HW02 Report: Virtual MRI Scanner Report

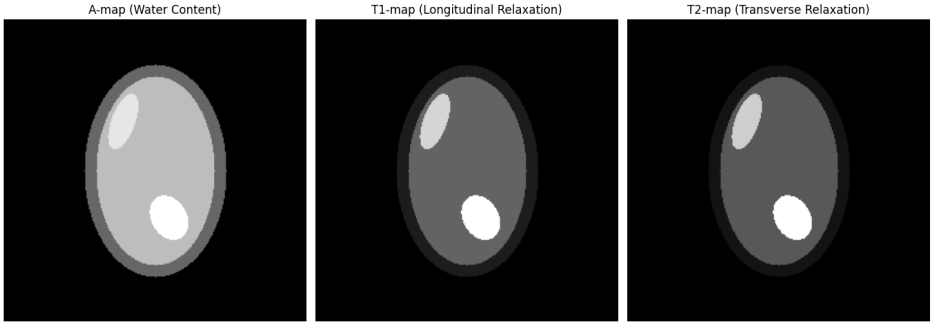
Introduction

In this assignment, a simple MRI scanner using a modified Shepp-Logan phantom was simulated . The phantom was divided into four distinct compartments, each with unique MRI properties such as water content (A), longitudinal relaxation time (T1), and transverse relaxation time (T2). These properties were then used to generate MRI images by calculating the signal intensity (SI) based on different acquisition parameters: repetition time (TR) and echo time (TE).

Q.1 Physical Properties Maps

The physical properties maps for the phantom are as follows:

- **A-map**: Shows the water content for each voxel.
- **T1-map**: Displays the longitudinal relaxation time for each compartment.
- **T2-map**: Displays the transverse relaxation time for each compartment.



Q.2 Signal Intensity for Different TR and TE Values

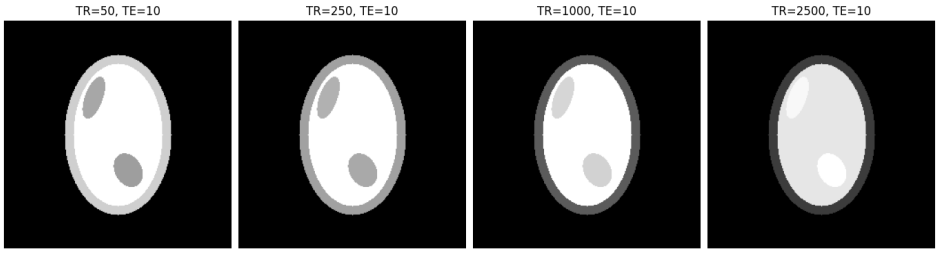
Q.2.1 Signal Intensity Calculation

The following table shows the signal intensity values for each compartment at different TR and TE values:

Compartment	A	T1	T2	SI (TR=50, TE=10)	SI (TR=250, TE=10)	SI (TR=1000, TE=10)	SI (TR=2500, TE=10)
1	1.0	250	10	0.20	0.38	0.58	0.73
2	0.85	625	35	0.17	0.32	0.47	0.60
3	0.40	1000	60	0.10	0.21	0.31	0.41
4	0.65	1375	85	0.12	0.22	0.33	0.43

Q.2.2 MRI Images for Different TR and TE

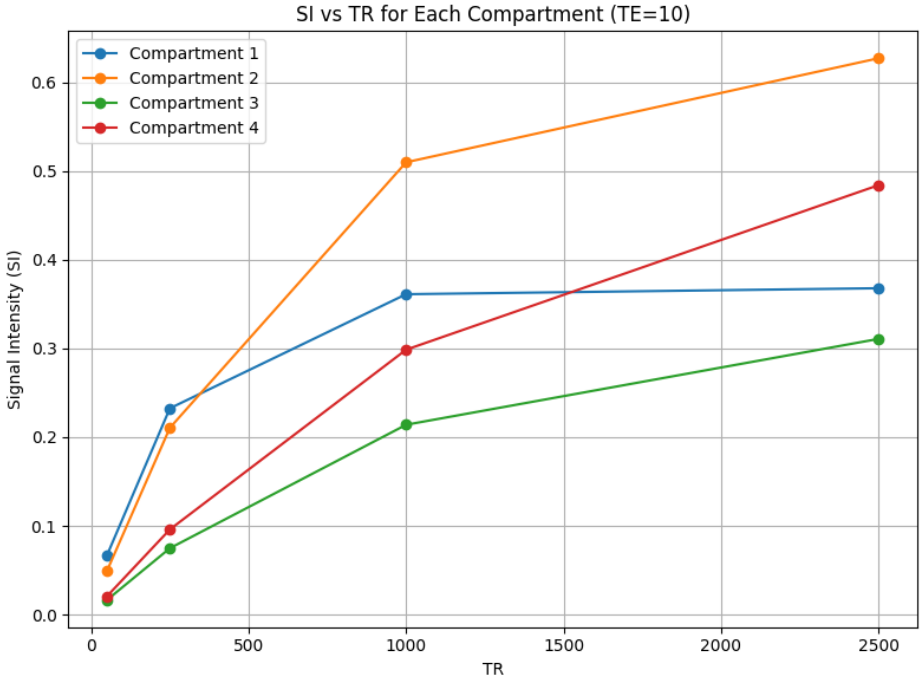
We generated four MRI images using the signal intensities calculated above for different TR and TE values. Each image contains a legend that displays the TR and TE values used for the acquisition and the calculated SI for each compartment.



Q.2.3 Effect of TR on Signal Intensity

We plotted the signal intensity (SI) versus TR for each compartment to observe how increasing TR affects the signal intensity.

Observation: As TR increases, the signal intensity also increases. This is especially noticeable for compartments with higher T1 values, as they take longer to recover their longitudinal magnetization.

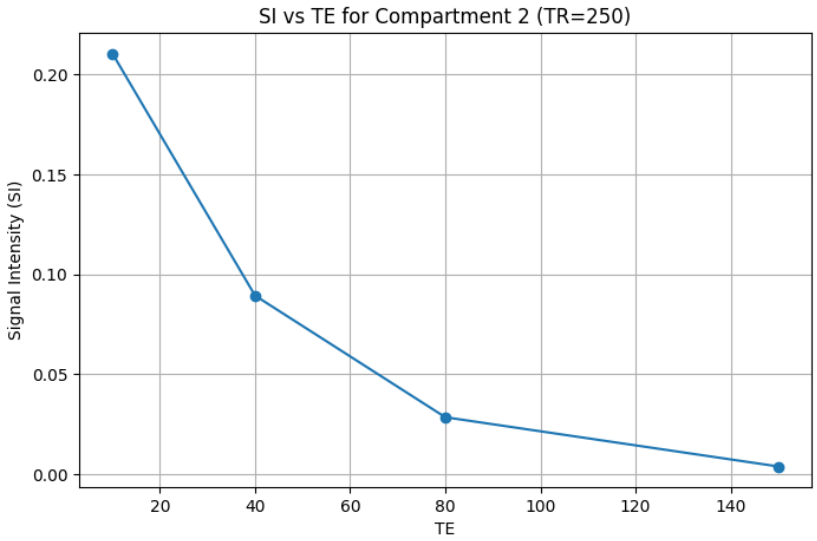


Q.2.4 Effect of TE on Signal Intensity for Compartment 2

For Compartment 2, we fixed TR at 250 and varied TE values at 10, 40, 80, and 150 to calculate the signal intensity. The results are shown in the table below:

TE	SI (for Compartment 2, TR=250)
10	0.22
40	0.09
80	0.03
150	0.01

Observation: As TE increases, the signal intensity decreases because transverse magnetization decays over time. Higher TE values allow more time for the decay, reducing the signal.



Q.3 Evaluation Metrics

Q.3.1 Structural Similarity Index (SSIM)

To assess the similarity between the generated images, we computed the Structural Similarity Index (SSIM) between Image 1 (TR=50, TE=10) and the other three images.

- **SSIM between Image 1 and Image 2 (TR=250)**: 0.801
- **SSIM between Image 1 and Image 3 (TR=1000)**: 0.741
- **SSIM between Image 1 and Image 4 (TR=2500)**: 0.734

Observation: As TR increases, the similarity between the images decreases, as shown by the decreasing SSIM values. This is expected because higher TR values lead to greater contrast differences between the tissues.

4. Conclusion

This assignment successfully simulated MRI images using a digital phantom with different compartments. By adjusting the acquisition parameters (TR and TE), we observed how signal intensity changes based on tissue properties (T1 and T2) and scanner settings. The SSIM analysis showed how image similarity changes as TR increases.