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ESTIMATING DIELECTRIC PROPERTIES OF BIOLOGICAL TISSUE

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INTRODUCTION

Microwave imaging has been of interest in recent decades, offering the potential of an affordable and non-ionizing medical diagnostic modality. This technique is sensitive to changes in dielectric properties such as permittivity and conductivity. One approach is microwave radar imaging, which creates images by focusing signals caused by reflections at material interfaces. In order to improve the images from radar approaches, patient-specific dielectric property estimations have been used to determine the speed of wave travel within the tissue [1]. Estimating dielectric properties of biological tissue can also be useful in emerging quantitative applications including bone health assessment. Methods such as local rod probes and antenna measurements of planar samples have been developed to estimate dielectric properties, but are of limited use for *in vivo* measurements. We have previously developed methods of permittivity estimation with a custom antenna, however this approach requires two measurements at different separation distances and is unable to estimate conductivity. This study aims to improve on methods of estimating permittivity and to add an estimate of conductivity of *in vivo* biological tissue by incorporating an antenna calibration method.

METHODS

In order to remove the influence of the antennas on measurements, a previously developed calibration method [2] was adapted to be used with a custom ultra-wideband antenna system [3], allowing permittivity and conductivity to be estimated over a range of frequencies. The two antennas are characterized as 2x2 matrices at each frequency, determined from two calibration measurements: the first is performed with the antennas separated by an electrical conductor, and the second measurement is done with the antennas in direct contact with one another. Measurements were performed using a vector network analyzer (Agilent, PNA-L, N5230A), and take less than 15 seconds. Measurement samples were placed between the two antennas, with their surfaces in contact with the entire antenna aperture. Dielectric properties were then estimated using the magnitude and phase of the calibrated transmission data. To validate this method, dielectric properties of several liquids were estimated and compared to literature values.

RESULTS

A general agreement was seen between the estimated and literature dielectric properties of several liquids, particularly for high permittivity materials. The estimated and literature permittivity of distilled water is shown in Figure 1. Several biological tissues were then measured such as human calf and heel, and porcine bone excisions. Literature values for these properties are limited as they are often done using local probes which only measure the properties at the surface of a sample.

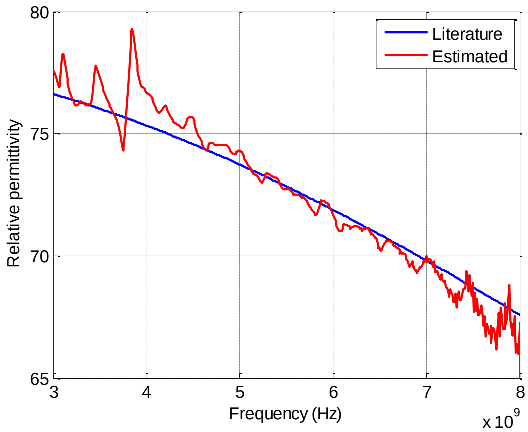

Figure 1: Estimated and literature values of relative permittivity as a function of frequency for distilled water.

DISCUSSION AND CONCLUSIONS

A calibration method has been adapted to enable an ultra-wideband antenna system to assess dielectric properties of *in vivo* tissue at microwave frequencies. The estimated properties of the tested liquids align closely to literature, providing confidence in estimates of biological tissues which have limited literature values. This technique can be used towards microwave radar signal speed estimates, and for quantitative property measurements. Future improvements could include a skin subtraction method to isolate the properties of bone or other tissue under the skin, and development towards microwave bone health assessment.

REFERENCES

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2. Bartley, PG and Begley, SB. *IMTC*. 372-375, 2005.
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