ENEL 571

Laboratory #2 – Digital Baseband Transmission

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PART I – Binary Polar PAM Using Rectangular Pulse Waveforms

A.1

a) There are technically 3 levels if you include the initial start value of 0. If you ignore that, then without noise there are two values that are output from the sample and hold, 7.5V and -7.5V.

b) Without noise there are two values at the output of the sign/lookup blocks – 5V and -5V.

c) Only in final amplitude. The received signal is slightly damped to be 5V while the original was closer to 7.5V.

A.2

a) The channel output gets increasingly more difficult to analyze by observation and patterns of transmission begin to get lost in the noise.

b) The detector appears to start making errors around a noise variance of 7.

c) No, the errors appear to correct themselves when the gain is raised to 15.

d) Higher signal strength results in lower error probability.

B.1

a) The spectrum is infinite because of the tail lobes that continue across the spectrum. The Fourier transform of rectangular pulses results in a Sinc function within the spectral domain.

b) The null-to-null bandwidth of this signal is approximately 1000Hz.

B.2

The side lobes become smeared because of the presence of the white noise. The white noise results in a relatively uniform spectrum across all frequencies. This is then added to the original side lobes but now they are being covered up by the relatively larger amplitudes.

C.1

The simulated channel is an ideal channel and thus, no noise is present within it. This results in a perfect transmission and thus there are a total of 0/10000 bits in error, and thus a BER of 0.

C.2

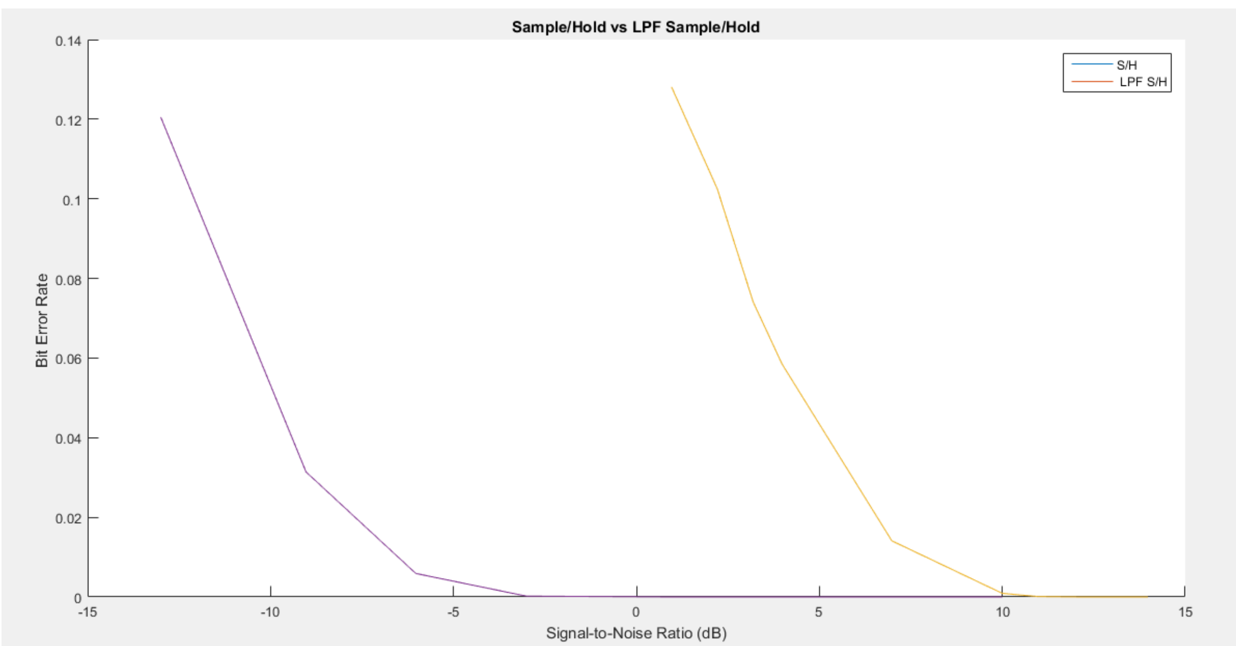
Noise Variance	SNR dB	BER for S/H
20	0.96	0.1281
15	2.21	0.1025

12	3.19	0.0741
10	3.98	0.0585
5	6.98	0.0141
2.5	10	0.0009
2	10.97	0.0001
1.5	12.21	0
1	13.98	0

C.3

Noise Variance	SNR dB	BER for S/H
500	-13.0	0.1205
200	-9.03	0.0314
100	-6.03	0.0059
50	-3.01	0.0002
20	0.96	0
10	3.98	0
5	6.98	0
2.5	10	0

C.4



a) The lower BER for a fixed SNR is always the LPF sample and hold circuit.

b) The regular sample and hold would require a higher SNR to achieve the same quality.

PART II – Binary PAM Using Sinc Pulse Waveforms

A.1

There are two noticeable changes between the input and the output. The first is that the pulses are replaced with sinc pulses (finite) which are also time delayed by 0.05 seconds.

B.1

a) The sinc pulse has the narrower null-to-null as it is approximately 500Hz or half that of the rectangular pulse.

b) The sinc pulse has the lower side lobes as well.

c) The sinc pulse is preferable because it uses less bandwidth, retains most of the information in the first lobe and has a much sharper roll off into higher frequencies.

C.1

The LPF is removing all the higher frequency noise components from the signal and allowing only the requested bandwidth to pass. This is smoothing out the waveform and giving us a much more accurate signal to process.

C.2

Noise Variance	SNR dB	BER for S/H
500	-13.13	0.0925
200	-9.15	0.0220
100	-6.14	0.0038
50	-3.13	0.0001
20	0.85	0
10	3.86	0
5	6.87	0
2.5	9.88	0

C.3

a) The Sinc PAM results in better BER performance.

b) The Sinc PAM would result in a slightly more complex design as you would need to shape the waveform.

PART III – Binary PAM Using Raised Cosine Pulse Waveforms

A.1

a) The greater the roll-off factor, the larger the main lobe's bandwidth becomes.

b) The greater the roll-off factor, the smaller the side lobes become.

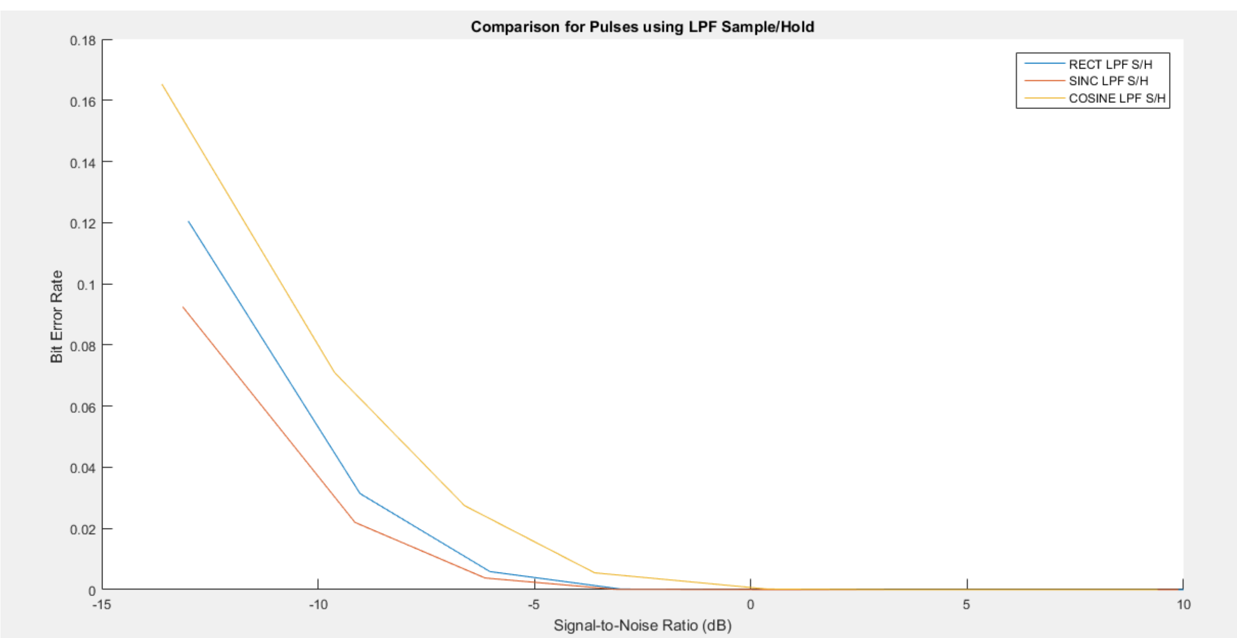
c) You would want a slightly higher roll-off to reduce the amount of spectral leakage that is occurring in the side lobes.

d) The width of the main lobe is about 50% wider with the raised cosine pulse at 0.5 roll off. The magnitudes of the side lobes are slightly smaller as well with raised cosine pulse – they are between 10-15 dB lower after the main lobe.

B.1

Noise Variance	SNR dB	BER for S/H
500	-13.61	0.1653
200	-9.62	0.0710
100	-6.62	0.0275
50	-3.61	0.0055
20	0.37	0.0002
10	3.38	0
5	6.39	0
2.5	9.40	0

B.2



a) The Sinc pulse showcases the best performance for BER vs SNR. The Raised Cosine showcases the worst performance for BER vs SNR.

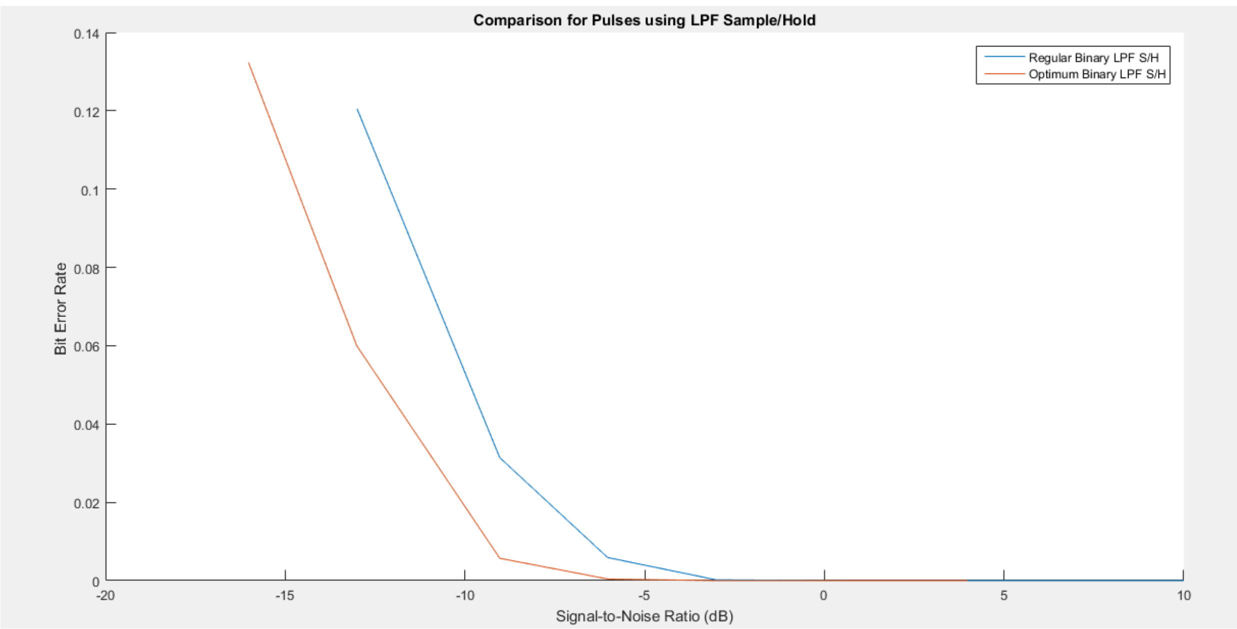
b) The Raised Cosine pulse would require the highest SNR level to achieve a set BER.

c) The Sinc pulse would require the least amount of power to achieve a set BER for known variance.

PART IV – Optimum Receiver – Correlation Receiver for Binary PAM

A.1

Noise Variance	SNR dB	BER for S/H
1000	-16.02	0.1323
500	-13.01	0.0600
200	-9.03	0.0057
100	-6.02	0.0004
50	-3.01	0
20	0.96	0
10	3.98	0



a) The optimum receiver is better for a set SNR and returns a lower BER.

b) The optimum receiver requires a lower SNR than the regular detector.

c) The optimum receiver would require less power to achieve a set BER.

PART V – M-ary PAM

<u>A.1</u>

a) The null-to-null bandwidth is approximately 500Hz.

b) It is half of the binary PAM's bandwidth.

<u>A.2</u>

E_b/N_0 dB	BER Natural Binary	BER Gray Code
0	0.1788	0.1373
2	0.1243	0.1000
4	0.0771	0.0627
6	0.0343	0.0303
8	0.0098	0.0072
10	0.0011	0.0010

<u>A.3</u>

See table above.

<u>A.4</u>

a) The BER of the Gray code was lower for all SNRs than that of natural binary.

b) The Gray encoded system would require a lower SNR.

c) The Gray code system would require less transmission power to achieve a set BER.

PART VI – Partial Response Signaling

A.1

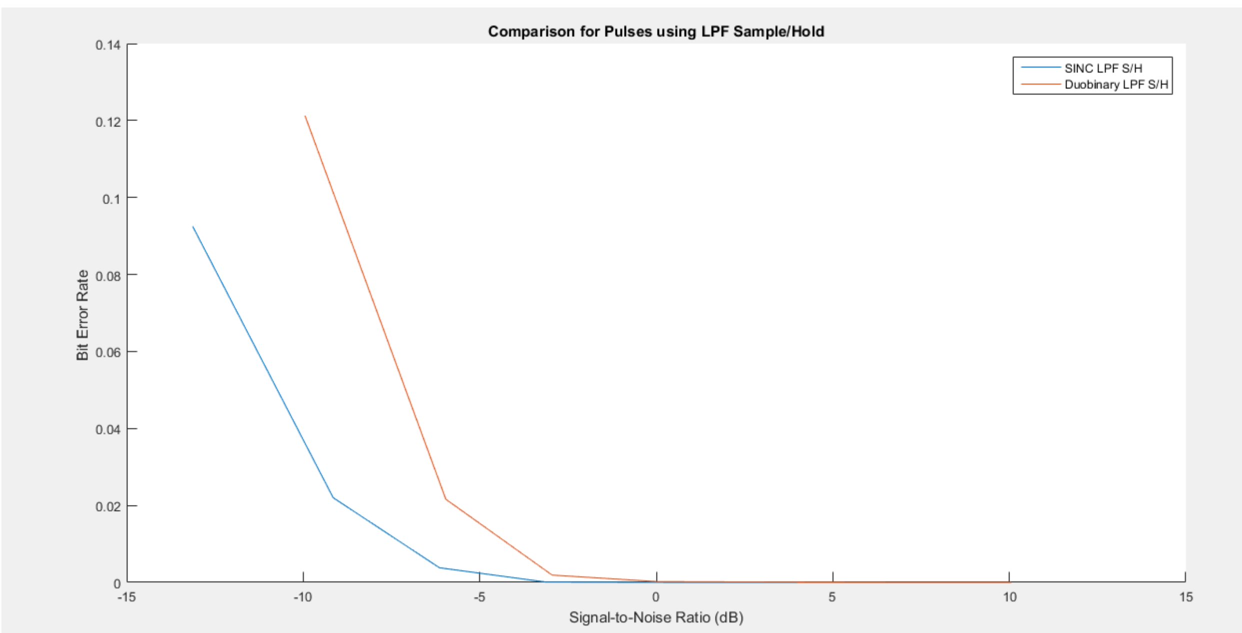
a) The null-to-null bandwidth is approximately 500Hz.

b) This is approximately the same null-to-null bandwidth as the Sinc pulse binary PAM.

A.2

Noise Variance	SNR dB	BER for S/H
500	-9.95	0.1213
200	-5.96	0.0216
100	-2.95	0.0019
50	0.05	0.0002
20	7.04	0
10	10.05	0
5	3.98	0

A.3



The sinc pulse is still better in regards to the BER for a given SNR. They are very similar however for SNR's over and around 0dB.