

2) Spatial Encoding

$$a) \text{TBW} = \tau_{RF} \cdot \Delta f$$

$$2 = 1 \text{ ms} \cdot \Delta f \rightarrow \Delta f = \frac{2}{1 \text{ ms}} = 2 \text{ kHz}$$

$$\Delta f = F \cdot G \cdot \Delta z$$

$$2 \text{ kHz} = 42.58 \frac{\text{MHz}}{\text{T}} \cdot G_{ss} \cdot 3 \text{ mm}$$

$$G_{ss} = \frac{2 \text{ kHz}}{42.58 \text{ MHz}} \cdot \frac{1}{T} \cdot \frac{1}{3 \text{ mm}} = 0.0157 \text{ T/m} = 15.7 \text{ mT/m}$$

$$\tau_{ss}^{\text{rise}} = \frac{G_{ss}}{\text{max slew}} = \frac{15.7 \text{ mT/m}}{180 \text{ mT/m/ms}} = 87.2 \mu\text{s}$$

$$\tau_{ss} = \tau_{RF} = 1 \text{ ms}$$

$$\begin{aligned} \text{Total time} &= \tau_{ss} + 2\tau_{ss}^{\text{rise}} \\ &= (1000 + 2 \cdot 87.2) \mu\text{s} \\ &= 1174.4 \mu\text{s} // \end{aligned}$$

$$b) \text{Relative to isocenter } k_{PE \text{ max}} = (1.2 \text{ mm})^{-1}$$

$$k_{PE \text{ max}} = (1.2 \text{ mm})^{-1} = F G_{PE}^2 \cdot \frac{1}{T}, \text{ setting } G_{PE} = G_{\text{max}} = 25 \text{ mT/m}$$

$$\Rightarrow \tau_{PE} = \frac{(1.2 \text{ mm})^{-1}}{42.58 \text{ MHz/T}} \cdot \frac{1}{25 \text{ mT/m}} = 7.828 \cdot 10^{-4} \text{ s} = 782.8 \mu\text{s}$$

$$\tau_{\text{PE}}^{\text{rise}} = \frac{G_{\text{max}}}{\text{maxSlew}} = \frac{25 \text{ mT/m}}{180 \text{ mT/m/ms}} = 138.9 \mu\text{s}$$

$$\tau_{\text{PE}}^{\text{total}} = (782.8 + 2 \cdot 138.9) \mu\text{s} \approx 1060.6 \mu\text{s} //$$

c) Receiver BW = 750 $\frac{\text{Hz}}{\text{pixel}} = \frac{1}{\text{sampling time}}$

$$\Rightarrow \tau_s = 1333.3 \mu\text{s} = \text{flat top time}$$

Finding G_{read} :

$$r \text{BW} = F \cdot G_{\text{read}} \cdot \Delta t_{\text{read}} = 750 \frac{\text{Hz}}{\text{pixel}}$$

$$\Rightarrow G_{\text{read}} = \frac{750 \text{ Hz/pixel}}{42.58 \text{ MHz/T}} \cdot \frac{1}{1.2 \text{ mm/pixel}} = 0.0147 \text{ T/m} \\ = 14.7 \text{ mT/m} //$$

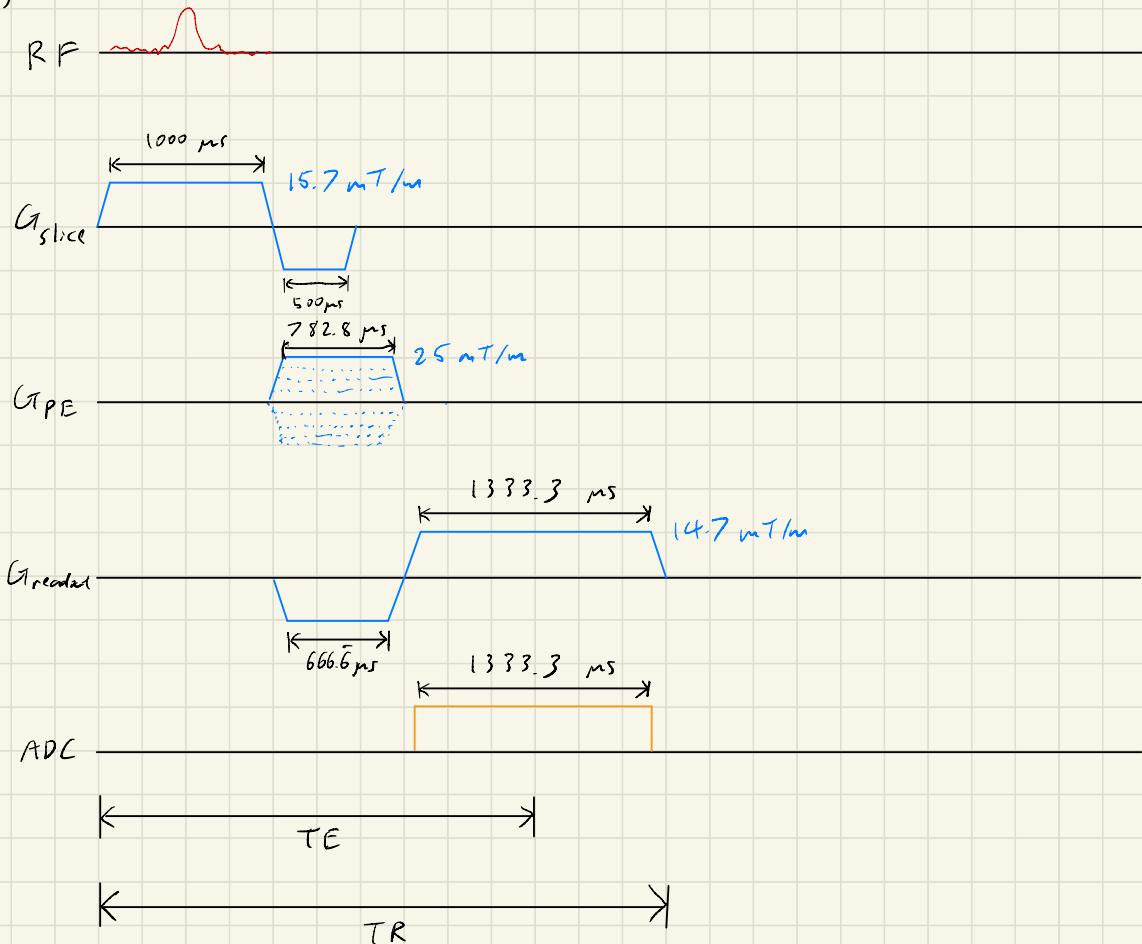
$$\text{Rise time } \tau_{\text{read}}^{\text{rise}} = \frac{14.7 \text{ mT/m}}{180 \text{ mT/ms}} = 81.7 \mu\text{s}$$

$$\text{Total duration} = \tau_s + 2 \cdot \tau_{\text{read}}^{\text{rise}}$$

$$= 1496.7 \mu\text{s} //$$

* Diagram not to scale

d)



$$TE = \tau_{ss} + \tau_{PE} + \frac{1}{2}\tau_{Read}$$

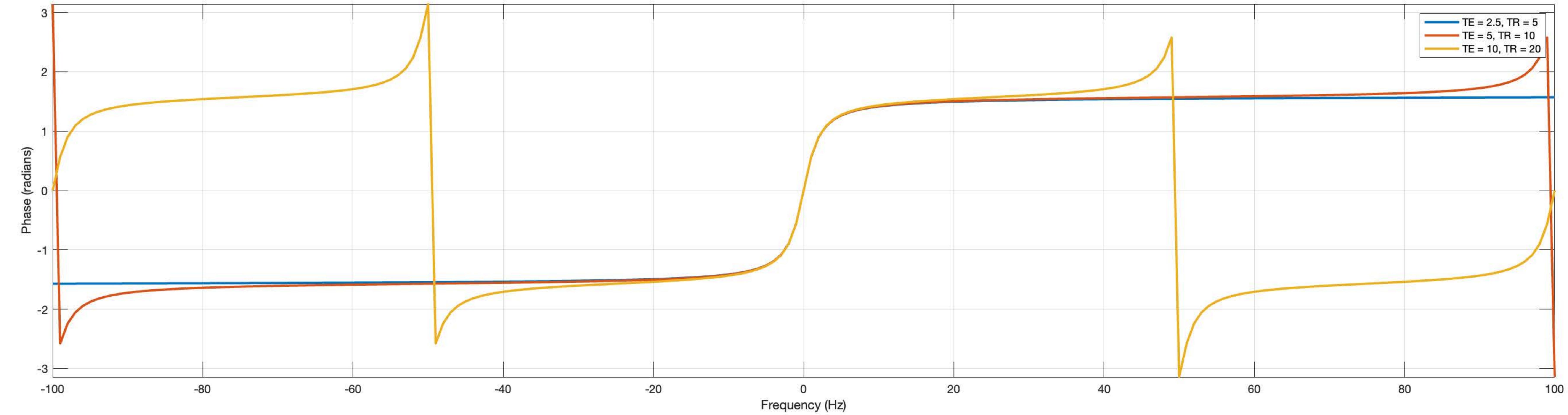
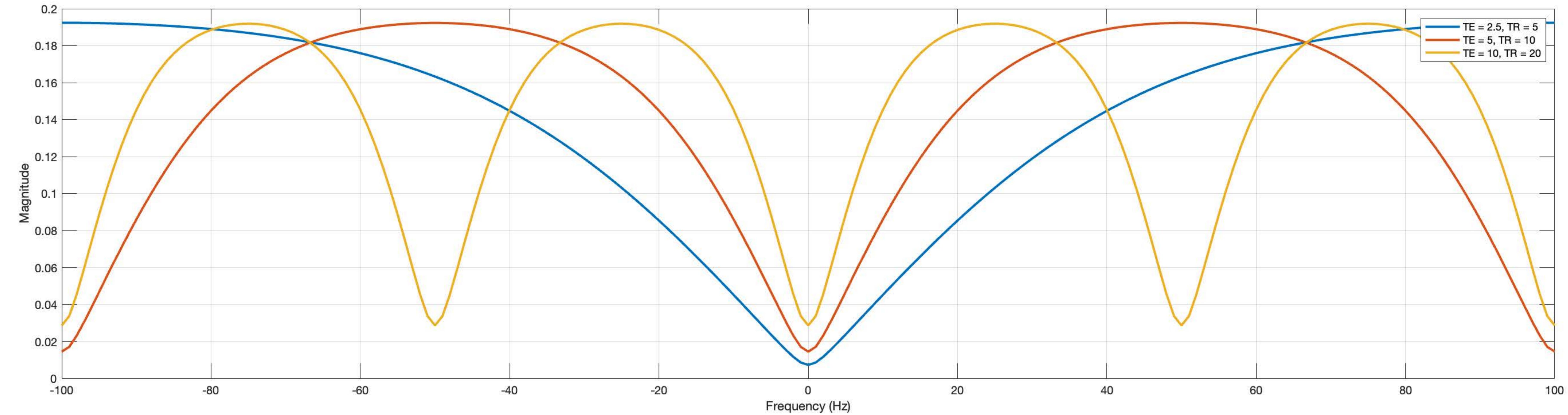
$$= (1174.4 + 1060.6 + \frac{1}{2} \cdot 1496.7) \mu s = 2983.3 \mu s //$$

$$\text{Shortest possible } TR = \tau_{ss} + \tau_{PE} + \tau_{Read}$$

$$= (1174.4 + 1060.6 + 1496.7) \mu s$$

$$= 3731.7 \mu s //$$

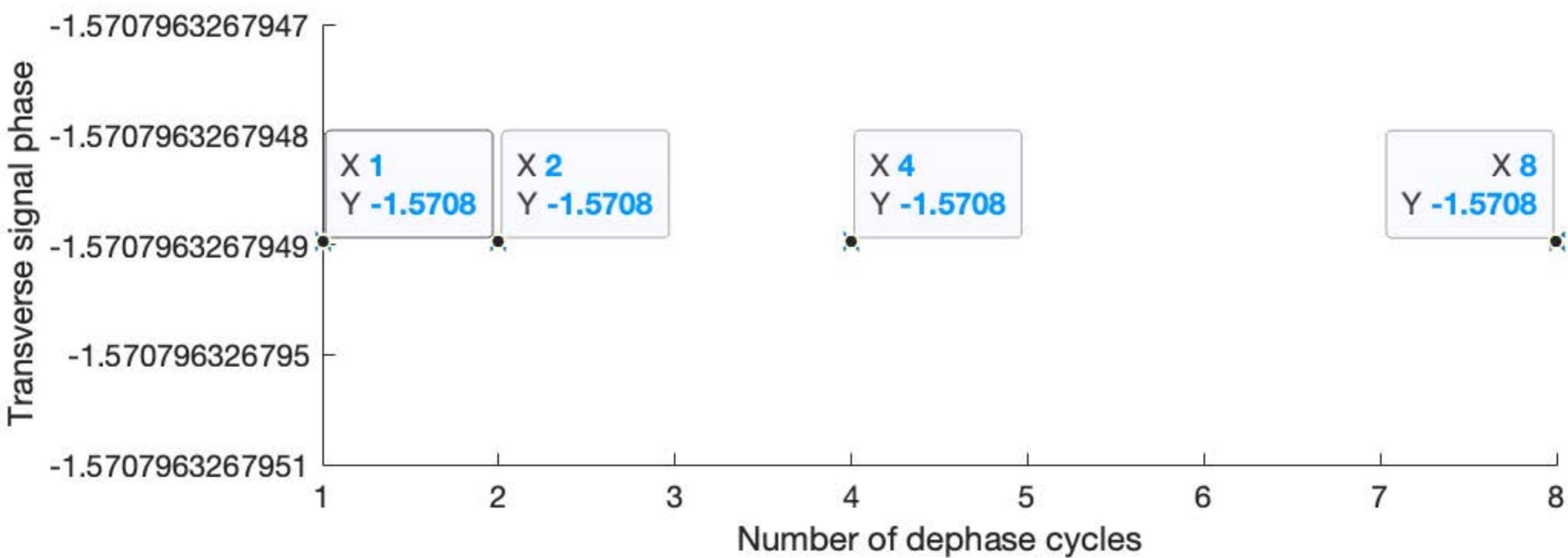
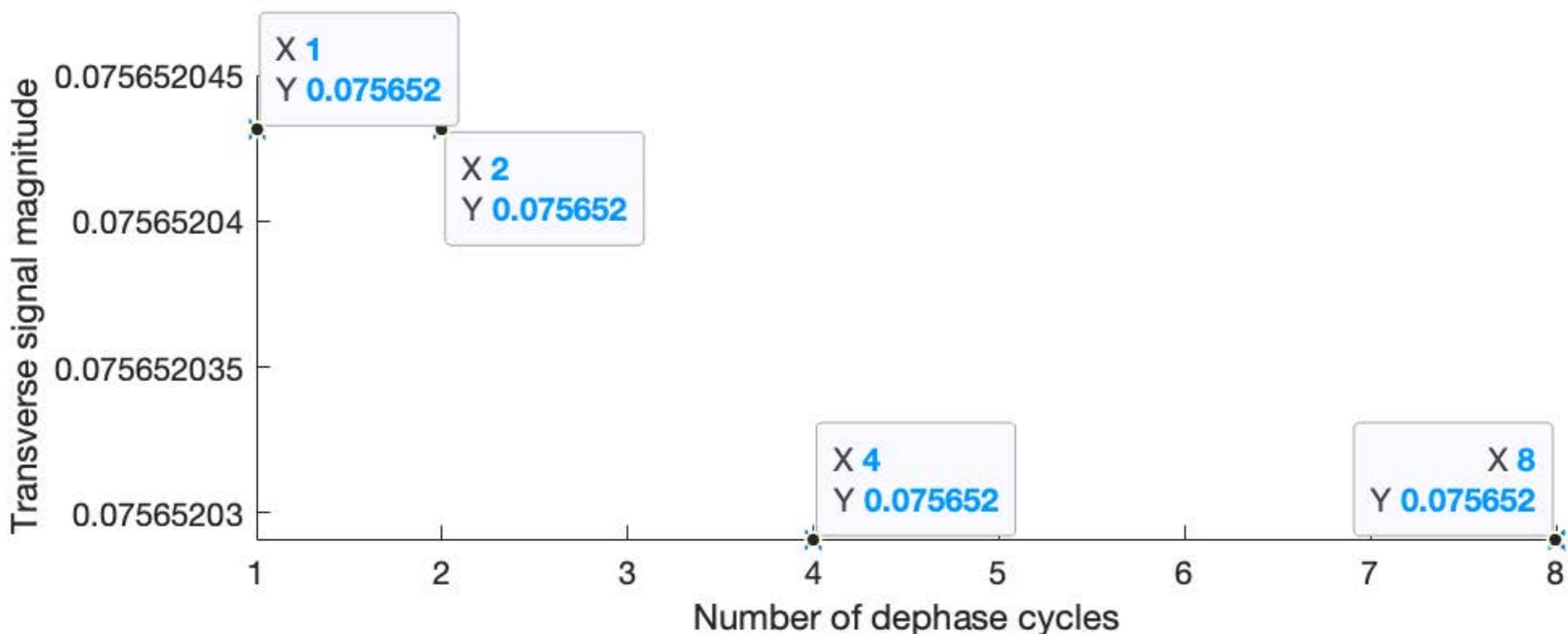
- e) 1. Use a scanner with a higher maximum gradient amplitude
- 2. Use a scanner with a higher maximum slew rate
- 3. Increase receiver bandwidth



Q2) Balanced & Spilted Steady-State Sequences

b) i)

$$\begin{bmatrix} m_x \\ m_y \\ m_z \end{bmatrix} = \begin{bmatrix} 0.0757 \\ 0 \\ 0.7377 \end{bmatrix}$$



Q3) Slice Profile Simulation

$$1) \text{TBW} = 8, \Delta_{\text{slice}} = 5 \text{ mm}, \tau_{\text{RP}} = 2 \text{ ms}$$

$$\Delta f = \frac{8}{2 \text{ ms}} = 4 \text{ kHz}$$

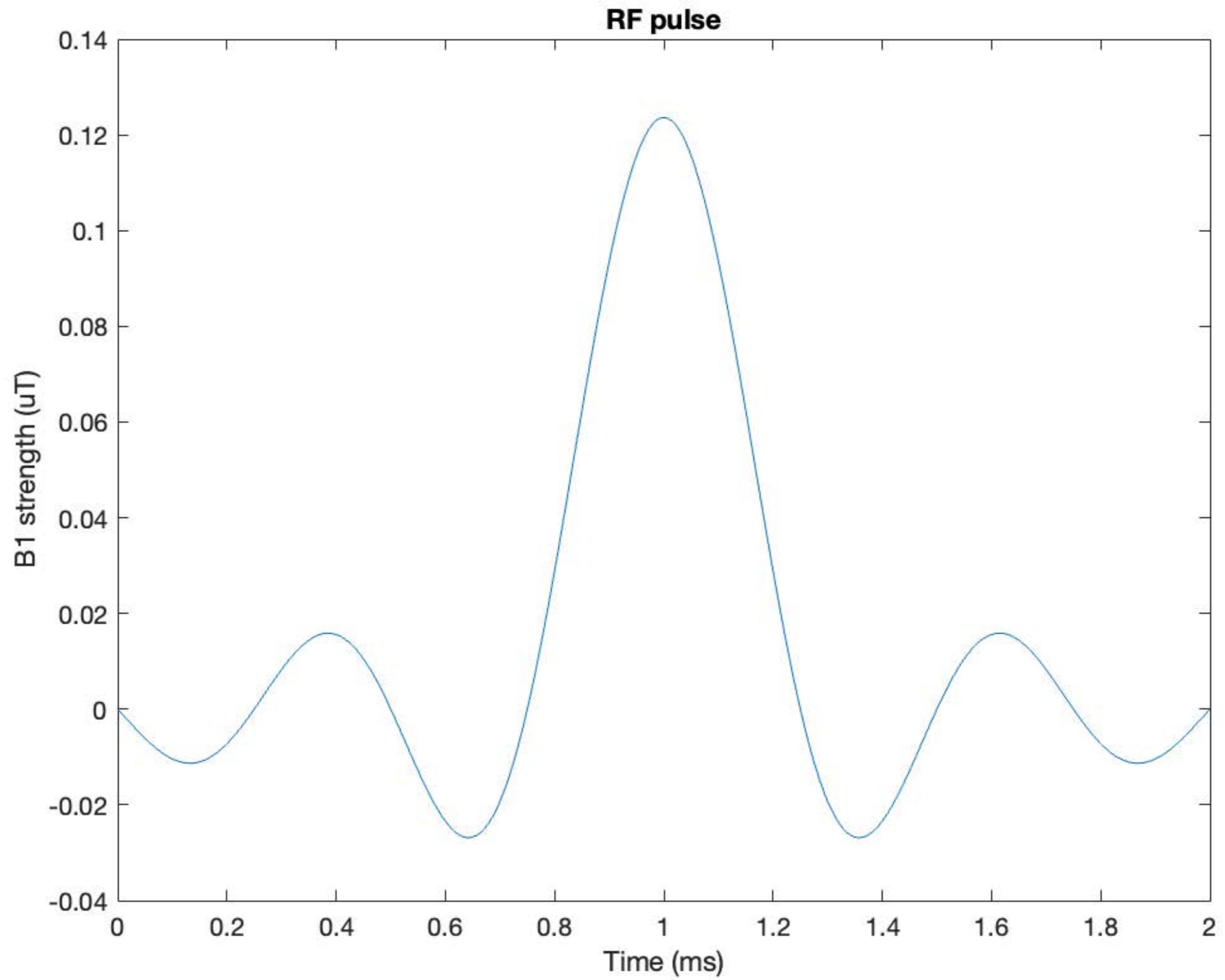
$$G_{\text{slice}} = \frac{\Delta f}{4 \Delta_{\text{slice}}} = \frac{4 \text{ kHz}}{42.58 \text{ MHz/T}} \cdot \frac{1}{5 \text{ mm}} = 18.8 \text{ mT/m} //$$

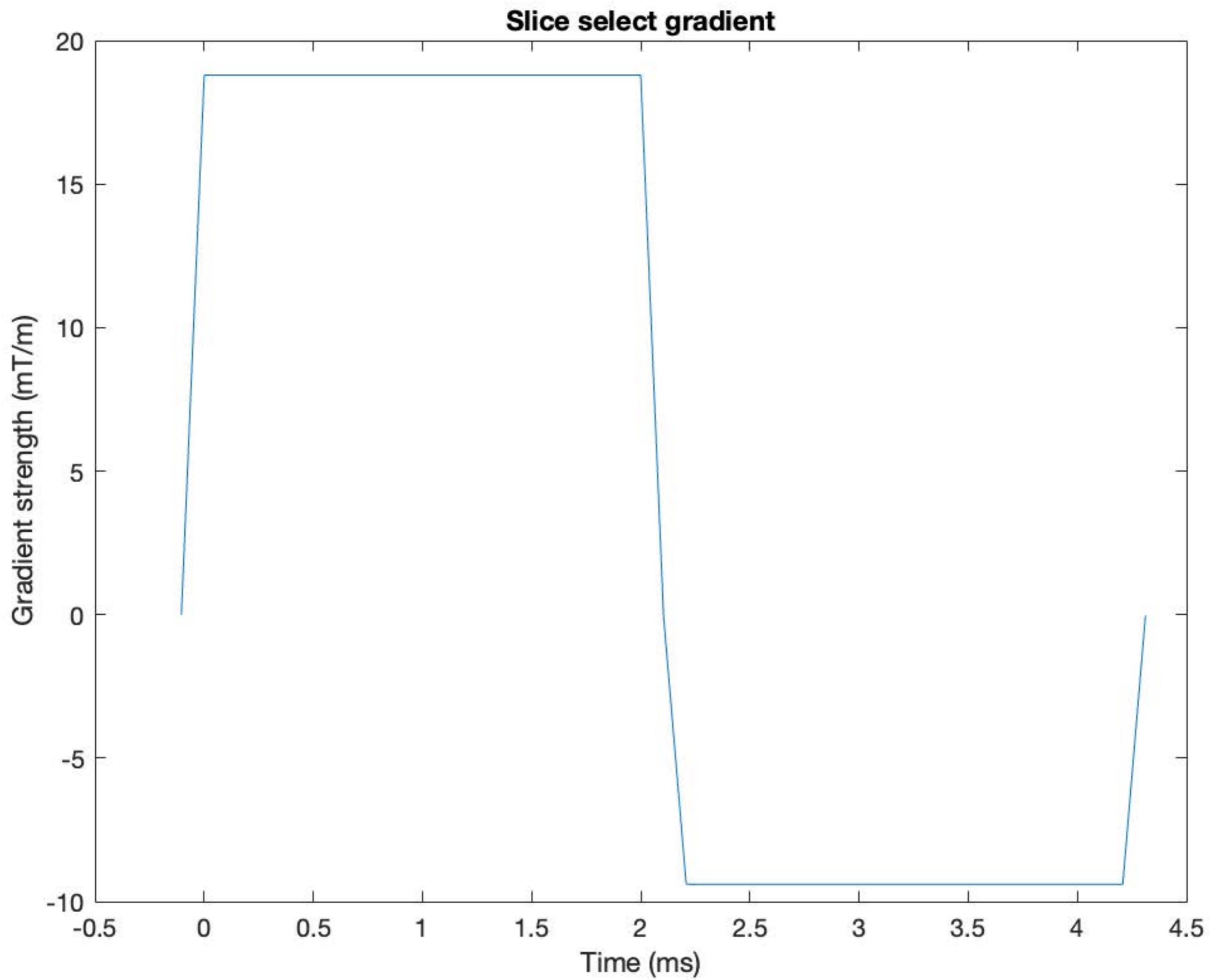
$$\text{ramp time} = \frac{18.8 \text{ mT/m}}{180 \text{ mT/m/ms}} = 104.4 \text{ } \mu\text{s}$$

$$\begin{aligned} \text{Total duration of } G_{\text{slice}} &= 2000 + 2 \cdot 104.4 \\ &= 2208.8 \text{ } \mu\text{s} // \end{aligned}$$

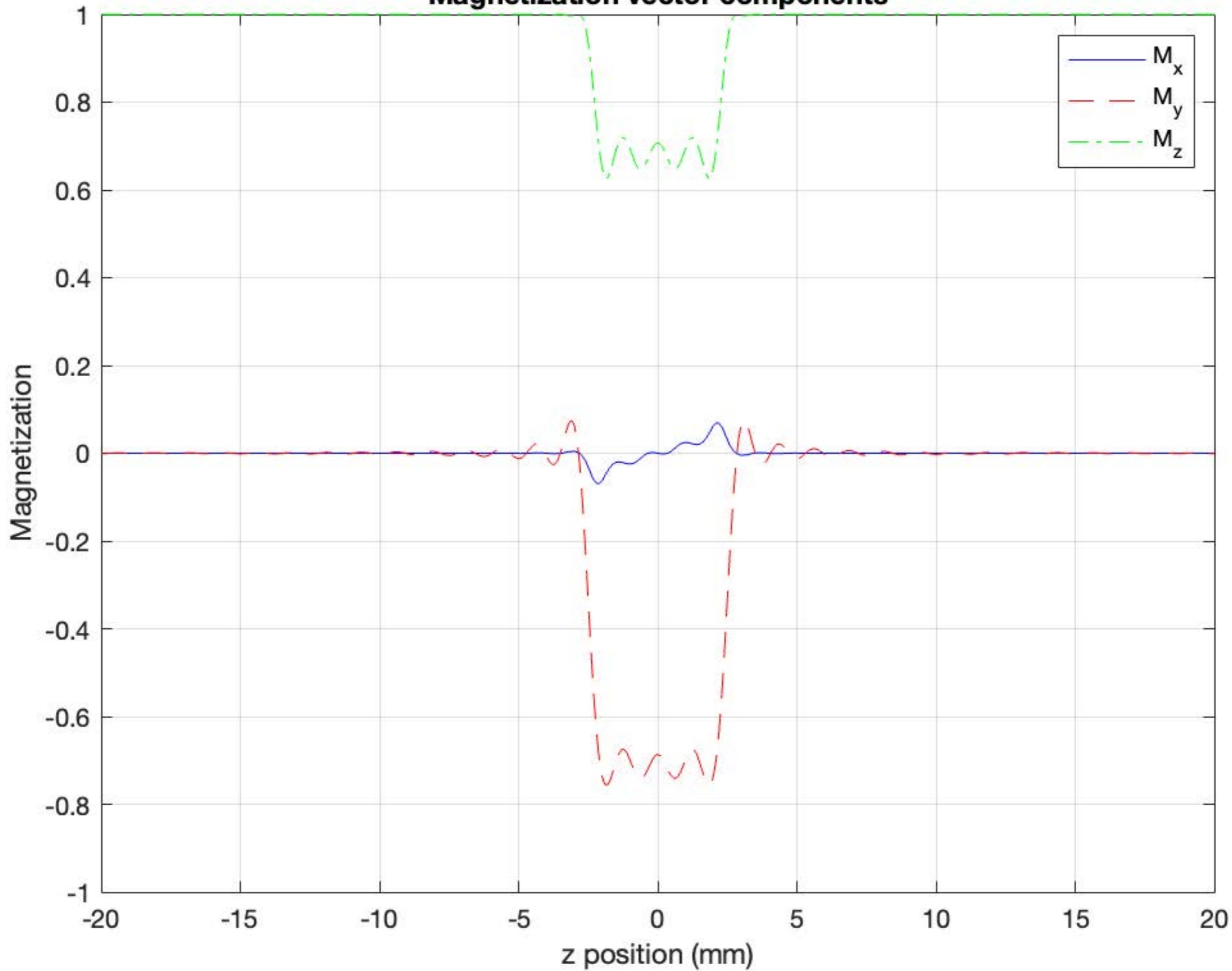
$$\text{Amplitude of rephasing gradient} = 18.8 \text{ mT/m} //$$

$$\begin{aligned} \text{Duration of rephasing gradient} &= 1000 + 2 \cdot 104.4 \\ &= 1208.8 \text{ } \mu\text{s} // \end{aligned}$$

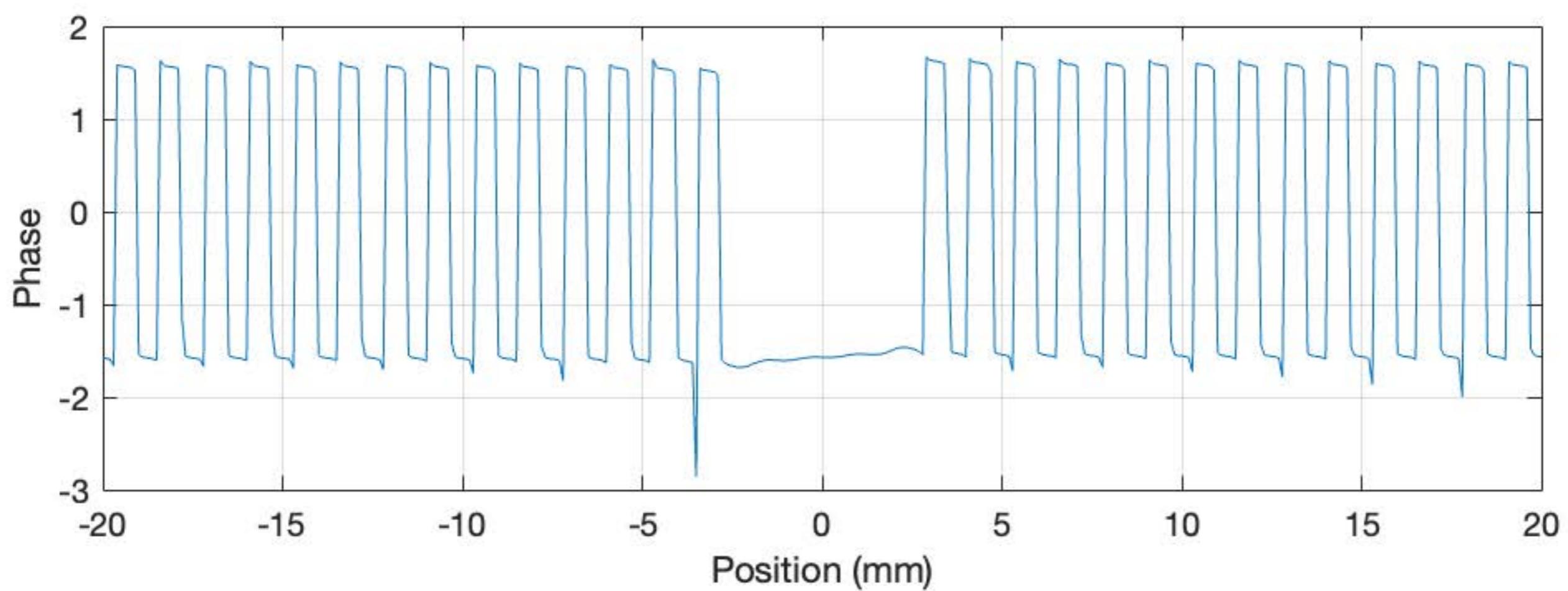
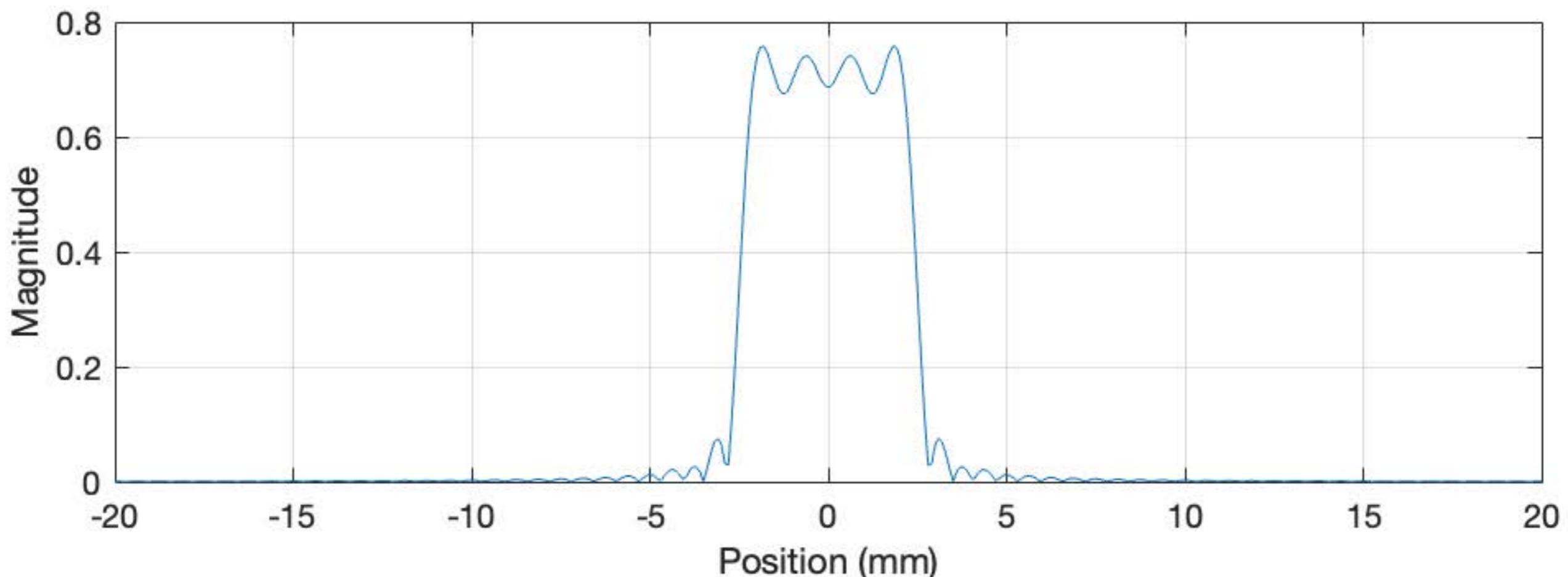




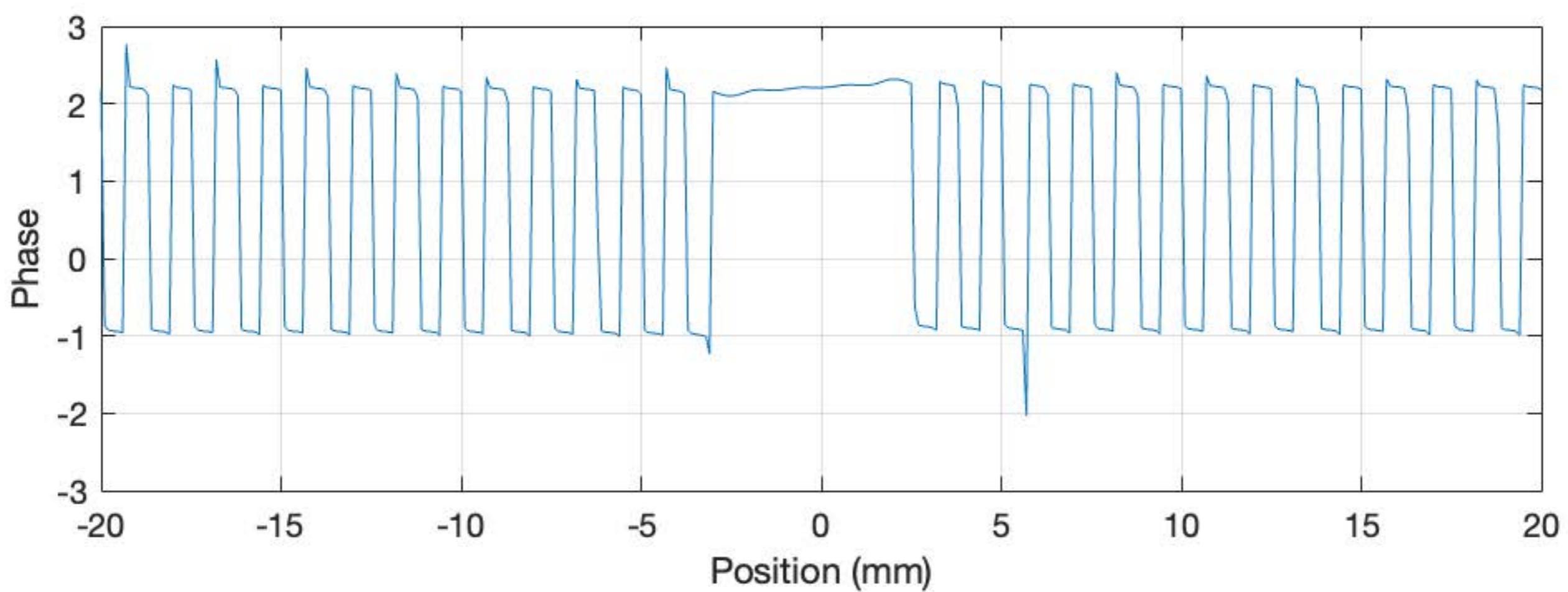
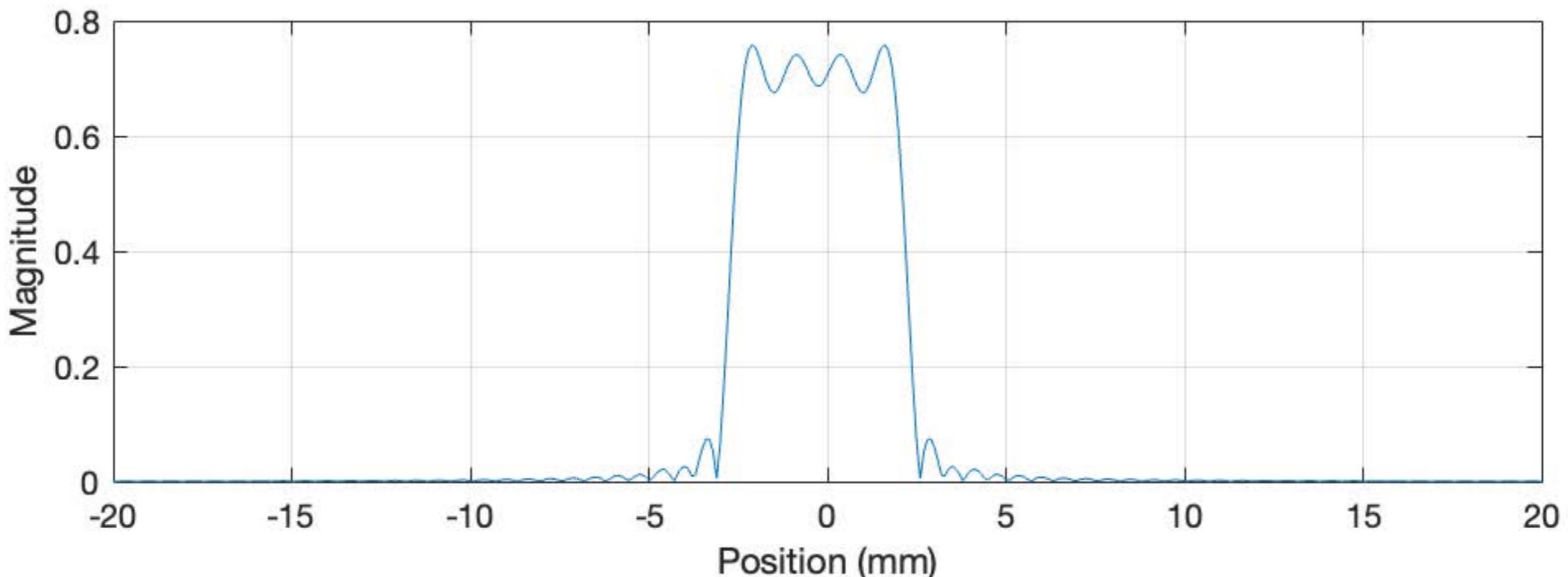
Magnetization vector components



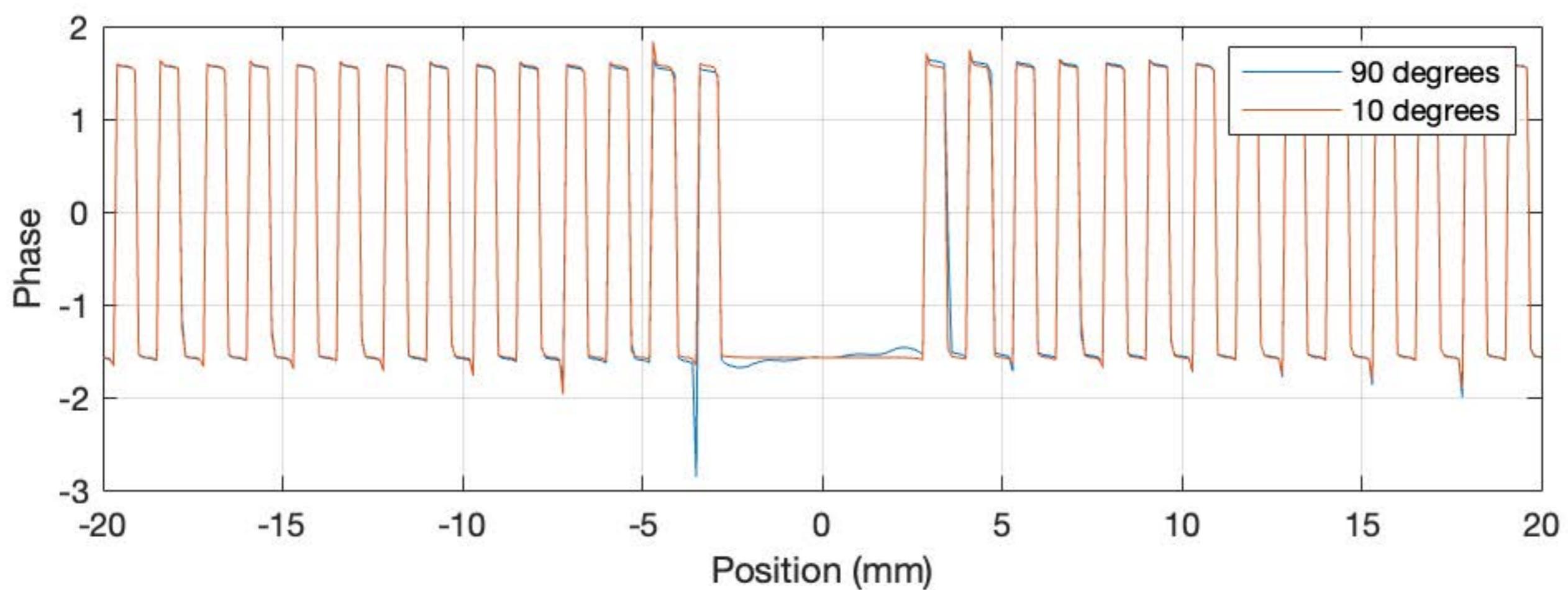
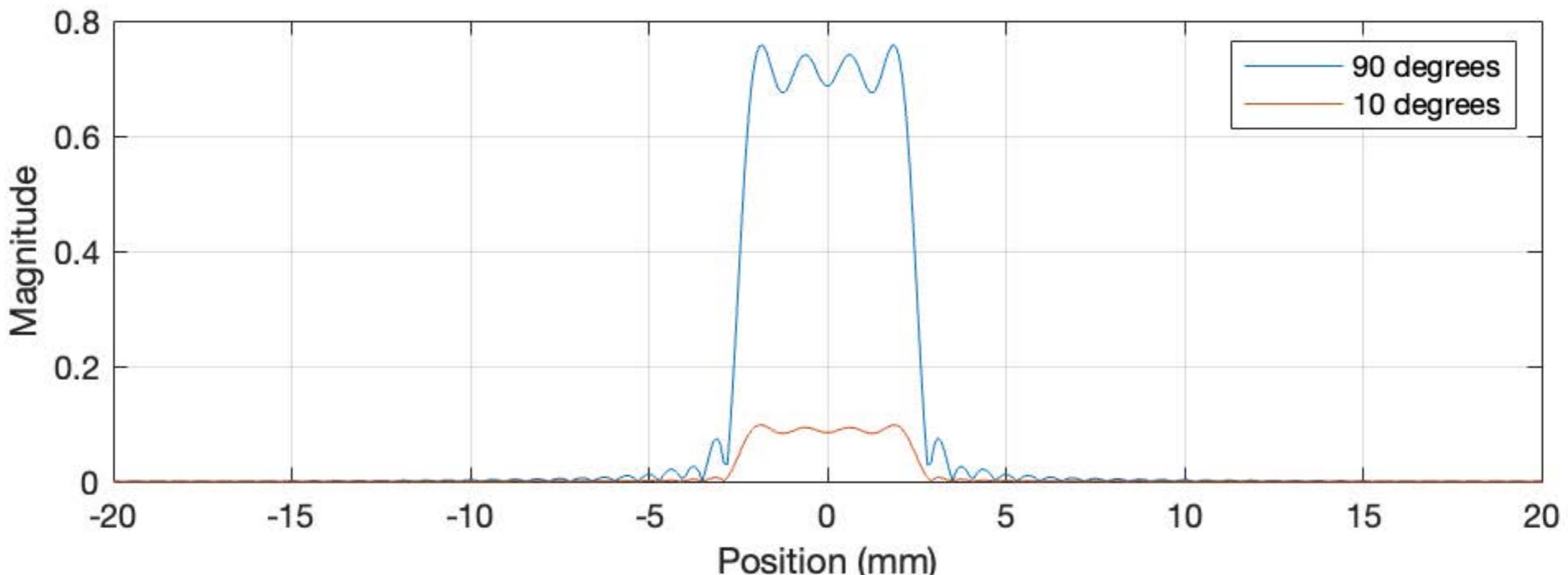
Transverse signal M_{xy}



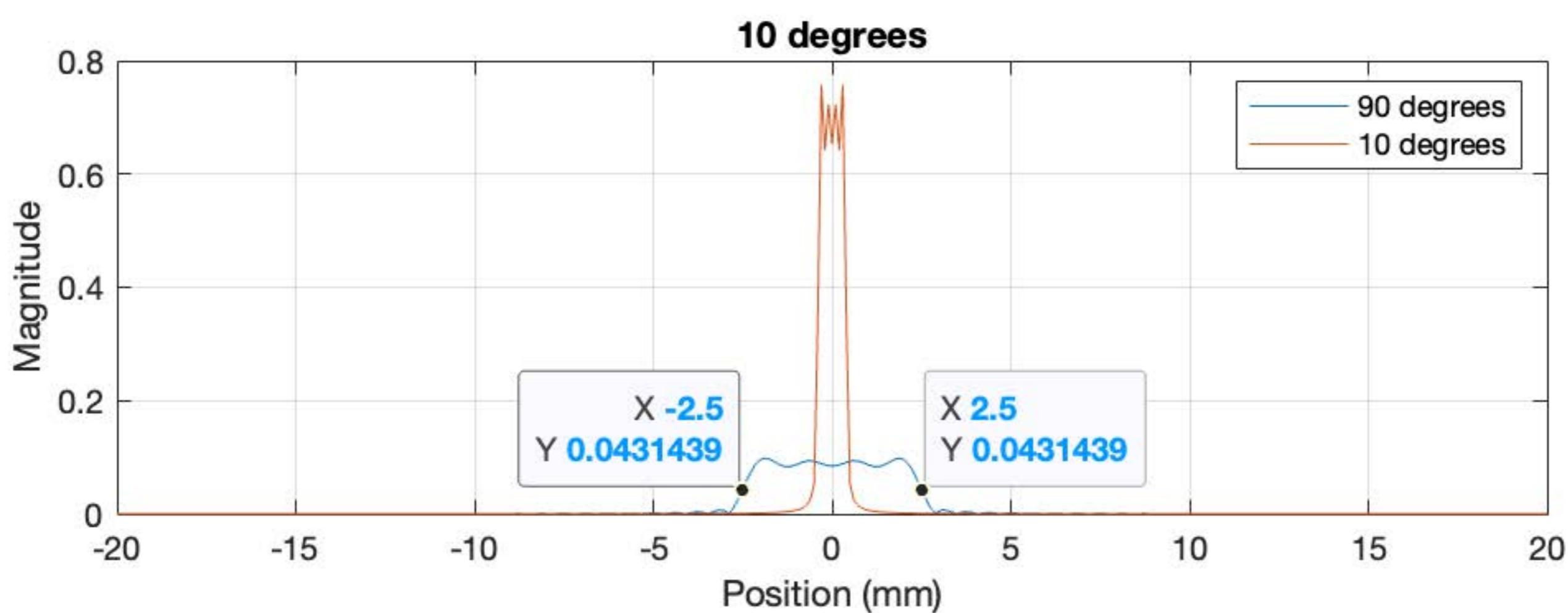
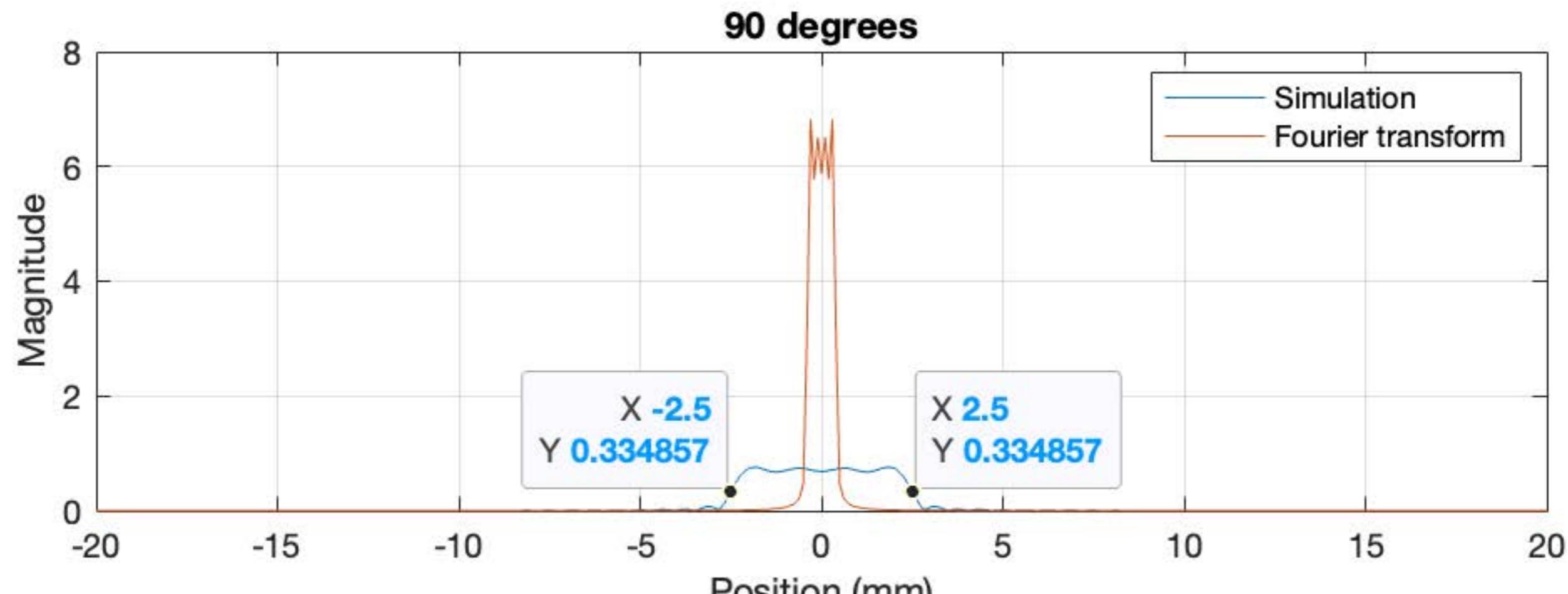
Transverse signal M_{xy} at 200 Hz off-resonance



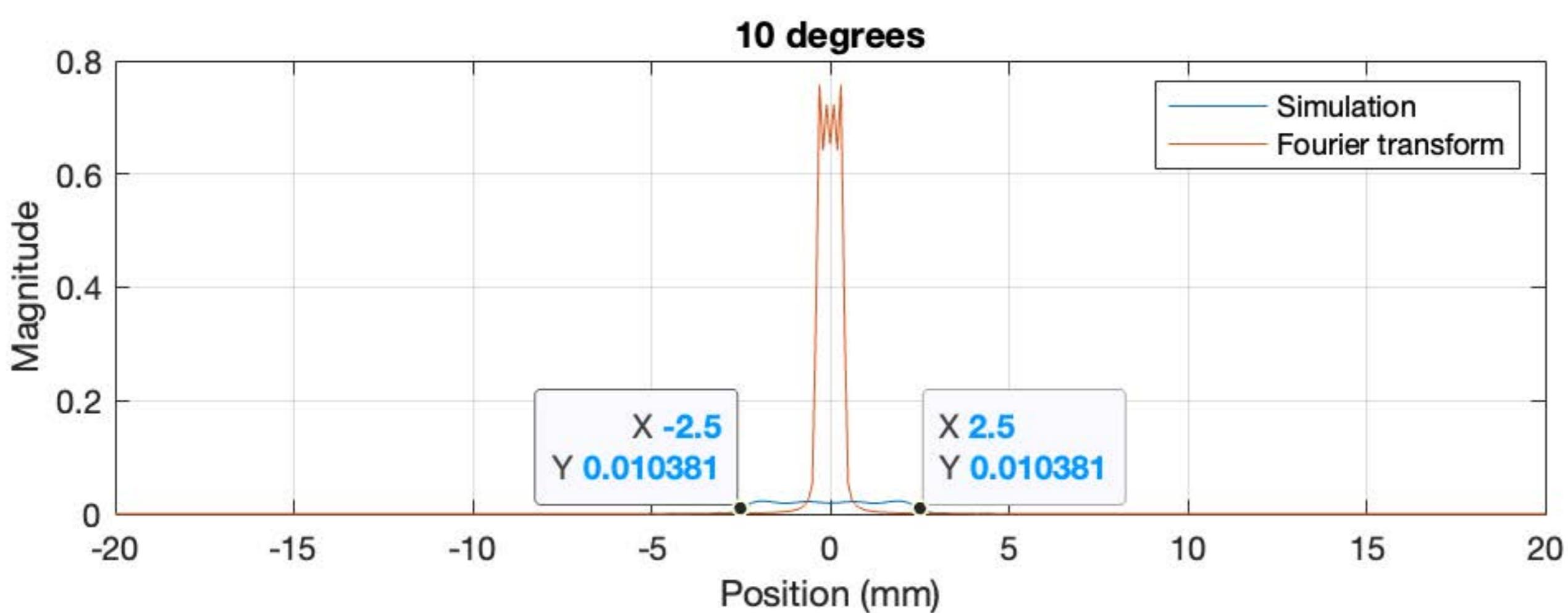
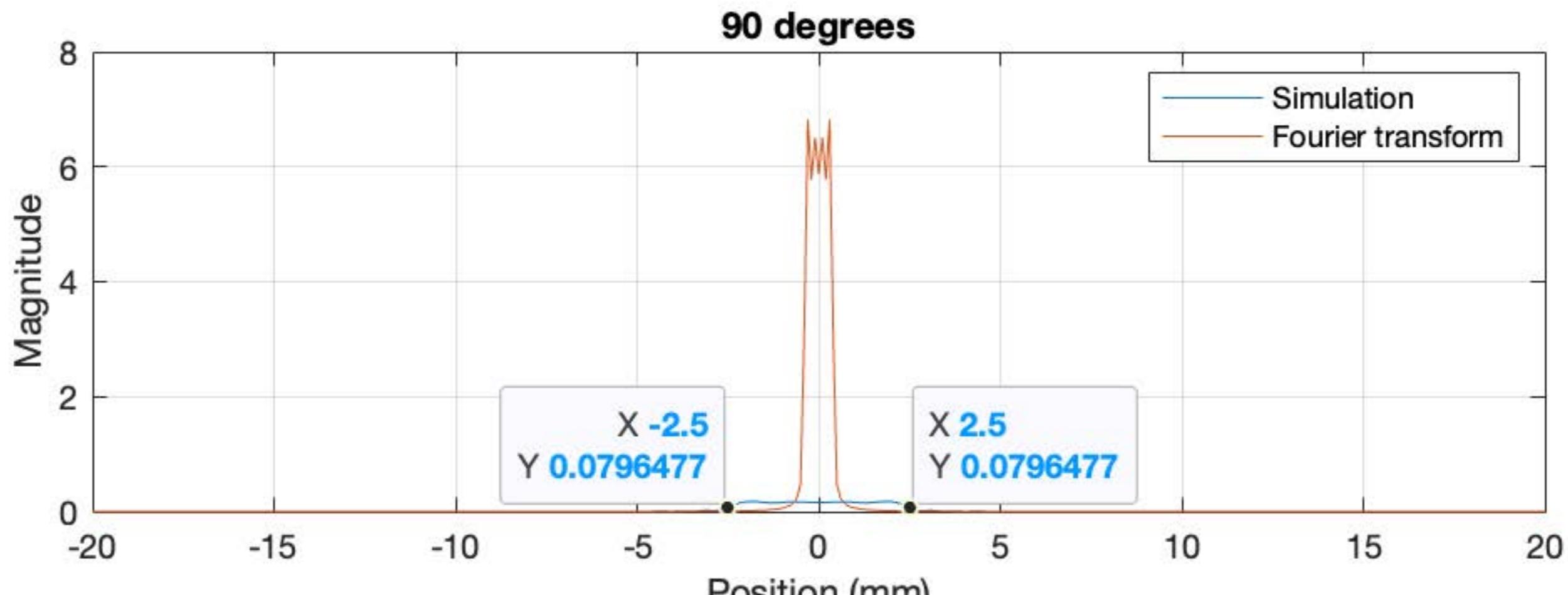
Transverse signal M_{xy} for different flip angles



Simulated vs FT slice profile for 90 and 10 degrees, T2 = 100 ms

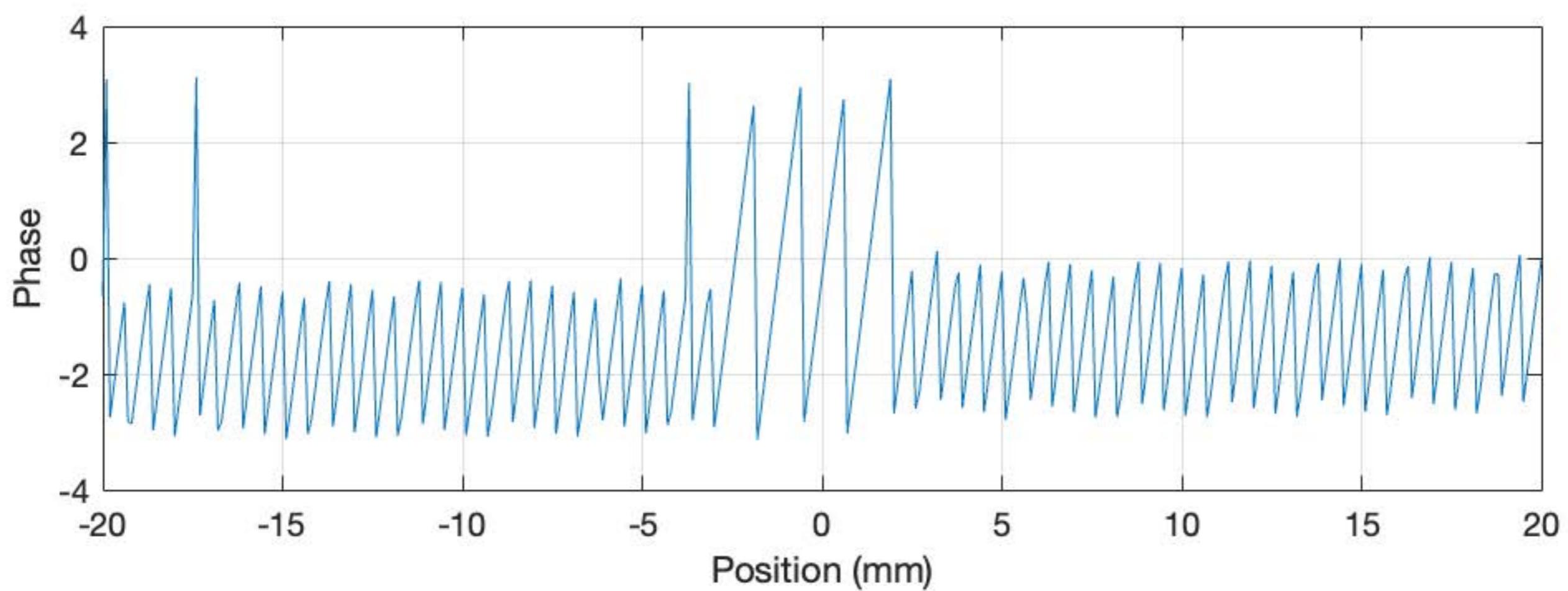
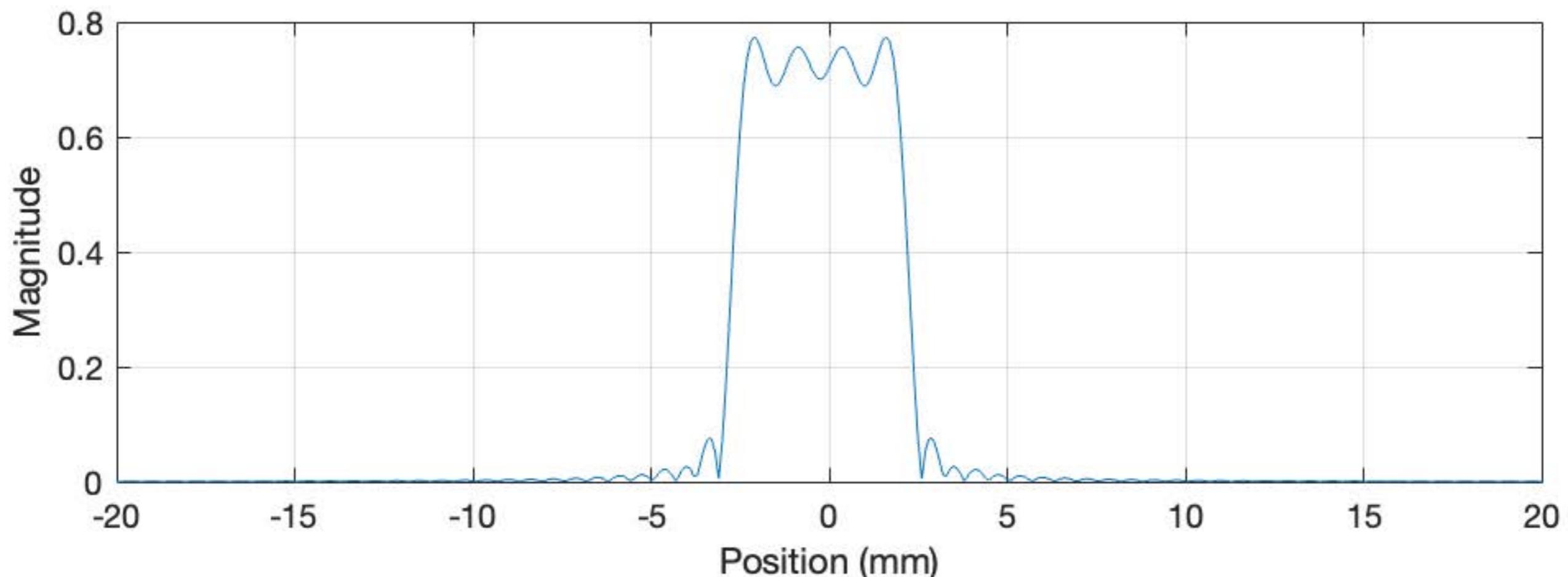


Simulated vs FT slice profile for 90 and 10 degrees, T2 = 2 ms

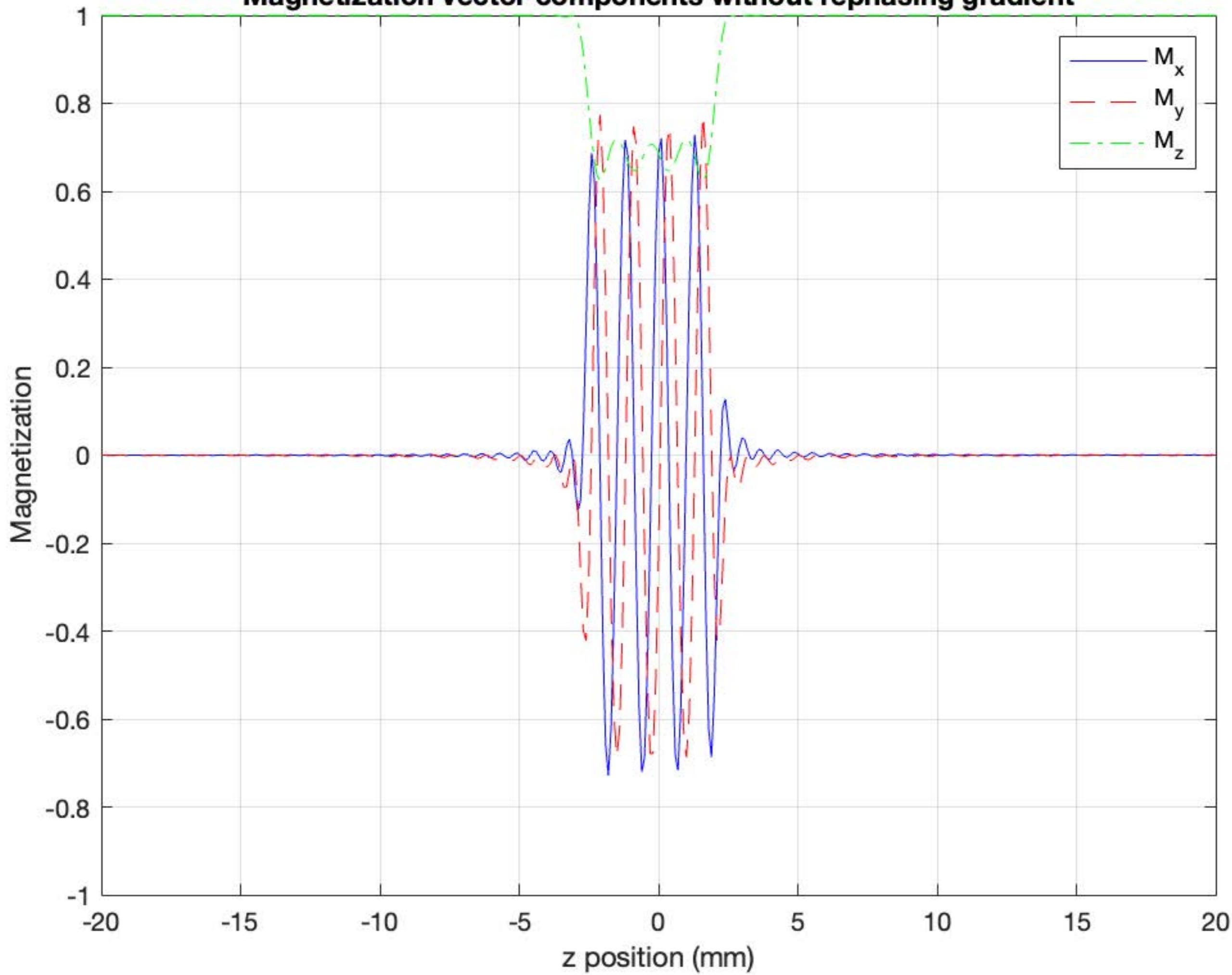


3) The slice profile obtained from Fourier Transforming the RF pulse results in a much narrower slice with much greater signal. The FT slice profile is also T2-independent, whereas the simulated slice profile basically decayed to zero when T2 decreased from 100 ms to 2 ms.

Transverse signal M_{xy} without rephasing gradient



Magnetization vector components without rephasing gradient



4) The slice rephasing gradient approximately cancels out the intraslice phase wrapping cause by the slice selection gradient.

Transverse signal M_{xy} for SMS excitation

