Magnetic Resonance Electrical Impedance Mammography (MREIM)

A new approach to breast cancer imaging

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What do we propose?

- Combination of magnetic resonance and electrical impedance for breast imaging
  - Combination of magnetic differences with electrical conductivity differences between normal and malignant breast tissue

Why this combination?

- All in the effort to increase specificity which is low to moderate in standard breast MRI and thus avoid false positive detections and negative biopsies
- All in the effort of developing a more sensitive and specific tool than mammography for breast cancer screening and diagnosis without any unwanted effects
- All in the effort of a highly sensitive and specific technique without the challenges of image reconstruction and patient risk (MREIT or Tomosynthesis)

MREIM in a nutshell

- Current is supplied to electrodes embedded within breast coil stabilization paddles during MR image acquisition
- Current creates magnetic field that interferes with the normal MR image acquisition mainly in areas of higher conductivity (malignant tissue)
- Subtraction of images obtained with current on and off will produce a signature of malignancy

Can it deliver?

- Theory
- Experiment
- Simulation

Theory

- Malignant breast tissue has higher electrical conductivity (3-40 times) than normal and benign breast tissue
- Current creates magnetic field that interferes with the normal MR field
  - Interference effect is particularly enhanced in areas of higher conductivity such as breast malignant tissues
- The subtraction of the images obtained with current on and off is likely to have a specific "signature" related to malignancy
- Mathematically … it works out!

THEORY: MREIM Effects

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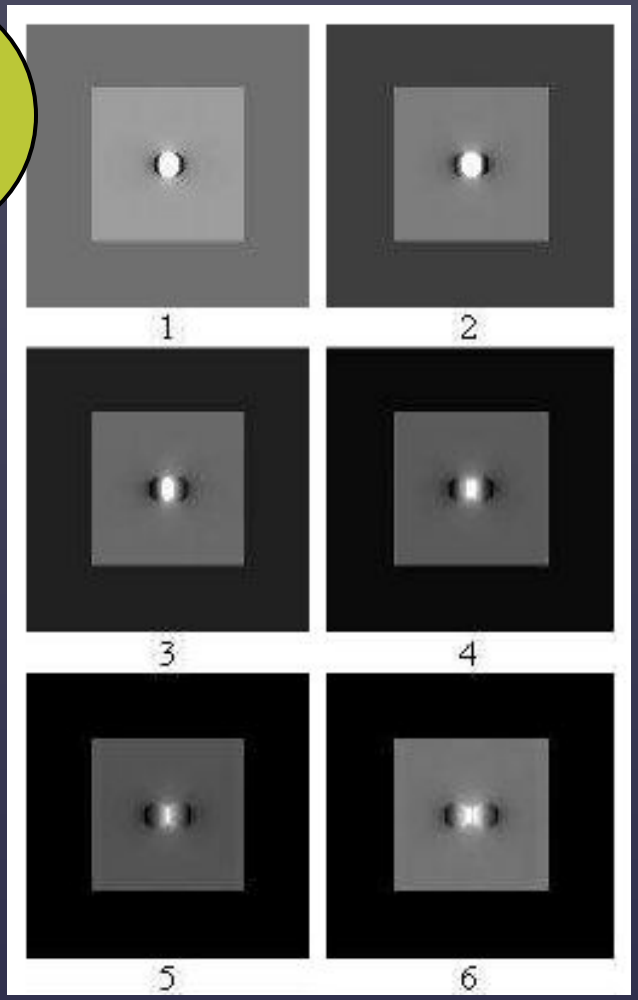

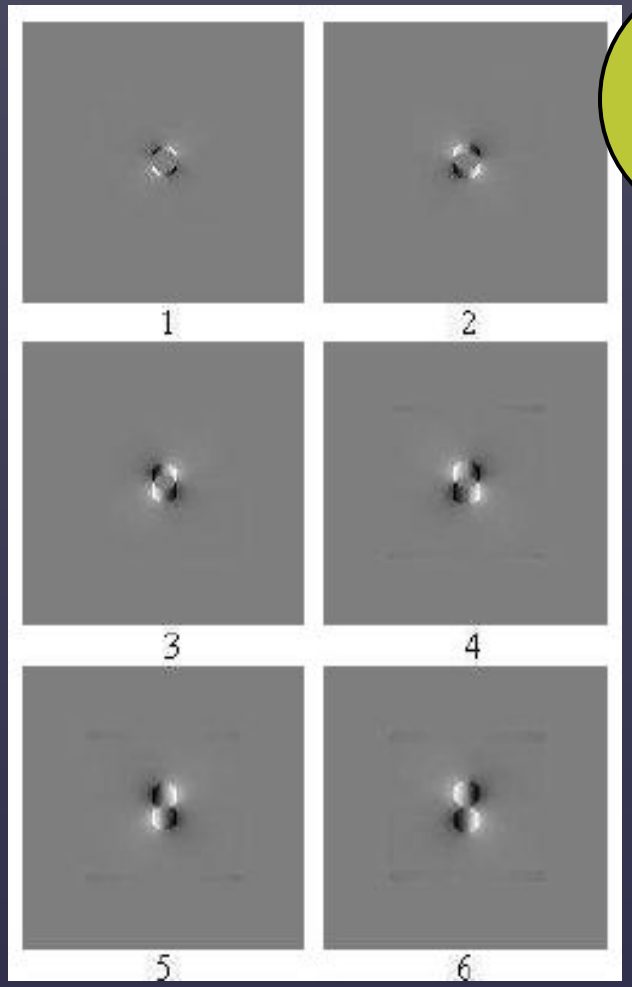

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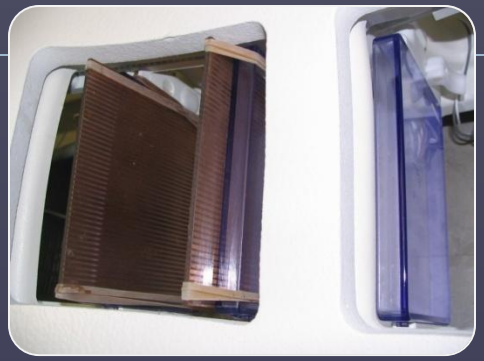
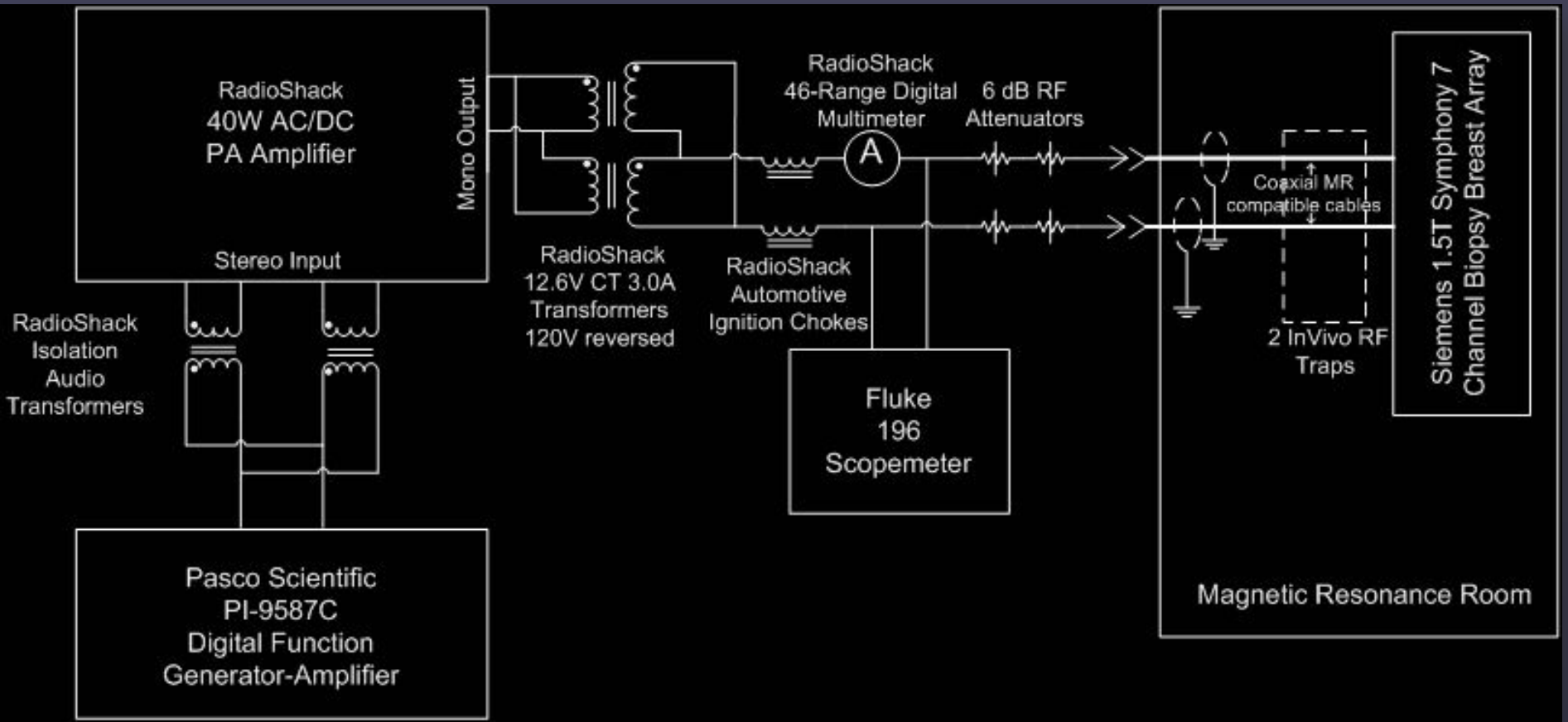
Experiment

- Breast Phantom
- Faraday Shields
- Phantom-Faraday Shields Coupling
- Circuitry
- Sequence for Phantom Imaging

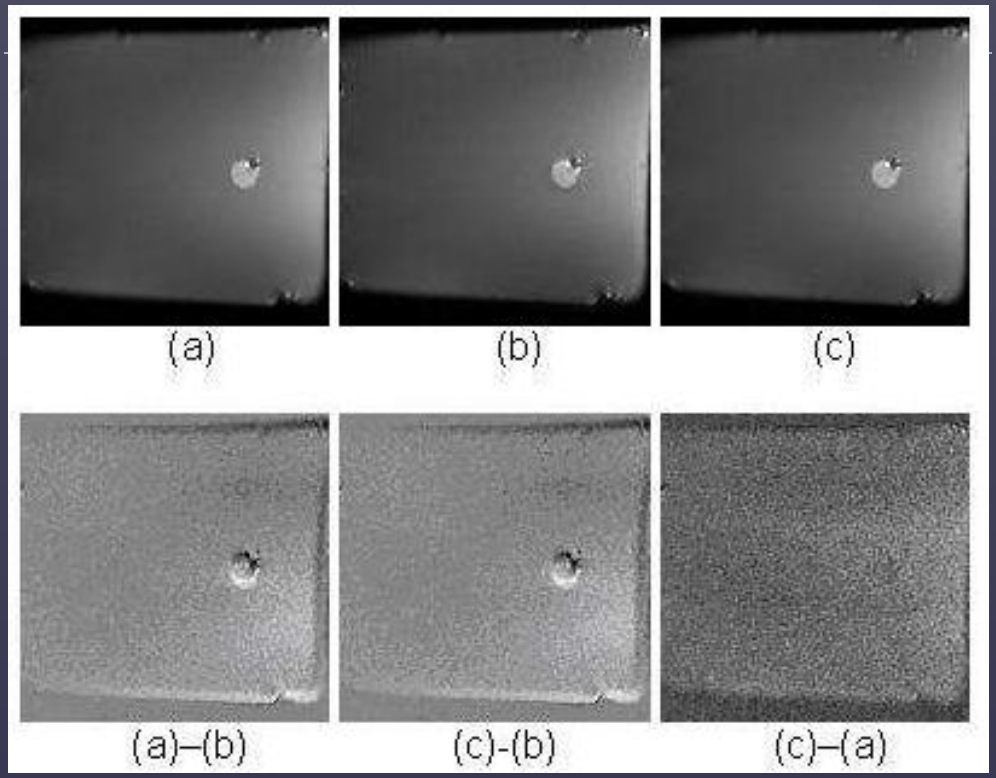
MREIM Apparatus & Circuitry





Experimental Result



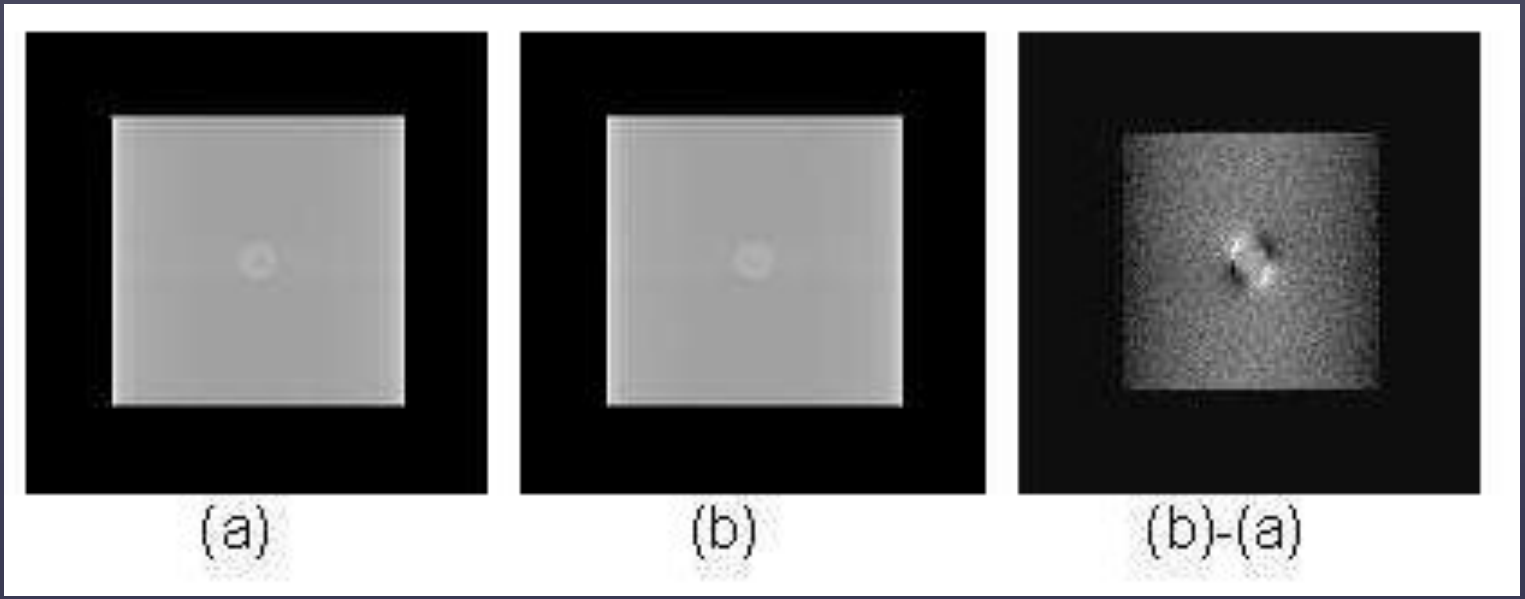
Images (sagittal view) of phantom with tumor surrogate acquired with a spin density spin echo sequence with *TE=50 ms, TR=2 s, NEX=1, slice thickness=4mm,* FOV=128 mm, *dx*=1 mm and *df =60 Hz/pix*

(a) Current off, (b) Current on ($i = 10\ A/m^2$ at $f = 300\ Hz$), (c) Current off.

Simulation

- Replicate and explain experimental results
- Determine MREIM effect for various tumor models
- Optimize MREIM sequence for well-defined differential signal at low applied currents
  - Used MR spin-echo sequence
    - Frequency encode effect
      - Detects the tumor bed
    - Phase encode effect
      - Detects boundaries where conductivity changes

Simulation Result



(a) Current off

(b) Current on ($i = 10\ A/m^2$ at $f = 300.008$ Hz, $df = 60$ Hz/pix and , $STD_{noise} = 2$)

(b)-(a) Subtraction image of current on and current off

Where we are

- Theory and simulation agree
- Theory, simulation, and experiment agree
- Proof of concept demonstrated

Next Step

- Develop modality specific phantom with stable electrical and physical properties
- Optimize MREIM sequence through phantom experiments
- Construct MR compatible, comfortable, and patient safe clinical system
- Clinical trial

Breaking News

- AB Miller, C Wall, CJ Baines, P Sun, T To, and SA Narod (BMJ 2014;348-g366)
  - 25-year follow up of mammography-based screening
    - "… education, early diagnosis, and excellent clinical care should continue to be provided to women to ensure that as many breast tumours as possible are diagnosed at or less than 2 cm."
    - " … the value of mammography screening should be reassessed."

Thank you

- And … special thanks to Nataliya Kovalchuk, who did most of the pilot experiments during her PhD work at University of South Florida and Moffitt Cancer Center & Research Institute