A Study of the Dielectric Properties of Biological Tissues: Ex-vivo vs Preserved Samples

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Abstract— Dielectric properties are the most important parameters determining energy deposition when biological tissues are exposed to microwave fields. Energy absorption is determined by the specific absorption rate (SAR), which distributions can be computed accurately only if the complex relative permittivity of the target tissue is known to a sufficiently high accuracy. Presently there is a lack of data on the dielectric properties of biological tissues at high frequencies. This work describes in detail the measurements of ex-vivo dielectric properties of fat tissue and their correlation to preserved samples. In addition, the temperature variability of fat tissue dielectric properties is shown. Measurements were conducted using an open-ended reflection technique and the frequency band considered for this study ranged from 1 GHz up to 20 GHz. The measurement system was controlled via a PC and the complex reflection coefficient was recorded for a given number of frequencies. The complex reflection coefficient (S_{11} parameter) was converted to complex permittivity (ε) utilizing the Agilent software 85070E. A one-pole Cole-Cole model was used to fit the measured data as a function of frequency and the dispersion parameters.

1. INTRODUCTION

The study on the characterization of the dielectric properties is a continuous field of research as the dielectric properties plays an important role in calculating the energy deposition when tissues are exposed to radiofrequency and microwave fields. Energy absorption is determined from the specific absorption rate (SAR) and can be accurately computed only if the dielectric properties of the target tissue is accurately known [1].

This study forms part of a larger project focusing on identifying the limiting factors of microwave imaging technique in detecting the dielectric inhomogeneous inclusions in the biological tissues. The ultimate aim is to create a unified breast phantom for experiments. Therefore, it is important to characterize the dielectric properties of breast tissues [2].

This work describes in detail the measurements of ex-vivo fat tissue dielectric properties and their correlation to preserved samples. In addition, the temperature variability of fat tissue dielectric properties from 21°C up to 37°C is presented.

2. EXPERIMENTAL SET-UP

During experiments an open-ended coaxial probe technique and a vector network analyzer (Rohde&Schwarz ZVA-50) with a dielectric measurement kit (85070E Agilent Dielectric Probe kit [3]) for measurement of the complex reflection coefficient (S_{11} parameters) were used (Fig. 1). The examined frequency band was from 1 GHz up to 20 GHz. The measurement system is controlled by a PC and the data is recorded for the given number of frequencies. The complex reflection coefficient (S_{11} parameter) was converted to complex permittivity (ε) utilizing the Agilent software 85070E. A one-pole Cole-Cole model was used to fit the measured data as a function of frequency and the dispersion parameters.

3. METHOD

The measurement procedure used to measure the dielectric properties of the biological tissues is outlined in detail below. This research was conducted at the University of Malta (Msida, Malta), in the Electromagnetics Laboratory using a vector network analyzer (Rohde & Schwarz) and the method of coaxial probe (85070E Agilent Dielectric Probe kit from Keysight Technologies, Fig. 2).

The necessary steps taken to obtain successful and repeatable measurements of the electromagnetic field strength E using the coaxial probe were:

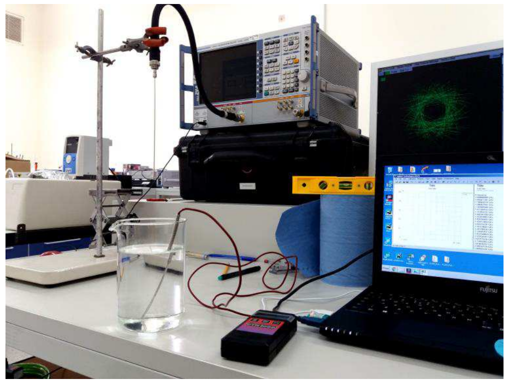

Figure 1: Experimental set-up.

Figure 2: Coaxial probe.

1. immobilize probe cable and eliminate the possibility of bending the cable, the probe, and the torsion nuts electrical connectors;
2. use a sample with a thickness of 10 mm diameter and 20 mm larger than the diameter of the probe.

Before conducting measurements, it is necessary:

1. to setup the measurement parameters (frequency, number of measurement points in the frequency range, the calibration parameters);
2. to calibrate the probe. During the calibration, make sure that at the end of the probe there are no air bubbles.

After calibration, it is important to ensure that the probe is wiped dry.

Measurements were conducting on two types of tissues: fresh and preserved fat tissue samples. The samples were placed in the Petri dish. In all six samples were used for these investigations: two used for 'fresh' ex-vivo measurements, another two were fixed in the formalin and the remaining

(a) (b)

Figure 3: Calibration procedure: (a) by using the calibration short; (b) by using the water.

Figure 4: Measurements of an adipose tissue samples.

two samples were used to study temperature variability from 21°C up to 37°C. The fixed samples placed in formalin and measured on third day at 21°C.

4. RESULTS

Figures 5–6 represent the dielectric constant and loss factor for fat tissues in the form of graphs.

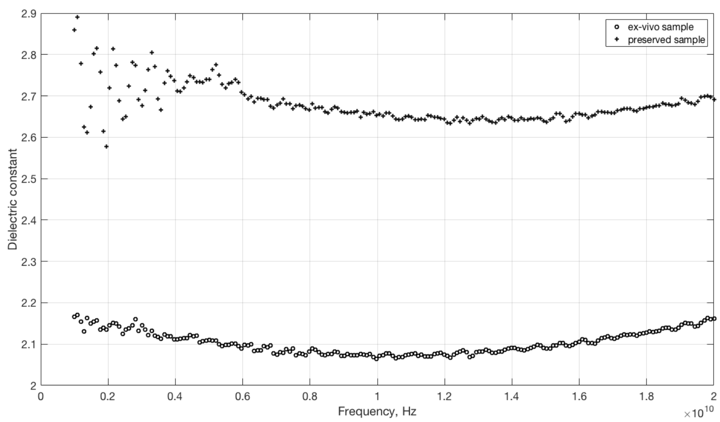

Figure 5: The measured dielectric constant of fresh and preserved fat tissue.

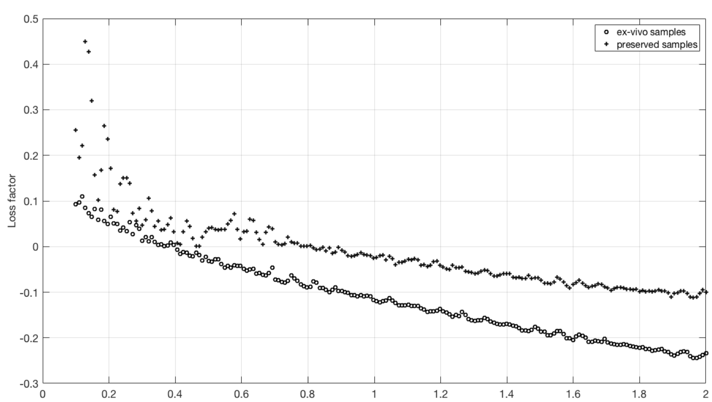

Figure 6: The measured loss factor of fresh and preserved fat tissue.

As it is shown on the graph the difference between dielectric constant amplitude of fresh and fixed sample are of 30%. While tangents of loss factors 1.4 times differ.

Figures 7–8 represent the temperature variability of fat tissue dielectric properties.

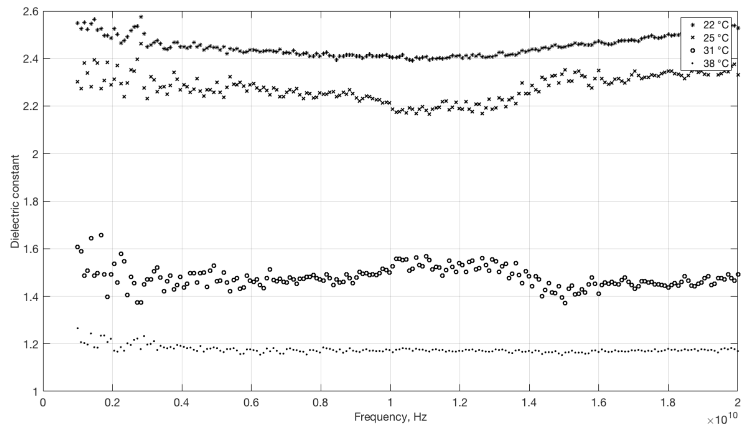

Figure 7: The measured of temperature variability of fat tissue dielectric constant.

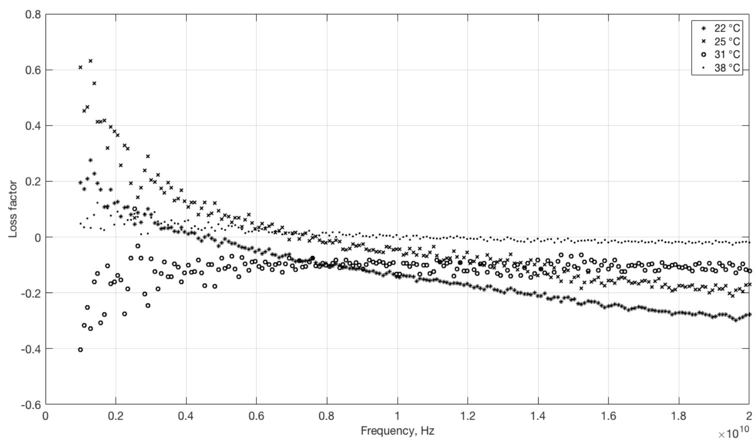

Figure 8: The measured of temperature variability of fat tissue loss factor.

The experimental data showed that increasing of samples' temperature from 22°C to 38°C results in reducing the dielectric constant amplitude from 2.6 to 1.2 (differences are more than twice). Moreover, tangent of loss factor is reduced.

5. CONCLUSION

The work deals with a procedure of biological tissues dielectric properties measurement which minimizes impact on the result. We compared the estimates of ex-vivo dielectric properties of fat tissue and their preserved samples. Furthermore, it was shown that the formalin has a great influence on the dielectric properties of the tissues thus the measurements of preserved tissue properties should be used with caution.

In addition, the temperature variability of fat tissue dielectric properties shows that dielectric properties change significantly with temperature.

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REFERENCES

1. Abdilla, L., C. Sammut, and L. Z. Mangion, "Dielectric properties of muscle and liver from 500 MHz–40 GHz," *Electromagnetic Biology and Medicine*, Vol. 32, No. 2, 244–252, 2013.

2. Obol, M., N. Al-Moayed, S. P. Naber, and M. N. Afsar, "Using coaxial probe for broadband microwave characterization of biological tissues," *Proceedings of the 38th European Microwave Conference*, 416–419, Amsterdam, The Netherlands, 2008.
3. Agilent Technologies, "Agilent 85070E dielectric probe kit 200 MHz–50 GHz," *Technical Overview*, Available online:http://cp.literature.agilent.com/litweb/pdf/5989-0222EN.pdf, 2012.