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MOBILE COMMUNICATION

Que) Explain the importance of Multiple access techniques in FDMA.

MULTIPLE ACCESS TECHNIQUES

- Multiple access techniques are used to allow a large number of mobile users to share the allocated spectrum in the most efficient manner.
- As the spectrum is limited, so the sharing is required to increase the capacity of cell or over a geographical area by allowing the available bandwidth to be used at the same time by different users.
- And this must be done in a way such that the quality of service doesn't degrade within the existing users.

MULTIPLE ACCESS TECHNIQUES FOR WIRELESS COMMUNICATION

- In wireless communication systems it is often desirable to allow the subscriber to send simultaneously information to the base station while receiving information from the base station.
- A cellular system divides any given area into cells where a mobile unit in each cell communicates with a base station.
- The main aim in the cellular system design is to be able to increase the capacity of the channel i.e. to handle as many calls as possible in a given bandwidth with a sufficient level of quality of service.

- There are several different ways to allow access to the channel. These includes mainly the following:
- Frequency division multiple-access (FDMA)
- Time division multiple-access (TDMA)
- Code division multiple-access (CDMA)

1) FREQUENCY DIVISION MULTIPLE ACCESS

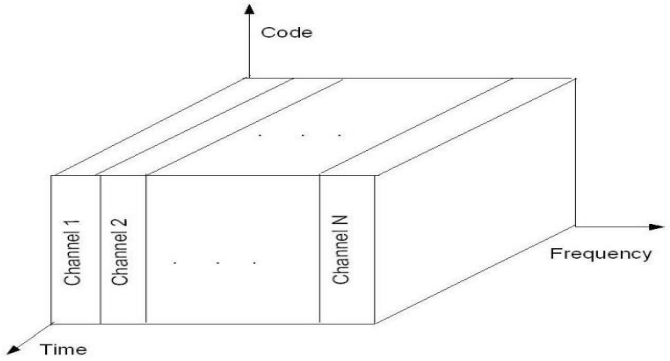


Figure : The basic concept of FDMA.

- This was the initial multiple-access technique for cellular systems in which each individual user is assigned a pair of frequencies while making or receiving a call as shown in Figure.
- One frequency is used for downlink and one pair for uplink. This is called frequency division duplexing (FDD).

- That allocated frequency pair is not used in the same cell or adjacent cells during the call so as to reduce the co channel interference.
- Even though the user may not be talking, the spectrum cannot be reassigned as long as a call is in place.
- Different users can use the same frequency in the same cell except that they must transmit at different times. The features of FDMA are as follows:
- The FDMA channel carries only one phone circuit at a time. If an FDMA channel is not in use, then it sits idle and it cannot be used by other users to increase share capacity.
- After the assignment of the voice channel the BS and the MS transmit simultaneously and continuously.
- The bandwidths of FDMA systems are generally narrow i.e. FDMA is usually implemented in a narrow band system The symbol time is large compared to the average delay spread.

- The complexity of the FDMA mobile systems is lower than that of TDMA mobile systems. FDMA requires tight filtering to minimize the adjacent channel interference.

FDMA/FDD in AMPS

- The first U.S. analog cellular system, AMPS (Advanced Mobile Phone System) is based on FDMA/FDD.
- A single user occupies a single channel while the call is in progress, and the single channel is actually two simplex channels which are frequency duplexed with a 45 MHz split.
- When a call is completed or when a handoff occurs the channel is vacated so that another mobile subscriber may use it.
- Multiple or simultaneous users are accommodated in AMPS by giving each user a unique signal.
- Voice signals are sent on the forward channel from the base station to the mobile unit, and on the reverse channel from the mobile unit to the base station.
- In AMPS, analog narrowband frequency modulation (NBFM) is used to modulate the carrier.

FDMA/TDD in CT2

- Using FDMA, CT2 system splits the available bandwidth into radio channels in the assigned frequency domain.
- In the initial call setup, the handset scans the available channels and locks on to an unoccupied channel for the duration of the call.
- Using TDD(Time Division Duplexing), the call is split into time blocks that alternate between transmitting and receiving.

FDMA and Near-Far Problem

- The near-far problem is one of detecting or filtering out a weaker signal amongst stronger signals.

- The near-far problem is particularly difficult in CDMA systems where transmitters share transmission frequencies and transmission time.
- In con- trast, FDMA and TDMA systems are less vulnerable. FDMA systems offer different kinds of solutions to near-far challenge.
- Here, the worst case to consider is recovery of a weak signal in a frequency slot next to strong signal.
- Since both signals are present simultaneously as a composite at the input of a gain stage, the gain is set according to the level of the stronger signal; the weak signal could be lost in the noise floor. Even if subsequent stages have a low enough noise floor to provide

2) TIME DIVISION MULTIPLE ACCESS

- In digital systems, continuous transmission is not required because users do not use the allotted bandwidth all the time.
- In such cases, TDMA is a complimentary access technique to FDMA. Global Systems for Mobile communications (GSM) uses the TDMA technique.
- In TDMA, the entire bandwidth is available to the user but only for a finite period of time. In most cases the available bandwidth is divided into fewer channels compared to FDMA.
- The users are allotted time slots during which they have the entire channel bandwidth at their disposal, as shown in Figure

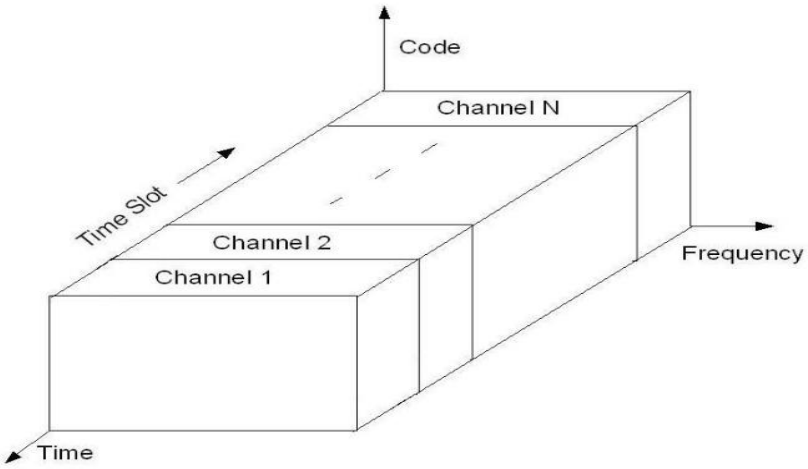


Figure : The basic concept of TDMA.

- 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.
- TDMA uses different time slots for transmission and reception. This type of duplexing is referred to as Time division duplexing (TDD).

- The features of TDMA includes the following:

a) TDMA shares a single carrier frequency with several users where each users makes use of non overlapping time slots.

b) The number of time slots per frame depends on several factors such as modulation technique, available bandwidth etc.

c) 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. Because of a discontinuous trans- mission 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.

d) TDMA uses different time slots for transmission and reception thus duplexers are not required.

- 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.

TDMA/FDD in GSM

- GSM is widely used in Europe and other parts of the world. GSM uses a variation of TDMA along with FDD.
- GSM digitizes and compresses data, then sends it down a channel with two other streams of user data, each in its

3) CODE DIVISION MULTIPLE ACCESS

- In CDMA, the same bandwidth is occupied by all the users, however they are all assigned separate codes, which differentiates them from each other shown in Figure.

- CDMA utilize a spread spectrum technique in which a spreading signal (which is uncorrelated to the signal and has a large bandwidth) is used to spread the narrow band message signal.

Direct Sequence Spread Spectrum (DS-SS)

- This is the most commonly used technology for CDMA. In DS-SS, the message signal is multiplied by a Pseudo Random Noise Code.
- Each user is given his own codeword which is orthogonal to the codes of other users and in order to detect the user, the receiver must know the codeword used by the transmitter.
- There are, however, two problems in such systems which are discussed in the sequel.

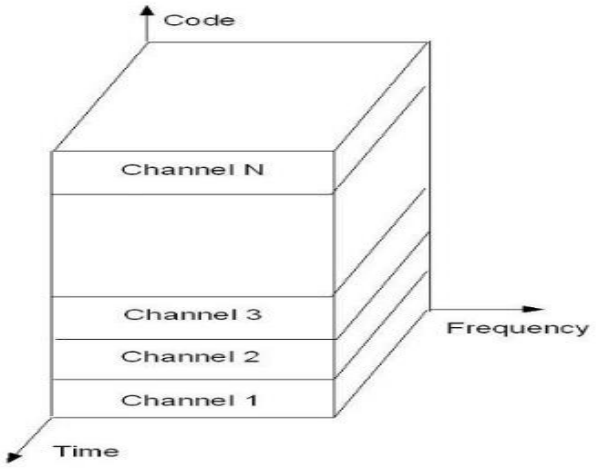


Figure : The basic concept of CDMA.

CDMA/FDD in IS-95

- In this standard, the frequency range is: 869-894 MHz (for Rx) and 824-849 MHz (for Tx).
- In such a system, there are a total of 20 channels and 798 users per channel.
- For each channel, the bit rate is 1.2288 Mbps.
- For orthogonality, it usually combines 64 Walsh-Hadamard codes and a m-sequence.

CDMA and Self-interference Problem

- In CDMA, self-interference arises from the presence of delayed replicas of signal due to multipath.
- The delays cause the spreading sequences of the different users to lose their orthogonality, as by design they are orthogonal only at zero phase offset.

- Hence in despreading a given user's waveform, nonzero contributions to that user's signal arise from the transmissions of the other users in the network.
- This is distinct from both TDMA and FDMA, wherein for reasonable time or frequency guardbands, respectively, orthogonality of the received signals can be preserved.

CDMA and Near-Far Problem

- The near-far problem is a serious one in CDMA. This problem arises from the fact that signals closer to the receiver of interest are received with smaller attenuation than are signals located further away.
- Therefore the strong signal from the nearby transmitter will mask the weak signal from the remote transmitter.
- In TDMA and FDMA, this is not a problem since mutual interference can be filtered. In CDMA, however, the near-far effect combined with imperfect orthogonality between codes (e.g. due to different time sifts), leads to substantial interference.
- Accurate and fast power control appears essential to ensure reliable operation of multiuser DS-CDMA systems.

Que) Explain the effect of Intermodulation with necessary equation.

- **Intermodulation** is the amplitude modulation of signals containing two or more different frequencies, caused by nonlinearities in a system.
- The intermodulation between each frequency component will form additional signals at frequencies that are not just at harmonic frequencies (integer multiples) of either, like harmonic distortion, but also at the sum and difference frequencies of the original frequencies and at multiples of those sum and difference frequencies.
- Intermodulation is caused by non-linear behaviour of the signal processing (physical equipment or even algorithms) being used.
- The theoretical outcome of these non-linearities can be calculated by generating a Volterra series of the characteristic, while the usual approximation of those non-linearities is obtained by generating a Taylor series.
- Practically all audio equipment has some non-linearity, so it will exhibit some amount of IMD, which however may be low enough to be imperceptible by humans.
- Due to the characteristics of the human auditory system, the same percentage of IMD is perceived as more bothersome when compared to the same amount of harmonic distortion.
- Intermodulation is also rarely desirable in radio, as it creates unwanted spurious emissions, often in the form of sidebands. For radio transmissions this increases the occupied bandwidth, leading to adjacent channel interference, which can reduce audio clarity or increase spectrum usage.
- IMD is only distinct from harmonic distortion in that the stimulus signal is different. The same nonlinear system will produce both THD (with a solitary sine wave input) and IMD (with more complex tones).
- In music, for instance, IMD is intentionally applied to electric guitars using overdriven amplifiers or effects pedals to produce new tones at *sub*harmonics of the tones being played on the instrument.

- IMD is also distinct from intentional modulation (such as a frequency mixer in superheterodyne receivers) where signals to be modulated are presented to an intentional nonlinear element (multiplied).
- See non-linear mixers such as mixer diodes and even single-transistor oscillator-mixer circuits. However, while the intermodulation products of the received signal with the local oscillator signal are intended,.
- superheterodyne mixers can, at the same time, also produce unwanted intermodulation effects from strong signals near in frequency to the desired signal that fall within the passband of the receiver.
- Intermodulation occurs when the input to a non-linear system is composed of two or more frequencies. Consider an input signal that contains three frequency components at fa,fb and fc are expressed as,

$$x(t) = M_a \sin(2\pi f_a t + \phi_a) + M_b \sin(2\pi f_b t + \phi_b) + M_c \sin(2\pi f_c t + \phi_c)$$

where the M and ϕ are the amplitudes and phases of the three components, respectively.

We obtain our output signal, $y(t)$, by passing our input through a non-linear function G:

$$y(t) = G(x(t))$$

$y(t)$ will contain the three frequencies of the input signal, f_a, f_b, and f_c (which are known as the *fundamental* frequencies), as well as a number of linear combinations of the fundamental frequencies, each of the form

$$k_a f_a + k_b f_b + k_c f_c$$

where k_a, k_b, and k_c are arbitrary integers which can assume positive or negative values. These are the **intermodulation products** (or **IMPs**).

In general, each of these frequency components will have a different amplitude and phase, which depends on the specific non-linear function being used, and also on the amplitudes and phases of the original input components.

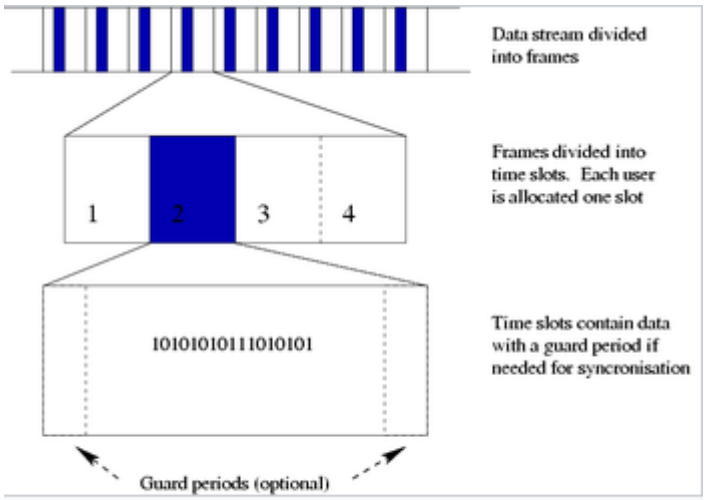
More generally, given an input signal containing an arbitrary number N of frequency components $f_a, f_b, \ldots, f_N$, the output signal will contain a number of frequency components, each of which may be described by

$$k_a f_a + k_b f_b + \cdots + k_N f_N,$$

where the coefficients $k_a, k_b, \ldots, k_N$ are arbitrary integer values.

Que) Explain TDMA Synchronization.

- **Time division multiple access** (TDMA) is a channel access method for shared medium networks. It allows several users to share the same frequency channel by dividing the signal into different time slots.
- The users transmit in rapid succession, one after the other, each using its own time slot.
- This allows multiple stations to share the same transmission medium (e.g. radio frequency channel) while using only a part of its channel capacity.
- TDMA is used in the digital 2G cellular systems such as Global System for Mobile Communications (GSM), IS-136, Personal Digital Cellular (PDC) and iDEN, and in the Digital Enhanced Cordless Telecommunications (DECT) standard for portable phones.
- It is also used extensively in satellite systems, combat-net radio systems, and PON networks for upstream traffic from premises to the operator.



TDMA frame structure showing a data stream divided into frames and those frames divided into time slots.

- Notice that a ``clock" is required for TDMA.
- All transmitters and receivers must be aware of this ``clock" to schedule their transmissions and receptions.
- We say that transmissions are *synchronized*.

- In cellular telephone systems a clock signal that indicates the beginning of time-slots is transmitted by the base stations. From this signals, mobile stations can determine when their turn comes up.

- In the digital telephone system, the transmitting exchange sends synchronization information together with the conversations.

Que) SS Transmission & Reception.

- In telecommunication and radio communication, **spread-spectrum** techniques are methods by which a signal (e.g., an electrical, electromagnetic, or acoustic signal) generated with a particular bandwidth is deliberately spread in the frequency domain, resulting in a signal with a wider bandwidth.
- These techniques are used for a variety of reasons, including the establishment of secure communications, increasing resistance to natural interference, noise and jamming, to prevent detection, and to limit power flux density (e.g., in satellite downlinks).
- This is a technique in which a telecommunication signal is transmitted on a bandwidth considerably larger than the frequency content of the original information.
- Frequency hopping is a basic modulation technique used in spread spectrum signal transmission.
- Spread-spectrum telecommunications is a signal structuring technique that employs direct sequence, frequency hopping, or a hybrid of these, which can be used for multiple access and/or multiple functions.
- This technique decreases the potential interference to other receivers while achieving privacy. Spread spectrum generally makes use of a sequential noise-like signal structure to spread the normally narrowband information signal over a relatively wideband (radio) band of frequencies. The receiver correlates the received signals to retrieve the original information signal.
- Originally there were two motivations: either to resist enemy efforts to jam the communications (anti-jam, or AJ), or to hide the fact that communication was even taking place, sometimes called low probability of intercept (LPI).
- Frequency-hopping spread spectrum (FHSS), direct-sequence spread spectrum (DSSS), time-hopping spread spectrum (THSS), chirp spread spectrum (CSS), and combinations of these techniques are forms of spread spectrum.
- Each of these techniques employs pseudorandom number sequences — created using pseudorandom number generators — to determine *and* control the spreading pattern of the signal across the allocated bandwidth.

- Ultra-wideband (UWB) is another modulation technique that accomplishes the same purpose, based on transmitting short duration pulses. Wireless standard IEEE 802.11 uses either FHSS or DSSS in its radio interface.