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.emfnews.org/articles/page/10/
Background

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

\[
C = \frac{2\pi \varepsilon_0 \varepsilon_r l}{\ln \left( \frac{R_2}{R_1} \right)}
\]

Capacitance

\[
L = \frac{\mu_0}{2\pi} \ln \left( \frac{R_2}{R_1} \right)
\]

Inductance

\[
Z = \sqrt{\frac{L}{C}}
\]

Measured impedance

- $l = 435$ mm
- $R_1 = 16.87$ mm    $R_2 = 38.79$ mm
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

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

Measured

Previously measured ideal values
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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