Functional BOLD MRI (fMRI) sequence settings

In this article, we will review the settings of fMRI BOLD acquisition. Gradient Echo (GE) Echo Planer Imaging (EPI) single shot sequence is mainly used for fMRI BOLD acquisition by the PBS researchers. We have also installed the same sequence, but highly customizable WIP by CMRR also. Thus, we have the generic Siemens' version and the versatile CMRR version of the same sequence. With CMRR BOLD sequence, we can also acquire multi-echo fMRI data which can be preprocessed with TEDANA or fMRIprep. The CMRR sequence is also capable of acquiring fMRI blip-up blip-down data that can be used for distortion correction in which AFNI has a built-in algorithm to process such data. How to choose the parameters for these options will be mentioned below.

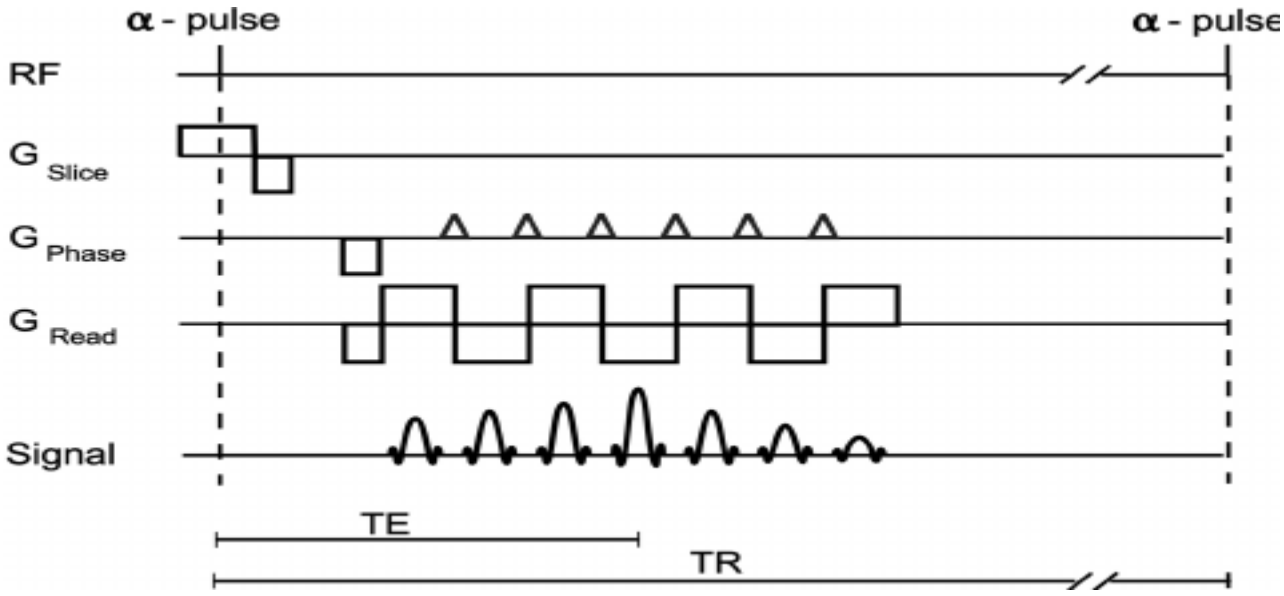


Figure 1: GE-EPI single shot (SS) sequence diagram

The GE-EPI-SS sequence is ultra-fast and can acquire the whole brain within one repetition time (TR). We will lay out some important parameters of the sequence and show how someone would see it on the sequence card at the console computer.

Number of slices and FOV

In general, field of view (FOV) and number of slices are chosen to cover the interested region of the brain. Researchers usually acquire the whole brain. The number of slices depends on the slice thickness and the slice gap (if any) to cover the interested region. In the case of simultaneous slice acquisition, the number of slices must be divisible to an integer by the multi-band acceleration factor (MB or SMA).

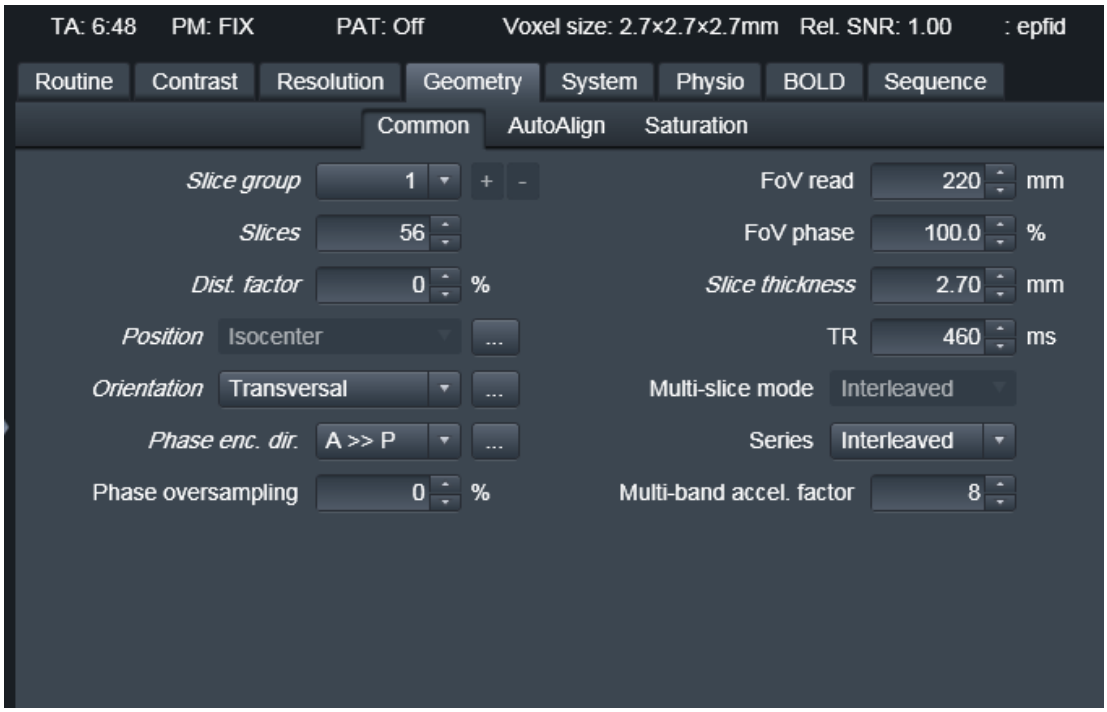


Figure 2: Geometry – slices, slice gap (Dist. factor), slice thickness, FOV

Echo time (TE) and Repetition Time (TR)

Echo Time ranges between 30ms to 35ms for BOLD scans of the whole brain. Value of TR depends on how many slices the researcher needs to acquire as well as simultaneous multiband factor (SMA/MB). The MB factor is equal to how many slices the sequence acquires simultaneously after one composite RF pulse.

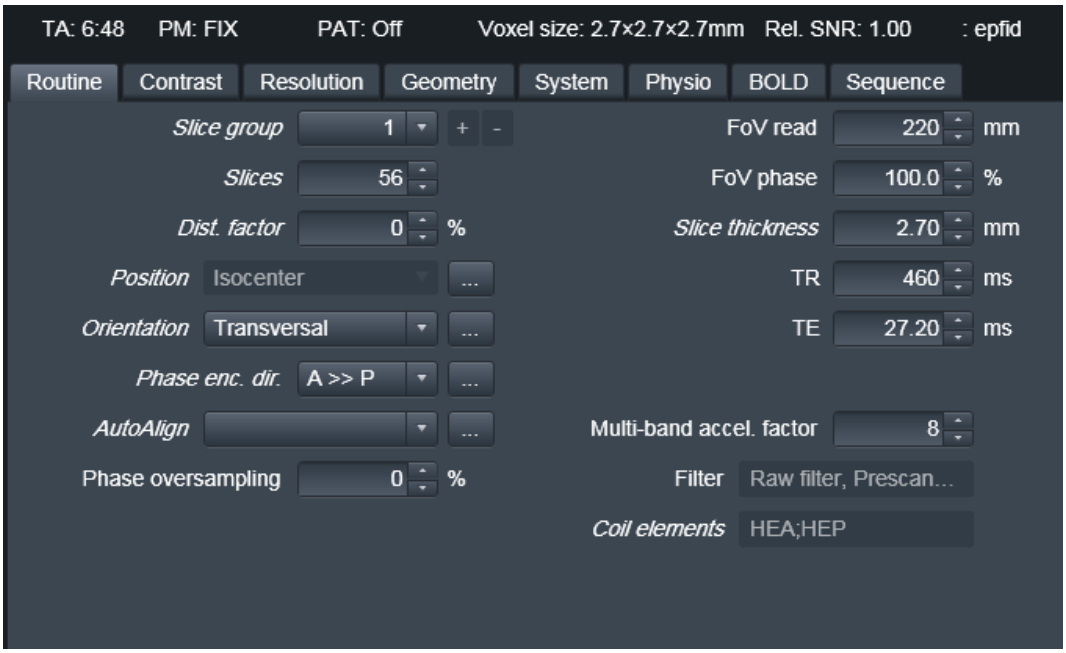


Figure 3: Echo Time (TE), Repetition Time (TR)

Phase Encoding Direction (PE)

We apply phase encoding direction along Anterior-Posterior (AP) or Posterior-Anterior (PA) directions of the head. Left-Right direction is prone to induce more artifacts and signal drops due to high variations magnetic field susceptibility gradients around temporal regions.

Flip Angle

We match the flip angle to Ernst angle to ensure the highest signal in the GE-EPI sequence. The flip angle depends on TR for GE sequences. Please use the website tool below to calculate the flip angle for your experiment. You must choose the appropriate T1 value for your brain region when calculating the flip angle. For the whole brain studies, we have been using T1 value of 1500ms.

Flip Angle Calculation: http://www.mritoolbox.com/ErnstAngle.html

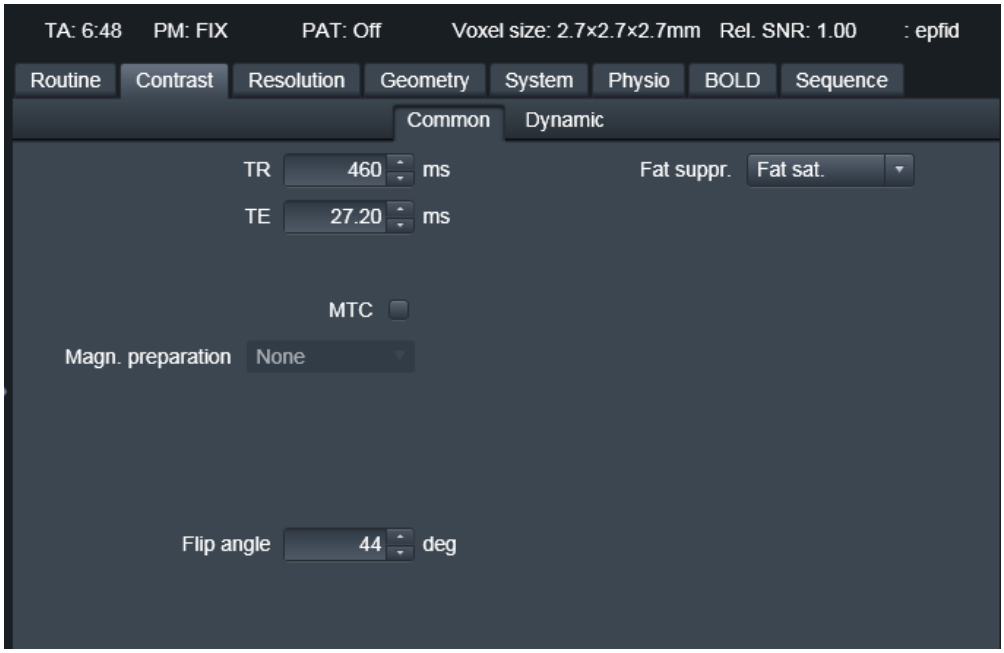
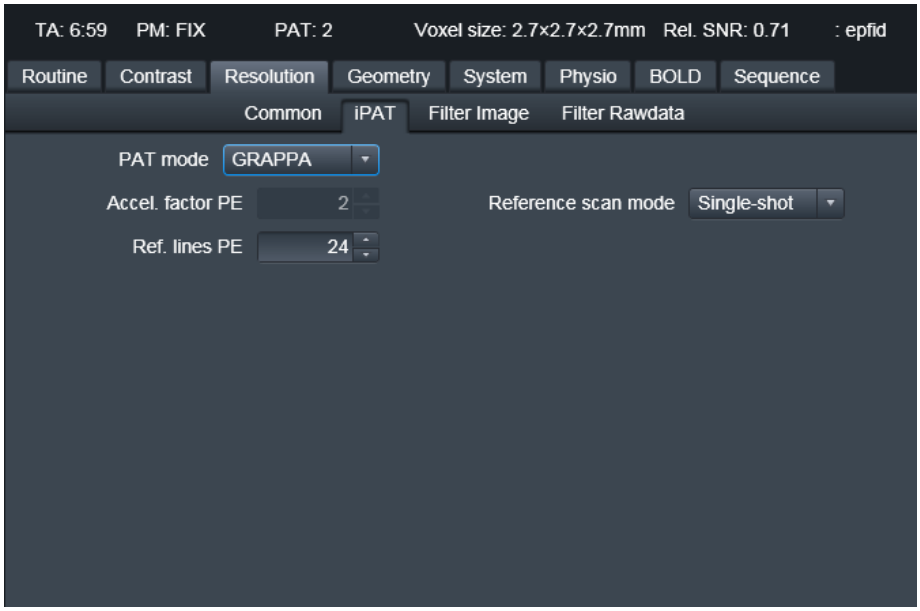


Figure 4: Flip Angle

Acceleration Techniques: GRAPPA, multiband factor (MB/SMA) and partial Fourier factor

GRAPPA is the in-plane acceleration factor; GRAPPA of 2 will reduce scan time almost by half. Multiband factor (SMA) is the slice acceleration factor; SMA of 4 will reduce scan time almost by ¼. Partial Fourier cuts back some of the k-space lines along Phase Encoding direction to accelerate acquisition; if used, most studies use factor of 6/8. We can apply all these acceleration techniques simultaneously if needed with a compromise to the image quality. Most studies use GRAPPA of 2 with SMA of 2 or 4. Some researchers just use SMA of 8 only. With SMA, some researchers also save reference scans for post-processing.



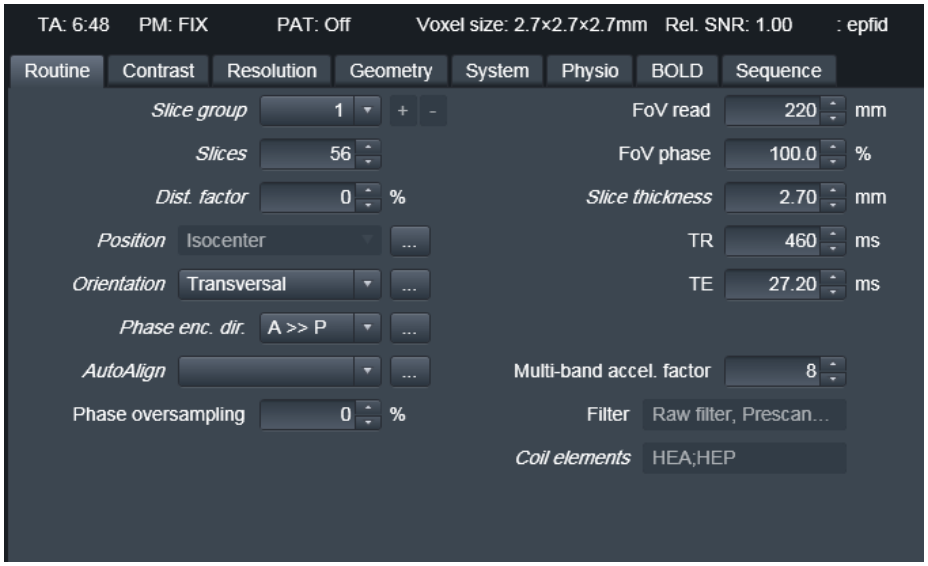


Figure 5: GRAPPA, MB/SMA, pF

Number of time points / volume

The number of time points/volumes on the tab shown below depends on your paradigm as to how many volumes are needed to cover the length of your experiment.

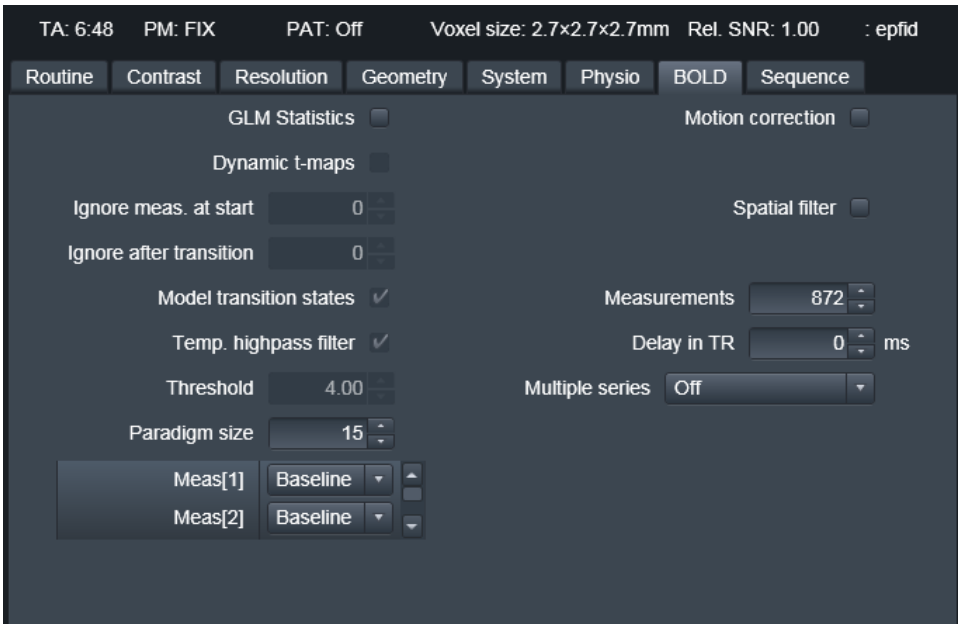


Figure 6: number of volumes

Choosing Number of Echoes for Multi-Echo fMRI on the CMRR sequence

Collecting Multi-Echo BOLD fMRI data can be done by setting '**Contrasts**' to the number of echoes and setting the values for **TE** as shown below on the CMRR sequence. The minimum of 3 echoes are required for the multi-echo analysis. For the three contrasts, there will be three different TE values. TEDANA (https://tedana.readthedocs.io/en/latest/multi-echo.html) and fMRIprep (https://fmriprep.org/en/1.5.2/index.html) can be used to process multi-echo data.

Figure 5: Multi-Echo BOLD fMRI data

Blip up/blip down scan

If you need to acquire blip-up/blip-down data, you can do so with the CMRR sequence. On the special card, you'll find a toggle switch "Invert RO/PE polarity". Just turn it on and you will have blip up/blip down data.

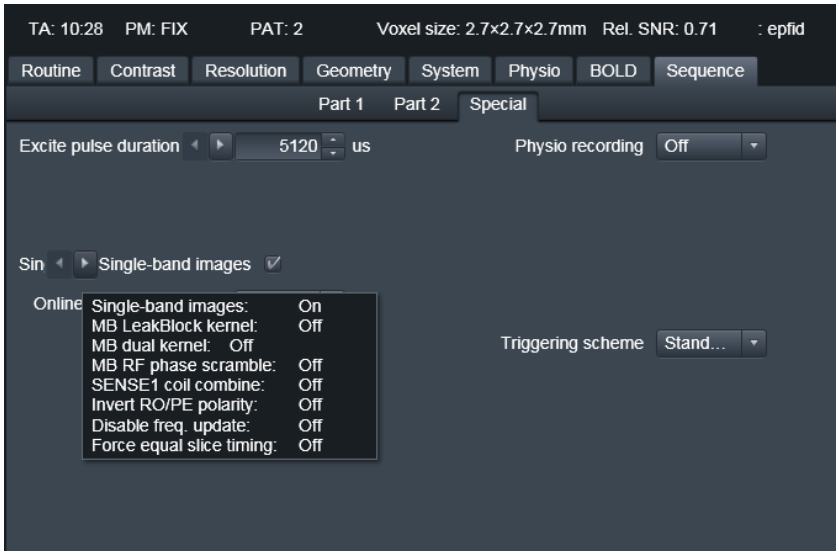


Figure 6: Blip up/ Blip Down

Coil Elements Selections

It’s necessary and utmost important to make sure the receiver head coil is correctly plugged into the scanner before collecting data. We have three different head coils: 32CH, 64CH and 20CH. You can see if the head coil is correctly plugged on the screen of the scanner itself or check on the examcard tab shown below. Make sure both HEA and HEP parts are plugged in.

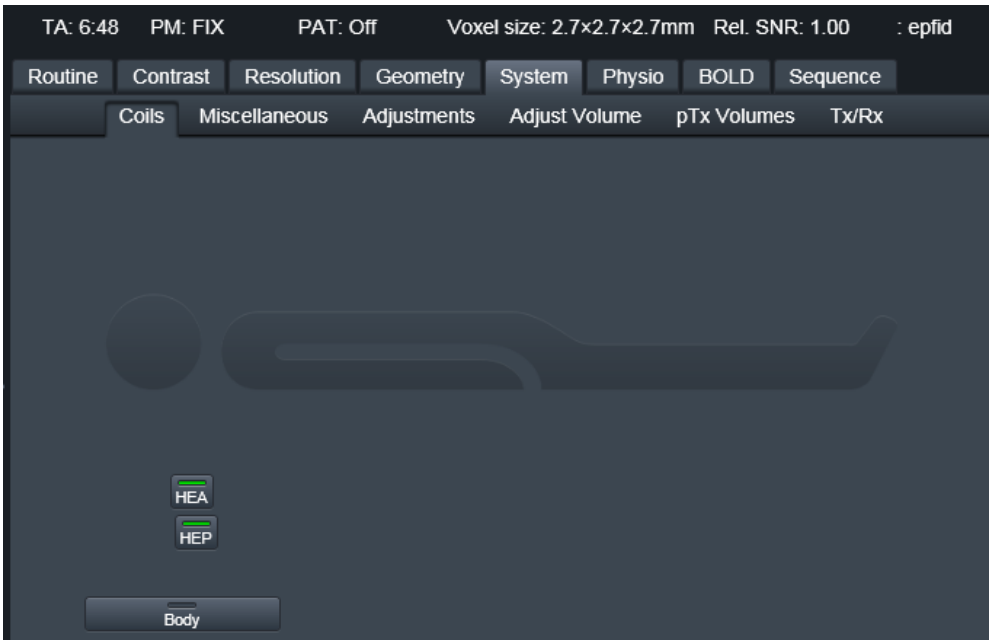


Figure 7: Head coil elements