Solving Dipole Inversion problem of Quantitative Susceptibility Mapping (QSM)

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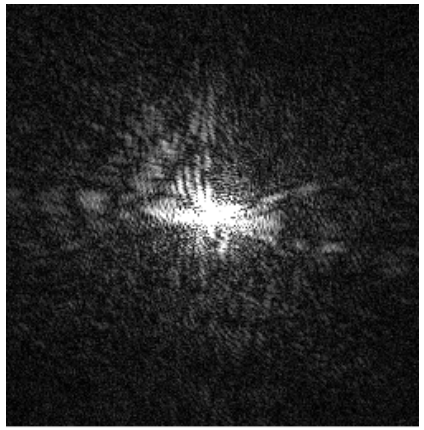
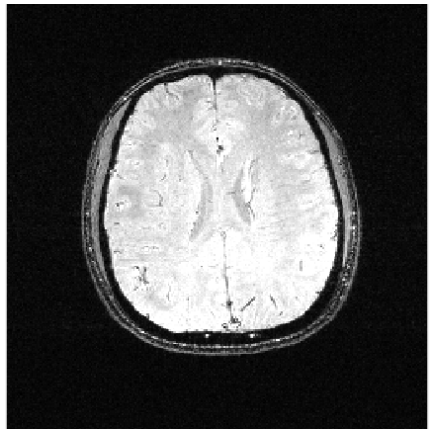
Fundamentals of MRI image

- MRI obtains data in the form of k-space
- Generally, magnitude image is interested.
- In recent, many researches using phase information have been going on.

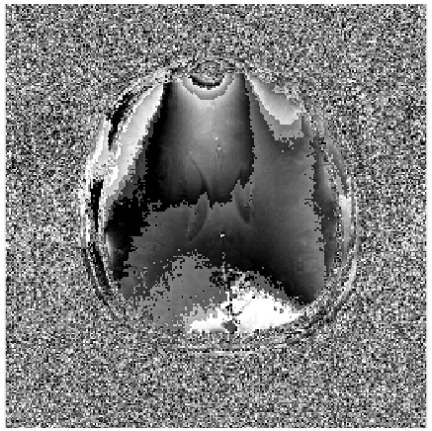


K-Space

Fourier Transform



Magnitude



Phase

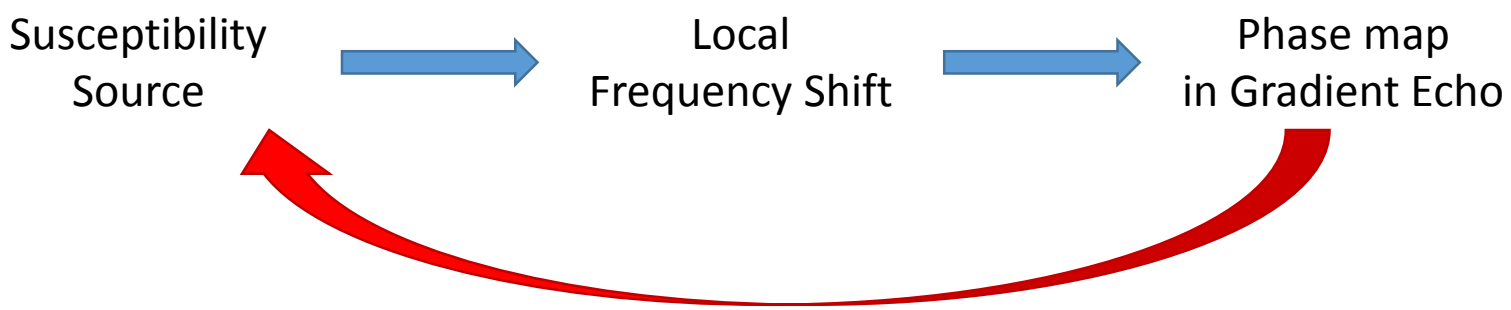
Phase Contrast : MR Susceptometry

- **(Signal Acquisition)**
  Frequency shift induce accumulation of **MR phase**

$$\Delta\phi = -\gamma * \Delta B * TE$$

- **(Signal Formation)**
  Local frequency shift within tissue is affected by **magnetic susceptibility**.

$$\Delta B = \frac{1}{6} * 4\pi * \Delta\chi * (3\cos^2\theta - 1)B_0$$



Magnetic Susceptibility (χ)

- χ : Physical quantity which a material is magnetized by an applied magnetic field.

Table 1
Susceptibility values of different structures in the brain model.

Structure	Susceptibility in ppm	Structure	Susceptibility in ppm
White matter	0	Veins	0.45
Gray matter	0.02	Red Nucleus	0.13
Globus Pallidus	0.18	Substantia Nigra	0.16
Putamen	0.09	Thalamus	0.01
Caudate Nucleus	0.06	Cerebrospinal Fluid	−0.014

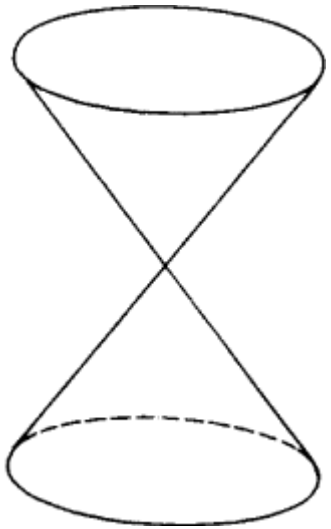
- Can be applied on estimation of
  - Myelination
  - Iron deposition
  - Calcification
  - Oxygenation level estimation

Quantitative Susceptibility Mapping (QSM)

- Susceptibility source forms **convolutive dipole field** in magnetic field.
- It can be directly estimated from k-space of phase map.

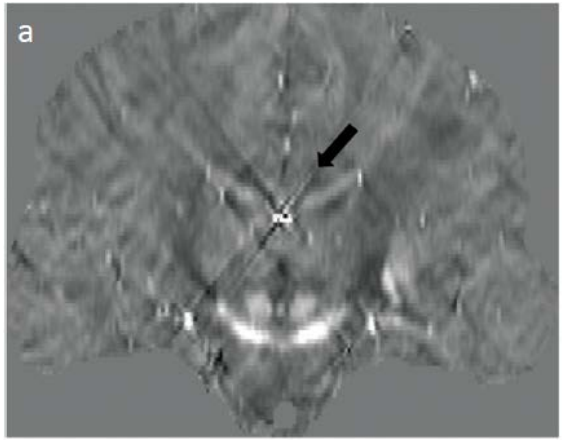
$$f(\hat{k}) = \gamma B_0 \left(\frac{1}{3} - \frac{k_z^2}{k^2}\right) \chi(\hat{k})$$

$$\rightarrow \chi(\hat{k}) = D^{-1} f(\hat{k})$$



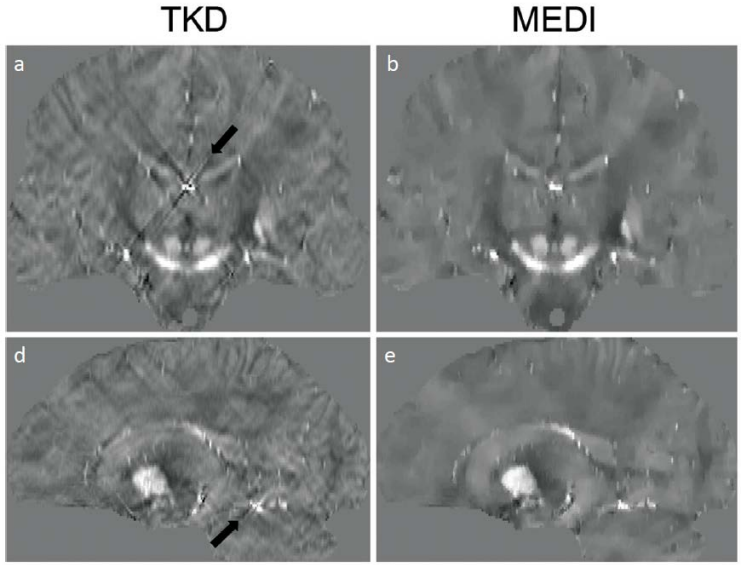
- We call this process, '**Dipole Inversion**'
- However, **dipole kernel has zero surface** near magic angle. Causing streaking artifact.

-> Several optimization approach has suggested.
(TKD , iLSQR, MEDI, MUDICK, etc…)



Proposed Scheme

- Current methods has some limitations
  - From regularization, image can be over-smoothing.
    -> Small veins are not shown clearly.
  - Under estimation of susceptibility content



1) Instead of MEDI, use additional information for sparsity term in optimization
   : T2* map, venogram
2) Use advanced technique for optimization
   : Compressed Sensing, ALOHA

Thank you