Lab 4: Digital Baseband Communications

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***Abstract*—The purpose of this lab is to expose and give an understanding of yet another common form of modulated signal, Pulse Code Modulation (PCM). PCM like any other transmission will have its share of noise and error, we will be focusing on quantization error.**

I. Introduction and Objectives

PCM is one of the most common forms of modulation and as such should be known. Understanding the simple background and application of PCM and its error can prove to be a great resource in further endeavours in the communications fields.

II. Background and Relevant Theory

One of the most common forms of modulated signal is PCM, Pulse Code Modulation. It is a modulation by way of both digital and analog signals. An analog signal is converted to a digital signal and the information from this signal is encoded by some arbitrary digital signal. The information of this signal is represented by digital words in a serial bit stream [1].
PCM can be advantageous for many real-world applications as it is inexpensive, versatile and resilient to noise, but it does require a relatively high bandwidth in order to operate.
Finding the signal to noise ratio (SNR) for the PCM signal is relatively simple and can be seen in Equation 1. However, this SNR is deceptive as it only takes into account the random noise contributed by quantization errors in the signal.

$$\frac{S}{N}_{out} = M^2 \tag{1}$$

Additionally, flipping the equation is useful to find the quantization error for a given SNR, Equation 2.

$$M = \sqrt{\frac{S}{N}_{out}} \tag{2}$$

Finding the SNR of a signal is easy enough given the input and output signal, from there the only operation is simple enough. To find the quantization error the follow equation, Equation 3.

$$(\frac{S}{N})_{out} = 6.02n + \alpha \tag{3}$$

Where α is the quantization error.

III. Results

The first step is getting the PCM data which can be seen in Figures 1 and 5.

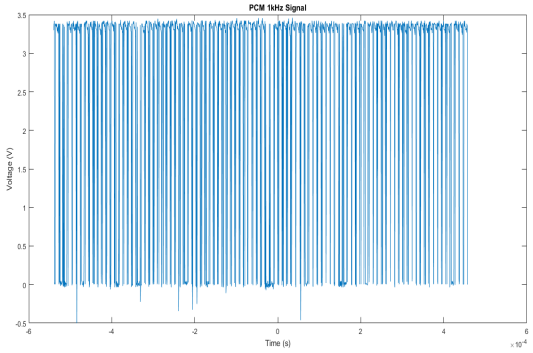

Fig. 1. Output 1 kHz PCM Signal

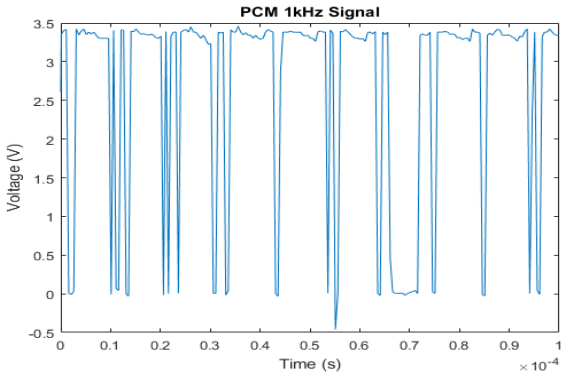

Fig. 2. Output 1 kHz PCM Signal zoomed in

Additionally the eye diagram was taken for the PCM signal and can be seen in Figure 3.

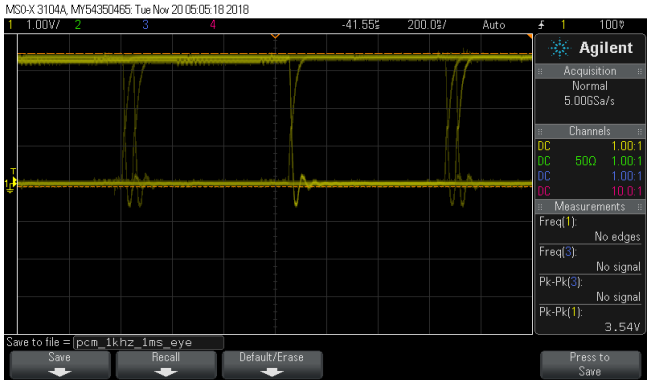

Fig. 3. Eye diagram for the PCM signal where each horizontal division is 200 ns and each vertical division is 1 V

Once the PCM data is taken decoding it would be the next step.

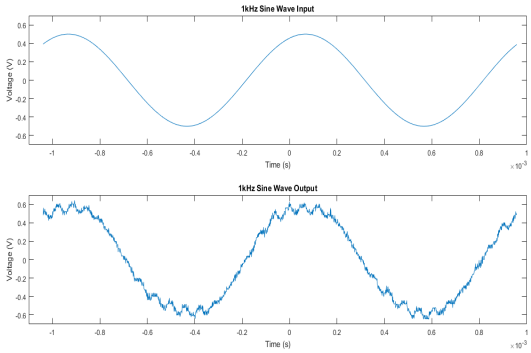

Fig. 4. 1kHz sine wave input and decoded PCM output

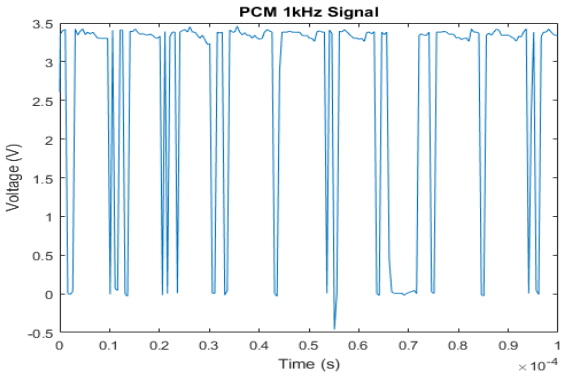

Fig. 5. Output 1 kHz PCM Signal zoomed in

The next figure,Figure 6, displays the quantization error over time.

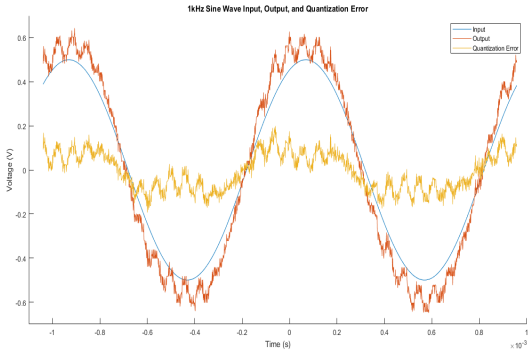

Fig. 6. Graph with input, output, and error for the decoded PCM signal

Additionally, the SNR for the entire signal is 21.8301 dB, which equates to 4.67 quantizer levels, M, meaning that 'n' can be approximated to be 2 or 3.

IV. Discussion

The PCM data plotted is moderately noisy, but otherwise is a typical PCM signal.

The quantization error can be calculated with Equation 3. For the calculated SNR of 21.8301 and for the n of 2 the quantization error would be 9.79 and the n of 3 the quantization error would be 3.77. So the quantization error ranges from 3.77-9.79 depending on how close the output is to the input.

V. Conclusions

The PCM signal is easily encoded and decoded although with some amount of error. The quantization error is moderately insignificant based on the SNR.

References

[1] Couch, L. *Digital and Analog Communication Systems: Eighth Edition*. NJ, USA: Pearson, 2013