E9 241 Digital Image Processing
Assignment 03 Report

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Discipline: Signal Processing

Department: Electrical Engineering

Q1. Radial Sinusoid and its Frequency Response:

Observations/Results:

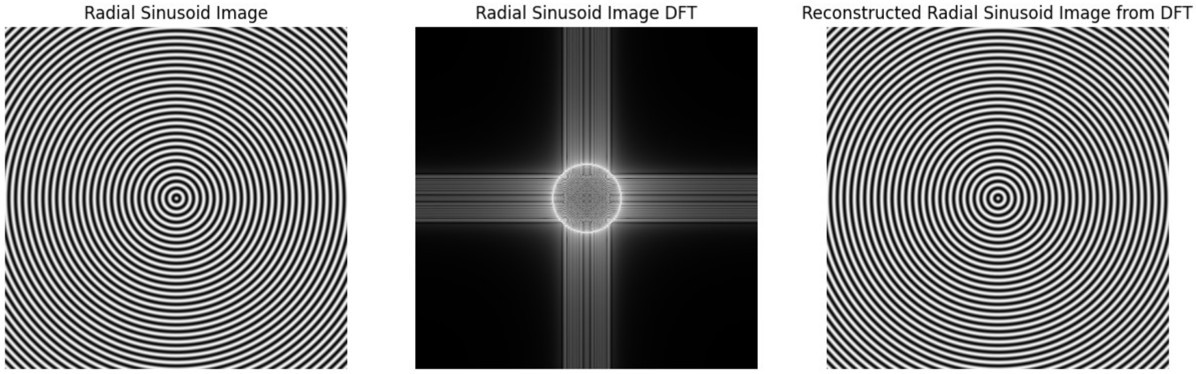

Figure 1

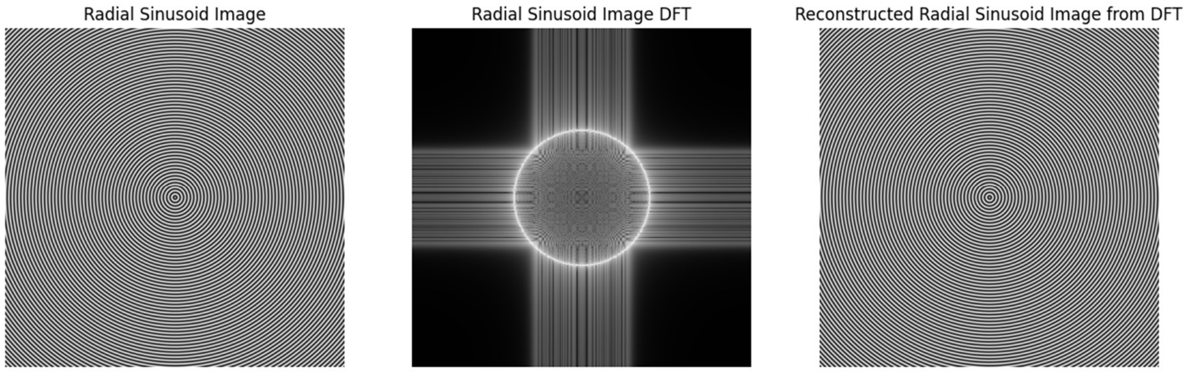

Figure 2

Figure 1 shows the generated radial sinusoid with frequency $\mathbf{f_0 = 50}$, its shifted DFT Magnitude Spectrum (shown using log(S+1)) and the inverse DFT of the spectrum.

Figure 2 shows the generated radial sinusoid with frequency $\mathbf{f_0 = 100}$, its shifted DFT Magnitude Spectrum (shown using log(S+1)) and the inverse DFT of the spectrum.

Comments/Inferences:

The shifted DFT of a radial sinusoid should produce a perfect ring in the frequency domain since it has a single frequency present in all directions of the image (starting from the center).

Increasing the frequency will increase the radius of the of the ring which can be seen from the above two figures where doubling the frequency has doubled the radius.

IDFT of the DFT response gives us the original radial sinusoid.

Ideally the DFT of a radial sinusoid should produce a perfect ring but it can be seen that there are additional horizontal and vertical lines corresponding to other frequencies in the spectrum. This phenomenon is called **Spectral Leakage**, and it has occurred here due to presence of non-integer multiple of the Time Period of the sinusoid (because of the rectangular edge of the image) which causes a part of the energy of the main frequency to be distributed around its neighboring frequencies.

Q2. Frequency Domain Filtering:

Observations/Results:

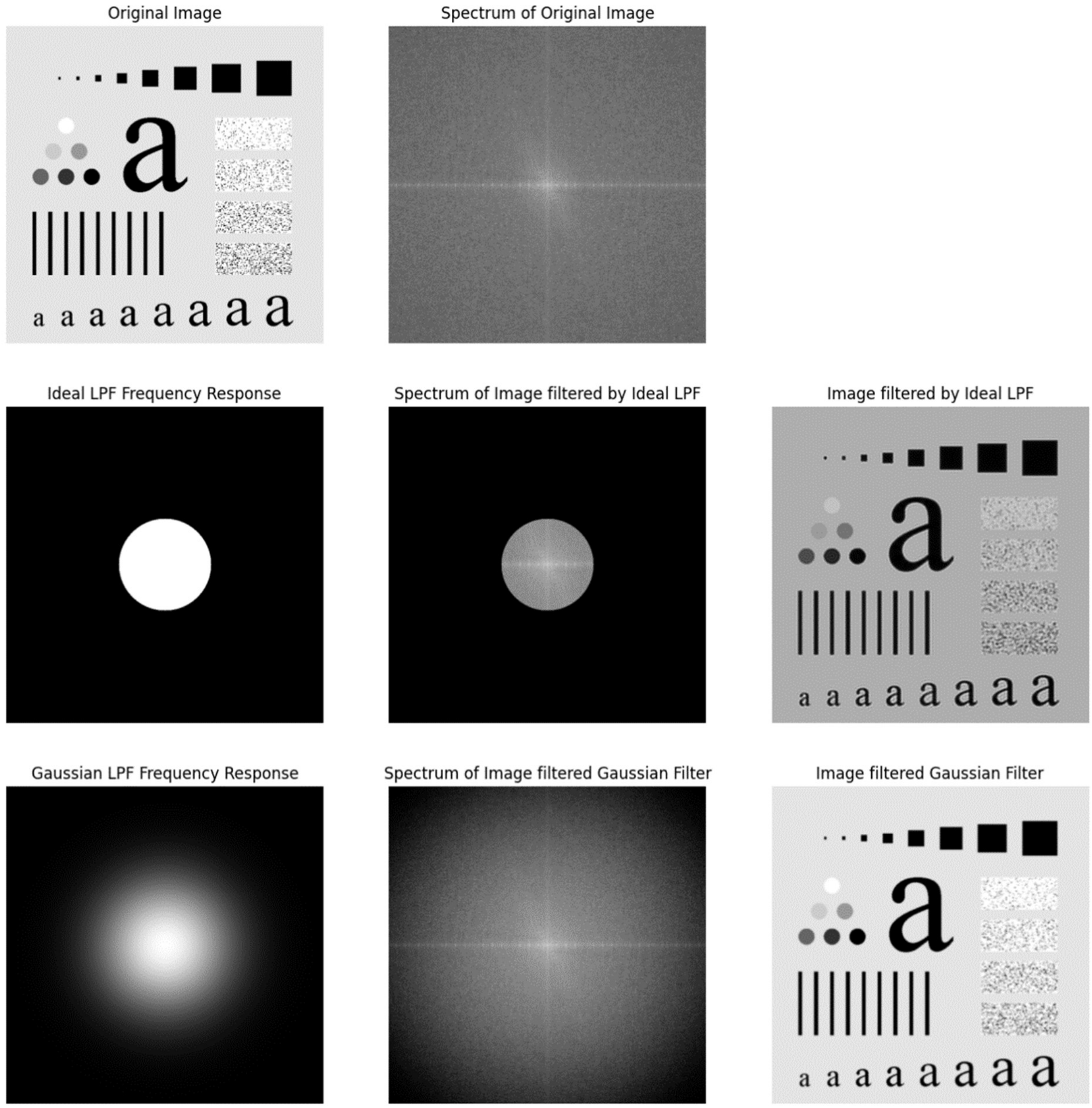

Figure 3 shows the original image, its DFT Spectrum, ILPF (Ideal Low Pass Filter) Filtered Image and Gaussian Filtered Image.

The Cutoff Frequency for the ILPF (D_0) = 100.

The Standard Deviation for the Gaussian Filter = 100 (=D_0)

Comments/Inferences:

In the Ideal Low Pass Filtered Image, the resultant image is a blurred version of the original image. It can be seen that in the image wherever there's an edge, around the edge there are oscillations of intensities (ringing artefacts). This occurs due to the presence of box-like (brick-wall) characteristic of the filter. Filtering the image with an Ideal Low Pass filter in the

Frequency domain is equivalent to convolving the original image with a 2-D Sinc function (contains oscillations). This results in those artefacts/oscillations. Because of these oscillations, the average intensity of the image has decreased, resulting in a darker image.

In the Gaussian Filtered Image we can see a Gaussian Blurred version of the original image. There are no artefacts in this image since, the IDFT of a Gaussian is still a Gaussian function which contains no oscillations.

Q3. Image Deblurring:

Observations/Results:

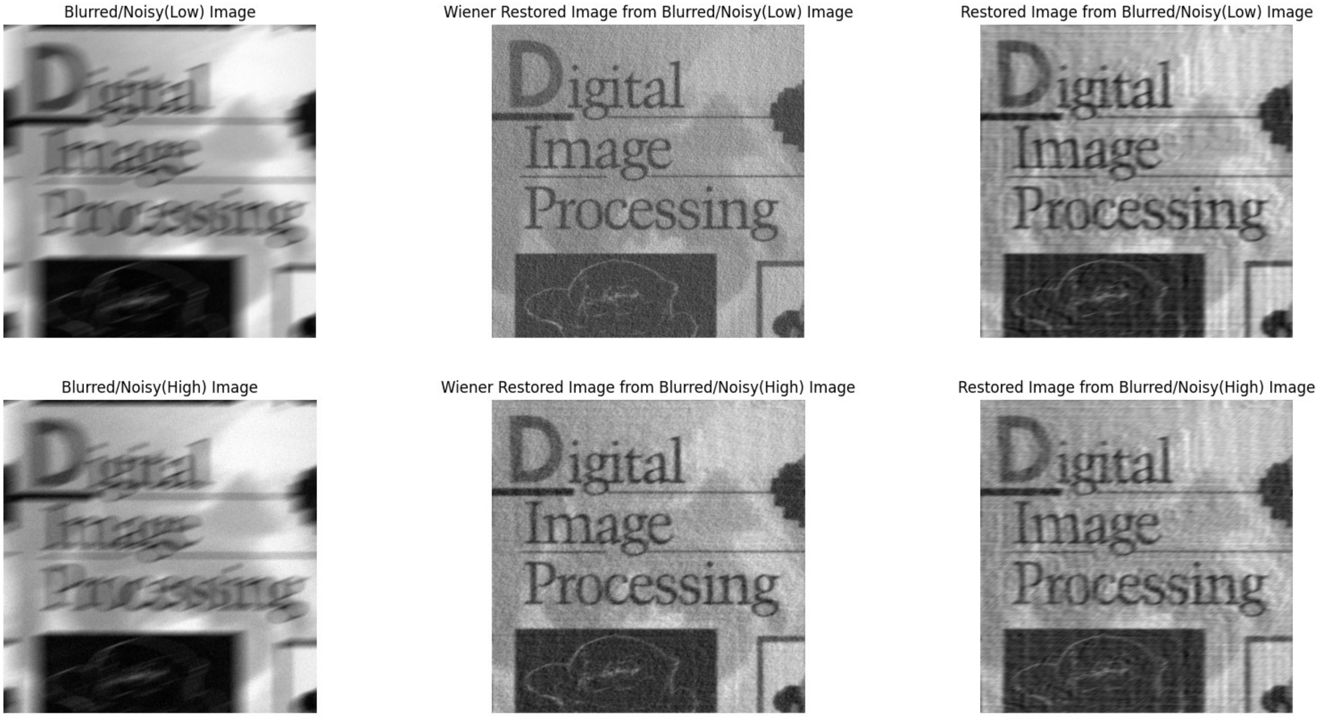

Figure 4

Figure 4 shows the original blurred images with Low and High Noise and the images restored via Inverse Filtering and Wiener Filter.

Comments/Inferences:

In Simple Inverse Filtering we get the DFT of the restored image as:

$$\tilde{F}(u,v) = \frac{1}{H(u,v)}\left[F(u,v)H(u,v) + W(u,v)\right]$$

Where, $\tilde{\boldsymbol{F}}$(u, v) = DFT of Restored Image

H(u, v) = DFT of the Blur-kernel

F(u, v) = DFT of Original Image

W(u, v) = DFT of Noise

In the above equation we can see that if H(u,v) is very small then W(u,v)/H(u,v) will get very large which will cause amplification of noise.

Because of this in the formation of H(u,v) the value is turned to 0 if H(u,v) below a threshold t = 0.1. This prevents the amplification of noise to a certain extent.

In the Wiener Filter no such amplification of noise occurs.

$$\tilde{F}(u,v) = \frac{H(u,v)^{*}\, G(u,v)}{\left[|H(u,v)|^{2} + \frac{S_w(u,v)}{S_f(u,v)}\right.}$$

Where, $\tilde{\boldsymbol{F}}$(u, v) = DFT of Restored Image

H(u, v) = DFT of the Blur-kernel

G(u, v) = DFT of Given Blurred Image

S_w(u, v) = PSD of Noise

S_f(u,v) = PSD of Natural Images

Here, even if H(u,v) is very small then $\tilde{F}$(u, v) will be 0 instead of a very high value. So, Wiener Filter is a more stable filter than Inverse Filtering.