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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

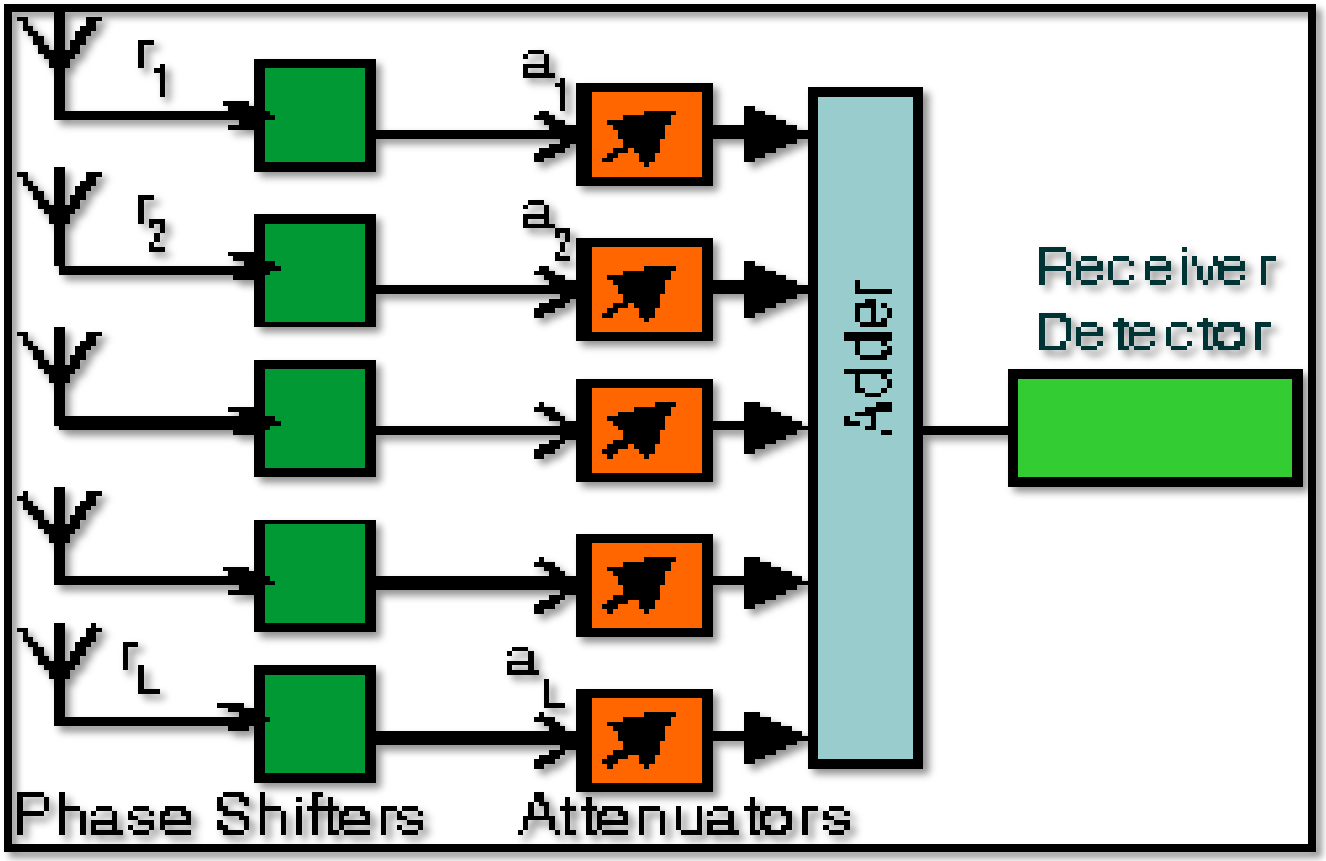
- Each branch is co-phased with the other branches
- Weighted by factor a_i where a_i depends on amplitude r_i

- 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: $a_i = \rho_i$.

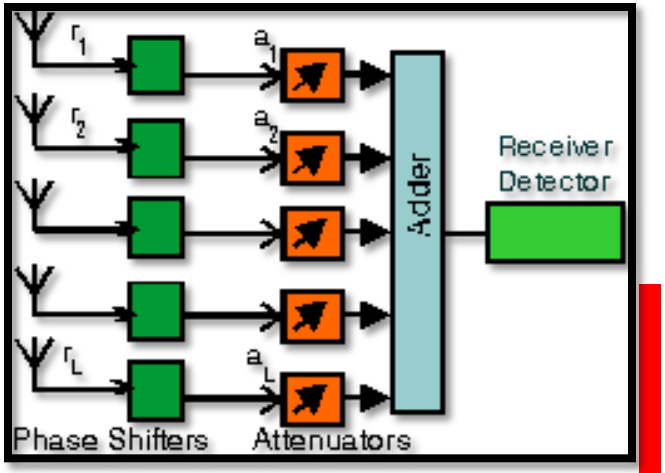
Selection diversity

- 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:

$$\Pr(\max(p) < p_{\text{thr}}) = \Pr(\text{all}(p) < p_{\text{thr}})$$
$$= \mathrm{P}_i \Pr(p_i < p_{\text{thr}})$$

- For L-branch selection diversity in Rayleigh fading:

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

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

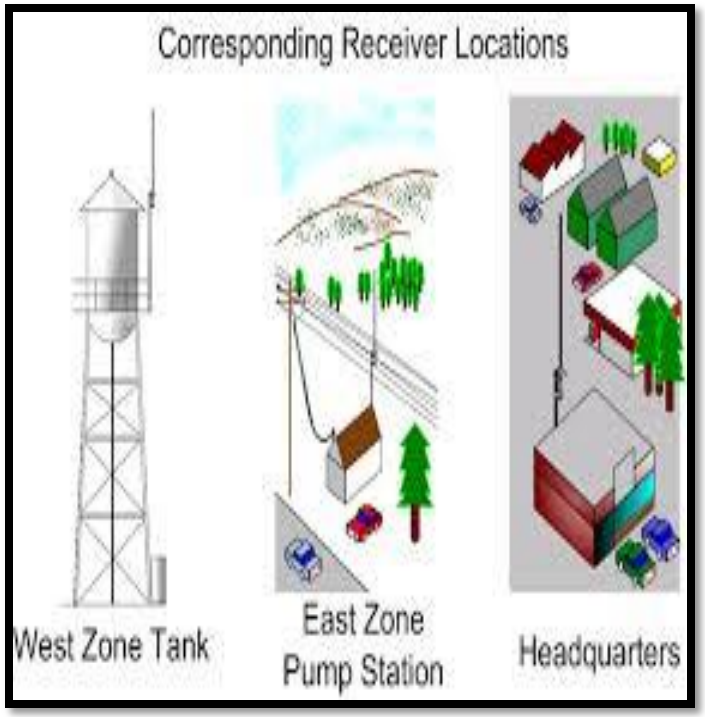
Selection Diversity

- 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.

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

Combining Diversity

- Selection diversity wastes signal energy by discarding (Nr − 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

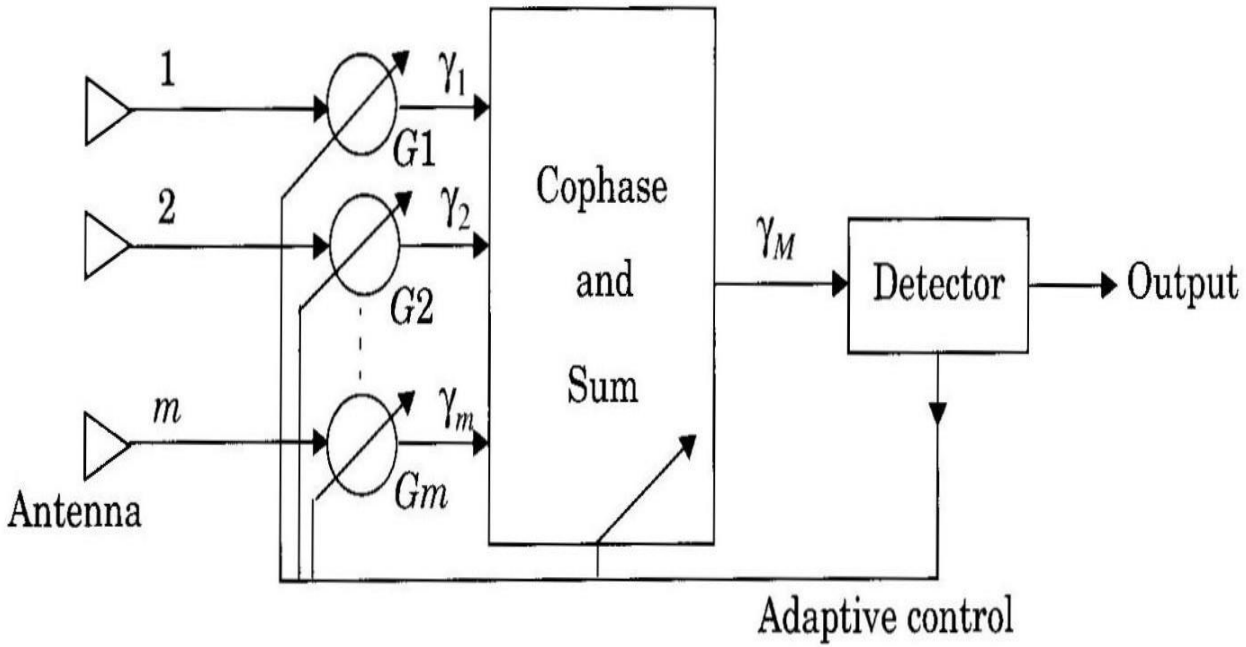


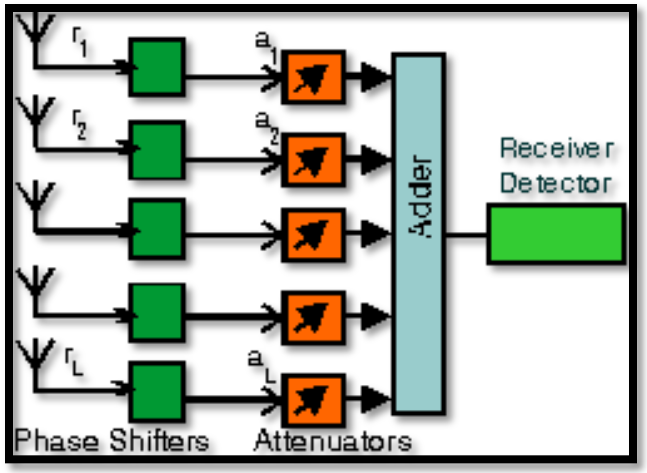
Figure 7.14 Maximal ratio combiner.

Maximum ratio combining

- Weigh signals proportional to their amplitude.

  MRC:

  a_i = 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

Technique:	**Circuit Complexity:**	**C/N improvement factor:**
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	$1 + 1/2 + .. + 1/L$
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