Multi-Layer RF Tissue Phantoms for Mimicking a Human Core

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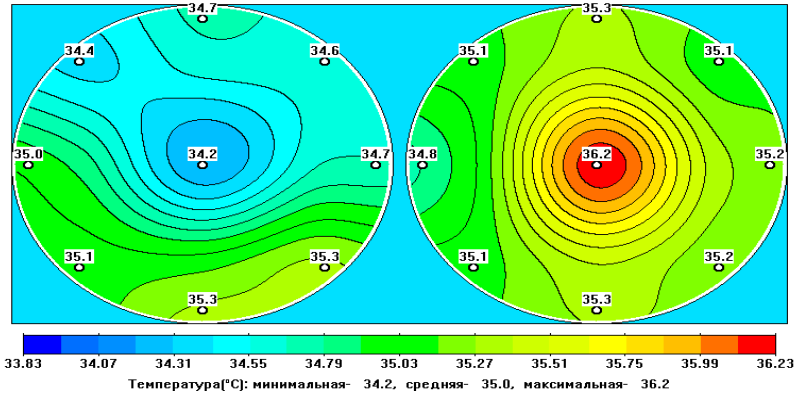
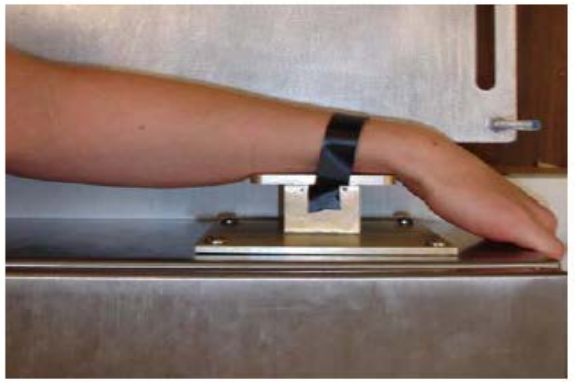
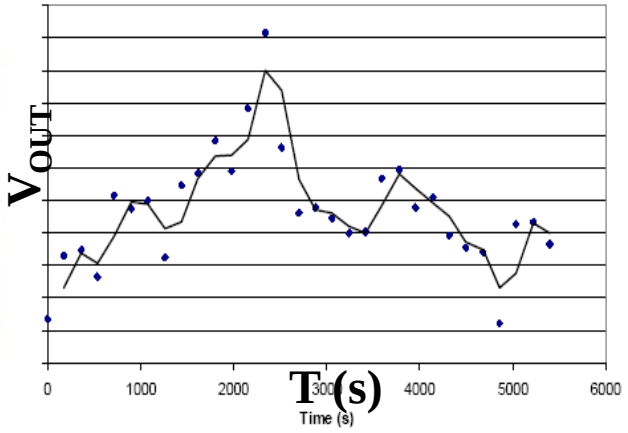
On-Body Sensing

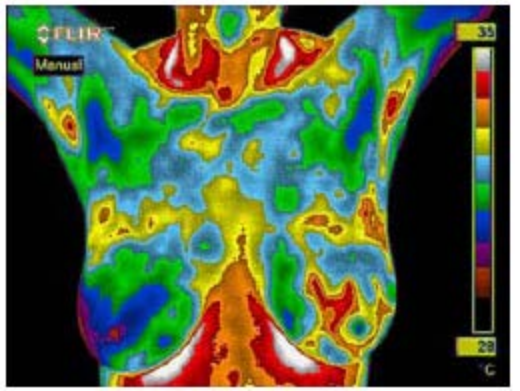
Current Applications

- Microwave Imaging
- Cancer Detection
- Blood Glucose Monitoring
- Neurology
- Urology





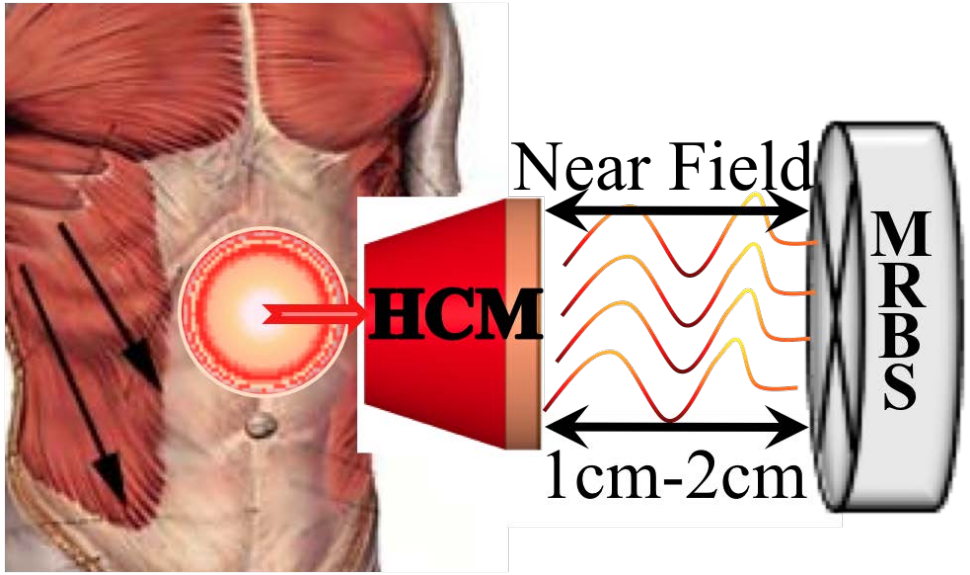




Challenges

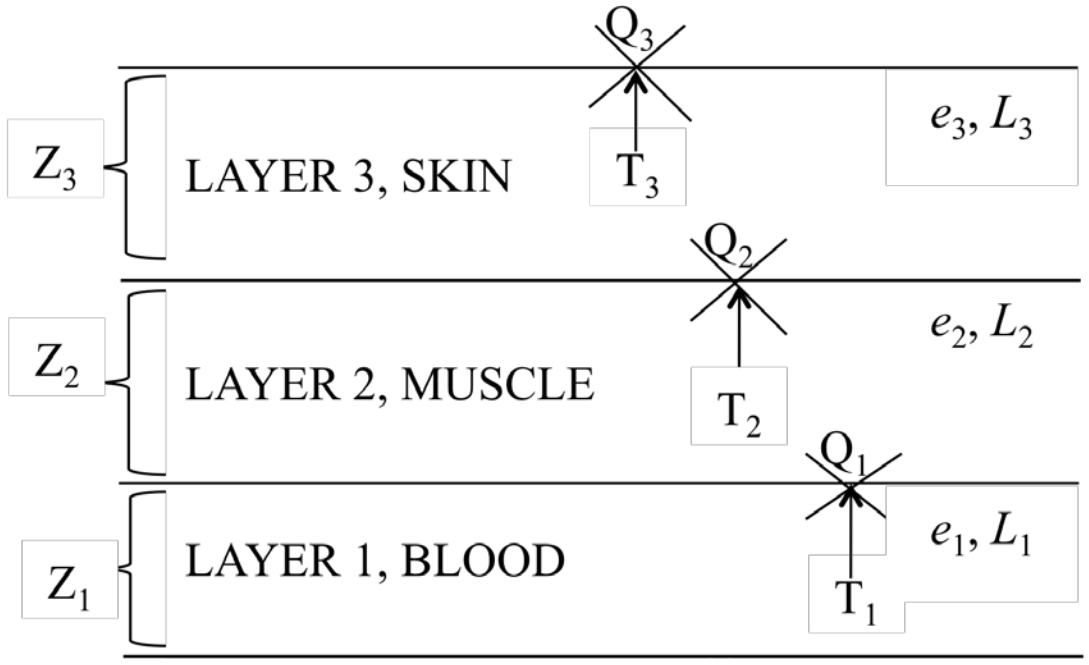
Objective: Develop a measurement test bed with electrical and physical properties analogous to the human body to test a Microwave Radiometer for Biomedical Sensing (MRBS).

- Sensor Design
  - Miniaturization
  - Internal Calibration
  - Antenna Design
- Antenna-Body Effects
  - Resonance Shifts
  - Bandwidth Reduction
  - Perspiration $\leftrightarrow \Delta Z_{Ant}$
  - $\Delta T_{Ant} \leftrightarrow$ Measurement Uncertainty
- Measurement Test Bed
  - Microwave Radiometer for Biomedical Sensing (MRBS)
  - Good Model of Human Body



EM Propagation Through Tissue

EM Propagation Through Human Tissue



$$Q_3=(Q_2(L_3)+T3(1-L_3))e_3+T_{DN}\Gamma_3$$

$$Q_2=(Q_1(L_2)+T_2(1-L_2))e_2+T_3\Gamma_2$$

$$Q_1=T_1e_1+T_2\Gamma_1$$

Q – Brightness temperature jut below the surface

T – Physical temperature of the layer

e – Emissivity of the layer

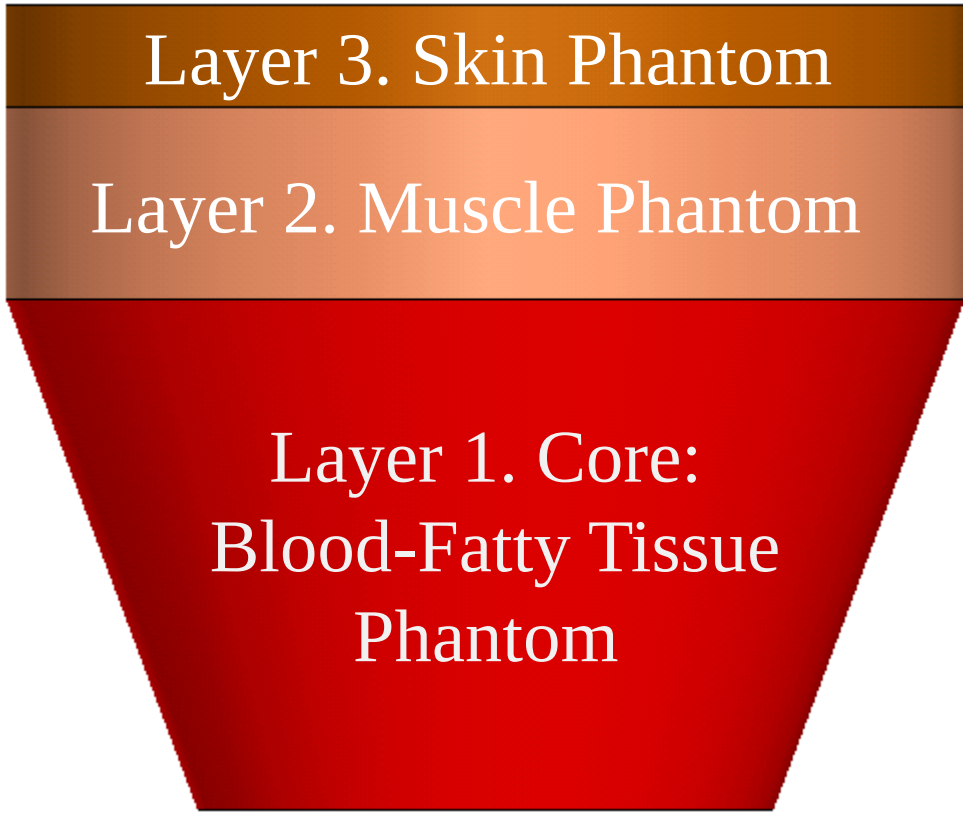
Z – Depth of the volume

L – Loss in the layer

Challenge: Single layer phantoms do not accurate model the electromagnetic characteristics of the human body and therefore can impede sensor design validation.

The Human Core Model

Comprised of Multi-Layer Tissue Mimicking Materials

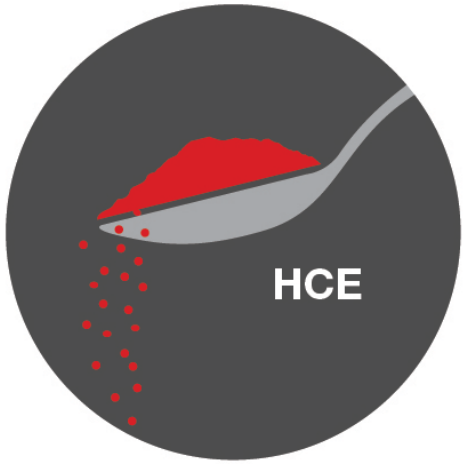


Blood Phantom Recipe

Heat water to boiling point.

Add sugar and salt.

Continue to boil the solution until the compounds are dissolved.



Add HEC.

Reduce heat, and continue stirring until the compound is dissolved.

The sample is now prepared for characterization.

Hybrid Skin/Muscle Phantom Recipe

Heat water to boiling point.

Add TX-151.

Knead the solution until "all" TX-151 particles are shaped into a single solid form.

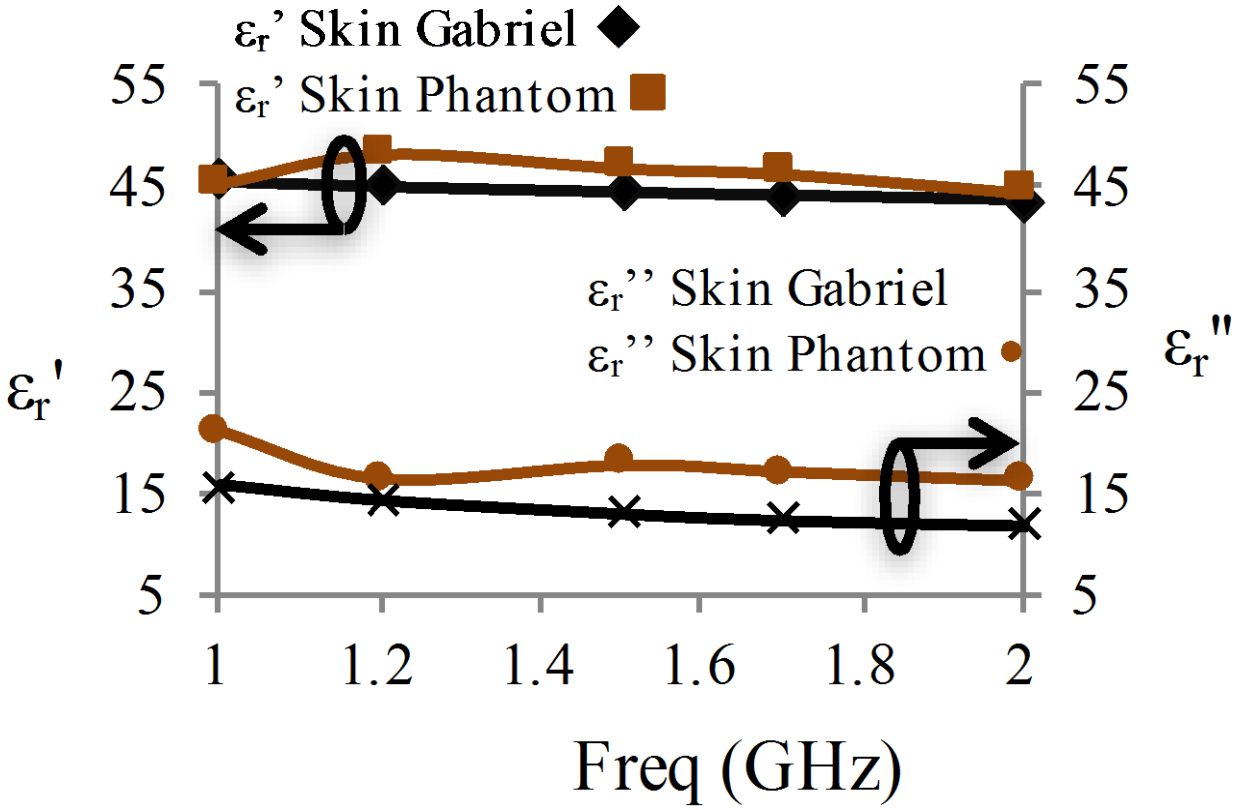
Let the phantom dry until a thin white film covers the surface of the phantom.

Using a sharp object, scrape off a thin (skin) layer on one face.

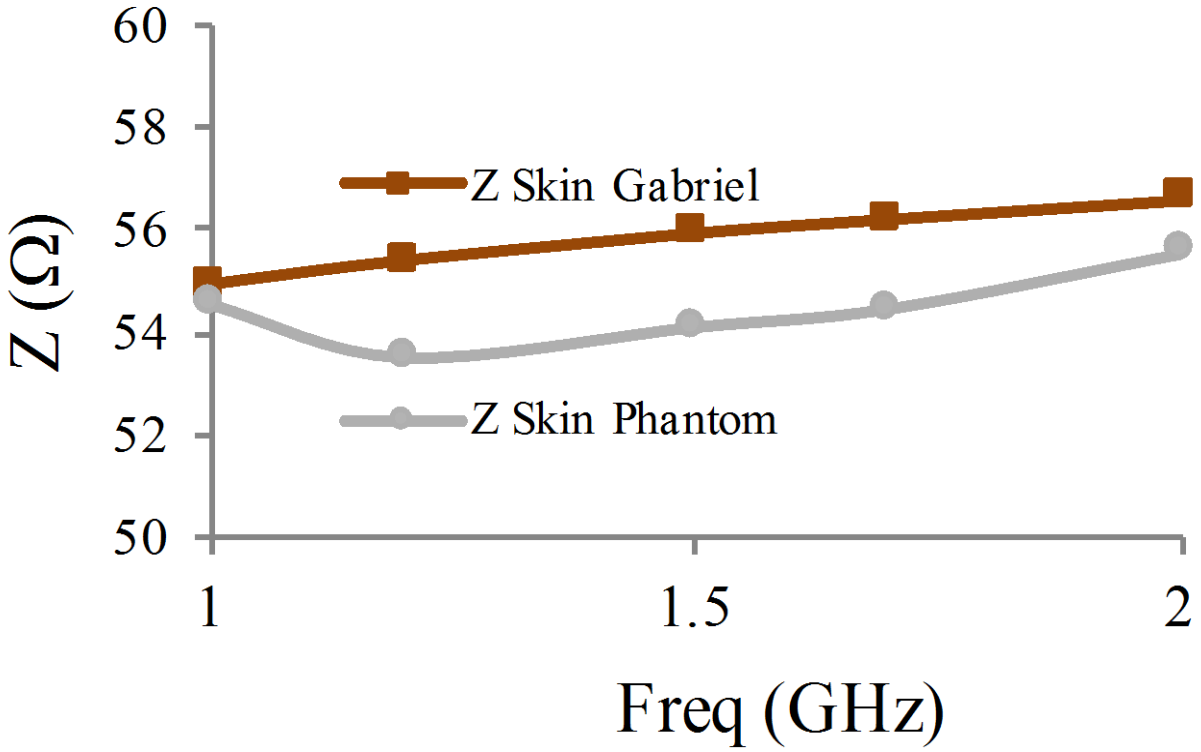
The sample is now prepared for characterization.

Skin Tissue Phantom Characterization

Complex Dielectric Constant ε_r

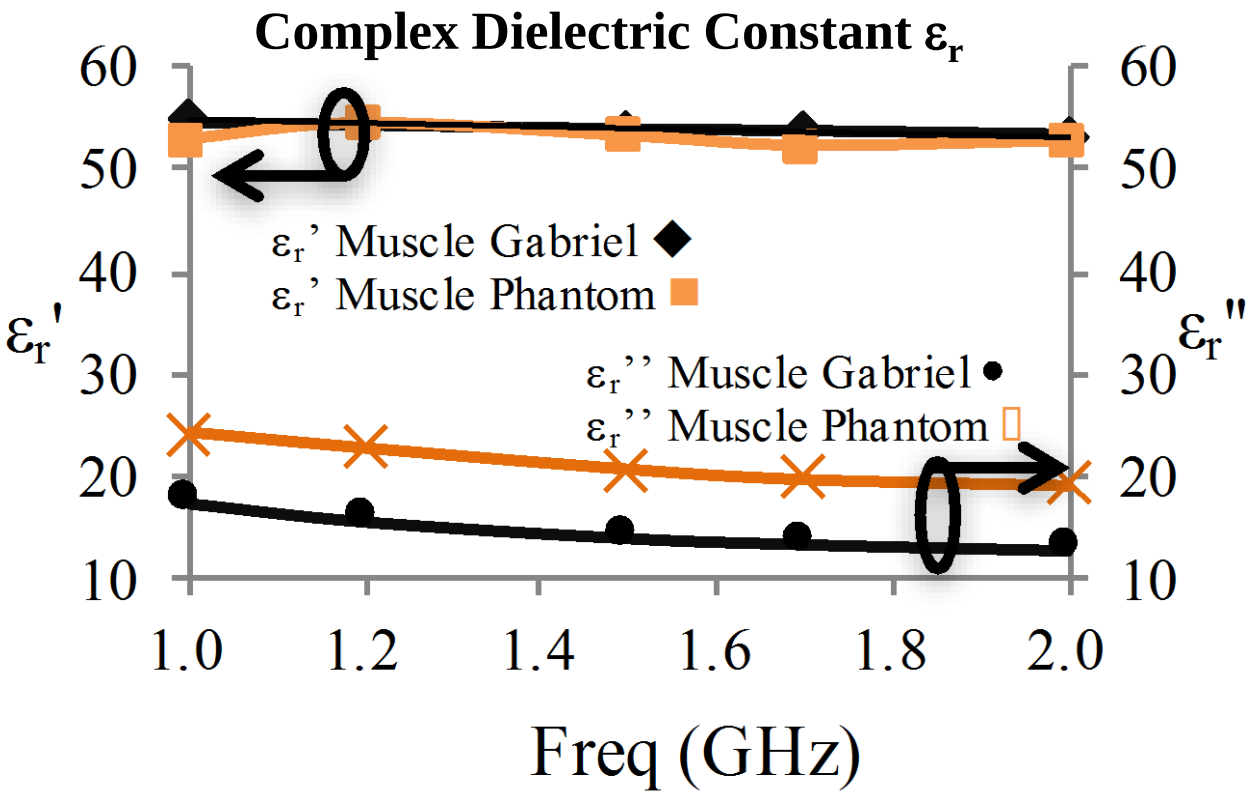


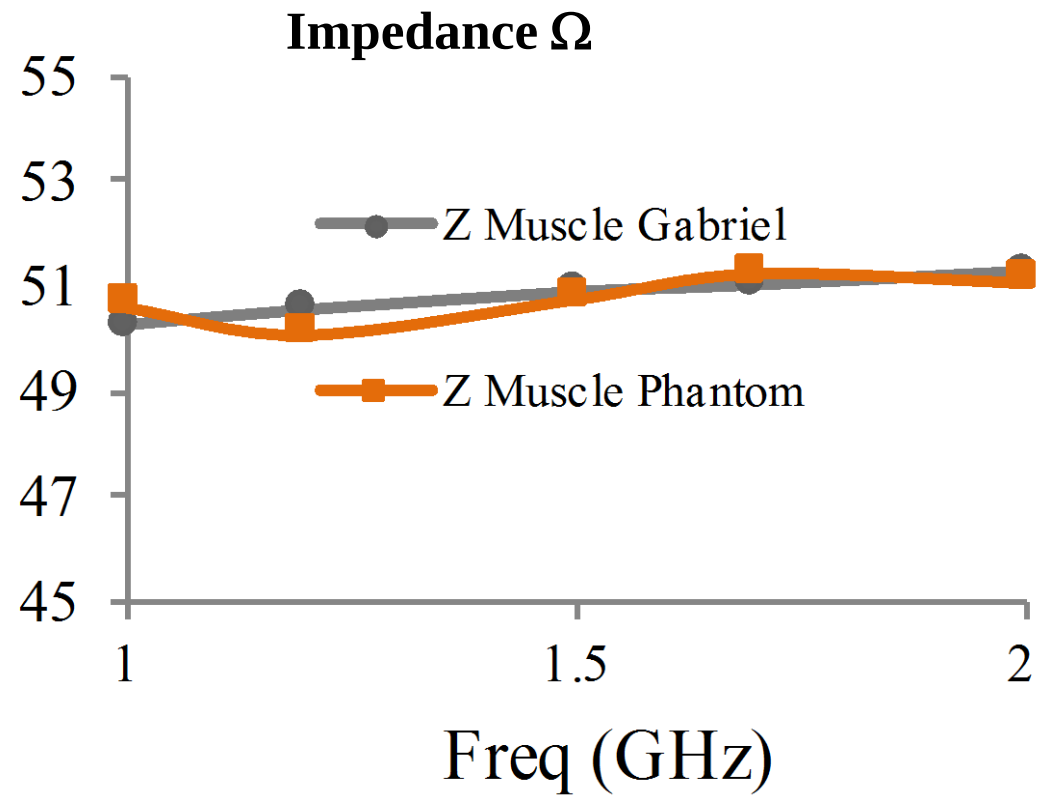
Impedance Ω



Results very similar to that of the Garbiel Model

Muscle Tissue Phantom Characterization





Results very similar to that of the Garbiel Model

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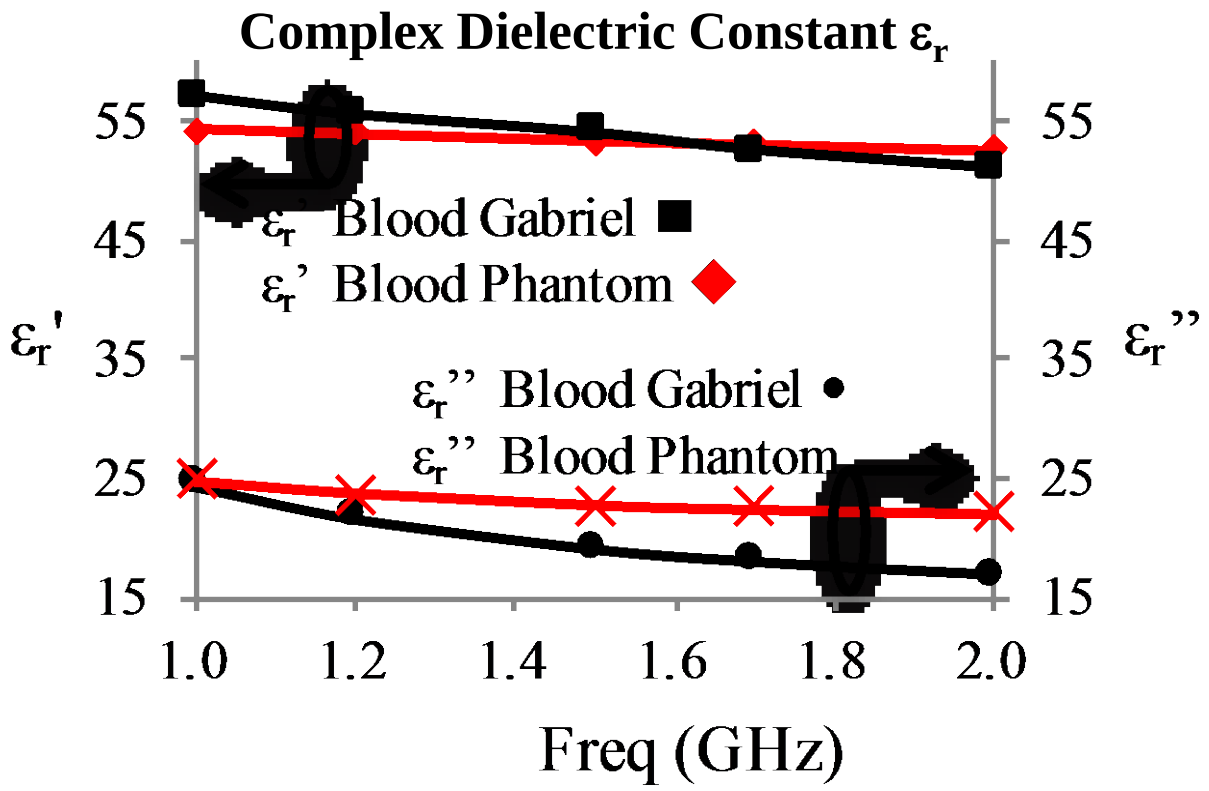
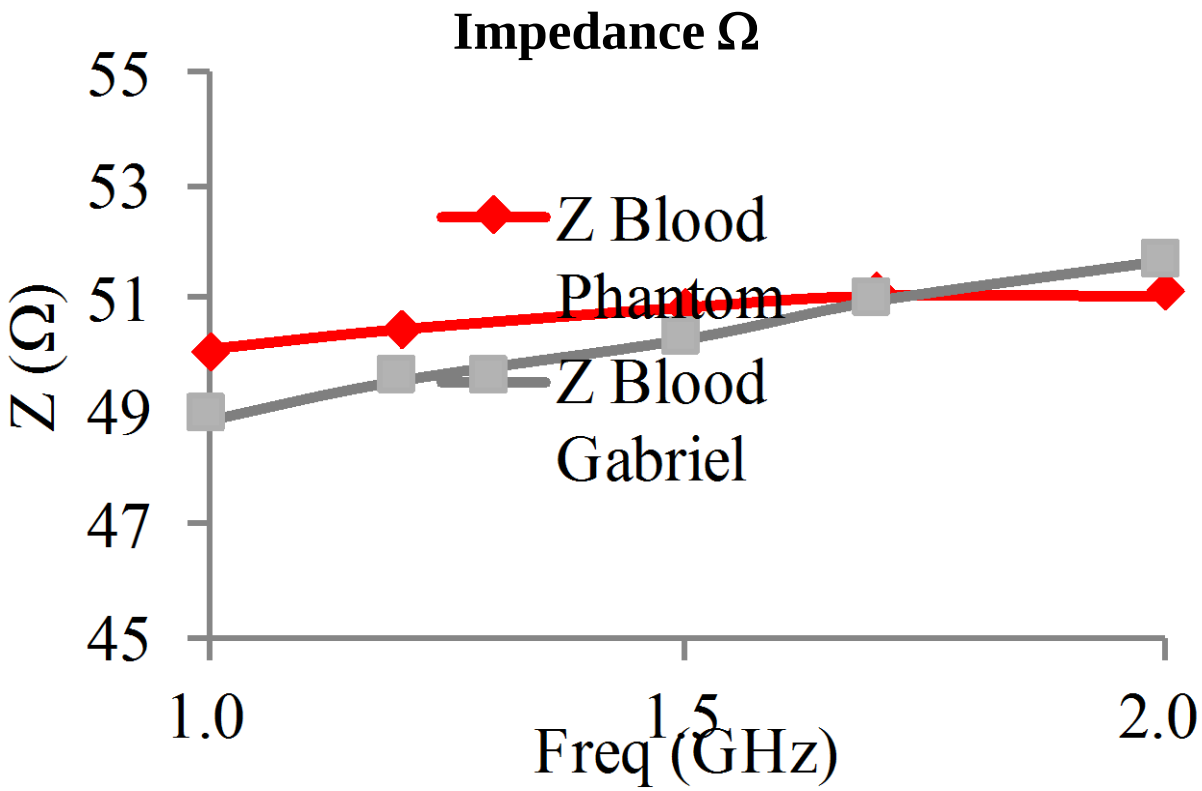
Blood-Fatty Tissue Phantom Characterization





Results very similar to that of the Garbiel Model

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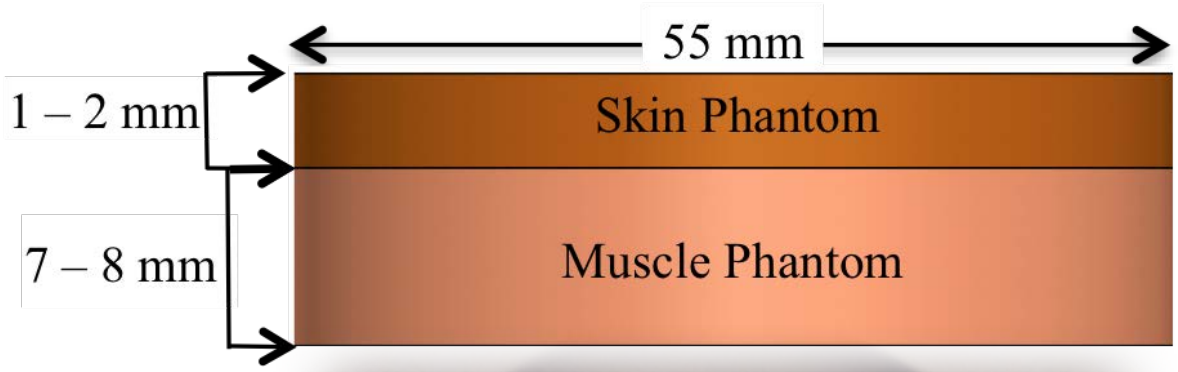
Hybrid Skin/Muscle Phantom



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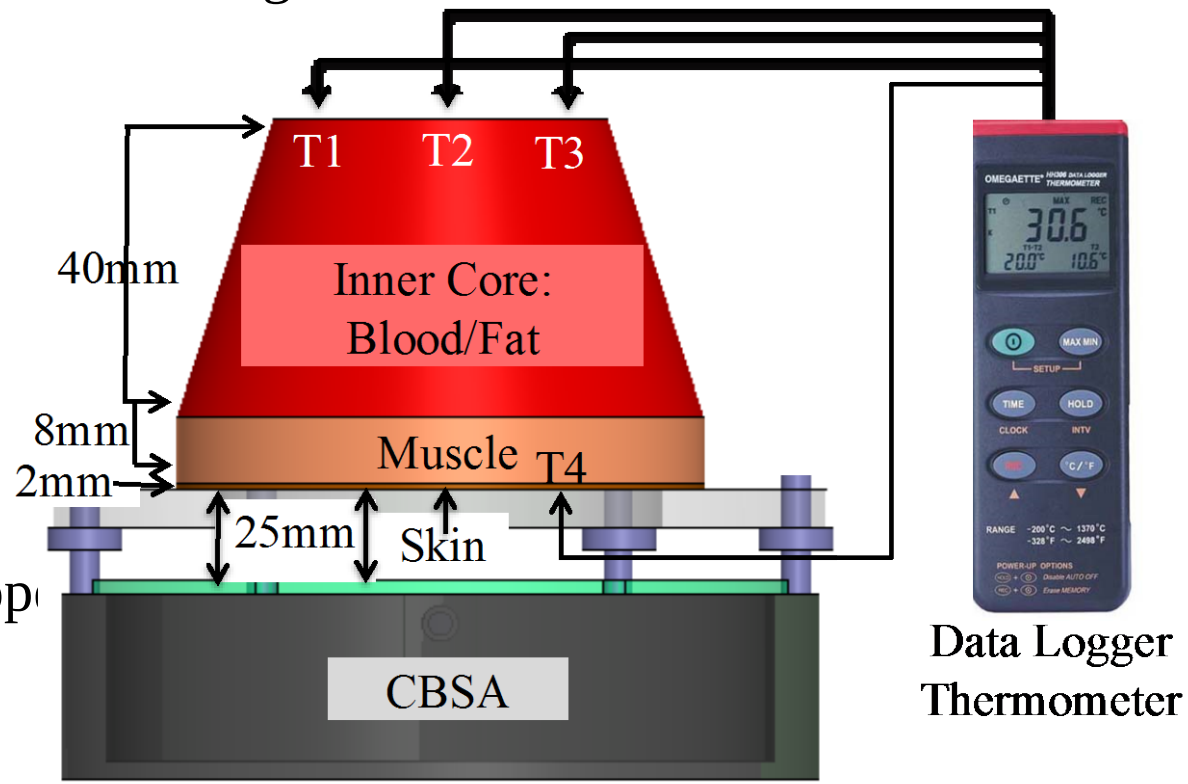
Enhanced Measurement Test Bed

The Enhanced Measurement Test Bed enables more accurate modeling of the physiological characteristics of the human body and other human body effects.

- Human Core Phantom Has Electrical & Physical Properties Analogous to a Human core
  - Skin 1 mm – 2 mm
  - Muscle 7 mm – 8 mm
  - Core 40 mm
- Core Body Temperature Changes Simulated
  - Change Blood Phantom Temperature
  - 107º F – 93º F
  - Sensor Tracks Electrical and Physical Properties
- Radiometer or Similar Sensor Tracks the Electrical Prop
- Physical temp tracked
  - T4 Skin Surface
  - T1 –T3 Core
    - 35 mm beneath skin
    - 22 mm beneath muscle.



Conclusion

- Hybrid Skin-Muscle Phantom Developed
  - First know skin-muscle phantom with electrical and physical properties similar to the human body
  - The development recipe has been presented
  - Phantom results match the literature and Grabriel Model very well

- Blood Phantom Developed
  - Results are also in close agreement to the literature and Grabriel Model
  - The development recipe has been presented
  - Enables the simulation of core body temperature changes

- Human Core Model Developed
  - By combining the Skin-Muscle and Blood phantoms, we can simulate the sensor main probing region
  - Other physiological properties of the body can be simulated and tracked
  - These materials can be easily manipulated to model other regions of the body and therefore can be used with essentially any RF sensor within the 1GHz – 2GHz frequency range.

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