EX-SITU ENDORECTAL PROBE FOR PROSTATE IMAGING

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Abstract

NMR and its descendant MRI are usually pursued in a setup based on a highly homogenous static magnetic field, *B*0, with variance < 1 ppm, creating nuclear spin precession at a corresponding narrow band of frequencies. This requirement is one of the main reasons why clinical MRI systems often employ large magnet and corresponding large radio frequency (RF) and gradient coils, leading to their relatively high complexity and cost. However, if one is interested only in a specific small region within the body, it could be highly advantageous to obtain NMR information by using either a non-invasive hand-held probe or an intra-cavity self-contained (magnet +RF and gradient coils) NMR probe, thus avoiding the requirement for a large external magnet. Such an approach for NMR measurement or NMR imaging without a sample-surrounding magnet is termed "inside-out", or *ex-situ* NMR. Here we present a bench prototype of a new ex-situ MRI probe aimed at the imaging of the prostate. The probe is designed for endorectal operation, combined with a provision for an ultrasound module which would direct the probe to the exact prostate region. The 60 mm high, 30 mm diameter probe demonstrated a relatively large field of view of ~ 50×50×20 mm, which is far beyond what was demonstrated to-date in the context of ex-situ MRI (scaled to the size of the probe). This capability was achieved by a unique magnet, RF coils and gradient coils design, along with sophisticated imaging and image correction algorithms. The clinical version of this probe prototype would be able to direct the physician during biopsy procedure, which is based today on "random biopsy" procedure, to specific suspicious areas. This should reduce the number of false negative biopsy readings and the number of unnecessary repetitions of the biopsy procedure.

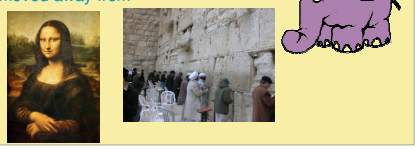
The general problem

Not all samples can be measured by conventional NMR/MRI systems

Large samples (cannot be placed inside the bore of the magnet)

Fixed samples (cannot be moved away from their natural environment)

Rare samples (cannot be dissected)



A general solution

Obtaining NMR and MRI information by using either a non-invasive surface- or an intra-cavity self-contained (magnet +RF coil) probe, where the sample is outside the magnet → **ex-situ NMR**

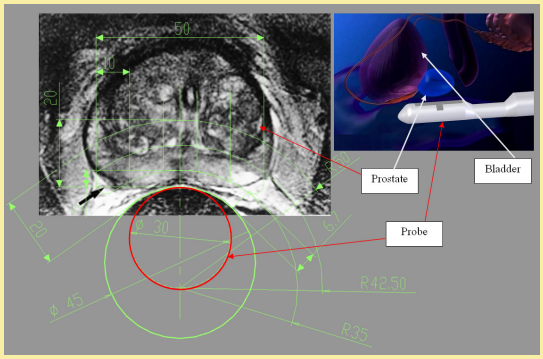
Additional benefit – simpler, mobile and more affordable systems

Our specific problem

Providing low resolution MRI of the prostate gland for needle biopsy targeting and possibly cancer staging.

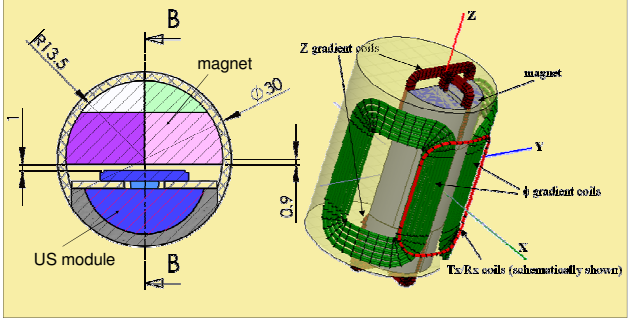
Suggested solution

A unique endorectal self contained MRI probe with relatively large field of view compared to its size and 3D low resolution imaging capability



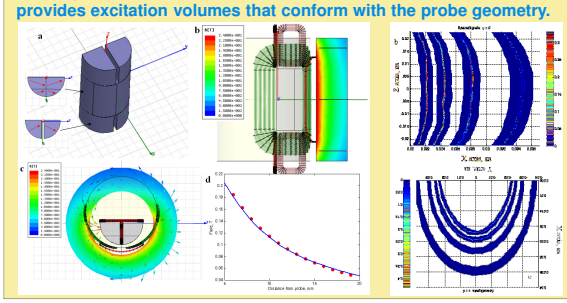
Probe description

- Dual US/MRI probe
- Length of 60 mm, diameter of 30 mm
- Field of view of ~20×50×50 mm
- Relatively low resolution of ~0.2-1 cc



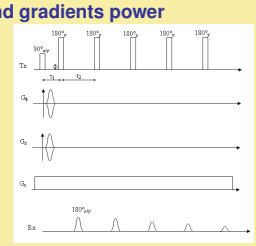
Static magnetic field and excitation volumes

Large filed of view with respect to the magnet leads to very distorted equi. B_0 lines → Unique magnet design along with an appropriate Tx coil provides excitation volumes that conform with the probe geometry.



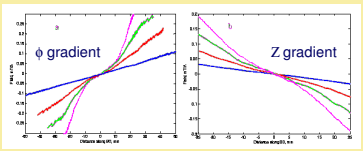
Imaging sequence and gradients power

- **Two phase gradients (ϕ and Z) and one constant static gradient**
- **Large static gradient results in:**
  - ✓ **Short echo duration (typically τ_2~30-50 μs)**
  - ✓ **Short phase encoding gradient pulses**
- **Single intense gradient pulse per echo train – low average power (50 A peak current)**



Gradients non-uniformity

The curved probe geometry leads to unavoidable large non-uniformities in the ϕ and Z- phase gradients → mathematical image correction



Representative imaging results

Imaging setup | **Image with no gradients non-linearity correction** | **Image with gradients non-linearity correction**