1 Non-Uniformity Effect on the Trajectory

The non-uniformity of B causes changes in the Larmor frequency ω of the molecules as

$$\omega = \gamma * B$$

where γ is the gyromagnetic ratio of the nuclei. Adding the non-uniformity effect would make our equation

$$\omega^{'} = \omega + \delta\omega = \gamma * (B + \delta B)$$

For our example we have $B = 1.5T$ and $\delta B = \pm 1$. So, $B_{+} = 2.5T$ and $B_{-} = 0.5T$ A change to the Larmor frequency $\delta\omega$ occurs

$$\delta\omega = \omega^{'} - \omega = \gamma * (B + \delta B) - \gamma * B = \gamma * \delta B$$

$$\delta\omega = \pm 1 * \gamma$$

For protons, $\gamma = 26.75 * 10^{7} T^{-1}.s^{-1}$

```
B = 1.5
BPositive = 2.5
BNegative = 0.5
gyroRatio = 30
w = gyroRatio * B
wPositive = gyroRatio * BPositive
wNegative = gyroRatio * BNegative
T1 = 490/1000
T2 = 43/1000
t = np.arange(start=0, stop=10, step=0.001)

omega = 2*np.pi*w*t
omegaPositive = 2*np.pi*wPositive*t + np.pi/8
omegaNegative = 2*np.pi*wNegative*t - np.pi/8
```

For precising of the protons in the X-Y plane

$$M_x(t)/M_o = e^{-\frac{t}{T_2}} \sin(\omega t)$$

$$M_y(t)/M_o = e^{-\frac{t}{T_2}} \cos(\omega t)$$

When there is a non-uniformity in B, hence, in ω,

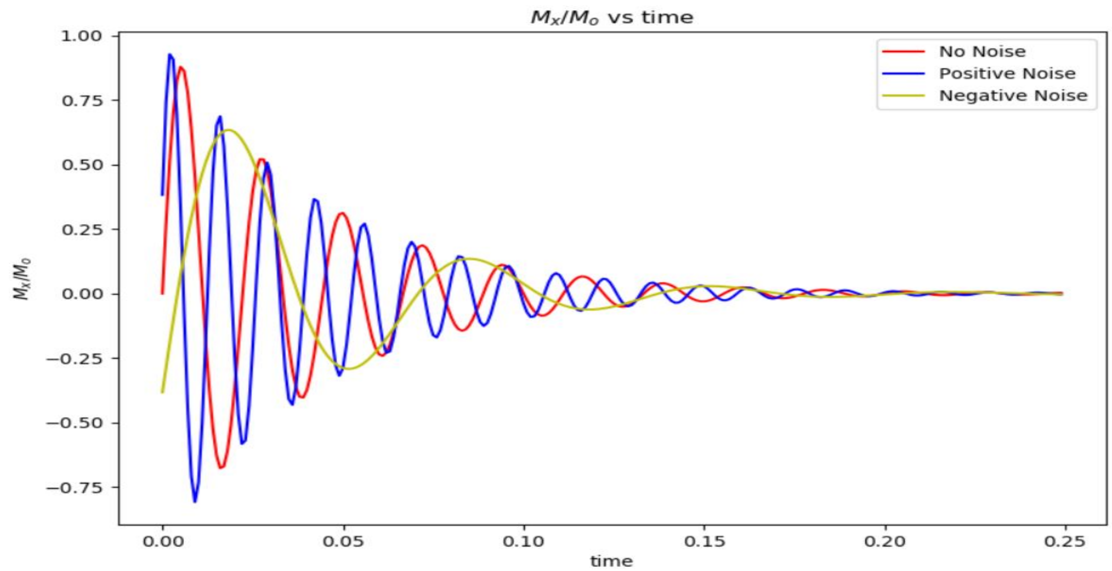
$$M_x^{'}(t)/M_o = e^{-\frac{t}{T_2}} \sin(\omega^{'} t)$$

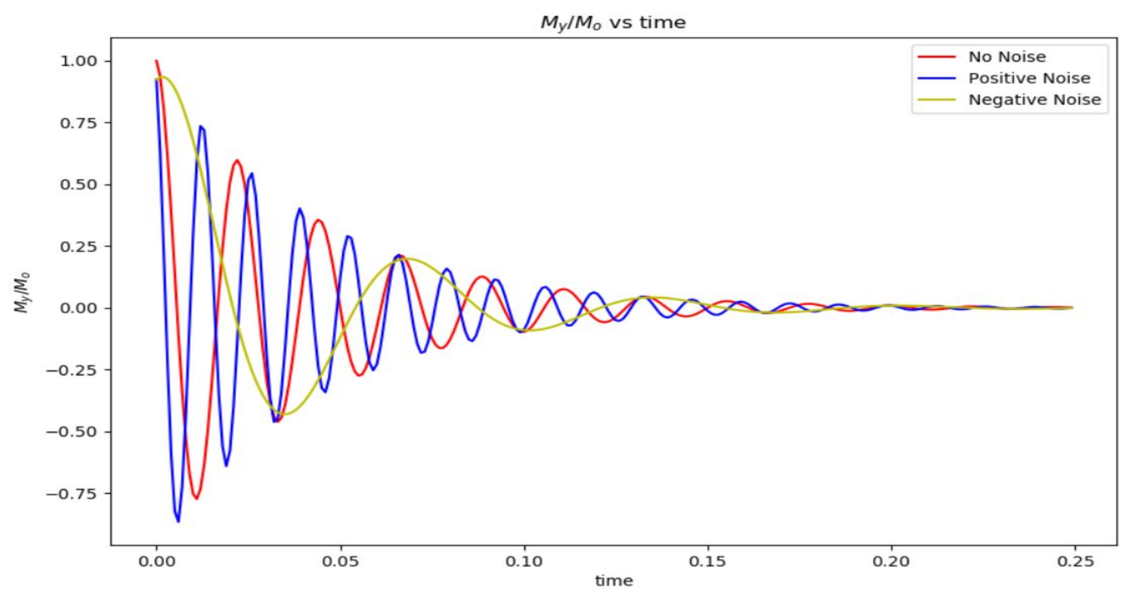
$$M_y^{'}(t)/M_o = e^{-\frac{t}{T_2}} \cos(\omega^{'} t)$$

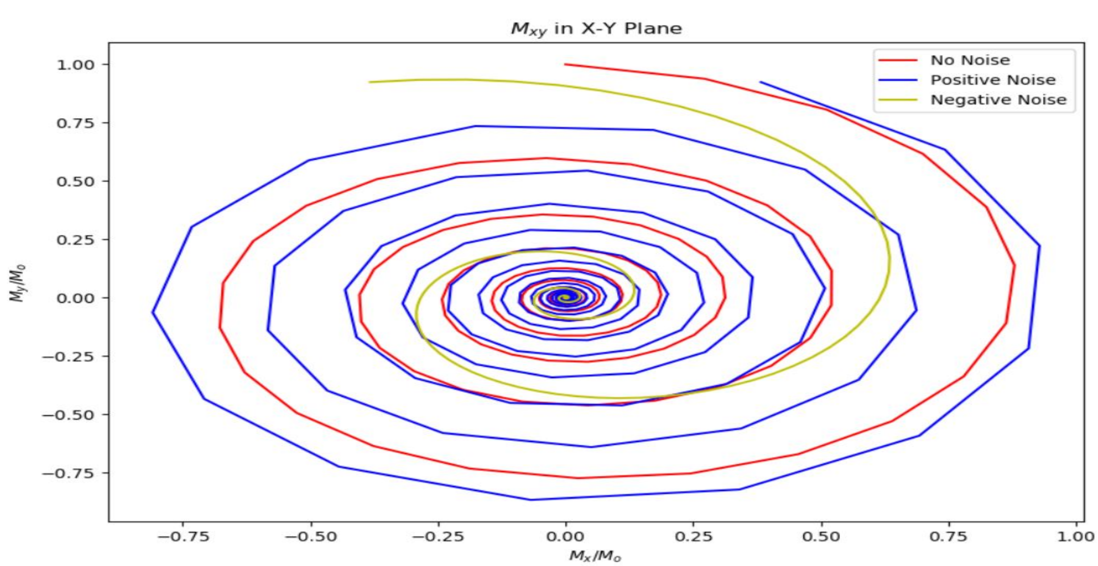
```
Mx = np.exp(-1*t/T2)*np.sin(omega)
MxPositive = np.exp(-1*t/T2)*np.sin(omegaPositive)
MxNegative = np.exp(-1*t/T2)*np.sin(omegaNegative)


My = np.exp(-1*t/T2)*np.cos(omega)
MyPositive = np.exp(-1*t/T2)*np.cos(omegaPositive)
MyNegative = np.exp(-1*t/T2)*np.cos(omegaNegative)
```

Plotting the results of M_x, M_y and M_{xy} with the non-uniformity effects for each, we get these results,







2 K-space

K-space is an array of numbers representing spatial frequencies in the MR image. Each number's value represents the relative contribution of its unique spatial frequency to the final image. The k-space and MR image may be converted to one another using the **Fourier Transform**. The cells of k-space are commonly displayed on rectangular grid with principal axes k_x and k_y. The k_x and k_y axes of k-space correspond to the horizontal (x-) and vertical (y-) axes of the image.

Note: The individual points (k_x,k_y) in k-space do not correspond one-to-one with individual pixels (x,y) in the image. Each k-space point contains spatial frequency and phase information about **every** pixel in the final image.