

Diversity Combining Techniques and Their Analysis

Lecture Outline

- Selection Combining (SC) and its Performance
- Maximal Ratio Combining (MRC)
- Performance of MRC with i.i.d. Rayleigh fading
- MGF Analysis of MRC
- Equal Gain Combining
- Transmit Diversity

1. 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.

2. Selection Combining (SC) and its Performance

- Combiner SNR γ_{Σ} is the maximum of the branch SNRs.
- This gives diminishing returns, in terms of power gain, as the number of antennas increases.
- CDF of γ_{Σ} easy to obtain, then pdf found by differentiating.
- Typically get 10-15 dB of gain for 2-3 antennas.

3. Maximal Ratio Combining (MRC)

- Branch weights optimized to maximize output SNR of combiner.
- Optimal weights are proportional to branch SNR.
- Resulting combiner SNR γ_{Σ} is sum of branch SNRs.
- Distribution obtained by characteristic function analysis (can be hard).

4. Performance of MRC with i.i.d. Rayleigh fading

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

5. MGF Approach to MRC Diversity Analysis.

- Distribution of γ_Σ hard to obtain when fading is not Rayleigh or not identically distributed.
- Can use alternate Q function representation to greatly simplify \bar{P}_b calculation.
- Using alternate representation and switching order of integration yields

$$\bar{P}_b = \frac{1}{\pi} \int_0^{.5\pi} \prod_{i=1}^M \mathcal{M}_i \left[\frac{-g}{\sin^2 \phi}, \gamma_i \right] d\phi,$$

for BPSK, where \mathcal{M}_i is the moment generating function for the distribution of the i th branch SNR γ_i . Similar formulas for more general modulations using P_s approximation.

6. Equal Gain Combining

- In EGC, each branch is co-phased and equally weighted.
- Easier to implement than MRC, but harder to analyze.
- Distribution of combiner SNR γ_Σ complicated for more than two branches. Hard to obtain P_{out} and \bar{P}_s .
- EGC is about 1 dB worse in performance than MRC.

7. Transmit Diversity

- When channel known at transmitter, similar to receiver diversity. Get same array and diversity gain.
- When channel unknown at transmitter, can use clever Alamouti scheme over two symbol times to obtain full diversity gain, but no array gain.

Main Points

- SC vs. MRC offer different levels of complexity vs. performance.
- Performance analysis of MRC greatly simplified using MGF approach.
- Performance of EGC about 1 dB worse than MRC, with somewhat less complexity.
- Transmit diversity can obtain diversity even without channel information at the transmitter using clever Alamouti scheme.