ECE 447 Fall 2025

Lesson 20
PCM (cont'd) and Pulse Modulations

Schedule and Admin

- Schedule
- Admin
  - **HW3**. Posted on course website. Due Lesson 20 (1 Oct, TONIGHT). Not on Prog grade.
  - **GR1 Grades**. Added a 5pt "curve" to everyone's GR1 grade in Blackboard. Not going to offer regrade opportunity (class Prog average is actually 1% higher than last semester's). Make sure you know what you missed, so you don't potentially miss it again on the Final.
  - Everything for Prog is graded and in Blackboard
    - Check your grades for any mistakes
    - Submit any regrade requests before 1600, 1 Oct

PCM Computer Example

- What has a larger impact on quantization error: sampling frequency or number of bits?

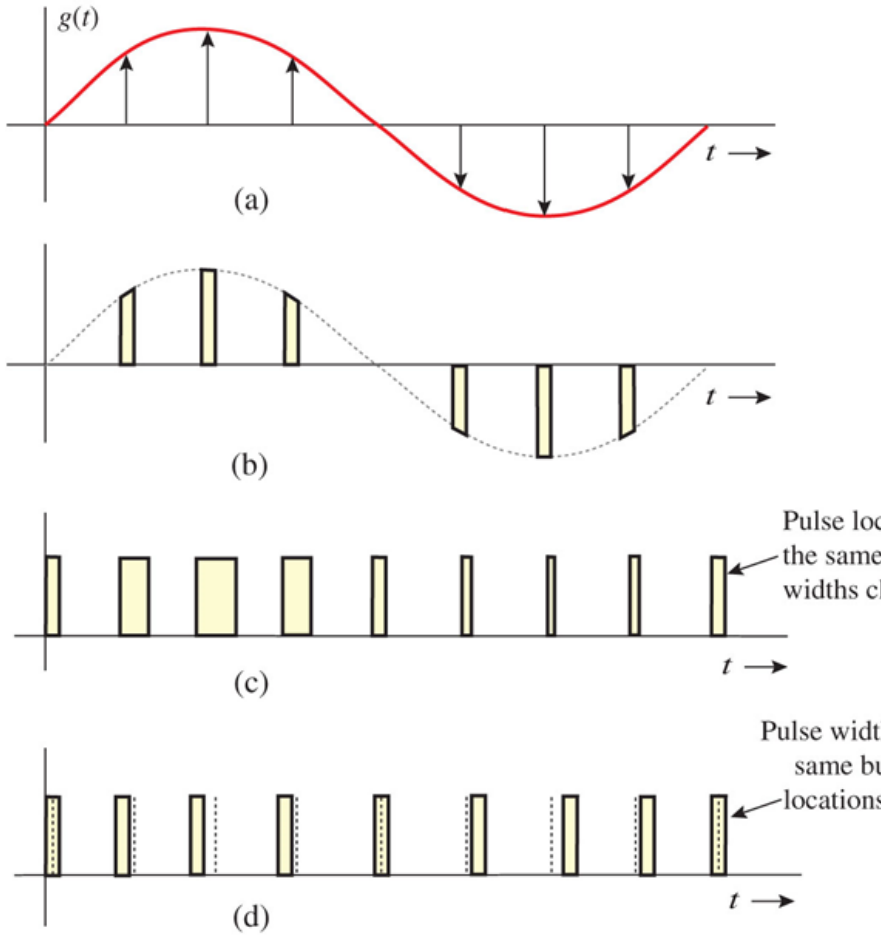
Binary PCM

- SNR
  - Rule of thumb: each additional bit adds 6dB of SNR (how many times greater is that?)
- Max information rate given finite bandwidth
  - Assuming a noiseless channel with bandwidth B, a max of $2B$ pieces of info (e.g., bits) per second can be transmitted error-free
  - Shannon-Hartley theorem defines limit in presence of noise
- Transmission Bandwidth
  - For $m(t)$ band-limited to BHz, min sample rate is $2B$ samples/s
  - Encoder output is then $2nB$ bit/s
  - Minimum required (theoretical) channel bandwidth,

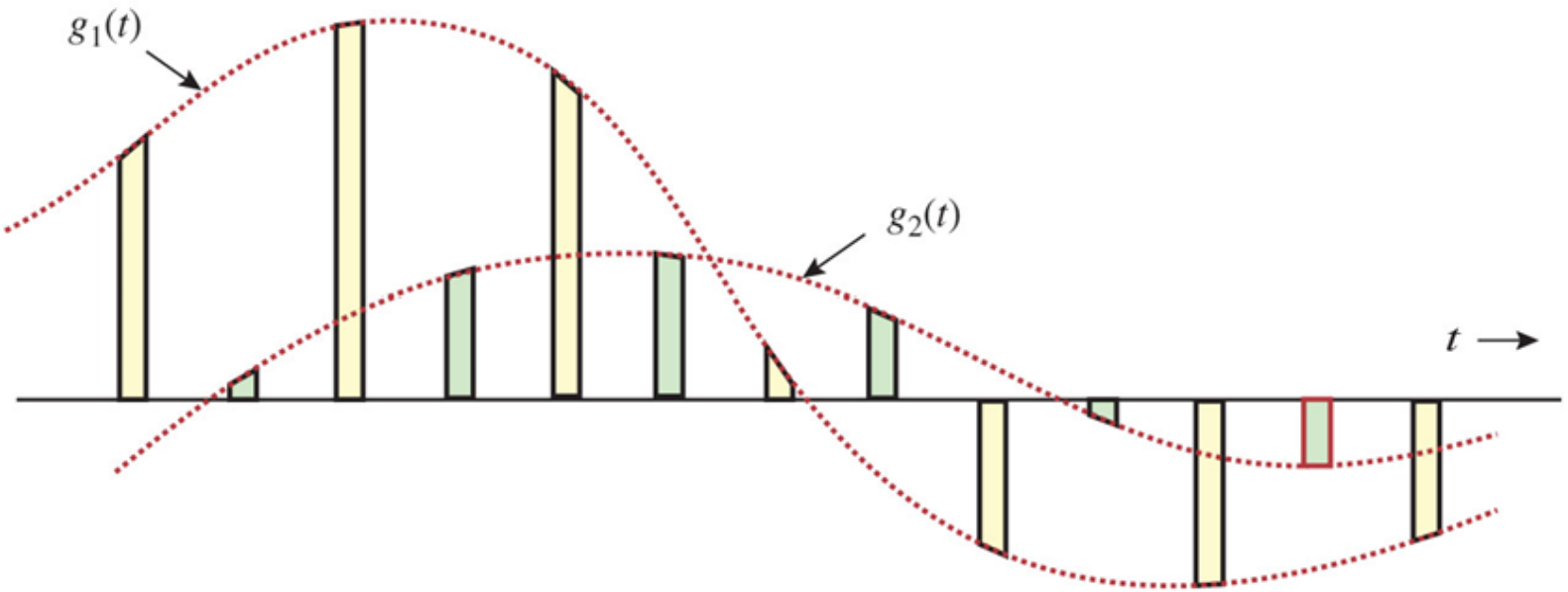
$$B_T =$$

Pulse Modulations

- **PAM**: primarily now used for baseband digital communications (e.g., USB4 Ver 2.0 uses PAM-3, or 3-level PAM)
- **PWM**: power or motor control (e.g., robotics, power supply regulation); minimal telecommunication applications
- **PPM**: fiber optical communications, deep-space communications, R/C applications



Time Division Multiplexing



Binary PCM - Example Problem 5.2

- $m(t)$ band-limited to 3kHz is sampled at 1/3 higher than the Nyquist rate
- Max acceptable quantization error is 0.5% m_p
- Find min channel bandwidth for transmission.
- If 24 signals combined via TDM, what is min required transmission bandwidth of multiplexed signal?