\documentclass[12pt, a4paper]{report}

\usepackage[utf8]{inputenc}

\usepackage{graphicx}

\title{Experiment 2}

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\begin{document}

\maketitle

\section\*{Introduction:}

This assignment deals with generating PRBS signal (or OOK) waveforms and their analysis when noise is added. Initially, we generate the PRBS9 sequence and plot their time, frequency domain representations by taking a defined value of samples/symbol. Additionally, for the noiseless PRBS sequence generated, we plot it's constellation diagram. Now, white gaussian noise is added and we see how the constellation diagram and the 'Eye diagram' turns out for SNR-5dB,10dB,15dB. The constellation diagrams are to tell the spread in the symbol values. The eye diagram tells us the distinction between the logic high and logic low.

\section\*{Generating PRBS9 waveforms:}

\subsection\*{Symbols plot:}

We have already seen in the last experiment how to generate PRBS9 sequences. We take $2^1^2$ symbols and make an OOK waveform with baud rate 10Gbaud implying each symbol period is 0.1ns. We plot a stem plot of symbols vs time for a 10ns duration ( hence, taking only symbols till that time). This is done by generating a time vector having timestamps spaced at 'Tbaud' intervals and positioning the symbol at the middle of the period( so the first timestamp is at Tbaud/2). This has been explained in the code. The plot is as shown in fig.1.

\begin{figure}[htb]

\hspace\*{-5cm}

\centering

\includegraphics[width=1.7\columnwidth]{symb\_prbs.jpg}

\begin{tikzpicture}

\end{tikzpicture}

\caption{Symbols vs time for PRBS9 for a 10ns time window at a 10Gbaud rate.}

\label{fg:terrace}

\end{figure}

\subsection\*{Time and Frequency Domain plots:}

Now we generate time domain equivalent waveforms which are actually sent. We use three cases of Nt (samples/ symbol)- 2, 4 and 8. For each Nt, we replicate the symbol in it's time slot of 'Tbaud', 'Nt' times done for all $2^1^2$ symbols. This is done by replicating the prbs sequences and concatenating values of each symbol window with the that of the rest of the symbols as explained in the earlier experiment. Now, for plotting purposes, the waveform is plotted only upto 10ns. For the PSD calculation, we account for the entire original length of the signal. The PSD calculation is carried out by finding the square of absolute values of the DFT normalizing with respect to 'N' (total no. of samples) and 'fs'. We also take twice to account for it being a real signal. This was also covered in the last experiment. The plots for time domain waveforms and the one-sided Power spectral density for the cases Nt = 2, 4 and 8 are given in fig. 2,3,4,5,6 and 7.

\\

The time window taken for plotting is the same: 10ns which is given.

\\

Sampling frequency=fs = Nt\*fbaud (samples/symb \* symb/s gives samples/s)

\\

Frequency window= fs/2 which is defined by DFT and it's a real signal, hence only 0 to fs/2 is required.

\\

No. of DFT samples N = Nt\*$2^1^2$ ( Nt samples/symbol \* total number of symbols)

\\\\

Frequency resolution= fs/N = fbaud/$2^1^2$ (the Nt factor gets cancelled) which is same for all: 2.441 MHz.

\\

\underline{Nt = 2:}

\\ Sampling frequency = 20GHz\\

Freq. window = 10GHz

\\\\

\underline{Nt = 4:}

\\ Sampling frequency = 40GHz\\

Freq. window = 20GHz\\

\underline{Nt = 8:}

\\

Sampling frequency = 80GHz\\

Freq. window = 40Ghz\\\\

Clearly, we see that as the Nt increases the waveform is more accurate and hence the nulls at various frequencies become more apparent.

\begin{figure}[htb]

\hspace\*{-5cm}

\centering

\includegraphics[width=1.7\columnwidth]{prbs\_nt=2.jpg}

\begin{tikzpicture}

\end{tikzpicture}

\caption{Voltage vs time for PRBS9 waveform with Nt = 2 samples/ symbol plotted only for 10ns.}

\label{fg:terrace}

\end{figure}

\begin{figure}[htb]

\hspace\*{-5cm}

\centering

\includegraphics[width=1.7\columnwidth]{prbs\_nt=2\_freq.jpg}

\begin{tikzpicture}

\end{tikzpicture}

\caption{Power spectral density of the PRBS9 time domain waveform with Nt= 2 samples/symbol done by fourier transform.}

\label{fg:terrace}

\end{figure}

\begin{figure}[htb]

\hspace\*{-5cm}

\centering

\includegraphics[width=1.7\columnwidth]{prbs\_nt=4.jpg}

\begin{tikzpicture}

\end{tikzpicture}

\caption{Voltage vs time for PRBS9 waveform with Nt = 4 samples/ symbol plotted only for 10ns.}

\label{fg:terrace}

\end{figure}

\begin{figure}[htb]

\hspace\*{-5cm}

\centering

\includegraphics[width=1.7\columnwidth]{prbs\_nt=4\_freq.jpg}

\begin{tikzpicture}

\end{tikzpicture}

\caption{Power spectral density of the PRBS9 time domain waveform with Nt= 4 samples/symbol done by fourier transform.}

\label{fg:terrace}

\end{figure}

\begin{figure}[htb]

\hspace\*{-5cm}

\centering

\includegraphics[width=1.7\columnwidth]{prbs\_nt=8.jpg}

\begin{tikzpicture}

\end{tikzpicture}

\caption{Voltage vs time for PRBS9 waveform with Nt = 8 samples/ symbol plotted only for 10ns.}

\label{fg:terrace}

\end{figure}

\begin{figure}[htb]

\hspace\*{-5cm}

\centering

\includegraphics[width=1.7\columnwidth]{prbs\_nt=8\_freq.jpg}

\begin{tikzpicture}

\end{tikzpicture}

\caption{Power spectral density of the PRBS9 time domain waveform with Nt= 8 samples/symbol done by fourier transform.}

\label{fg:terrace}

\end{figure}

\section\*{Constellation diagrams:}

\subsection\*{Noiseless:}

The constellation diagram for a given sequence of symbols is directly plotted using the 'scatterplot' function since we already have the vector of modulated OOK symbols. Here, it is done for all $2^1^2$ symbols. The plot is as shown in fig. 8. There's no noise, so the points are exactly at (0,0) and (1,0).

\subsection\*{With noise:}

Noise is added to the symbols vector by the 'awgn' function. We measure the power of the input symbols vector and add approriate amount of noise to give a desired SNR, which is taken as 5dB, 10dB and 15dB here. The output symbols vector is plotted via 'scatterplot' as shown in fig. 9 10 and 11 for SNR= 5dB, 10dB and 15dB respectively. Here, the noise is added directly to the discrete symbols. Even if we were to have a waveform to which we add noise and we take one sample for each symbol and plot the constellation diagram we will get the same effect. This is because since its white gaussian noise, the probability density of noise added at each sample would be independent and identical and hence, the dispersion caused in amplitude for the same SNR and same total number of symbols plotted on the constellation diagram, for both cases on an average is the same. Clearly, we see that the signal is more distinguishable as 0 or 1 when the SNR increases. The variation is also along only the I-axis, since real white gaussian noise is added. In OOK, we are concerned only about the intensity/ amplitude noise, hence phase noise is irrelevant.

\begin{figure}[htb]

\hspace\*{-9.2cm}

\centering

\includegraphics[width=2.3\columnwidth]{const\_no\_noise.jpg}

\begin{tikzpicture}

\end{tikzpicture}

\caption{Constellation diagram for OOK with no noise.}

\label{fg:terrace}

\end{figure}

\begin{figure}[htb]

\hspace\*{-9.2cm}

\centering

\includegraphics[width=2.3\columnwidth]{const\_5dB.jpg}

\begin{tikzpicture}

\end{tikzpicture}

\caption{Constellation diagram for OOK with SNR 5dB}

\label{fg:terrace}

\end{figure}

\begin{figure}[htb]

\hspace\*{-9.2cm}

\centering

\includegraphics[width=2.3\columnwidth]{const\_10dB.jpg}

\begin{tikzpicture}

\end{tikzpicture}

\caption{Constellation diagram for OOK with SNR 10dB}

\label{fg:terrace}

\end{figure}

\begin{figure}[htb]

\hspace\*{-9.2cm}

\centering

\includegraphics[width=2.3\columnwidth]{const\_15dB.jpg}

\begin{tikzpicture}

\end{tikzpicture}

\caption{Constellation diagram for OOK with SNR 15dB}

\label{fg:terrace}

\end{figure}

\section\*{Eye diagram:}

\end{document}