Lab 5: Manipulating data in the time, space, and frequency domains

GAIA Statement: I **did** use a form of generative AI during the completion of this assignment. If I did, I understand that I must also turn in a completed copy of the course's GAIA Disclosure Worksheet for this assignment.

Part 1: Setting up the oscilloscope and function generator.

[Nothing required]

Part 2: Generating and visualizing waveforms.

[Nothing required]

Part 3: Understanding DC offsets.

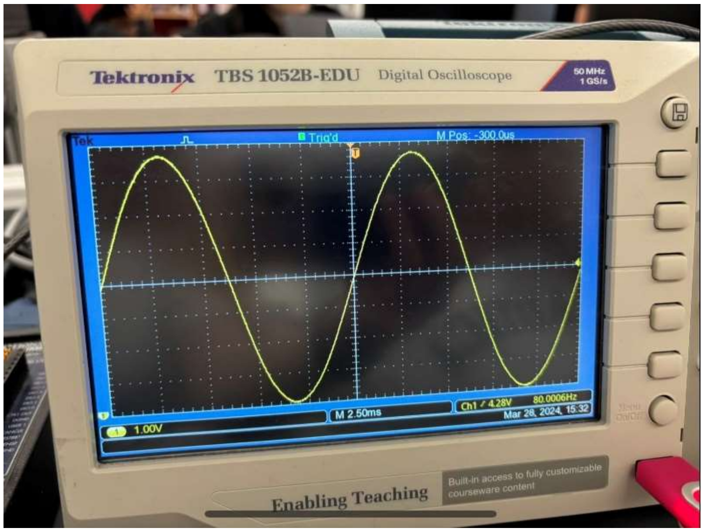
[Nothing required]

Part 4: Understanding triggering.

Include the settings calculated in **Part 4, Step 1**.

Voltage: 1V **Time:** 2ms

Include a photograph of the oscilloscope with a triggered display of the 80 Hz sine wave you acquired in **Part 4, Step 5**.



Part 5: Acquiring and filtering signals.

Frequency of Input (Hz)	Unfiltered Filename	Lowpass, 1μF Filename	Lowpass, 10μF Filename
0.5	Lab5_p5_0.5.csv	Lab5_p5_1uF_0.5.csv	Lab5_p5_10uf_0.5.csv
2	Lab5_p5_2.csv	Lab5_p5_1uF_2.csv	Lab5_p5_10uf_2.csv

8	Lab5_p5_8.csv	Lab5_p5_1uF_8.csv	Lab5_p5_10uf_8.csv
32	Lab5_p5_32.csv	Lab5_p5_1uF_32.csv	Lab5_p5_10uf_32.csv
128	Lab5_p5_128.csv	Lab5_p5_1uF_128.csv	Lab5_p5_10uf_128.csv

Part 6: Examining waveforms in the time and frequency domains.

Include the figures you generated in **Part 6** (**Figures 1-3**). Don't forget to include appropriate titles, axis labels, font sizes, etc.

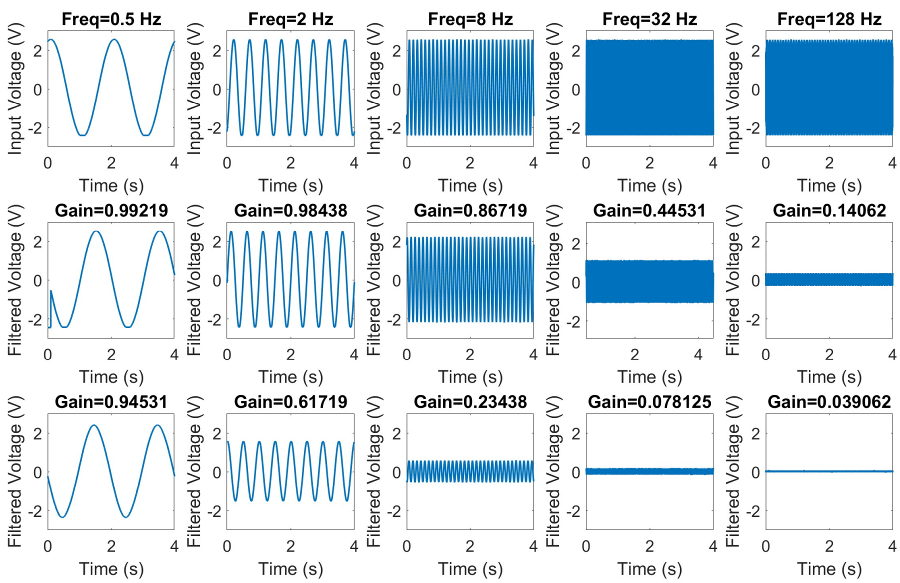


Figure 1. Filtered voltage vs. time signals at 0.5 Hz, 2 Hz, 8 Hz, 32 Hz, and 128 Hz with no capacitor,1uF capacitor, and 10uF capacitor.

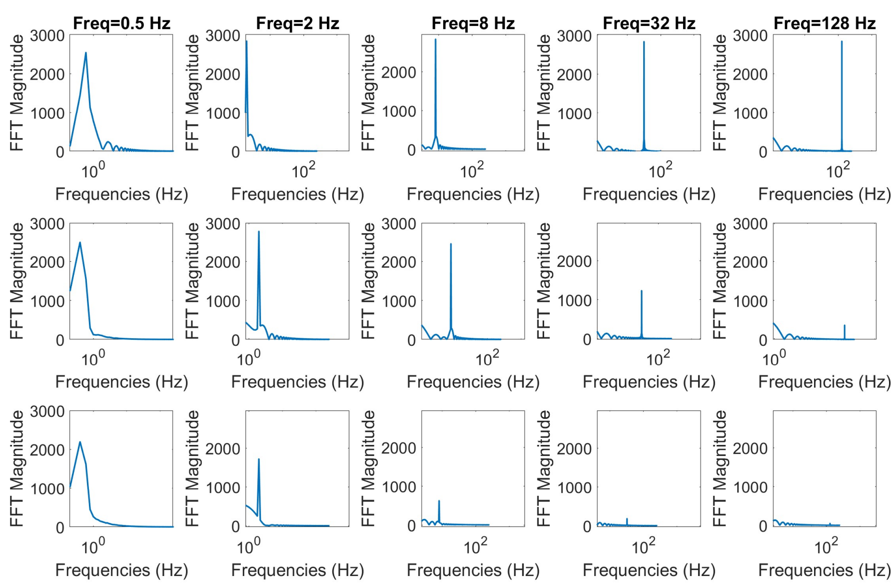


Figure 2. FFT Magnitude vs Frequencies of Figure 1 signals at 0.5 Hz, 2 Hz, 8 Hz, 32 Hz, and 128 Hz with no capacitor,1uF capacitor, and 10uF capacitor.

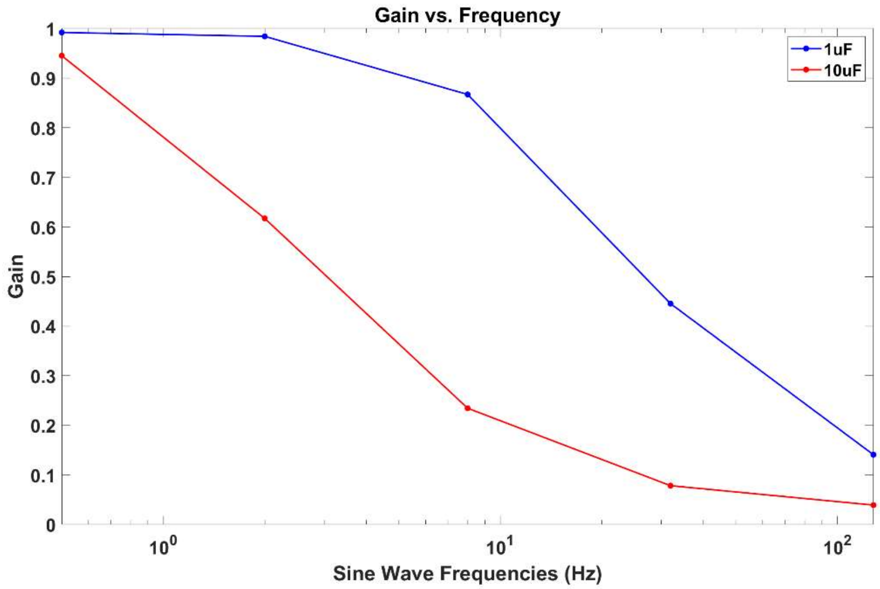


Figure 3. Gain vs Sine wave frequencies for 1uF and 10uF capacitors

Short answer: Describe what happened to the sine waves when the capacitor in your RC circuit increased in value. How did the amplitude and shape of the signal depend on the value of the capacitor?

As the size of the capacitor increased and the frequency increased, the amplitude of the signal became smaller as the voltage was filtered out (low-pass filter). The higher the capacitor value, the lower the voltage (the lower the cutoff frequency) that is able to pass through the RC circuit as seen in Figure 1, subplots 8-10 and 13-16.

Short answer: Describe how the waveform's FFTs changed as a function of frequency and capacitor value.

As the frequencies increased, the peaks for each FFT became more narrow. When the capacitor value increased, the magnitude of the peak at each peak gradually diminished, more so for the 10uF capacitor in comparison to the 1uF capacitor as seen in Figure 2.

Part 7: Testing the frequency response of a low-pass filter with impulses

Include the figure you generated in **Part 7** (**Figure 4**). Don't forget to include appropriate titles, axis labels, font sizes, etc.

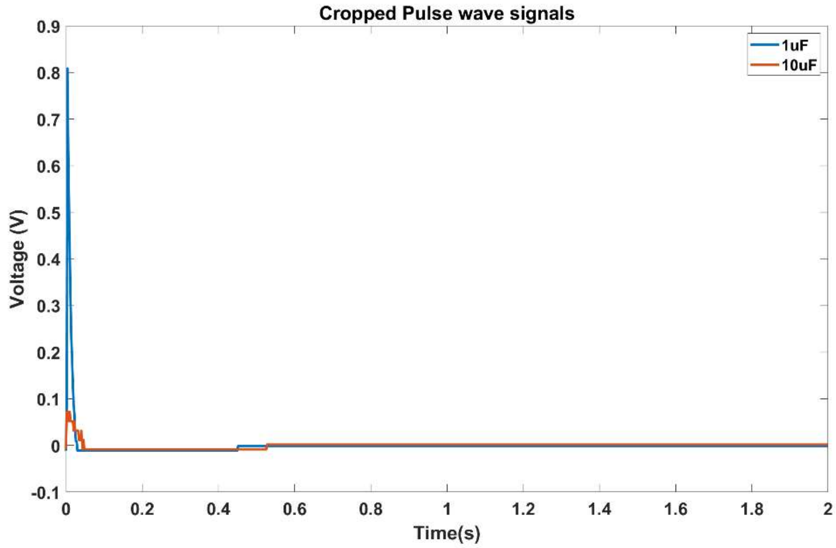


Figure 4. Normalized Impulse response signals for 1uF and 10uF capacitors

Short answer: Describe how filters can be characterized with impulses. Qualitatively describe the impulse response of the low pass filter in the time domain and frequency domain, and how it depends on the capacitor value (and thus, cutoff frequency).

As viewed in Figure 4, the impulse response of each capacitor value describes the maximum voltage that is allowed to be passed through the circuit as well as the time period at which one response is able to pass through. The 1uF capacitor and 10uF capacitor have approximately the same time period but the difference in amplitude is large. The larger the capacitor value, the lower the magnitude of the impulse, thus, lower the cutoff frequency value.

Part 8: Characterizing the low-pass filter using multiple methods

Include the figure you generated in **Part 8** (**Figure 5**). Don't forget to include appropriate titles, axis labels, font sizes, etc.

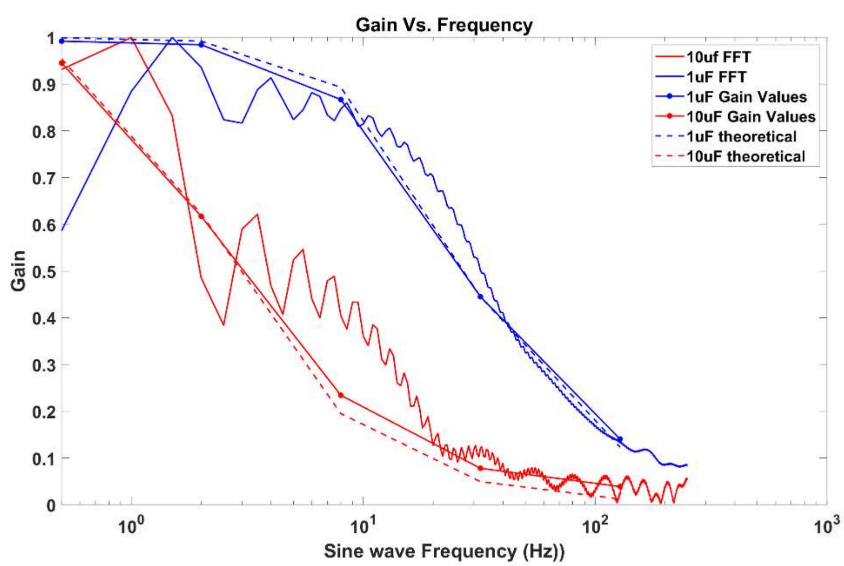


Figure 5. Gain vs Sine wave frequencies using 3 different methods: Experimental, theoretical, and FFT.

Short answer: Describe three methods for characterizing filters in the frequency domain and how they were achieved.

The first method was to divide the maximum output voltage by the capacitors at each frequency by the maximum output voltage signal with no capacitors, given by the dots connected with lines(experimental data). The second method was to plot the FFT of the impulse response from Figure 4 for both capacitors, given by the plain lines. Lastly, the theoretical gain values were plotted using a mathematical formula, given by the dashed lines in Figure 5.

Part 9: Examining a real-world image in the spatial and frequency domains

[Nothing required]

Part 10: Filtering an image in the spatial frequency domain

Include the figures you generated in **Part 10** (**Figures 6** and **7**). Don't forget to include appropriate titles, axis labels, font sizes, etc.

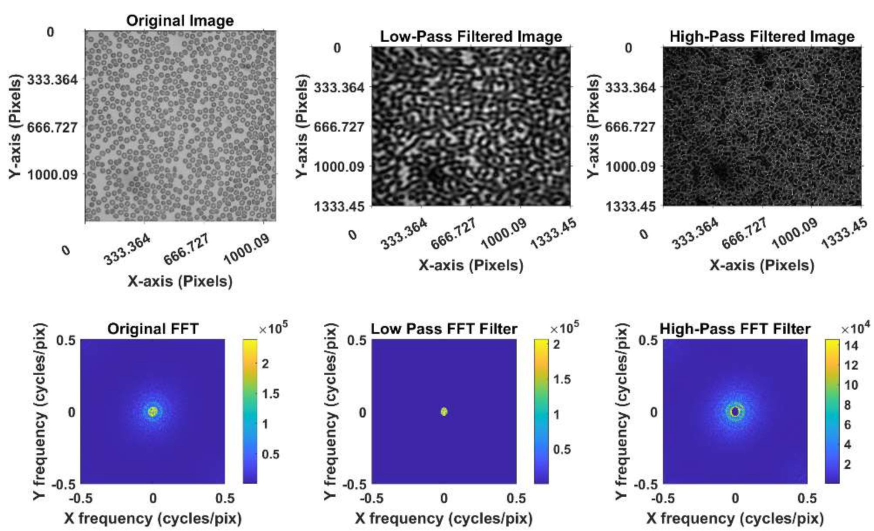


Figure 6. Filtered 40x red blood cell images (radius=30)

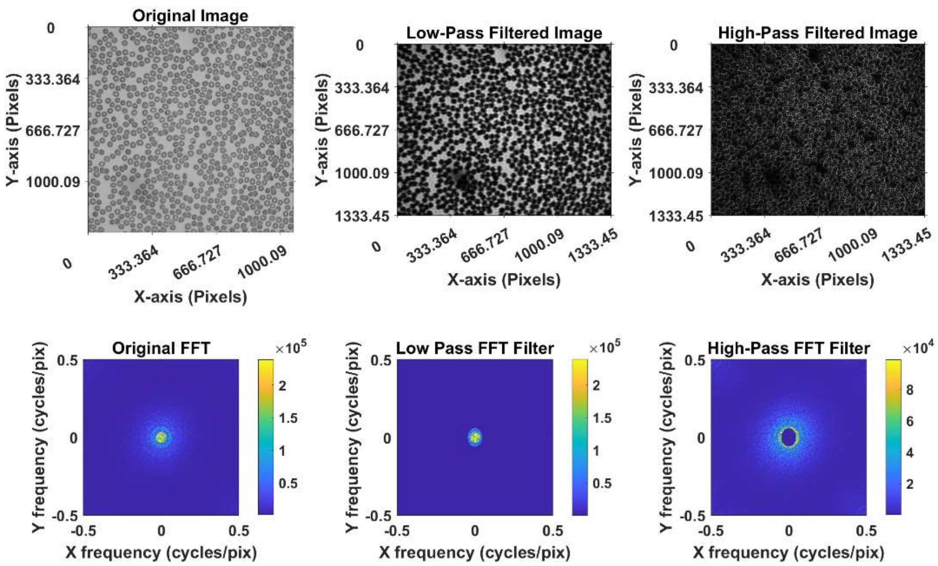


Figure 7. Filtered 40x red blood cell images (radius=60)

Short answer: Describe the features of your image that have high spatial frequencies and the features that have low spatial frequencies.

Subplots 3 and 6 in Figures 6 and 7 have high spatial frequencies, and in comparison to the original image, the shape of the RBCs are much more sharper and defined (especially the edges) and in comparison to the original FFT, the lower frequencies in the center of the FFT image are filtered out. Subplots 2 and 5 in Figures 6 and 7 have low spatial frequencies, and in comparison to the original image, the shape of the RBCs are blurry and almost indistinguishable in comparison to the original FFT, the higher frequencies around the center of of the FFT image are filtered out, leaving the lower frequency signals in the middle.

Short answer: Describe your strategy for low-pass and high-pass filtering the image in the frequency domain and the results of this procedure.

With the aid of ChatGPT-4, to create the high pass filter, the mean of the image was subtracted from the image, and then the fft was taken of this result and then shifted (using *fftshift* command) and then the magnitude of this result was plotting, resulting in the lower frequencies being filtered out from the rbc image. Then a mask was created using the code provided to us and applied to the original FFT image, resulting in the lower frequency signals being passed through in the center of the image, and higher frequencies filtered out. This result was then shifted and multiplied by the mask again, but this time, the high pass radius is set to be lower than or equal to the high pass mark (radius=30), and the magnitude of this was displayed, resulting in the lower frequencies in the middle of the FFT being filtered out.

Short answer: Describe how changing the mask radius changed the filtered images.

Increasing the radius from 30 to 60 resulted in the frequency cutoff to be higher. In the high pass images, only higher than (Figure 6) before frequencies were passed through, where as in the low pass images, higher than before frequencies were also allowed to be passed through.

Short answer: Describe when you might want to low-pass filter or high-pass filter an image.

To sharpen features of an image, a high -pass filter could be used. To blur in image, a low-pass filter could be used.

Part 11: Deblurring an Image

Include the in-focus and the unshifted out-of-focus images you generated in **Part 11** (**Figures 8** and **9**). Don't forget to include appropriate titles, axis labels, font sizes, and scale bars.

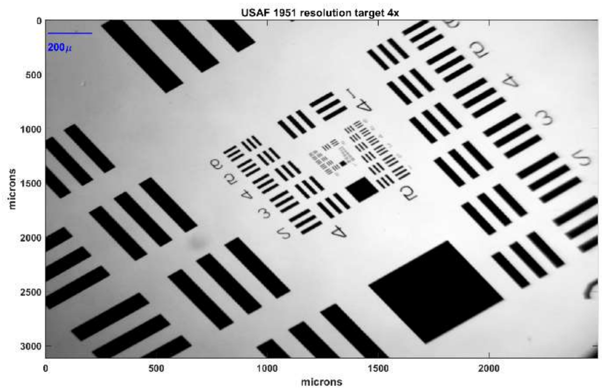


Figure 8. Focused image of USAF 1951 Resolution Target

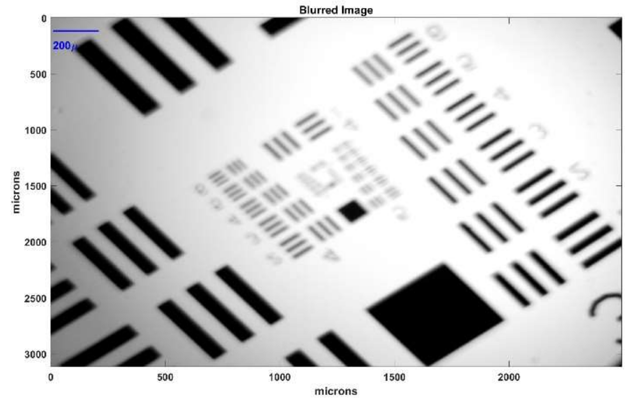


Figure 9. Blurred image of USAF 1951 Resolution Target

Include an image of the filter function you generated in **Part 11** (**Figure 10**). Don't forget to include appropriate titles, axis labels, font sizes, and scale bars.

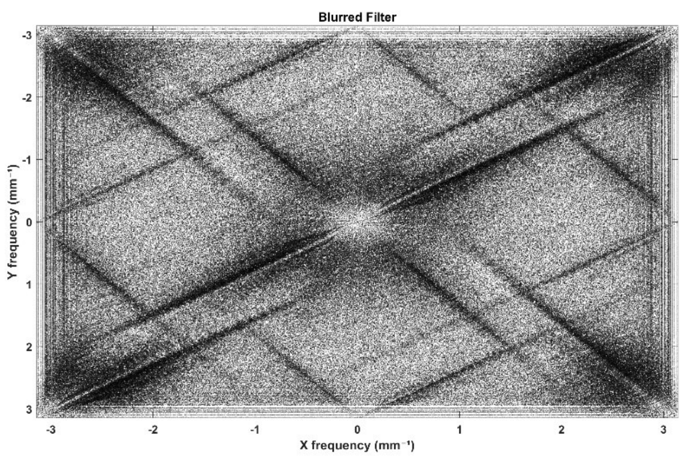


Figure 10. Filter function applied on Blurred image of USAF 1951 Resolution Target

Include the before and after results you generated for the shifted out-of-focus image in **Part 11** (**Figures 11** and **12**). Don't forget to include appropriate titles, axis labels, font sizes, and scale bars. Remember to report the value of ϵ.

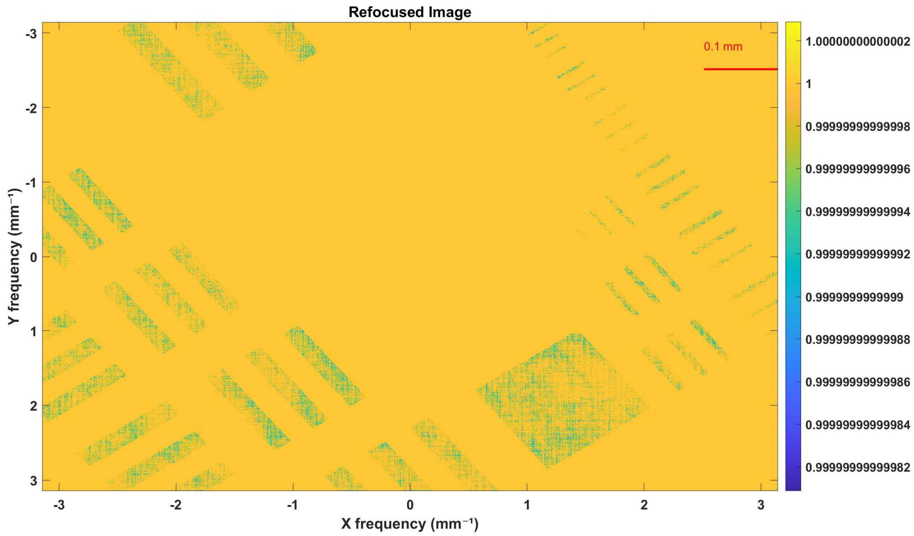


Figure 11. Blurred and shifted image of USAF 1951 Resolution Target

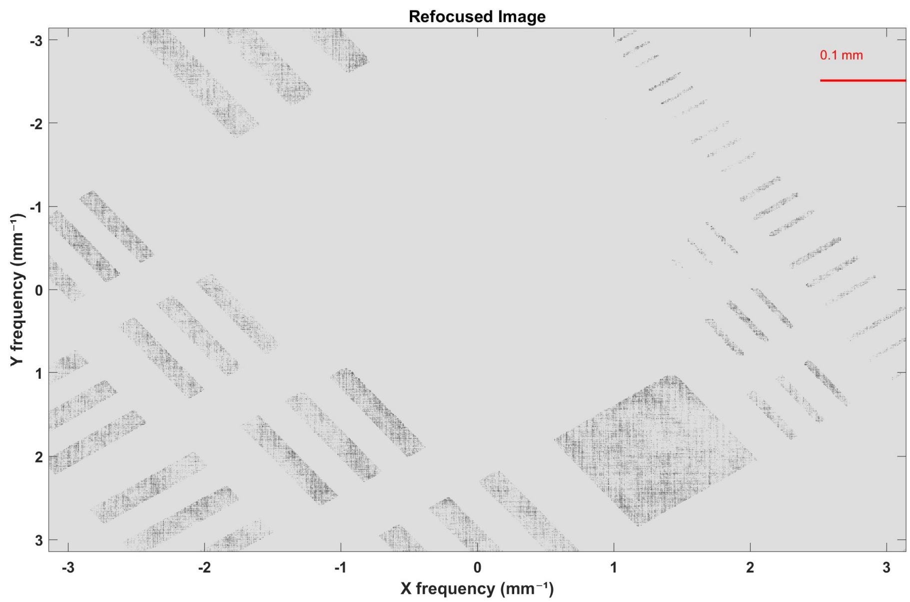


Figure 12. Refocus filter on Blurred and shifted image of USAF 1951 Resolution Target

Value of ϵ:1x10^-20

REMEMBER TO UPLOAD ALL IMAGES AND MATLAB CODE ALONG WITH THIS WORKSHEET.