R 23/11/16

UNIT - IV MULTIPLE ACCESS TECHNIQUES

SYLLABUS:

SS & MA TECHNIQUES: FDMA, TDMA, CDMA, SDMA APPLICATION IN WIRE AND WIRELESS COMMUNICATION: ADVANTAGES:

(1) SPREAD SPECTRUM:

(1.1) Introduction In digital communication efficient utilization of Bandwidth and power are the two major factors

In some situations, it is necessary to sacrifice this efficiency. such that the transmitted signal is not easily detected by unauthorized users. This requirement is achieved by a signaling techniques called as Spread Spectrum Modulation.

Spread spectrum Modulation is required to provide a secure communication in a hostile environment (i-e Military communication).

Definition:-

In spread spectrum modulation a modulated signal is modulated second time in such a way to generate a wideband signal.

(or)

Spread spectrum means, a transmission in which the message sequence occupies a bandwidth in excess of the minimum bandwidth necessary to send it.

* spreading is achieved by code (PN Sequence) which is independent of the message sequence the same code (PN sequence) is used the receiver to despread, the received signal so that the original message sequence may be recovered.

* Spreading is accomplished before the transmission.

Advantages:

* It provides a secure communication.
* It's ability to tolerate a considerable amount of signal Interference.
* It has ability to reject intentional interference by a transmitter attempting to jam the transmission.
* In wireless communication It's increased capacity and spectral efficiency.
* Several users can independently use same higher B.W with little Interference
* It has the ability to reject unintentional interference by another user simultaneously attempting to transmit through the channel.

Disadvantages:-

* Multiple access interference is present.
* Very poor bandwidth utilization

Applications:-

* It's used in Satellite communication
* It can be used for multiple access communications.
* Spread - Spectrum signals can be used for for ranging or determination of position location.
* It's used is in Satellite Communication and local area networks

(1.2) General Model of Spread Spectrum Communication System.

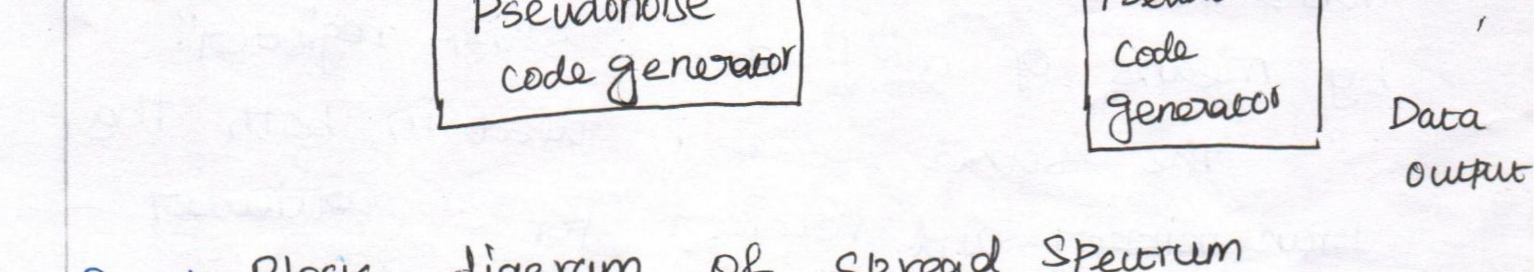


Fig: 1 Block diagram of Spread Spectrum communication.

* Input data is fed into a data encoder that produces an analog signal with a relatively narrow bandwidth.

* The encoded signal is modulated using a sequence of digits known as a spreading code (or spreading sequence, generated by a pseudonise code generator

* Bandwidth of the signal increased by spread spectrum modulation.

* At the receiver, the same de-spreading code sequence is used to demodulate the spread spectrum signal.

* The demodulated signal is processed by a data decoder to recover the output data.

(1.2) PSEUDO - NOISE SEQUENCES: (PN)

Definition:-

"A periodic binary sequence with a noise like waveform that is usally generated by means of a feedback shift register."

The same code is used in both the transmitter and receiver for a particular user for spreading and despreading.

PN Sequence Generator

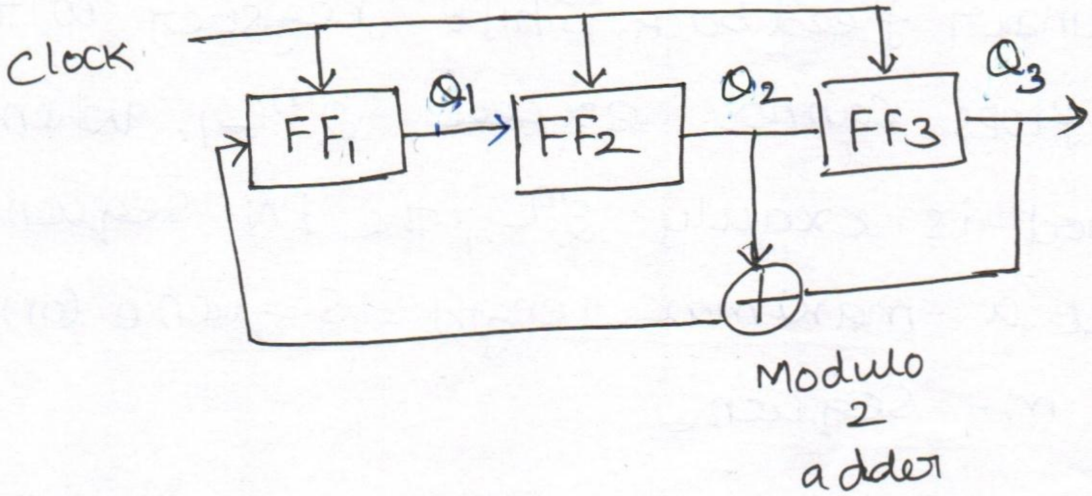


Fig: 2 PN sequence generator.

* A shift register of 'm' flip flops will have 2^m number of states. The output will repeat itself after 2^m bits.

* To generate the PN sequence assume initial state of $Q_3 Q_2 Q_1$ to 100. The outputs Q_2, Q_3 are connected to a modulo-2 adder.

* The duration of every bit in PN sequence is known as chip duration (T_c) and chip rate (R_c) is defined as the number of bits per second.

$$R_c = \frac{1}{T_c}$$; The period of Pseudo-noise sequence } $T_b = NT_c$.

* The period of a PN sequence produced by a linear feedback shift register with m flip flops cannot exceed $2^m - 1$. When the period is exactly $2^m - 1$, the PN sequence is called a maximal length - sequence (or) simply m- sequence

Properties:

Three properties of Maximal Length sequence are,

1. Balance property
2. Correlation Property
3. Run Property.

PN Sequence Generation.

Clock	Shift register output Q_3	Q_2	Q_1	$Q_3 \oplus Q_2$	PN sequence Q_3
0	1	0	0	$1 \oplus 0 = 1$	1
1	0	0	1	$0 \oplus 0 = 0$	0
2	0	1	0	$0 \oplus 1 = 1$	0
3	1	0	1	$1 \oplus 0 = 1$	1
4	0	1	1	$0 \oplus 1 = 1$	0
5	1	1	1	$1 \oplus 1 = 0$	1
6	1	1	0	$1 \oplus 1 = 0$	1
7	1	0	0	$1 \oplus 0 = 1$	1
8	0	0	1	$0 \oplus 0 = 0$	0
9	0	1	0	$0 \oplus 1 = 1$	0
10	1	0	1	$1 \oplus 0 = 1$	1

(1.3) Types of Spread Spectrum (SS)

1. Direct Sequence Spread Spectrum (DS-SS)
2. Frequency Hop Spread Spectrum (FH-SS).

Direct Sequence Spread Spectrum with Binary Phase Shift Keying (DS-BPSK).

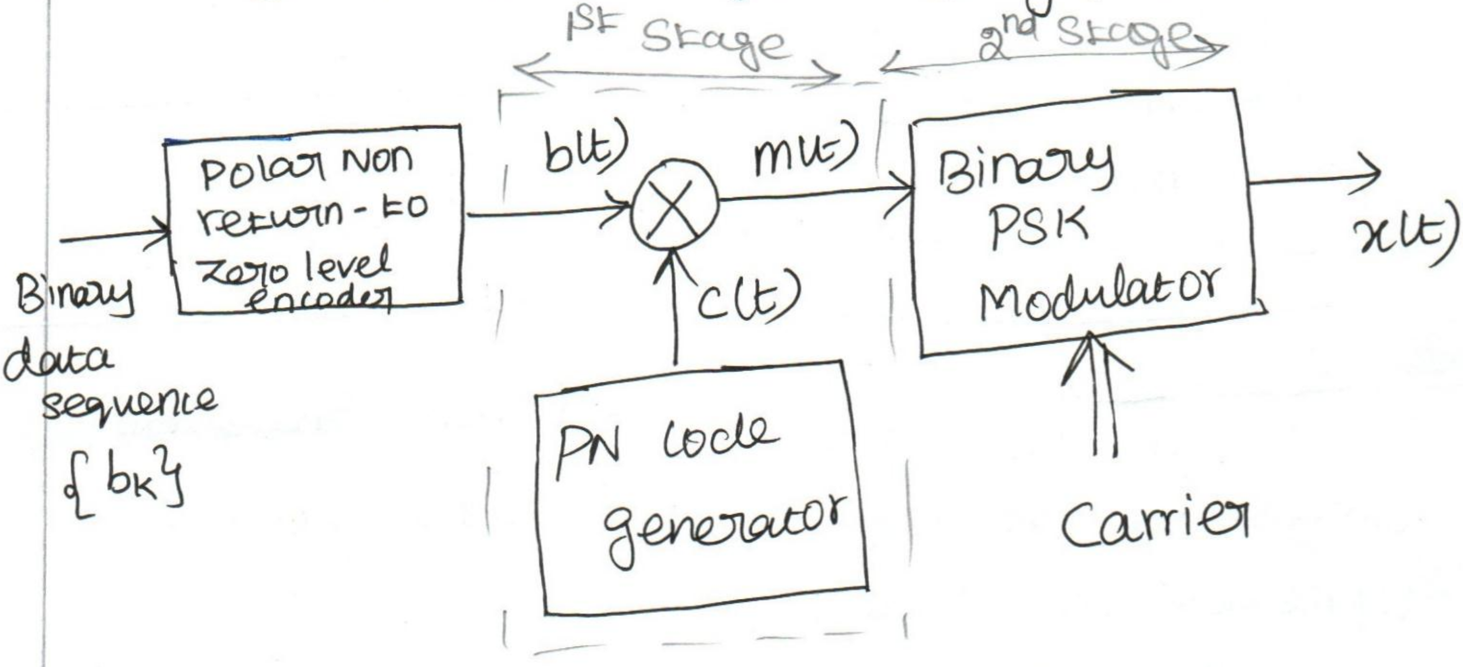


Fig:- 3 DS-BPSK Transmitter

* The incoming binary data sequence {bK} is converted into polar NRZ wave form b(t).
* Two stages of modulation is available. The First stage consists of a product modulator (or) multiplier with data signal b(t) and PN sequence c(t) as inputs.
* The second stage consists of a binary PSK modulator with the inputs of m(t) and carrier.

* The output m(t) is modulated with BPSK modulation and the output of BPSK modulator is x(t).
* The phase (θ(t)) of x(t) has two values, '0' and 'π' with respect to polarities of message signal b(t) & PN signal c(t).

Truth table for phase Modulation

		Polarity of Data sequence b(t)	
Polarity of PN Sequence c(t)		+	−
	+	0	π
	−	π	0

* In the output signal x(t), phase 180° represents the logic '0' and output phase 0° represents the logic 1.
* Thus the narrow band signal b(t) will be spread over the wide band and PN sequence performs the role of a spreading code.

(1.3.1) Direct sequence spread spectrum phase shift Keying Receiver

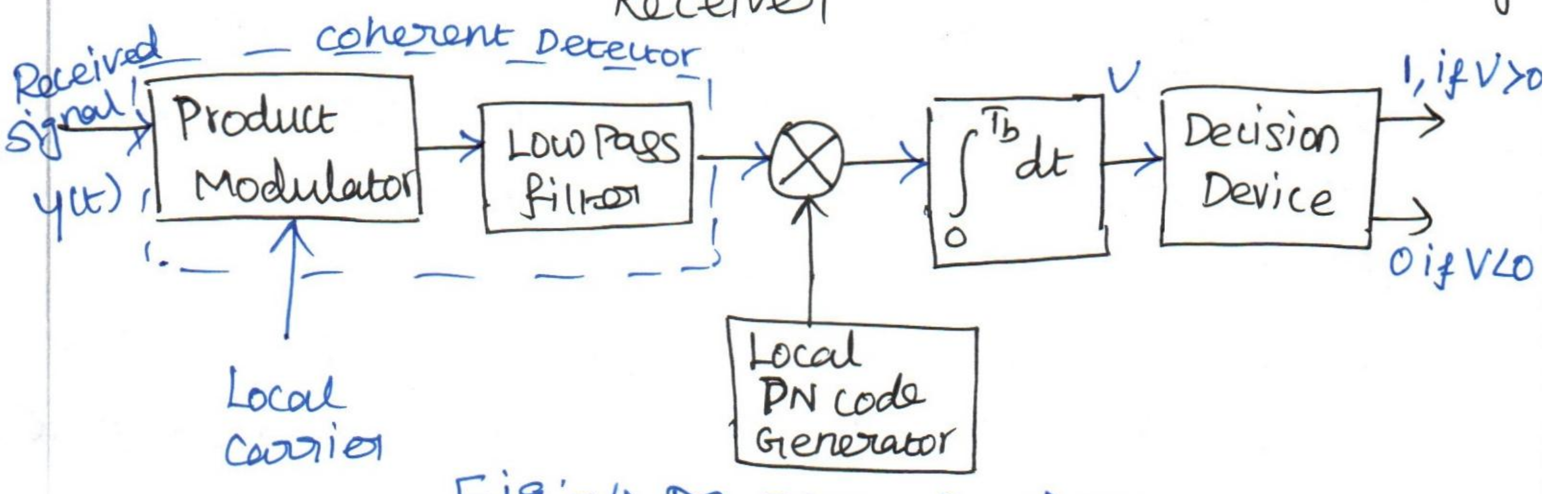


Fig:- 4 DS-BPSK Receiver.

* The receiver consists two stages of demodulation
* In the first stage, the received signal y(t) and a locallly generated carrier are applied to a product modulator followed by a low-pass filter whose bandwidth is equal to that of the original message signal m(t).
* This stage detects the signal from BPSK modulated signal.
* The second stage of demodulation performs Spectrum despreading by multiplying the low pass filter output by a locally generated PN signal c(t).
* The integrator circuit detect the bit one by one in the respective bit period (T_b) & finally decision device based on threshold value it detect the bit whether it is '0' or '1'.

(1.3.1.1) Model of DS - BPSK System.

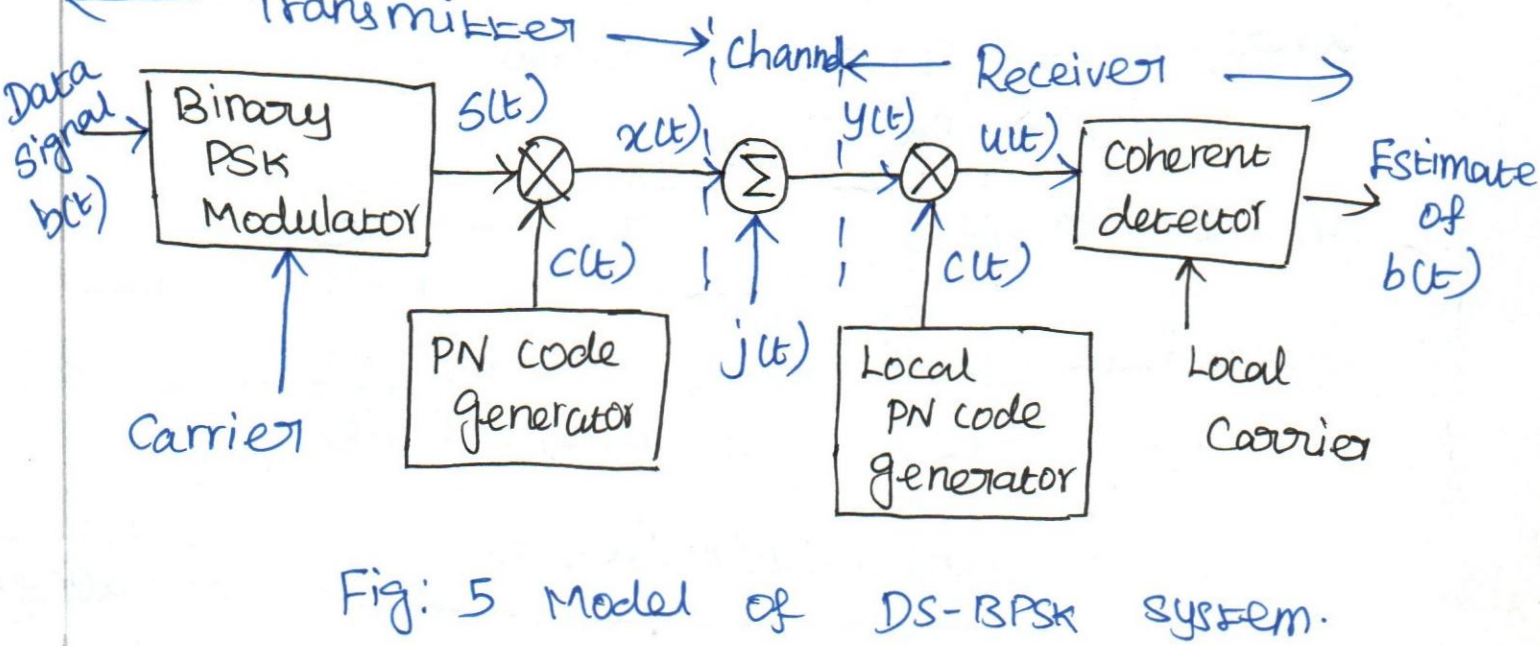


Fig: 5 Model of DS-BPSK system.

* In the previous case of Transmitter and receiver spectrum spreading is performed prior to phase modulation

* In this case it's more convenient to interchange the order of these operations. as shown in above diagram.

* It's important to synchronize the incoming data sequence and PN sequence.

* The model also includes representations of Channels and receiver.

The channel output is given by

$$y(t) = x(t) + j(t) \quad \text{— ①}$$

Where, $j(t) \rightarrow$ Interference.

& $x(t) = c(t)s(t) \rightarrow$ ② (From previous diagram)

Substitute ② in ①

$$y(t) = c(t)s(t) + j(t) \quad \text{— ③}$$

Where, $s(t) \rightarrow$ Binary PSK signal

$c(t) \rightarrow$ PN Signal.

In Receiver $\boxed{u(t) = c(t)\, y(t)} \rightarrow$ ④

Substitute ③ in ④

$$u(t) = c^2(t)s(t) + c(t)\, j(t)$$

$$\boxed{u(t) = s(t) + c(t) j(t)}$$

$\because c^2(t) = 1$ for all 't'.

1.3.1.2 Waveforms of DS- BPSK

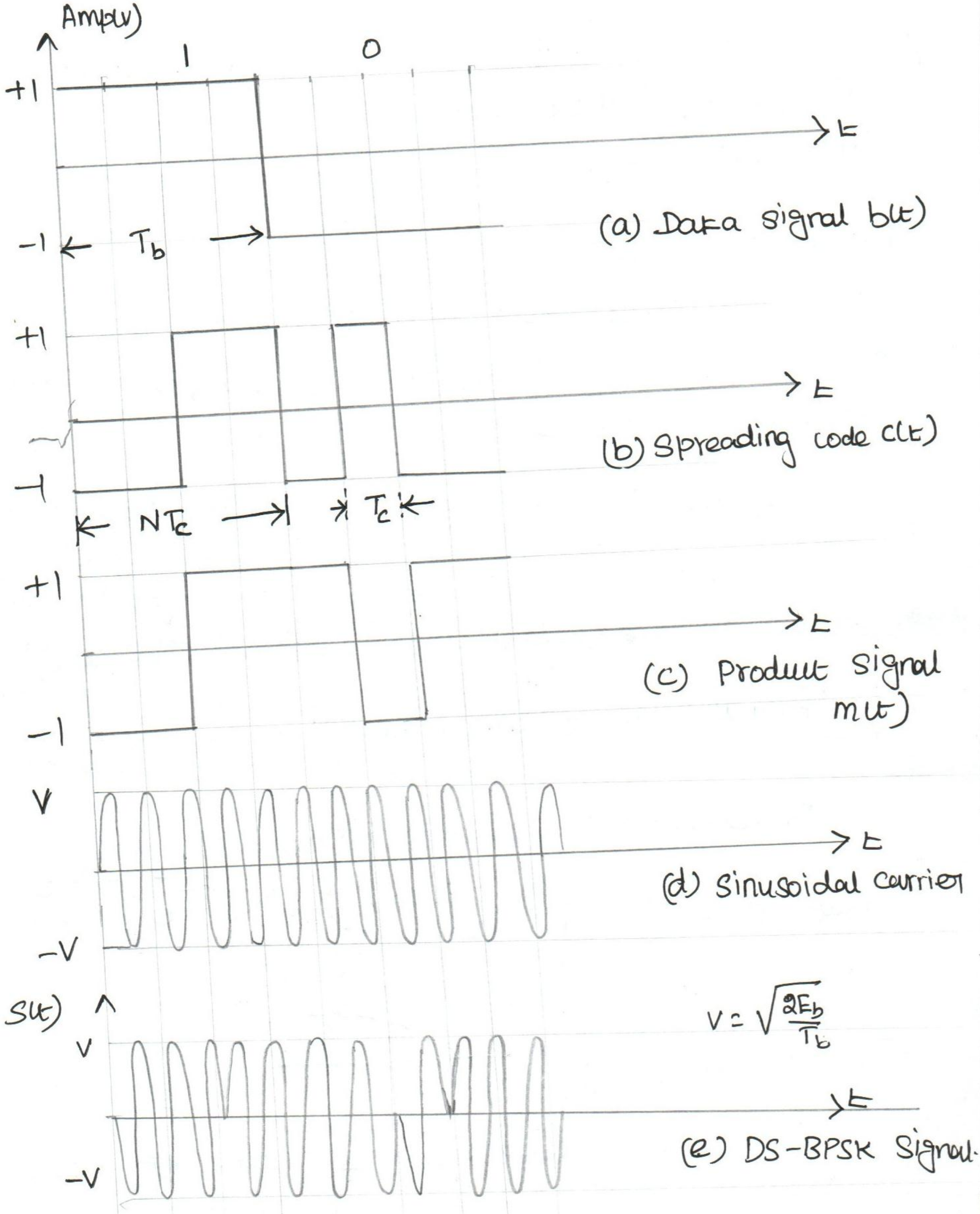


Fig: 6 Waveforms of Direct sequence Spread spectrum BPSK - ~~Transmitter~~.

1.3.1.3 PERFORMANCE MEASURE OF DS-SS SYSTEMS

(i) Processing Gain
(ii) Probability of Error
(iii) Anti jamming

Processing Gain:-

Defined as the ratio of the bandwidth of the spread spectrum signal to the bandwidth of the unspread signal.

$$\text{Processing gain (PG)} = \frac{\text{Bandwidth of spread spectrum signal}}{\text{Bandwidth of unspreaded signal.}}$$

$$\text{Bandwidth of unspread signal} = \frac{1}{T_b} \rightarrow (1)$$

$$\text{Bandwidth of spread signal} = \frac{1}{T_c} \rightarrow (2)$$

Sub (1) & (2) in

$$\boxed{PG = \frac{T_b}{T_c}}$$

Probability of Error:-

The error probability of coherent BPSK is

$$P_e = \frac{1}{2} \operatorname{erfc} \sqrt{\frac{E_b}{N_0}} \quad \text{--- (3)}$$

Where,

$E_b \rightarrow$ Energy per bit

$N_0/2 \rightarrow$ Power spectral density of white noise.

* In DS- BPSK the interference may be treated as a wide band noise with PSD of $\frac{JT_c}{2}$.

(i-e) $\frac{N_0}{2} = \frac{jT_c}{2}$

$$\boxed{N_0 = jT_c} \quad — (4)$$

J → Average interference power

T_c → chip duration.

Sub (4) in (3) ∴ $\boxed{P_e = \frac{1}{2}\,\text{erfc}\sqrt{\frac{E_b}{jT_c}}} \rightarrow (5)$.

(iii) Anti Jamming :-

The ratio of J/P is called as Jamming margin. which is defined as the ratio of average interference power 'J' and the signal power 'P'.

$$\boxed{\frac{J}{P} = \frac{PG}{(E_b/N_0)_{min}}} \quad — (6)$$

in decibels,

$$(\text{Jamming margin})_{dB} = (\text{Processing gain})_{dB} - 10\log_{10}\left(\frac{E_b}{N_0}\right)_{min}$$

where, PG → Processing Gain (T_b/T_c)

(E_b/N_0) → Minimum bit energy to noise density ratio needed to support average error probability.

1.3.2 FREQUENCY HOPPING SPREAD SPECTRUM (FH-SS) SIGNALS

Definition:-

"The type of spread spectrum in which the Modulated Data carrier hops randomly from one frequency to another."

* A common modulation format for FH systems is that of M-ary frequency-shift keying (MFSK).

* The spectrum of the transmitted signal is spread sequentially rather than instantaneously

* The FH/MFSK systems are classified into two categories.

1. Fast Frequency Hopping
2. Slow Frequency Hopping.

SLOW FREQUENCY HOPPING:-

In which the symbol rate 'R_s' of the MFSK signal is an integer multiple of the hop rate 'R_h'. That is, several symbols are transmitted on each frequency hop.

1.13.2.1 * FH/FMSK Transmitter:

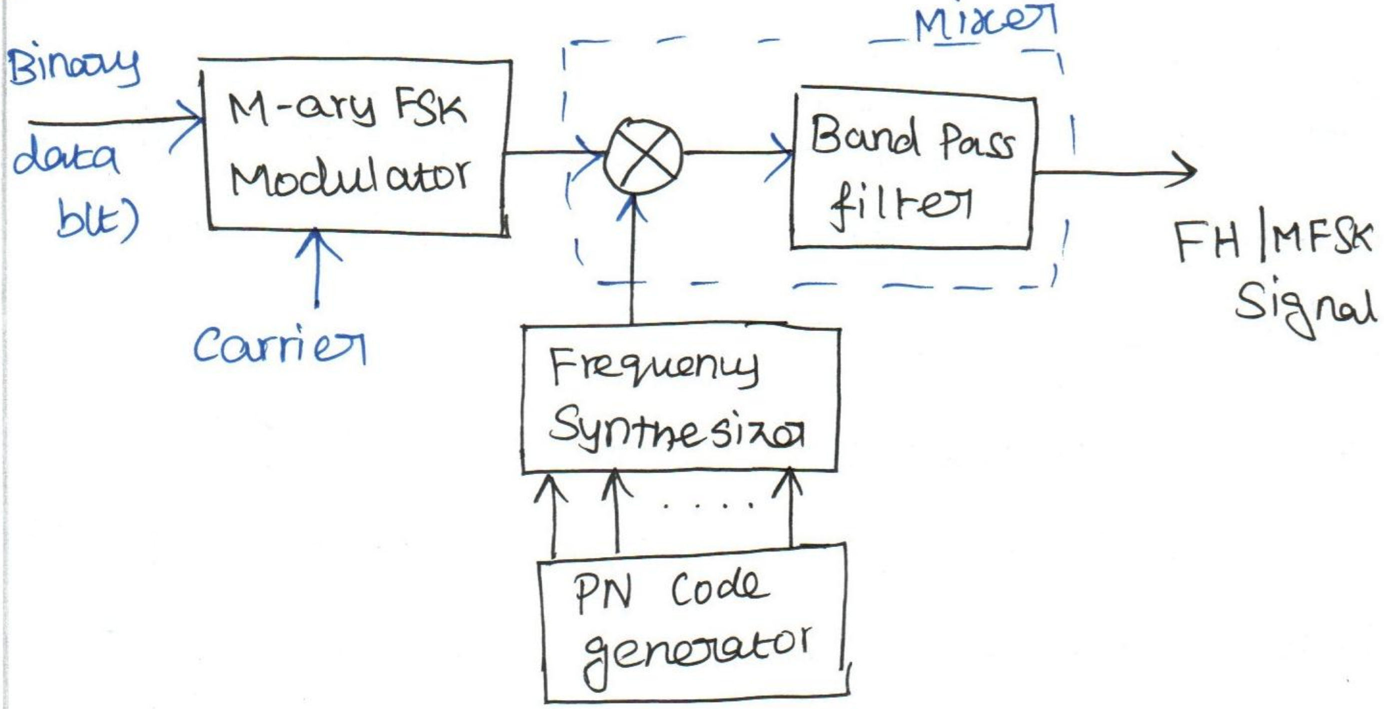


Fig:- 7 Frequency - hop spread M-ary frequency shift keying Transmitter.

* Binary data sequence b(t) is applied to M-ary FSK modulator the output of which goes to the input of the mixer.

* The mixer block receives another input from frequency synthesizer.

* The mixer consists multiplier and band pass filter; which is designed to select the sum frequency component rejecting all other components. This sum component of frequency is then transmitted.

* The successive K-bits of input binary data sequence will form one symbol.

'M' such symbols can be transmitted using the M-ary FSK system with $M = 2^K$.

* The M-ary FSK modulator will assign a different frequency for each of these 'M' symbols

* The synthesizer output at a given instant of time is the 'frequency hop'. Each frequency hop is mixed with MFSK signal to produce the transmitted signal.

* The output bits of the PN generator change randomly. Therefore the synthesizer output frequency will also change randomly. Hence frequency hops produced will vary in a random manner.

* If the number of successive bits at the output of PN generator is 'n', then the total number frequency hops will be 2^n.

* The total bandwidth of the FH/MFSK signal is equal to the sum of all the frequency hops.

(1.3.2.2) FH / MFSK Receiver:-

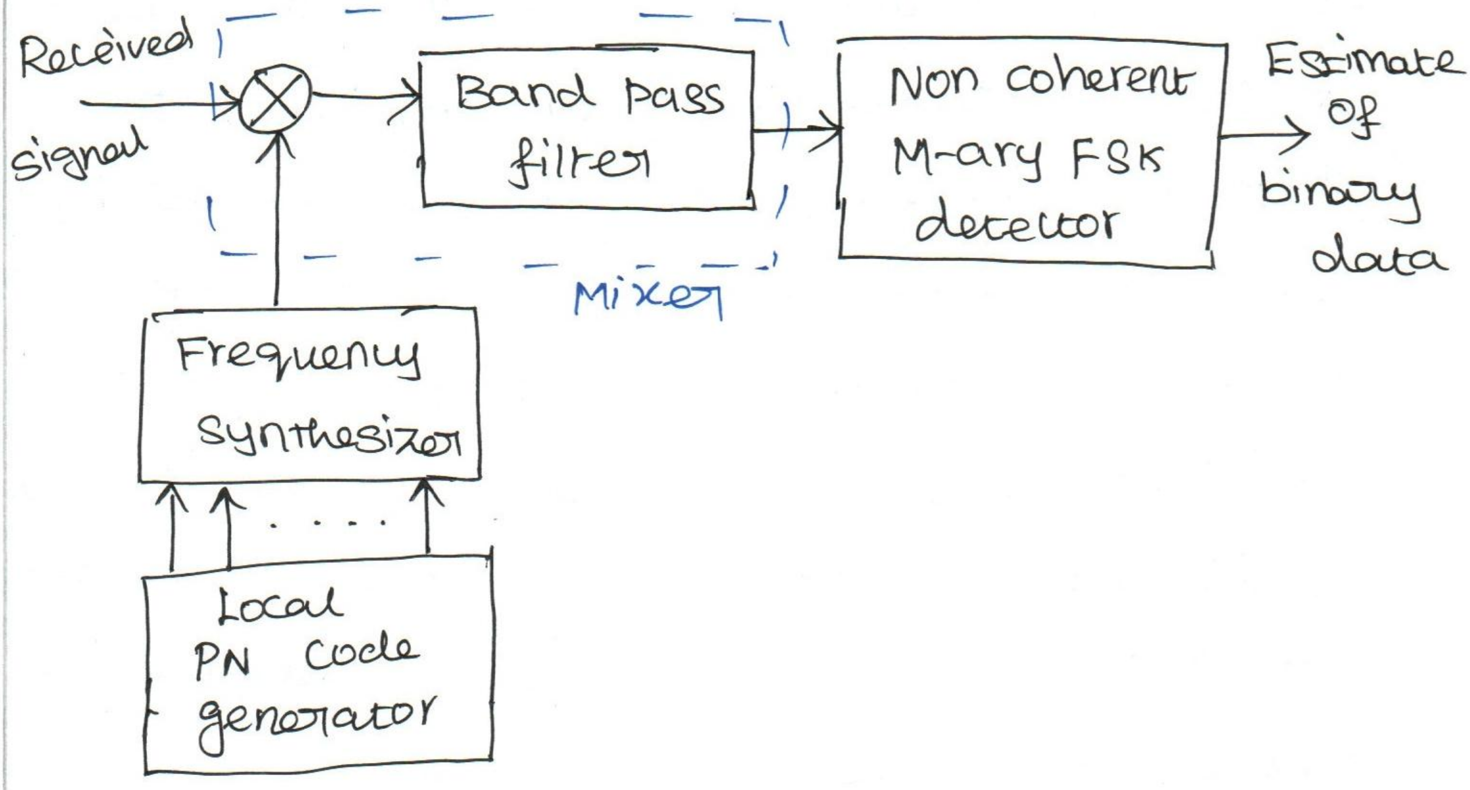


Fig: 8 Frequency - hop spread M-ary Frequency Shift Keying Receiver.

* The received signal is applied to a mixer. The other input to the mixer comes from a frequency synthesizer.

* The frequency synthesizer is driven by a PN code generator. It's also synchronized with the PN code generator at the transmitter and generates the same code sequence.

* So the frequency hops produced at the synthesizer output will be identical to those at the synthesizer output at the transmitter.

* At the output of the multiplier we get the input signals, their sum and difference.

* Out of these frequency components, the difference frequency component is selected by the band pass filter that follows the multiplier.

* This difference signal is the MFSK signal. The MFSK signal at the mixer output is then applied to a non-coherent MFSK demodulator.

* At the output of MFSK detector we obtain the digital modulating signal.

Chip Rate:- (R_c)

The individual tone (frequency) of shortest duration is referred to as a chip.

$$\text{Chip Rate } (R_c) = \max(R_h, R_s); \quad R_s \geq R_h$$

Where, $R_h \rightarrow$ Hop Rate

$R_s \rightarrow$ Symbol Rate.

Processing Gain:-

PG is given by

$$\boxed{PG = \frac{W_c}{R_s}}$$

$$PG = 2^k$$

$W_c \rightarrow$ Frequency Hopping Bandwidth

$k \rightarrow$ Length of PN segment to select freq Hop

R_s → symbol Rate.

FAST FREQUENCY HOPPING:-

* The hop rate 'R_h' is an integer multiple of the MFSK symbol rate 'R_s' so during the transmission of one symbol, the carrier frequency will hop several times.

Thus the frequency hopping takes place at a fast rate.

Each symbol transmission consists several frequency hops.

* Chip rate R_c = Rate of hopping R_h.

* Fast frequency hopping is used to defeat a smart jammer's tactic that involves two functions measurements of the spectral content of the transmitted signal and retuning of the interfering signal to that portion of the frequency band.

* To overcome the jammer, the transmitted signal must be hopped to a new carrier frequency before the jammer is able to complete the processing of these two functions.

* For data recovery at the receiver, two procedures may be considered.

1. For each FH/MFSK symbol, seperate decisions are made on the 'K' frequency-hop chips received, and a simple rule based on majority vote is used to make an estimate of the dehopped MFSK Symbol

2. For each FH/MFSK symbol, likelihood functions are computed as functions of the total signal received over 'K' chips, and the largest one is selected.

* The Second procedure will minimizes the probability of symbol error.

Advantages and Disadvantages of FH-SS system.

1. Very high Processing Gain than DS-SS system.
2. The Synchronization is not dependent on distance.

Disadvantages:-

1. It requires High Bandwidth.
2. It's need complex and expensive frequency synthesizers.

(2) MULTIPLE ACCESS TECHNIQUES FOR WIRELESS COMMUNICATION

(2.1) INTRODUCTION:

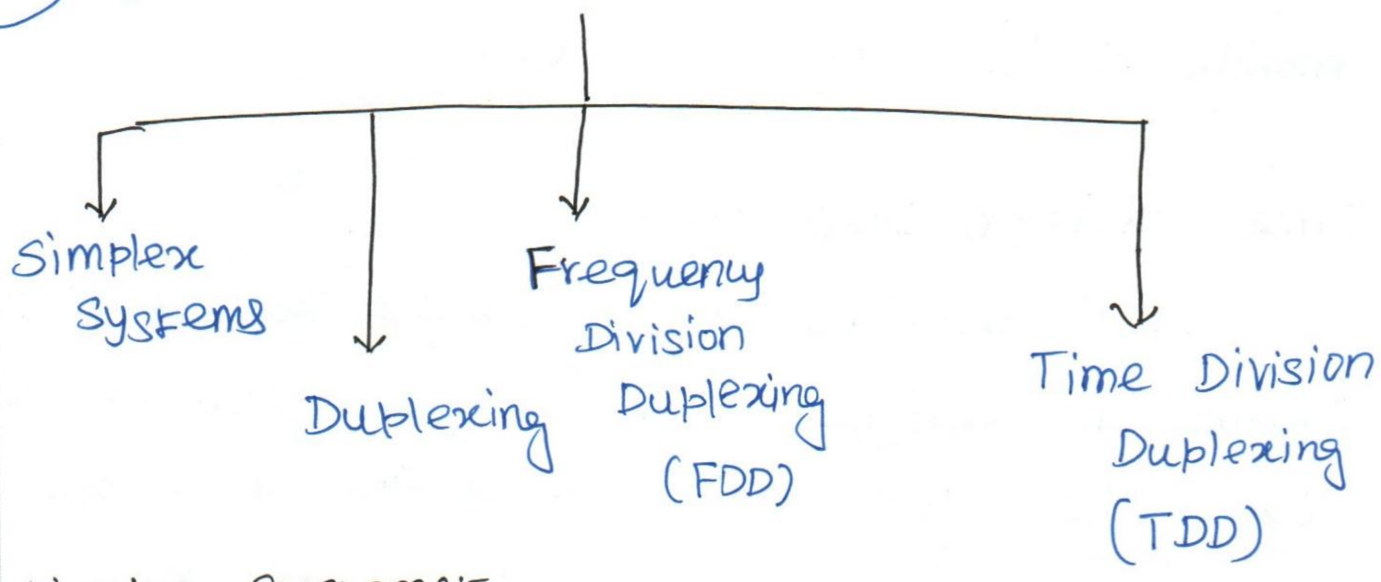
Definition:-

Multiple access is defined as two or more users simultaneously communicate with each other using the same channel.

* The multiple access methods are used in

1. Underwater acoustic networks
2. Military communication
3. Satellite networks
4. Cellular and mobile communication.

(2.1.1) Types of wireless communication systems.



Simplex Systems:-

A single transmitter sends information to multiple receivers Ex: TV broadcasting & Radio.

Duplexing:-

Defined as two way communication in which both terminals can transmit simultaneously.

Ex: wireless telephone systems.

Fig: (1) A two way communication channel.

Frequency Division Duplexing (FDD):-

FDD provides two different bands (Forward & reverse band) of frequencies for every user.

* Forward band transmit data from base station to the mobile.
* The Reverse band transmit data from the mobile to the base station.

Time Division Duplexing:-

Individual users are allowed to access the channel in assigned time slots and each duplex channel has both a forward and a reverse time slots for bidirectional communication.

(2.2) Multiple Access Schemes:-

* In the radio systems we have two types of resources, Frequency and time.

* Division by frequency, so that each pair of communications are allocated part of the spectrum for all of the time, results in Frequency Division Multiple Access.

* Division by time, so that each pair of communications are allocated all or large part of the spectrum for part of the time, results in Time Division multiple access (TDMA).

* In Code Division multiple Access (CDMA), every communicator will be allocated the entire spectrum all of the time. CDMA uses PNcodes to identify connections

Types:-

1. Time Division Multiple Access (TDMA)
2. Frequency Division Multiple Access (FDMA)
3. Code Division Multiple Access (CDMA)
4. Space Division Multiple Access (SDMA).

22.1 TIME DIVISION MULTIPLE ACCESS

Time division multiple access (TDMA) is a digital transmission technology that allows a number of users to access a single Radio-Frequency (RF) channel without interference by allocating unique time slots to each user within each channel.

22.1.1 Definition:-

TDMA systems divide the radio spectrum into time slots, and in each slot only one user is allowed to either transmit or receive.

22.1.2 Basic Block diagram of TDMA system.

* Each Input message signal is first restricted in bandwidth by a low pass filter to remove the frequencies that are non essential to an adequate signal representation.
* The LPF outputs are applied to commutator the function of commutator to take a narrow sample of each 'N' input messages at a rate of Ps that is slightly higher than '2W' & to sequentially interleave these 'N' samples inside the sampling interval 'T_s'.

* The multiplexed signal is applied to a pulse modulator in order to transmit the multiplexed signal in to a common channel in suitable form.
* At the receiver end of the system, the received signal is applied to a pulse demodulator that performs the reverse operation of pulse modulator.

* The output signal from pulse demodulator is passed over the LPF through decommutator which operates in synchronism with the commutator and finally the average signals are taken out.

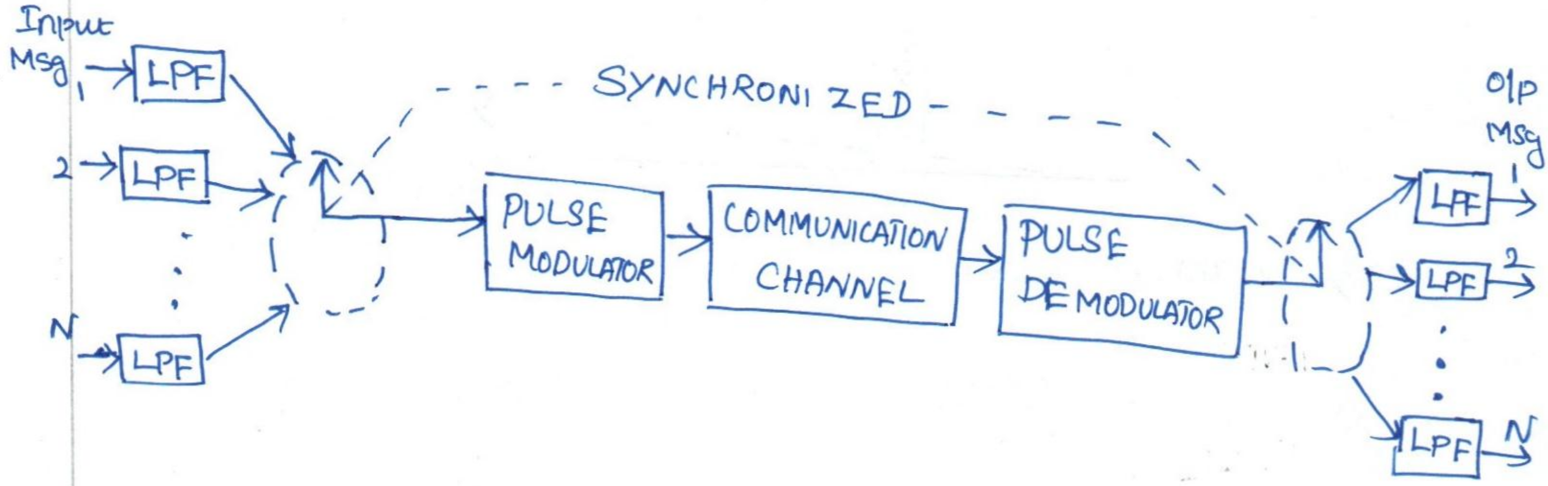


Fig: 2 Block diagram of TDMA system.

* Generally, the communication resources are shared by assigning each of M-signals or users the full spectral occupancy of the system for a short duration of time called a "time slot".

Frames:-

Time is segmented into intervals called Frames. Each frames are further partitioned into assignable user time slots.

Time Slots:-

Short duration of time is called time slots.

Guard time:-

The unused frame is Guard time, that acts as a buffer zones to reduce interference.

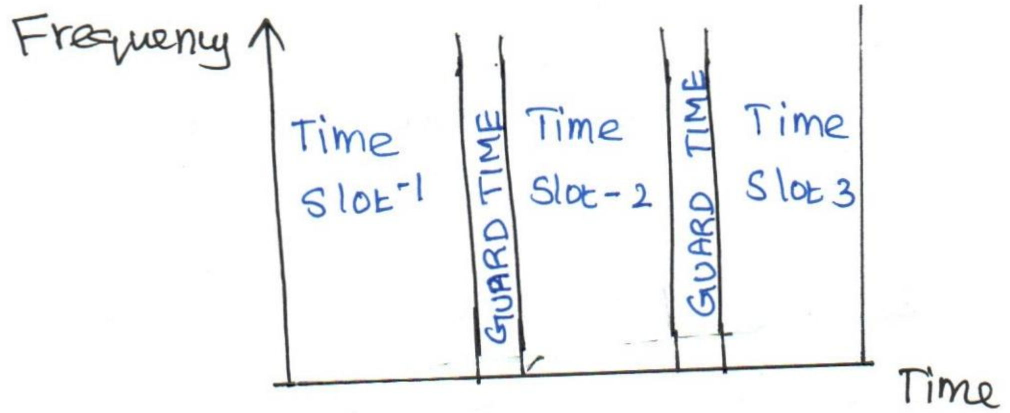


Fig: 3 Channalized Spectrum

* In a TDMA system, the channel time is partitioned into frames. Every user in service has an opportunity to transmit once per frame.

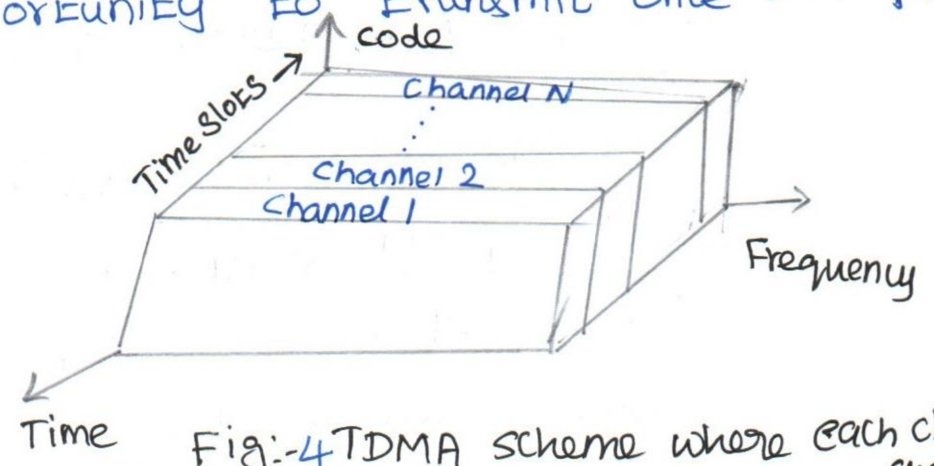


Fig:-4 TDMA scheme where each chanel occupies a cyclically repeating time slot

(2.2.1.3) TDMA Frame:

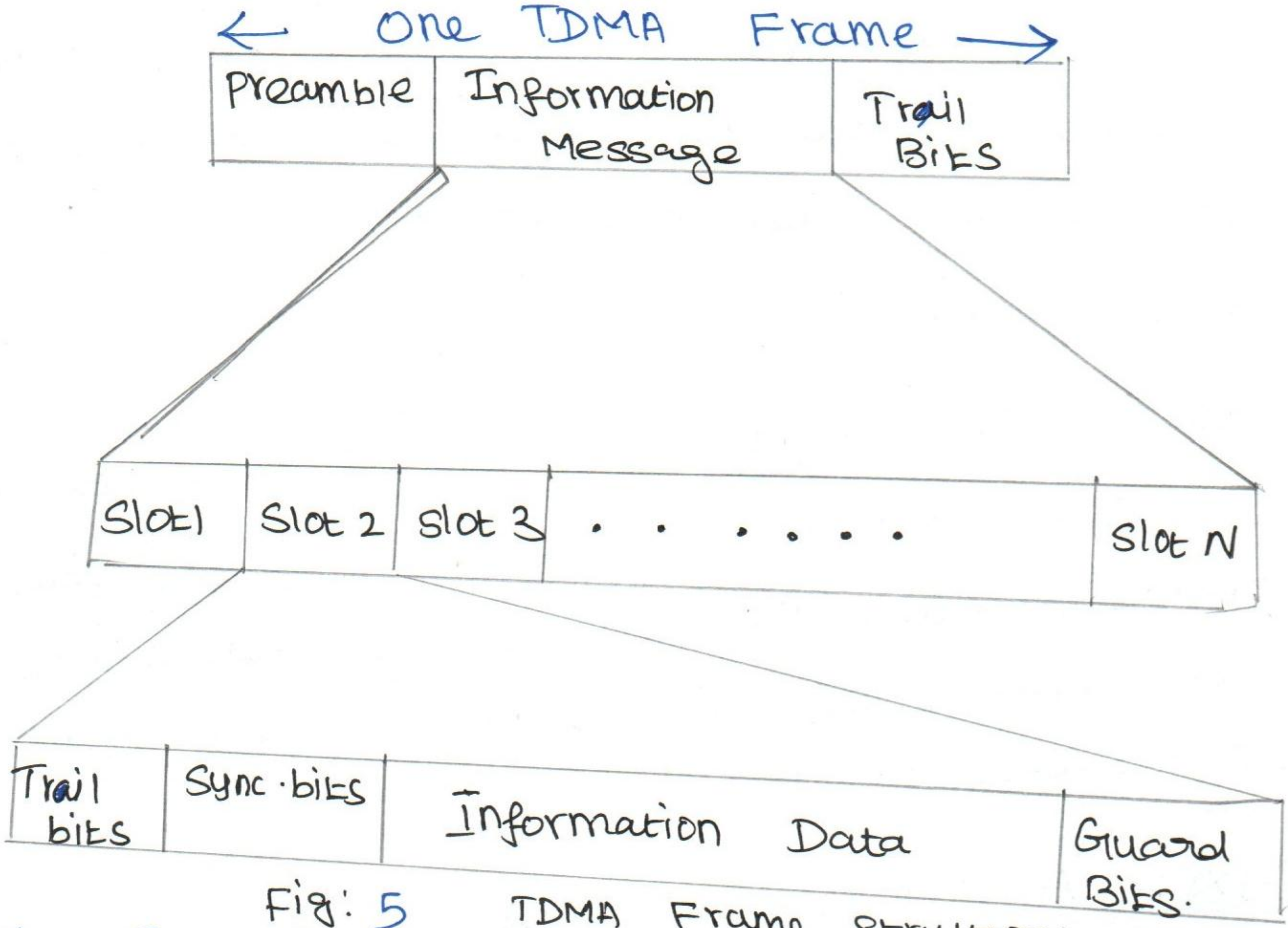


Fig: 5 TDMA Frame structure:

* Each frame consists Preamble, an information message and Tail bits.

* Preamble:-
 Used to carry address & synchronization information. that both the base station and subscribers use to identify each other.

(2.2.1.4) Types of TDMA:-

Depending on the slot assignment TDMA can be divided into two types

1. Fixed Assignment TDMA
2. Dynamic Assignment TDMA.

Fixed Assignment TDMA:- (or) Synchronous TDMA

If the assigned slot is fixed from frame to frame for the duration of the connection, the users have to synchronize to their respective assigned slots.

Dynamic Assignment TDMA (or) Asynchronous TDMA:-

A user is not assigned a fixed time slot for the duration of its connection. Transmission slots are dynamically assigned from frame to frame depends on the request.

1. FIXED ASSIGNMENT TDMA:-

* The simplest TDMA scheme, called fixed assignment TDMA, is so named because the M time slots that make up each frame are preassigned to signal sources, long term.

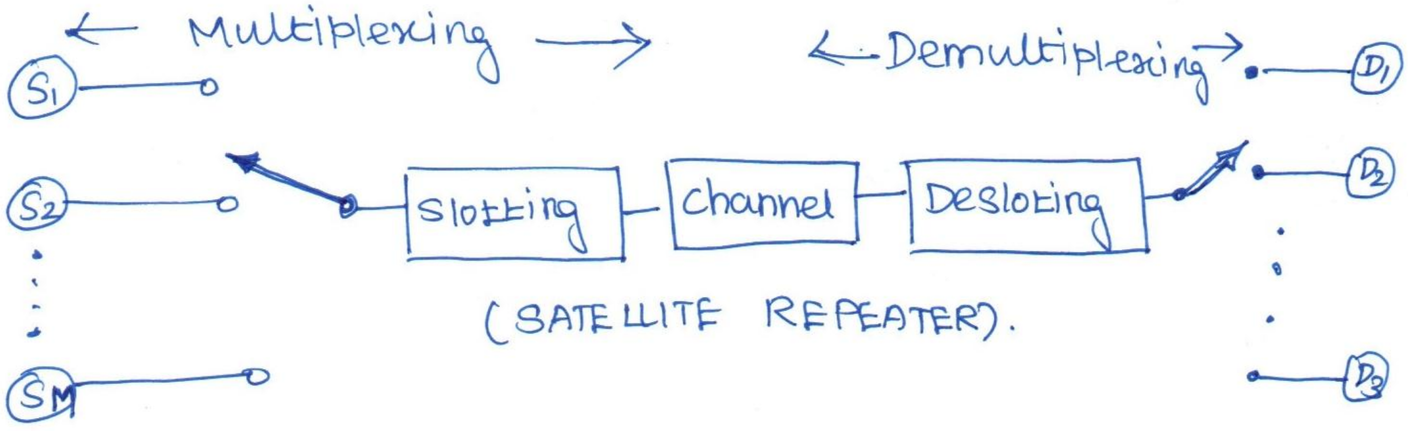


Fig: 6 Block diagram of Fixed Assignment TDMA

* The multiplexing operation consists of providing each source with an opportunity to occupy one or more slots.

* The demultiplexing operation consists of deslotting the information and delivering the data to the intended Destination.

* A fixed-assignment TDMA scheme is extremely efficient when the source requirements are predictable, and the traffic is heavy.

* Consider the simple example shown in below figure.

* There are four time slots per frame, each slot is preassigned to users P, Q, R, & S respectively.

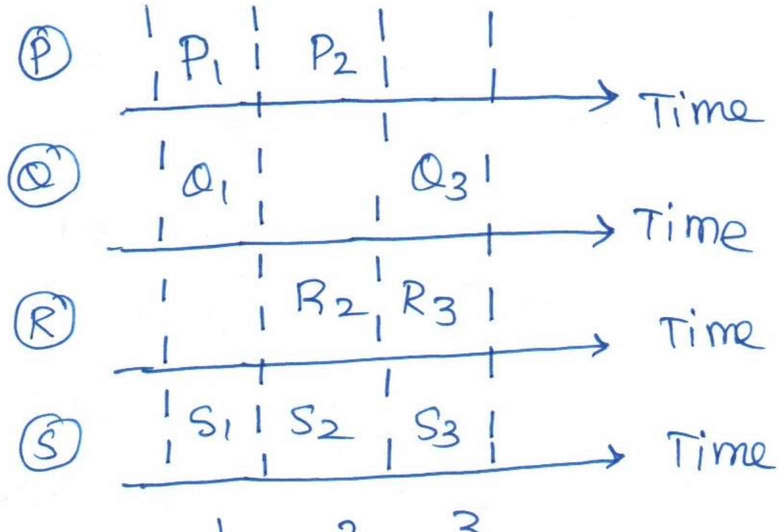


Fig: 7 Activity profile of four users.

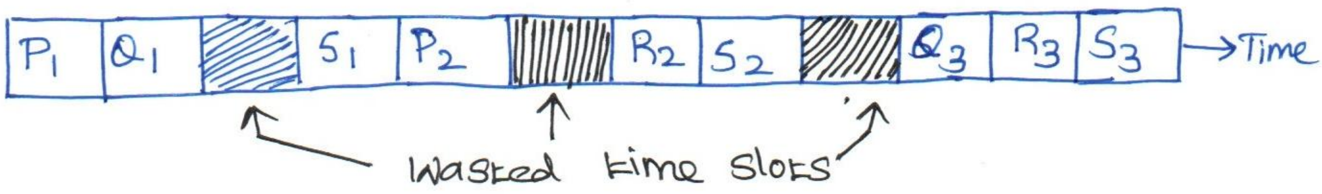


Fig: 8.1 Fixed Assignment TDMA Time Slots

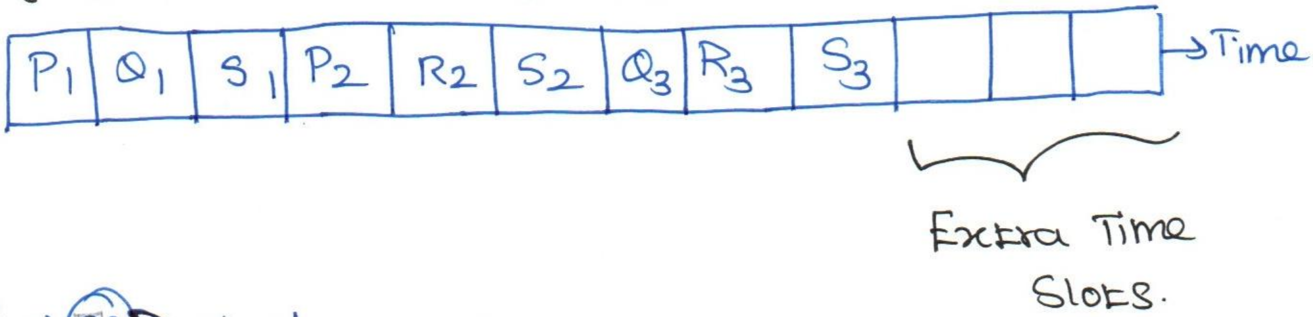


Fig: 8.2 Dynamic Assignment TDMA Time Slots.

* In the above example, during the first frame time, user 'R' has no data to transmit, during the second frame time user Q has none, and during third frame time, user P has none.

* In fixed assignment TDMA scheme all of the slots within a frame are pre assigned. If the 'owner' of a slot has no data to send during a particular frame, that slot is wasted.

* The data stream shown in Fig: 8.1 illustrates the wasted time slots in this example.

* When source requirements are unpredictable there can be more efficient schemes, involving the dynamic assignment of the slots rather than a fixed assignment. Such a schemes are called as Dynamic Assignment TDMA or Packet switching systems.

* The effect, shown in Fig: 8.2 is to use the slots in a frame in such a way that capacity is conserved.

* Operation mode of TDMA is classified into two types.

1. Wide band TDMA (W-TDMA)

In wideband TDMA, the entire frequency spectrum is available to any individual user.

2. Narrow band TDMA (N-TDMA)

The whole frequency band is divided into subbands,

BURST TRANSMISSION:-

* TDMA systems transmit data in a buffer-and-burst method, thus the transmission for any user is non-continuous.

* This type of data has low value of duty cycle. (i-e) the time for which data is being transmitted is much shorter than the silent time.

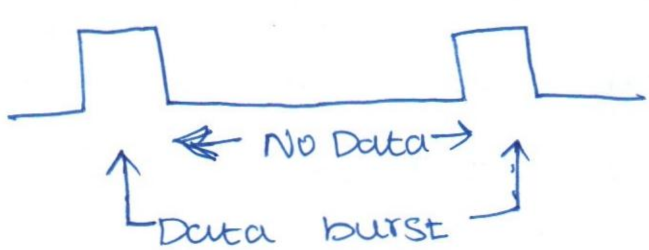


Fig: 9 Bursty Data signal with low duty cycle.

Efficiency of TDMA:-

The Frame efficiency η_f is the percentage of bits per frame which contain transmitted data.

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

Where,

$b_{OH} \rightarrow$ overhead bits per frame.

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

$N_r \rightarrow$ Number of reference bursts per frame.

$N_t \rightarrow$ Number of traffic bursts per frame.

$b_r \rightarrow$ Number of overhead bits per reference burst

$b_g \rightarrow$ Number of equivalent bits in each guard time interval.

$$\boxed{b_T = T_f R}$$

$b_T \rightarrow$ Total Number of bits per frame.

$T_f \rightarrow$ Frame Duration

$R \rightarrow$ channel bit rate.

Number of Channel:-

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

$B_C \rightarrow$ Channel B.W

$B_{tot} \rightarrow$ Total B.W

$B_{guard} \rightarrow$ Guard Band B.W

* $m \rightarrow$ TDMA users / each channel.

ADVANTAGES OF TDMA:-

* Data transmission for users of a TDMA system 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.

* TDMA uses different time slots for transmission & reception, thus duplexers are not required.

* It's possible to allocate different numbers of time slots per frame to different users.

* Power efficiency is better.

* TDMA shares a single carrier frequency with several users, where each user makes use of non- overlapping time slots.

Disadvantages:-

* The guard time should be minimized for higher efficiency.

* High synchronization over head is required in TDMA systems, because for each user has to identify the time slot and transmit & receive accordingly. * Requires very high Bandwidth.

2.2.2 FREQUENCY DIVISION MULTIPLEXING

Commonly used multiple access method is Frequency Division Multiple access (FDMA) for voice and data transmission.

2.2.2.1 Definition:-

The total bandwidth is divided into non- overlapping frequency subbands. Each user is allocated a unique frequency subband for the duration of the connection, whether the connection is in an active (or) idle state

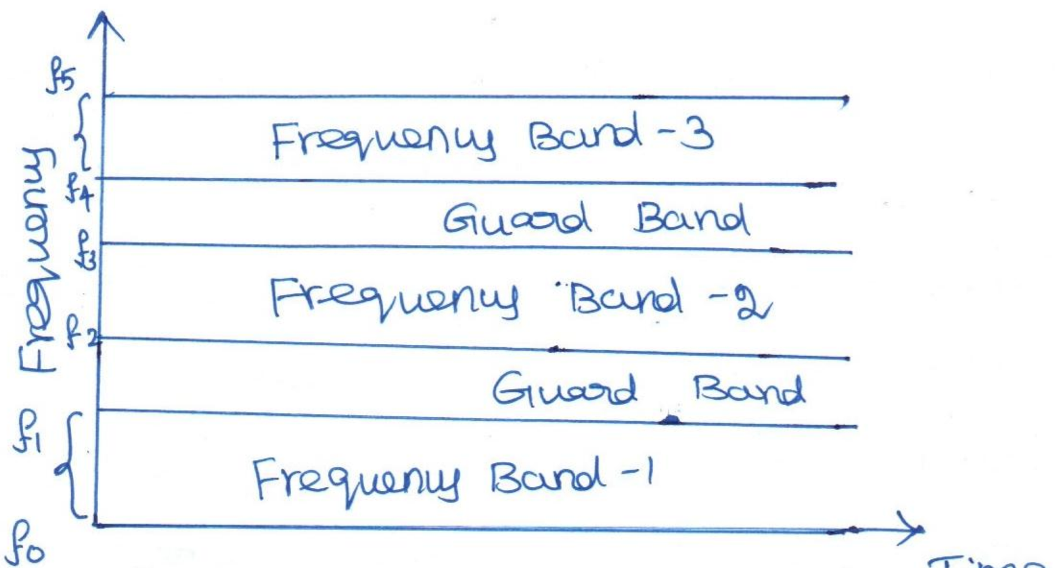


Fig: 10 Channalized Spectrum.

* The Channalized Spectrum shown above is an example of FDM (or) FDMA

* The frequency band-1 contains signals that can operate between frequencies f_0 & f_1.

The Second between frequencies f_2 & f_3.

Guard bands:-

* The Spectral regins between assignments called Guard bands. It acts as a buffer zones to reduce interference between adjacent frequency Channels.

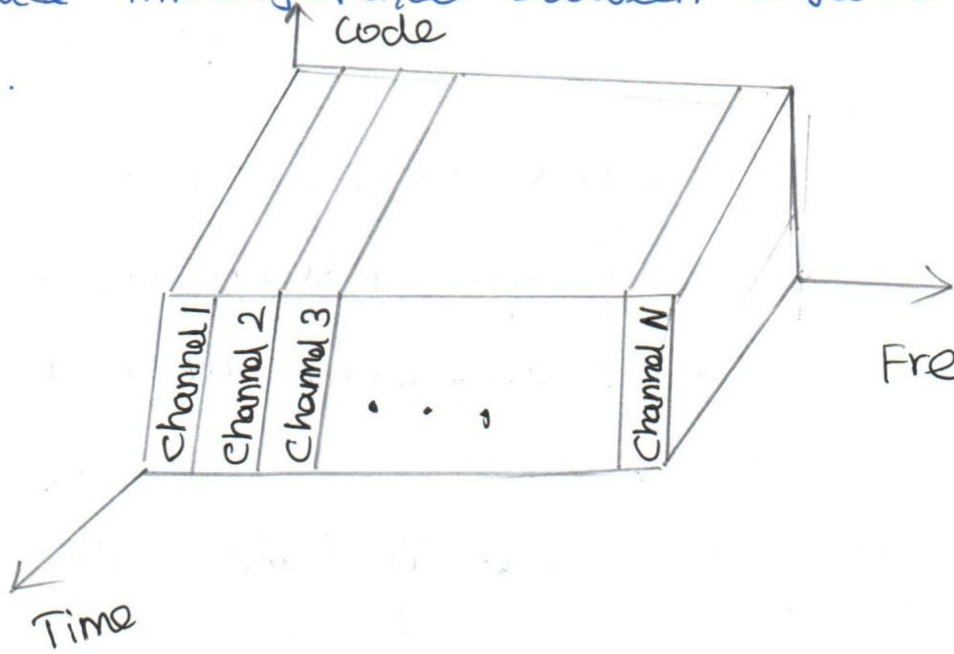


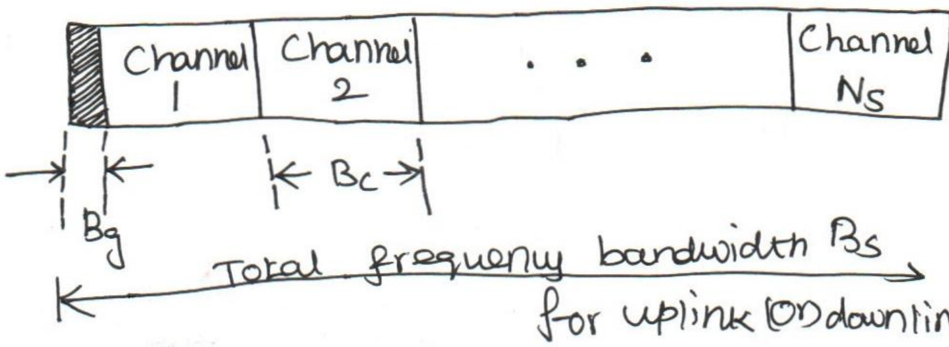
Fig: 11 FDMA where different Channels are assigned different frequency bands.

* These Channels are assigned on demand to users who request service.

* During the period of the call, no other user can share the same channel.

Number of channels:-

Fig: 12 Channel spacing & guard bands in FDMA uplink or Downlink.



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

$$N_S = \frac{B_S - 2B_g}{B_C}$$

Where, B_S → Total spectrum allocation (or) system bandwidth

B_g → Guard band allocated at the edge of the allocated spectrum band

B_C → Channel Bandwidth.

2.2.2.2 Basic operation of Frequency Division Multiplexing.

* A simple example with three translated voice channel is used to explain the basic operation of FDM.

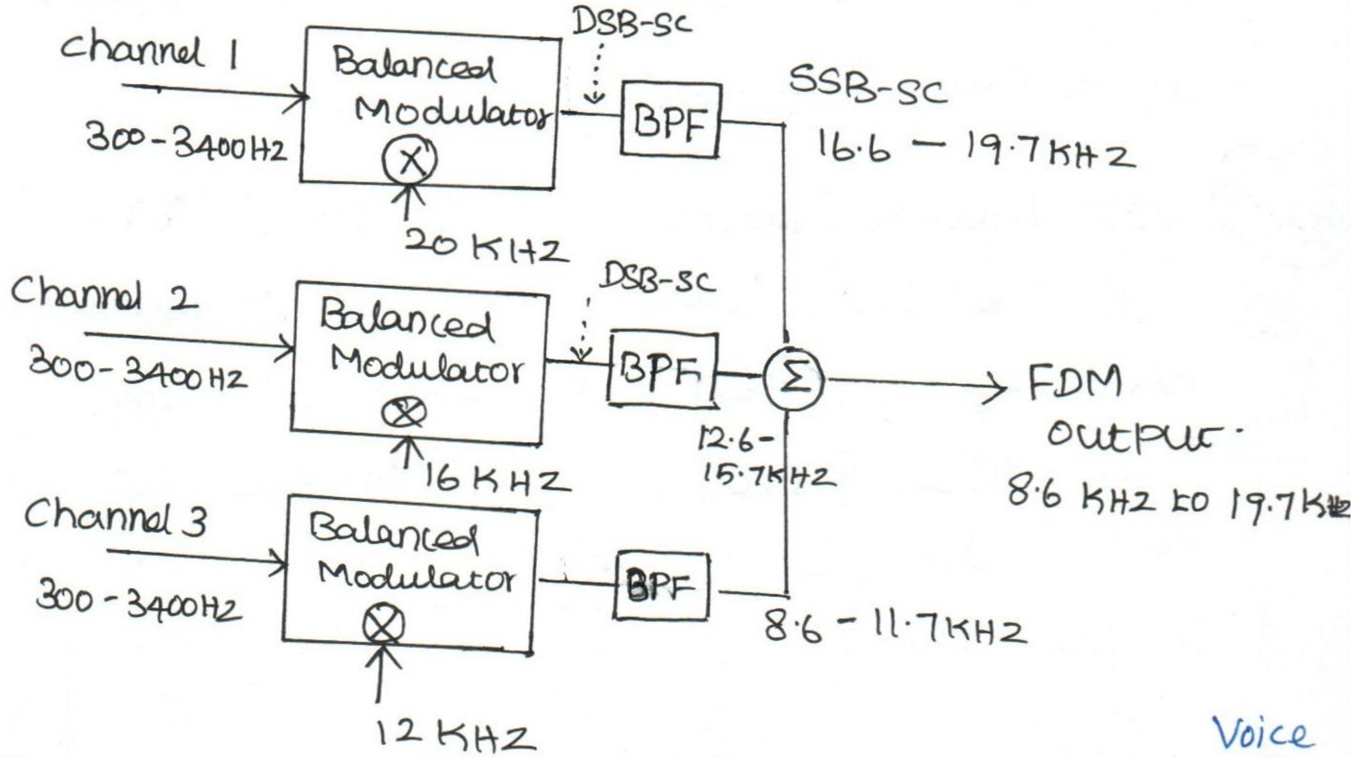


Fig:-13 Simple FDM example. Three frequency shifted Voice Channel

* A simple FDM example with three translated voice channel has shown above.

* In channel-1 the 300-3400 Hz voice signal is modulated with 20 KHz carrier at balanced modulator

* In channel-2 & 3, a similar type of voice signal is modulated with 16 KHz & 12 KHz carrier respectively.

* Only the lower sidebands are retained, the result of modulation and filtering (to remove the upper sidebands) yields the frequency shifted voice channels

* The output waveforms is just the sum of the three signals, having the total bandwidth in a range of 8.6 to 19.7 KHz.

2.2.2.3 Two lowest level of FDM Hierarchy:-

* The two lowest level of FDM multiplex hierarchy is used for telephone channels

* The first level consists of a group of 12 channels modulated on to subcarriers in the range of 60 to 108 KHz.

* The second level 2 is made up of 5 groups (60 CH) called a super group modulated on to the subcarriers in the range of 312 to 552 KHz.

* The multiplexed channels are now treated as a composite signal that can be transmitted over cables (or) can be further modulated on to a carrier for radio transmission.

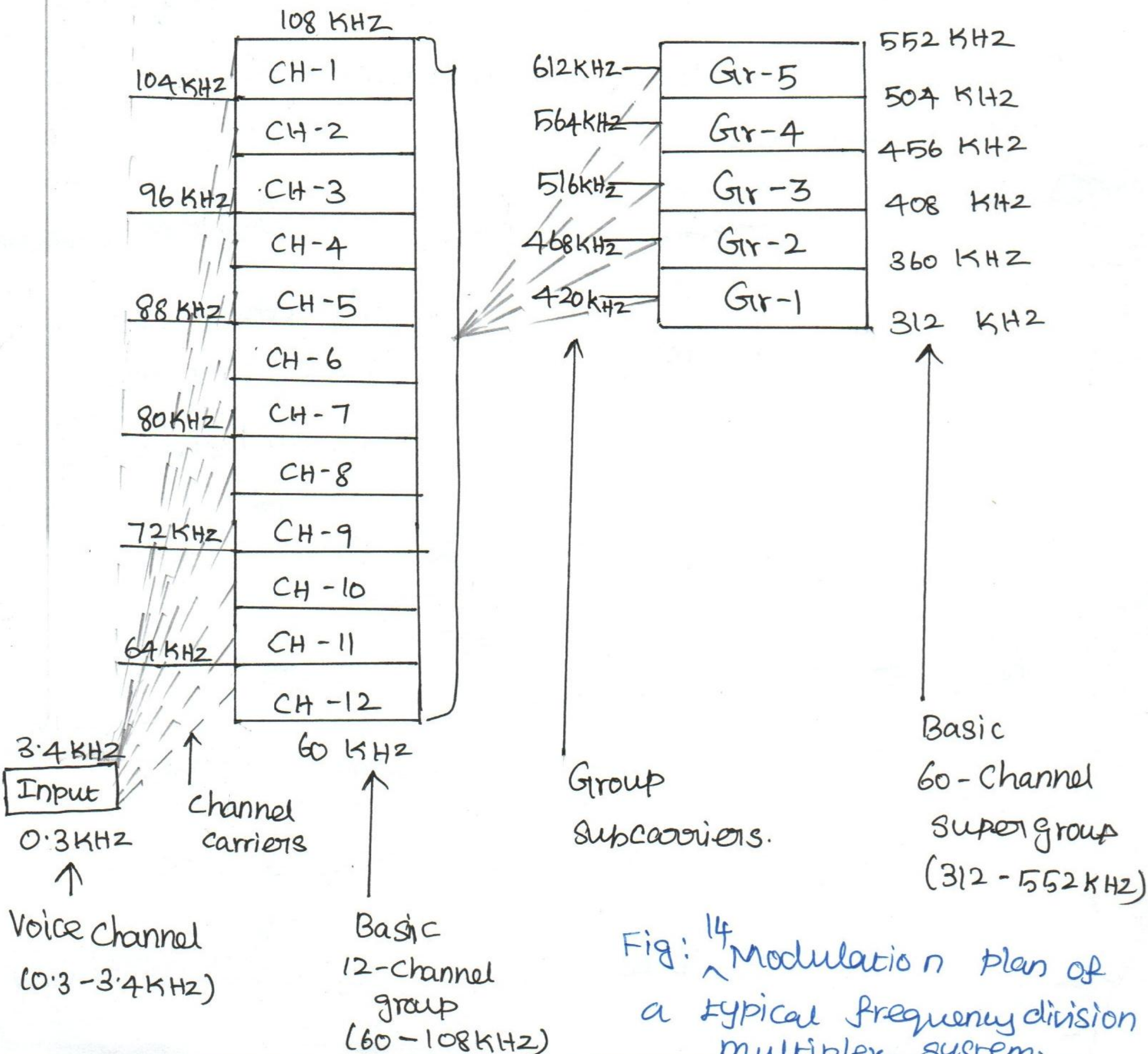


Fig: 14 Modulation plan of a typical frequency division multiplex system.

2.2.2.4 Non Linear Effects in FDMA:-

In a FDMA system, many channels share the same antenna at the base station.

The power amplifiers and power combiners, are non linear. The nonlinearities cause signal spreading in the frequency domain and generate intermodulation (IM) frequencies.

* To minimize the effects of intermodulation distortion, stringent RF filters are required to reject intermodulation distortion. RF filters are heavy, and costly.

2.2.2.5 Spectral Efficiency of FDMA:-

$$\eta_{FDMA} = \frac{\text{Bandwidth available for data transmission}}{\text{System bandwidth.}}$$

$$\eta_{FDMA} = \frac{N_{data} B_c}{B_s} < 1.$$

Number of data channels in the system } $N_{data} = N_S - N_{CH}$

where,

$N_{CH} \rightarrow$ Number of allocated control channels

$N_S \rightarrow$ Total number of available channel in the system.

Advantages of FDMA:-

* FDMA is a continuous transmission scheme, fewer bits are needed for overhead purposes as compared to TDMA.

* The complexity of FDMA mobile systems is lower when compared to TDMA systems.

* The symbol time of a narrowband signal is large as compared to the average delay spread. This implies that the amount of intersymbol interference is low and, thus little (or) no equalization is required in FDMA narrow band systems.

* The band widths of FDMA channels are relatively narrow (30KHz in AMPS) to each channel thus FDMA is usually implemented in narrow band systems.

* Absence of synchronization

* FDMA is relatively simple to implement.

* To provide interference - free transmissions between the uplink and the down link channels, the frequency allocations have to be separated by a sufficient amount. (guard bands)

Disadvantages of FDMA:-

* FDMA requires tight RF filtering to minimize adjacent channel interference.
* The FDMA mobile unit uses duplexers since both transmitter and receiver operate at the same time. This results in an increase in the cost of FDMA subscriber units & base stations.
* FDMA needs to use costly bandpass filters to eliminate spurious radiation at the base station.
* FDMA support narrow band systems and is not suitable for multimedia communications with various transmission rates.
* If an FDMA channel is not in use, then it's idle and cannot be used by other users to share capacity. It is essentially a wasted resource.

2.2.3 CODE DIVISION MULTPLE ACCESS (CDMA).

The communication resources being partitioned by the use of a hybrid combination of FDMA & TDMA known as code Division multiple access.

In CDMA, multiple access is achieved by assigning each user a different code. The code is used in transforming the narrow band user Signal into wide band signal.

* Coded wide band signals from others will be sent on the common communication Channel being shared.

2.2.3.1 Definition:-

"In code Division multiple Access (CDMA), every communicator will be allocated the entire spectrum all of the time. CDMA uses codes to identify connections".

* CDMA is a spread spectrum multiple access method.
* CDMA scheme is also said to be Spread spectrum Multiple Access (SSMA).

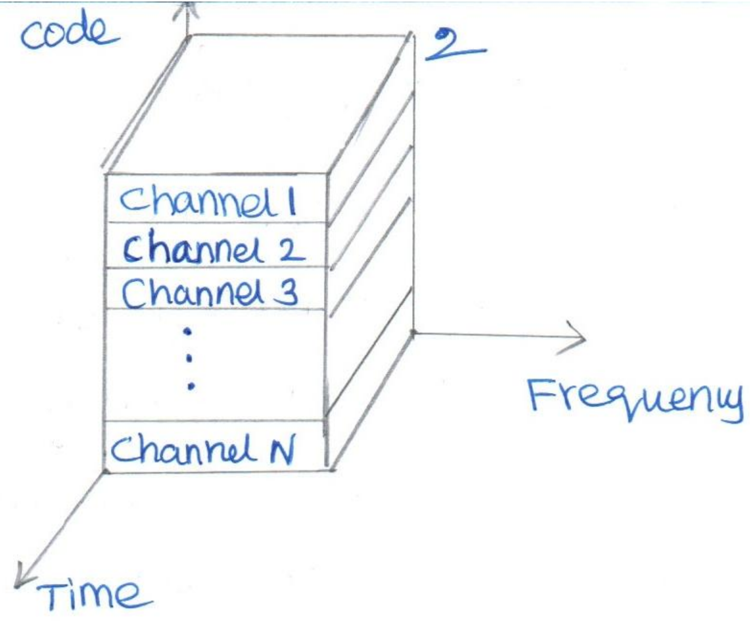


Fig: 15 CDMA Scheme.

* All users in a CDMA system use the same carrier frequency and may transmit simultaneously

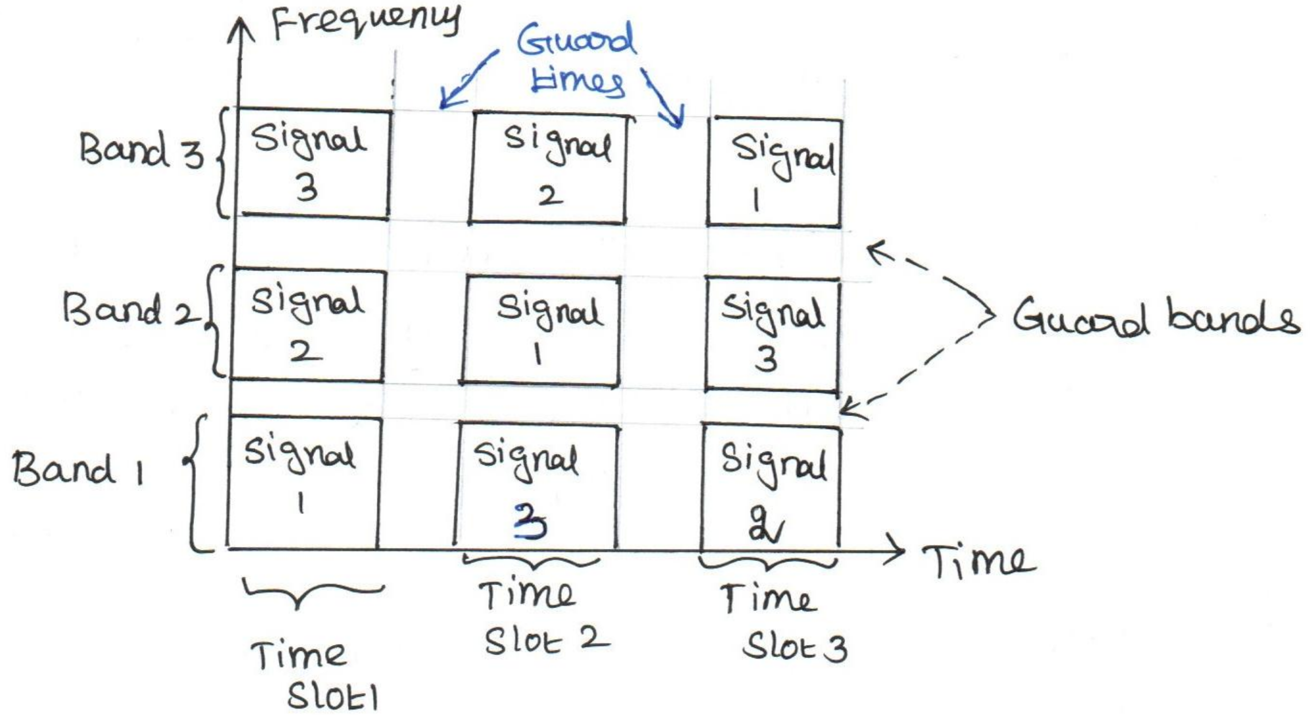


Fig:- 16 Structure of CDMA showing the guard bands and the guard times.

* At each successive time slot, whose duration is usually brief, the frequency band assignments are reordered.

* During slot-1, signal-1 occupies band 1, signal 2 occupies band-2 & the signal - occupies band '3'.

* During slot-2, signal 1 hops to band-2, signal 2 hops to band 3 & the signal 3 hops to band 1.

* The communication resources can thus be fully utilized but the participants, having their frequency bands re-assigned at each time slots.

* CDMA is an applications of spread spectrum (SS) techniques.

(2.12.3.2) Types of CDMA:-

1. Direct-sequence spread spectrum CDMA
2. Frequency-Hopping spread spectrum CDMA

1. Direct-Sequence spread spectrum CDMA:-

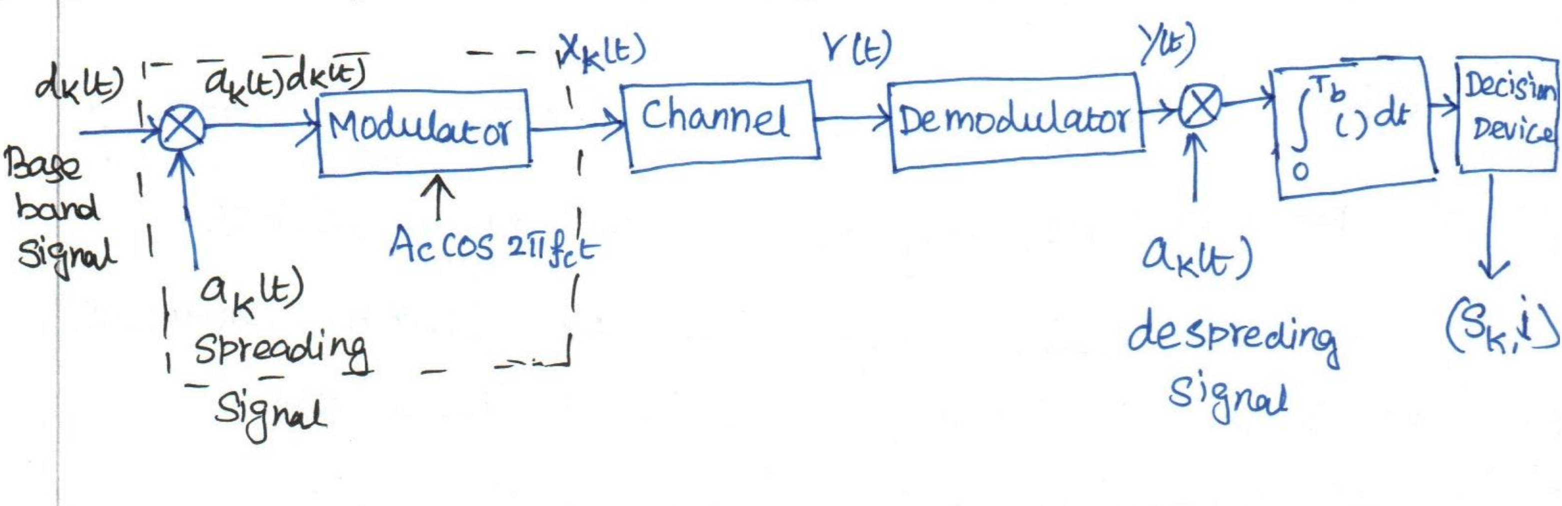


Fig: 17 Functional block diagram of DS-CDMA system.

* The base band signal $d_k(t)$ is modulated by a spreading code $a_k(t)$.

* The output of the multiplier $a_k(t) d_k(t)$ is data modulated signal. This data modulated signal is again modulated with High frequency carrier ($A_c \cos 2\pi f_c t$).

* The output of modulator $x_k(t)$ is transmitted to the receiver through communication channel.

* The received signal $r(t)$ is received by receiver and demodulated thus yields $y(t)$.

* The output of demodulator $y(t)$ is despread by the same code $a_k(t)$.

* Integrator integrates the resultant signal and pass it to the Decision device.

* Decision device make the decision about received symbol with respect to output of integrator

CDMA - Frequency Hopping Modulation Process/ Frequency Hopping spread spectrum CDMA.

* The main attraction of CDMA compared to TDMA is that, there is no need for synchronization among user groups.

*

* At frequency hop time the PN generator feeds a code sequence to a device called "Frequency Hopper".

* Assume that, the data modulation has an M-ary frequency shift keying (MFSK) format.

* The essential difference between a conventional MFSK system & Frequency Hopping (FH-MFSK) system is that in the conventional system, a data symbol modulates a carrier wave that is frequency fixed.

* But in hopping system, the data symbol modulates a carrier wave that hops across the total communication Resource bandwidth.

* At each frequency hop time, a PN generator feeds the frequency synthesizer (or) Hopper a freq word (i-e) PN code (a sequence of l - chips) which indicates one of 2^l symbol set positions.

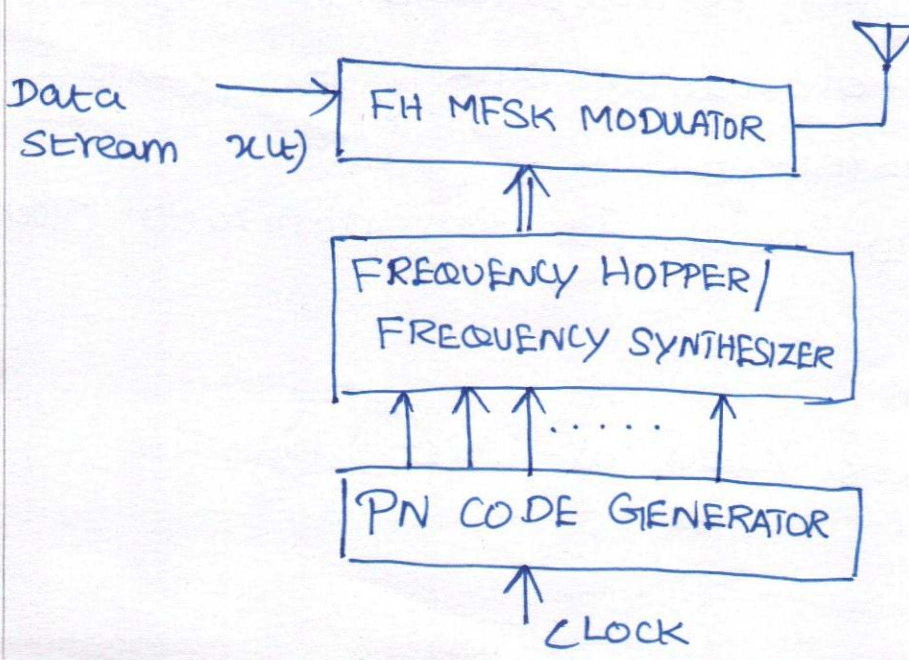


Fig: 18 FREQUENCY HOPPING CDMA MODULATOR.

* The frequency-hopping bandwidth 'W_s' & a minimum frequency spacing between concecutive hop positions Δ_f, decides the minimum number of chips necessary in the frequency word.

* For a given hop, the occupied transmission bandwidth is equal to the bandwidth of conventional MFSK.

CDMA offers some unique advantages:-

1. Privacy:

* The CDMA process provides communications privacy, since the transmissions cannot easily be intercepted by unauthorized users without the code.

2. Frequency Reuse:

Many users of CDMA system share the same frequency. Either TDD or FDD may be used.

3. Flexibility:-

* The most important advantage of CDMA compared to TDMA, is that there need be no precise time co-ordination among the various simultaneous transmitter.

* That is no need for synchronization among users.

4. Data Rate:-

Channel data rates are very high in CDMA systems.

5. Reduction in MultiPath Fading:-

* Multipath fading may be substantially reduced because the signal is spread over a larger spectrum.

6. Soft capacity:

* During peak traffic hours, if the users can tolerate a lower Quality of service to a certain degree, the system can accommodate more users to satisfy the high service demands in that period.

7. Soft Handoff:-

When the mobile user is at the cell boundary it can establish a connection with new base station before terminating the connection with the old base station. This will improve handoff performance.

Disadvantages:-

1. Near-Far Problem:

Some of the mobile units are close to the base station while others are far from it. A strong signal received at the base from a near-in mobile unit masks the weak signal from a far-end mobile unit. This Phenomenon is called the near-far problem.

2. Since the different PN codes used are not perfectly orthogonal, the signal components from other users also contribute in the demodulated signal

This may cause a problem in the decision circuit when the number of other users is high.

2.2.4 SPACE DIVISION MULTIPLE ACCESS.

In cellular communication systems, the Space Division Multiple Access (SDMA) controls the radiated energy for each user in space.

Definition:-

"Assigning space to each channel with a minimum of interference and a maximum of medium utilization".

2.2.4.1 Basic structure of an SDMA system:

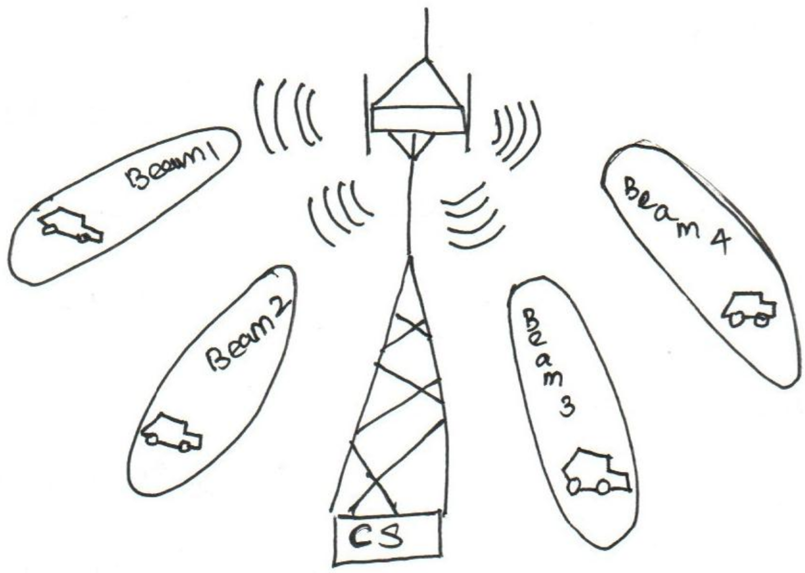


Fig: 19 Structure of an SDMA system.

* A simplified version of transmission using SDMA is shown above.
* The cell site (i-e Base Station) forms different antenna beams for each spatially separable subscriber on the forward and reverse channels.

* These spatially separable subscribers are covered by antenna beam may be served by the same frequency or different frequencies.

* Adaptive antennas will be used to simultaneously steer energy in the direction of many users at once.

* In the limiting case of infinitesimal beam width and infinitely fast tracking ability adaptive antennas implement optimal SDMA, thereby providing a unique channel that is free from the ~~the~~ interference of all other users in the cell.

* In SDMA all users with in the system would be able to communicate at the same time using the same channel.

* The perfect adaptive antenna system would be able to track individual multipath components for each user. and combine them in an optimal manner to collect all of the available signal energy from each user.

2.12.4.2 Features of SDMA:

* Reduction in the total transmitted power since all power would be transmitted in the desired direction only.

* Reduction in the amount of interference generated by each transmitter because total transmit power is reduced and localised.

* Receiving a stronger signal by the receiver due to directional antenna gain & less interference.

* It allows many subscribers to operate on the same frequency (or) time slot in the same cell.

* It can be applied with FDMA, TDMA (or) CDMA

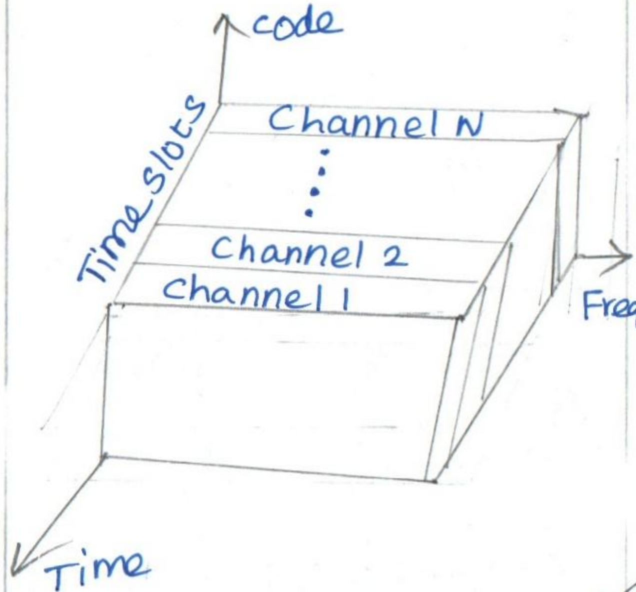
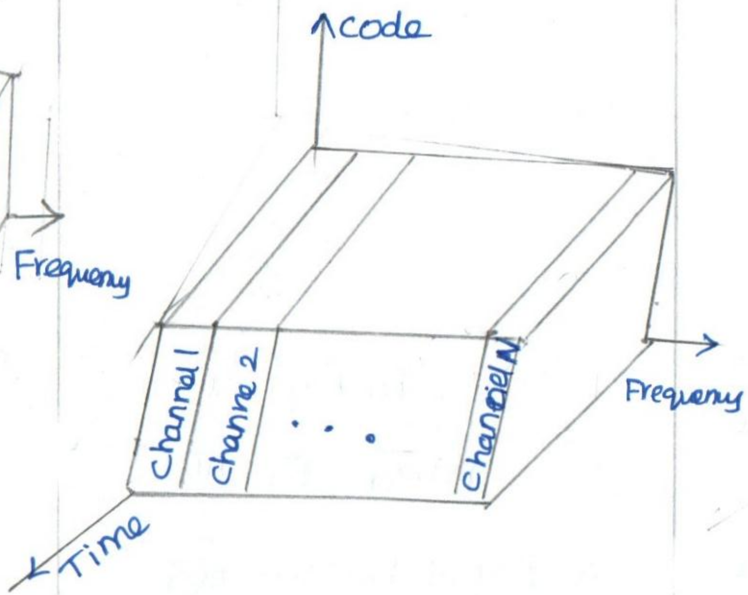
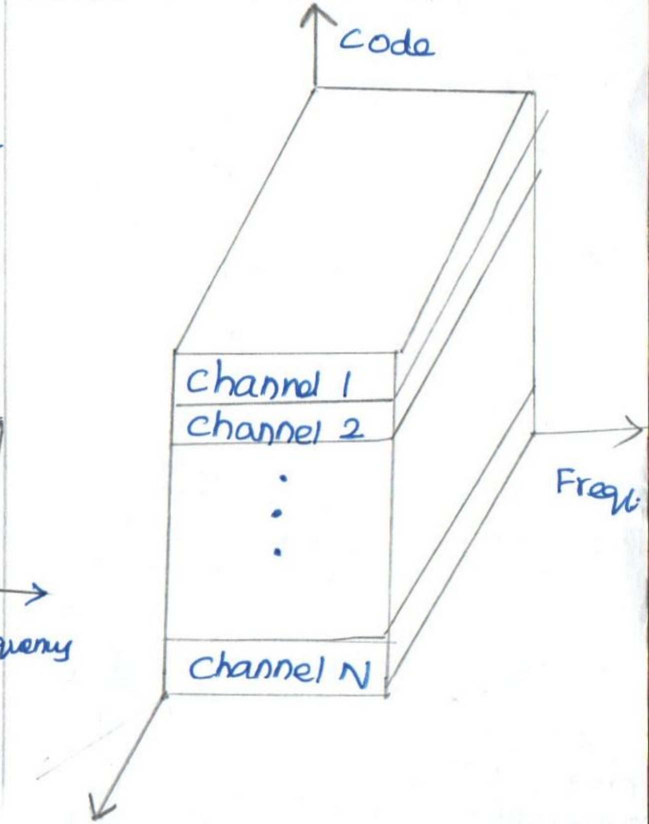
* It leads to more number of subscribers with in the same allocated frequency spectrum with enhanced user capacity.

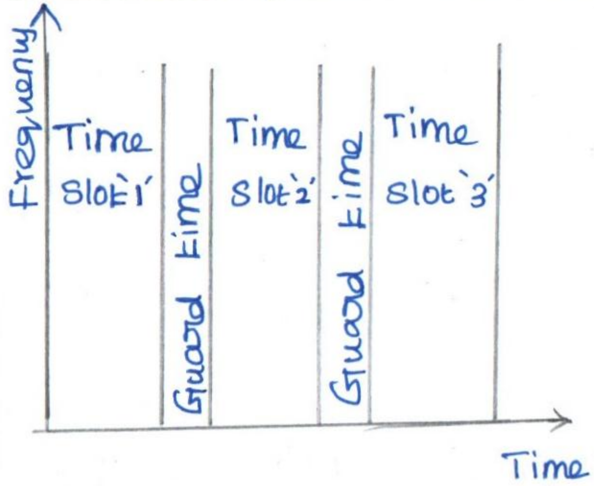
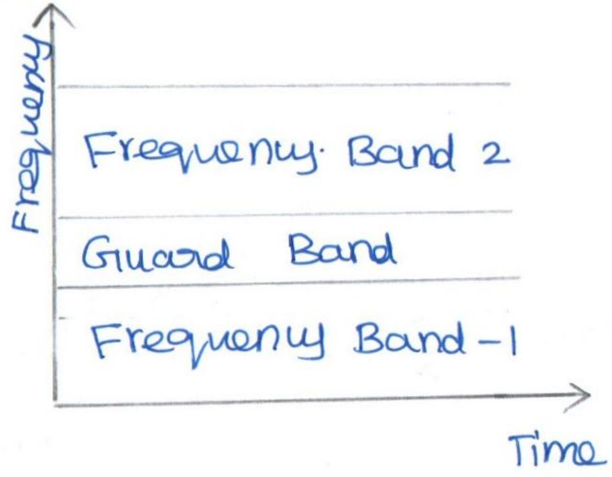
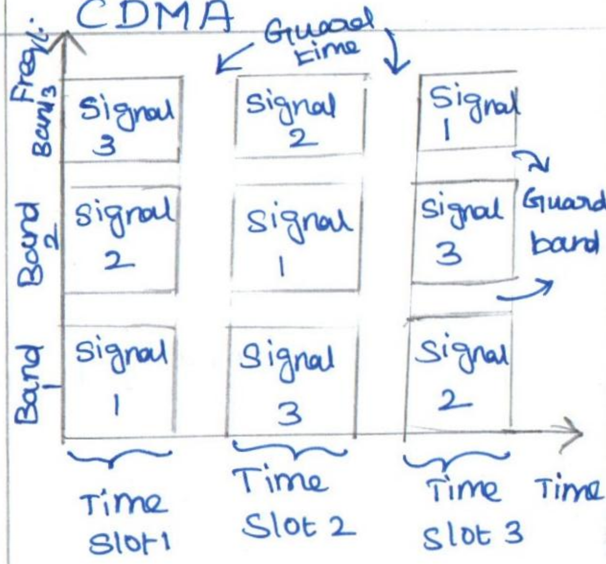
Disadvantages:-

* Separate space for each channel results in waste of space. like old analog telephone system.

* The perfect adaptive antenna system is not feasible since it requires infinitely large antennas.

2.2.5 COMPARISON OF TDMA, FDMA & CDMA

S.NO	Parameter	TDMA	FDMA	CDMA
1.	Definition:	TDMA systems divide the radio spectrum in to time slots, and in each slot only one user is allowed to either transmit or receive.	FDMA systems divide the radio spectrum in to Non-overlapping frequency subbands. Each user is allocated a unique frequency subband for the duration of the connection.	In CDMA system every communicator will be allocated the entire spectrum all of the time
2.	Scheme.			

S.NO	Parameter	TDMA	FDMA	CDMA
3.	Channalized Spectrum.			
4.	Types	1) Fixed Assignment TDMA 2) Dynamic Assignment TDMA	1. Two level of FDM hierarchy	1. Direct-sequence spread spectrum CDMA 2. Frequency hopping spread spectrum CDMA.
5.	Interference	Due to incorrect synchronization there can be an interference between the adjacent time slots.	Due to interference between adjacent channels intermodulation occurs.	Both types adjacent channel and adjacent time slot interferences will be present.
6.	High carrier Frequency Stability	Not necessary	Required	Not necessary.

S.No	Parameter	TDMA	FDMA	CDMA
7.	Near Far problem	NO	NO	yes
8.	Fading Mitigation	Equalizer May be needed	Equalizer not needed	RAKE Receiver possible.
9.	Synchronization	Required	Not Required	Required.
10.	Zone size	Any size	Any size	Large size difficult
11.	Applications	* Used in second generation mobile Ex: GSM, PCS, DAMPS * commonly used for data and digital voice signals	* Used in first generation cellular communication systems Ex: NMT, ETACS, AMPS * commonly used for the voice and data Transmission	* Used in ultry high frequency (UHF) cellular telephone systems in the 800 MHz & 1.9 GHz bands. * commly used for digital voice signals & Multimedia services.
12.	System Type	* Narrow band or wide band system	* Narrow band system	* Wide band system.

2.2.6 COMPARISON OF TDMA, FDMA, CDMA & SDMA

S.No	Parameter	TDMA	FDMA	CDMA	SDMA
1.	Principle	Allotted time slots for each user	Sub-bands are allotted for each user	codes are used for each user	Allotted seperate space for each user.
2.	Transmission Scheme	Discontinuous	continuous	continuous.	continuous
3.	Terminals	All terminals are active for short periods of time on the same frequency	Every terminal has it's own frequency uninterrupted	All terminals can be active at the same place at the same moment uninterrupted	only one terminal can be active in one cell / one sector.
4.	Cell capacity	Limited	Limited	No absolute limit on channel capacity but it is an interference limited system	Depends on cell area.

S.NO	Parameter	TDMA	FDMA	CDMA	SDMA
5.	Signal Separation	Synchronization in the time domain	Filtering in the frequency domain	Code plus special receivers are used.	cell structure has directional antennas.
6.	Advantages	Fully digital Very flexible.	Narrow band	Flexible, less planning needed, soft handover.	Very simple increases capacity per Km^2.
7.	Disadvantages	Guard time needed.	Inflexible, frequencies are a scarce resource	complex receivers needs more complicated power control for sending.	inflexible, antennas fixed.
8.	Comment.	Standard in fixed networks, together with FDMA / SDMA used in many mobile networks	Typically combined with TDMA & SDMA	Used in 3G systemes, integrated with TDMA / FDMA	only in combination with TDMA, FDMA or CDMA is useful.

Ploblems:-

Example:-1 If a normal GSM time slot consists of six trailling bits, 8.25 guard bits 26 training bits and two traffic bursts of 58 bits of data, find the frame efficieny.

Solution:

Time slot :

Trail bits	Training bits	Traffic burstsbits	Guard bits

Given,

Trailing bits = 6

Guard bits = 8.25

Training bits = 26

Traffic bursts bits = 2×58

Total bits per time slots = $6 + 26 + 2 \times 58 + 8.25$

= 156.25 bits.

A frame has 8 times slots = $8 \times 156.25 = 1250$ bits

∴ Total Number of bits per frame, b_T = 1250 bits/frame

* The number of overhead frame is given by

b_{OH} = Number of time slots x [Trailing bits + Guard bits + Training bits]

$= 8 \times [6 + 8.25 + 26]$

$b_{OH} = 322$ bits

∴ Frame Efficieny η_f is

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

$$= \left(1 - \frac{322}{1250}\right) \times 100$$

$$\eta_f = 74.25\%$$

Example:-2 In the AMPS system, the system bandwidth is 12.5 MHz, the channel spacing is 30 KHz and edge guard spacing is 10 KHz. The number of channel allocated for control signaling is 21 Find

(i) The number of channels available for message transmission

(ii) Spectral efficiency of FDMA.

Solution

(i) No; of available channels is

$$N_S = \frac{B_S - 2B_g}{B_c}$$

$$= \frac{12.5 \times 10^6 - 2 \times 10^3}{30 \times 10^3}$$

$N_S = 416$ channels

(ii) spectral efficieny η_f.

$$\eta = \frac{N_{data} B_c}{B_S}$$

$N_{data} = N_S - N_{ctl}$

$N_{data} = 416 - 21$

$N_{data} = 395$

$$\eta = \frac{395 \times 30}{12.5 \times 1000}$$

$\eta = 0.948$

$\eta = 94.8\%$