IQ RX Report

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1. Introduction

This report presents the results of an IQ receiver (RX) simulation to calculate the image rejection ratio, which was found to be -25 dB. The IQ demodulation process is described mathematically below.

2. Mathematical Model

In order to estimate the gain (g) and phase offset (ϕ) of the system, consider the input signal:

$$r(t) = \cos(2\pi f_{\text{RF}} t + \theta) \tag{1}$$

where f_{RF} is the radio frequency and θ is the phase of the input signal.

The in-phase ($z'_I(t)$) and quadrature ($z'_Q(t)$) components of the demodulated signal are given by:

$$z'_I(t) = \cos\left(2\pi(f_{\text{RF}} - f_c)t + \theta\right) \tag{2}$$

$$z'_Q(t) = -g\sin\left(2\pi(f_{\text{RF}} - f_c)t + \theta - \phi\right) \tag{3}$$

where: - f_c is the carrier frequency, - g is the amplitude mismatch (gain), - ϕ is the phase offset.

2.1. Amplitude Offset Estimation

The gain ($\hat{g}$) can be estimated as:

$$\hat{g} = \sqrt{\frac{\sum |z'_Q(n)|^2}{\sum |z'_I(n)|^2}} \tag{4}$$

2.2. Phase Offset Estimation

The phase offset ($\hat{\phi}$) can be estimated as:

$$\hat{\phi} = \frac{\sum z'_I(n) \cdot z'_Q(n)}{\sqrt{\sum |z'_I(n)|^2 \cdot \sum |z'_Q(n)|^2}} \tag{5}$$

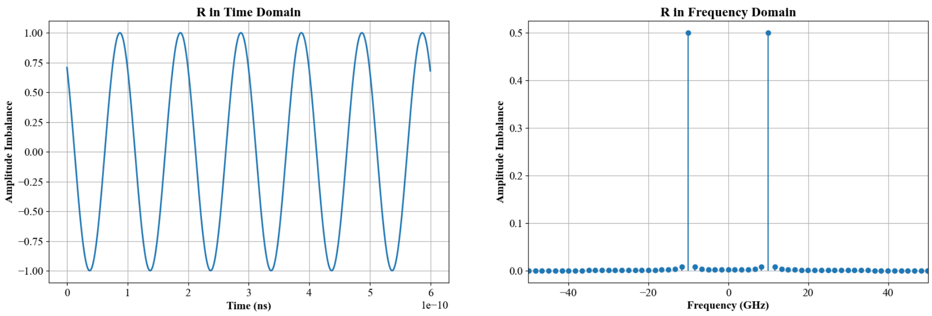

Figure 1. Input signal R_t

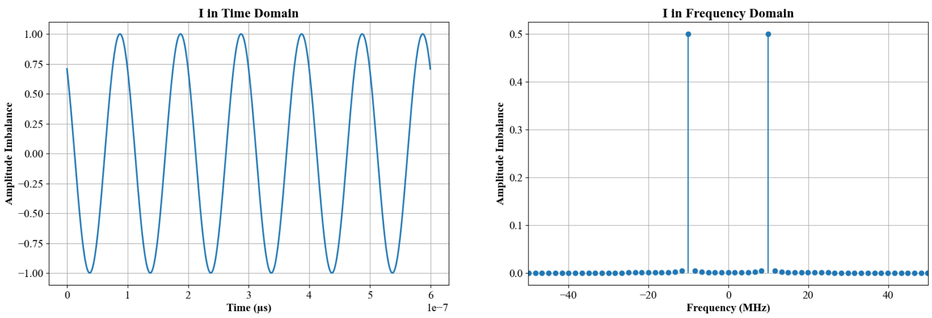

Figure 2. Output signal I vector

3. Assumptions

Assuming the image rejection is -25 dB, and based on the equation for the Image Rejection Ratio (IMRR), for a given value of gain imbalance g and phase imbalance ϕ, the IMRR is defined as:

$$IMRR = \frac{g^2 + 1 - 2g\cos(\phi)}{g^2 + 1 + 2g\cos(\phi)} \tag{6}$$

The goal is to find the values of g and ϕ that correspond to an image rejection of -25 dB. The closest values obtained are $g = 1.1$ and $\phi = 3.4°$.

$$f_c = 10^{10}\,\text{Hz} \quad \text{(carrier frequency of 10 GHz)} \tag{7}$$

$$f_m = 10^{7}\,\text{Hz} \quad \text{(message frequency of 10 MHz)} \tag{8}$$

$$f_{\text{rf}} = f_c + f_m \quad \text{(RF frequency)} \tag{9}$$

$$\theta = \frac{\pi}{4} \quad \text{(phase of the input signal)} \tag{10}$$

4. Simulation Results

The signal described by Equation 1 is simulated in the time domain over the interval $[0, 0.6\,\text{ns}]$ and converted to the frequency domain using FFT, as shown in Figure 1.

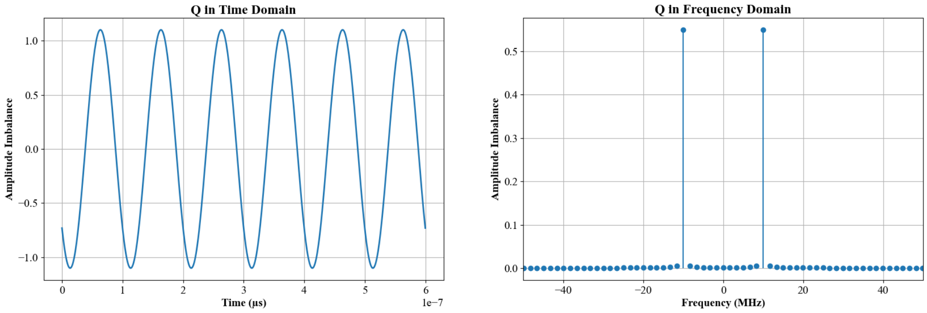

Figure 3. Output signal Q vector

Similarly, the signals from Equations 2 and 3 were simulated in the time domain over the interval $[0, 0.6\,\mu s]$ and transformed into the frequency domain using FFT. The results are presented in Figures 2 and 3, respectively.

5. References

References

Kunal Sankhe, Mauro Belgiovine, Fan Zhou, Shamnaz Riyaz, Stratis Ioannidis, and Kaushik Chowdhury, "ORACLE: Optimized Radio Classification through Convolutional Neural Networks," *IEEE INFOCOM 2019*, Paris, France, May 2019.