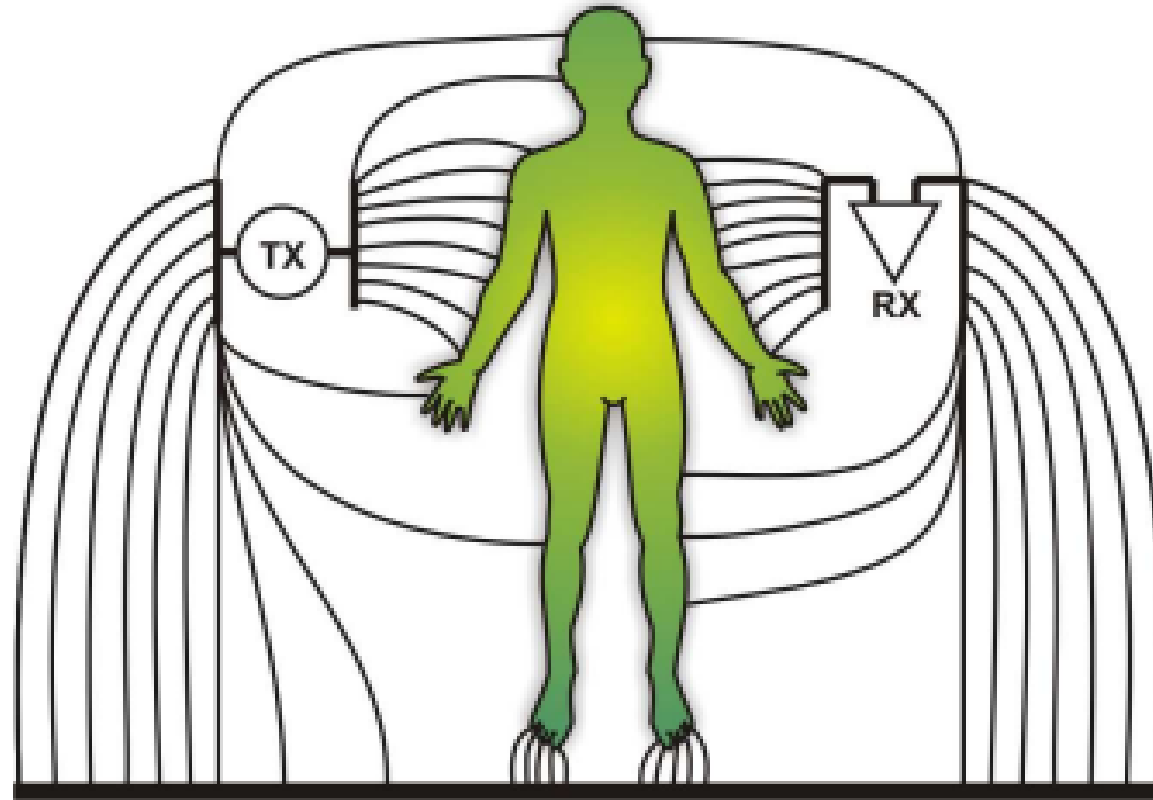
- Simulate frequencies in the 300 kHz - 40 MHz range
- The phantom will only model the torso
- Accuracy of dielectric properties of at least 75% when compared to a human body
- Multiple means of transmission coupling
- Only low power signals will be used

Non-functional Requirements

- 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

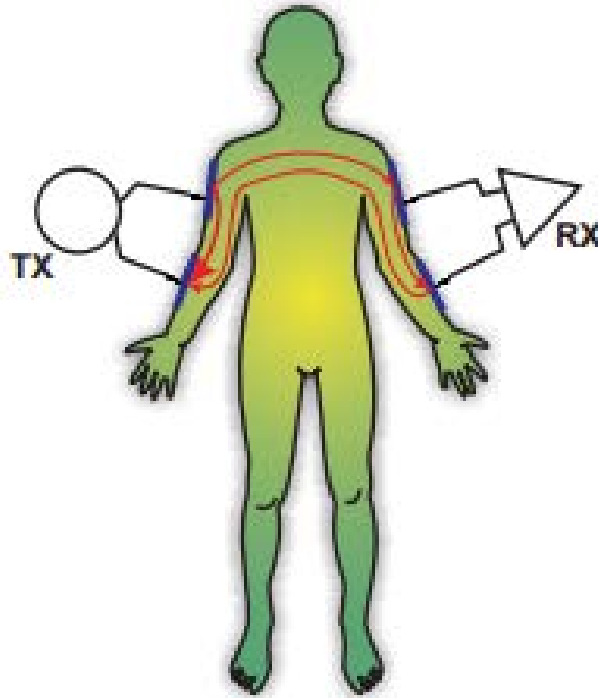
Means of Transmission

Capacitive Coupling



Means of Transmission

Galvanic Coupling



Approach

- Research
- Properties/Equations
- Materials
- Simulation
- Testing

Tissue Properties Research

- Tissue properties
 - Which tissues to consider
 - Which tissues to leave out
 - Reasons for selecting certain tissues
 - Tissue percentage by total body weight
- Average conductivity of human body
 - Baseline value of .46 S/m

Phantom Research

- Phantom types
 - Resin based
 - Saline solution based
 - Gelatin based
 - Agar based

Electromagnetics Research

- Target conductivity versus permittivity
- Skin acts as an insulator at DC
- Skin acts more like conductor as frequency increases
- More accurate to treat the body as a dielectric waveguide

Properties/Equations

- Conductivity

- $\sigma \text{ [S/m]} = \frac{l}{RA}$

- Complex Conductivity

- $\sigma'' \text{ [S/m]} = \sigma' + j\omega\varepsilon$

- Capacitance

- $X_C \text{ [\Omega]} = \frac{1}{j\omega C}$

- Permittivity

- $\varepsilon \text{ [F/m]} = \varepsilon_r * \varepsilon_0$

Properties/Equations Continued

One Port

- S – Parameter
 - S11
- Z– Parameter
 - Z11
- Conversion
 - $Z_{11} = Z_0 \frac{(1+S_{11})}{(1-S_{11})}$

Two Port

- S – Parameters
 - S11
 - S12
 - S21
 - S22

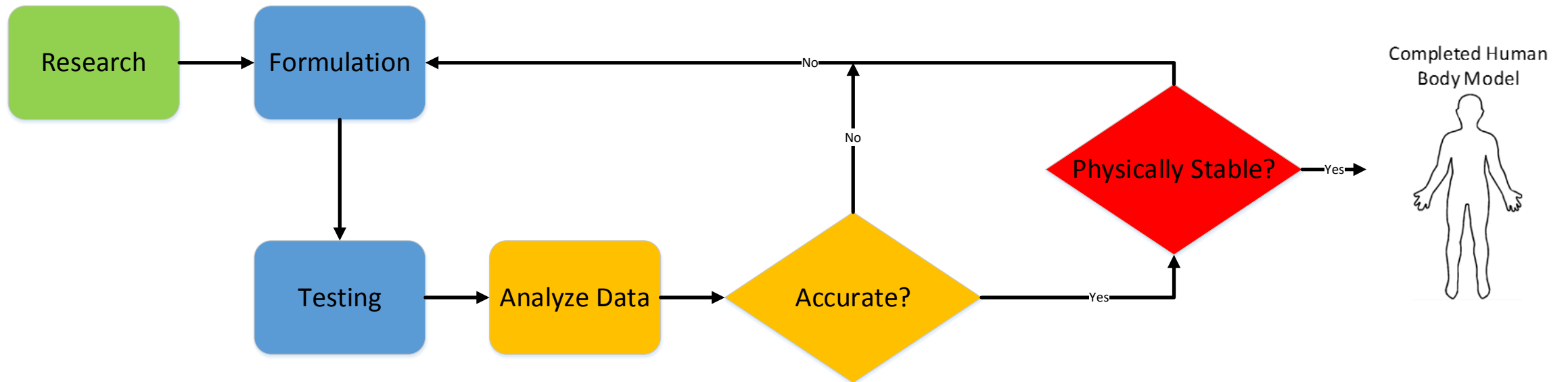


Materials

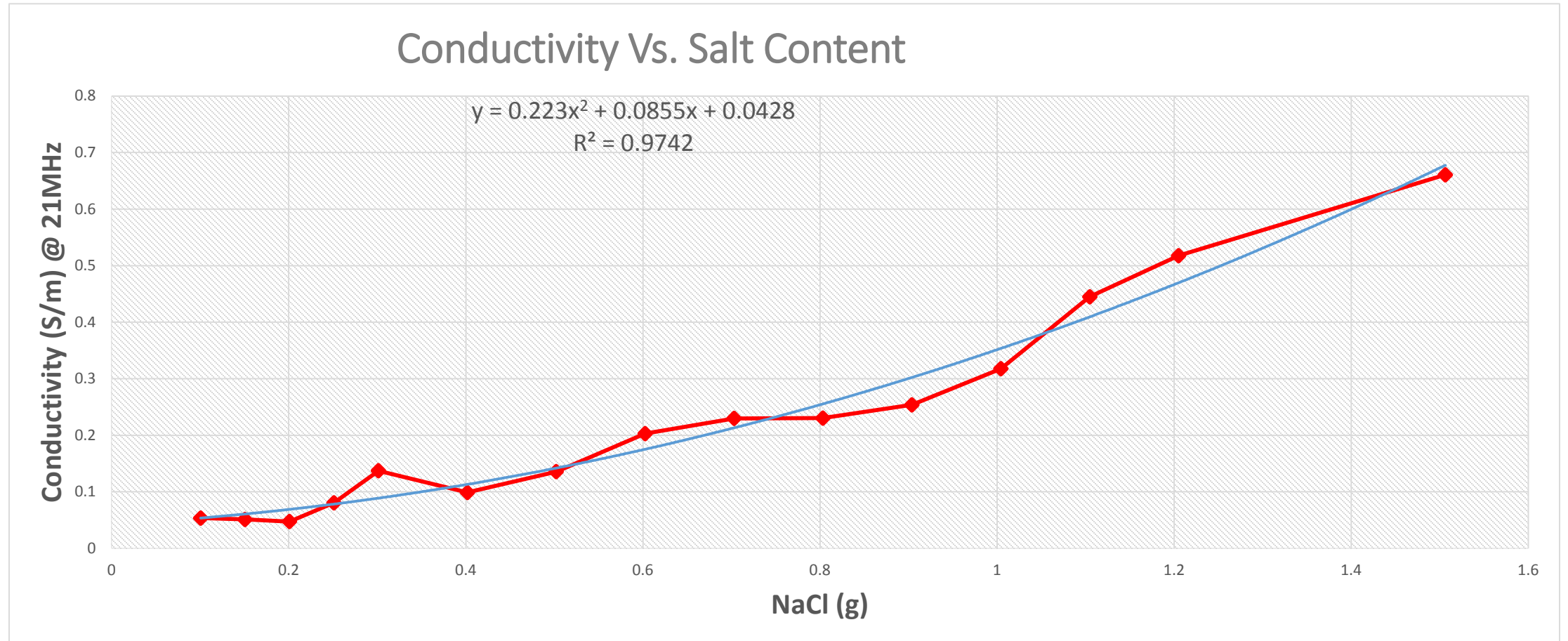
- Gelatin Based
 - Animal Hide Gelatin
 - Sodium Chloride
 - De-ionized Water
- Physiological Saline Based
 - 4 Mil PVC Sheeting
 - .9 % Physiological Saline
- Agar Based
 - Agar
 - TX-151
 - De-ionized Water
 - Sodium Chloride
 - Sucrose
 - Suttocide A
 - Germall Plus



Design Process

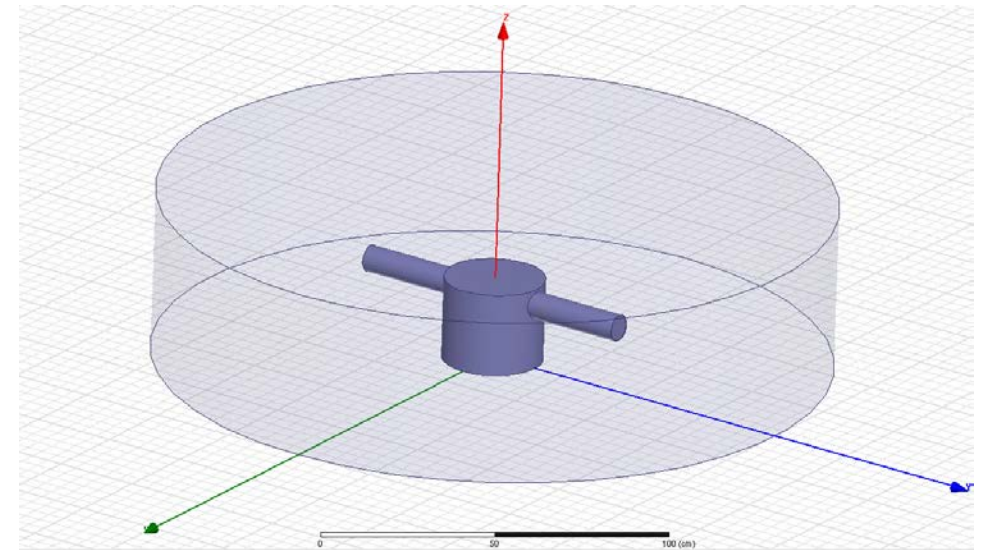


Design Process

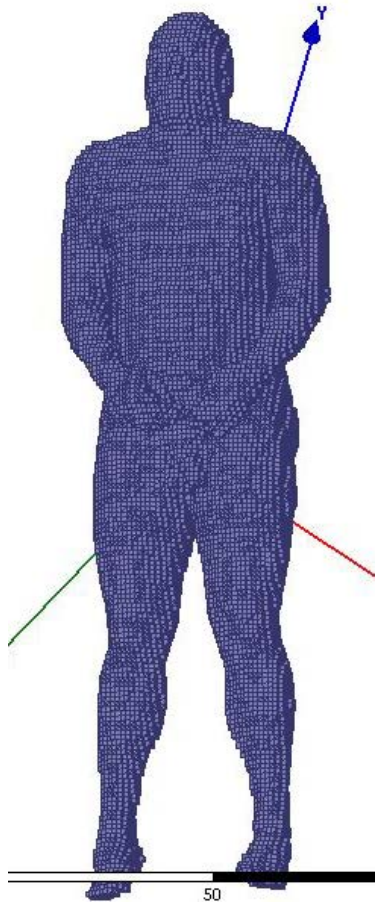


Simulation

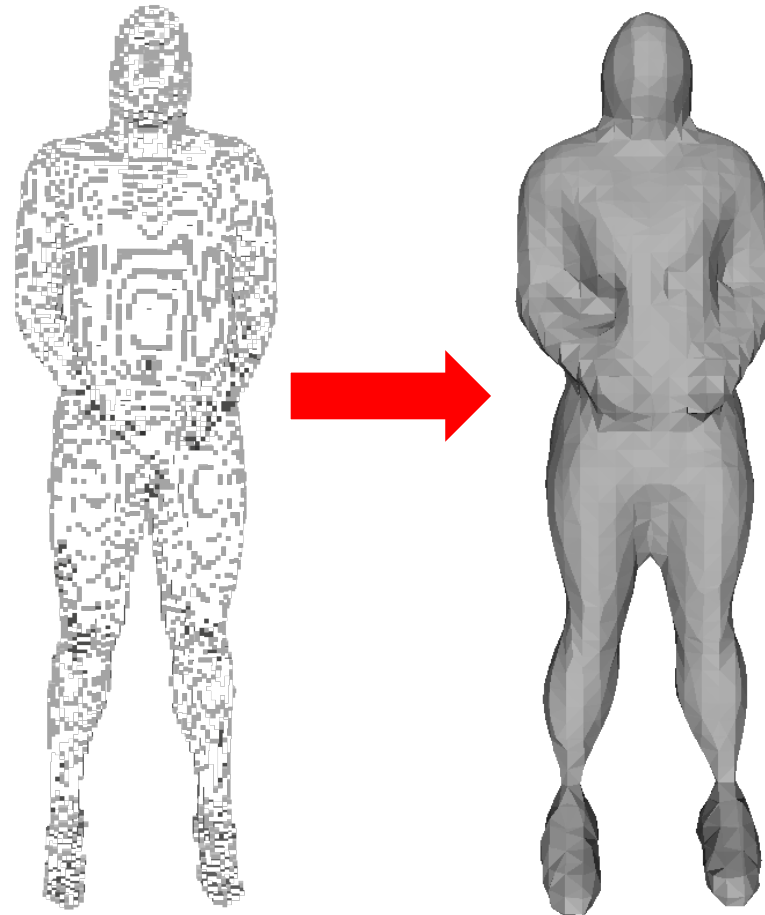
- Primary motivation
 - Use results from simulation to validate accuracy of physical model
- Process
 - Obtain model and choose simulation software
 - Zupal Model and High Frequency Structural Simulator (HFSS)
 - Convert model into a HFSS compatible format
 - Run simple verifiable simulations in HFSS
 - Incrementally increase simulation complexity
 - Run simulation with human model and compare results with physical model



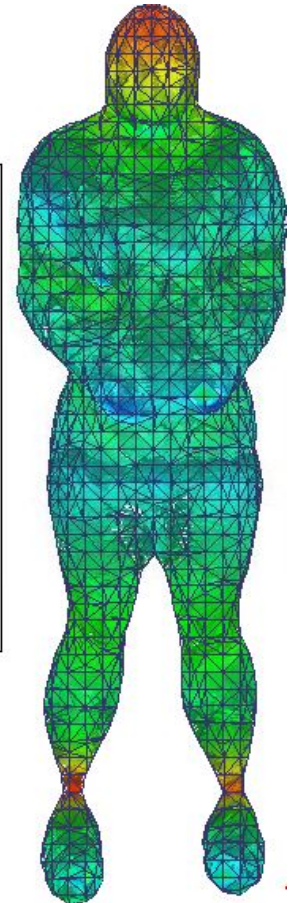
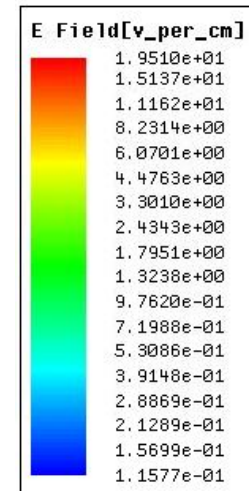
Zubal Model



Zubal model in HFSS



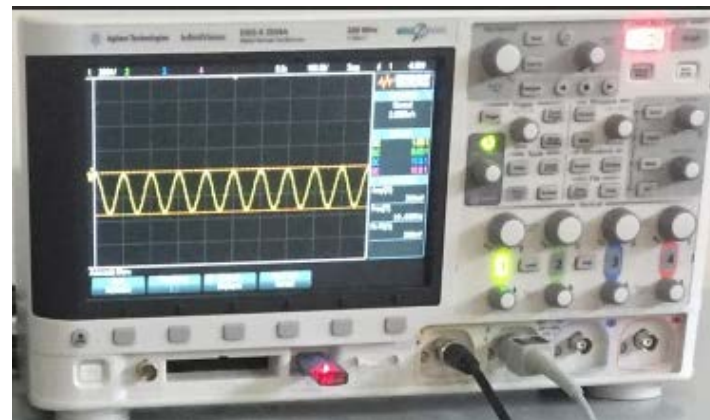
Poisson surface reconstruction



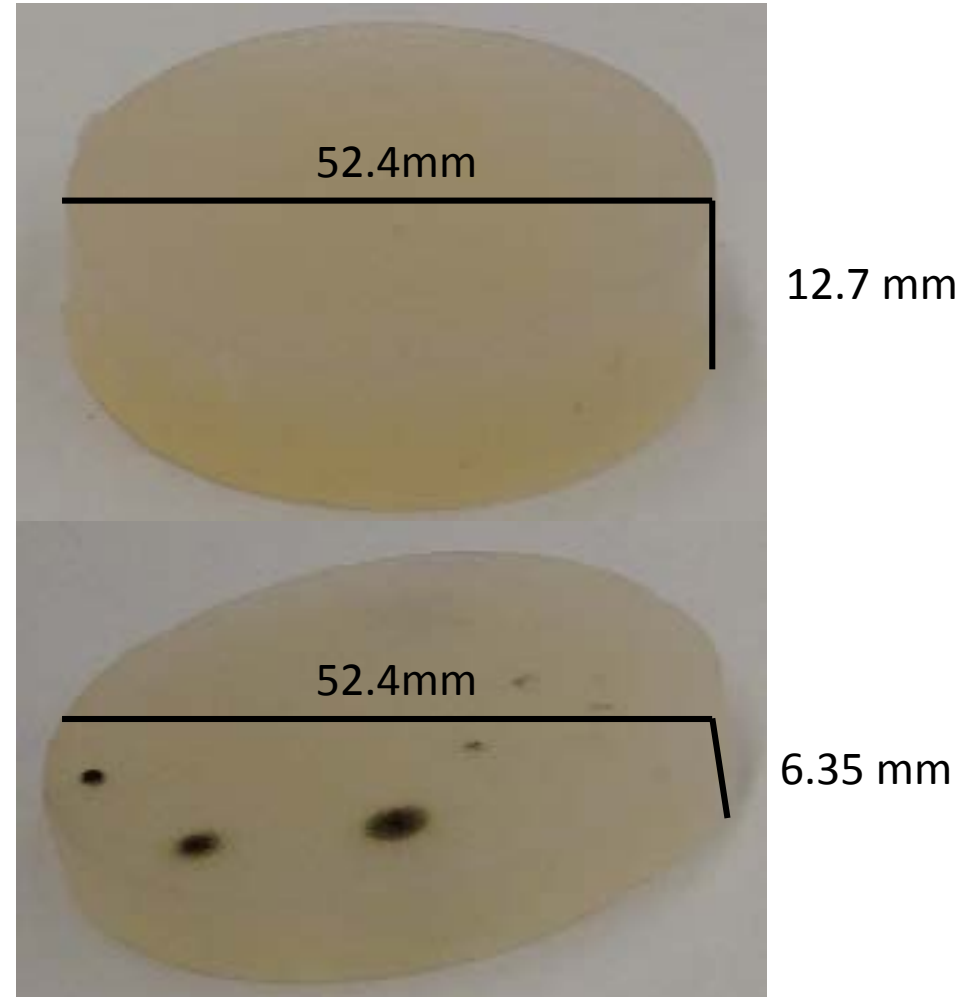
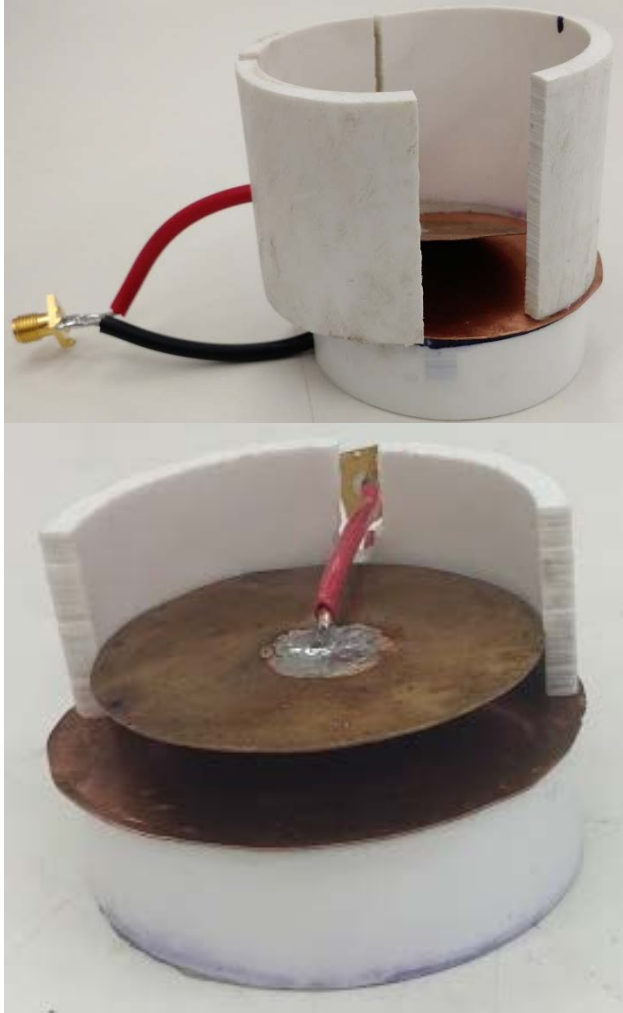
Simulation Results₂₀

Test Equipment

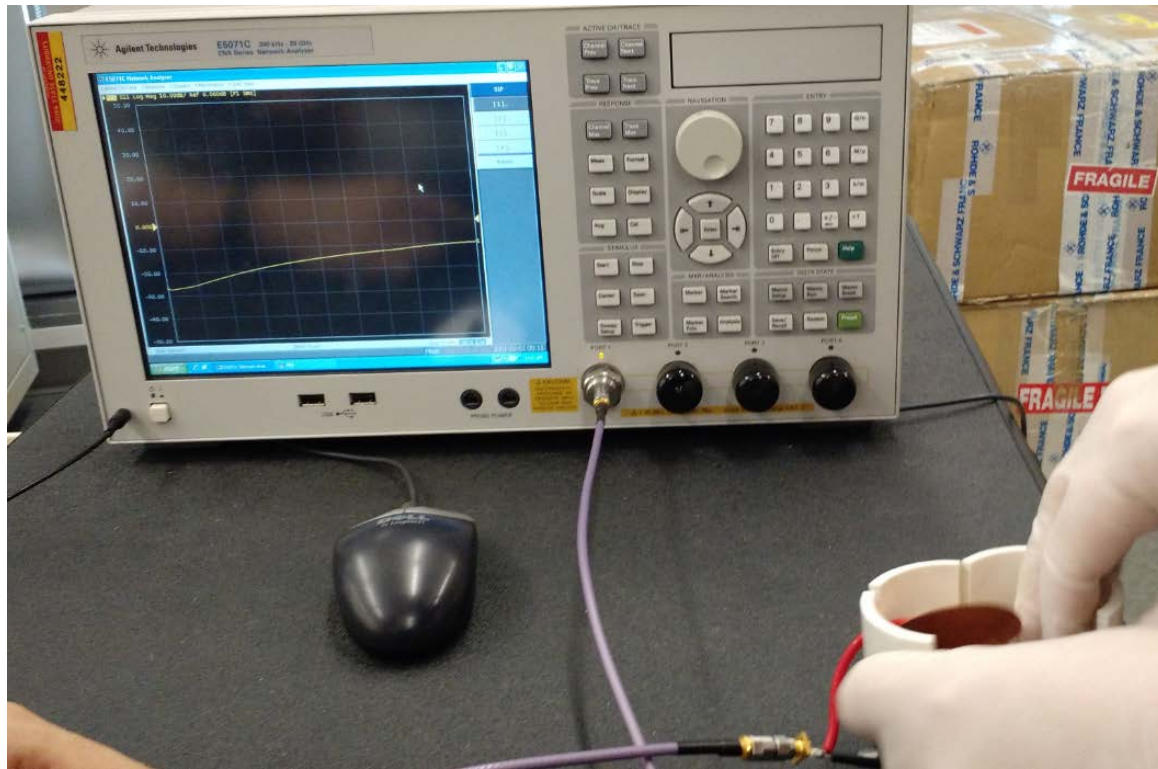
- Function generator
- Oscilloscope
- LCR meter
- Conductivity Meter
- Network Analyzer



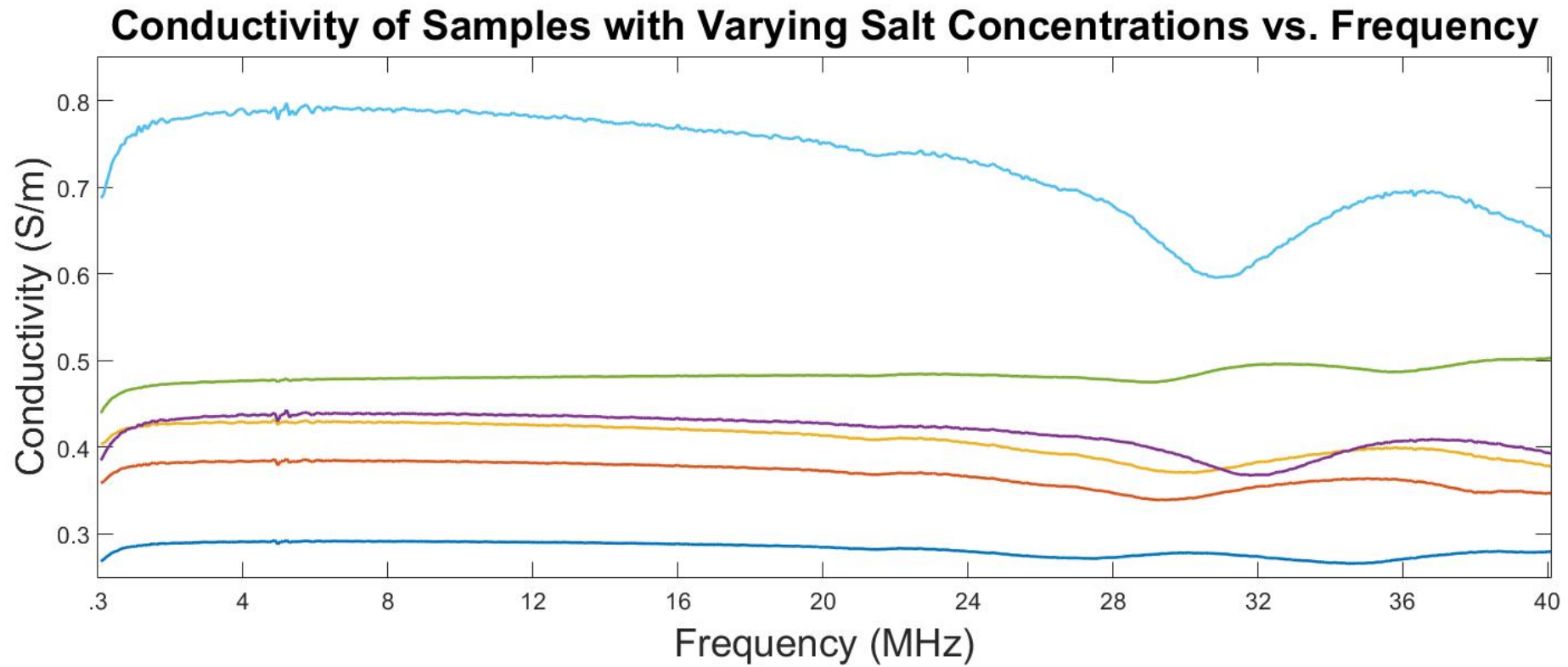
Testing



Testing



Results



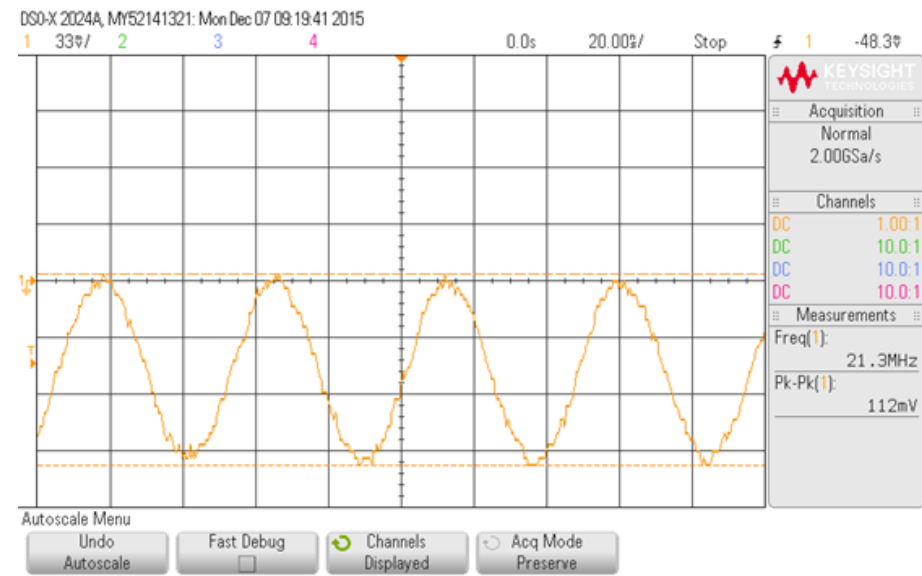
Results

Phantom



The Oscilloscope signal was captured using a 20 Vpp input at 21 MHz from the function generator. 117 mV equates to -44.65 dB.

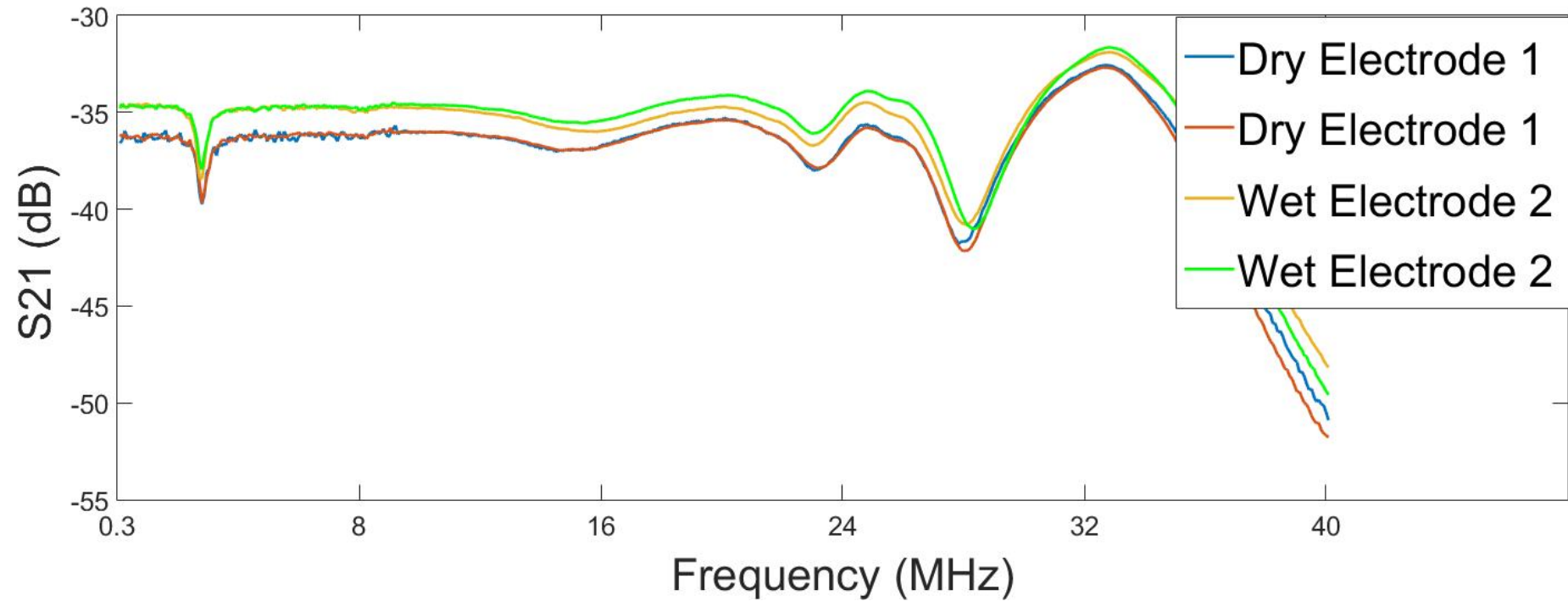
Human



The Oscilloscope signal was captured using a 20 Vpp input at 10 MHz from the function generator. 112 mV equates to -45.03 dB.

Results

S21 for 0.3 MHz to 40 MHz for the Torso Model



Questions/Comments

Formulation



BOM

Item	Description	Unit of Measure	Quantity	Price/Unit	Total Price
De-ionized Water	De-ionized water serves as base material for phantom	Liters	41.6	\$0.50	\$20.80
Agar Powder	Solidifying agent provides the phantom with rigidity	Grams	1289.6	\$0.06	\$77.38
TX-151	Gelling agent strengthens the phantom and resists tearing	Grams	703.04	\$0.02	\$14.06
Sucrose	Used to lower the permittivity of the phantom	Grams	6755.84	\$0.001	\$6.76
Sodium Chloride	Used to lower the permittivity of the phantom	Grams	96.07936	\$0.002	\$0.19
Suttocide A	Antiseptic additive to extend shelf life	Liters	0.1664	\$38.04	\$6.33
Germall Plus	Antiseptic additive to extend shelf life	Liters	0.0416	\$36.69	\$1.53
Phantom Mold	Provide a rigid protective shell to the Phantom	Pieces	1	\$71.03	\$71.03
		Cost Per Liter	4.761321123	Total Cost	\$198.07