Measuring the Dielectric Properties of Biological Simulants

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Purpose

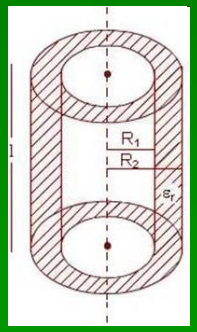
- Measure dielectric properties of biomaterials
  - Dielectric constant for various liquids
  - Dependence on frequencies 10MHz to 100MHz
- Support theoretical analysis and modeling of energy absorbed from wireless devices on or near the human body

http://www.sensortips.com/hot-topic/wireless/mobile-sensors/wireless-implantable-medical-devices/

http://www.emfnews.org/articles/page/10/

Background

- Cylindrical capacitor
  - Inner cylindrical conductor, radius R1
  - Coaxial cylindrical shell, radius R2
- Capacitance depends only on dielectric constant, ε_r
- Measure impedance -- Use equations to work backwards to extract ε_r from capacitance



l = 435 mm

R1 = 16.87 mm R2 = 38.79 mm

$$C = \frac{2\pi\varepsilon_0\varepsilon_r l}{\ln\left(\frac{R2}{R1}\right)}$$

Capacitance

$$L = \frac{\mu_0}{2\pi}\ln\left(\frac{R2}{R1}\right)$$

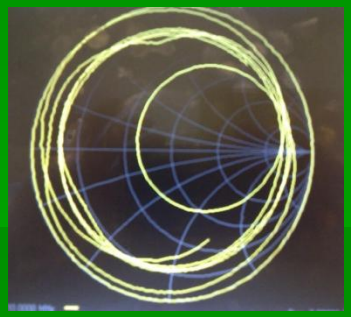
Inductance

$$Z = \sqrt{\frac{L}{C}}$$

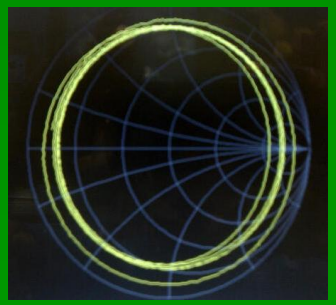
Measured impedance

Experiment

- "Open-coax" technique
  - Air-filled, open-ended coaxial line is immersed in dielectric material
  - Magnetic and electric fields are confined entirely between inner and outer conductors
    - Less stray fields and power loss, providing high precision measurements
- Connected to network analyzer at frequency range 10MHz to 100MHz
  - Plot complex reflection coefficients of system
  - Outputs values of input impedance that can be analyzed to get the dielectric constant



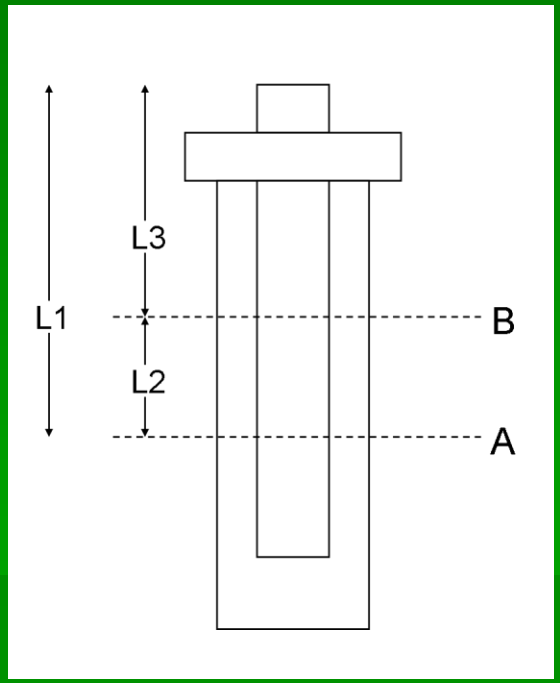
Tap water



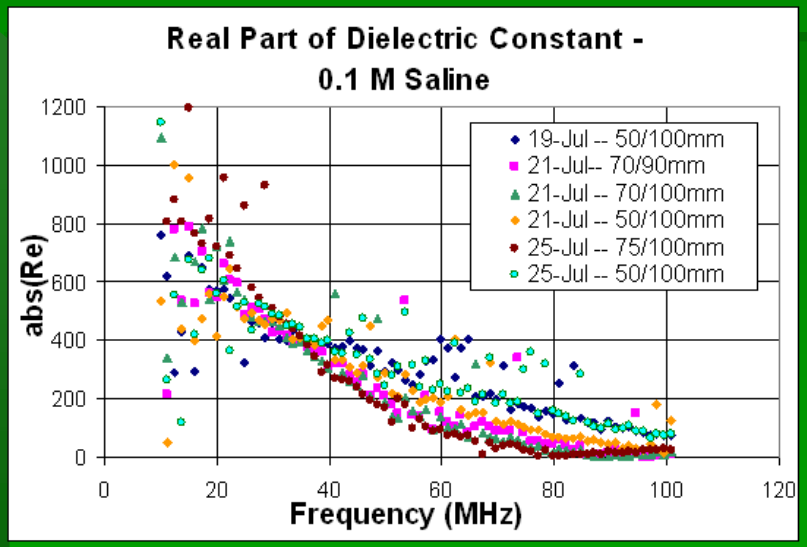
0.1 M Saline

Analysis

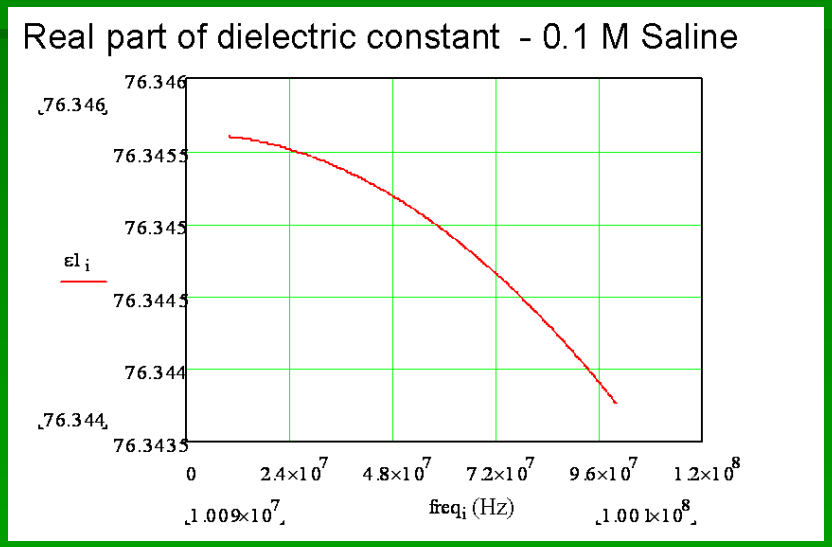
- Dielectric constant analysis involves measuring impedance of system with 2 different lengths of liquid
- Crucial to determine exact amount of liquid system is immersed in
- Need correct amount of air the system has during each measurement
  - Largest source of error in current analysis



Dielectric Constant Analysis -- 0.1 M Saline



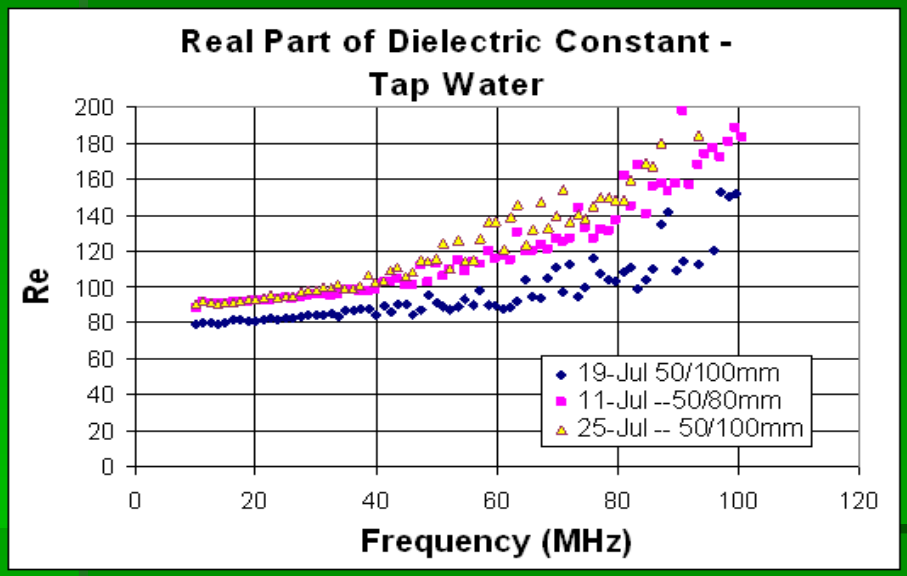
Measured

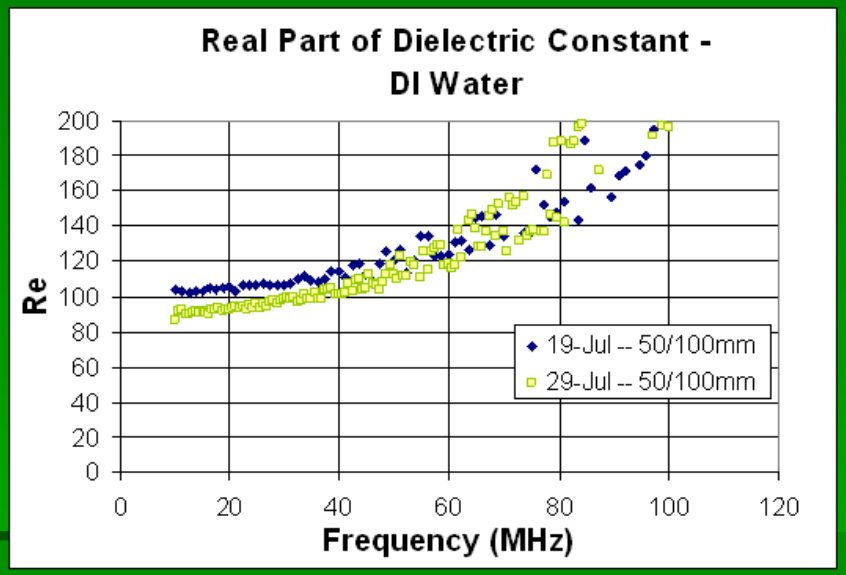


Previously measured ideal values

- Inconclusive
- Analysis program is too sensitive to noise and exact length measurements

Dielectric Constant Analysis -- Water





- Expect saline to be more accurate than water, especially tap water
- DI water is more pure than tap, should see better results

Conclusion and Future Work

- Promising measurement technique
- Analysis must be refined to minimize sensitivity to noise
- Develop more accurate way to measure length of material system is immersed in
- Create mixtures simulating biological materials
- Apply to current models of how human body absorbs radiation from wireless devices

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