Digital Downconversion

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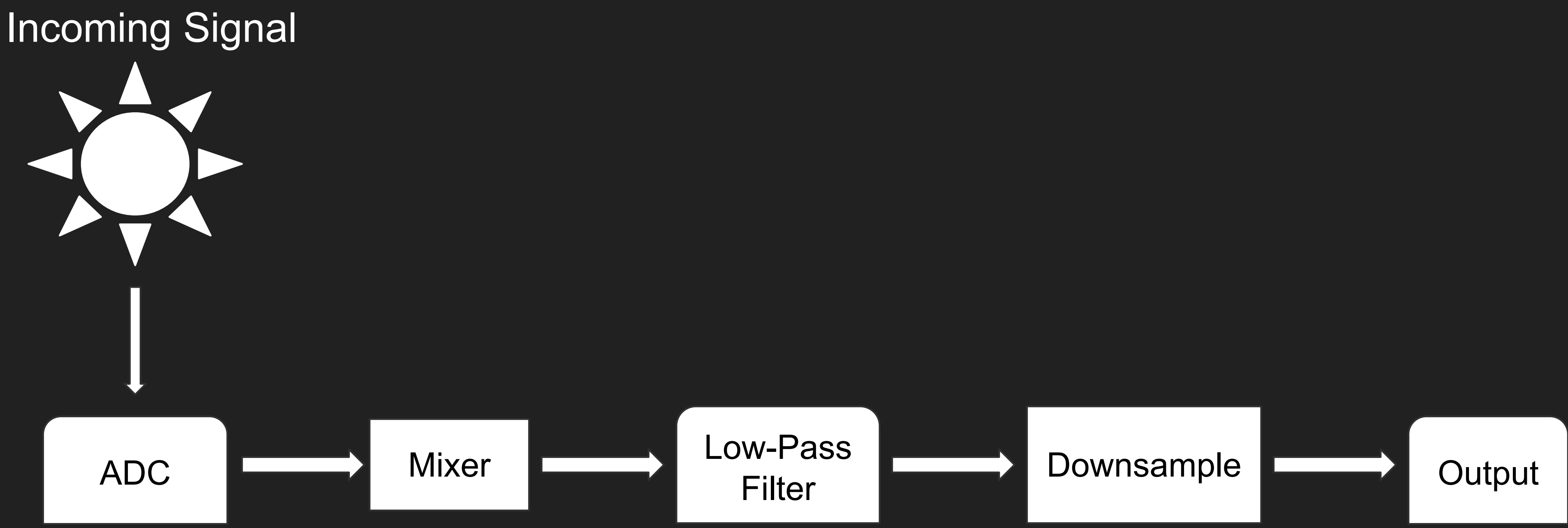
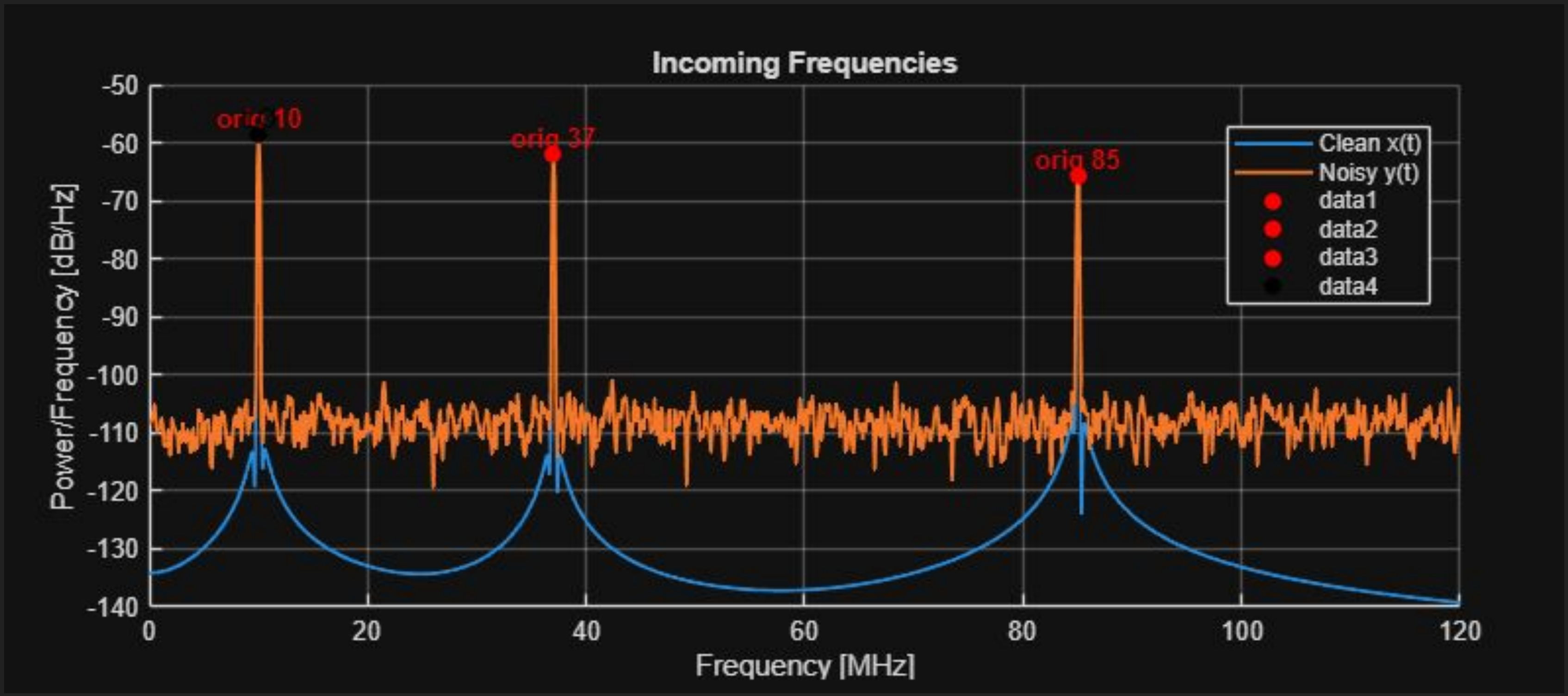
Description

This assignment goes through the process of creating a digital down converter using MATLAB. A high-frequency input signal is mixed with a 10 MHz local oscillator to create sum and difference frequency components. A 2 MHz low-pass filter is then applied to isolate the baseband tone and remove high-frequency content, followed by downsampling to reduce the data rate. The process shows how mixing, filtering, and decimation work together to translate a signal from radio frequency (RF) to baseband for easier analysis in digital systems.

The Digital Converter



Input Spectrum (Before Mixing)



Mixing Stage

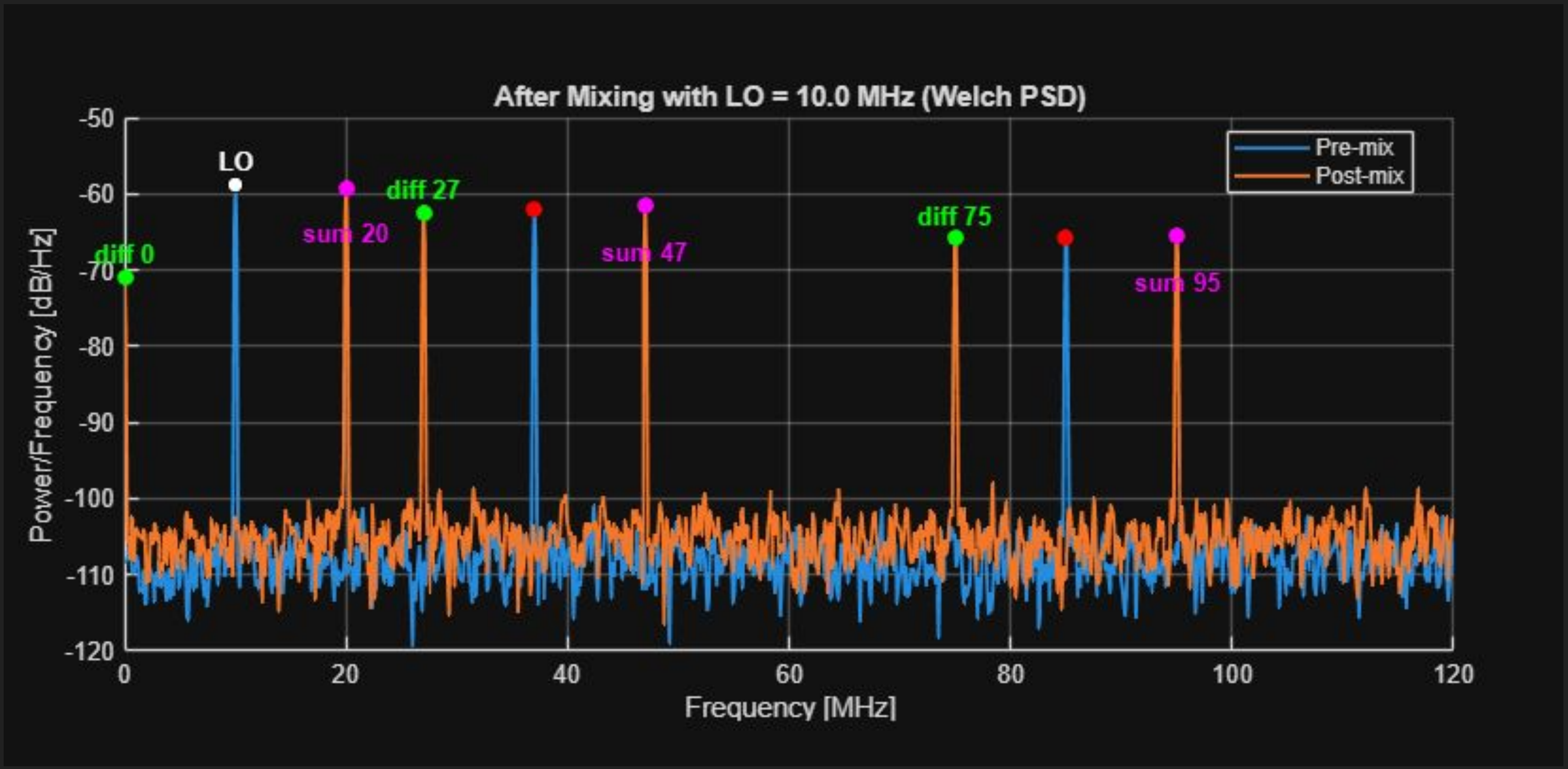
Mathematical Explanation:

Mixing multiplies the input signal x(t) by a local oscillator **cos(2π*f_LO*t)**, generating sum and difference frequencies: **f_sum=f+f_LO** and **f_diff = |f - f_LO|**. This effectively shifts the input spectrum by the LO frequency, translating high-frequency signals down to baseband for easier processing.

Plots:

Before mixing, the input tones appear at 10, 37, and 85 MHz. After mixing with the 10 MHz LO, new components emerge at the sum and difference frequencies, clearly showing how the spectrum is translated toward baseband. Each tone and mixing product is labeled to highlight the frequency translation process.

Spectrum After Mixing with LO = 10 MHz



Low-Pass Filter Stage

Mathematical Explanation:

After mixing, the signal contains both the **sum (f+f_LO)** and **difference |f−f_LO|** components. A low-pass filter removes the high-frequency sum terms, keeping only the baseband difference tone. The cutoff frequency, around 2 MHz, is set well below the nearest spur at 27 MHz to ensure those unwanted components are strongly suppressed. This filtering step is crucial before downsampling. Otherwise, high-frequency energy could fold back into the baseband as aliasing.

Plots:

The spectrum before filtering shows both sum and difference frequencies created by the LO mixing stage. After applying the 2 MHz LPF, the sum frequencies are suppressed, and only the baseband difference tone remains within the passband.The shaded region in the plot represents the LPF passband, which captures the desired signal while rejecting all higher-frequency energy. This clean, narrowband spectrum is then safely downsampled without introducing aliasing artifacts.

Low-Pass Filter and Downsampling

What I learned

- Mixing with a local oscillator creates sum and difference frequencies, shifting signals toward baseband.
- A 2 MHz low-pass filter isolates the baseband (difference) tone and removes unwanted high-frequency components.
- Filtering before downsampling prevents aliasing
- Downconversion enables high-frequency signals to be analyzed at much lower sampling rates without losing key information.