Dielectric Permittivity Estimation of Biological Tissues using Sensor Array Technology

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(Invited Paper)

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***Abstract* — Dielectric permittivity maps are created using a previously reported transmission measurement system, as well as a commercially available multi-sensor array. Comparison of the average properties and the property distribution in dielectric slabs and breast models indicate that increased accuracy and information about spatial distribution is obtained with the multi-sensor array.**

***Index Terms* — transmission measurements, microwave breast imaging**

I. Introduction

Electrical properties measurement of biological tissue over microwave frequencies is the object of great interest. In the case of breast tissues, correlation between electrical properties and density has been observed in vivo [1] suggesting the possibility of microwave measurement to predict breast density. Studies also show a large variation of electrical properties within the breast, while tumors show greatest permittivity and conductivity [2] which could potentially be detected by a microwave-based imaging technique.

At the University of Calgary we are working on microwave imaging and sensing systems dedicated to the breast [3]. One of our latest prototypes consists of two sensor arrays between which the breast is placed. Each array consists of 5 sensors as shown in Fig. 1 (left). This system measures the transmission from 1.5GHz to 10GHz between the two arrays for all available sensor pairs. Transmission data are then transformed in the time domain in order to use a time delay spectroscopy technique to create a two dimensional permittivity distribution map of the object under test. From this map the average permittivity value is calculated along with some statistical parameters.

In this contribution a commercially available dense sensor array (EMxpert) developed by EMSCAN Corp. (Calgary, Canada) is evaluated as a receiving array instead of our original sensor array. EMxpert consists of H-field (magnetic) probes spaced every 7.5 mm into an electronically switched array. The system operates from 150 kHz to 8 GHz.

II. Method

The transmission measurement system shown in Fig.1 can be modified in order to accommodate the EMxpert array (right) instead of the original lower array (left). This setup permits comparison between the original system and the one composed of the EMxpert in a very straight-forward manner. Measurement of a low loss dielectric slab and a simple breast model are done with both versions of the system. Comparison of permittivity distribution and average values is then performed.

The low loss dielectric slab consists of a 50mm thick Eccostock material (Emerson and Cuming Microwave Products) exhibiting a relative permittivity of $\varepsilon_r = 15$ (+/- 3%). The breast model is composed of a flexible skin membrane ($\varepsilon_r = 10$, $\sigma = 0.1$ S/m) with a cylindrical object mimicking glandular tissue ($\varepsilon_r = 30$, $\sigma = 4$ S/m) [4] placed inside the breast model. It has a diameter of 40mm and extends through almost the entire breast model length. This breast model can be filled with different liquids to represent surrounding tissues. In this instance the model is filled with canola oil ($\varepsilon_r = 2.5$, $\sigma = 0.04$ S/m). The breast model between the original array and the EMxpert can be observed in Fig. 1. A slight deformation is applied to insure proper contact with the sensors leading to a separation distance of about 70mm.

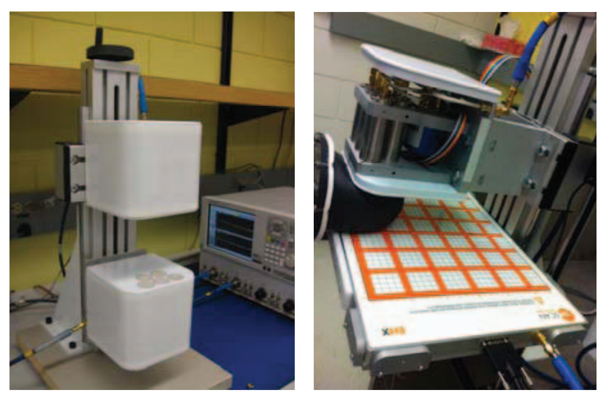

Fig. 1. View of the original system (left) and the modified version incorporating the EMxpert.

III. Result

The data collected are processed in the same manner for both systems as described in [5]. We first look at the permittivity measured with the dielectric slab in Fig. 3. We observe a slight increase in permittivity estimate from 15.5 to 16.5 with the EMxpert board, which is likely due to different

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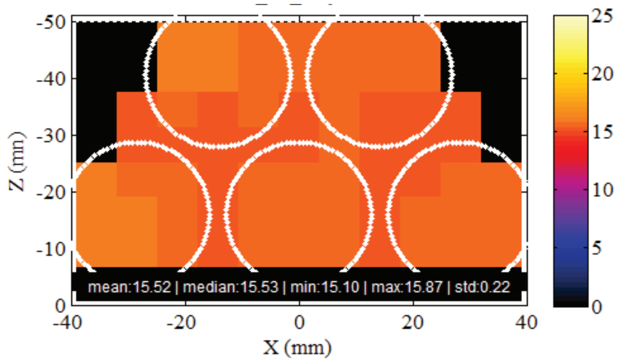
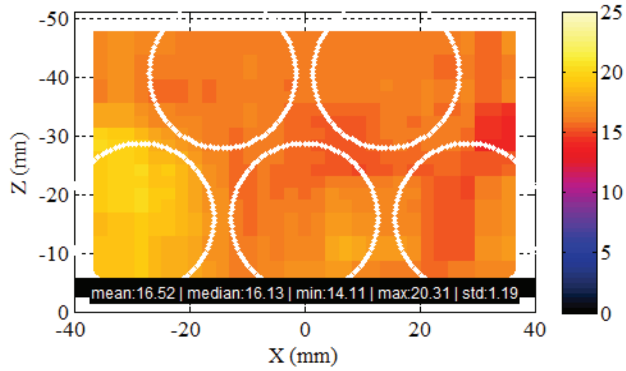
sensor loading when the object to be measured is present. We also note the increased variation in the permittivity distribution with a standard deviation increasing from 0.22 to 1.19.



(a)



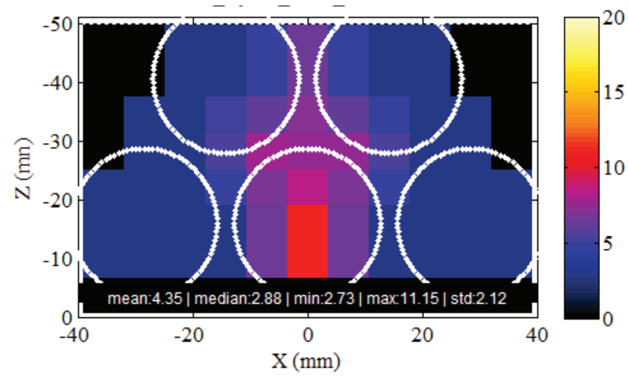
(b)

Fig. 2. Relative Permittivity Distribution and statistical data of the a dielectric slab (ε_r = 15) with the original system (a) and EMxpert board (b)

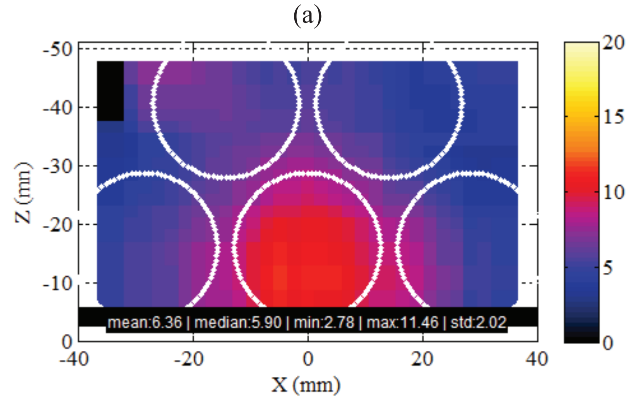
The images obtained using the breast model show improvements with the EMxpert (Fig. 3 (b)) compared to the original system (Fig. 3 (a)). In particular the diameter of the inclusion (40 mm) is better captured in Fig. 3 (b) however the tip of the inclusion is not clearly visible. It is also observed that a hot spot appears on the upper left corner when the EMxpert is used. The average permittivity value increases from 4.35 to 6.36 with the EMxpert, which is an improvement since the theoretical value is around 7.9. Because the minimum and maximum values are very similar for both systems, the average value increase is due to a better representation of the permittivity map.

IV. Conclusion

The EMxpert demonstrated its capability to sample signals over a surface with high density (7.5mm spacing) and over a wide frequency range up to 8 GHz. These signals enabled the calculation of more refined two dimensional dielectric distribution maps. Used on the inhomogeneous breast model the EMxpert was able to refine the outline of the dielectric inclusion placed in the breast model. A more accurate average permittivity value was also achieved with the EMxpert. These results are very encouraging and show the potential of this technology for microwave imaging. The EMxpert will be further tested in our current clinical study in order to compare images obtain from volunteers.



(a)



(b)

Fig. 3. Relative Permittivity Distribution and statistical data of the breast model with the original system (a) and EHX board (b)

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