UNIT 5

SPREAD SPECTRUM AND MULTIPLE ACCESS

## INTRODUCTION

- Conventional wireless communication consist of a transmitter, transmitting information at a frequency which remains constant with time, as constant as technology permits, thus the bandwidth is kept within certain limits
- With conditions such as these it leaves the transmitted signal very susceptible to interception and interference. In order to circumvent such disastrous outcomes that could arise from such vulnerabilities, the theory of spread spectrum was introduced.
- Spread spectrum involves the deliberate variations in frequency of the transmitted signal over a comparatively large segment of the electromagnetic spectrum. This variation is done in accordance with a specific, complicated mathematical function. This frequency-versus-time function must be ‘known’ by both sender and receiver to ensure synchronization.
- Spread Spectrum uses wide band, noise-like signals. Because Spread Spectrum signals are noise-like, they are hard to detect. Spread Spectrum signals are also hard to Intercept or demodulate.
- Further, Spread Spectrum signals are harder to jam (interfere with) than narrowband signal because Spread Spectrum signals are so wide, they transmit at a much lower spectral power density, measured in Watts per Hertz, than narrowband transmitters
- For a signal transmitted in such a manner to be incepted, a receiver must be tuned to frequencies that vary precisely according to this frequency-versus-time function, and must also have knowledge of the starting point at which the function begins.
- It is imperative for the spread spectrum function be kept very confidential and out of the hands of unauthorized persons

## SPREAD SPECTRUM TECHNOLOGIES

There are two main types of spread spectrum techniques that are employed. These are Direct Sequence Spread Spectrum (DSSS) and Frequency Hopping Spread Spectrum (FHSS).

### Direct Sequence Spread Spectrum

- Direct Sequence Spread Spectrum also known as Direct Sequence Code Division Multiple Access (DS-CDMA) entails the division of the stream of information into small pieces, each of which is allocated to a frequency channel across the spectrum
- A data signal at the point of transmission is combined with a higher data-rate bit sequence, also known as the 'chipping code', which divides the data according to a spreading ratio. The redundant chipping code helps the signal resist interference and enables the original data to be recovered if data bits are damaged during transmission.
- For a more practical example of the techniques employed by DSSS, consider a direct sequence spread spectrum radio. A DSSS radio works by mixing a Pseudorandom Noise (PN) sequence with the data. This mixing is done either by generating a wideband signal which, in turn, is used to modulate the Radio Frequency (RF) carrier, or by modulating the carrier source with the data and then spreading the signal prior to transmission. On the receiving end, the incoming Direct Sequence (DS) signal is reconstructed by generating local replica of the transmitter's PN code, and synchronizing the signal with this local PN sequence.
- By removing the effects of the spreading sequence through the second time modulation of the incoming signal by the local PN sequence, the spread signal collapses into a data-modulated carrier. Using correlation techniques the identity of a signal that has been spread with a particular PN sequence can be discovered.

### Frequency Hopping Spread Spectrum

- Frequency Hopping Spread Spectrum (FHSS) also known as Frequency Hopping Code Division Multiple Access (FH-CDMA) involves a signal being transmitted across a frequency band that is much wider than the minimum bandwidth required by the information signal
- The transmitter 'spreads' the signal originally in the narrowband, across a number of frequency band channels on a wider electromagnetic spectrum.

- In a FHSS system, a transmitter ‘hops’ between available frequencies according to a spreading algorithm. The transmitter operates in synchronization with the receiver, which remains tuned to the same center frequency as the transmitter.

- The transmitter is therefore capable of hopping its frequency over a given bandwidth several times a second, transmitting on one frequency for a certain period of time known as the ‘dwell time’, then hopping to another frequency in the same spreading bandwidth and transmitting again.

- Ideally each frequency should be occupied with equal probability and the probability of hopping from one channel to any other channel should also be equal.

## CLASSIFICATION OF DIRECT SEQUENCE SPREAD SPECTRUM SYSTEMS

- In DSSS, the data signal is directly spread by means of a wide spread code sequence. The main idea is to spread the spectrum of the modulated (modulation that can be baseband or digital) data signal a second time by the use of a wideband spreading signal.
- The wideband spreading signal is selected in such a way as to make demodulation possible only by the intended receiver and to make demodulation by an unintended receiver impossible.
- Direct sequence contrasts with the other spread spectrum process, in which a broad slice of the bandwidth spectrum is divided into many possible broadcast frequencies.
- In general, frequency-hopping devices use less power and are cheaper, but the performance of DS-CDMA systems is usually better and more reliable.

- DSSS systems can be classified into:
  - Baseband DSSS
  - Modulated DSSS

- The baseband DSSS system applies the direct sequence spread spectrum technique directly to the baseband digital data

- Similarly, the modulated DSSS applies the spread spectrum technique to the data that is already modulated by some digital modulation technique. Different types of modulation are used before the DSSS technique is applied. Most common are BPSK and QPSK modulation.

### BASEBAND DSSS SYSTEM

The baseband direct sequence spread spectrum system spreads the baseband digital signal using the wide-bandwidth spreading-code signal. The spreading is done to the baseband signal directly without any digital modulation. The technique and hence the system is called as baseband DSSS. The block diagram of a baseband DSSS system is shown in Figure 2.1.

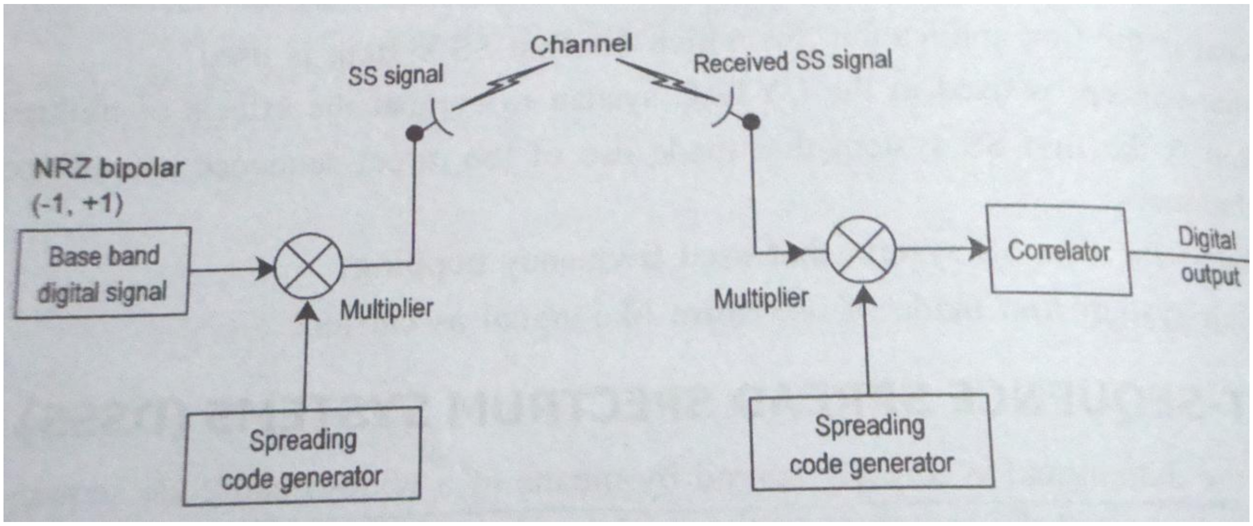



**Fig 5.1 Block diagram of Baseband DSSS System**

The original data signal which is of low bandwidth is multiplied with the wide-bandwidth direct sequence spreading code. This operation widens the bandwidth of the data signal. Figure 5.2 a) shows the original digital signal (NRZ bipolar +1, -1) and the spectrum of the signal is shown in Figure 5.2 b). A sample digital bit pattern of 1010011 is used as the baseband digital signal. The digital signal bandwidth is very narrow and the spectrum is wrapped-around FFT of the digital signal. The spectrum shows that the signal is centered on zero frequency with a very narrow bandwidth extending over a few frequency bins (approximately 100).

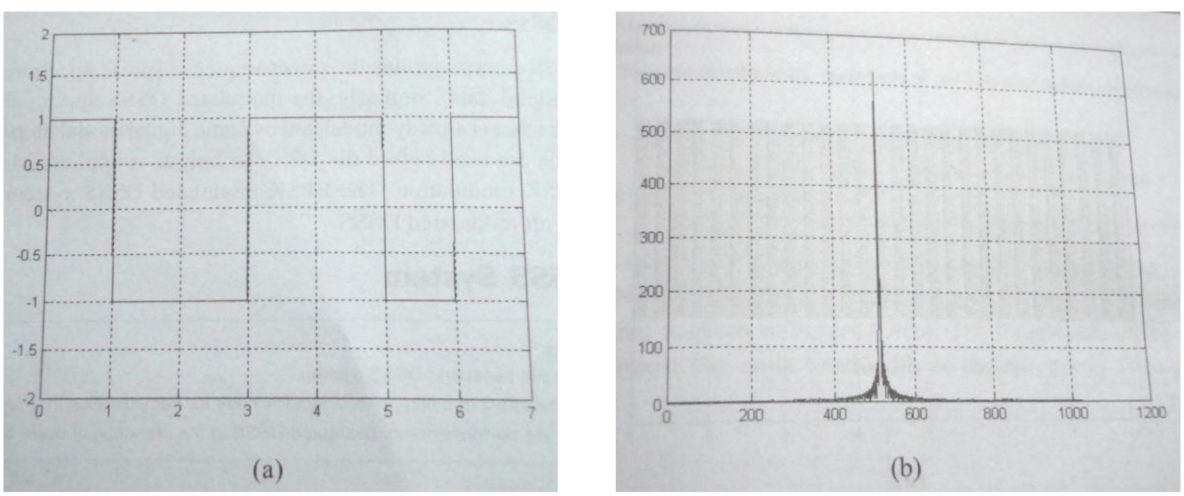



**Fig 5.2 Digital Signal b) Spectrum of Digital signal**

There is no ambiguity in the correlator output for the despread signal even in the presence of the jammer signal and the AWGN signal.

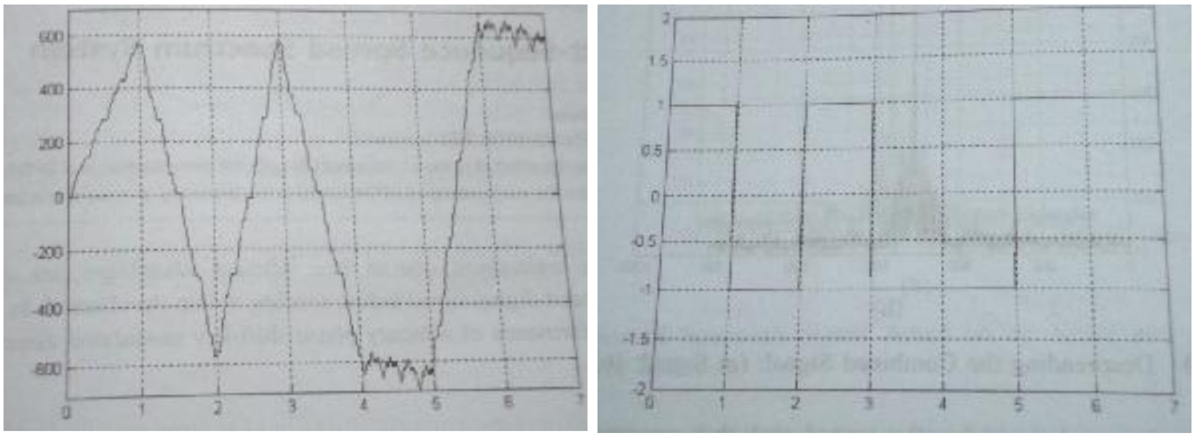


**Fig 5.3 a.Correlator Outpu** **b.Final Digital Signal Output**

The digital signal is perfectly recovered at the receiver end even in the presence of noise and jammer signal by the application of direct sequence spread spectrum technique to the baseband digital signal.

## MODULATED DIRECT SEQUENCE SPREAD SPECTRUM SYSTEM

Digital modulation techniques, due to their inherent advantages, are often employed to modulate the baseband digital signal before sending it onto the channel. The performance of modulated DSSS is analyzed with Binary Phase Shift Keying (BPSK) modulation technique. The general block diagram of modulated DSSS system is shown in Figure 2.32.

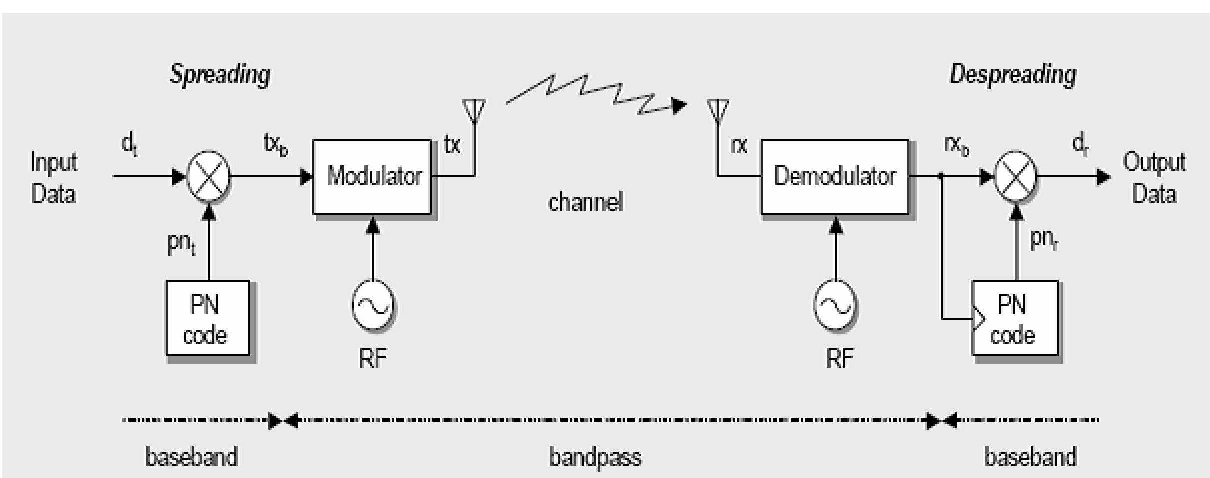



**Fig 5.4 Block Diagram of Direct Sequence Spread Spectrum system**

There are two versions of BPSK DSSS system:

- In the first type, the digital signal is first BPSK modulated using the BPSK carrier. The modulated signal is then spread across the wide bandwidth by means of the spreading code. At the receiver end, the signal is first despread by multiplication with the spreading code and then it is BPSK modulated.
- In second type, the digital system is first spread using the spreading code, just as in the baseband DSSS system. The resulting signal is then BPSK modulated using the BPSK carrier. At the receiver, the signal is first BPSK demodulated and then it is despread using the spreading code.

**BPSK MODULATE DSSS SYSTEM (I type)**

BPSK modulated DSSS of first type is shown in Figure 2.33. First the digital signal is BPSK modulated and is then multiplied with the spreading code to obtain the BPSK DSSS signal. This signal is then sent down the channel. At the receiver signal is despread by multiplication with the spreading code. It is then demodulated using the correlator receiver and the same reference carrier.

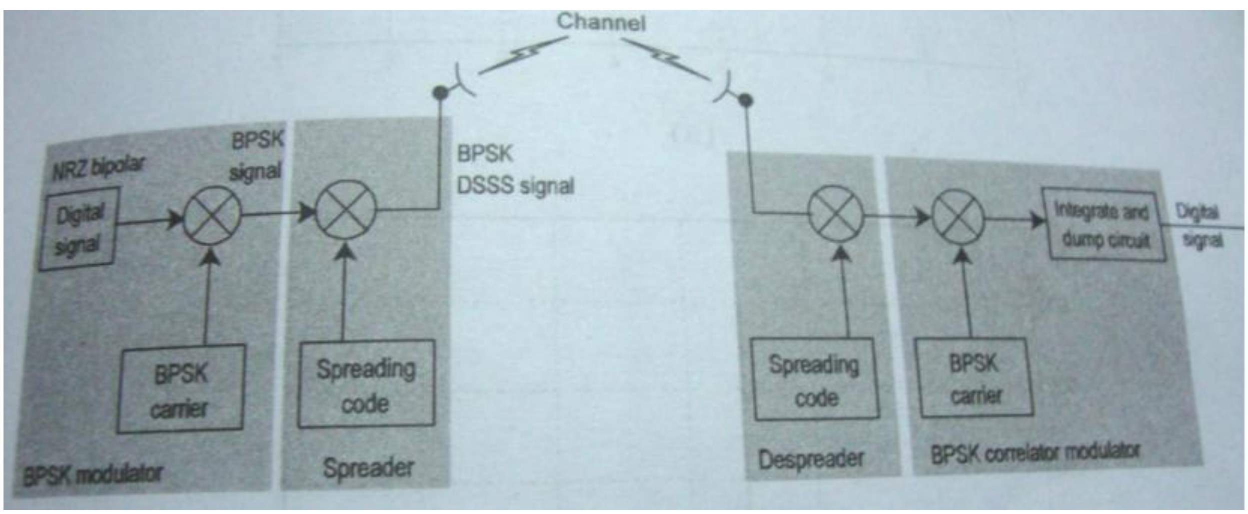



**Fig 5.5 Block Diagram of BPSK Direct Sequence Spread Spectrum system**

The original digital signal sequence is 1011001, which is BPSK DSSS modulated. The signal and its spectrum are shown in Figure. The spectrum of the digital signal is narrow and is centered on the zero frequency. BPSK carrier signal and its spectrum are shown in Figure in Figure 5.6 and the final decoded digital signal after the correlator output is given to the decision circuit. This is shown in figure 5.7 and the digital sequence recovered is 1011001, which is the same as the actual digital signal modulated at the transmitted end. The BPSK DSSS system performed well even in the presence of noise and a jammer signal.

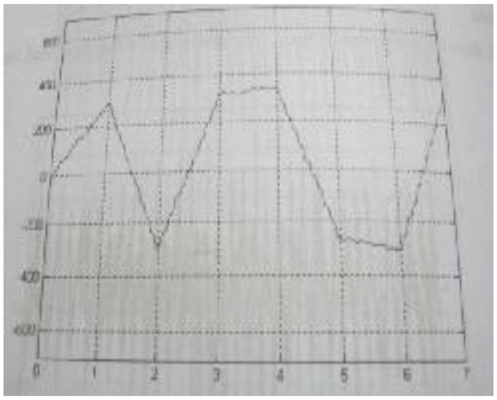


**Fig 5.6 Correlator Output**

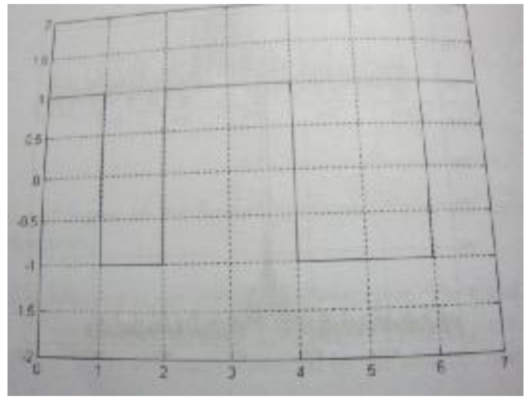


**Fig 5.7 Final Digital Signal Output**

**BPSK MODULATE DSSS SYSTEM (II type)**

The second method of BPSK DSSS is also the digital system is first spread using the spreading code, just as in the baseband DSSS system. The resulting signal is then BPSK modulated using the BPSK carrier. At the receiver, the signal is first BPSK demodulated and then it is despread using the spreading code.

**BPSK DS- SS TRANSMITTER**

- The information signal undergoes primary modulation by PSK, FSK or other narrow band modulation; but the most widely modulation scheme is BPSK (Binary Phase Shift Keying) and secondary modulation with spread spectrum modulation
- Spread spectra are obtained by multiplying the primary modulated signal and the square wave, called the PN sequence. In Direct Sequence-Spread Spectrum the baseband waveform is XOR by the PN sequence in order to spread the signal. After spreading, the signal is modulated and transmitted
- The equation 5.1 that represents this DS-SS signal and the block diagram of the BPSK DSSS Transmitter is shown in Figure 5.8 a)

$$x(t) = \sqrt{(2 E_s/T_s)}\ [b(t) \otimes c(t)] \cos(2 \pi f_c t + \theta) \qquad (5.1)$$

where

b*(t)* is the data sequence
$T_s$ is duration of data symbol
*c(t)* is the PN spreading sequence
$f_c$ is the carrier frequency
θ is the carrier phase angle at t=0

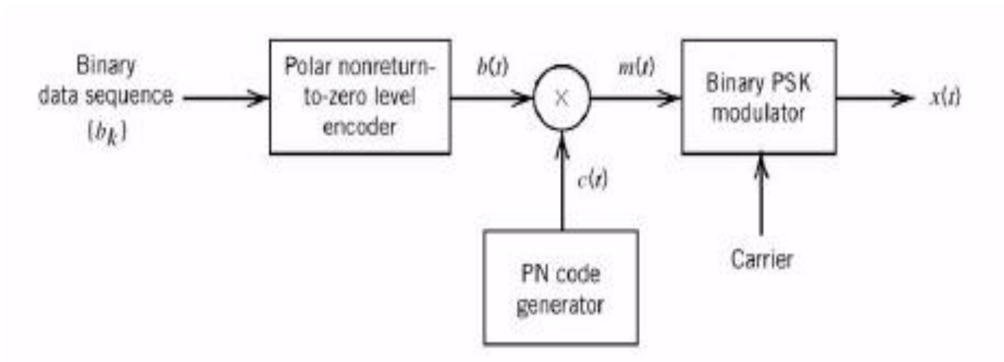



**Fig 5.8 a) Block Diagram of DS- SS Transmitter**

The block diagram of the BPSK DSSS Transmitter is shown in Figure 5.8 b). The demodulator, de-modulates the modulated (PSK) signal first, low Pass Filter the signal, and then de-spread the filtered signal, to obtain the original message.

The process is described by the following equation 5.2,

$$y(t) = [\ x(t) * \cos(2\pi f_c t + \theta)\ ] \otimes c(t) \qquad 5.2$$

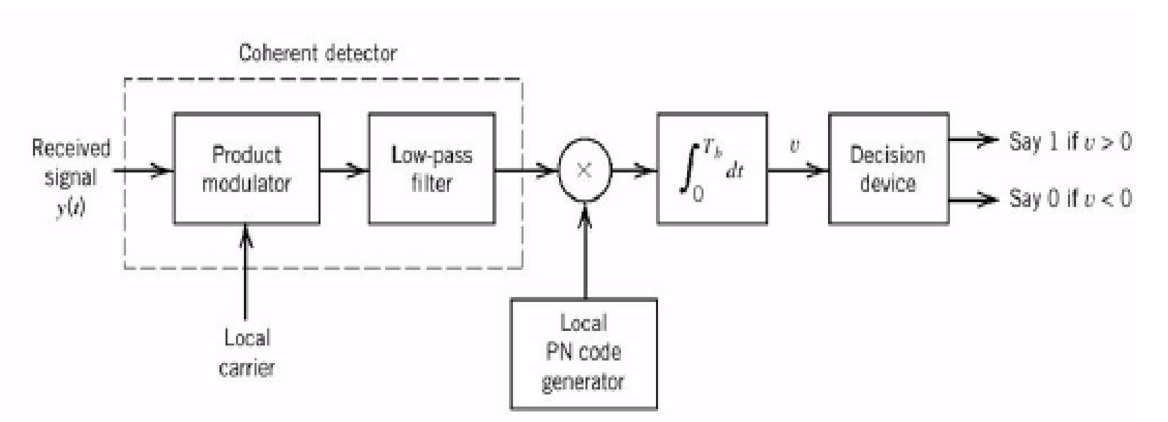



**Fig 5.8 b) Block Diagram of DS- SS Receiver**

It is clear that the spreading waveform is controlled by a Pseudo-Noise (PN) sequence, which is a binary random sequence. This PN is then multiplied with the original baseband signal, which has a lower frequency, which yields a spread waveform that has noise-like properties. In the receiver, the opposite happens, when the pass-band signal is first demodulated, and then de-spread using the same PN waveform. An important factor here is the synchronization between the two generated sequences.

If despreading is applied to the received diffuse wave, it returns to the PSK or FSK modulated wave resulting from primary modulation. Then, as with narrowband demodulation, if the despread wave and local signal are multiplied, and appropriate low pass processing is applied, the information signal is obtained. Despreading involves multiplying the same PN code as that used at the transmitting end for the receiving wave. At this time, it's necessary to synchronize the receiving wave and PN code. The interference component power that falls into the demodulation frequency band is reduced.

There are two processing methods on the receiving side, demodulation of the information signal after despreading, and obtaining a positive and negative PN code by multiplying the local signal by the receiving wave and despreading using correlation detection. With the former there is process gain but the problem of synchronization remains. With the latter, the spectrum density of the receiving wave itself is low and regeneration of the local carrier for performing synchronous detection is a problem.

The occurrence of errors is calculated using a stochastic process, so ultimately, using a spread spectrum results in fewer errors and this is why spread spectrum communication is resistant to interference.

## ADVANTAGES AND LIMITATIONS OF DSSS SYSTEMS

The advantages include:

- Best noise Performance
- Very low probability of interception and therefore most difficult to detect
- Best anti-jam performance
- Best possible discrimination in multi-path environments

The limitations are:

- Long acquisition time due to large code length
- Fast code generator is required because the chip rate is much higher than the data rate
- Requires wideband channel with very little distortion
- Susceptible to the near-far problem

### Far-Near Problem

Consider the situation, when a particular mobile is very far away from the mobile base-station. Since the mobile is very far from the base-station, the effective power of the received signal is very low. Consider another mobile, which is positioned right next to the first mobile. The power of the signal from the second mobile is very high compared to the weak power signal of the first mobile. Since two signals are positioned very close in the frequency spectrum, it is possible that the high powered signal may completely overpower the low powered signal. As a result, the first mobile will not be able to receive the signal from the mobile station. The problem repeats at the base-station, when the base-station is trying to receive a low powered signal from a far-off mobile and at the same time another mobile, which is in close proximity to the base-station sends out a high powered signal that is close in spectrum to the weak signal frequency. This causes the signal to be garbled and causes distortion. This situation is commonly referred as near-far problem in wireless communication.

## JAMMING CONSIDERATIONS

### *The Jamming Game*

- The goal of a jammer are to deny reliable communications to his adversary and to accomplish this at minimum cost
- The goals of the communicator is to develop a jam-resistant communication system under the following assumptions:
    - Complete invulnerability is not possible
    - The jammer has a prior knowledge of most system parameters, frequency bands, timings, traffic
    - The jammer has no prior knowledge of PN spreading or hopping codes
- Protection against jamming waveforms is provided purposely making the information-beating signal occupy a bandwidth far in excess of minimum Bandwidth necessary to transmit it
- This has the effect of making the transmitted signal assume noise like appearance so as to blend into background
- The transmitted signal is thus enabled to propagate through the channel undetected by anyone who may be listening
- Spread spectrum is a method of “camouflaging” the information-bearing signal

### *Tools of the Anti-Jam Communicator*

- The usual design goal for an anti-jam (AJ) communication system is to force a jammer to expend its resources over
    - a wide-frequency band
    - for a maximum time
    - from a diversity of sites
- The most prevalent design options are
    - Frequency diversity – by the use of DSSS and FHSS techniques
    - Time diversity – by the use of time hopping
    - Spatial discrimination – by the use of a narrow beam antenna, which forces a jammer to enter the receiver via an antenna sidelobe and hence, suffer a 20 to 25 dB disadvantage
    - Combination of the previous three options

## CLASSIFICATION OF JAMMERS

- Broad band noise Jamming
- Partial-band noise Jamming
- Multi-tone Jamming
- Pulse Jamming
- Repeat-back Jamming
- BLADES systems

***Pulse Jammer***

A pulse noise jammer is one that transmits pulses of band-limited white Gaussian noise with a total average power of J. The effect of the jammer is more if it is successful in modelling its central frequency and bandwidth to be identical with the communication channel.

The probability of bit error is given by

$$P_b = Q\left(\sqrt{\frac{2E_b}{N_0}}\right)$$

Where,

$Q(x) = 0.5*\mathrm{erfc}(x/\sqrt{2})$

$E_b$ - Energy per bit

$N_0$ - Receiver front end thermal noise

While transmitting the noise pulse within the receiver bandwidth, the noise jammer will cause the receiver front-end thermal noise power spectral density to increase.

$$N_0' = N_0 + (N_j/\rho)$$

Where,

$N_0'$ - New thermal noise power spectral density of the receiver

$N_j$ - Jammer power spectral density

$\rho$ - duty factor

The jammer power spectral density $N_J$ is related to the total average noise power of the jammer by the following relation:

$$N_J = J/BW$$

Where BW –bandwidth of the transmitted signal

The new increased average probability of error is

$$\overline{P_b} = (1-\rho)Q\left(\sqrt{\frac{2E_b}{N_0}}\right) + \rho Q\left(\sqrt{\frac{2E_b}{N_0 + N_j/\rho}}\right)$$

Compared to noise introduced by jammer, the thermal noise of RADAR, the first term in the above equation is negligible. The probability of bit error is given by

$$\overline{P_b} = \rho Q\left(\sqrt{\frac{2E_b\rho}{N_j}}\right)$$

Using the Q function and maximizing the resultant error probability with respect to ρ, the maximum value of the duty factor is

$\rho = N_j / 2E_b$

The corresponding error probability is

$$\overline{P}_{b,\max} \approx \frac{1}{\sqrt{2\pi e}} \frac{1}{2E_b/N_j}$$

As a result, the maximized new error probability is proportional to $N_J$, the jammer noise power spectral density.

### *Partial Band Jammer*

The partial-band noise jammer, which consists of noise whose total power, is evenly spread over some frequency band that is a subset of the total spread bandwidth. Owing to the smaller bandwidth, the partial-band noise jammer is easier to generate than the barrage noise jammer. A PBNJ where the jammer transmits noise over a fraction of the total spread spectrum signal band spreads noise of total power J evenly over some frequency range of bandwidth $W_j$, which is a subset of the total spread bandwidth $W_{ss}$.

The fraction ρ is defined as the ratio

$$\rho = \frac{w_j}{w_{ss}}$$

where r is (0, 1) which is the fraction of the total spread spectrum band that has noise of power spectral density

$$\frac{J}{W_J} = \frac{J}{W_{SS}} \cdot \frac{W_{ss}}{W_J} = N_J / \rho$$

$$N_J = N_J / \rho$$

A Gaussian noise jammer is chosen to restrict its total power J to a fraction r of the full SS bandwidth $W_{ss}$. A corresponding degraded SNR level

$$\frac{E_b}{N_t} = \frac{\rho E_b}{N_t}$$

It is assumed that the jammer hops the jammed band over $W_{ss}$, relative to the FH dwell time $1/R_h$, but often enough to deny the FH system the opportunity to detect that it is being jammed in a specific portion of $W_{ss}$ and take remedial action.

### *Multitone Jammer*

In tone jamming (TM), one or more jammer tones are strategically placed in the spectrum where they are placed and their number affects the jamming performance. Two types of tone jamming are

- Single-tone jamming (STJ) places a single tone where it is needed
- Multiple-tone jamming (MTJ) which distributes the jammer power among several tones

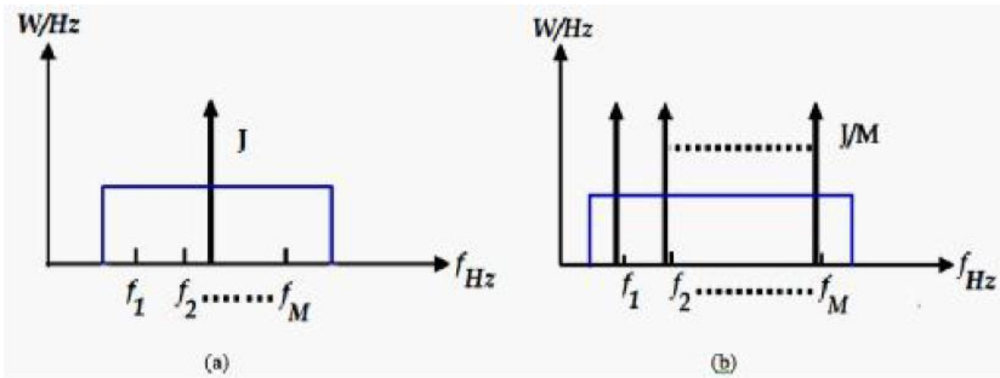



**Figure 5.9 Power spectral density of (a) STJ and (b) MTJ**

Single-tone jamming (STJ)

A jamming signal transmitted at a single frequency was shown in Figure 5.9. Thus, the jamming signal is a continuous wave tone placed at a single frequency. STJ is also called spot jamming. A continuous wave tone centered at the carrier frequency is well known to be a good jamming signal against a direct sequence system. The STJ can be expressed as:

$$J(t) = A \cos(2\pi f_0 t + \theta)$$

Where:

A is the amplitude
$f_0$ is frequency of STJ and
$\theta$ is the initial phase which is uniform distribution between $(0, 2\pi)$.

Multiple-tone jamming (MTJ)

The multitone jammer, which is the tone equivalent of the partial-band noise jammer. A jamming signal transmitted at multi tones, randomly placed, or placed at specific frequencies. Tone-jamming is impulse signal having high power. So, MTJ means there are some impulse signals in certain frequency of whole bandwidth. Because total power of jamming signal is limited, the more the number of tone jamming signals is increasing, the more power of each tone jamming signal is lower.

For MTJ using $N_T$ equal power tones each tone-jamming signal can be expressed as:

$$j(t) = \sqrt{\frac{2P_J}{N_T}} \sum_{j=1}^{N_T} \cos(2\pi f_j t)$$

Where $P_J$ and $N_T$ are total jamming power and the number of multi tone jamming respectively. $P_J$ is divided into same power equally depending on the number of multi tone jamming and $f_j$ is jamming frequency. All phases are assumed to be independent and uniformly distributed over $(0, 2\pi)$.

## 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

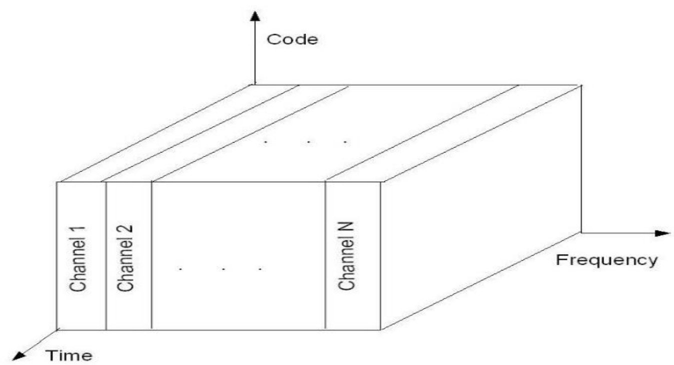



**Fig 5.10 The basic concept of FDMA.**

- 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

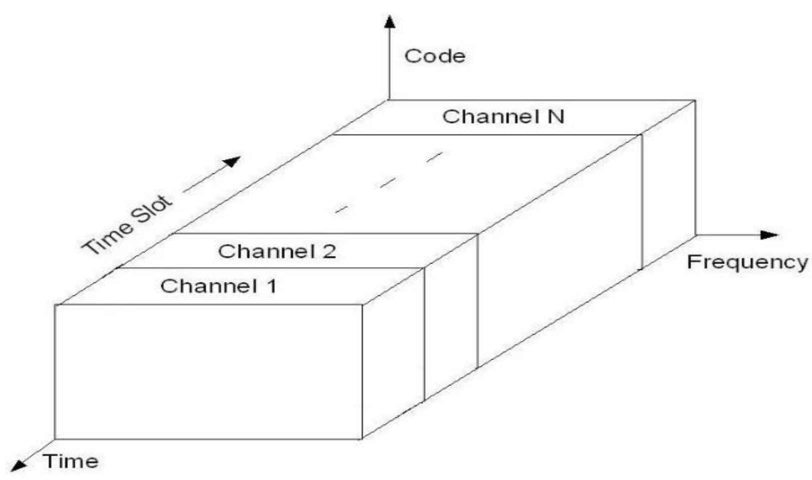



**Fig 5.11 The basic concept of TDMA**.

- 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.

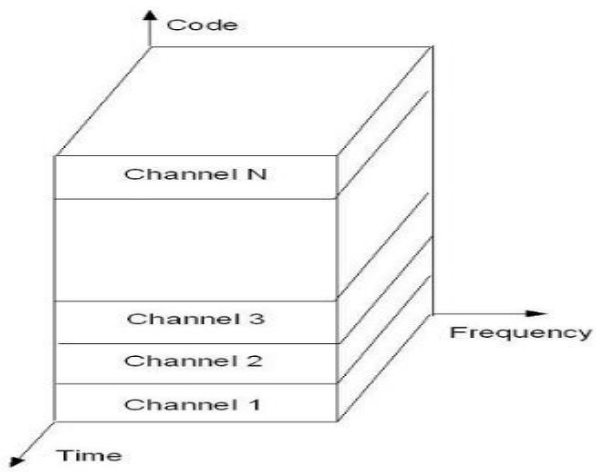



**Fig 5.12** The basic concept of CDMA.

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.

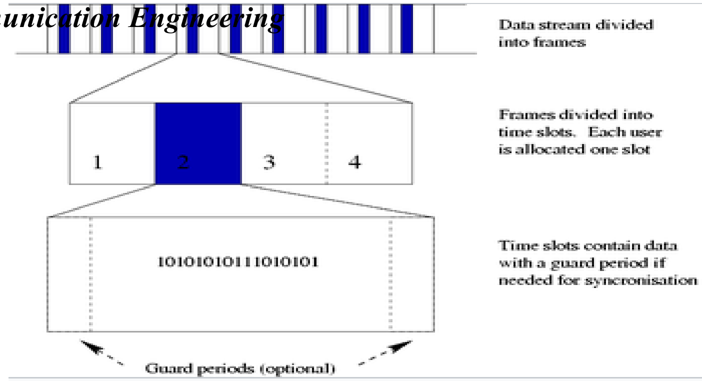
- Hence in despreading a given user's waveform, nonzero contributions to that user's signal arise from the transmissions of the other users in the network.
- This is distinct from both TDMA and FDMA, wherein for reasonable time or frequency guardbands, respectively, orthogonality of the received signals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

**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*.

**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.