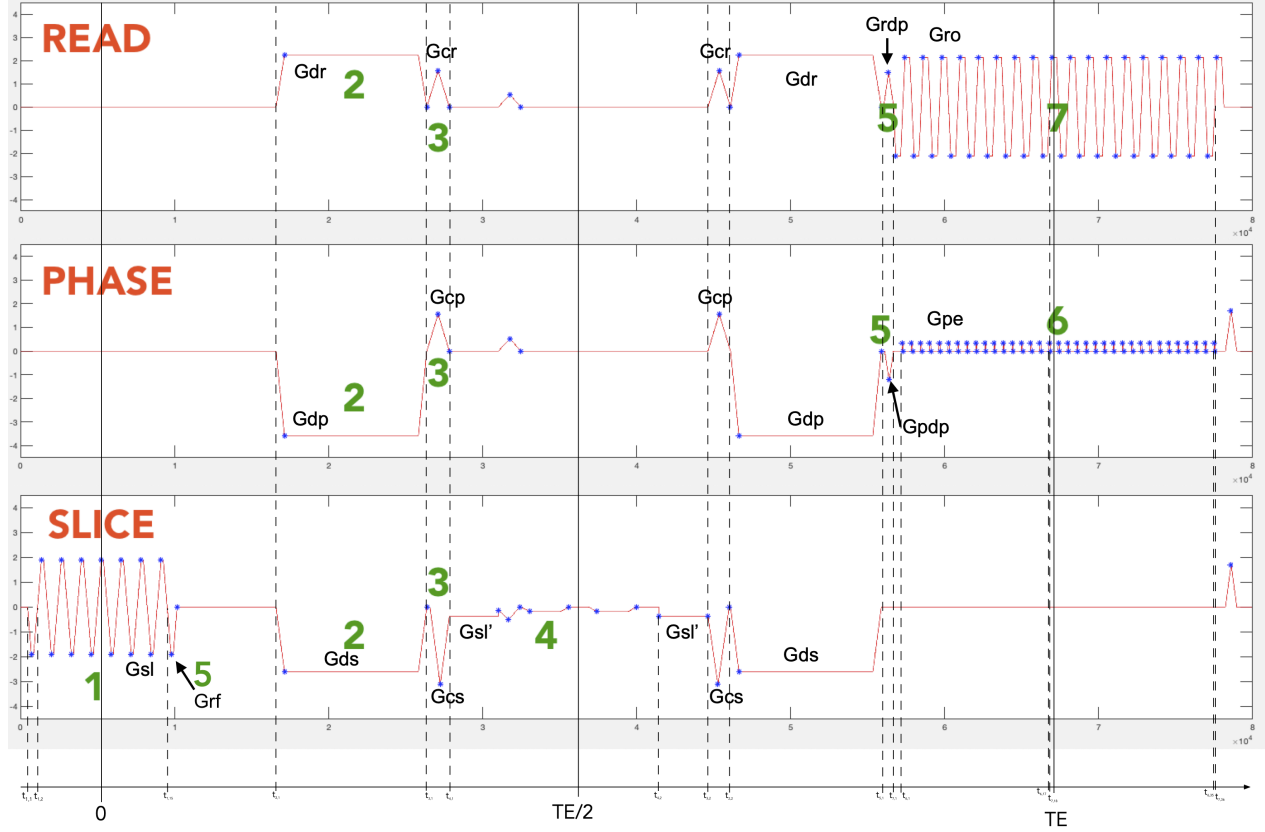


## 1 Pulse sequence



## 2 General analytic form

$$\begin{aligned}
 b_{ij} = \gamma^2 & \left[ G_{1i}G_{1j}\tau_{11} + (G_{1i}G_{2j} + G_{2i}G_{1j})\tau_{12} + (G_{1i}G_{3j} + G_{3i}G_{1j})\tau_{13} + \right. \\
 & + (G_{1i}G_{4j} + G_{4i}G_{1j})\tau_{14} + (G_{1i}G_{5j} + G_{5i}G_{1j})\tau_{15} + (G_{1i}G_{6mj} + G_{6mi}G_{1j})\tau_{16m} + \\
 & + (G_{1i}G_{71j} + G_{71i}G_{1j})\tau_{171} + G_{2i}G_{2j}\tau_{22} + (G_{2i}G_{3j} + G_{3i}G_{2j})\tau_{23} + \\
 & + (G_{2i}G_{4j} + G_{4i}G_{2j})\tau_{24} + (G_{2i}G_{5j} + G_{5i}G_{2j})\tau_{25} + (G_{2i}G_{6mj} + G_{6mi}G_{2j})\tau_{26m} + \\
 & + (G_{2i}G_{71j} + G_{71i}G_{2j})\tau_{271} + G_{3i}G_{3j}\tau_{33} + (G_{3i}G_{4j} + G_{4i}G_{3j})\tau_{34} + \\
 & + (G_{3i}G_{5j} + G_{5i}G_{3j})\tau_{35} + (G_{3i}G_{6mj} + G_{6mi}G_{3j})\tau_{36m} + (G_{3i}G_{71j} + G_{71i}G_{3j})\tau_{371} + \\
 & + G_{4i}G_{4j}\tau_{44} + (G_{4i}G_{5j} + G_{5i}G_{4j})\tau_{45} + (G_{4i}G_{6mj} + G_{6mi}G_{4j})\tau_{46m} + \\
 & + (G_{4i}G_{71j} + G_{71i}G_{4j})\tau_{471} + G_{5i}G_{5j}\tau_{55} + (G_{5i}G_{6mj} + G_{6mi}G_{5j})\tau_{56m} + (G_{5i}G_{71j} + G_{71i}G_{5j})\tau_{571} \\
 & + G_{6mi}G_{6mj}\tau_{6m6m} + (G_{6i}G_{71j} + G_{71i}G_{6j})\tau_{671} + G_{71i}G_{71j}\tau_{7171} + \\
 & \left. + (G_{7mi}G_{7(m+1)j} + G_{7(m+1)i}G_{7mj})\tau_{7m7(m+1)} \right]
 \end{aligned} \tag{1}$$

### 3 Diagonal terms

For the read direction we have:  $G_1 = 0$ ;  $G_2 = G_{dr}$ ;  $G_3 = G_{cr}$ ;  $G_4 = 0$ ;  $G_5 = G_{rdp}$ ;  $G_6 = 0$ ;  $G_7 = G_{ro}$  which gives the following for the diagonal readout term

$$b_{rr} = \gamma^2 \left( G_{dr}^2 \tau_{22} + 2G_{dr}G_{cr}\tau_{23} + 2G_{dr}G_{rdp}\tau_{25rp} + 2G_{dr}G_{ro}\tau_{271} + G_{cr}^2 \tau_{33} + 2G_{cr}G_{rdp}\tau_{35rp} + \right. \\ \left. + 2G_{cr}G_{ro}\tau_{371} + G_{rdp}^2 \tau_{55rp} + 2G_{rdp}G_{ro}\tau_{5rp71} + G_{ro}^2 (\tau_{7171} + \tau_{7m7(m+1)}) \right) \quad (2)$$

taking into account refocused gradient pairs we get:

$$b_{rr} = \gamma^2 \left( G_{dr}^2 \tau_{22} + 2G_{dr}G_{cr}\tau_{23} + G_{cr}^2 \tau_{33} + G_{rdp}^2 \tau_{55rp} + 2G_{rdp}G_{ro}\tau_{5rp71} + G_{ro}^2 (\tau_{7171} + \tau_{7m7(m+1)}) \right) \quad (3)$$

For the phase direction we have:  $G_1 = 0$ ;  $G_2 = G_{dp}$ ;  $G_3 = G_{cp}$ ;  $G_4 = 0$ ;  $G_5 = G_{pdp}$ ;  $G_6 = G_{pe}$ ;  $G_7 = 0$  which gives the following for the diagonal phase-encoding

$$b_{pp} = \gamma^2 (G_{dp}^2 \tau_{22} + 2G_{dp}G_{cp}\tau_{23} + 2G_{dp}G_{pdp}\tau_{25rp} + 2G_{dp}G_{pe}\tau_{26m} + G_{cp}^2 \tau_{33} + 2G_{cp}G_{pdp}\tau_{35rp} \\ + G_{cp}G_{pe}\tau_{36m} + G_{pdp}^2 \tau_{55rp} + 2G_{pdp}G_{pe}\tau_{5rp6m} + G_{pe}^2 \tau_{6m6m}) \quad (4)$$

taking into account refocused gradient pairs we get:

$$b_{pp} = \gamma^2 (G_{dp}^2 \tau_{22} + 2G_{dp}G_{cp}\tau_{23} + G_{cp}^2 \tau_{33} + G_{pdp}^2 \tau_{55rp} + 2G_{pdp}G_{pe}\tau_{5rp6m} + G_{pe}^2 \tau_{6m6m}) \quad (5)$$

For the slice direction we have:  $G_1 = G_{sl}$ ;  $G_2 = G_{ds}$ ;  $G_3 = G_{cs}$ ;  $G_4 = G'_{sl}$ ;  $G_5 = G_{rf}$ ;  $G_6 = 0$ ;  $G_7 = 0$  which gives the following for the diagonal slice-select:

$$b_{ss} = \gamma^2 \left( \frac{14}{3} G_{sl}^2 \tau_{11} + G_{sl}G_{ds}\tau_{12} + G_{sl}G_{cs}\tau_{13} + G_{sl}G'_{sl}\tau_{14} + G_{sl}G_{rf}\tau_{15s} + G_{ds}^2 \tau_{22} + 2G_{ds}G_{cs}\tau_{23} + \right. \\ \left. + G_{ds}G'_{sl}\tau_{24} + G_{ds}G_{rf}\tau_{25s} + G_{cs}^2 \tau_{33} + G_{cs}G'_{sl}\tau_{34} + 2G_{cs}G_{rf}\tau_{35} + G_{sl}'^2 \tau_{44} + G'_{sl}G_{rf}\tau_{45s} + \right. \\ \left. + G_{rf}^2 \tau_{55s} \right) \quad (6)$$

with refocused gradient pairs one arrives to:

$$b_{ss} = \gamma^2 \left( \frac{14}{3} G_{sl}^2 \tau_{11} + G_{ds}^2 \tau_{22} + 2G_{ds}G_{cs}\tau_{23} + G_{ds}G'_{sl}\tau_{24} + G_{ds}G_{rf}\tau_{25s} + G_{cs}^2 \tau_{33} + G_{cs}G'_{sl}\tau_{34} + \right. \\ \left. + 2G_{cs}G_{rf}\tau_{35s} + \frac{1}{4} G_{sl}'^2 \tau_{44} + G'_{sl}G_{rf}\tau_{45s} + \frac{1}{4} G_{rf}^2 \tau_{55s} \right) \quad (7)$$

### 4 Off-diagonal terms

Summarizing all gradients together in one place:

$G_{1r} = 0$	$G_{1p} = 0$	$G_{1s} = G_{sl}$
$G_{2r} = G_{dr}$	$G_{2p} = G_{dp}$	$G_{2s} = G_{ds}$
$G_{3r} = G_{cr}$	$G_{3p} = G_{cp}$	$G_{3s} = G_{cs}$
$G_{4r} = 0$	$G_{4p} = 0$	$G_{4s} = G'_{sl}$
$G_{5r} = G_{rdp}$	$G_{5p} = G_{pdp}$	$G_{5s} = G_{rf}$
$G_{6r} = 0$	$G_{6p} = G_{pe}$	$G_{6s} = 0$
$G_{7r} = G_{ro}$	$G_{7p} = 0$	$G_{7s} = 0$

Then starting from the read-out/phase term plugging the gradients  $G_r$  and  $G_p$  into equation Eq. 1:

$$b_{rp} = b_{pr} = \gamma^2 \left( G_{dr}G_{dp}\tau_{22} + (G_{dr}G_{cp} + G_{cr}G_{dp})\tau_{23} + (G_{dr}G_{pdp} + G_{rdp}G_{dp})\tau_{25rp} + G_{dr}G_{pe}\tau_{26m} + \right. \\ \left. + G_{ro}G_{dp}\tau_{271} + G_{cr}G_{cp}\tau_{33} + (G_{cr}G_{pdp} + G_{rdp}G_{cp})\tau_{35rp} + G_{cr}G_{pe}\tau_{36m} + G_{ro}G_{cp}\tau_{371} + \right. \\ \left. + G_{rdp}G_{pdp}\tau_{55rp} + G_{rdp}G_{pe}\tau_{5rp6m} + G_{ro}G_{pdp}\tau_{5rp71} + G_{pe}G_{ro}\tau_{6m71} \right) \quad (8)$$

taking into account refocused gradient pairs we get:

$$b_{rp} = b_{pr} = \gamma^2 \left( G_{dr}G_{dp}\tau_{22} + (G_{dr}G_{cp} + G_{cr}G_{dp})\tau_{23} + G_{cr}G_{cp}\tau_{33} + G_{rdp}G_{pdp}\tau_{55rp} + G_{rdp}G_{pe}\tau_{5rp6m} + \right. \\ \left. + G_{ro}G_{pdp}\tau_{5rp71} + G_{pe}G_{ro}\tau_{6m71} \right) \quad (9)$$

the read-out/slice select term gives:

$$b_{rs} = b_{sr} = \gamma^2 \left( G_{dr}G_{sl}\tau_{12} + G_{cr}G_{sl}\tau_{13} + G_{rdp}G_{sl}\tau_{15s} + G_{ro}G_{sl}\tau_{171} + G_{dr}G_{ds}\tau_{22} + \right. \\ \left. + (G_{dr}G_{cs} + G_{cr}G_{ds})\tau_{23} + \frac{1}{2}G_{dr}G'_{sl}\tau_{24} + \left( \frac{1}{2}G_{dr}G_{rf} + G_{rdp}G_{ds} \right)\tau_{25s} + G_{ds}G_{ro}\tau_{271} + \right. \\ \left. + G_{cr}G_{cs}\tau_{33} + \frac{1}{2}G_{cr}G'_{sl}\tau_{34} + (G_{cr}G_{rf} + \frac{1}{2}G_{rdp}G_{cs})\tau_{35s} + G_{rdp}G'_{sl}\tau_{45s} + \right. \\ \left. + G_{ro}G'_{sl}\tau_{471} + \frac{1}{2}G_{rdp}G_{rf}\tau_{55rp} + \frac{1}{2}G_{ro}G_{rf}\tau_{5s71} \right) \quad (10)$$

again by taking into account refocused gradient pairs the expression simplifies to:

$$b_{rs} = b_{sr} = \gamma^2 \left( (G_{dr}G_{cs} + G_{cr}G_{ds})\tau_{23} + \frac{1}{2}G_{dr}G'_{sl}\tau_{24} + \frac{1}{2}(G_{dr}G_{rf})\tau_{25s} + G_{cr}G_{cs}\tau_{33} \right. \\ \left. + \frac{1}{2}G_{cr}G'_{sl}\tau_{34} + \frac{1}{2}G_{cr}G_{rf}\tau_{35s} + \frac{1}{2}G_{rdp}G_{rf}\tau_{55rp} + \frac{1}{2}G_{ro}G_{rf}\tau_{5s71} \right) \quad (11)$$

and the last term the phase/slice select:

$$b_{sp} = b_{ps} = \gamma^2 \left( G_{sl}G_{dp}\tau_{12} + G_{sl}G_{cp}\tau_{13} + G_{sl}G_{pdp}\tau_{15rp} + G_{sl}G_{pe}\tau_{16m} + G_{dp}G_{ds}\tau_{22} + \right. \\ \left. + (G_{ds}G_{cp} + G_{ds}G_{cp})\tau_{23} + \frac{1}{2}G_{dp}G'_{sl}\tau_{24} + \left( \frac{1}{2}G_{dp}G_{rf}\tau_{25s} + G_{ds}G_{pdp}\tau_{25rp} \right) + G_{pe}G_{ds}\tau_{26m} + \right. \\ \left. + G_{cp}G_{cs}\tau_{33} + \frac{1}{2}G_{cp}G'_{sl}\tau_{34} + \left( \frac{1}{2}G_{cp}G_{rf} + G_{pdp}G_{cs} \right)\tau_{35s} + G_{pe}G_{cs}\tau_{36m} + G_{pdp}G'_{sl}\tau_{45s} + \right. \\ \left. + G_{pe}G'_{sl}\tau_{46m} + \frac{1}{2}G_{pdp}G_{rf}\tau_{55rp} + \frac{1}{2}G_{pe}G_{rf}\tau_{5s6m} \right) \quad (12)$$

with refocused gradient pairs gives final expression:

$$b_{sp} = b_{ps} = \gamma^2 \left( G_{dp}G_{ds}\tau_{22} + (G_{ds}G_{cp} + G_{dp}G_{cs})\tau_{23} + \frac{1}{2}G_{dp}G'_{sl}\tau_{24} + \frac{1}{2}G_{dp}G_{rf}\tau_{25s} + G_{cp}G_{cs}\tau_{33} + \right. \\ \left. + \frac{1}{2}G_{cp}G'_{sl}\tau_{34} + \frac{1}{2}G_{cp}G_{rf}\tau_{35s} + \frac{1}{2}G_{pdp}G_{rf}\tau_{55rp} + \frac{1}{2}G_{pe}G_{rf}\tau_{5s6m} \right) \quad (13)$$

## 5 Timing multipliers

$$\tau_{11} = \delta_1^3 \quad (14)$$

$$\tau_{22} = \delta_2^2 \left( \Delta_2 - \frac{1}{3}\delta_2 \right) + \frac{1}{30}\epsilon_2^3 - \frac{1}{6}\delta_2\epsilon_2^2, \quad \Delta_2 = t_{22} - t_{21} \quad (15)$$

$$\tau_{23} = \delta_2\delta_3\Delta_3, \quad \Delta_3 = t_{32} - t_{31} \quad (16)$$

$$\tau_{24} = \delta_2\delta_4\Delta_4, \quad \Delta_4 = t_{42} - t_{41} \quad (17)$$

$$\tau_{25rp} = \frac{1}{2}\delta_{5rp}\delta_2\Delta_2, \quad \Delta_2 = t_{22} - t_{21} \quad (18)$$

$$\tau_{25s} = \frac{1}{2}\delta_{5s}\delta_2\Delta_2, \quad \Delta_2 = t_{22} - t_{21} \quad (19)$$

$$\tau_{33} = \delta_3^2 \left( \Delta_3 - \frac{1}{3}\delta_3 \right) + \frac{1}{30}\epsilon_3^3 - \frac{1}{6}\delta_3\epsilon_3^2, \quad \Delta_3 = t_{32} - t_{31} \quad (20)$$

$$\tau_{34} = \delta_3\delta_4\Delta_4, \quad \Delta_4 = t_{42} - t_{41} \quad (21)$$

$$\tau_{35rp} = \frac{1}{2}\delta_{5rp}\delta_3\Delta_3, \quad \Delta_3 = t_{32} - t_{31} \quad (22)$$

$$\tau_{35s} = \frac{1}{2}\delta_{5s}\delta_3\Delta_3, \quad \Delta_3 = t_{32} - t_{31} \quad (23)$$

$$\tau_{44} = \delta_4^2 \left( \Delta_4 - \frac{1}{3}\delta_4 \right) + \frac{1}{30}\epsilon_4^3 - \frac{1}{6}\delta_4\epsilon_4^2, \quad \Delta_4 = t_{42} - t_{41} \quad (24)$$

$$\tau_{45rp} = \frac{1}{2}\delta_{5rp}\delta_4\Delta_4, \quad \Delta_4 = t_{42} - t_{41} \quad (25)$$

$$\tau_{45s} = \frac{1}{2}\delta_{5s}\delta_4\Delta_4, \quad \Delta_4 = t_{42} - t_{41} \quad (26)$$

$$\tau_{55rp} = \delta_{5rp}^2 \left( \Delta_{5rp} - \frac{1}{3}\delta_{5rp} \right) + \frac{1}{30}\epsilon_{5rp}^3 - \frac{1}{6}\delta_{5rp}\epsilon_{5rp}^2, \quad \Delta_{5rp} = \text{TE} - t_{5rp} \quad (27)$$

$$\tau_{55s} = \delta_{5s}^2 \left( \Delta_{5s} - \frac{1}{3}\delta_{5s} \right) + \frac{1}{30}\epsilon_{5s}^3 - \frac{1}{6}\delta_{5s}\epsilon_{5s}^2, \quad \Delta_{5s} = \text{TE} - t_{5s} \quad (28)$$

$$\tau_{5rp6m} = \epsilon_{5rp}\delta_{5rp} \sum_{m=1}^{\text{res}/2} (\Delta_{6m} - \epsilon_6), \quad \Delta_{6m} = \text{TE} - t_{6i} \quad (29)$$

$$\tau_{5s6m} = -\epsilon_{5s}\delta_{rf} \sum_{m=1}^{\text{res}/2} (\Delta_{6m} - \epsilon_6), \quad \Delta_{6m} = \text{TE} - t_{6i} \quad (30)$$

$$\tau_{5rp71} = \delta_5 \left[ \delta_7 \left( \Delta_{75} - \frac{1}{4}\delta_7 \right) + \frac{1}{12}\epsilon_7^2 - \frac{1}{2}\delta_7\epsilon_7 \right], \quad \Delta_{75} = \Delta_{71} = \text{TE} - t_{71} \quad (31)$$

$$\tau_{5s71} = \delta_5 \left[ \delta_7 \left( \Delta_{75} - \frac{1}{4}\delta_7 \right) + \frac{1}{12}\epsilon_7^2 - \frac{1}{2}\delta_7\epsilon_7 \right], \quad \Delta_{75} = \Delta_{71} = \text{TE} - t_{71} \quad (32)$$

$$\tau_{6m6m} = \epsilon_6^2 \sum_{m=1}^{\text{res}/2} \left[ (2m-1)\Delta_{6m} - \left(m\frac{67}{30} - 1\right)\epsilon_6 \right], \quad \Delta_{6m} = \text{TE} - t_{6i} \quad (33)$$

$$\tau_{6m71} = \frac{1}{4}\epsilon_6 \left( \delta_7 \Delta_{71} - \frac{1}{60}\epsilon_7^2 \right), \quad \Delta_{71} = \Delta_{75} = \text{TE} - t_{71} \quad (34)$$

$$\tau_{7171} = \frac{1}{4} \left[ \delta_7^2 \left( \Delta_{71} - \frac{1}{3}\delta_7 \right) + \frac{1}{30}\epsilon_7^3 - \frac{1}{2}\delta_7^2\epsilon_7 \right], \quad \Delta_{71} = \Delta_{75} = \text{TE} - t_{71} \quad (35)$$

$$\tau_{7m7(m+1)} = \left( \frac{\text{res}}{2} - 1 \right) \left[ \frac{1}{12}\delta_7^3 + \frac{1}{60}\epsilon_7 + \frac{1}{4}\delta_7^2\epsilon_7 - \frac{1}{12}\delta_7\epsilon_7^2 \right], \quad \text{res} = 34 \quad (36)$$