Explanation : Slow fading and fast fading occurs due to Doppler or frequency shift.

Q.7 The received power is attenuated by a factor called _____.

a Path loss b Free space loss

c Both of the mentioned d None of the mentioned [Ans. : d]

Explanation : The received power expressed in terms of transmitted power is attenuated by a factor called path loss or free space loss.

Q.8 Line-of-sight propagation lies above

a kHz b 30 MHz c 15 MHz d kHz [Ans. : b]

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4 Multiple Access Technology

Syllabus

Introduction, Comparisons of multiple Access Strategies TDMA,CDMA, FDMA, OFDM , CSMA Protocols.

Contents

4.1 Introduction

- Multiple access schemes are used to allow many mobile users to share simultaneously a finite amount of radio spectrum.
- Multiple access system enable many mobile users to share simultaneously radio spectrum.
- Multiple access technique is used when high capacity is required. The multiple access technique must be done without severe degradation in the performance.
- Duplexing is needed to allow subscribers send and receive information simultaneously. e.g., telephone systems.

4.1.1 Duplexing Methods

- There are two types of duplexing methods.
  1. Frequency Division Duplexing (FDD) 2. Time Division Duplexing (TDD)

4.1.2 Frequency Division Duplexing (FDD)

- FDD is employed in radio systems to provide an uplink and downlink radio channel between the sender and the receiver.
- When forward (base station to mobile station - downlink) and reverse (Mobile station to base station-uplink) use different carrier frequencies that are sufficiently separated, the duplexing system referred to as **Frequency Division Duplexing (FDD)**.
- In FDD, the total available bandwidth is allocated separately for the forward and reverse directions of transmission.

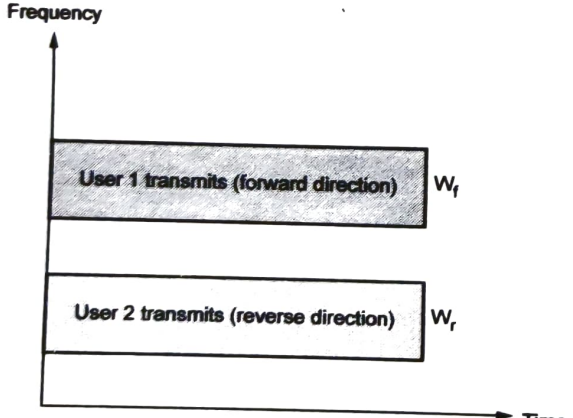

Fig. 4.1.1 Frequency Division Duplexing

- FDD is used for large coverage areas

4.1.3 Time Division Duplexing (TDD)

- When both forward and reverse channels use the same frequency band for communications but forward and reverse channels employ alternating time slots, the duplexing system referred to as **Time Division Duplexing (TDD)**.
- TDD can share one RF circuitry between forward and reverse channel. The reciprocity of channels allow accurate open-loop power control (IS-95).
- Two directions of the transmission are created by alternating the transmission in time.
- The maximum bit rate supportable for a given bandwidth W is allocated between the two directions.

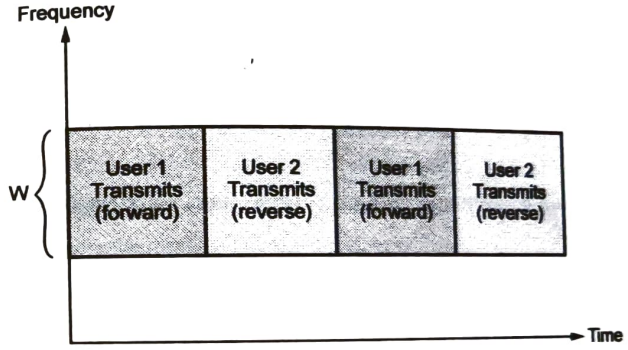

Fig. 4.1.2 Time division multiplexing

- TDD is preferred usually for low-power local communications.

4.1.4 Multiple Access Methods

- The multiple access methods refer to the method of creating multiple channels for each transmission direction.
- There are three main types of multiple access methods :
  1. Frequency Division Multiple Access (FDMA)
  2. Time Division Multiple Access (TDMA)
  3. Code Division Multiple Access (CDMA)

4.2 Frequency Division Multiple Access (FDMA)

GTU : Summer-15, Winter-15

- In FDMA, all users are separated by their frequency of operation. All users may transmit simultaneously using a distinct carrier channel.

- A basic of Frequency Division Multiple Access (FDMA) is Frequency Division Multiplexing (FDM).
- A user is assigned a carrier f_i for each direction (uplink and downlink). A user may employ continuous transmission.
- Data (user's info) is modulated using the assigned carrier. Analog circuitry (VCO) is required to keep track of frequency shifts.

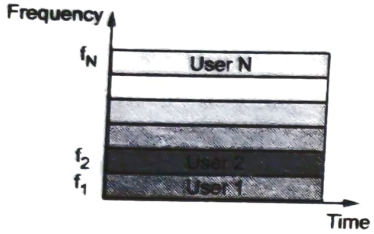

Fig. 4.2.1 FDMA

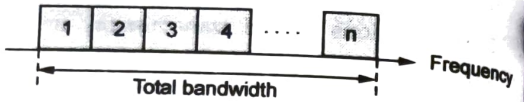

Fig. 4.2.2 FDMA bandwidth structure

Design Issues of FDMA system :

- Adjacent channel interference (specifically reverse channel).
- RF spectrum mask.
- Near-far problem is a concern specially on reverse link. Carriers belonging to one set are not adjacent.
- Guard bands - reduces overall spectral efficiency.

4.2.1 Features of FDMA

- There are many features of FDMA some of them are listed below :
  1. Channel bandwidth relatively narrow (30 kHz), i.e. usually narrowband systems
  2. Simplest method
  3. Best suited for analog links
  4. Continuous transmission implies no framing or synchronization bits needed
  5. Requires tight filtering to minimize interference
  6. Usually combined with FDD for duplexing

4.2.2 Nonlinear Effects in FDMA

1. Many channels - same antenna
2. For maximum power efficiency operate near saturation
3. Near saturation power amplifiers are nonlinear
4. Nonlinearities causes signal spreading

5. Intermodulation frequencies
6. IM are undesired harmonics
7. Interference with other channels in the FDMA system
8. Decreases user C/I - decreases performance
9. Interference outside the mobile radio band : adjacent-channel interference
10. RF filters needed - higher costs

4.2.3 Number of Channels in a FDMA System

The number of channels that can be simultaneously supported in a FDMA system is given by-

$$N = \frac{B_t - 2B_{guard}}{B_c}$$

Where,

N = Number of channels

B_t = Total spectrum allocation

B_{guard} = Guard band

B_c = Channel bandwidth

4.2.4 Advantages of FDMA

1. FDMA technique doesn't need any base-control station.
2. Data that transferred between each station to another during the transmission process will not be lost.
3. After the transmission of data, the effect of the delay distortion will be so small and it can be ignored.
4. There is no need for network timing.
5. The channel operations in FDMA are simple.
6. In FDMA, the reduction of the information bit rate has a good effect on the capacity.
7. No need for any equalization.
8. Because of the transmission is continuous, there is almost no need for bits that are responsible for synchronization.
9. Simplicity in FDMA algorithms.

4.2.5 Disadvantages of FDMA

1. In the FDMA technique, it is impossible for the stations to receive data from mo than one transmission source.
2. One of most important thing in communication systems is the maximum data ra which is small and fixed for every channel in FDMA.
3. Because of the guard bands, the capacity of the FDMA decreased.
4. FDMA requires special filters to avoid any interference between the narro channels.

University Questions

1. *Which are various multiple access schemes used in wireless communicmions ?* GTU : Summer-15, Marks 7
2. *Write short note on frequency division multiple access (FDMA). Describe non linear effects in FDMA.Also write equation for number of channels that can be simultaneously supported in a FDMA system.* GTU : Winter-15, Marks 7

4.3 Time Division Multiple Access (TDMA) GTU : Summer-15, Winter-15

- In TDMA system, a number of users share the same frequency band by taki assigned turns in using the channel.
- A base station controller assigns time slots to users and slot released upon t completion of call.
- The entire band is used by the user during his slot. Fixed assignment emplo predetermined order. Slot is wasted if there is no information for transmission.

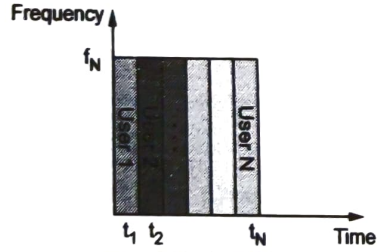

Fig. 4.3.1 TDMA

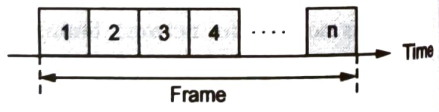

Fig. 4.3.2 TDMA frame structure

Advantage :

Flexibility - can provide different access rates at no cost.

Disadvantages :

1. Requires accurate synchronization with BS and rest of users.
2. Guard times.

4.3.1 Features of TDMA

The features of TDMA includes the following :

1. TDMA shares a single carrier frequency with several users where each users makes use of non overlapping time slots. The number of time slots per frame depends on several factors such as modulation technique, available bandwidth etc.
2. TDMA requires careful time synchronization since users share the bandwidth in the frequency domain. The number of channels are less, inter channel interference is almost negligible.
3. Data transmission in TDMA is not continuous but occurs in bursts. This results in low battery consumption since the subscriber transmitter can be turned OFF when not in use.
4. Because of a discontinuous transmission in TDMA the handoff process is much simpler for a subscriber unit, since it is able to listen to other base stations during idle time slots.
5. TDMA uses different time slots for transmission and reception thus duplexers are not required.
6. TDMA has an advantage that is possible to allocate different numbers of time slots per frame to different users. Thus bandwidth can be supplied on demand to different users by concatenating or reassigning time slot based on priority.

4.3.2 TDMA Frame Structure

The transmission from various users is interlaced into a repeating frame structure as shown in Fig. 4.3.3.

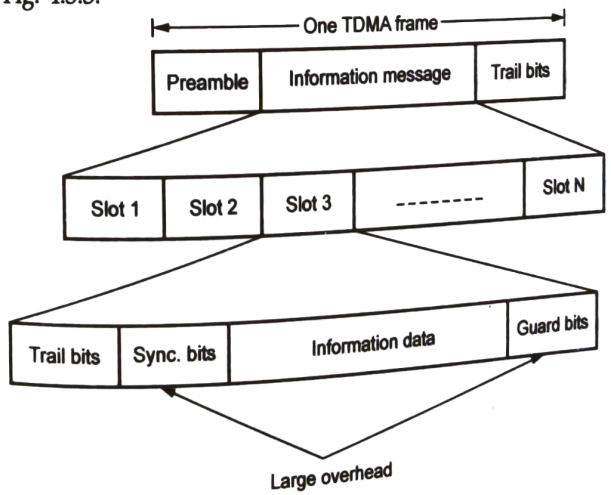

Fig. 4.3.3 TDMA frame

4.3.3 Efficiency of TDMA

- The efficiency of a TDMA system is a measure of the percentage of transmitted d that contains information as compared to overhead for the access scheme.
- The frame efficiency (η_f)is the percentage of bits per frame which conta transmitted data. Note that the transmitted data may include source and chann coding bits, so the raw end-user efficiency of a system is generally less than η_f.
- The number of overhead bits per frame is computed by :

$$b_{oH} = N_r b_r + N_t b_p + N_t b_g + N_r b_g$$

Where,

N_r is the number of reference bursts per frame,

N_t is the number of traffic bursts per frame,

b_r is the number of overhead bits per reference burst,

b_p is the number of overhead bits per preamble in each slot, and

b_g is the number of equivalent bits in each guard time interval

- The total number of bits per frame (b_T) is given by :

$$b_T = T_f R$$

Where,

T_f is the frame duration, and

R is the channel bit rate.

- The frame efficiency is calculated as -

$$\eta_f = \left(1 - \frac{b_{OH}}{b_T}\right) \times 100\ \%$$

4.3.4 Number of Channels in TDMA System

- The number of TDMA channel slots that can be provided in a TDMA system is given by -

$$N = \frac{m(B_{tot} - 2B_{guard})}{B_c}$$

Where,

m is the number of TDMA slots per channel

B_t is the total spectrum allocation

B_{guard} is the guard band allocated at the edge of the allocated spectrum

B_c is the channel bandwidth.

Solved Examples

Example 4.3.1 *If GSM uses a frame structure where each frame consists of 8 time slots and each time slot contains 156.25 bits and data is transmitted at 270.833 kbps in the channel find :*

(i) The time duration of a bit.

(ii) The time duration of a slot.

(iii) The time duration of a frame.

(iv) How long must a user occupying a single time slot wait between two successive transmissions.

GTU : Winter-15, Marks 7

Solution :

(i) The time duration of a bit is calculated as-

$$T_b = \frac{1}{270.833\ \text{kbps}} = 3.692\ \mu s$$

(ii) The time duration of a slot is calculated as -

$$T_{slot} = 156.25 \times T_b = 0.577\ \text{ms}$$

(iii) The time duration of a frame is calculated as -

$$T_f = 8 \times T_{slot} = 4.615\ \text{ms}$$

(iv) A user has to wait 4.615 ms, the arrival time of a new frame, for its next transmission

Example 4.3.2 *If a normal GSM time slot consists of 6 trailing bits, 8.25 guard bits, 26 training bits and two traffic bursts of 58 bits of data. Find the frame efficiency.*

GTU : Winter-15, Marks 7

Solution : A time slot has 6 + 8.25 + 26 + 2(58) = 156.25 bits.

A frame has 8 × 156.25 = 1250 bits/frame.

The number of overhead bits per frame is given by-

$$b_{OH} = N_r b_r + N_t b_p + N_t b_g + N_r b_g$$

$$b_{OH} = 8(6) + 8\ (8.25) + 8(26) = 322\ \text{bits}$$

The frame efficiency is calculated as -

$$\eta_f = \left(1 - \frac{b_{OH}}{b_T}\right) \times 100\ \%$$

$$\eta_f = \left[1 - \frac{322}{1250}\right] \times 100 = 74.24\ \%$$

University Questions

1. *Which are various multiple access schemes used in wireless communicmions ?* **GTU : Summer-15, Marks 7**
2. *Describe : Time Division Multiple Access (TDMA) in detail. Write the equation for efficiency of TDMA and The number of channels in TDMA system.* **GTU : Winter-15, Marks 7**

4.4 Code Division Multiple Access (CDMA) GTU : Summer-15, Winter-15

- CDMA system is implemented based on spread-spectrum technology. CDMA can accommodate various wireless users with different bandwidth requirements switching methods and technical characteristics.
- User transmits all the time (not in a particular slot) and using all the frequency bandwidth.
- Every user is assigned a distinct code that acts as the key to identify that user.
- A frequency reuse factor of one is potentially possible with CDMA. Multiple users use the same band at the same time.
- CDMA requires an excellent power control mechanism to utilize its interference suppression advantage.
- Code Division Multiple Access (CDMA) is also called as spread spectrum communication. The term "spread spectrum" refers to the expansion of signal bandwidth, by several orders of magnitude in some cases, which occurs when a key is attached to the communication channel.
- In CDMA, the transmitted signals are not discriminated by their frequency assignment (as in FDMA), nor by their time slot assignment (as in TDMA), but by a characteristic code which is superposed on the information signal. This feature has allowed CDMA to gain attention in commercial satellite communication.
- CDMA was adopted in cellular mobile telephone as an interference-tolerant communication technology that increases capacity above analog systems.
- All concerned earth stations simultaneously share the same bandwidth and recognize the signals by various processes such as code identification.
- The two most common CDMA techniques are :
  1. Direct Sequence Spread Spectrum (DSSS), also called Pseudo-Noise (PN) modulation, which is the dominant technique.
  2. Frequency Hopping Spread Spectrum (FHSS)
- Spread Spectrum signals use fast codes that run many times the information bandwidth or data rate. These special "Spreading" codes are called "Pseudo Random" or "Pseudo Noise" codes. They are called "Pseudo" because they are not real Gaussian noise.

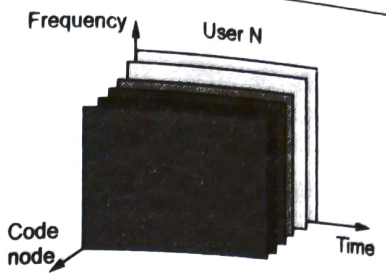

Fig. 4.4.1 CDMA

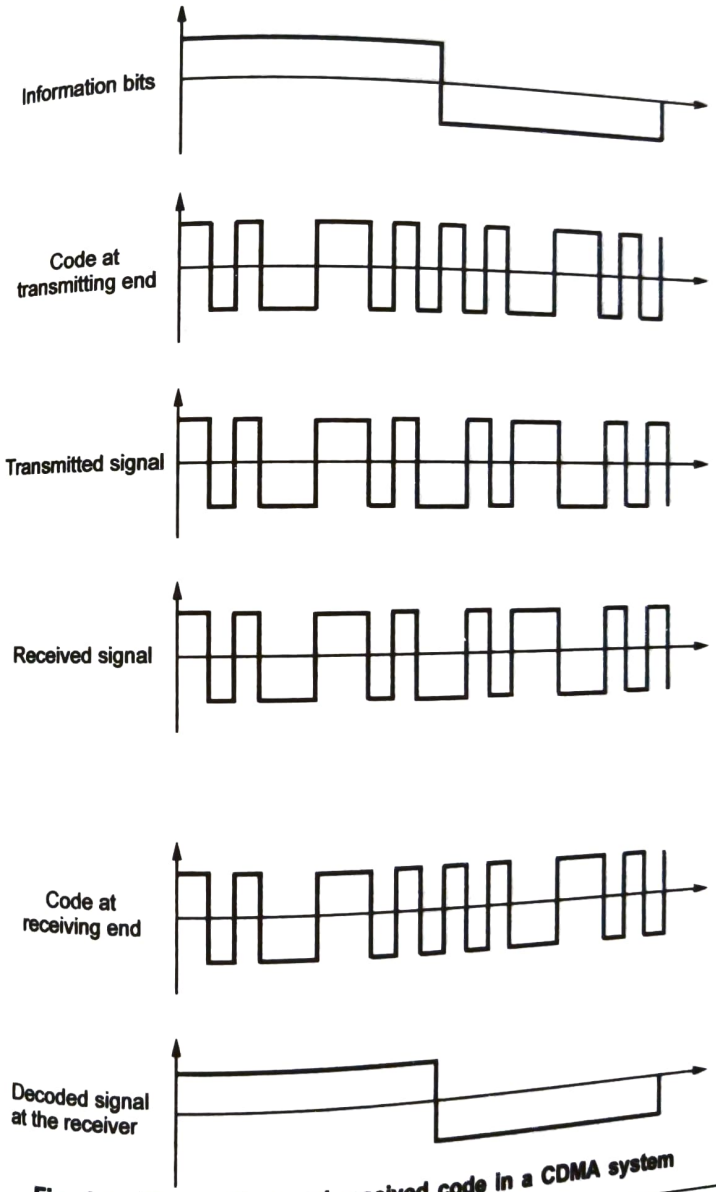

Fig. 4.4.2 Transmitted and received code in a CDMA system

4.4.1 Near-far Problem

- The near-far problem is a serious one in CDMA. If the power is not controlled, t CDMA signal of a user near to the base station will overshadow those signa originated from a distance away.
- The near-far problem occurs when many mobile users share the same channe Generally the strongest received mobile signal will capture the demodulator at base station.
- In CDMA, stronger received signal levels raise the noise floor at the base statio demodulators for the weaker signals, thereby decreasing the probability that weak signals will be received.
- The power of multiple users at a receiver determines the noise floor afte decorrelation.

4.4.2 Power Control

- Power control eliminates the problem of near-far problem.
- The power control is provided by each base station in a cellular system and assure that each mobile within the base station coverage area provides the same signal leve to the base station receiver.
- The problem of a nearby subscriber is solved by overpowering the base statio receiver and drowning out the signals of far away subscribers.
- Power control is implemented at the base station by rapidly sampling the radi signal strength indicator (RSSI) levels of each mobile and then sending a powe change command over the forward radio link.
- Out-of-cell mobiles provide interference which is not under the control of th receiving base station.
- Power control is necessary for CDMA systems.

4.4.3 Features of CDMA Systems

- Many users of a CDMA system share the same frequency. Resulting in coexistence o multiple users on the same frequency band.
- CDMA has a soft capacity limit. Increasing the number of users in a CDMA syste raises the noise floor. Thus, there is no absolute limit on the number of users i CDMA.
- The system performance gradually degrades (improves) for all users as the numbe of users increased (decreased).
- Inherent frequency diversity (multi-path diversity) can be exploited to mitigate th adverse effects of small-scale fading.

- Adjacent cells can use the same frequency. A mobile station at the boundary of two adjacent cells can simultaneously receive signals from the two base stations. It is a diversity effect and can be used to improve the performance for mobile stations at the boundary. The handoff process is called soft handoff.
- Adjacent cells use different sets of spreading codes but can be operated at the same carrier frequency. The frequency reuse factor is therefore one.
- Multiple-access interference (MAI) is a problem in CDMA systems. MAI occurs because the spreading sequences of all users are not exactly orthogonal, leading to interference to other users' signals.
- The near-far problem occurs at a CDMA receiver if an undesired user has a high detected power as compared to the desired user.

4.4.4 Problems Associated with TDMA, CDMA and FDMA

i) At high data rate, the symbol duration T_s becomes very small and the required system bandwidth becomes very large.

ii) If the symbol duration becomes vary small in TDMA, then the impulse response becomes very long. Hence computational effort increases.

iii) CDMA requires Rake receiver in addition to an equalizer.

iv) In FDMA, there is large spacing between carriers. This is wastage of precious spectrum.

OFDM overcomes above problems :

- OFDM increases the symbol duration and all its carriers are mutually orthogonal. Above problems are almost removed by OFDM.

4.4.5 Comparison of FDMA, TDMA, CDMA

Technique	FDMA	TDMA	CDMA
Concept	Divide the frequency band into disjoint subbands	Divide the time into non-overlapping time slots	Spread the signal with orthogonal codes
Active terminals	All terminals active on their specified frequencies	Terminals are active in their specified slot on same frequency	All terminals active on same frequency
Signal separation	Filtering in frequency	Synchronization in time	Code separation
Handoff	Hard handoff	Hard handoff	Soft handoff
Advantages	Simple and robust	Flexible	Flexible
Disadvantages	Inflexible, available frequencies are fixed, requires guard bands	Requires guard space, synchronization problem	Complex receivers, requires power control to avoid near-far problem
Current applications	Radio, TV and analog cellular	GSM and PDC	2.5G and 3G

University Questions

1. *Which are various multiple access schen es used in wireless communicmions ?*

GTU : Summer-15, Marks 7

2. *Write short note on Code Division Multiple Access (CDMA).*

GTU : Winter-15, Marks 7

4.5 Orthogonal Frequency Division Multiplexing (OFDM)

- OFDM is a multi-carrier transmission scheme. OFDM transform high-speed serial transmission to low-speed parallel transmission. It increase symbol duration, robust to multipath interference
- Multiplexing is an important signal processing operation in which a number of signals are combined and transmitted parallelly over a common channel. In order to avoid interference during parallel transmission, the signals can be separated in frequency and then the resulting technique is called Frequency Division Multiplexing (FDM).
- In FDM, the adjacent bands are non overlapping but if overlap is allowed by transmitting signals that are mutually orthogonal (that is, there is a precise mathematical relationship between the frequencies of the transmitted signals) such that one signal has zero effect on another, then the resulting transmission technique is known as **Orthogonal Frequency Division Multiplexing (OFDM).**
- OFDM is a technique of transmitting high bit rate data into several parallel streams of low bit rate data. At any instant, the data transmitted simultaneously in each of these parallel data streams is frequency modulated by carriers (called subcarriers) which are orthogonal to each other.
- Fig.4.5.1 shows basic concept of OFDM.
- For high data rate communication the bandwidth (which is limited) requirement goes on increasing as the data rate increases or the symbol duration decreases. Thus in OFDM, instead of sending a particular number of symbols, say P, in T seconds serially, the P symbols can be sent in parallel with symbol duration now increased to T seconds instead of T/P seconds as was previously.
- This offers many advantages in digital data transmission through a wireless time varying channel. The primary advantage of increasing the symbol duration is that the channel experiences at fading instead of frequency selective fading since it is ensured that in the time domain the symbol duration is greater than the r.m.s. delay spread of the channel. Viewed in the frequency domain this implies that the bandwidth of the OFDM signal is less than coherent bandwidth of the channel.

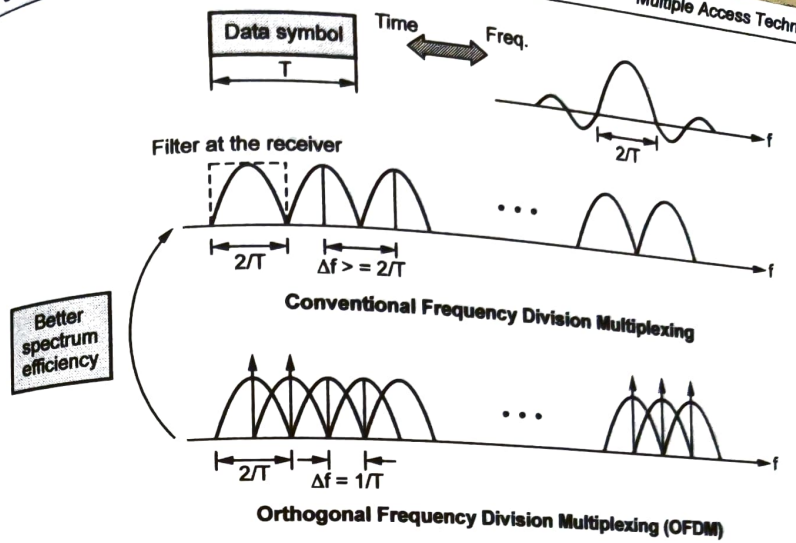

Fig. 4.5.1 OFDM concept

Orthogonality of Signals

- Orthogonal signals can be viewed in the same perspective as we view vectors which are perpendicular/orthogonal to each other. The inner product of two mutually orthogonal vectors is equal to zero. Similarly the inner product of two orthogonal signals is also equal to zero.

OFDM Transmitter and Receiver

- The OFDM transmitter and receiver block diagram is shown in Fig. 4.5.2.

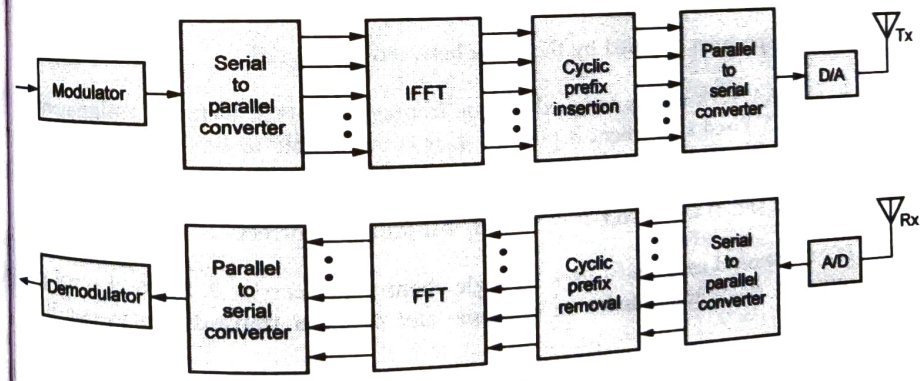

Fig. 4.5.2

Advantages of OFDM

1. Easy to mitigate the adverse effects of channel dispersion by the use of cyclic prefix.
2. Low-complexity implementation based on FFT/IFFT.
3. Support high-rate transmission at a low implementation cost.

Disadvantages of OFDM

1. High peak-to-average power ratio, so that *highly linear* power amplifiers are required at the transmitters in order to avoid intermodulation interference.
2. The use of cyclic prefix reduces transmission efficiency. Some power is wasted by transmitting cyclic prefix, which are redundant.

4.6 Multiple Choice Questions

Q.1 Cable television is an example of _____ .

[a] TDMA [b] FDMA [c] CDMA [d] SDMA **[Ans. : b]**

Q.2 FDMA is the division of _____ .

[a] Time [b] Phase [c] Spectrum [d] Amplitude **[Ans. : c]**

Q.3 Guard band is _____ .

[a] The small unused bandwidth between the frequency channels to avoid interference

[b] The bandwidth allotted to the signal

[c] The channel spectrum

[d] The spectrum acquired by the noise between the signal **[Ans. : a]**

Q.4 In FDMA,1. Each user is assigned unique frequency slots 2. Demand assignment is possible 3. Fixed assignment is possible 4. It is vulnerable to timing problems

[a] Only 1) and 2) are correct [b] 2) and 4) are correct

[c] 1), 2) and 3) are correct [d] All four are correct **[Ans. : c]**

Q.5 FDMA demand assignment uses 1. Single channel per carrier 2. Multi channel per carrier 3. single transmission in one time slot 4. multi transmission in one time slot

[a] 1) and 2) are correct [b] 2), 3), and 4) are correct

[c] 1), 2), and 3) are correct [d] All four are correct **[Ans. : a]**

Q.6 The advantages of FDMA over TDMA includes 1. Division is simpler 2. Propagation delays are eliminated 3. Cheaper filters with less complicated logic functions 4. Linearity

[a] 1), 2) and 3) are correct [b] 1) and 2) are correct

[c] 1) and 4) are correct [d] All four are correct **[Ans. : b]**

Q.7 TDMA is a multiple access technique that has _____ .

[a] Different users in different time slots

[b] Each user is assigned unique frequency slots

[c] Each user is assigned a unique code sequence

[d] Each signal is modulated with frequency modulation technique **[Ans. : a]**

Q.8 In TDMA, the user occupies the whole bandwidth during transmission.

[a] True [b] False **[Ans. : a]**

Q.9 TDMA allows the user to have _____ .

[a] Use of same frequency channel for same time slot

[b] Use of same frequency channel for different time slot

[c] Use of same time slot for different frequency channel

[d] Use of different time slot for different frequency channels **[Ans. : b]**

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