# EE 352 LAB REPORT

## LAB 8: FM in Noise

**Student Name:** Harun Durmuş **Date:** 08.06.2023

**Student ID:** 270206025

### 8.1 Image Reading

Image Processing Toolbox of MATLAB contains imread(.) and im2double(.) functions that are used for obtaining a matrix of pixels of a picture with proper size. Frequency modulation and demodulation is implemented to the image file "testpat1.png" in this laboratory experiment.

### 8.2 Modulation

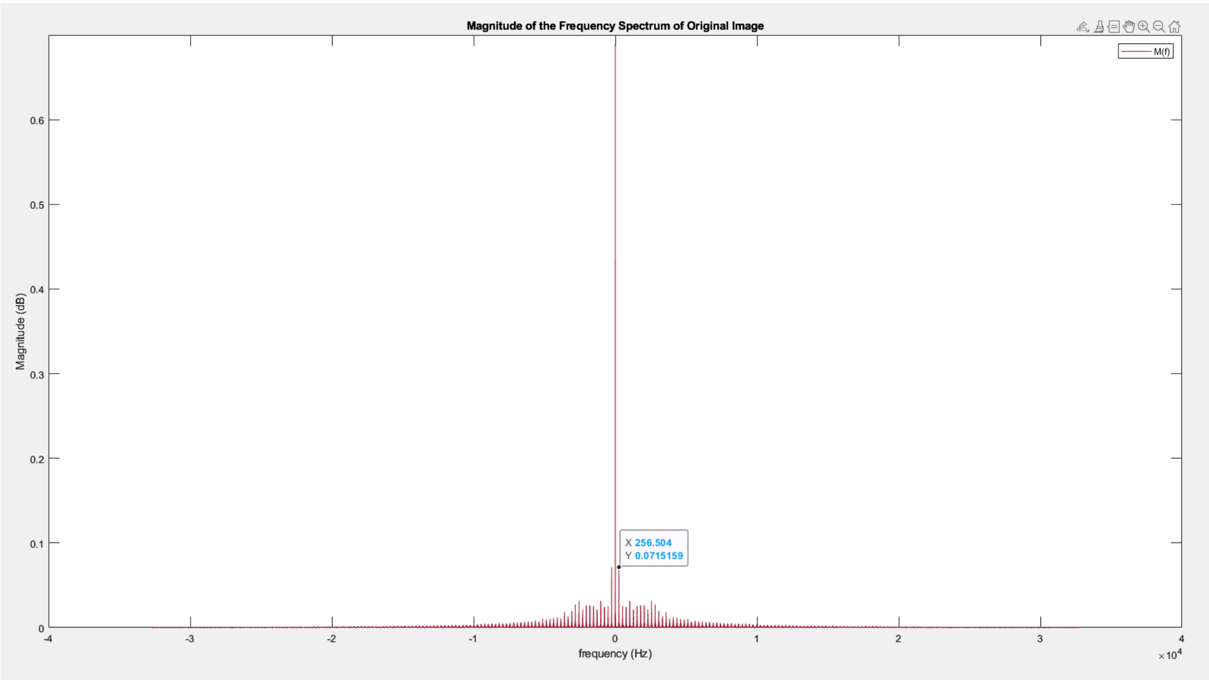


**Figure 8.1:** Magnitude of Frequency Spectrum of the Original Image

Time vector (t) and sampling frequency are created according to the size parameters of the reshaped original image by using numel(.) and size(.) functions.

- In order to calculate modulation indices $\beta_1$ and $\beta_2$, maximum amplitude and frequency of the original image ($A_m$ and fm) are needed. Frequency of the original image can be determined by analyzing the second maximum frequency magnitude component. From the figure 8.2 it is observed that original image has 256.504 Hz fm value. Also $A_m$ is 1. By using the formula,
- $\beta = k_f * A_m/fm$, $\beta_1$ is 0.39 and $\beta_2$ is 1.562.
- The results above indicates that first modulation is narrow-band FM since modulation index $\beta<1$, while second one is wide-band FM.

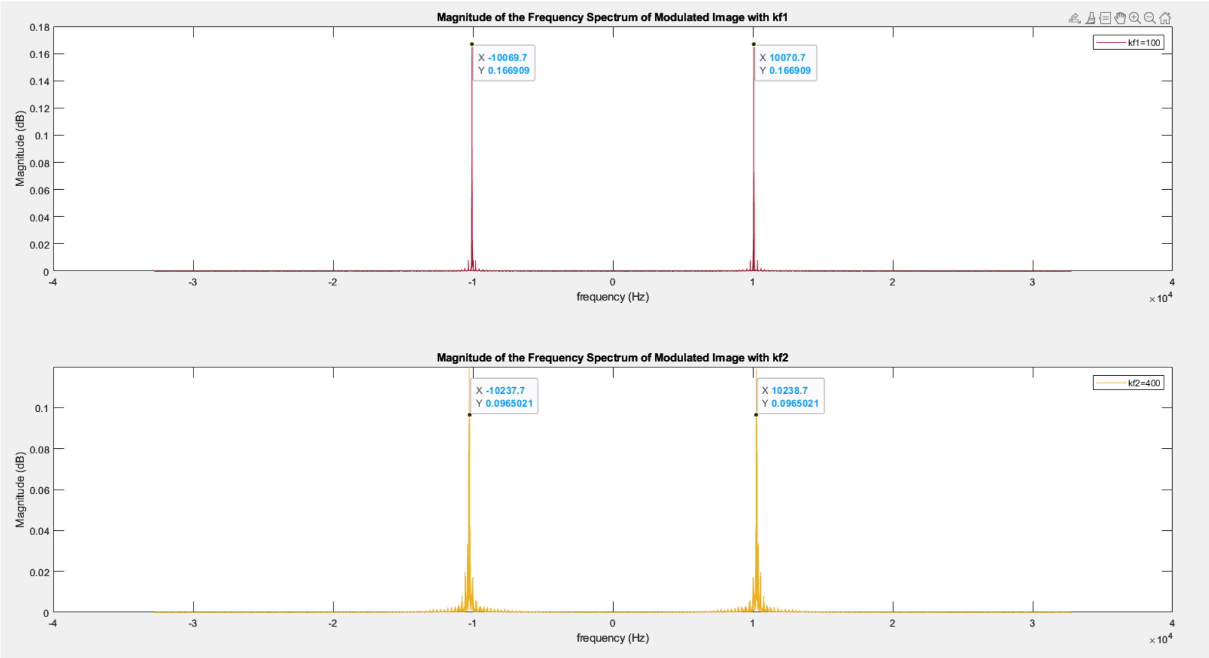


**Figure 8.2:** Magnitude of Frequency Spectrum of Modulated Images with $kf_1$ and $kf_2$ values

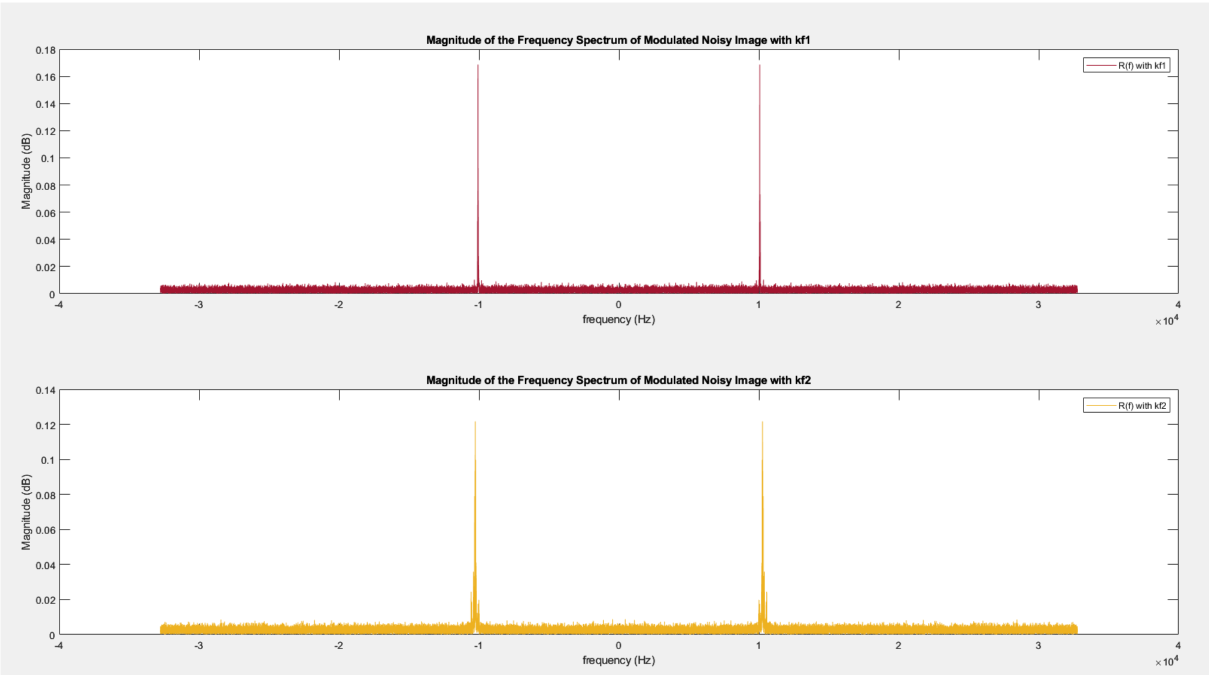


**Figure 8.3:** Magnitude of Frequency Spectrum of Modulated Noisy Images

White noise is added to modulated images by using awgn(.) function. Figure 8.3 is magnitude frequency spectrum of the white noise added modulated image with 0 dB SNR value. A SNR value of 0 dB means that the power of the signal is equal to the power of the noise. In other words, the signal and the noise have the same strength.

## 8.3 Demodulation

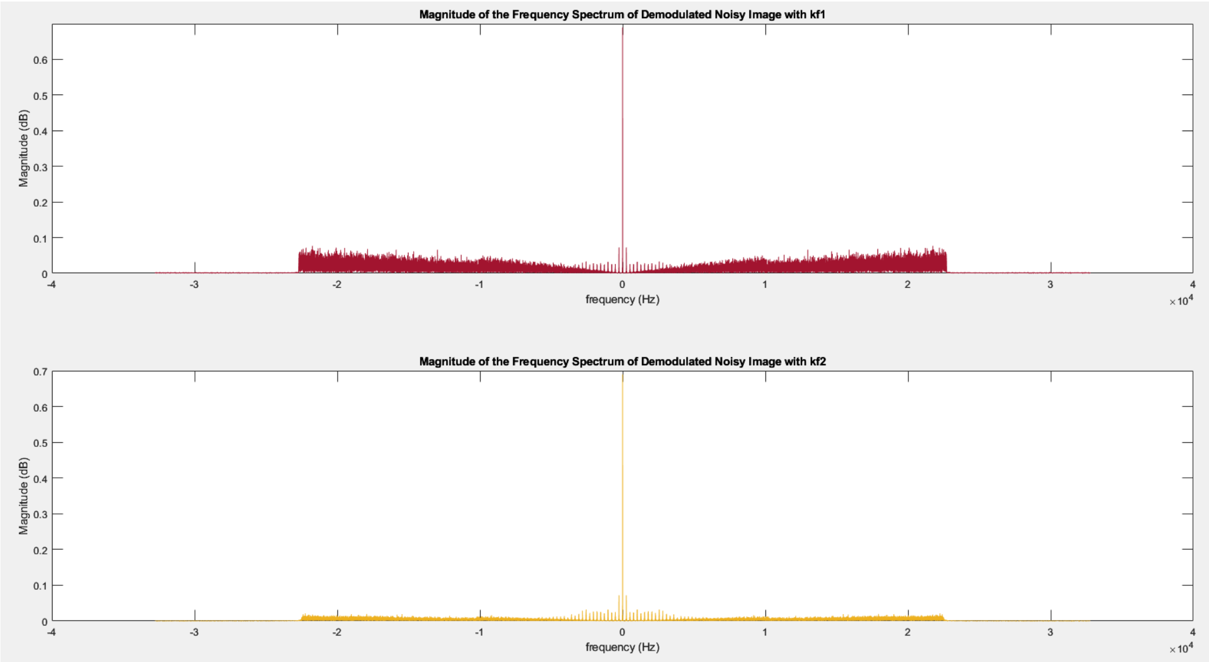


**Figure 8.4:** Magnitude of Frequency Spectrum of Demodulated Noisy Images

Figure 8.4 indicates that, lower frequency deviation constant (kf) makes lower power of the FM signal compared to the carrier and noise. With the SNR value 25 dB signal became stronger compared to noise by analyzing two figures (8.3 and 8.4).

Ranking from most bandwidth-efficient to least bandwidth-efficient for noise reducing:

- SSB (Single Sideband) System: Most efficient as it transmits only one sideband along with the carrier, reducing bandwidth by half.
- VSB (Vestigial Sideband) System: Less efficient than SSB but more than FM and PM. It transmits one full sideband and a portion of the other sideband.
- FM (Frequency Modulation) System: Requires a larger bandwidth due to the frequency deviation caused by the modulating signal.
- PM (Phase Modulation) System: Similar to FM, it requires a wider bandwidth due to phase deviation caused by the modulating signal.

| | |
|---|---|
| PSNR0_1 | -36.3358 |
| PSNR0_2 | -24.2076 |
| PSNR25_1 | -7.9642 |
| PSNR25_2 | 3.2767 |
| PSNR50_1 | 10.1476 |
| PSNR50_2 | 11.1343 |

**Figure 8.5:** Power of SNR Values

The required cut-off frequency is the value that makes power of 50 dB SNR value over 10 dB. In order to obtain that range 14.5 kHz is enough for LPF.

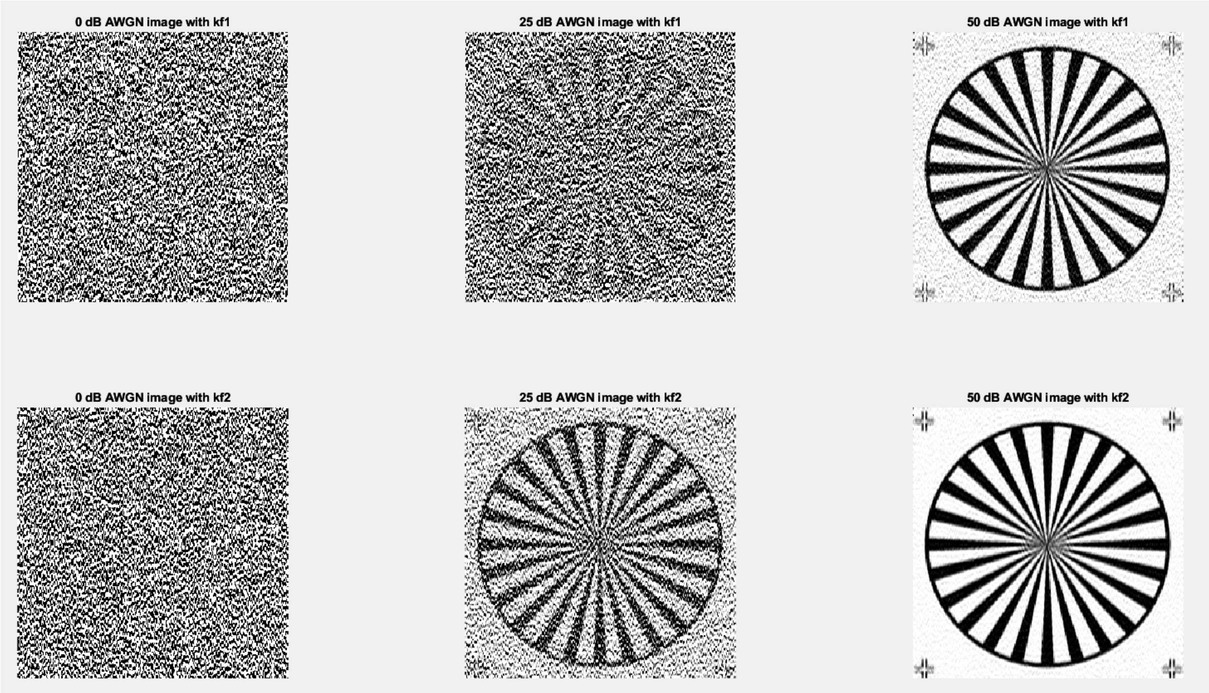


**Figure 8.6:** Noise Reducted Demodulated Images

Since the power of SNR is very high at 50 dB SNR values (from the figure 8.5), it is understood that higher SNR value is important to observe higher quality.

- By analyzing the images and comparing according to $k_f$ values, when kf value increases, according to the following formula: $s_{FM}(t) = A_c * (\cos(2\pi f_c t) + k_f \int m(\tau)d\tau)$ , when kf increases, power of the message signal also increases compared to the noise. That means SNR value increases. So it can be obtained that higher β, indicates higher SNR.

## 8.4 Mean Square Error (MSE) and PSNR Comparison

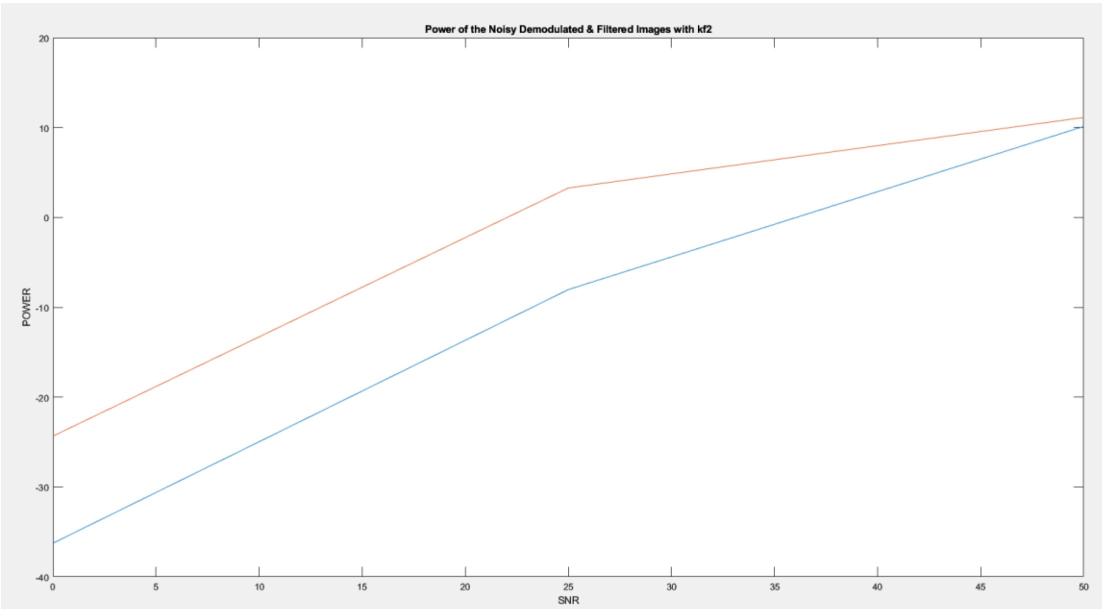


**Figure 8.7:** Power with different SNR values

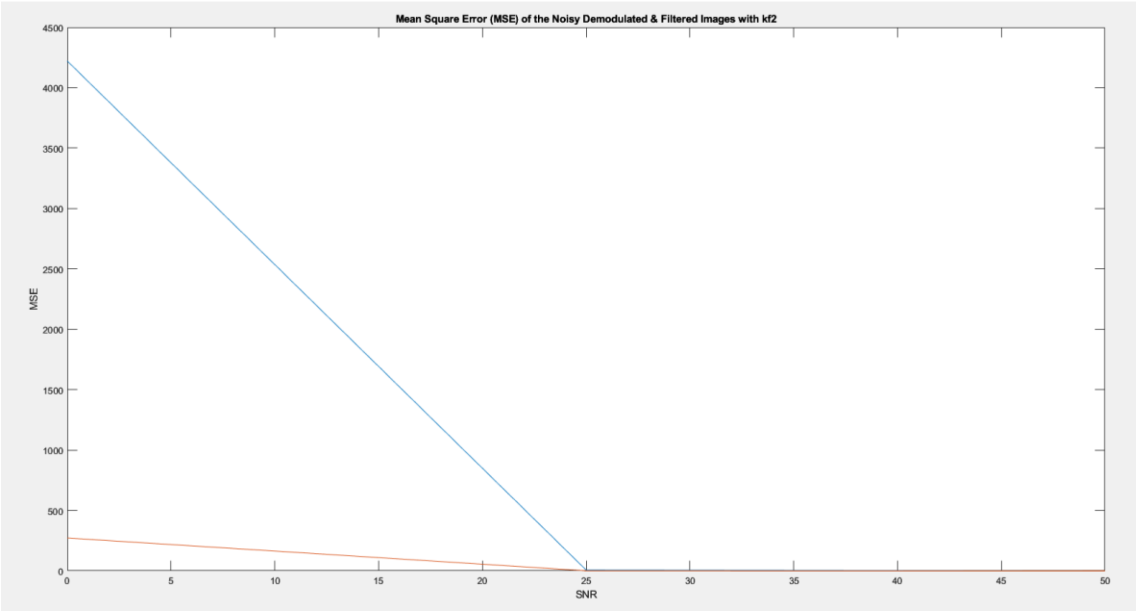


**Figure 8.8:** MSE with different SNR values

From the figures 8.7 and 8.8 above, it is obtained that mean square error is decreased when power of the signal compared to noise ratio (SNR) is increased. This indicates that better image quality is obtained while power of the signal is much stronger compared to the noise.