4.4 Multiple Access Techniques

- The transmission from the BS in the downlink can be heard by each and every mobile user in the cell, and is referred as *broadcasting*. Transmission from the mobile users in the uplink to the BS is many-to-one, and is referred to as multiple access.

- Multiple access schemes to allow many users to share simultaneously a finite amount of radio spectrum resources.

  - Should not result in severe degradation in the performance of the system as compared to a single user scenario.
  - Approaches can be broadly grouped into two categories: narrowband and wideband.

- Multiple Accessing Techniques : with possible conflict and conflict - free

- Random access
- Frequency division multiple access (FDMA)
- Time division multiple access (TDMA)
- Spread spectrum multiple access (SSMA) : an example is Code division multiple access (CDMA)
- Space division multiple access (SDMA)

Duplexing

For voice or data communications, must assure two way communication (duplexing, it is possible to talk and listen simultaneously). Duplexing may be done using frequency or time domain techniques.

- ❖ Forward (downlink) band provides traffic from the BS to the mobile
- ❖ Reverse (uplink) band provides traffic from the mobile to the BS.

4.4.1 Frequency division duplexing (FDD)

Provides two distinct bands of frequencies for every user, one for downlink and one for uplink.

A large interval between these frequency bands must be allowed so that interference is minimized.

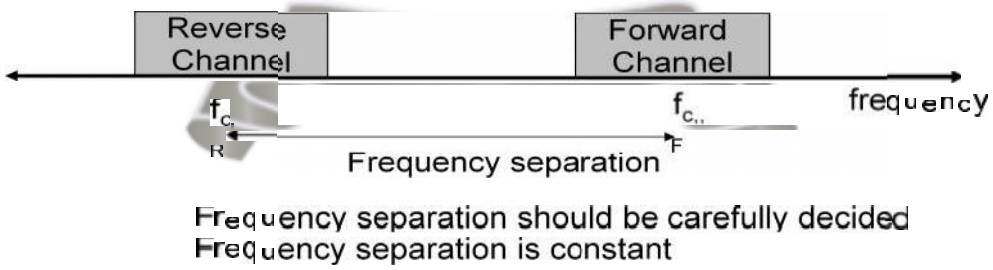


Figure 4.5 Frequency Separation

4.4.2. Time division duplexing (TDD)

- ❖ In TDD communications, both directions of transmission use one contiguous frequency allocation, but two separate time slots to provide both a forward and reverse link.

- Because transmission from mobile to BS and from BS to mobile alternates in time, this scheme is also known as “ping pong”.
- As a consequence of the use of the same frequency band, the communication quality in both directions is the same. This is different from FDD.

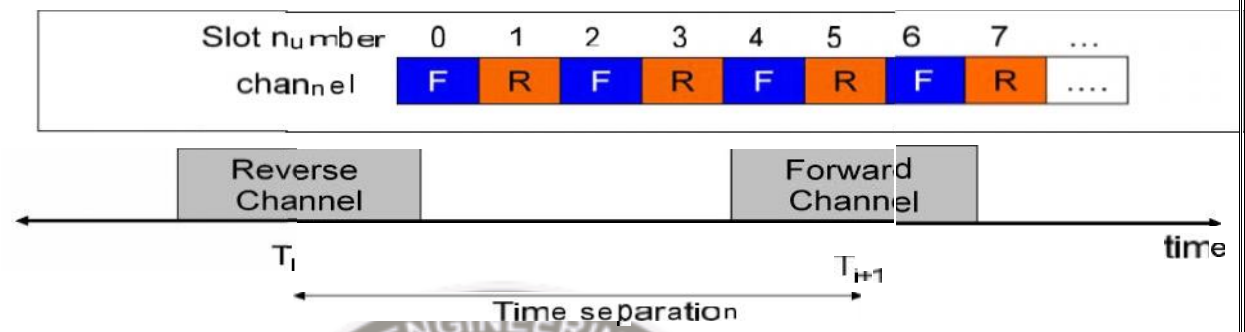


Figure 4.6 Time Slot

4.4.3 FDMA

- In FDMA, each user is allocated a unique frequency band or channel. During the period of the call, no other user can share the same frequency band.

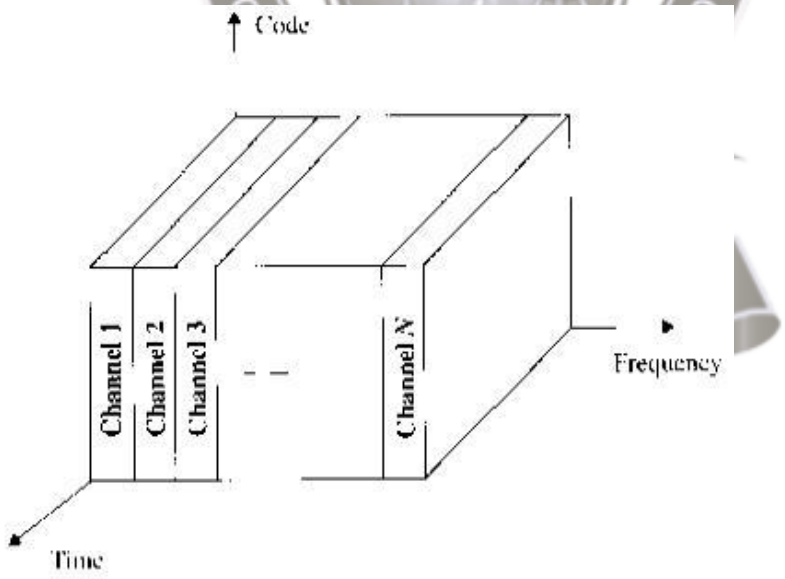


Figure 4.7 FDMA Channels

- All channels in a cell are available to all the mobiles. Channel assignment is carried out on a first-come first- served basis.

- The number of channels, given a frequency spectrum BT , depends on the modulation technique (hence Bw or Bc) and the guard bands between the channels $2Bguard$.

- These guard bands allow for imperfect filters and oscillators and can be used to minimize adjacent channel interference.
- FDMA is usually implemented in narrowband systems.

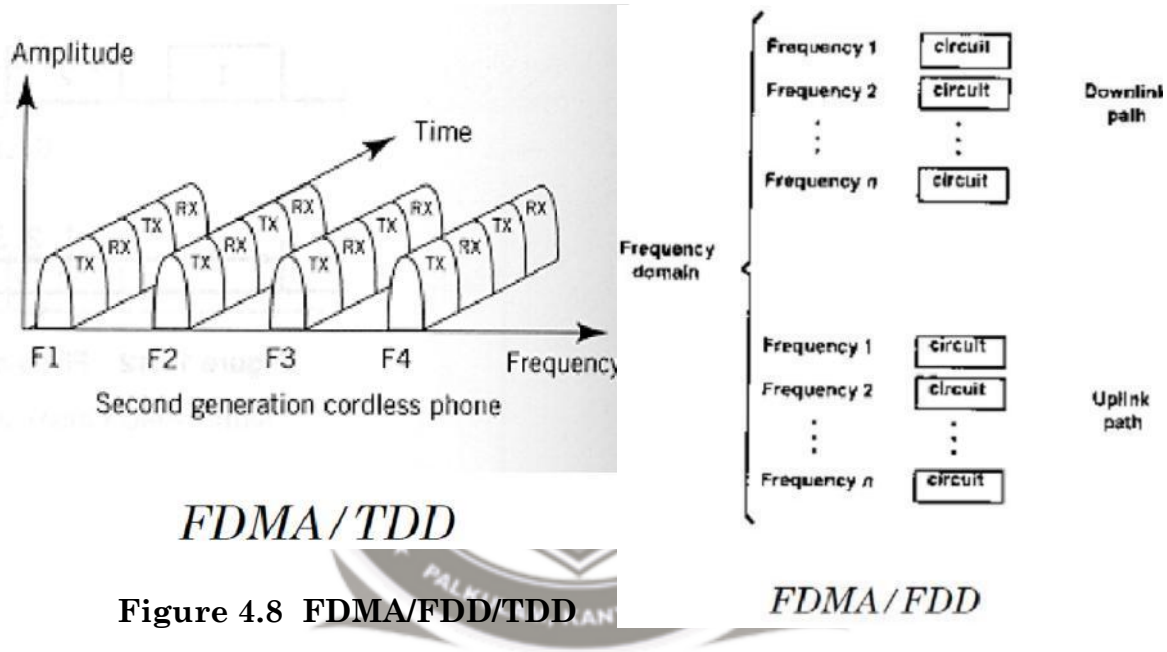


Figure 4.8 FDMA/FDD/TDD

Nonlinear effects in FDMA

- In a FD MA system, many channels share t he same antenna at the BS. The power amplifiers or the power combiners, when operated at or near saturation are non linear.
- The nonlinear ties generate inter-modulation frequencies.
- Undesirable harmonics generated outside the mobile radio band cause interference to adjacent services.
- Undesirable harmonics present inside the band ca use interference to other users in the mobile system.

4.4.4 TDMA

- TDMA systems divide the channel time into frames. Each frame is further partitioned into time slots. In each slot only one user is allowed to either transmit or receive.
- Unlike FDMA, only digital data and digital modulation must be used.
- Each user occupies a cyclically repeating time slot, so a channel may be thought of as a particular time slot of every frame, where *N* time slots comprise a frame.

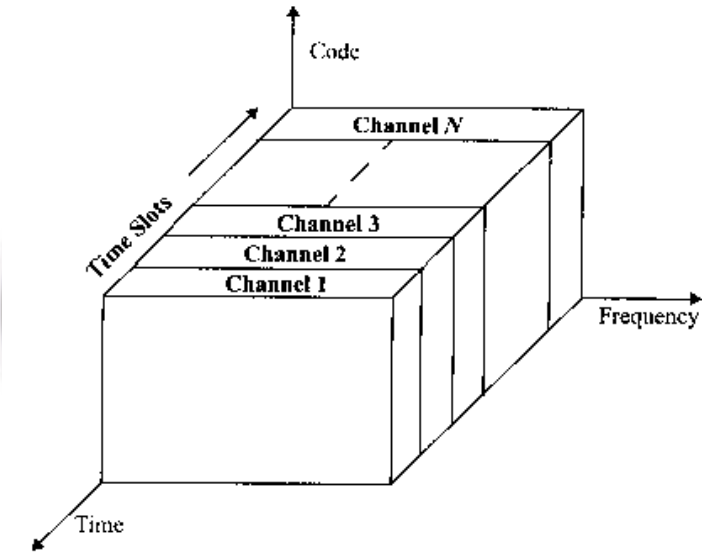


Figure 4.9 TDMA Channels

Features

- ❖ Multiple channels per carrier or RF channels.
- ❖ Burst transmission since channels are used on a timesharing basis.
  - o Transmitter can be turned off during idle periods.
- ❖ Narrow or wide bandwidth – depends on factors such as modulation scheme, number of voice channels per carrier channel.
- ❖ High ISI – Higher transmission symbol rate, hence resulting in high ISI.
  - o Adaptive equalizer required.

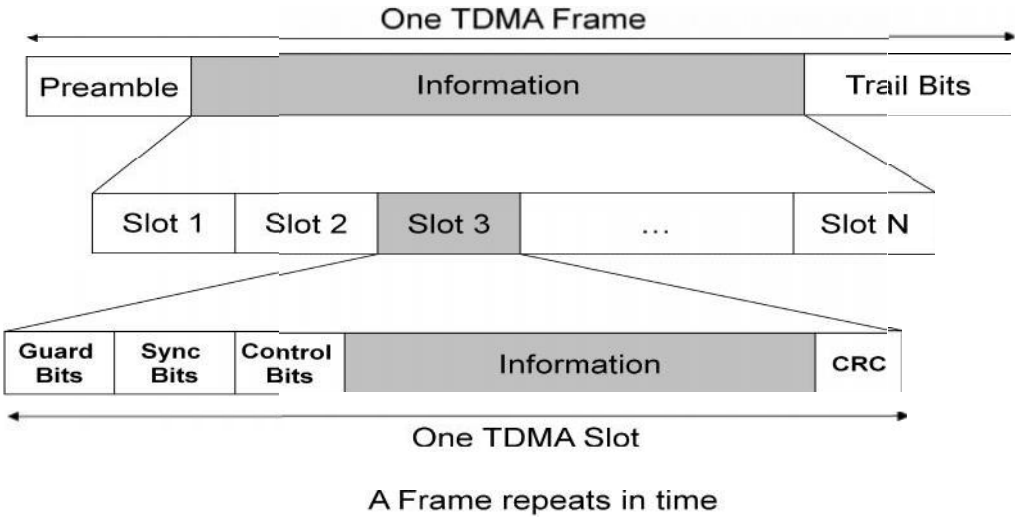


Figure 3.10 TDMA Channels time slot

- A guard time between the two time slots must be allowed in order to avoid
  - interference, especially in the uplink direction. All synchronize with BS to minimize interference.
- mobiles should

- Efficient power utilization : FDMA systems require a 3- to 6-dB power back
  - off in order to compensate for inter-modulation effects.

- Efficient handoff : TDMA systems can take advantage of the fact that the transmitter is switched off during idle time slots to improve the handoff procedure. An enhanced link control, such as that provided by mobile assisted handoff (MAHO) can be carried out by a subscriber by listening to
  - neighboring base station during the idle slot of the TDMA frame.

- Efficiency of TDMA

- Efficiency of TDMA is a measure of the percentage of bits per frame whi ch contain transmitted data. The transmitted data include source and channel coding bits.

$$\eta_f = \frac{b_T - b_{OH}}{b_T} \cdot 100\%$$

- *bOH* includes all overhead bits such as preamble, guard bits, etc.

4.4.5 Code Division Multiple Access (CDMA)

- Spreading signal (code) consists of chips
    - Has Chip period and and hence, chip rate
    - Spreading signal use a pseudo-noise (PN) sequence (a pseudo-random sequence)
    - PN sequence is called a codeword
    - Each user has its own cordword
    - Codewords are orthogonal. (low autocorrelation)
    - Chip rate is order of magnitude larger than the symbol rate.
- The receiver correlator distinguishes the senders signal by examining the wideband signal with the same time-synchronized spreading code
- The sent signal is recovered by despreading process at the receiver.

CDMA Advantages:

- Low power spectral density.
    - Signal is spread over a larger frequency band
    - Other systems suffer less from the transmitter
- Interference limited operation
    - All frequency spectrum is used
- Privacy
    - The codeword is known only between the sender and receiver. Hence other users can not decode the messages that are in transit
- Reduction of multipath affects by using a larger spectrum

CDMA data

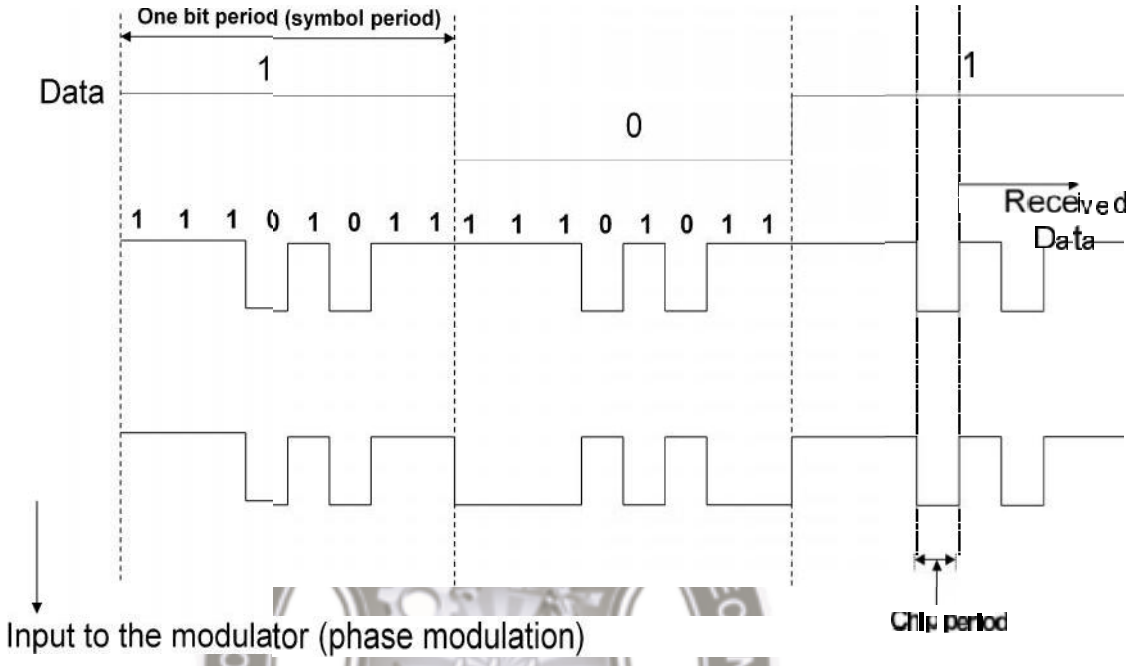


Figure 4.11 CDMA Channels transmission

DSSS Transmitter:

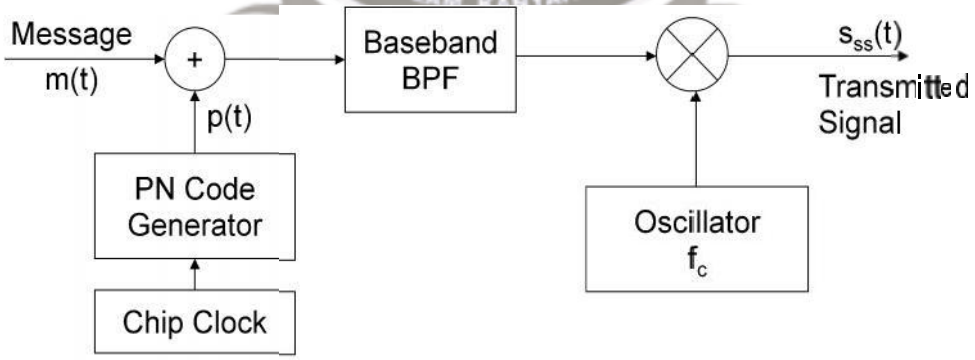
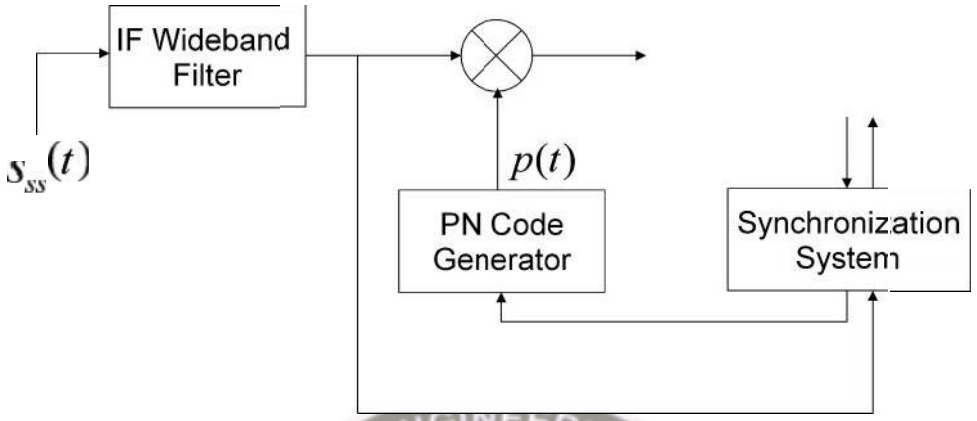


Figure 4.12 CDMA Transmitter

$$s_{ss}(t) = \sqrt{\frac{2E_s}{T_s}} m(t)\, p(t) \cos(2\pi f_c t + \theta)$$

DSSS Receiver



$$s_1(t) = \sqrt{\frac{2E_s}{T_s}} m(t) \cos(2\pi f_c t + \theta)$$

Figure 4.13 CDMA Receiver

- FDMA/CDMA
  - Available wideband spectrum is frequency divided into number narrowband radio channels. CDMA is employed inside each channel.
- DS/FHMA
  - The signals are spread using spreading codes (direct sequence signals
  - are obtained), but these signal are not transmitted over a constant
  - carrier frequency; they are transmitted over a frequency hopping carrier frequency.
- Time Division CDMA (TCDMA)

  Each cell is using a different spreading code (CDMA employed between cells) that is conveyed to the mobiles in its range.

  Inside each cell (inside a CDMA channel), TDMA is employed to multiplex multiple users.

- Time Division Frequency Hopping

  At each time slot, the user is hopped to a new frequency according to a pseudo-random hopping sequence.

  Employed in severe co-interference and multi-path environments.

Bluetooth and GSM are using this technique

- A large number of independently steered high-gain beams can be formed without any resulting degradation in SNR ratio.
- Beams can be assigned to individual users, thereby assuring that all links operate with maximum gain.
- Adaptive beam forming can be easily implemented to improve the system capacity by suppressing co channel interference.

Advantage of CDMA

- It is recognized that CDMA's capacity gains over TDMA
- FDMA are entirely due to Its tighter, dynamic control over the use of the power domain.
- Choosing a new non-orthogonal PN sequence a CDMA system does not encounter the difficulties of choosing a spare carrier frequency or time slot to carry a Traffic Channel
- Ensure that interference will not be too great if it begins to transmit -that there is still enough space left in the power domain.

Disadvantages of CDMA

- Satellite transponders are channelized too narrowly for roadband CDMA, which is the most attractive form of CDMA.
- Power control cannot be as tight as it is in a terrestrial system because of long round-trip delay.

4.5. Channel allocation schemes

In radio resource management for wireless and cellular network, channel allocation schemes are required to allocate bandwidth and communication channels to base stations, access points and terminal equipment.

The objective is to achieve maximum system spectral efficiency in bit/s/Hz/site by means of frequency reuse, but still assure a certain grade of service by avoiding co-channel interference and adjacent channel interference among nearby cells or networks that share the bandwidth. There are two types of strategies that are followed:-

- Fixed: FCA, fixed channel allocation: Manually assigned by the network operator
- Dynamic:
  - DCA, dynamic channel allocation,
  - DFS, dynamic frequency selection
  - Spread spectrum

4.5.1 FCA

In **Fixed Channel Allocation** or **Fixed Channel Assignment** (FCA) each cell is given a predetermined set of frequency channels.

FCA requires manual frequency planning, which is an arduous task in TDMA and FDMA based systems, since such systems are highly sensitive to co-channel interference from nearby cells that are reusing the same channel.

This results in traffic congestion and some calls being lost when traffic gets heavy in some cells, and idle capacity in other cells.

4.5.2. DCA and DFS

Dynamic Frequency Selection (DFS) may be applied in wireless networks with several adjacent non-centrally controlled access points.

A more efficient way of channel allocation would be **Dynamic Channel Allocation** or **Dynamic Channel Assignment** (DCA) in which voice channel are not allocated to cell permanently, instead for every call request base station request channel from MSC.

4.6 Spread spectrum

Spread spectrum can be considered as an alternative to complex DCA algorithms. Spread spectrum avoids cochannel interference between adjacent