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Investigation on Dielectric Properties in Gelatin-Based Phantom for Human Brain

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***Abstract* - This paper presents the investigation on material characteristic in gelatin-based phantom, which observed through dielectric measurement that is performed from 1 to 6 GHz. Gelatin and water are used in the investigation. The study focuses on dielectric variation due to the ratio of gelatin and water. The obtained results in this study are useful for the development of realistic human brain phantom.**

***Index Terms* —Brain; gelatin-based; microwave; phantom.**

I. Introduction

In microwave imaging, phantom is important which is used to simulate the interaction of electromagnetic wave with biological tissues. Many researchers developed their own phantom for their system as reported in [1-3] using simple and cheap material such as polyacrylamide, dough (consisting flour and oil) and gelatin. Gelatin-based material is seen as potential material as reported in [3] since it can mimic properties of human tissues.

Although the gelatin-based phantom is discovered and presented its composition in previous research, there is no detailed explanation on the behavior of gelatin-based phantom. Because of that matter, the experimental study is conducted in this paper to understand the characteristic of gelatin-based material for guidance in producing gelatin based-phantom for selected human brain tissues This paper presents the variation of dielectric properties of gelatin-based phantom concerning to the certain ratio of its main materials, which are gelatin and water.

II. Material and Method

To obtain the dielectric variation results of selection specific ratios of gelatin and water, the experimental study is conducted. The experimental study concerns five gelatin-based samples containing 10g gelatin with different ratio of water. The ratio of gelatin and water used for each sample is listed in Table 1. All measured data is then analyzed and compared. The measurement in this experimental study is obtained using special coaxial probe in conjunction with a vector network analyzer (VNA). Three measurements are taken for each sample to ensure its accuracy then the averaged results are plotted. The measurements data in this paper are plotted in form of relative permittivity (ε_r) and conductivity (σ).

TABLE I
Gelatin-based Samples in Different Ratio of Gelatin and Water

Sample No.	Gelatin (g)	Water (g)
Sample 1	10	50
Sample 2	10	40
Sample 3	10	30
Sample 4	10	20
Sample 5	10	15

III. Results and Discussion

Fig. 1 shows the relative permittivity of five gelatin-based samples with different ratio of water. The observation shows that the relative permittivity of sample is increased every time the amount of water is increased. The same trend demonstrated by the conductivity plots in Fig. 2, the conductivity also shows an increment when the amount of water is increased. From this result, the gelatin-based phantom is can be easily composed and tuned to the desired dielectric level. Through the observation on Fig.1 and 2, the data for these gelatin-based samples actually mimic the properties of water. The gelatin acts as solidify agent for the water and in the same time decrease the relative permittivity of sample based on the relative permittivity of water.

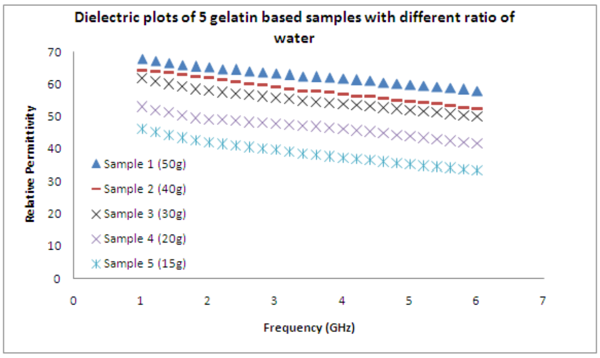


Fig. 1. Relative permittivity of five gelatin-based samples with different ratio of water.

Gelatin is a family of gels, which have formation between soft and hard, depends on its composition. Gels can be recognized as semisolid or solid substance which is basically from a liquid, then three dimensional cross-linked networks that exist within the liquid act as bonding material that bond molecules of the liquid and force it to behave like a solid. Fig. 3 shows the stages in the formation of a gel.

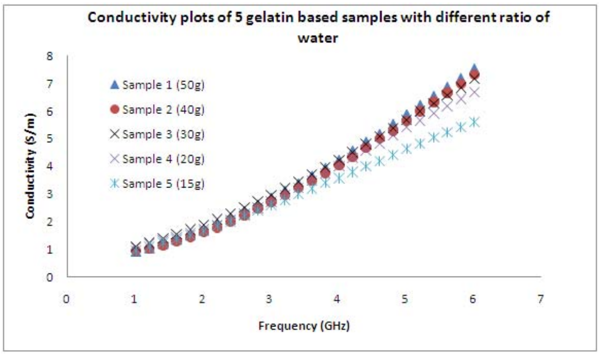
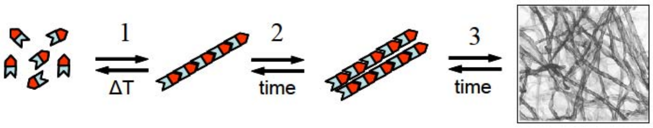


Fig. 2. Conductivity of 5 gelatin based samples with different ratio of water.



(a) (b) (c) (d)

Fig. 3. Schematic representation of the formation of a 3D-network starting form dissolved gelator molecules.

At high level of temperatures, molecules of gel completely dissolve as in Fig. 3 (a). The temperatures are capable to reduce strong intermolecular interaction, which avoid the aggregation of liquid. When these temperatures decreased, the intermolecular interaction will force the molecules of liquid to form self-assemble as in Fig. 3 (b). Due to this interaction self-assembly, it actually produce a thin fiber in one dimension. As the time varies, this fiber can grow then producing bundles of thin fibers which minimize the molecules of liquid from moving as in Fig. 3 (c). Then over certain time period, these bundles of thin fibers grow and can split for the formation of a 3D-network, which also recognized as the formation of a gel as in Fig. 3 (d).

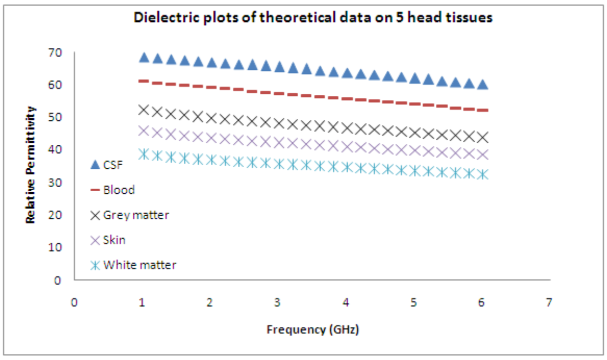


Fig. 4. Relative permittivity of theoretical data on 5 selected tissues.

In addition from Fig. 1 and 2, several data results similar dielectric properties with the theoretical data for several tissues in human brain. Fig. 4 and 5 show the relative permittivity and conductivity plots of theoretical data for brain tissues, which are cerebral spinal fluid (CSF), blood grey matter skin and white matter obtained from [4]. From the observation on the theoretical plots, it shown that several data have similar plot with measured data in Fig. 1 and 2. Sample 1 is almost similar with CSF, Sample 3 is similar to blood, while Sample 4 and 5 is similar with grey matter and skin tissue, respectively.

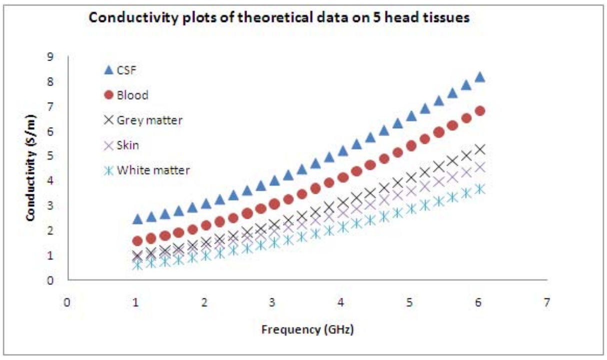


Fig. 5. Conductivity of theoretical data on 5 selected tissues.

IV. CONCLUSION

In the development of human brain phantom, it is important to understand the characteristic of the material. From the finding in this paper, the method to compose and tune gelatin-based phantom is discovered. Several compositions of gelatin-based samples have been measured in the experimental study, which discovered to be mimicking several of human brain tissues. The finding presented in this paper could be used to obtain the most suitable and accurate phantom material in the purpose of the realistic human brain phantom development for microwave imaging system.

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