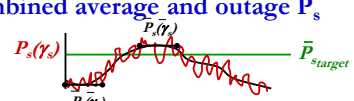


EE359 – Lecture 11 Outline

- **Announcements**
 - Midterm announcements
 - No HW next week (practice MTs)
- Introduction to Diversity
- Combining Techniques
- Selection Combining
- Maximal Ratio Combining
- MGF Approach to MRC Performance
- EGC and Transmit Diversity

Review of Last Lecture

- Average P_s (P_b):
$$\bar{P}_s = \int P_s(\gamma_s) p(\gamma_s) d\gamma_s$$
- MGF approach for average P_s
 - Average P_s becomes a Laplace transform
- Combined average and outage P_s

- P_s due to Doppler: error floor unless $T_s \ll T_c$
- P_s due to ISI: error floor unless $T_s \gg T_c$
- Must compensate for fading and ISI

Combining Techniques

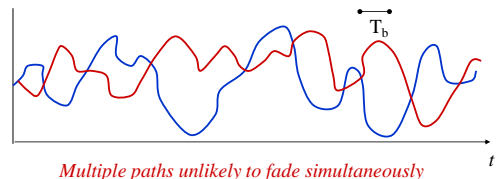
- Selection Combining
 - Fading path with highest gain used
- Maximal Ratio Combining
 - All paths cophased and summed with optimal weighting to maximize combiner output SNR
- Equal Gain Combining
 - All paths cophased and summed with equal weighting
- Array/Diversity gain
 - Array gain is from noise averaging (AWGN and fading)
 - Diversity gain is change in BER slope (fading)

Midterm Announcements

- Midterm Thur Nov. 10, 6-8pm, Room 200-030
 - Open book/notes (bring textbook/calculators)
 - Covers Chapters 1-7
- Review session preference (Sun, Mon)?
- Extra OHs to be announced Wednesday
- No HW next week
- Midterms from past 3 MTs posted this week
 - 10 bonus points for “taking” a practice exam
 - Solns for all exams given when you turn in practice exam

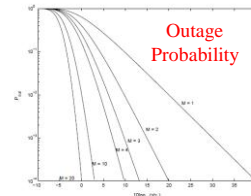
Introduction to Diversity

- Basic Idea
 - Send same bits over independent fading paths
 - Independent fading paths obtained by time, space, frequency, or polarization diversity
 - Combine paths to mitigate fading effects



Selection Combining Analysis and Performance

- Selection Combining (SC)
 - Combiner SNR is the maximum of the branch SNRs.
 - CDF easy to obtain, pdf found by differentiating.
 - Diminishing returns with number of antennas.
 - Can get up to about 20 dB of gain.



MRC and its Performance

- With MRC, $\gamma_{\Sigma} = \sum \gamma_i$ for branch SNRs γ_i
 - Optimal technique to maximize output SNR
 - Yields 20-40 dB performance gains
 - Distribution of γ_{Σ} hard to obtain

- Standard average BER calculation

$$\bar{P}_b = \int P_b(\gamma_{\Sigma}) p(\gamma_{\Sigma}) d\gamma_{\Sigma} = \int \dots \int P_b(\gamma_{\Sigma}) p(\gamma_1) \cdot p(\gamma_2) \cdot \dots \cdot p(\gamma_M) d\gamma_1 d\gamma_2 \dots d\gamma_M$$

- Hard to obtain in closed form
- Integral often diverges

- MGF Approach

$$\bar{P}_b = \frac{1}{\pi} \int_0^{\frac{\pi}{2}} \prod_{i=1}^M \mathcal{M}_i \left[\frac{-g}{\sin^2 \varphi}; \gamma_i \right] d\varphi$$

EGC and Transmit Diversity

- EGC simpler than MRC

- Harder to analyze
- Performance about 1 dB worse than MRC

- Transmit diversity

- With channel knowledge, similar to receiver diversity, same array/diversity gain
- Without channel knowledge, can obtain diversity gain through Alamouti scheme: works over 2 consecutive symbols

Main Points

- Diversity overcomes the effects of fading by combining fading paths
- Diversity typically entails some penalty in terms of rate, bandwidth, complexity, or size.
- Techniques trade complexity for performance.
 - MRC yields 20-40 dB gain, SC around 20 dB.
- Analysis of MRC simplified using MGF approach
- EGC easier to implement than MRC: hard to analyze: Performance about 1 dB worse than MRC
- Transmit diversity can obtain diversity gain even without channel information at transmitter.