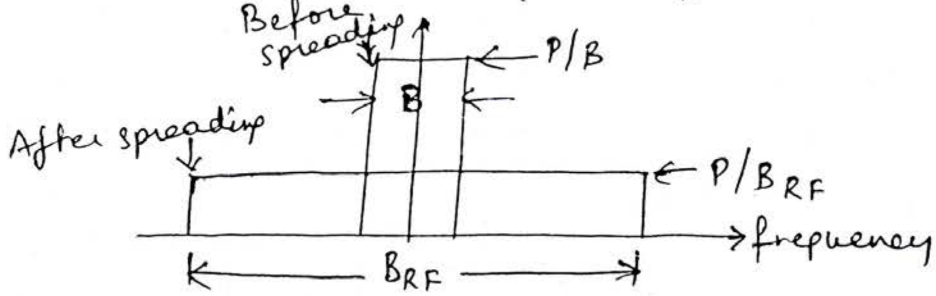
UNIT – VIII

Spread Spectrum modulation

It is defined as a technique in which a transmitte signal occupies a bandwidth which is kept much larg than that which is required by a baseband info sign. This technique trades transmission bandwidth for enhanc detectability and interference rejection. The ratio of the spread bandwidth to the information bandwidth is a measu of performance of the communication system.

Principle of spread spectrum

The basic concept of spread spectrum is shown in fig. The idea is to take the energy in bandwidth B and sprea it over the wider bandwidth B_{RF}.



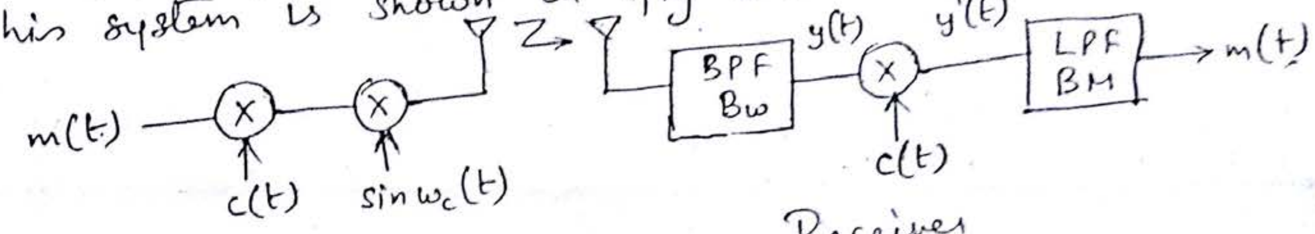
The techniques to accomplish the spread spectrum are

(i) Direct sequence
(ii) Frequency hopping
(iii) Time hopping

Direct Sequence Spread Spectrum

One of the most common method to widen the spectrum of a signal is to multiply (modulate) it by a wideband signal. The spreading signal must have properties which aid in acquiring and tracking the signal.

These properties are essential to enable the
ceiver to despread (demodulate) the received signal,
a binary PN signal (pseudo noise) possesses these properties
e most common spread spectrum technique is direct sequence
v spreading. in conjunction with PSK data modulation.
his system is shown in fig below.



Receiver

Transmitter

m(t) — message signal waveform

$\sqrt{2} P_s\, m(t)$

P_s - signal power

m(t) — binary waveform which takes values ± 1

c(t) — Pseudo noise PN sequence, with values ± 1 whose bit rate is higher than bit rate of message signal

The received signal $\gamma(t)$ may be expressed as

$$\gamma(t) = \sqrt{2} P_s\, m(t) \sin 2\pi f_c t$$

where f_c = freq of the carrier

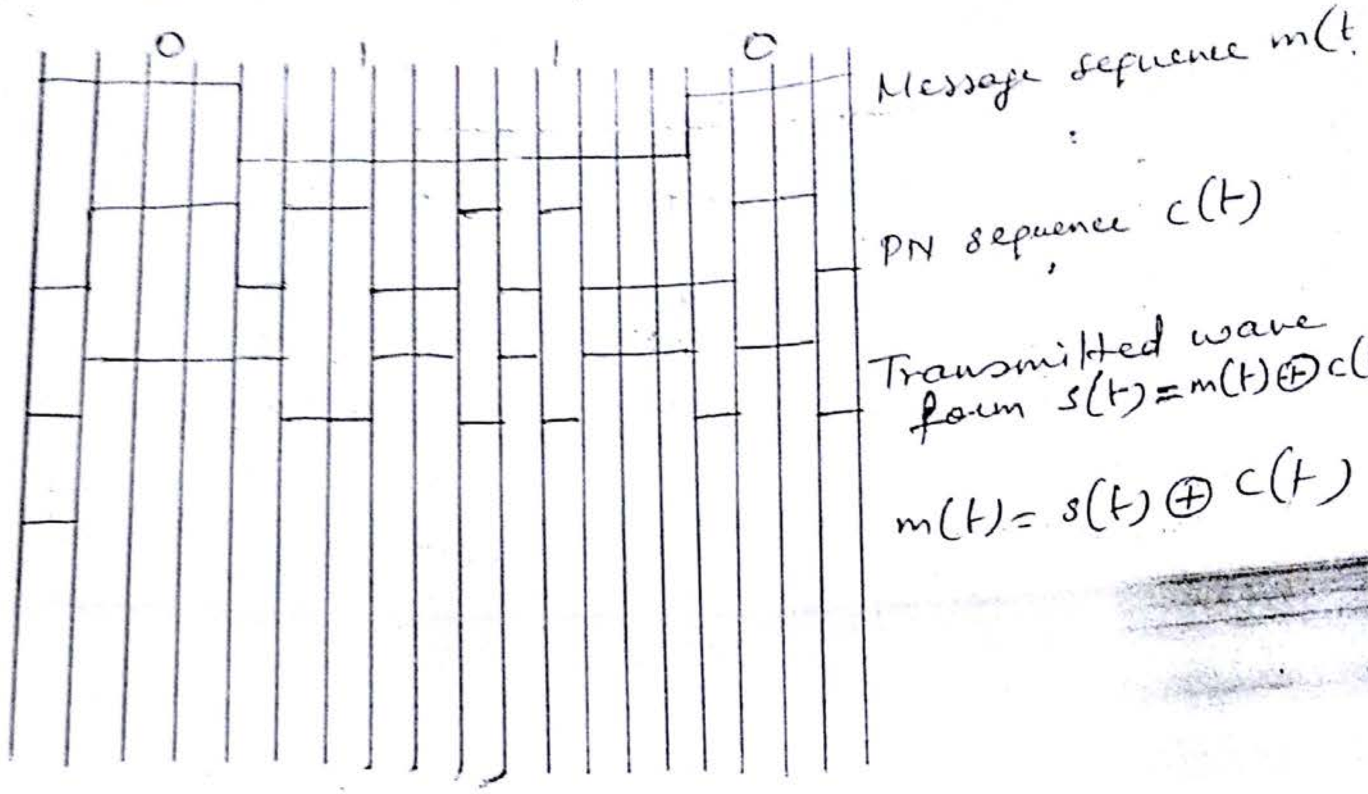
the term $m(t) \sin 2\pi f_c t$ represents a PSK signal that may be demodulated using a PSK demodulator

The transmitted sequence $s(t)$ is obtained as

$$s(t) = m(t) \oplus c(t)$$

The receiver output $m(t)$ is obtained as

$$m(t) = s(t) \oplus c(t)$$



$m(t) = s(t) \oplus c(t)$

PN Sequence

PN sequence is random within its length because 1's and 0's are randomly distributed.

Properties of PN

1) Balance property

the total no. of 1's and 0's in the period of the PN sequence is almost equal.

If n = no. of bits in the shift register

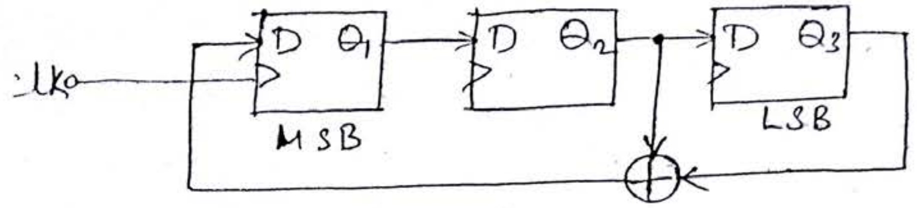
length of the PN sequence $= 2^N - 1$

Ex. If N=4 (4-bit shift register)

length $= 2^4 - 1 = 15$

This sequence is generated by a 4-bit shift register.

3-bit Shift register



The PN sequence is generated by a 3-bit shift register by obtaining the feedback signal using the mod-2 addition (XOR) of the 2nd and 3rd bits from the register. The resulting states of the shift register after each clock beginning with an initial state of 111 are shown below.

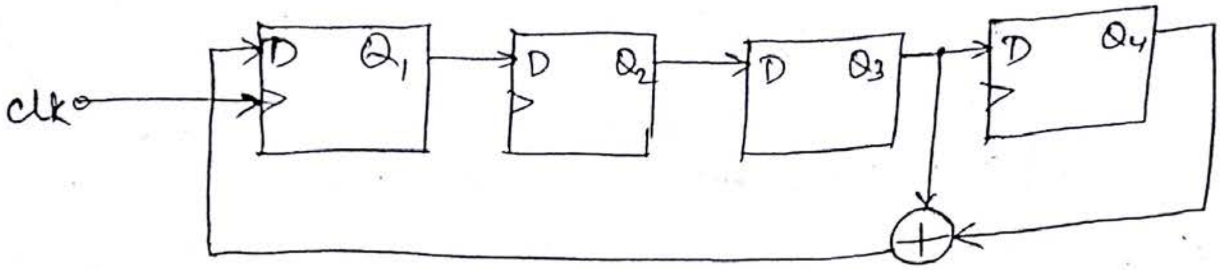
The sequence repeats after 7 clock cycles, hence this PN sequence has a period of 7

clk	Q_1	Q_2	Q_3
1	1	1	1
2	0	1	1
3	0	0	1
4	1	0	0
5	0	1	0
6	1	0	1
7	1	1	0
8	1	1	1

Table:- States of 3-bit PN generator

The shift register generating the PN sequence goes through all states (000 to 111) randomly except the all zero state.

4-bit shift register PN generator



The feedback signal is obtained by mod-2 addition of 3rd and 4th bits of the shift register.

states of 4-bit PN generator

clk	Q_1	Q_2	Q_3	Q_4
1	1	1	1	1
2	0	1	1	1
3	0	0	1	1
4	0	0	0	1
5	1	0	0	0
6	0	1	0	0
7	0	0	1	0
8	1	0	0	1
9	1	1	0	0
10	0	1	1	0
11	1	0	1	1
12	0	1	0	1
13	1	0	1	0
14	1	1	0	1
15	1	1	1	0
16	1	1	1	1

2) Run property

A consecutive sequence of 1's and 0's is known as a run, Thus a subsequence of consecutive 1's or 0's within a PN sequence is a run of length n. A PN sequence generated in a N-bit register will have one run of N ones, one run of (N-1) zeros.

Then there is one run of 2 ones and 2 zeros. Further there are ~~one~~ two runs of 1 one and 1 zero.
In general, for a sequence of length 2^N-1, the no. of runs of 1's and 0's are shown in the table.

Run of length	No. of runs of 1's	No. of runs of 0's
N	1	0
N-1	0	1
N-2	1	1
N-3	2	2
⋮	⋮	⋮
2	2^{N-4}	2^{N-4}
1	2^{N-3}	2^{N-3}

Problem :- A PN sequence generator is described by the polynomial $g(x) = 1 + x^3 + x^5$. Find the total no. of 1's and 0's in the sequence, find the runs of three 1's and three 0's, two 1's and two 0's.

length of sequence $L = 2^N - 1$

No. of 1's $= \left(\frac{L+1}{2}\right)$ No. of zeros $= \left[L - \left(\frac{L+1}{2}\right)\right]$

sol:- $N = 5$

i, length of the sequence $= 2^N - 1$

$L = 2^5 - 1 = 31$

ii, No. of 1's in the sequence $= \frac{L+1}{2} = \frac{31+1}{2}$

$= 16$

iii, No. of 0's in the sequence $= 31 - 16 = 15$

iv, No. of runs of 1's of length 5 $= 1$

v, No. of runs of 0's of length $(N-1)$ (4) $= 1$

vi, No. of runs of 3 ones from the table $\begin{bmatrix}(N-2) \\ (5-2) = 3\end{bmatrix}$ $= 1$

vii, No. of runs of 3 zeros $= 1$

viii, Two ones and two zeros $= 2$

3) Auto correlation property

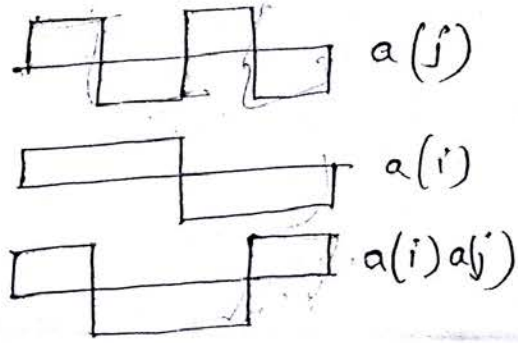
the PN sequence has an auto correlation that is periodic with the period equal to the period of the sequence. the discrete auto correlation for a sequence is defined as

$$R(M) = \sum_{K=0}^{(L-1)} a(k)\, a(K+m)$$

Here the sequence $a(k+m)$ is the sequence $a(k)$ shifted by m bits to the left. the auto correlation is the product of the two sequences bit by bit and summation over the length L of the sequence

Consider the binary values of the symbol a(k) is (+1) and (−1) i.e. $a(K) \in (+1, -1)$. The products of the different combinations of the two symbols are given in the table and wave forms shown below.

a(i)	a(j)	a(i) a(j)
+1	+1	+1
+1	−1	−1
−1	+1	−1
−1	−1	+1



If the symbol a(K) has two binary values 0 and 1, $a(K) \in (1, 0)$, then the output a(i) & a(j) resembles XNOR operation. If the symbol a(K) has two binary values 0 and 1, if the bipolar values +1 and −1 are mapped as 0 and 1, then the multiplication operation on bipolar signals is same as XNOR operation on binary signals.

Hence autocorrelation is obtained through XNOR operation

<u>Digital Correlation of PN Sequences</u>

The auto correlation for a digital sequence is

$$R(m) = \sum_{K=0}^{(L-1)} x(K)\, x(K+m)$$

The auto correlation is obtained by multiplying (equivalent to XNOR operation) the sequence with an m-bit circularly shifted sequence and adding the product over its length.

The discrete autocorrelation is defined as

$$= \frac{\text{No. of agreements} - \text{No. of disagreements}}{\text{No. of agreements} + \text{No. of disagreements}}$$

$$= \frac{\text{No. of 1's} - \text{No. of 0's}}{\text{No. of 1's} + \text{No. of 0's}}$$

Example

- For a PN sequence of length $2^4 - 1 = 15$, the auto correlation outputs at shifts 0 $(m=0)$ and 3 $(m=3)$ are as follows.

$m=0$

$x(k)$	1	1	1	1	0	0	0	1	0	0	1	1	0	1	0
$x(k+0)$	1	1	1	1	0	0	0	1	0	0	1	1	0	1	0
$x(k) \overline{\oplus} x(k+0)$	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Discrete auto correlation $R(0)$ $= \dfrac{\text{No. of 1's} - \text{No. of 0's}}{\text{No. of 1's} + \text{No. of 0's}}$

$$= \frac{15-0}{15+0} = 1$$

$m=3$

$x(k)$	1	1	1	1	0	0	0	1	0	0	1	1	0	1	0
$x(k+3)$	1	0	0	0	1	0	0	1	1	0	1	0	1	1	1
$x(k) \overline{\oplus} x(k+3)$	1	0	0	0	0	1	1	1	0	1	1	0	0	1	0

Discrete auto correlation $R(3)$ $= \dfrac{7-8}{15} = \dfrac{-1}{15}$

Hence for any value of m other than 0

$$R(m) = \frac{-1}{15}$$

$$R(0) = 1$$

CDMA

CDMA differs from FDMA because only one channel occupies the entire bandwidth of the link. It differs from TDMA because all stations can send data simultaneously.

CDMA means communication with different codes.

Example:-

In a large room with many people, two people can talk in English if nobody else understands English. Another two people can talk in chinese if they are the only ones who can understand Chinese. i.e in the common channel (the space of the room) can allow communication between several couples but in different languages (codes)

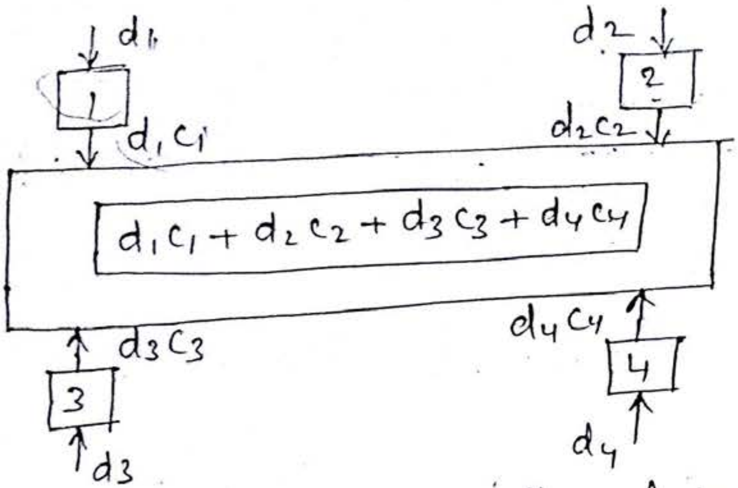
Basic idea

Let us assume we have four stations 1, 2, 3, 4 connected to the same channel. The data from station 1 is d_1, from station 2 is d_2 and so on. The code assigned to the first station is c_1, to the second c_2 and so on. we assume that the assigned codes have two properties.

→ If we multiply each code by another, we get 0.

→ If we multiply each code by itself, we get 4 (4 = no. of stations)

with these 2 assumptions let us see how the above four stations can send data using the same common channel



station 1 multiplies its data by its code to get $d_1 c_1$. Station 2 multiplies its data by its code to get $d_2 c_2$ and so on. The data on the channel is the is the sum of all terms.

$$\text{data on the channel} = (d_1 c_1 + d_2 c_2 + d_3 c_3 + d_4 c_4)$$

Any station that wants to receive data from one of the other three stations multiplies the data on the channel by the code of the sender.

For example, station 1 and station 2 are talking to each other. Station 2 wants to hear what station 1 is is talking. Station 1 multiplies the data on the channel by c_1 (code of station 1).

Because $(c_1 \cdot c_1)$ is 4, $(c_2 \cdot c_1) = 0$

$(c_3 \cdot c_1) = 0$

$(c_4 \cdot c_1) = 0$

$$\text{data} = (d_1 c_1 + d_2 c_2 + d_3 c_3 + d_4 c_4) \cdot c_1$$

$$= d_1 c_1 c_1 + d_2 c_2 c_1 + d_3 c_3 c_1 + d_4 c_4 c_1$$

$$= 4 d_1$$

Now station 2 divides the result by 4 to get the data from station 1 $\therefore \frac{4 d_1}{4} = d_1$

Ranging using DSSS

It is a method of finding the distance of a target measured using electromagnetic signal transit time to the target and back. It has wide applications in Radar, radio astronomy and satellite communication. Traditional signals used are sine and pulse waveforms. Both these waveforms have certain limitations.

Sine wave

For unambiguous range resolution, the sine wave period should be larger than twice the range. But larger wavelengths have lower resolution. This problem is solved by transmitting two waveforms, one with a higher frequency and another with a lower frequency.

Pulse wave

In pulse radar, the pulse width should be smaller for better resolution. The period should be larger to avoid range ambiguity. Therefore the duty cycle of the pulse must be very small.

Synchronization

Code synchronization is one of the most important functions the spread spectrum receiver must perform. Both the code phase and carrier frequency uncertainties are to be resolved before the receiver could operate. If accurate frequency sources are contained in both the transmitter and receivers, then much of the uncertainty is removed.

Doppler freq shift, however cannot be necessarily predicted, because it is a function of velocity. Considering a transmitted frequency f_t, the received frequency

for large velocities, $f_r = f_t\sqrt{\frac{C-V}{C+V}}$

where V = relative velocity between transmitter and receiver

C = speed of light 3×10^8 m/s

or for small velocities

$$f_r = f_t \pm \frac{f_t V}{C}$$

The plus sign is applicable for increasing frequency when the transmitter and receiver are approaching each other. The minus sign is applicable when they are moving away from each other.