

Parallel Transmission transmit field shimming at 7 Tesla with Deep Learning

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Background

Nuclear Magnetic Resonance - simplified step-by-step intro:

1. Use of a strong, static magnetic field (\vec{B}_0) to align magnetic moment of protons ("spins")
2. Excite the spins with an EM-wave ("RF pulse") with a specific frequency $f = \gamma |\vec{B}_0|$
 - Spins precess about (\vec{B}_0)
 - Precession gives rise to a measurable signal

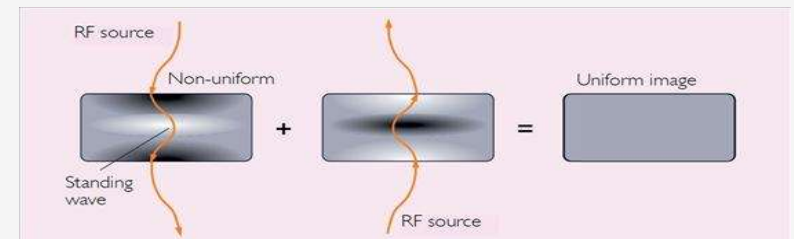
This is the part my project is concerned with

In short, we want **contrast** (i.e. difference in signal) **of our images to be reflected by the density of spins, rather than how well we manage to excite them.**

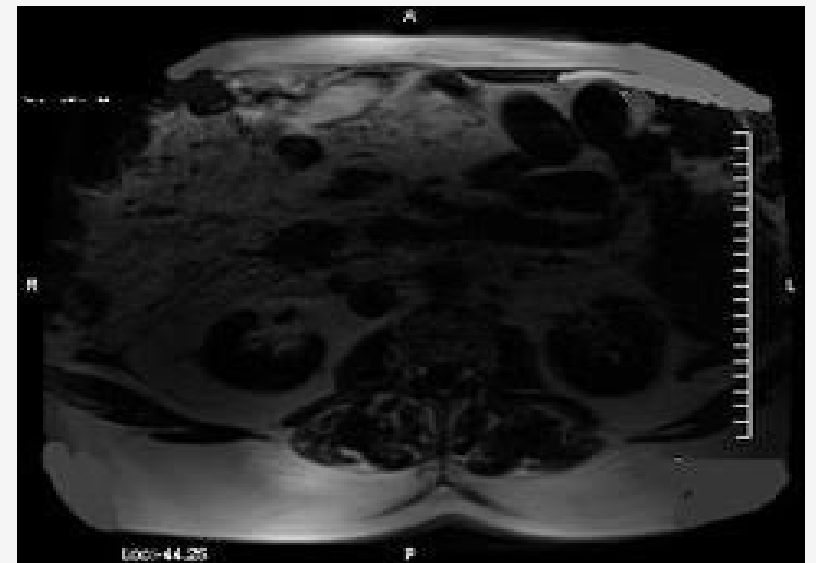
- This is difficult at $|\vec{B}_0| \geq 7$ T
 - **Solution:** Transmitting RF-pulses in parallel (Parallel Transmission, **PTx**)
 - Achieved by several **independent** transmission channels
 - **Independency** – different waveforms on each channel
 - Full spatial and temporal control of each channel

Why is this difficult?

- Dimensions of human head $\sim 15 \times 20 \times 24 \text{ cm}^3$
- Wavelength of RF pulse in tissue at 7T $\sim 12 \text{ cm}$
 - We can fit more than half a wavelength across e.g. the human head
 - Interference effects become prominent (e.g. standing waves, see fig)
 - **Shading artifacts**



Courtesy Philips Medical Systems



<https://radiopaedia.org/articles/shading-artifact-1>

Summary

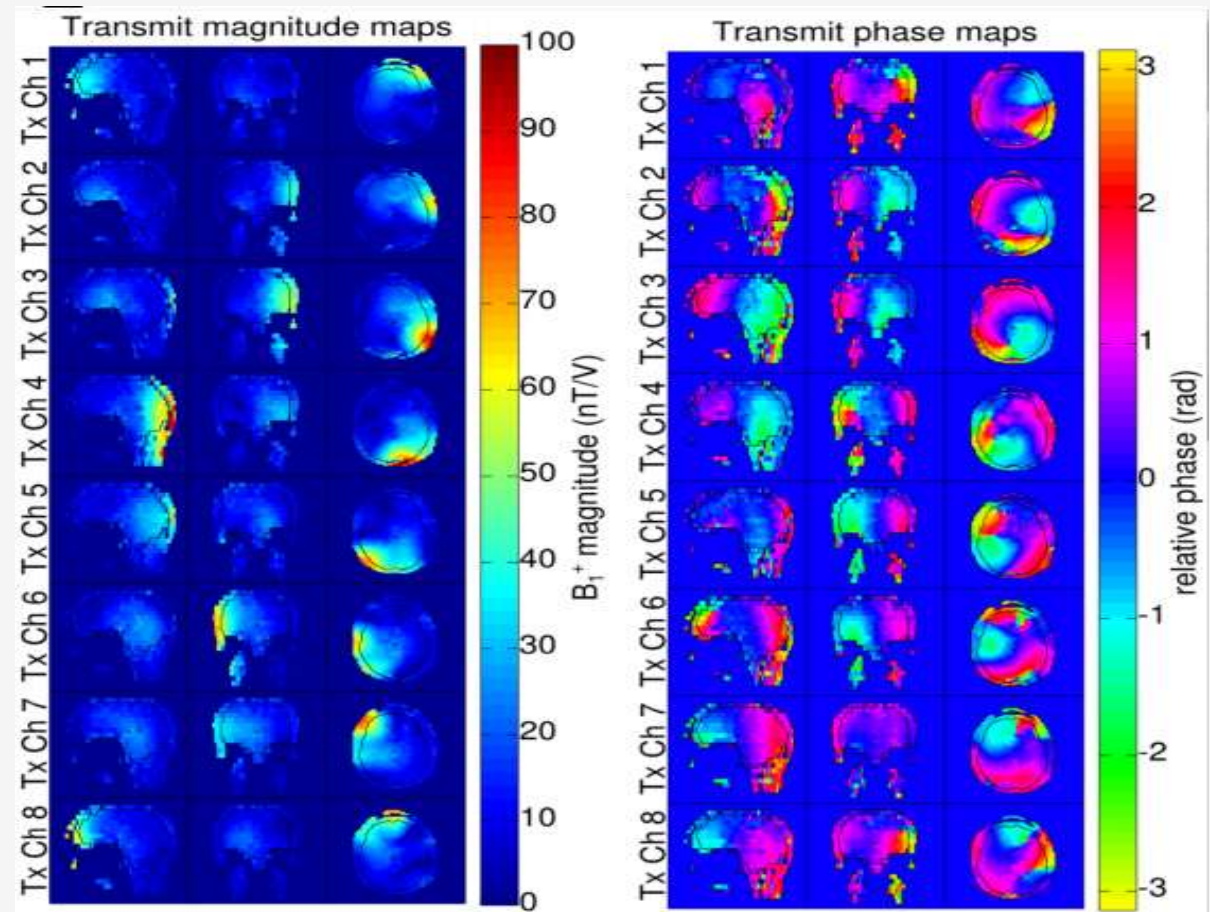
NMR-active component of the \mathbf{B} -field of RF-pulse:

$$B_1^+(\mathbf{r}, t) = \sum_{j=1}^{N_T} B_{1,j}^+(\mathbf{r}, t)$$

- **Static** PTx: “ B_1^+ -shimming / transmit field shimming”

$$B_1^+(\mathbf{r}, t) = p(t) \sum_{j=1}^{N_T} w_j s_j(\mathbf{r})$$

- **Goal:** Make $|B_1^+(\mathbf{r}, t)|$ as homogenous as possible by deciding the optimal w_j 's
- **Methods:**
 - Usually done by a (slow) method of optimization
 - Want to see how well a Deep Neural Network (faster) will do



Courtesy of Desmond H. Tse