# Breast Permittivity Imaging

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**Introduction:** In ex-vivo studies, malignant breast tissue has been found to have higher permittivity and conductivity relative to surrounding healthy tissue[1], generating interest in non-invasive methods to image breast tissue electrical properties. While non-invasive electrical properties imaging using B1+ maps has been demonstrated in the brain for normal and pathological cases[2, 3], the method has not been extended to other anatomical parts, partly due to the lack of transmit/receive coils to acquire accurate B1+ maps. In this work, we investigate the feasibility of breast permittivity imaging using B1+ maps acquired from an eight channel phased array receiver.

$$\varepsilon_r(\mathbf{x}) = \frac{-1}{\omega^2 \mu \varepsilon_0} \left\{ \frac{\nabla^2 |B_1^+(\mathbf{x})|}{|B_1^+(\mathbf{x})|} \right\} \text{ -- (1)}$$
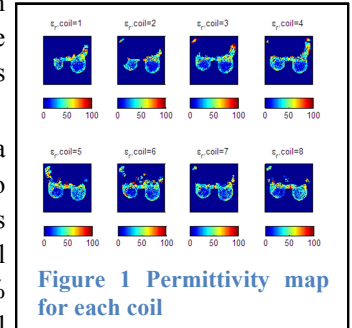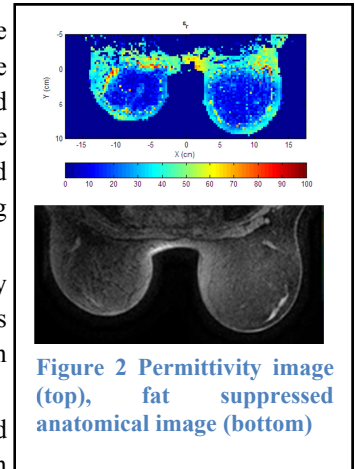


**Figure 1 Permittivity map for each coil**

**Methods:** Following informed consent, B1+ maps were acquired from a healthy volunteer using a breast imaging array in a 3.0T scanner (Discovery MR 750, GE, Waukesha, USA). A spin-echo based, Bloch-Siegert shift B1+ mapping sequence[4] (6ms Fermi pulses at +/- 4kHz off resonance) was used to acquire three axial plane data at 5mm slice thickness and 30mm gap. B1+ maps for each coil were calculated off-line, using Matlab (Mathworks, Natick, MA, USA) and masked (threshold 5% relative to peak value in positive off resonance intensity image) to eliminate regions with lower signal strength.

For each coil, the permittivity was calculated for the central axial plane, using B1+ data from the three axial planes. The Laplacian of B1+ was used in the calculation[5-7] as shown in equation (1). The Laplacian was calculated in several scales, permittivity accepted if in the range of 0 to 100, discarded otherwise. Missing points were then filled in with average values of neighboring points. Next, the intensity image (positive off resonance) of each coil was normalized by the root sum of squared reconstructed intensity image for the array. These intensity images were used as weights in combining the permittivity maps from each coil to compile a final permittivity image.



**Figure 2 Permittivity image (top), fat suppressed anatomical image (bottom)**

**Results:** The estimated B1+ maps for each coil are shown in Fig. 1. The final compiled permittivity image and a fat suppressed[8] anatomical image are shown in Fig. 2. The estimated permittivity values for left and right breasts, covering an area of 2.7mm x 2.7mm and centered on each breast are shown in Table 1.

**Discussion:** In previous work, electrical properties of the head, calculated from B1+ maps acquired from T/R head coils have been presented.[2, 3] However, breast imaging is carried out with transmission from body coil and reception from phased array breast coil. The B1+ homogeneity of body coil can be less than a local transmit coil, but the phased array receive coils can be used to generate multiple B1+ maps of the same region, leading to combination methods to optimize final estimate. We have used the intensity of positive off-resonance images as weights in the combining step.

The B1+ maps from each coil, after 5% threshold masking, still covered a significant region due to coil coupling. As a result, permittivity images from each coil covered significant regions of FOV (Fig. 1). The final permittivity image showed mostly lower permittivity values (Table 1). The results are consistent with reported permittivity for normal, adipose breast tissue.[1, 9, 10]

|  | Permittivity (mean) |
|---|---|
| Left breast | 12.2 |
| Right breast | 14.4 |

**Table 1 Breast permittivity**

Localized regions showed higher permittivity and these regions correlated with brighter regions in fat suppressed image, identifying water content. As water permittivity is much higher (72 – 80), the overall permittivity image is consistent with expected values from literature as well as fat suppressed anatomical image.

**References:** [1]Chaudhary, et al.,Indian Journal of Biochem. and Biophys.,1984, [2]Voigt, et al.,Magn Reson Med,2011, [3]Van Lier, et al.,ISMRM,2011 [4]Sacolick, et al.,Magn Reson Med,2010, [5]Wen,Proc. of SPIE,2003, [6]Bulumulla, et al.,ISMRM,2009, [7]Cloos, et al.,ISMRM,2009 [8]Dixon,Radiology,1984, [9]Surowiec, et al.,Biomed. Eng., IEEE Transactions on,1988, [10]Joines, et al.,Medical Physics,1994