Diffusion imaging is typically performed using diffusion weighted spin-echo EPI images. These images will be very sensitive to non-zero off-resonance fields. Such fields will be caused by the susceptibility distribution of the subjects head (known as a susceptibility-induced off-resonance field) and by eddy currents (EC) from the rapid switching of the diffusion weighting gradients (known as an eddy current-induced off-resonance field). In addition to that a diffusion protocol can be quite long, making it almost inevitable that the subject will move.

1/1

The susceptibility induced field will be (to a first approximation) constant for all the acquired images, which means that the set of images will be internally consistent. It is a problem mainly because it will cause a geometric mismatch between the structural images (which are typically unaffected by distortions) and the diffusion image. topup is a tool for estimating the susceptibility induced field. In order to estimate and correct also for EC-induced distortions one will either need to run a tool like e.g. eddy_correct prior to running applytopup. Or one can feed the output from topup into the eddy tool.

The method that topup uses to find the susceptibility off-resonance field is to use two, or more, acquisitions where the acquisition parameters are different so that the mapping field \rightarrow distortions are different. A typical example of this is two acquisitions with opposing polarities of the phase-encode blips which means that the same field leads to distortion going in opposing directions in the two acquisitions.

Given the two images and knowledge of the acquisition parameters topup will then attempt to estimate the field by finding the field that when applied to the two volumes will maximise the similarity of the unwarped volumes. The similarity is gauged by the sum-of-squared differences between the unwarped images. This measure allows us to use Gauss-Newton for jointly finding the field and any movement that may have occurred between the two acquisitions.

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