04/19/2023. Wednesday. DSP Lecture

announcements: Quantization, 64 QAM } NOT tested on Midterm 2.

Performance Analysis of PAM starting @ (Slides 15-11) (only channel impairment = AWGN additive white gaussian noise)

usually, $T_{symb} = 1$ to make analysis easier

d = voltage of Txed symbol (the amplitude of Txed signal)

⇒ for now, we assume the Rxer knows what value d is.

★ matched filter will have same bandwidth/shape as the pulse shaping filter

↳ no difference/change to signal, aside from adjusting signal gain.

Best Matched Filter:

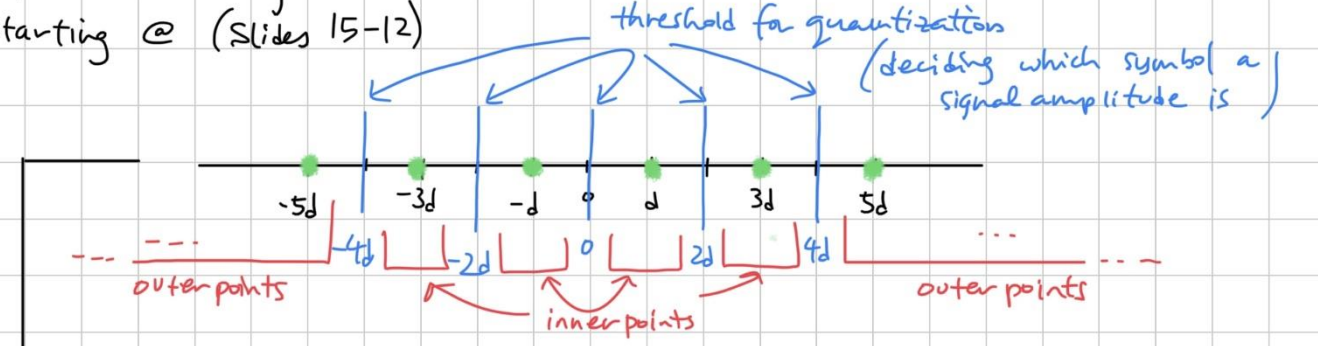
$$g_r(t) = k\, g^*(T_{symb} - t)$$

any integer multiple of T_{symb} will do! (ok!)

↓

optimizes the Rxed SNR. if only channel impairment is AWGN

Performance Analysis of PAM starting @ (Slides 15-12)



Q: previously we had decision regions dependent on T_{symb}

does this mean as T_{symb} increases, our decision region also increases?

↓

Ans: yes, if T_{symb} ↑ you can think of it as the Rxer has more time to look at the symbol.

⇒ meaning, the Matched Filter is averaging longer

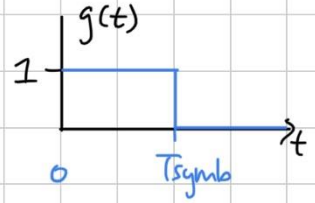
the longer the Matched Filter "looks at" or averages the Rxed signal, the potentially more accurate the Rxer will be in deciding the Rxed symbol

(longer T_{symb}

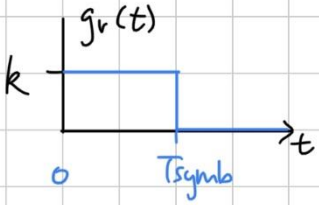
⇒ longer time to decide the symbol in time domain

⇒ removes more out-of-band noise in freq. domain)

↳ b/c null BW = $\frac{1}{T_{symb}}$, as T_{symb} ↑ Bandwidth ↓)



⇒ Tx pulse shape with null Bandwidth(BW) = $\frac{1}{T_{symb}}$



⇒ Matched Filter Response with null BW = $\frac{1}{T_{symb}}$

what's the cost?

⇒ longer delay to Rx the signal! (slower speed)

Criteria	Channels	
	Control	Data
Tsymb	High	Low
Bit Rate	Low	High
Reliability	High	Low
Bit Error Rate (with Error correction codes)	$10^{-5} \to 10^{-6}$ (low error)	$10^{-1} \to 10^{-4}$ (higher error)

★ bit rate = $J \cdot f_{symb}$

back to PAM Analysis of Symbol Error Probability

inner points have different probability of symbol error : $P_i(e)$

i = inner point

outer points have a separate probability of symbol error : $P_o(e)$

o = outer point

total error = ...

$$P(e) = \frac{\#\text{inner points}}{\text{total \# points}} \cdot P_i(e) + \frac{\#\text{outer points}}{\text{total \# points}} \cdot P_o(e)$$

moving onto QAM Performance Analysis ⇒ Correct Symbol Detection

★ PAM discussion was on Symbol Error Detection.

$P(c) = 1 - P(e)$

instead of inner / outer points in PAM,

QAM has Type I ⇒ 4 sides (interior) $P_1(c)$

Type II ⇒ 3 sides (edge) $P_2(c)$

Type III ⇒ 2 sides (corner) $P_3(c)$

$$P(e) = 1 - P(c)$$

$$P(c) = \frac{\#\text{ Type I}}{\text{total \# points}} \cdot P_1(c) + \frac{\#\text{ Type II}}{\text{total \# points}} \cdot P_2(c) + \frac{\#\text{ Type III}}{\text{total \# points}} \cdot P_3(c)$$

the difficulty ⇒ determining the Decision Boundaries for a QAM constellation.

(break @ 11:13 AM)

(return @ 11:18 AM)

Q: disadvantage of QAM?

Ans: First advantage: better spectral efficiency
better symbol error speeds

now, disadvantage: Rxer complexity is more than 2x compared to PAM
much more sensitive to amplitude & phase distortion

Discussion of Review Slides @ 11:20 AM

Review

on Tx side:
- Upsampling + Interpolation Pulse Shaping Filter (@ 11:29 AM)
  - vs. Polyphase Filter Bank for Interpolation

on Rx side:
- Anti-Aliasing Filter & Downsampling
  - vs. Polyphase Filter Bank for Decimation

Communication Channel: Tx ⟶ Channel ⟶ Rx

we focus on Baseband Digital Processing in both Txer & Rxer

Discuss... Midterm Questions @ 11:44AM

1. Communication System Tradeoff (Fall 2020 Midterm #2.4)
2. Symbol Timing Recovery (Spring 2021 Midterm #2.1)