Diversity

Lecture Outline

- Introduction to Diversity
- Selection Combining (SC) and its Performance
- Maximal Ratio Combining (MRC)
- Performance of MRC with i.i.d. Rayleigh fading

1. Introduction to Diversity
   - Basic concept is to send same information over independent fading paths.
   - Paths are combined to mitigate the effects of fading.

2. Realization of Independent Fading Paths
   - Space Diversity: Multiple antenna elements spaced apart by decorrelation distance.
   - Polarization Diversity: Two antennas, one horizontally polarized and one vertically polarized.
   - Frequency diversity: Multiple narrowband channels separated by channel coherence bandwidth.
   - Time diversity: Multiple timeslots separated by channel coherence time.

3. Array and Diversity Gain
   - Array gain is the gain in SNR from noise averaging over the multiple antennas. Gain in both AWGN and fading channels.
   - Diversity gain is the change in slope of the probability of error due to diversity. Only applies to fading channels.

4. Techniques for Combining Independent Fading Paths
   - Selection Combining: largest fading path chosen.
   - Maximal Ratio Combining: all paths cophased and summed with optimal weighting to maximize SNR at combiner output.
   - Equal Gain Combining: all paths cophased and summed with equal weighting.
   - We use space diversity as a reference for analysis; same analysis applies for any mechanism used to obtain independent fading paths.

5. Selection Combining (SC) and its Performance
   - Combiner SNR $\gamma_\Sigma$ is the maximum of the branch SNRs.
   - This gives diminishing returns, in terms of power gain, as the number of antennas increases.
   - CDF of $\gamma_\Sigma$ easy to obtain, then pdf found by differentiating.
• Typically get 10-15 dB of gain for 2-3 antennas.

6. Maximal Ratio Combining (MRC)
• Branch weights optimized to maximize output SNR of combiner.
• Optimal weights are proportional to branch SNR.
• Resulting combiner SNR $\gamma_\Sigma$ is sum of branch SNRs.
• Distribution obtained by characteristic function analysis (can be hard).

7. Performance of MRC with i.i.d. Rayleigh fading
• For $M$ branch diversity with i.i.d. Rayleigh fading on each branch, $\gamma_\Sigma$ is chi-squared with $2M$ degrees of freedom.
• Can obtain $P_{out}$ and $P_s$ from this distribution.
• For BPSK, get 15 dB gain at $10^{-3}$ BER. Larger gains obtained at lower BERs.

Main Points
• Diversity is a powerful technique to overcome the effects of flat fading by combining multiple independent fading paths
• Diversity typically entails some penalty in terms of rate, bandwidth, complexity, or size.
• Both selection combining and MRC significantly reduce the impact of fading.
• SC vs. MRC offer different levels of complexity vs. performance.
• Performance analysis of MRC greatly simplified using MGF approach.