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Mobile and Personal Communications

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"Mobile and Personal Communications"
Outline of Lectures

- Personal communication system requirements
- Multiple Access Techniques
  - Frequency Division Multiple Access
  - Time Division Multiple Access
  - Code Division Multiple Access
- Techniques to improve performance
  - Equalisation
  - Diversity and Diversity Combining

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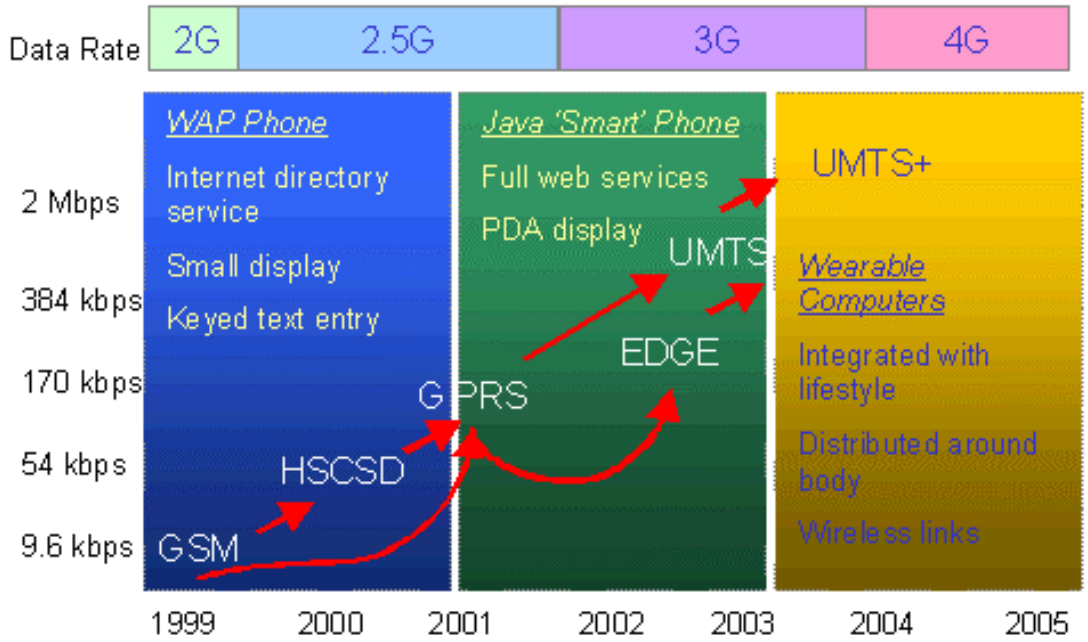
Evolution of personal cellular communications



- Cellular systems are expanding in capacity and services
- Increasing integration between wireless systems
  - Wireless LAN, wireless PAN (Bluetooth), etc

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Multiple Access

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Multiple Access Requirements

A cellular system employs a *multiple access technique* to control the allocation of the network resources. The purposes of a multiple access technique are:

- To provide each user with unique access to the shared resource: the *spectrum.*
- To minimise the impact of other users acting as interferers.
- To provide efficient use of the spectrum available.
- To support flexible allocation of resources (for a variety of services).

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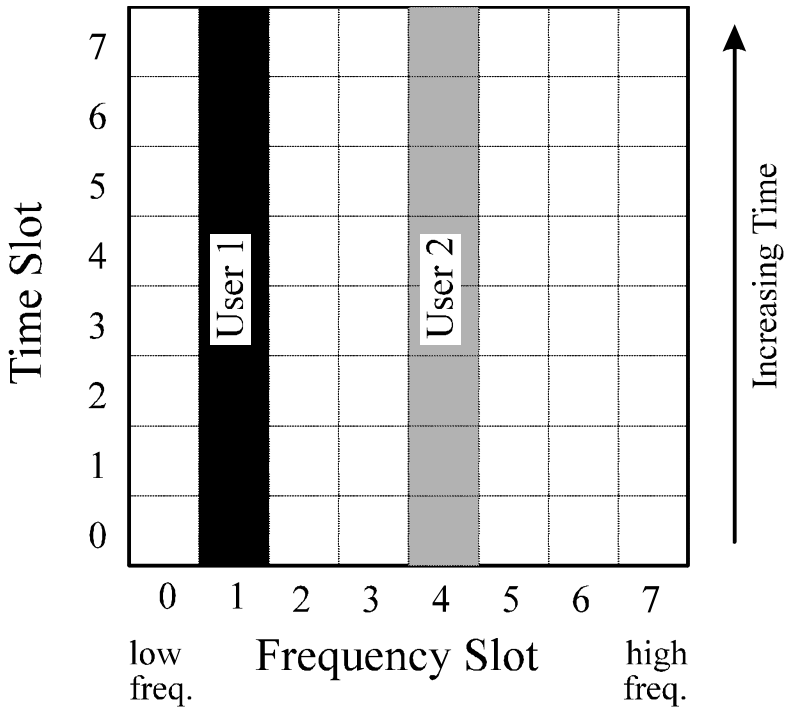
Frequency Division Multiple Access (FDMA)



2 users shown

- Each user is assigned a unique frequency for the duration of their call.
- Severe fading and interference can cause errors.
- Complex frequency planning required. Not flexible.
- Used in analogue systems, such as TACS (Europe), and AMPS (USA).

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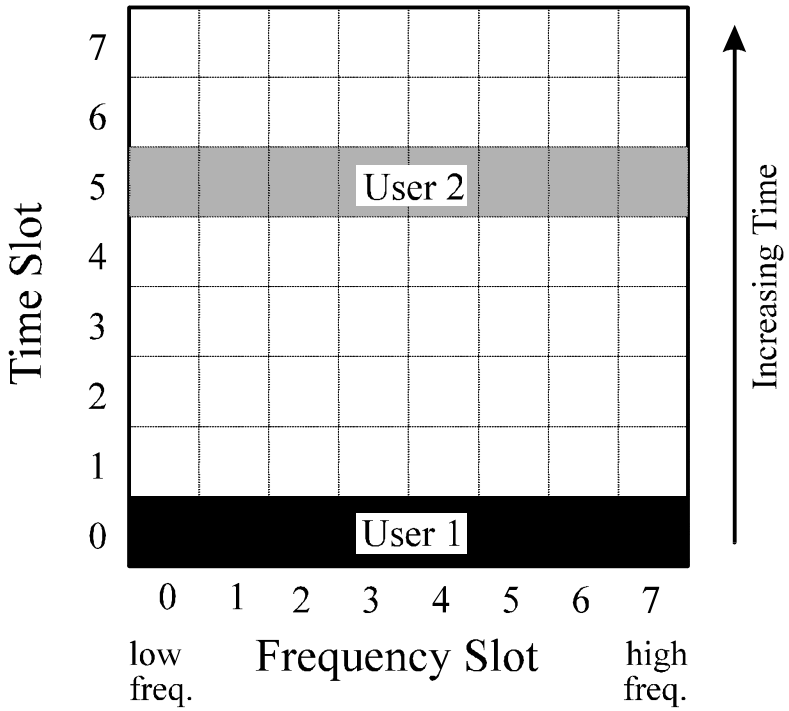
Time Division Multiple Access (TDMA)



2 users shown

- Each user can use *all* available frequencies, for a limited period. The user must not transmit until its next turn.
- High bit rates required, therefore possible problems with intersymbol-interference.
- Flexible allocation of resources (multiple time slots).
- Used in second generation digital networks, such as GSM (Europe), and D-AMPS (USA).

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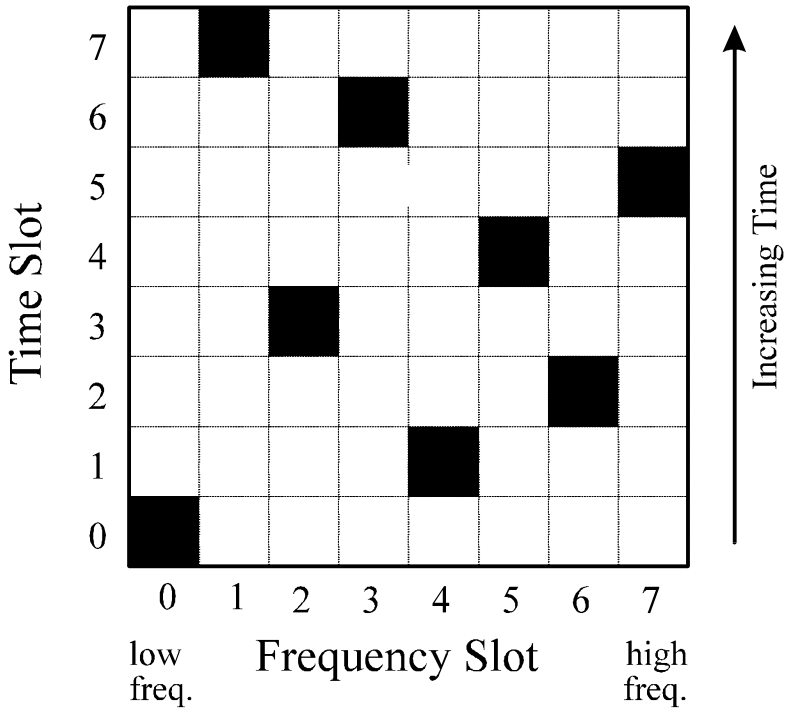
Frequency Hopping Code Division Multiple Access (FH-CDMA)



only 1 user shown

- Each user regularly *hops* frequency over the available spectrum.
- Users are distinguished from each other by a unique hopping pattern (or *code*).
- Interference is randomised.
- Used in Bluetooth™

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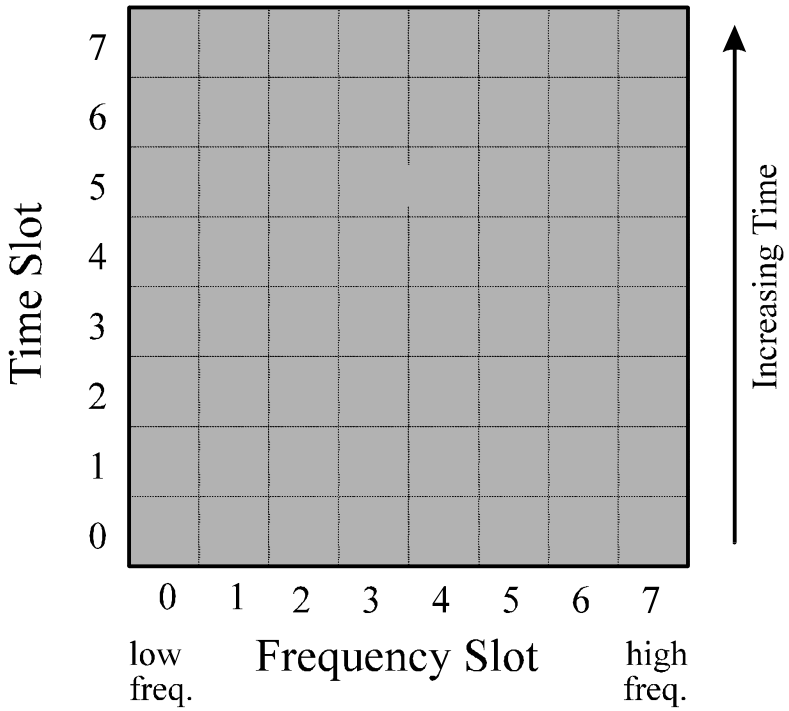
Direct Sequence Code Division Multiple Access (DS-CDMA)



only 1 user shown

- All users occupy the *same spectrum* at the *same time*.
- The modulated signal is *spread* to a much larger bandwidth than that required by multiplying with a *spreading code*. Users are distinguished from each other by a unique spreading code.
- Very flexible, but complex.
- Currently used in 3G and 2nd generation IS-95

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Summary of Multiple Access Techniques: The Cocktail Party

To illustrate the nature of the multiple access techniques, consider a number of guests at a cocktail party. The aim is for all the guests to hold an intelligible conversation. In this case the resource available is the house itself.

- FDMA: each guest has a seperate room to talk to their partner.
- TDMA: everyone is in the same room, and has a limited time to hold their conversation (so they must talk very quickly).
- FH-CDMA: the guests run from room to room to talk.
- DS-CDMA: everyone is in the same room, talking at the same time, but each pair talks *in a different language*.

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Duplex Communication

- Two way communication is called *duplex* (eg. for cellular radio). One way is called *simplex* (eg. for paging).
- The link from the base-station to mobile is the *down-link*. The link from the mobile to base-station is the *up-link*.
- The up-link and down-link can exist simultaneously on different frequencies: *Frequency Division Duplex* (FDD).
- The up-link and down-link can exist on the same frequency at different times: *Time Division Duplex* (TDD).

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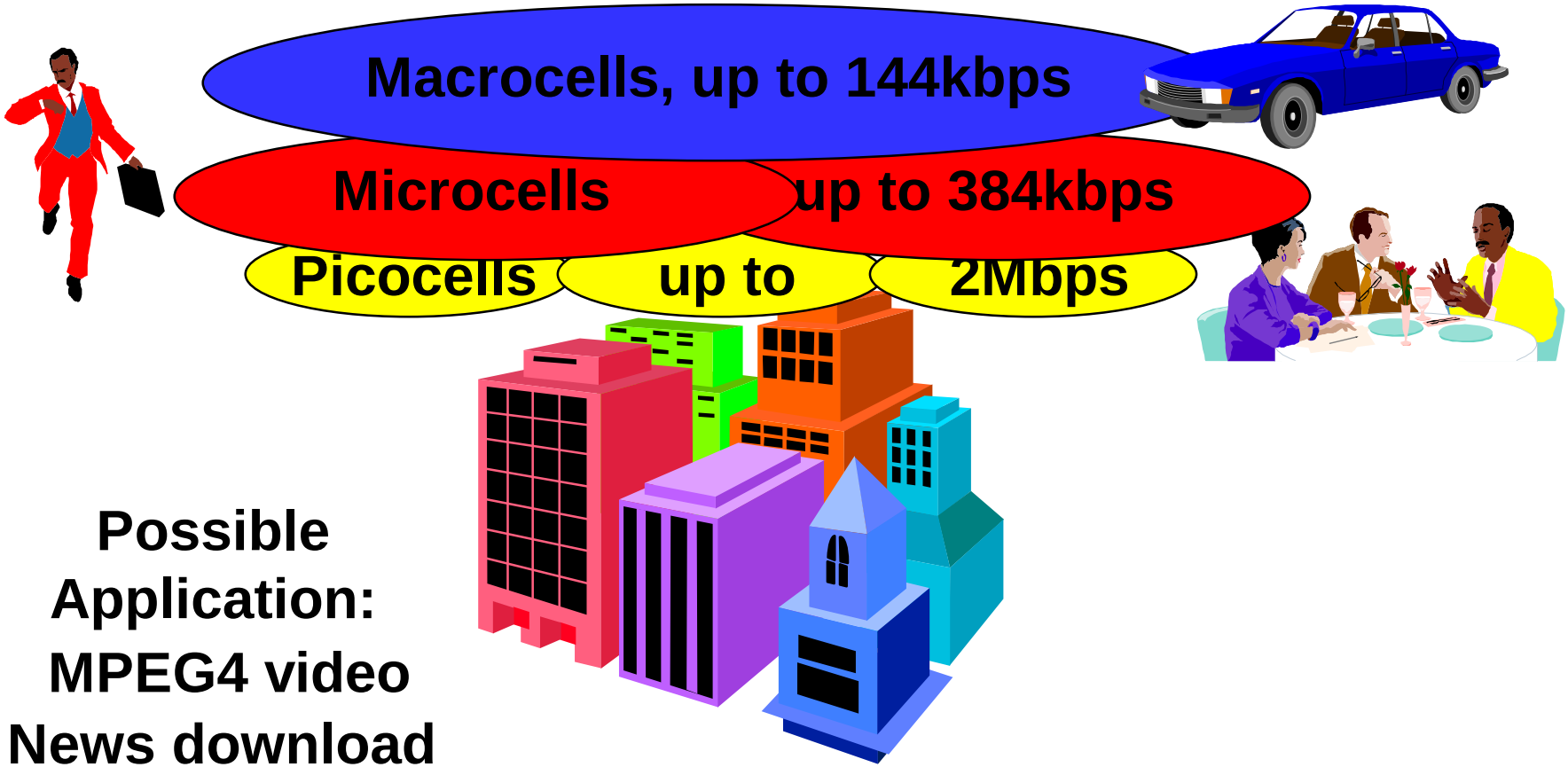
Hierarchical cell structure



Possible Application:
MPEG4 video
News download
File transfer

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Performance enhancements

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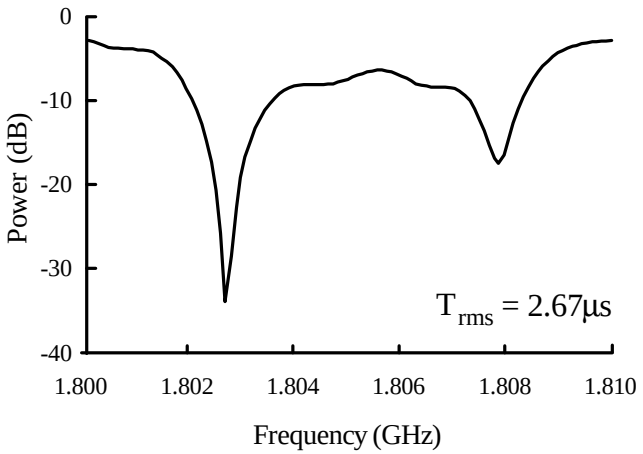
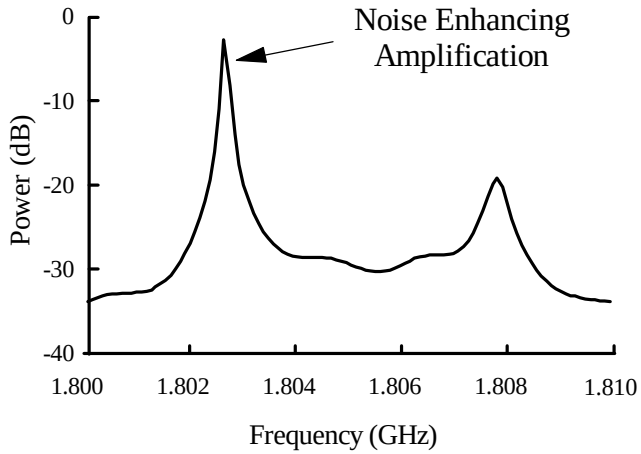
The effects of Equalisation



(i) Channel (Frequency Domain)



(ii) Forward Filter (Frequency Domain)

- *Frequency-selective fading* arises due to time-dispersion in the multipath channel. This type of *wideband* fading causes *irreducible* errors, unless its effects are mitigated.
- Equalisation is employed to remove the harmful frequency-selective fading. It acts as an adaptive filter, to produce an output signal with a flat frequency response. Consequently, error-free transmission at high data rates is possible.

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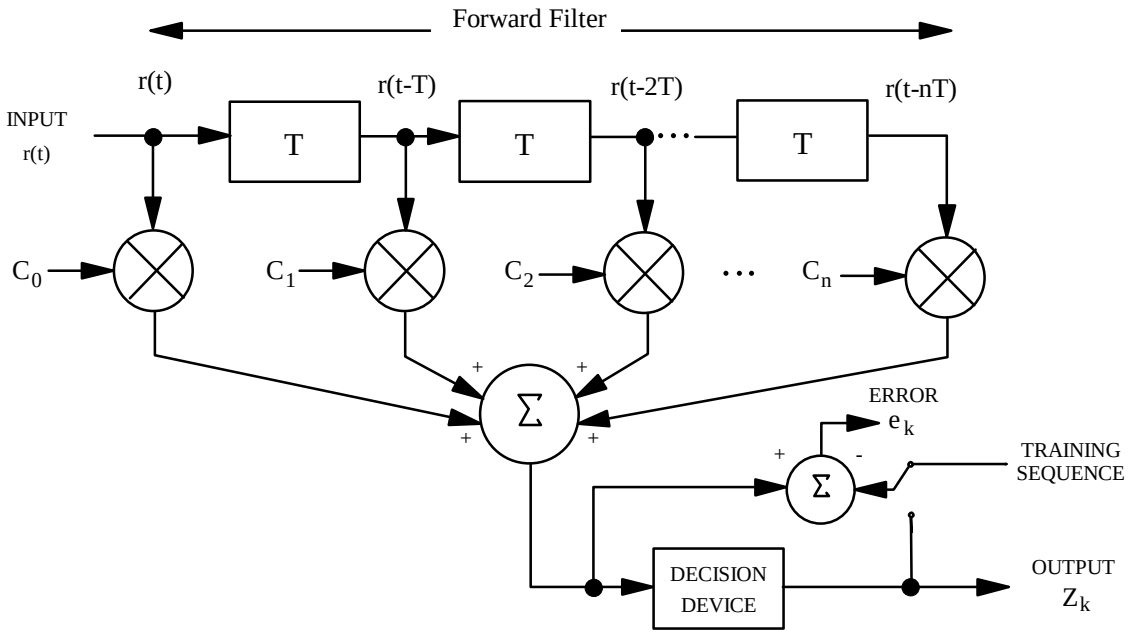
Linear Transversal Equaliser



- The linear transversal equalisation (LTE) is one of the simplest forms of equaliser.
- The tap coefficients (C1 to Cn) are adapt to suit the current channel conditions. Normally this adaptation is done on a training sequence.
- In the presence of severe amplitude and phase distortion, the required inverse filter tends to result in an unacceptable degree of noise amplification.

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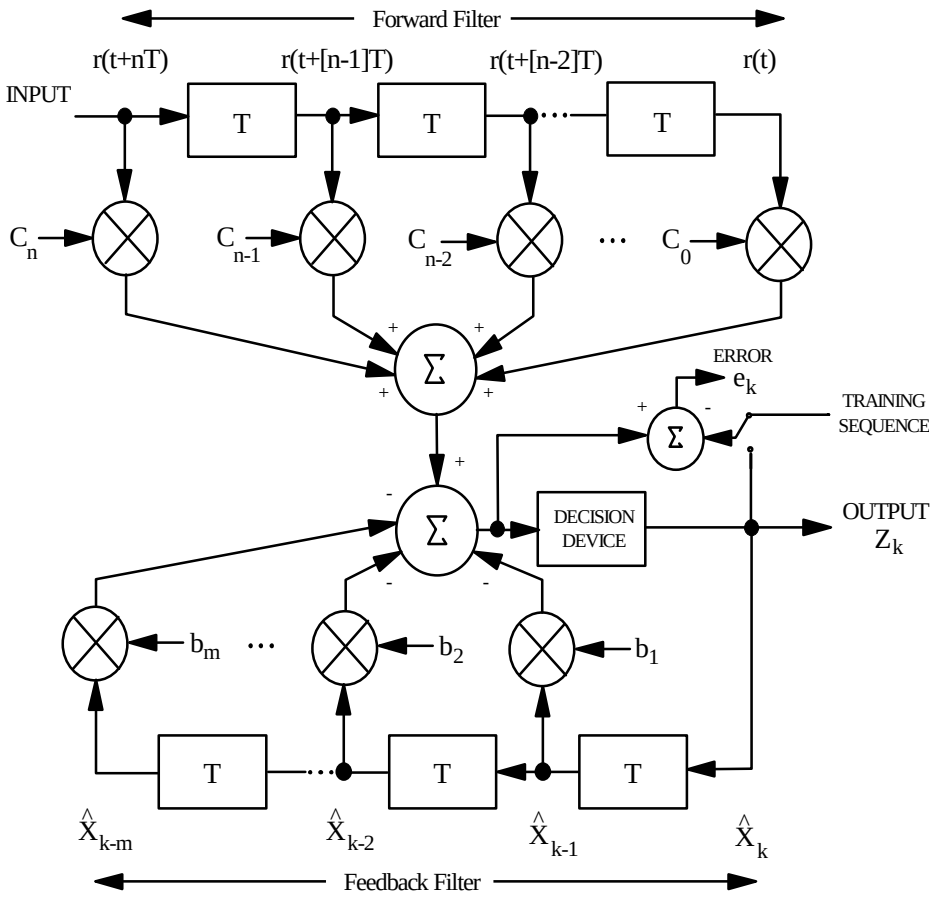
Decision Feedback Equaliser



- The equaliser output signal is the sum of the outputs of the *feedforward* and *feedback* sections of the equaliser.
- The forward section similar to the LTE
- Decisions made from the output of the equaliser are now feed back through a second filter.
- If these decisions are correct, the ISI caused by these symbols can be cancelled without noise enhancement
- However, errors made in hard decisions are fedback through the equaliser and can cause error propagation

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Diversity

- Diversity: the provision of two or more *uncorrelated* (or *independent*) fading paths between transmitter and receiver.
- The uncorrelated fading statistics are combined or selected in some form.
- Performance improvement results as it is unlikely that all the diversity paths will be poor at the same time. Consequently, the probability of *outage* is reduced.
- Methods for generating uncorrelated paths for diversity combining include time, frequency, polarisation, angle, and space diversity.

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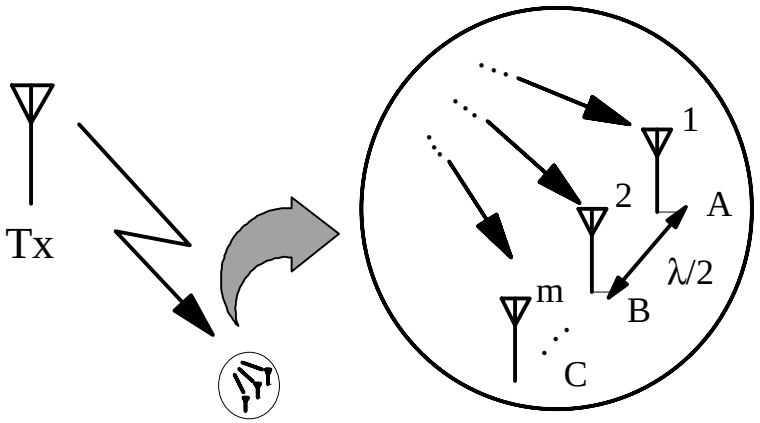
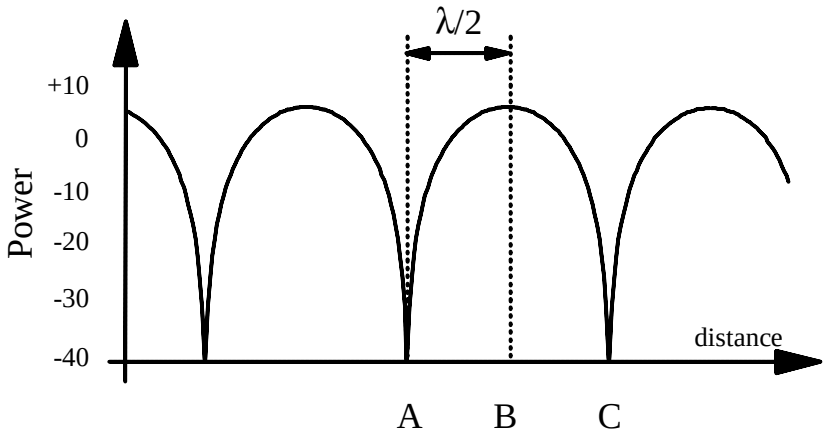
Space Diversity



(i) Space Diversity



(ii) Power Variation with Distance

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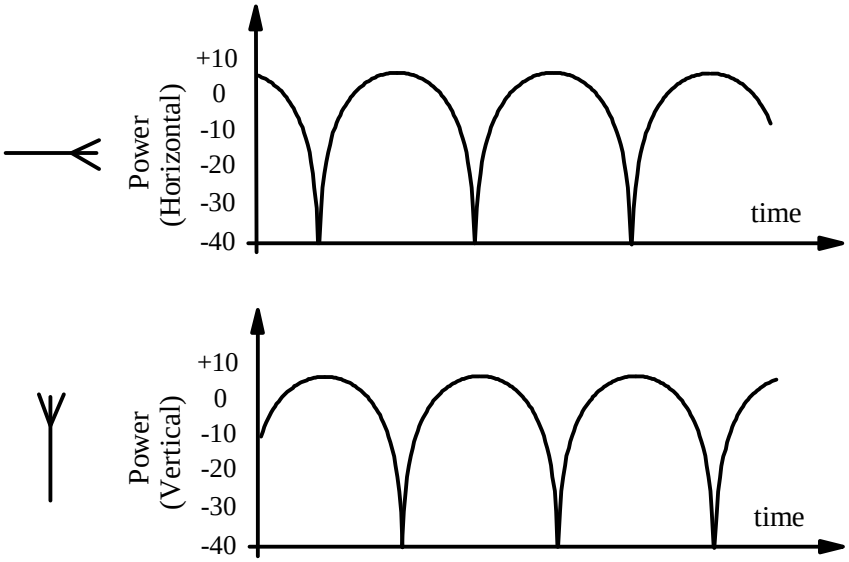
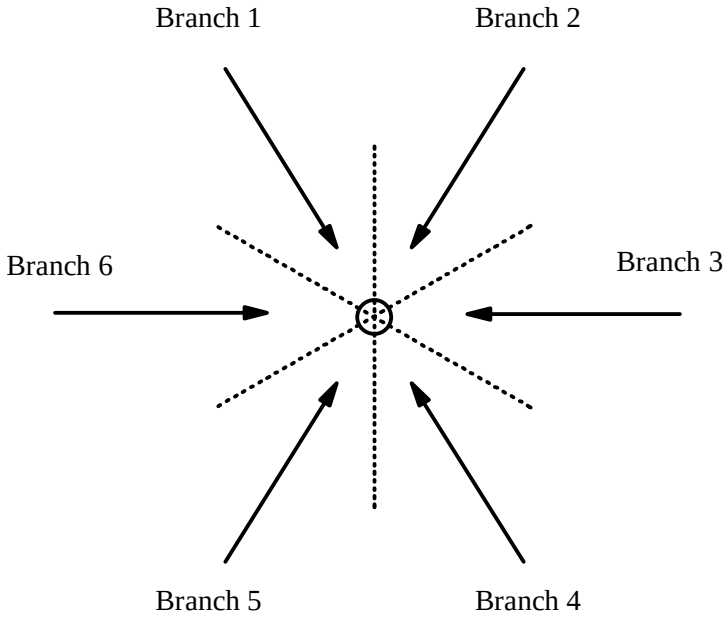
Polarisation and Angle Diversity



(i) Polarisation Diversity



(ii) Angle (Pattern) Diversity

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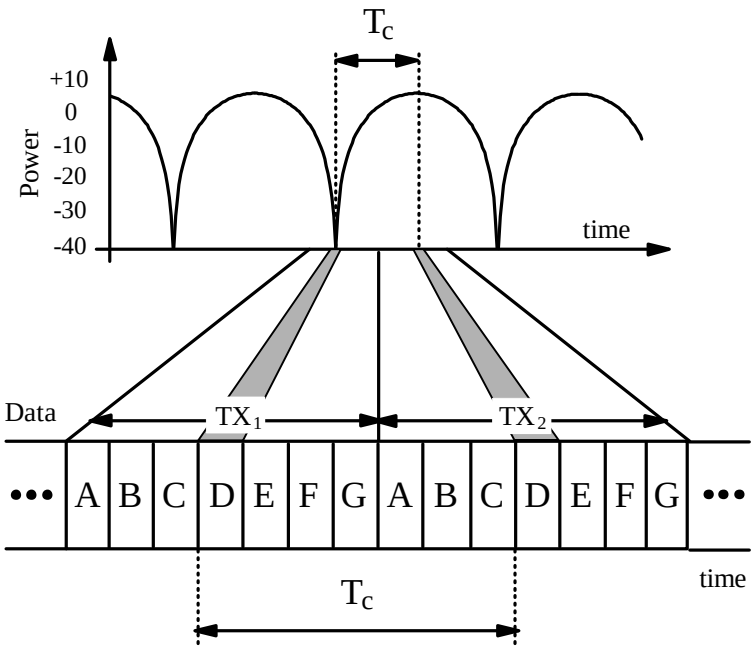
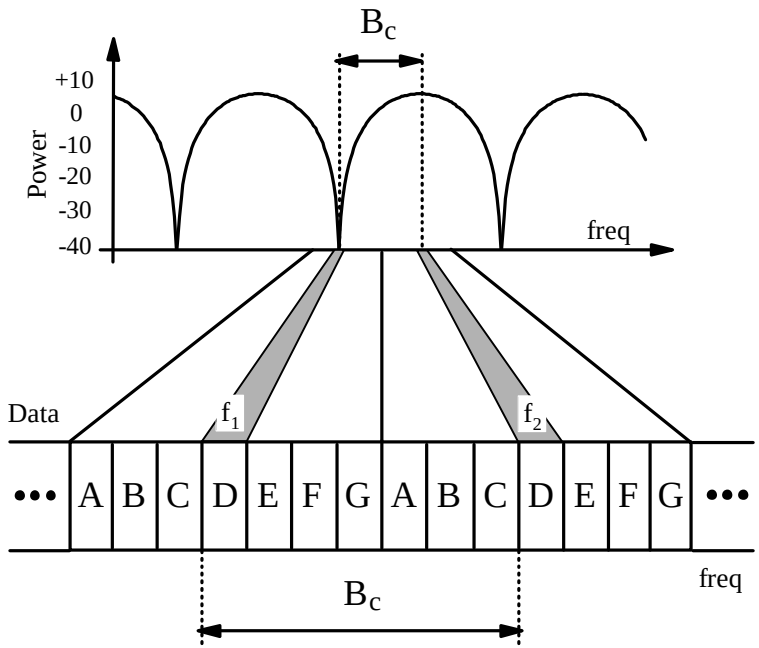
Time and Frequency Diversity



(i) Time Diversity



(ii) Frequency Diversity

- Less desirable: extra signal bandwidth is required

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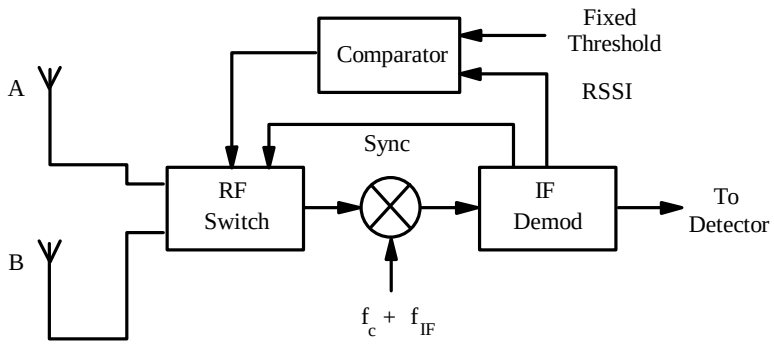
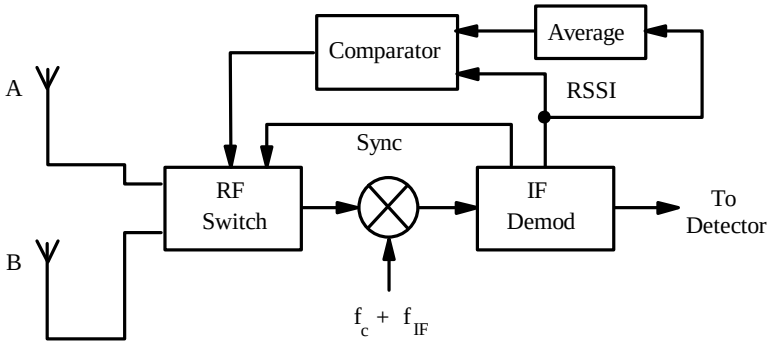
Diversity Combining: Switched (or Scanning) Combining



(i) Switch Diversity with Fixed Threshold



(ii) Switch Diversity with Adaptive Threshold

- The current branch remains selected until a metric fails a certain threshold, usually the *Received Signal Strength Indicator* (RSSI). The next branch is then blindly selected.
- An adaptive threshold removes unnecessary switching. When the signal fades relative to the mean, switching occurs.
- This system is cheap and simple, but not ideal.

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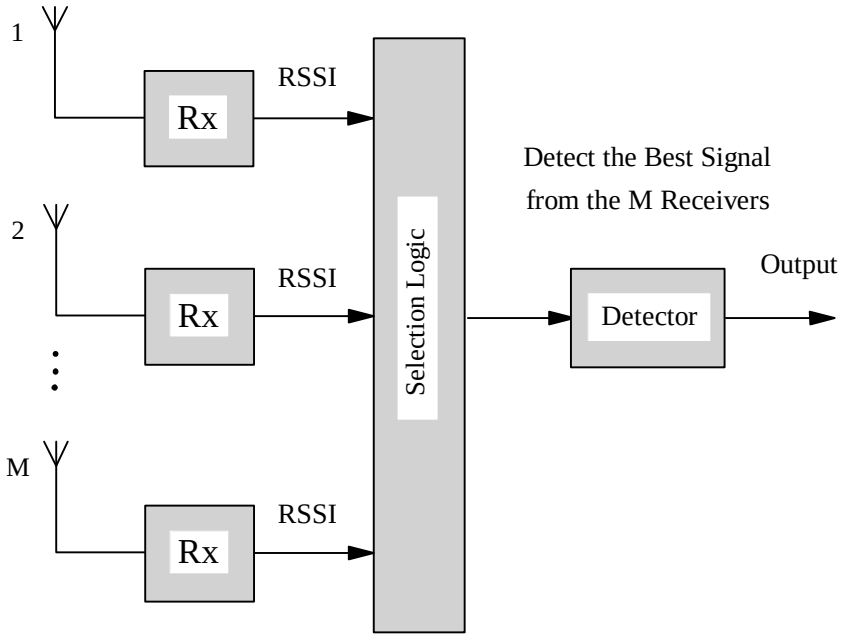
Diversity Combining: Selection Combining



- The most appropriate branch is always selected. Slight performance advantage over switch diversity.
- The system is expensive, as all branchs have to be analysed.
- Using RSSI as a indication of quality is non-ideal, since it is unduly affected by interference.

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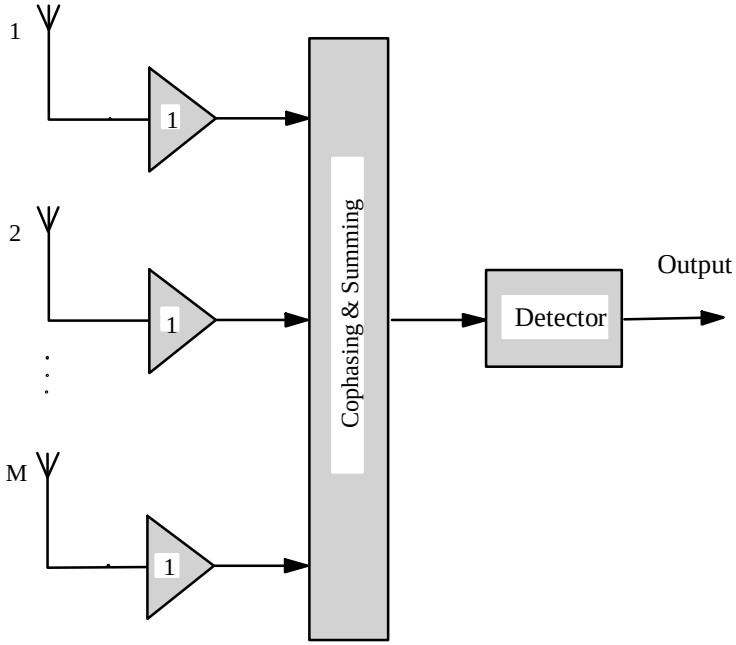
Diversity Combining: Equal Gain Combining (EGC)



- *Post-detection* combining.
- All branchs are merely cophased and summed.

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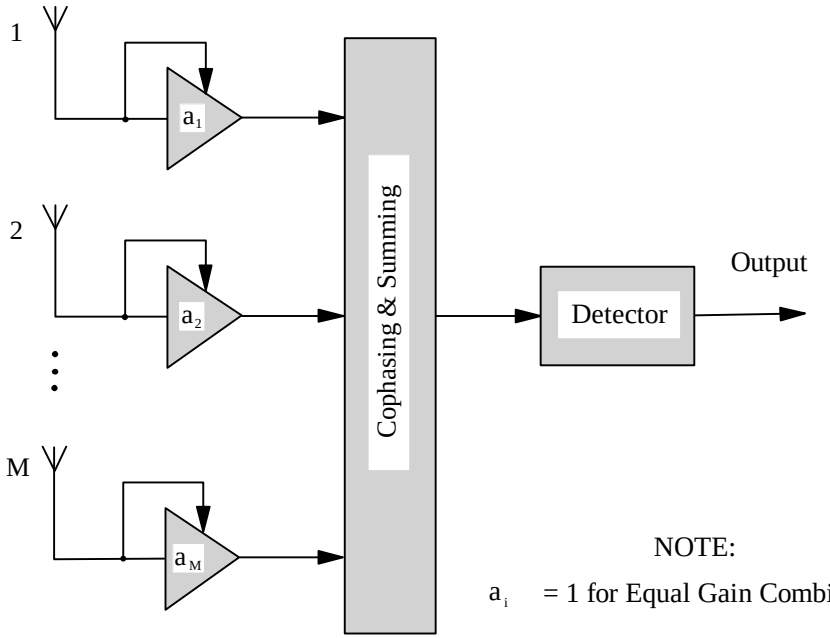
Diversity Combining: Maximal Ratio Combining (MRC)



- Each branch is weighted before summation in proportion to its own *signal-to-noise* ratio.
- Slightly better performance than EGC, but requires the complexity of estimating signal-to-noise ratio.

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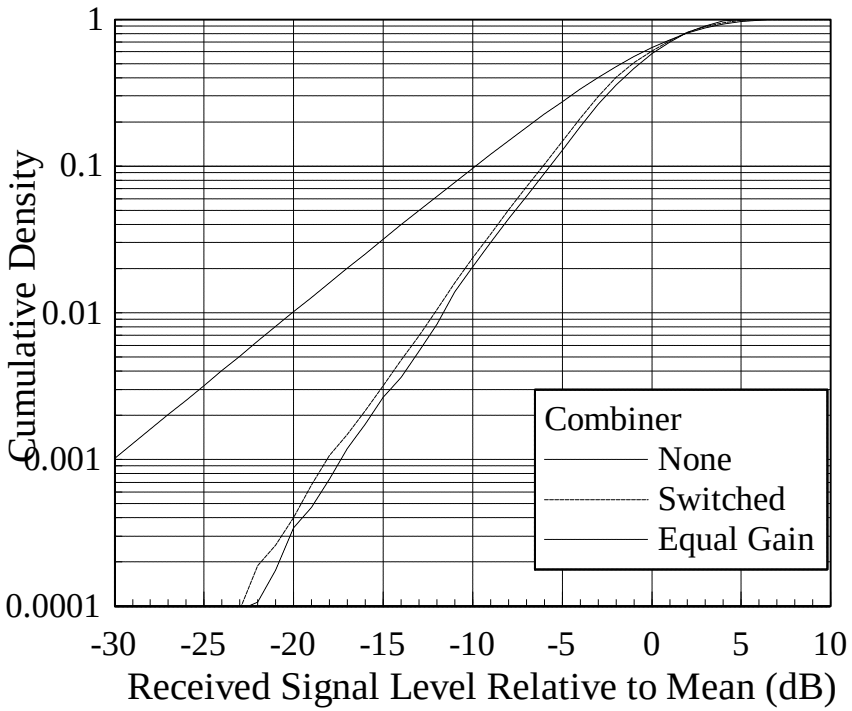
The Effect of Diversity on Fading Statistics



- The fading statistics are improved with the applications of diversity.
- It is much less likely for deep fades to occur.

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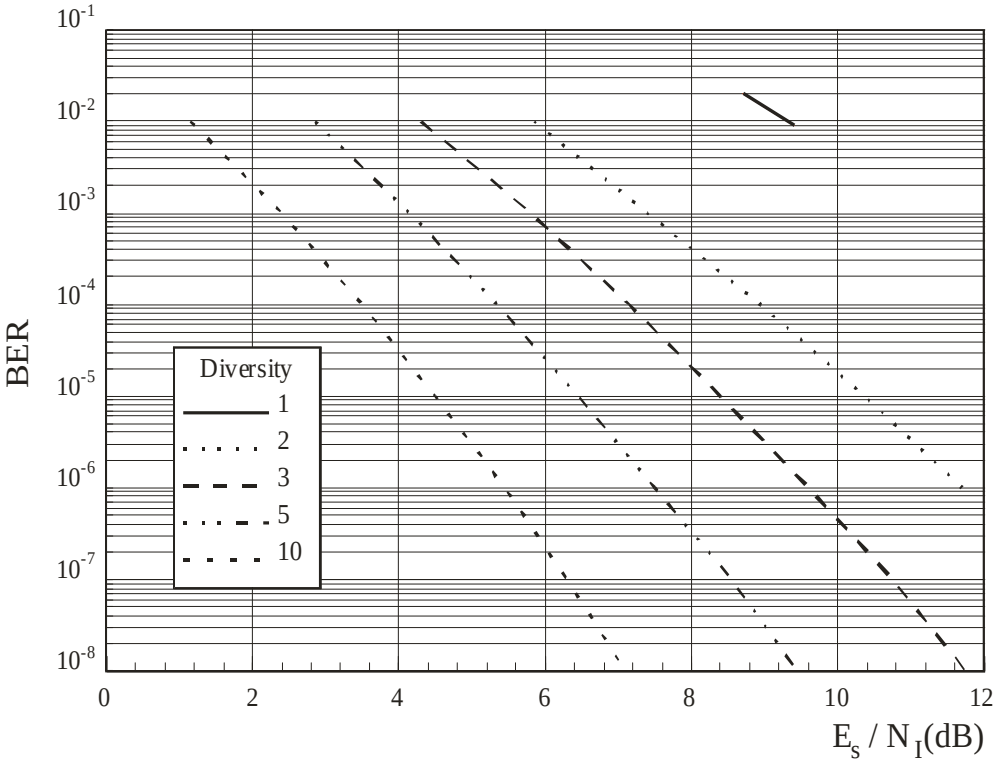
The Effect of Diversity on Performance



- The BER in a Rayleigh fading channel can be significantly reduced with the use of diversity.
- Diversity can offer an 8-12 dB gain in Rayleigh channels.
- It can also increase the maximum bit rate in a dispersion limited environment by a factor of two.