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Temperature-dependent Dielectric Properties of Breast Tissue Phantoms for Hyperthermia Applications

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Abstract

Microwave diagnostic and treatment technologies for breast cancer have been a popular research interest among researchers. To test the proposed systems many different tissue mimicking phantom materials have been proposed in the literature for testing of microwave breast cancer imaging and hyperthermia devices. One popular tissue mimicking phantom, named oil-in-gelatin dispersion phantoms, are used widely to replicate the dielectric properties different tissue types. These phantoms are used for testing of implantable antennas, microwave imaging devices, and hyperthermia devices. However, the temperature dependent dielectric properties of the phantoms have not been investigated in the literature. This work investigates the dielectric properties of the phantoms with respect to temperature to validate the phantoms can replicate the temperature-dependent dielectric properties of the tissues.

1 Introduction

Dielectric properties of materials govern the interaction of the electromagnetic wave with the target medium. Therefore, knowledge of the medium dielectric properties is vital for design of microwave medical diagnostics and therapeutic technologies. It is well known that these properties are dependent on the molecular structure of the materials and also other factors such as frequency and temperature. The dielectric properties of the biological tissues and phantom materials mimicking the dielectric properties of these tissues are well documented with respect to frequency at the relevant microwave frequency ranges [1-3]. However, the literature reports limited studies on temperature dependence of biological tissues and the temperature dependent dielectric properties of phantom materials have not been reported in the literature.

This paper investigates the temperature dependent dielectric properties of the oil-in-gelatin dispersion phantoms. To do so, two phantom mimicking materials were chosen as a high water content tissue blood mimicking material and a low water content tissue fat mimicking material. The phantom mimicking materials are heated until 50 C° and the dielectric properties are measured and recorded during both heating and cooling cycle with 5 C° resolution. The phantom recipes as well as the measurement results are given in the rest of this paper.

2 Method

Oil-in-gelatin tissue mimicking materials are characterized by preparing bae gelatin solution and mixing in different percentage of oil to the solution in order to replicate the dielectric properties of the desired biological tissue type. To characterize the blood and fat mimicking phantoms 34 grams of gelatin is mixed with 190 ml deionized water in a beaker. The beaker is covered with a cling film and the mixture was placed in a water bath where the temperature was set to 90 C°. When the mixture was clear amber color without air bubbles it is removed from the water bath and left to cool down to 50 C°. Note that the gelatin solution was clear between 75 to 80 C°. At 50 C°, 95 ml gelatin solution was measured and mixed with 5 ml oil were mixed in a magnetic stirrer to form the blood mimicking material. Once the oil is homogeneously distributed in the gelatin solution, 0.28 ml dishwashing detergent (fairy platinum) was mixed in slowly. Finally, 1.71 grams of 37% by weight formaldehyde solution was mixed in to polymerize the solution. Similarly, for fat mimicking material 20 ml of gelatin solution is mixed with 20 ml oil until oil is well distributed in gelatin solution. Then, 4.48 ml dishwashing detergent is slowly mixed in to the gelatin and oil solution. When the mixture is homogenized and ivory-like color remaining oil is added slowly. Finally, 0.39 grams of 37% by weight formaldehyde solution was added to polymerize the fat mimicking material. It should be noted that this procedure form chemical gels. Therefore, the gels keep their form, does not de-jellify, when heated.

The phantoms left for solidifying for 5 days and dielectric properties of the phantoms at room temperature 24 C° were collected. Then the phantoms are wrapped with cling film to minimize the evaporation. Next, the cling film is pricked at two points to enable direct contact between the dielectric probe tip as well as the thermometer and the phantom. The phantom under test is then placed in the water bath and the probe aperture placed on directly to the phantom and fixe at the point. Then, the water bath was set to 50 C° and dielectric properties were collected with 5 C° temperature resolution. Both the heating and cooling cycles were investigated to understand the stability of the dielectric properties.

3 Results

The dielectric properties of the phantoms were collected with the N5230A PNA Series Network Analyzer and

85070 slim form dielectric probe kit. The probe was calibrated with the standard open, short, and deionized water. The calibration was checked by measuring the dielectric properties of methanol, a well-documented material. A comparison of dielectric properties between phantom material and literature data is given in Figure 1. Figure 2 shows the dielectric properties collected from fat mimicking material. Both results shows a well agreement with the literature data.

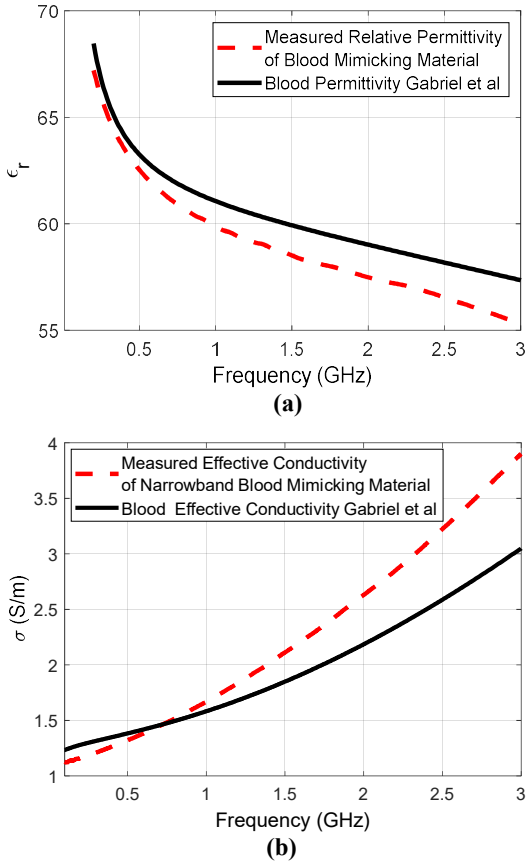
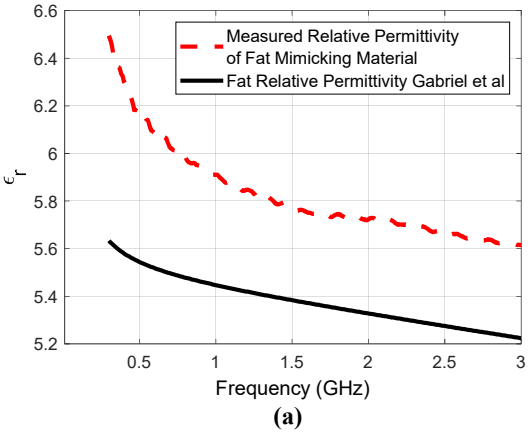


Figure 1. Measured dielectric properties of the blood mimicking material and the literature values: (a) Relative permittivity comparison, (b) conductivity comparison.



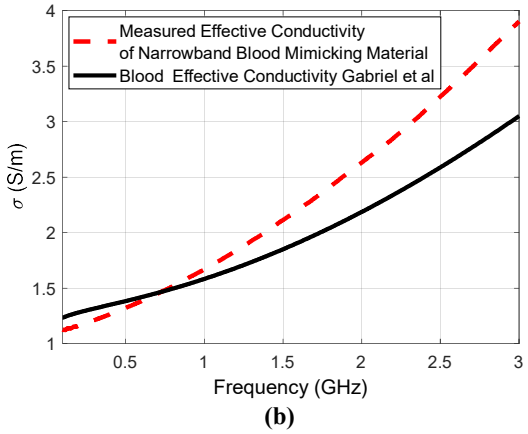


Figure 2. Measured dielectric properties of the fat mimicking material and the literature values: (a) Relativ permittivity comparison, (b) conductivity comparison.

3 Conclusion

In this work, temperature dependent dielectric properties of widely used oil-in-gelatin-dispersion materials were investigated. Two phantom mimicking materials were produced with 5% oil rate the blood mimicking phantom and with 80% oil rate fat mimicking material. The dielectric properties of tissue mimicking materials were collected with 5 C° temperature resolution. The results indicate that the temperature significantly effects the dielectric properties of the phantoms.

6 Acknowledgements

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7 References

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