EPR
Instrumentation and Methodology

Boris Epel
Commercial instrumentation

EPR Imaging E 540

L-Band
The L-band imaging system comprises a dedicated magnet equipped with 3D planar gradients. Various probes are available for specific applications. An intuitive graphical user interface is provided by Xepr, the data acquisition and processing program.

(1.1 GHz / 40 mT)
Commercial instrumentation

O2M Technologies

• JIVA-25
• Commercial 25 mT small animal pulse EPR oxygen imager
• Full body mice, small rats
• Built-in acquisition and reconstruction protocols
• Registration tools ready for multi modality imaging research
EPR instrumentation

Power sources

RF electronics

Resonators

Magnets, gradient systems

Computer control

Methodology

Software
Magnets and gradients
4-coil magnet design

Sample position

$B_0$
Gradient coils

X-gradient

Y-gradient

Z-gradient

Sample position
Solenoidal magnet

Designed by Philips for EPR/DNP-MRI
## 25 mT Magnet (720 MHz)

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational field</td>
<td>25(±1) mT</td>
</tr>
<tr>
<td>Operational frequency</td>
<td>700 MHz</td>
</tr>
<tr>
<td>Free gap</td>
<td>15 cm</td>
</tr>
<tr>
<td>Homogeneity for Ø50mm</td>
<td>20ppm</td>
</tr>
<tr>
<td>Homogeneity for Ø80mm</td>
<td>100ppm</td>
</tr>
<tr>
<td>Maximum field gradient</td>
<td>155 mT/m</td>
</tr>
<tr>
<td>Dimension</td>
<td>40cm x 40cm x 30.6cm</td>
</tr>
<tr>
<td>Weight</td>
<td>150 kg</td>
</tr>
</tbody>
</table>
25 mT Permanent Magnet

Advantages

- Small footprint
- No power supply
- No heat dissipation issues

Disadvantages

- Needs additional field offset coil
- Temperature drift
- Lower field homogeneity

<table>
<thead>
<tr>
<th>Magnetic Field (23 C)</th>
<th>25.5 mT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum gradient</td>
<td>30 mT/m</td>
</tr>
<tr>
<td>Field inhomogeneity, 25mm DSV</td>
<td>&lt; 40 ppm</td>
</tr>
</tbody>
</table>
Radiofrequency electronics
Operational frequency

Signal to noise ratio grows with imager frequency.

However, biological samples contain large proportion of water, which is highly dielectric. This results in
(i) ‘non-resonant’ absorption of energy (sample heating) and
(ii) poor penetration of samples.
These get worse with frequency

What is the optimum frequency? - depends on sample size

<table>
<thead>
<tr>
<th>Frequency</th>
<th>~250 MHz</th>
<th>~750 MHz</th>
<th>1-2 GHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penetration</td>
<td>&gt; 10 cm</td>
<td>6-8 cm</td>
<td>1-1.5 cm</td>
</tr>
<tr>
<td>Object</td>
<td>Mouse, rat, rabbit</td>
<td>Mouse, full body</td>
<td>Mouse part</td>
</tr>
</tbody>
</table>

~10mT ~25mT
Imaging - static gradients

Application:
in vivo

Low frequencies (<1 GHz)
Large objects

Continuous wave methodologies

Field modulation, first harmonic detection

Rapid Scan with direct detection

Spin Echo Imaging

Single Point Imaging

Pulse methodologies

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Continuous wave EPR

Field modulation

Resonator

Field

RF source

Bridge

Locking amplifier

Signal

\[ v = 9388.2 \text{ MHz} \]

Magnetic Field Strength (G)

Absorbance

First Derivative

\[ S(B) \]
Pulse EPR

Field
RF source
Mod
Bridge
Resonator
Software (FT)
S(B)

Pulse bandwidth

\( B_0 \)
\( B \)

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AWG - Design EPR sequences with the extended bandwidth

Improve image uniformity by implementing resonator and image bandwidth compensation

Comparison of the bandwidths of the square and 3-lobe sinc pulses
Acquisition Schemes

“Digital”

Arbitrary waveform generator

PA

LN A

Digitizer

Software

“Analog”

Arbitrary waveform generator

PA

LN A

Digitizer
On our request TOMCO reduced pre-gating from 1.2 µs to 0.25 µs

This increased the duty cycle ~5 times and allowed us to collect data more efficiently
Resonators
Loop-Gap resonator
Resonators: Alderman-Grant bimodal resonator

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excitation

detection

EPROI
Surface coil for mammary gland imaging

1 cm diameter surface coil

Last problem to solve before using it as a standard coil: image registration
Bimodal Cross-Wire Resonator

- Pulse EPR image
Software
SpecMan4EPR ver. 2.5

- Support for multiple AWGs
- Elaborated AWG interface
- Number of pattern parameters is reduced without compromising of the flexibility
- Easy switching between pulse patterns. Secant pulses are added to the internal library
- Software mixer implementation
Image reconstruction

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http://epr-it.specman4epr.com/
Acknowledgements

http://epri.uchicago.edu

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