



SNS COLLEGE OF TECHNOLOGY

Coimbatore – 35

An Autonomous Institution



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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

16EC401 / Wireless Communication

IV ECE/ VII SEMESTER

Unit IV - **MULTIPATH MITIGATION TECHNIQUES**

Topic 6,7 : Diversity Combining Techniques



Diversity Combining Methods

- Each branch is co-phased with the other branches
 - Weighted by factor a_i where a_i depends on amplitude r_i
- Selection diversity
 - $a_i = 1$ if $\rho_i > \rho_j$, for all $j \neq i$ and 0 otherwise.
 - Equal Gain Combining: $a_i = 1$ for all i .
 - Maximum Ratio Combining: $a_i = \rho_i$.

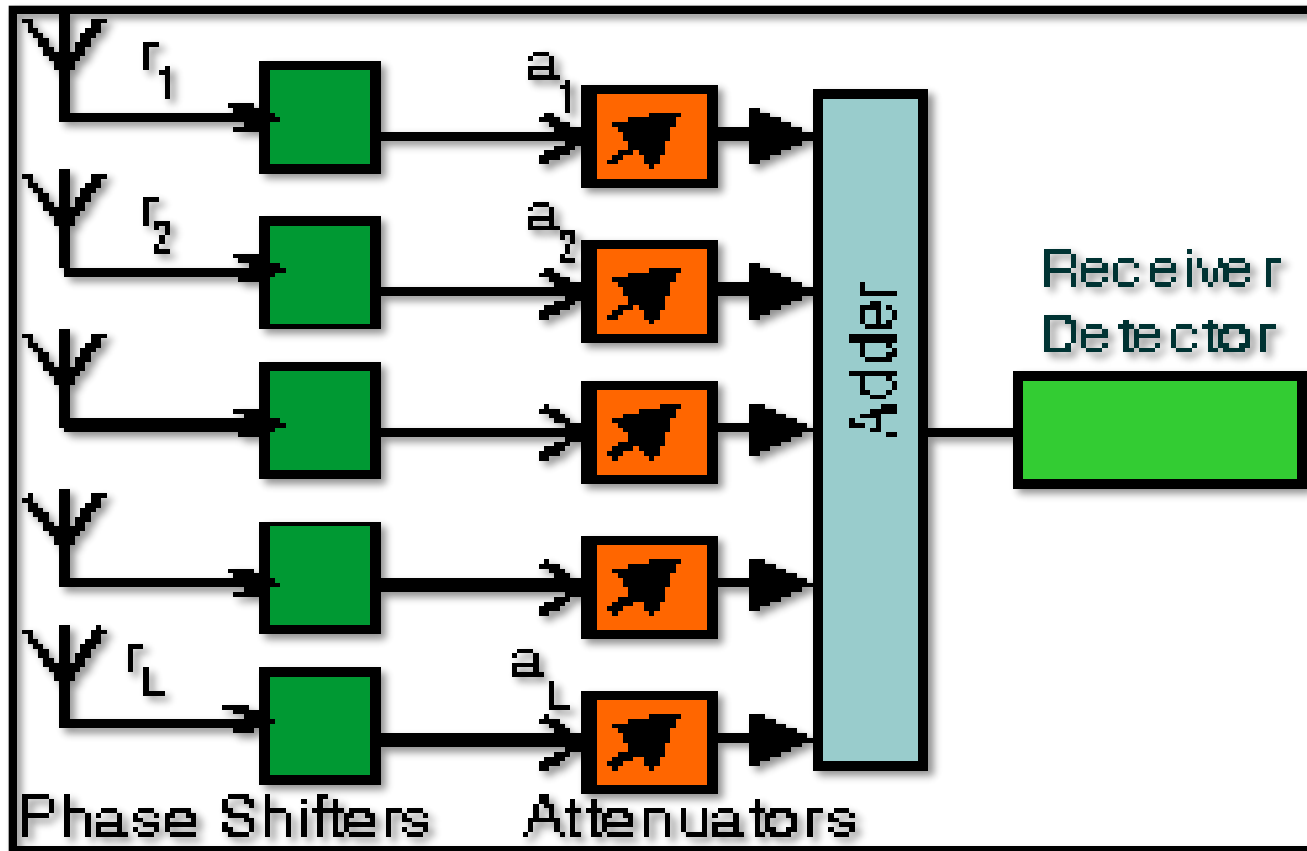


Selection diversity

- Select only the strongest signal
- In practice: select the highest signal + interference + noise power.
- Use delay and hysteresis to avoid ping-pong effects (excessive switching back and forth)
- Simple implementation: Threshold Diversity
- Switch when current power drops below a threshold
- This avoids the necessity of separate receivers for each diversity branch.



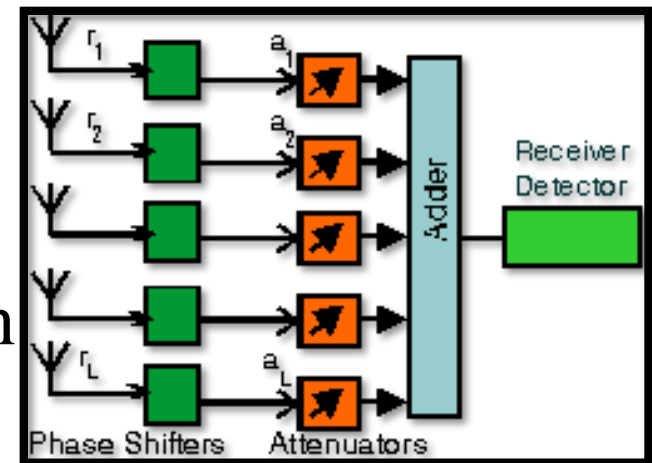
Selection diversity





Selection diversity

- Diversity rule:
- Select strongest signal
- Outage probability for selection diversity:



$$\begin{aligned}\Pr(\max(p) < p_{\text{thr}}) &= \Pr(\text{all}(p) < p_{\text{thr}}) \\ &= \prod P_i \Pr(p_i < p_{\text{thr}})\end{aligned}$$

- For L -branch selection diversity in Rayleigh fading:

$$\Pr(\max(p) < \bar{p} / \eta) = [1 - \exp\{-1/\eta\}]^L$$



Selection Diversity

Selection Diversity → simple & cheap

- Rx selects branch with highest **instantaneous SNR**
 - New selection made at a time that is the reciprocal of the fading rate
 - This will cause the system to stay with the current signal until it is likely the signal has faded
- *SNR* improvement :
 - $\bar{\gamma}$ is new avg. *SNR*
 - Γ : avg. *SNR* in each branch



Selection Diversity

- A block diagram of this method is similar to space diversity
- m demodulators are used to provide m diversity branches
- whose gains are adjusted to provide the same average SNR for each branch.
- The receiver branch having the highest instantaneous SNR is connected to the demodulator.

$$\bar{\gamma} = \Gamma \sum_{k=1}^m \frac{1}{k} = \Gamma \left(1 + \frac{1}{2} + \frac{1}{3} + \frac{1}{4} + \dots + \frac{1}{m} \right) > \Gamma$$

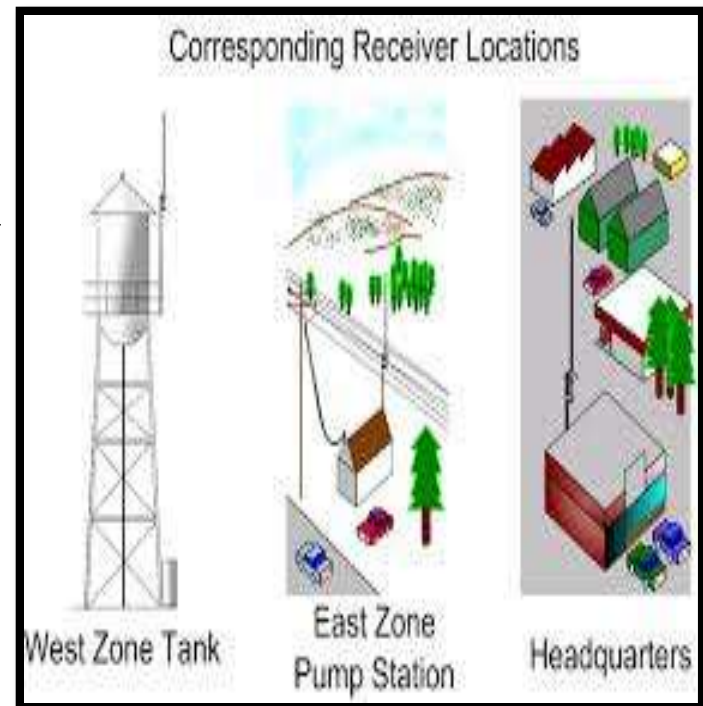


Combining Diversity

➤ Selection diversity wastes signal energy by discarding $(N_r - 1)$ copies of the received signal

➤ This drawback is avoided by combining diversity, which exploits all available signal copies

➤ Each signal copy is multiplied by a (complex) weight and then added up





Combining Diversity-Types

1. Maximum Ratio Combining (MRC)

- a. Weighs all signal copies by their amplitude
- b. This is an optimum combination strategy

2. Equal Gain Combining (EGC)

- a. Where all amplitude weights are the same



Activity



- Imagine folding a paper in half once
- Then take the result and fold it in half again; and so on
- How many times can you do that?



MAXIMAL RATIO COMBINING

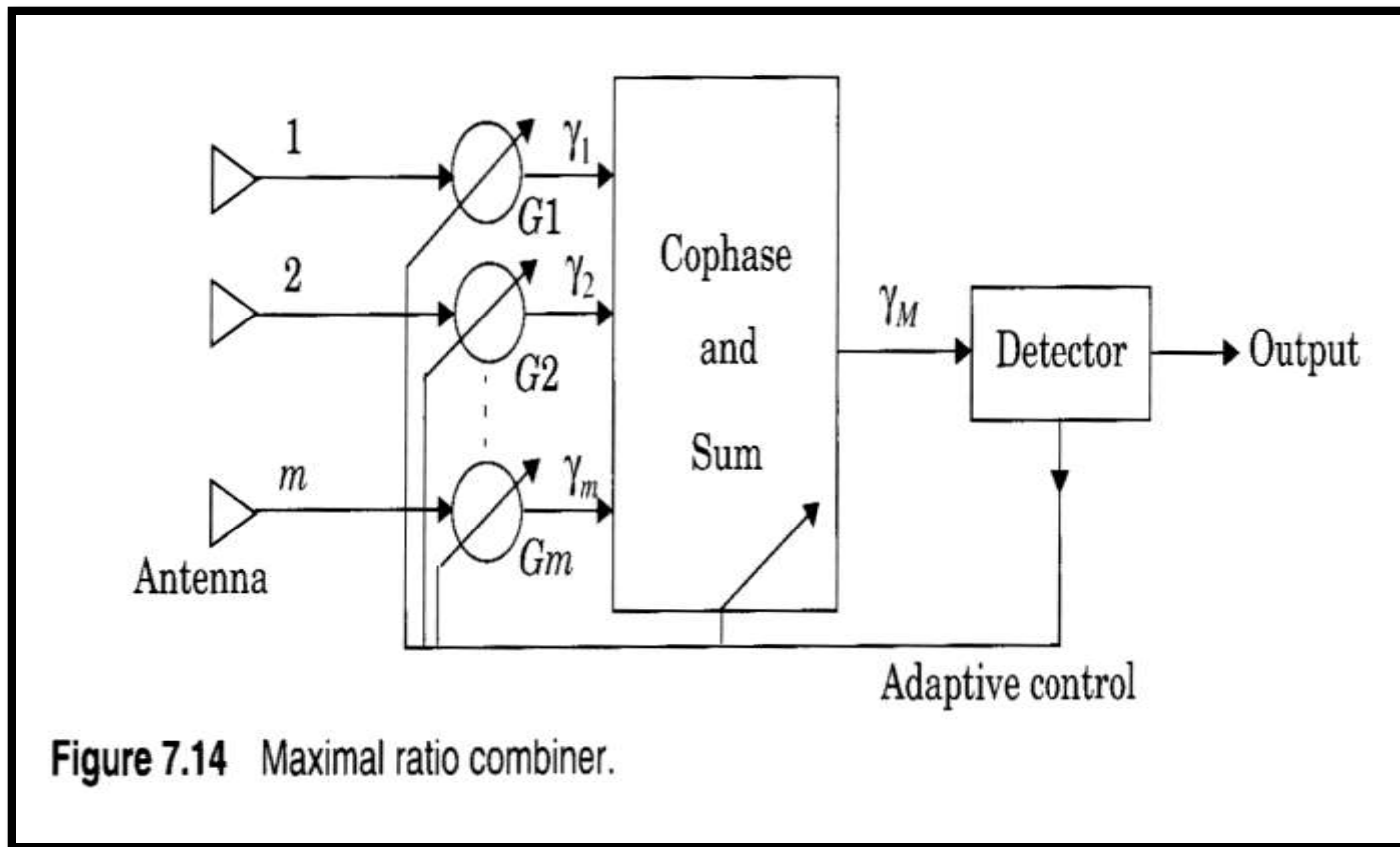


Figure 7.14 Maximal ratio combiner.



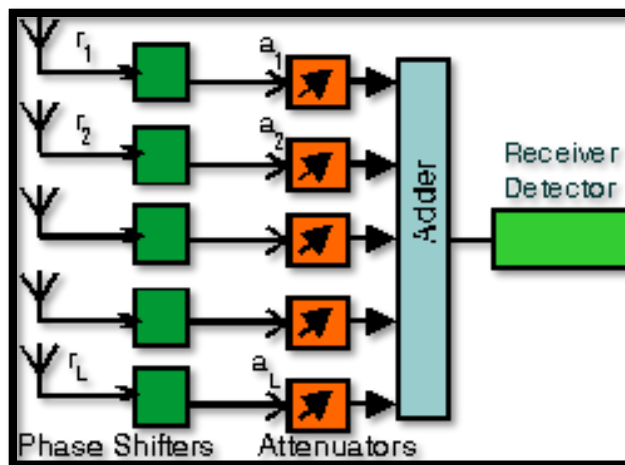
Maximum ratio combining

- Weigh signals proportional to their amplitude.

MRC:

$$a_i = \text{constant } r_i$$

- This is the same as matched filter
- SNR at the output is the sum of the SNRs at all the input branches





Maximum Ratio Combining



Maximal Ratio Diversity

- signal amplitudes are weighted according to each SNR
- summed **in-phase**
- most complex of all types
- a complicated mechanism, but modern DSP makes this more practical → especially in the base station Rx where battery power to perform computations is not an issue



EQUAL GAIN DIVERSITY



Equal Gain Diversity

- combine multiple signals into one
- $G = 1$, but the phase is adjusted for each received signal so that
 - The signal from each branch are co-phased
 - vectors add in-phase
- better performance than selection diversity



Comparison

<u>Technique:</u>	<u>Circuit Complexity:</u>	<u>C/N improvement factor:</u>
Threshold	simple, cheap single receiver	$1 + \gamma_T/\Gamma \exp(-\gamma_T/\Gamma)$ for $L = 2$ optimum for γ_T/Γ : $1 + e \approx 1.38$
Selection	L receivers	$1 + 1/2 + \dots + 1/L$
EGC	L receivers co-phasing	$1 + (L - 1) \pi/4$
MRC	L receivers co-phasing channel estimator	L



Assessment



- **1. In maximal ratio combining, the output SNR is**
 - a) Mean of all individual SNRs
 - b) **Maximum of all SNRs**
 - c) Sum of individual SNR
 - d) Minimum of all SNRs

- **2. The technique for combining diversity signals are**
 - a) Feedback
 - b) Maximal ratio
 - c) Equal gain
 - d) **All of the mentioned**

