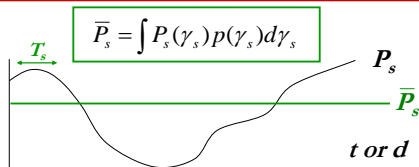


EE359 – Lecture 10 Outline

- **Announcements:**
 - Project proposals due this Friday at 5pm (post, email link)
 - HWs due Friday 5pm SHARP (and going forward)
 - Nima OH moved from Wed to Thur 6-8pm, 3rd floor tables
 - Midterm will be @ Nov. 10, 6-8pm (no HW that week)
 - More MT announcements next week (practice MTs)
- Average P_s (P_b)
- MGF approach for average P_s
- Combined average and outage P_s
- P_s due to Doppler ISI
- P_s due to ISI

Average P_s

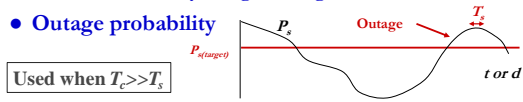


- Expected value of random variable P_s
- Used when $T_c \sim T_s$
- Error probability much higher than in AWGN alone
- Alternate Q function approach: $Q(z) = \frac{1}{\pi} \int_0^{\pi/2} e^{-z^2 / (\sin^2 \phi)} d\phi$
 - Simplifies calculations (Get a Laplace Xfm)

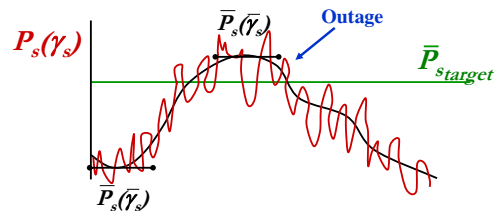
Doppler Effects

- High doppler causes channel phase to decorrelate between symbols
- Leads to an irreducible error floor for differential modulation
 - Increasing power does not reduce error
- Error floor depends on $B_d T_s$

Review of Last Lecture

- Linear modulation more spectrally efficient but less robust than nonlinear modulation
- P_s approximation in AWGN: $P_s \approx \alpha_M Q(\sqrt{\beta_M \gamma_s})$
- Probability of error in fading is random
 - Characterized by outage, average P_s , combination
- Outage probability
 
 - Probability P_s is above target; Probability γ_s below target
- Fading severely degrades performance

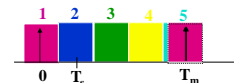
Combined outage and average P_s



- Used in combined shadowing and flat-fading
- \bar{P}_s varies slowly, locally determined by flat fading
- Declare outage when \bar{P}_s above target value

ISI Effects

- Delay spread exceeding a symbol time causes ISI (self interference).



- ISI leads to irreducible error floor
 - Increasing signal power increases ISI power
- ISI requires that $T_s \gg T_m$ ($R_s \ll B_c$)

Main Points

- In fading P_s is a random variable, characterized by average value, outage, or combined outage/average
 - Outage probability based on target SNR in AWGN.
 - Fading greatly increases average P_s .
 - Alternate Q function approach simplifies P_s calculation, especially its average value in fading (Laplace Xfm).
- Doppler spread only impacts differential modulation causing an irreducible error floor at low data rates
- Delay spread causes irreducible error floor or imposes rate limits
- Need to combat flat and frequency-selective fading
 - Focus of the remainder of the course