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Research Article

Study of the Effects of Changing Physiological Conditions on Dielectric Properties of Breast Tissues

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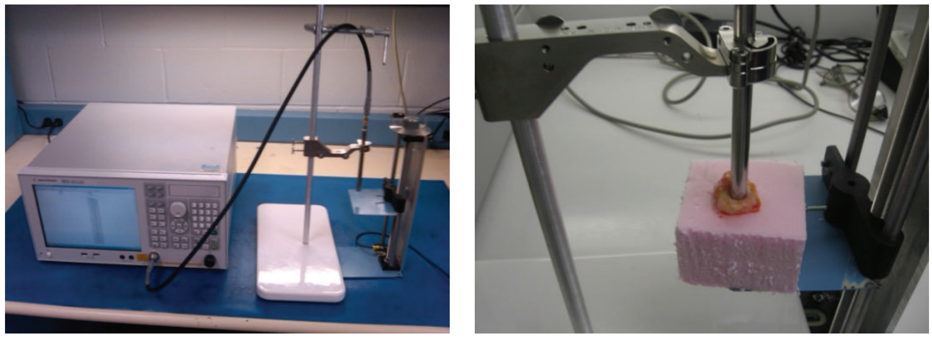
This paper addresses the changes in the physical characteristics (temperature and water/blood content) of breast tissue under different physiological conditions. We examined *ex vivo* specimens of breast tissue excised at the time of surgery to study the effects of physiological conditions on dielectric properties. We observed that the dielectric properties strongly depend on tissue physiological state. When the biological tissues undergo physiological changes, such as those due to disease or those induced by external changes such as variations in the environmental temperature, the microscopic processes deviate from their normal state and impact the overall dielectric properties. This suggests that microwave imaging might be used to monitor the physiological conditions of the body.

1. Introduction

In recent years microwave imaging (MWI) has attracted significant interest for biomedical applications. This is due to the fact that microwave signals are able to transmit through and be absorbed and reflected by biological tissues. The difference arises from molecular (dielectric) rather than atomic (density) based interactions of the microwave radiation with the target when compared with X-ray imaging. These factors make microwaves suitable to be used for diagnosis in medicine, especially for the imaging of the biological structures which depend on the tissue's dielectric properties, that is, the permittivity and the conductivity. The permittivity of a material is linked to the material's ability to change polarity. Polar compounds, like water, have a high permittivity. Conductivity is related to the amount of electricity that can be transferred through the material. Physiological conditions can have pronounced effects on a tissue's dielectric properties.

Dielectric properties of biological tissue have been investigated for almost eighty years [1–10]. It has been twenty-eight years since Chaudhary et al. measured the dielectric properties of healthy and malignant breast tissues within 3 MHz–3 GHz [2]. Their studies generated interest in the possibility of using nonionizing electromagnetic waves to image the breast to detect tumours. In 1994, a similar study was repeated by Joines et al. [7]. A literature survey by Gabriel et al. reports the characterization of biological tissues over the range of 0.01–20 GHz [5, 6]. In 1988, Surowiec et al. [11] found that the tissue at the infiltrating edge of the tumour had increased dielectric properties. Recent extensive characterization of the dielectric properties of different tissue types, including normal, malignant, and benign breast tissues obtained from breast reduction and cancer surgeries, in the frequency range of 0.5–20 GHz, has been performed by Lazebnik et al. [8, 9]. In 2009, similar measurement was performed by Halter et al. for *in vivo* tissues [12]. They have investigated the dielectric properties of the breast tissues with and without tumour presence with steady physiological conditions. In the large-scale study of dielectric properties of breast tissue performed by Lazebnik et al. [8, 9], it has been reported that the time between excision and measurement of dielectric properties of breast tissues varied between 5 to 80 minutes, and the authors concluded that the time



(a) (b)

Figure 1: Measurement setup for breast tissues dielectric properties: (a) ENA network analyzer and Agilent 85070E dielectric probe kit and (b) tissue under the performance probe measurement.

(a) (b)

Figure 2: Breast tissue samples from mastectomy surgery: (a) the entire breast sample, (b) benign tissue sample.

between excision and measurement had negligible effects on the dielectric properties. The goal of this paper is to demonstrate the significant changes in dielectric properties in the first few seconds after the excision of tissue. These changes are due to the effects of temperature and water content quickly after excision. In this paper, we study these effects based on results of *ex vivo* breast tissue measurement. The sample tissues that were measured were from women undergoing surgery to exclude or treat breast cancer.

2. Dielectric Properties Measurement of Breast Tissues

In order to characterize the dielectric properties of the *ex vivo* breast tissues based on the time of excision and temperature, different dielectric properties measurements from women undergoing breast surgery were performed at the Altru Hospital, Grand Forks, ND, USA. Agilent E5071C ENA network analyzer and Agilent 85070E dielectric probe kit with high-performance probe were used for these measurements. Prior to each measurement, all probes were calibrated using short and open circuit loads and 25°C distilled water as described in [13]. In order to minimize calibration errors associated with the bending of the signal transmission cable attached to the network analyzer during the measurement procedure, all cables were fixed. Figure 1 shows pictures of dielectric properties measurement setup. Women scheduled for surgical resection were referred to our clinical coordinator for possible inclusion in this study. The protocol was approved by Institutional Review Board, and all women enrolled in this study signed consent forms. Immediately, after surgery, the biopsy specimen was taken to the site where the dielectric properties measurements took place. After measurements were completed the tissue was transferred to the pathology department where it was sectioned and processed for histological evaluation. Figure 2 illustrate tissue samples from mastectomy surgery (black ink present for assessment of surgical margins).

2.1. Dielectric Properties versus Temperature. For this study our goal was to demonstrate whether frozen sample could be brought up to body temperature and their measured dielectric properties could be used in MWI. Therefore we selected a tissue sample that was left in the room temperature for approximately half an hour after the surgery. Then we measured its permittivity and conductivity at 27°C. We moved the tissue into freezer and gradually lowered its temperature. Then we measured the dielectric properties at 20°C, 5°C, 10°C, and −10°C. These results are shown in Figures 3(a) and 3(b). After freezing, we took the same sample, left it in room temperature, and measured its permittivity and conductivity as it thawed. The results of these measurements are shown in Figures 3(c) and 3(d). By comparing these two sets of results one can conclude that freezing will change

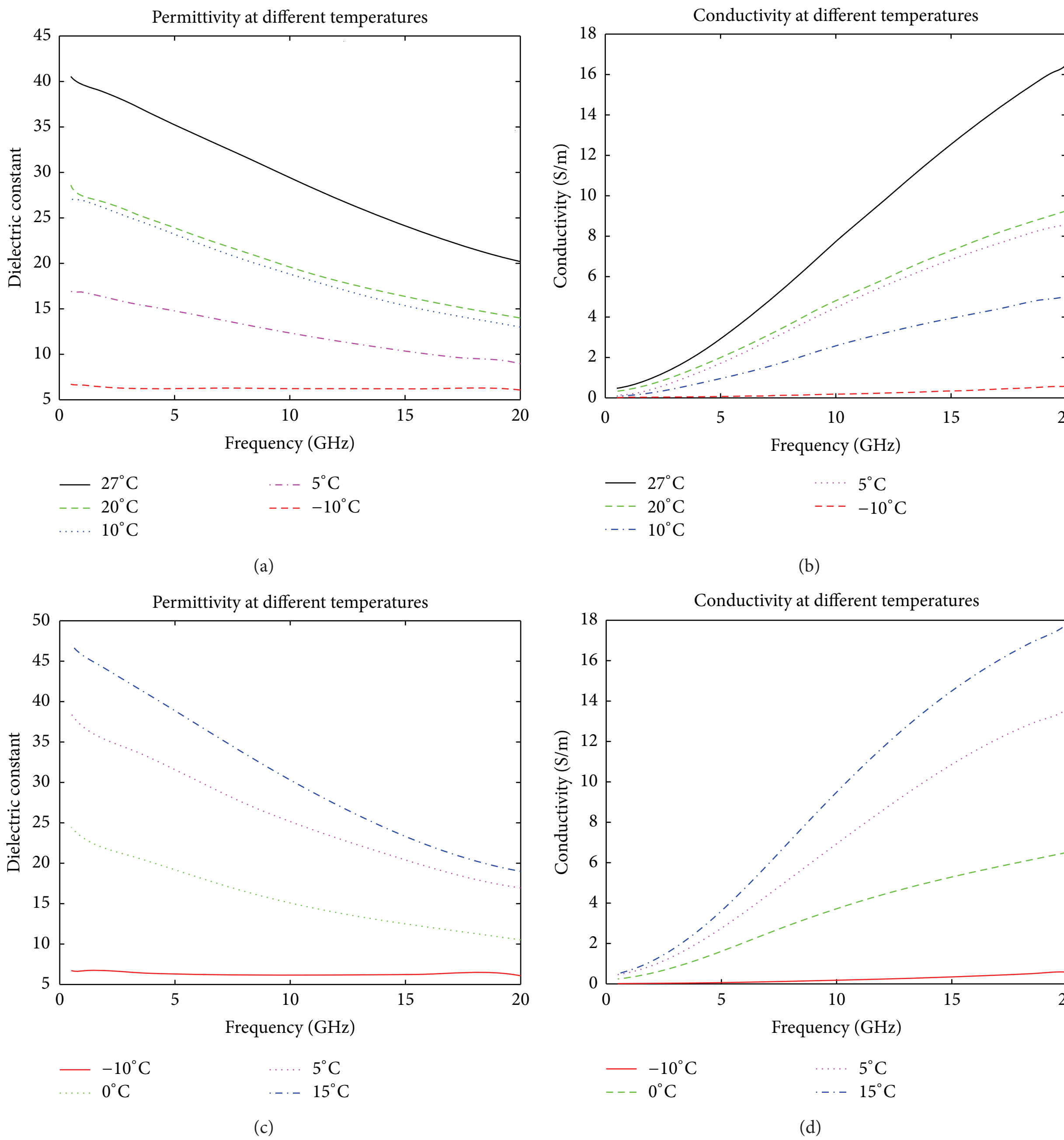


FIGURE 3: Dielectric properties of breast tissue versus frequency at different temperatures (a) permittivity when temperatures decreased from room temperature to freezing, (b) conductivity when temperatures decreased from room temperature to freezing, (c) permittivity when temperature increased from freezing to room temperature, and (d) conductivity when temperature increased from freezing to room temperature.

the tissue properties such that it does not go back to its original states. Therefore it is not possible to use frozen sample. For accurate dielectric properties measurement, the temperature of the tissue needs to be as close as possible to the body temperature.

2.2. Dielectric Properties versus Time of Excision. For this study a specimen from a full mastectomy surgery was selected from a 47-year-old woman with fibrocystic changes. The entire breast was transferred to the pathology department within 5 minutes of removal. The mastectomy surgery has been selected for this part, because a fresh tissue was required. Since the entire breast is removed in mastectomy surgery, if a sample is cut from inside breast at the pathology laboratory, this can be considered as a fresh sample. A sample from central breast was measured at different times, with the sample fixed under the probe for the entire measurement period (0–180 sec). After the measurement, a selected sample was processed for histopathology and identified as fibrocystic breast tissue. Figure 4 shows the results of permittivity and

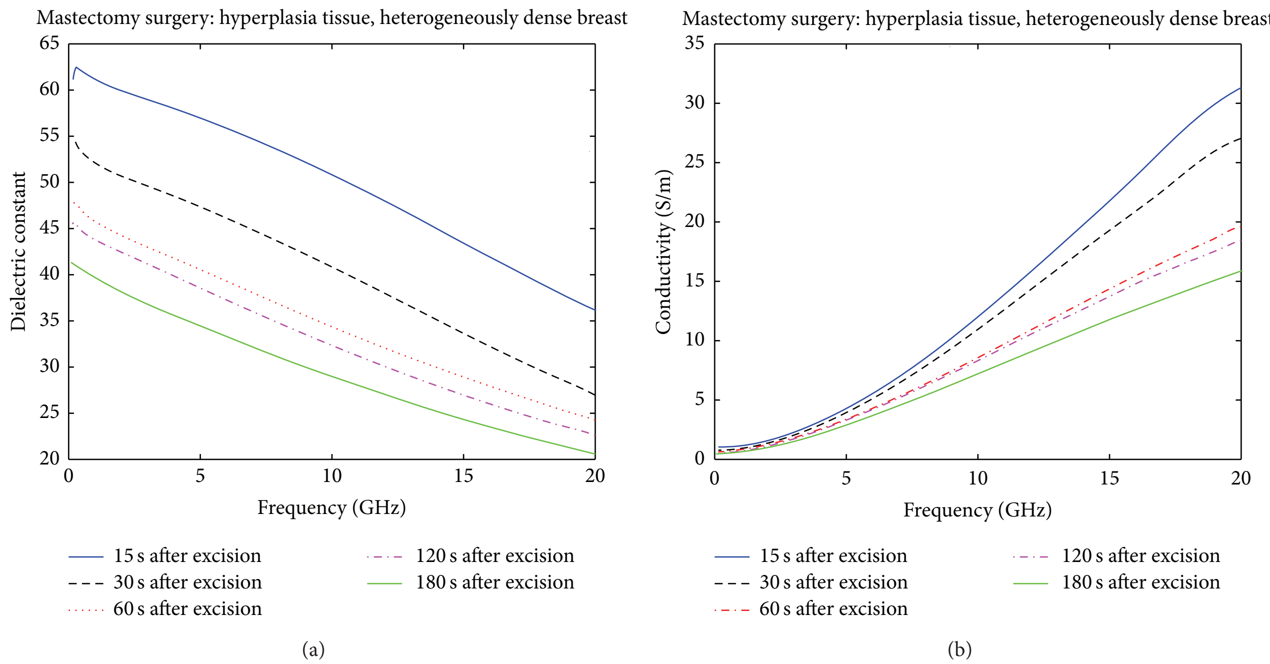


Figure 4: Dielectric properties for fibroglandular tissue from mastectomy surgery at different times after excision: (a) permittivity and (b) conductivity.

conductivity at different frequencies for different times after excision. Both parameters decreased with increasing time. This decrease may be due to changes in the physiological condition of the tissue, such as water content, blood content, and blood oxygenation. We only considered measurements between 15 and 180 seconds after excision. We did not see significant changes in dielectric properties after this time, which agreed with what has been reported by Lazebnik et al. [8, 9].

3. Conclusion

In this paper, we have shown that the physical characteristics that change almost immediately following surgical removal of tissue from the body may have significant impact on the dielectric properties of tissue samples. The primary results indicate that the dielectric properties strongly depend on tissue physiological state. These properties might also be related to other physiological conditions such as density, molecular constituents, ion concentration, mobility, blood oxygenation, blood vessel occlusion, and myocardial ischemia. MWI's accuracy strongly depends on the accuracy of information about tissues' dielectric properties. Considering the significant change we observed in tissue properties after excision, one should measure them *in vivo* [12]. Therefore, further investigation into measuring the *in vivo* dielectric properties is needed. Although the measurement of dielectric properties during the open surgery before tissue removal might be an option, but the effects of surgery on the tissue are unknown and likely variable, depending on the extent of tissue ischemia, if there was any content loss or cooling due to inserting the needle. Any changes in the specimen temperature and blood pressure can cause changes in the dielectric properties. In addition, the changes should be observed over time which is only possible with an implanted device from which continuous data could be obtained.

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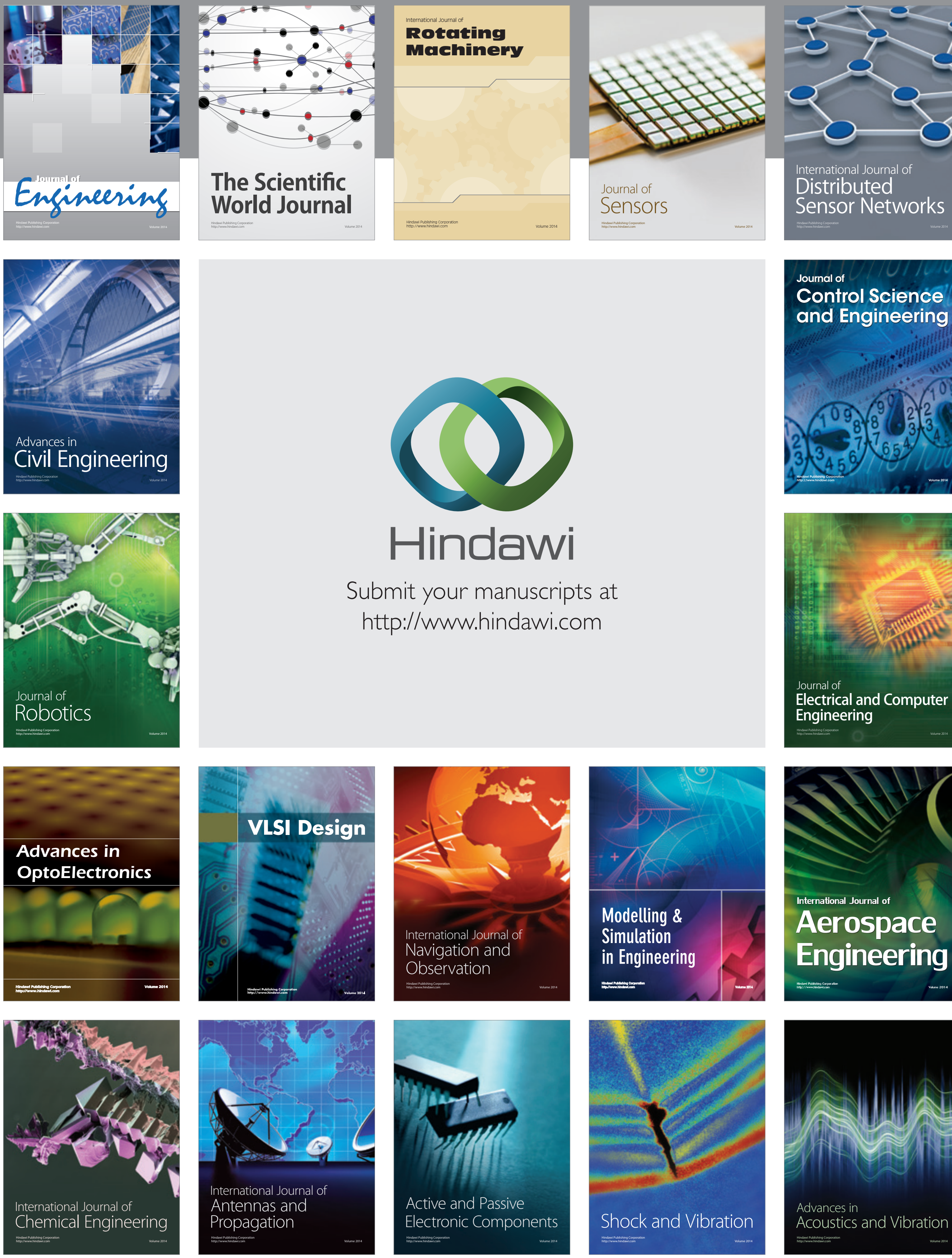

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