AV312 - Lecture 15

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Figures from "Communication Systems" by Haykin and "An Intro. to Analog and Digital Commn." by Haykin and Moher

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Announcements

- Please check the marks for the first quiz; uploaded to the class webpage/exams
- Class tests on 23rd September and 26th September

Review of last classes

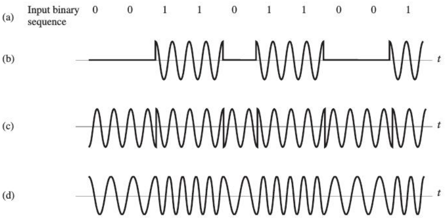
- Digital transmission
  - Line codes for transmission over baseband channels
  - BASK, BPSK, BFSK for transmission over passband channels
  - Generation and detection of BASK, BPSK, and BFSK
  - BPSK spectrum for bandwidth requirements

Today's class

- BASK and BFSK spectrum and bandwidth requirements
- Quadriphase shift keying
- Today's scribes are Prashant G. Iyer and Priyanka Meena

Review of shift keying techniques

- A sinusoidal carrier signal $c(t) = A_c cos(2\pi f_c t + \phi_c)$
- Binary amplitude shift keying (BASK)
- Binary phase shift keying (BPSK)
- Binary frequency shift keying (BFSK)
- A convenient normalization for unit carrier energy for a bit duration; $A_c = \sqrt{\frac{2}{T_b}}$



Power spectrum of BPSK

- The BPSK-ed $s(t) = b(t)c(t)$, where $b(t)$ is a pulse train with $\sqrt{E_b}$ and $-\sqrt{E_b}$ levels.
- Suppose we have a rectangular pulse $p(t)$ of duration T_b (assume non-zero in $[0, T_b)$) and amplitude A. What is the normalized energy spectrum $|P(f)|^2$ of this pulse?
- $|P(f)|^2 = A^2 T_b^2 sinc^2(\pi f T_b)$
- Suppose we take bit sequences of length n and compute their normalized energy spectrums
- An average normalized power spectrum can be obtained as $\frac{1}{nT_b} \times$ energy spectrum of n bit sequence.
- Turns out that the normalized energy spectrum for n pulses is $nA^2 T_b^2 sinc^2(\pi f T_b)$
- Therefore, the normalized power spectrum $|B(f)|^2$ is $A^2 T_b sinc^2(\pi f T_b)$

Power spectrum of BPSK

- So $|B(f)|^2$ is $A^2 T_b sinc^2(\pi f T_b)$
- We are translating this baseband spectrum to f_c and $-f_c$ when we are multiplying it by the carrier signal $c(t)$
- What is the normalized power spectrum of the BPSK signal?
- It is approximately $\frac{1}{4}\left[A^2 T_b sinc^2(\pi(f-f_c)T_b) + A^2 T_b sinc^2(\pi(f+f_c)T_b)\right]$
- Bandwidth requirements for transmission - usually the main lobe width so $\frac{2}{T_b}$.

Power spectrum of BASK

- A BASK $s(t)$ is $\frac{A}{2}cos(2\pi f_c t) + \frac{s_{PSK}(t)}{2}$!
- We think of the BASK signal as a carrier component along with a BPSK signal.
- The spectrum has a carrier component at f_c, which is not present for BPSK.

Power spectrum of BFSK

- A BFSK $s(t)$ is the sum of two BASK signals
- $s(t) = b(t)\sqrt{\frac{2}{T_b}}cos(2\pi f_1 t) + (1 - b(t))\sqrt{\frac{2}{T_b}}cos(2\pi f_2 t)$
- The approximate spectrum of $s(t)$ can be obtained as the “sum” of two BASK spectrums!

A general formula for the power spectrum

- Suppose a general pulse shape $g(t)$ is used, i.e., $g(t)$ is used for transmitting a 1 and $-g(t)$ for a 0
- If $G(f)$ is the FT of $g(t)$, then the normalized power spectrum of the signalling scheme is $\frac{1}{T_b}|G(f)|^2$

Quadriphase shift keying (QPSK)

- For $kT \leq t < (k+1)T$

$$s(t) \quad = \quad \sqrt{\frac{2E}{T}} cos \left(2\pi f_c t + (2i-1)\frac{\pi}{4} \right),$$

  where $i \in \{1, 2, 3, 4\}$
- Note that the time interval T is possibly different from T_b
- A generalized version is M-ary PSK
- Recall quadrature carrier multiplexing - two signals multiplexed together using quadrature carriers but no increase in bandwidth
- $s(t) = \sqrt{\frac{2E}{T}} cos\left((2i-1)\frac{\pi}{4}\right) cos(2\pi f_c t) - \sqrt{\frac{2E}{T}} sin\left((2i-1)\frac{\pi}{4}\right) sin(2\pi f_c t)$
  - Combination of two BPSK signals - the bits can be chosen independently
  - A representation using vectors - constellation diagram

QPSK - generation and detection