

Lab 7 - QPSK

Goal

Characterizing QPSK signals.

Pre- lab

Reading

1. Sections 8.1.1, 8.1.2, 8.1.4, 8.1.5 and 8.1.7 in ZT
2. Notes on QPSK on the class Web site.

Problems and Simulations

1. *Verification of Gardner algorithm*

Show that substituting

$$x_I(t) = y_I(t) \cos \Delta\theta - y_Q(t) \sin \Delta\theta$$

$$x_Q(t) = y_I(t) \sin \Delta\theta + y_Q(t) \cos \Delta\theta$$

into

$$u_\ell(t) = x_I(t - T/2) [x_I(t) - x_I(t - T)] + x_Q(t - T/2) [x_Q(t) - x_Q(t - T)]$$

produces

$$u_\ell(t) = y_I(t - T/2) [y_I(t) - y_I(t - T)] + y_Q(t - T/2) [y_Q(t) - y_Q(t - T)]$$

and thus the Gardner symbol timing recovery algorithm is immune to a carrier phase error $\Delta\theta$.

2. *Error rates of QAM and QPSK*

- a) Sketch the constellation of 4-QAM based on ZT Figure 8.11(a) and identify the type of decision region(s).

- b) Show that for small P_e the error rate of 4-QAM is the same as the error rate for QPSK listed in ZT Eq. (8.13). (Note that for 4-QAM, there is only one type of decision boundary.)

3. *Modification of Costas loop*

Starting with the LabView diagram of the Costas loop used for BPSK, sketch the modifications required to implement the QPSK loop shown in the QPSK notes. These modifications will be implemented in lab to test the loop's ability to track QPSK and QAM data streams.

4. *Effect of phase noise and fading on QPSK*

- a) Modify the code used for phase noise for BPSK to determine the effect of phase noise on QPSK. This involves changing the conditional error rate expression from that used for BPSK to that listed in the notes on QPSK. Use the same values as in the Figure in the QPSK notes. The curves should be the same where the x-axis uses the energy per bit instead of the energy per symbol.
- b) Repeat for the case of fading. In this case, the conditional error rate is ZT Eq. (8.13).

1 QPSK

1.1 BPSK vs. QPSK Spectrum

1. Open the PSK generator VI used last week and generate the same test BPSK waveform using 0.5 V peak signal. Using *Cal_SA*, measure the bandwidth of the signal to the first null and the total power. Save the data trace.
2. Repeat for a QPSK waveform with the same peak output voltage. Are the spectra the same?

1.2 Demodulation using PLL

1. Modify the BPSK Costas loop VI used last week according the figure in the QPSK notes to produce a PLL that can lock to a QPSK signal.
2. Qualitatively compare the BPSK loop using a hard limiter in the in phase arm with the QPSK loop. Use the constant sinusoidal generator used Lab 5. Use a natural frequency of 100k and $\zeta = 1/\sqrt{2}$. Test the performance of the two loops at $\Delta f = 100$ kHz and $\Delta f = 50$ kHz.
3. Now use the QPSK data VI with an offset of $\Delta f = 50$ kHz. Repeat for BPSK data with an offset of $\Delta f = 50$ kHz.
4. Now try to lock 8-PSK signal. Does the loop work? Why or why not?

1.3 BER Measurements

1. Open *QPSK BER* and *BPSK BER*. View the block diagram for each VI and describe the differences.
2. Using the *QPSK BER* VI measure a BER vs. E_b/N_0 curve using the *BPSK* data generator VI. One of the channels should produce the same curve as last week while the other channel should produce a BER of 0.5 because there is no data on it.

3. Now repeat with *QPSK* data. In this case, both channels should produce the same results as the last step. Use values of E_b/N_0 in the range of 0.01 to 1 (-20 dB to 0 dB).

2 Digital Satellite TV

2.1 Spectrum

The signal is downlinked from a satellite using a carrier in the range of 10-12.5 GHz which is the Ku band. This signal is collected by a dish antenna and fed into a low noise block (LNB). The downconverted signal is the range of 1-2.5 GHz. The downconverted signal out of the LNB is our input signal which is amplified using the RF pre-amplifier, and then down converted again to an IF in the range of 10 MHz.

1. Using *Cal_SA* and the input the TA provide, examine the satellite spectrum. Noting that the LO frequency for the LNB 10.75 GHz, identify the major (20 MHz or greater) Ku bands on Horizons 1 using the channel assignment chart at the end of the lab.

2.2 Demodulation of a Satellite Channel

1. Using *Cal_SA*, find the channel broadcasting at 1.02226 GHz. Measure the total transmitted power and dump the spectrum.
2. Tune the QPSK receive onto the channel and see if you can get the QPSK constellation to lock. Once locked, adjust the relevant parameters to optimize the constellation. When you are done, dump the constellation to a plot. A sample constellation is shown b

3 Post Lab

1. Under what conditions are the spectra of QPSK and BPSK signals the same?
2. Which loop (BPSK with hard limiter or QPSK) works better for constant sinusoidal signals? Provide reasons for your conclusion.
3. What modifications are required in order for the QPSK loop to work with higher order constellations?
4. Plot the BER vs, E_b/N_0 for the measured cases: 1) BPSK data only on the *I* channel, 2) BER on the *I* channel for QPSK data, 3) BER on the *Q* channel for QPSK data.
5. On a different curve, plot:
 - a) The exact and approximate symbol error rate P_e vs. E_b/N_0 for QPSK.
 - b) Assuming a Gray code, the corresponding BERs using $BER \approx \frac{1}{2}P_e$
6. Compare the approximate BER derived from the theoretical curves with measured curves. Comment on the result.
7. Describe and justify your methodology for adjusting the receiver parameters to optimize the constellation.


SR -- symbol rate - typical rates are 19.51 MSymbols/s and 29270

FEC - convolutional code rate

SID - The Service Identifier is used by the receiver to identify a certain service within a transmission

VPID:Video program identification number- defines the data substream containing the video signal.

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Freq. Tp	Provider Name Channel Name		Video Encryption	SR-FEC SID-VPID	NID-TID Audio	Beam	Source Updated	
11720 H tp 1	Pi TV	A U	DVB	26800-3/4		Ku	Xuthus 061022	
	Da-Ai TV	A N	PrediWave	44				
	Sky Link TV	A	PrediWave	1	42			39 C
	Chongqing TV	A	PrediWave	7	106			36 C
	Asia After Dark (21-16 ET)	A	PrediWave	14	83	107 C	91 J	
11727 V tp 2	(feeds)		DVB	6620-?		Ku	R Caylor 051111	
11980 V tp 14	(feeds)		NTSC			Ku	J Hotsenpiller 040119	
12050 H tp 17	(feeds)		DVB	13020-?		Ku	J Everett 060219	
12087 V tp 20	(feeds)		DVB	6111-?		Ku	J Hotsenpiller 040306	
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Freq. Tp		Provider Name Channel Name	Video Encryption	SR-FEC SID-VPID	NID-TID Audio	Beam	Source Updated
12120 H tp 21		(feeds)	NTSC			Ku	Rick 050214
12140 V tp 22		@ HughesNet	A	DVB	30000-3/4	Ku	Greg 921 060604
12160 H tp 23		(feeds)	NTSC			Ku	J Hotsenpiller 040316
12180 V tp 24		(feeds)	DVB	16278-?		Ku	M Reynolds 040428
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Colour codes on this satellite chart: analog/clear analog/encrypted digital/clear digital/encrypted HD/clear HD/encrypted internet/interactive feeds