Supplement Information

XY-profiles and corresponding $bSSFPX_{asym}$ for $\Delta_{ws} \approx 1, 3, 9$ ppm and exchange rates from slow to fast exchange regime with $k_{sw} = 0.5\Delta_{ws}, \Delta_{ws}, 2\Delta_{ws}, 3\Delta_{ws}, 5\Delta_{ws}$ using $\alpha = 30^{o}$ and 45^{o} which are translated to $B_{1,field} \approx 0.97$ and 1.45 µT assuming TR = 2.025 ms are shown in Figs. S1 and S2, respectively.

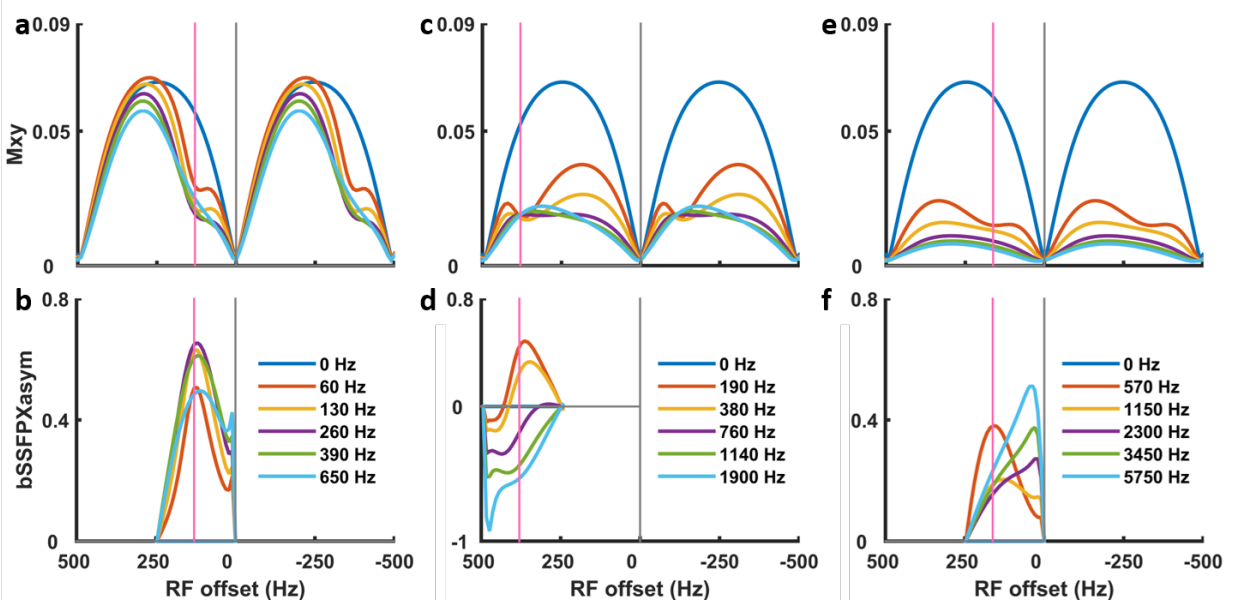

Figure S1. Two-pool simulations of bSSFPX profiles (a,c,e) and corresponding $bSSFPX_{asym}$ (b,d,f) for $\Delta_{ws} \approx$ 1ppm (a,b), $\Delta_{ws} \approx 3$ ppm (c,d), $\Delta_{ws} \approx 9$ ppm (e,f), assuming exchange rates from slow to fast exchange regime with $k_{sw} = 0.5\Delta_{ws}, \Delta_{ws}, 2\Delta_{ws}, 3\Delta_{ws}, 5\Delta_{ws}$ and using $\alpha = 30^{o}$ ($B_{1,field} \approx 0.97$ µT with TR = 2.025 ms).

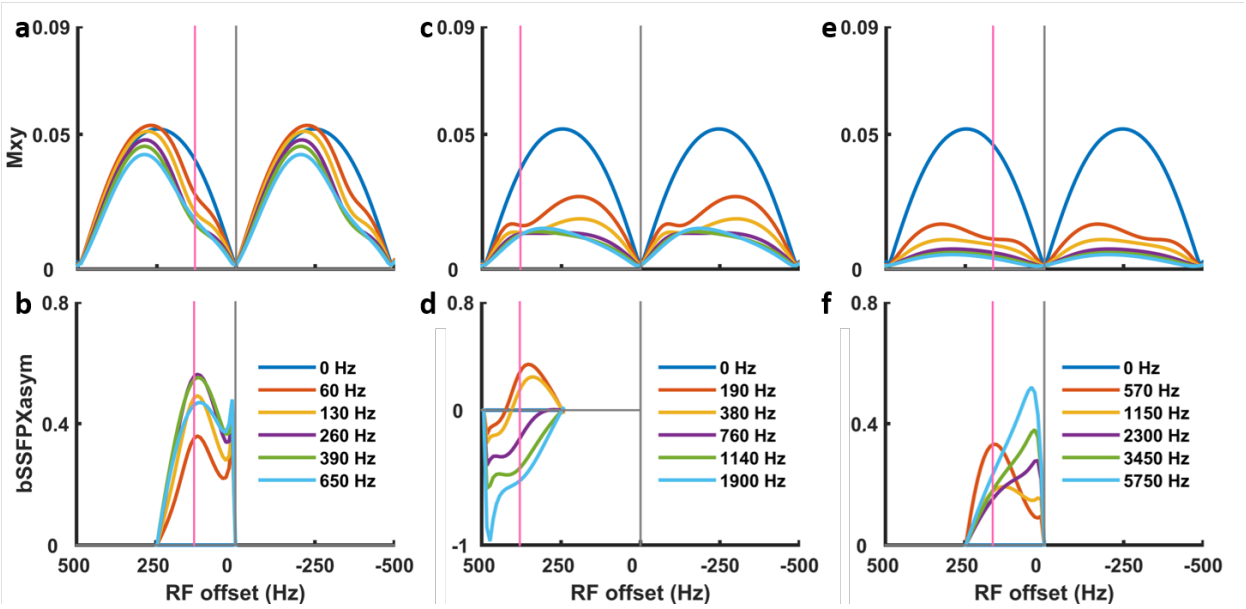

Figure S2. Two-pool simulations of bSSFPX profiles (a,c,e) and corresponding $bSSFPX_{asym}$ (b,d,f) for $\Delta_{ws} \approx 1$ ppm (a,b), $\Delta_{ws} \approx 3$ppm (c,d), $\Delta_{ws} \approx 9$ ppm (e,f), assuming exchange rates from slow to fast exchange regime with $k_{sw} = 0.5\Delta_{ws}$, Δ_{ws}, $2\Delta_{ws}$, $3\Delta_{ws}$, $5\Delta_{ws}$ and using $\alpha = 45^{o}$ ($B_{1,field} \approx 1.45$ µT with TR = 2.025 ms).

$bSSFPX_{asym}$ and MTR_{asym} are compared (Fig. S3) to evaluate the bSSFPX performance for different exchange rates and saturation powers.

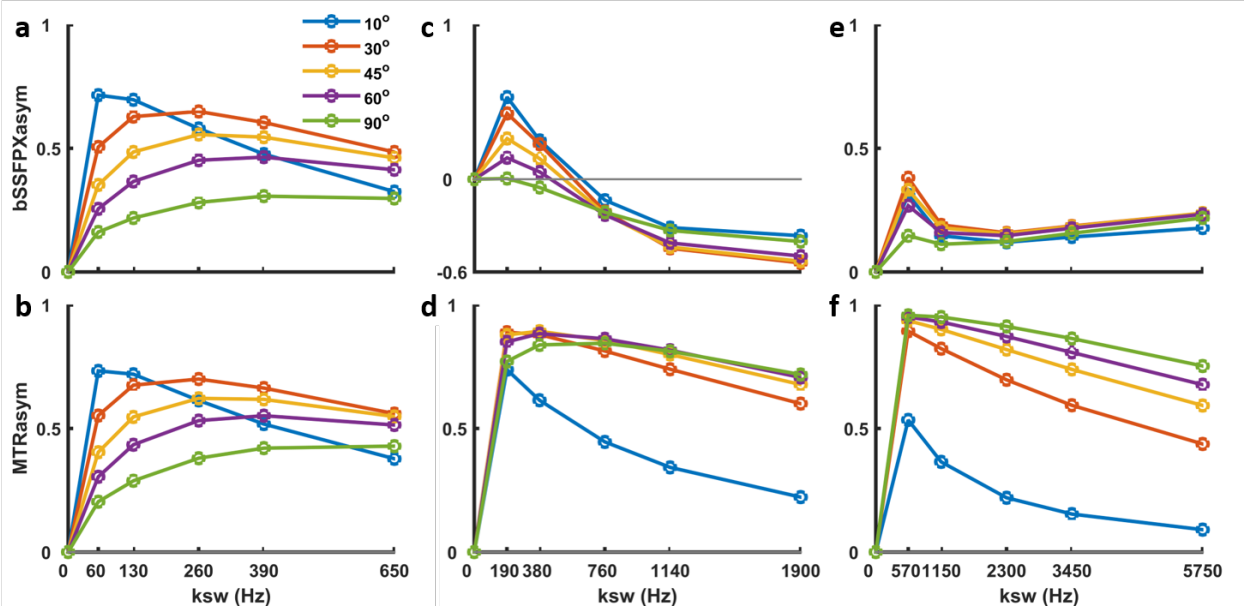

Figure S3. Two-pool simulations of $bSSFPX_{asym}$ (a-c) and MTR_{asym} (d-f) for $\Delta_{ws} \approx 1$ ppm (a,b), $\Delta_{ws} \approx 3$ ppm (c,d) and $\Delta_{ws} \approx 9$ ppm (e,f), assuming exchange rates from slow to fast exchange regime with $k_{sw} = 0.5\Delta_{ws}$, Δ_{ws}, $2\Delta_{ws}$, $3\Delta_{ws}$, $5\Delta_{ws}$ and using $\alpha = 10^{o}$, 30^{o}, 45^{o}, 60^{o}, 90^{o} ($B_{1,field} \approx 0.32$, 0.97, 1.45, 1.93 and 2.90 µT with TR = 2.025 ms).

Two special conditions for the CEST metric $bSSFPX_{asym}$ are shown in Fig. S4.

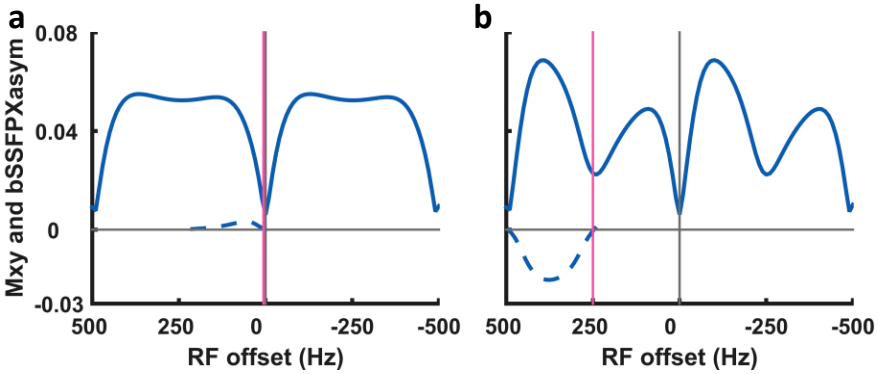

Figure S4. Two-pool simulations of bSSFPX profiles (solid line) and corresponding $bSSFPX_{asym}$ normalized to the water pool size (dotted line) for Δ_{ws} = 250 Hz (a) and 500 Hz (b). For TR = 2.025 ms, Δ_{ws} = 250 Hz is about one half cycle and 500 Hz is about one full cycle. In the simulation, k_{sw} = 250 Hz and $\alpha = 10^{o}$, other simulation parameters are the same as described in the Section 3.1.

The $bSSFPX_{asym}$ and MTR_{asym} are compared (Fig. S5) to further characterize the performance of bSSFPX for different exchange rates and saturation powers.

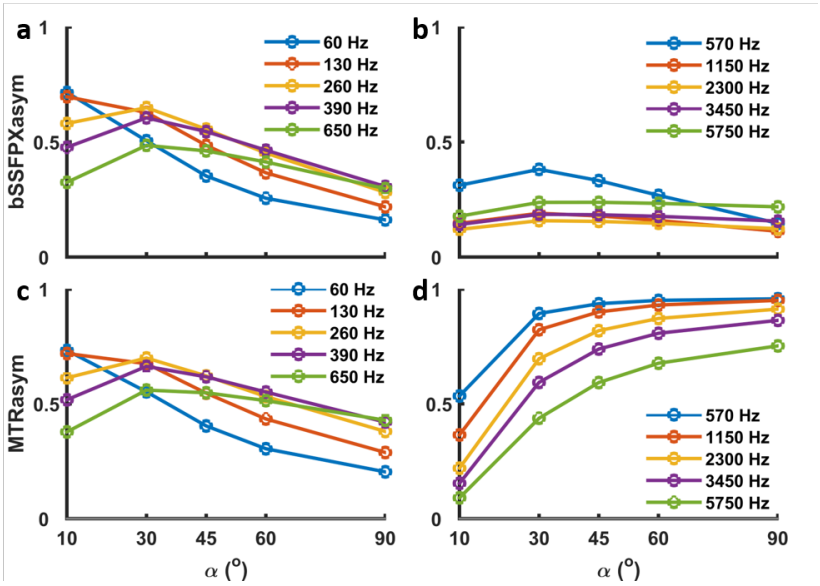

Figure S5. Two-pool simulations of $bSSFPX_{asym}$ (a,b) and MTR_{asym} (c,d) for $\Delta_{ws} \approx 1$ (a,c) and $\Delta_{ws} \approx 9$ ppm (b,d), assuming exchange rates from slow to fast exchange regime with $k_{sw} = 0.5\Delta_{ws}$, Δ_{ws}, $2\Delta_{ws}$, $3\Delta_{ws}$, $5\Delta_{ws}$ and using $\alpha = 10^{o}$, 30^{o}, 45^{o}, 60^{o}, 90^{o} ($B_{1,field} \approx 0.32$, 0.97, 1.45, 1.93 and 2.90 μT with TR = 2.025 ms).

Standard Z-spectra of phantoms I and II (Fig.S6) were acquired using sequence and parameters described in Methods.

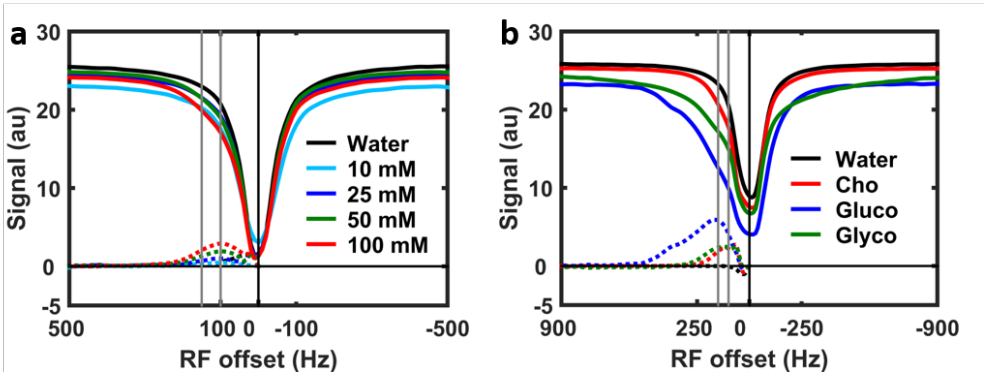

Figure S6. Z-spectra and non-normalized MTR_{asym} for (a) different concentrations of choline solutions: 0 (black), 10 mM (light blue), 25 mM (indigo), 50 mM (green) and 100 mM (red) and (b) different molecules: water (black), choline (Cho, red), glucose (Gluco, blue) and glycogen (Glyco, green). The solid and dotted lines correspond to profiles and asymmetry, respectively. A set of two vertical lines on the downfield side indicates the frequency range 100-150 Hz in which the MTR_{asym} is averaged as shown in Figs. 9c and 10c.