320 (after Mid) Date: 23/03/24

Chapter: 06

Bandwidth Utilization: Multiplexing and Spreading

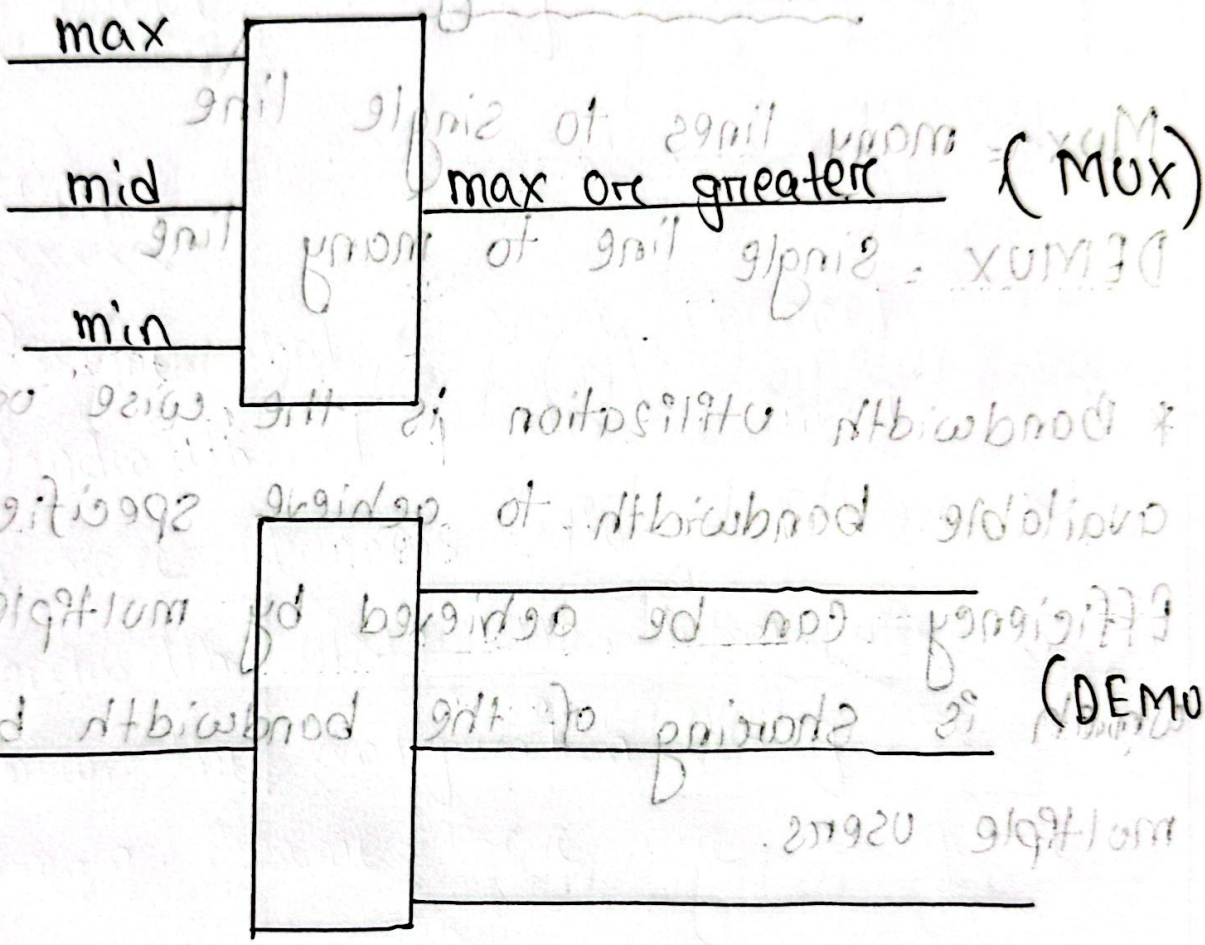
Mux = many lines to single line
DEMUX = single line to many line

* Bandwidth utilization is the wise use of available bandwidth to achieve specific goals Efficiency can be achieved by multiplexing which is sharing of the bandwidth between multiple users.

What is multiplexing?

=) Multiplexing is the set of techniques that allows the (simultaneous) transmission of multiple signals across a single data link.

Visualization of MUX and DEMUX

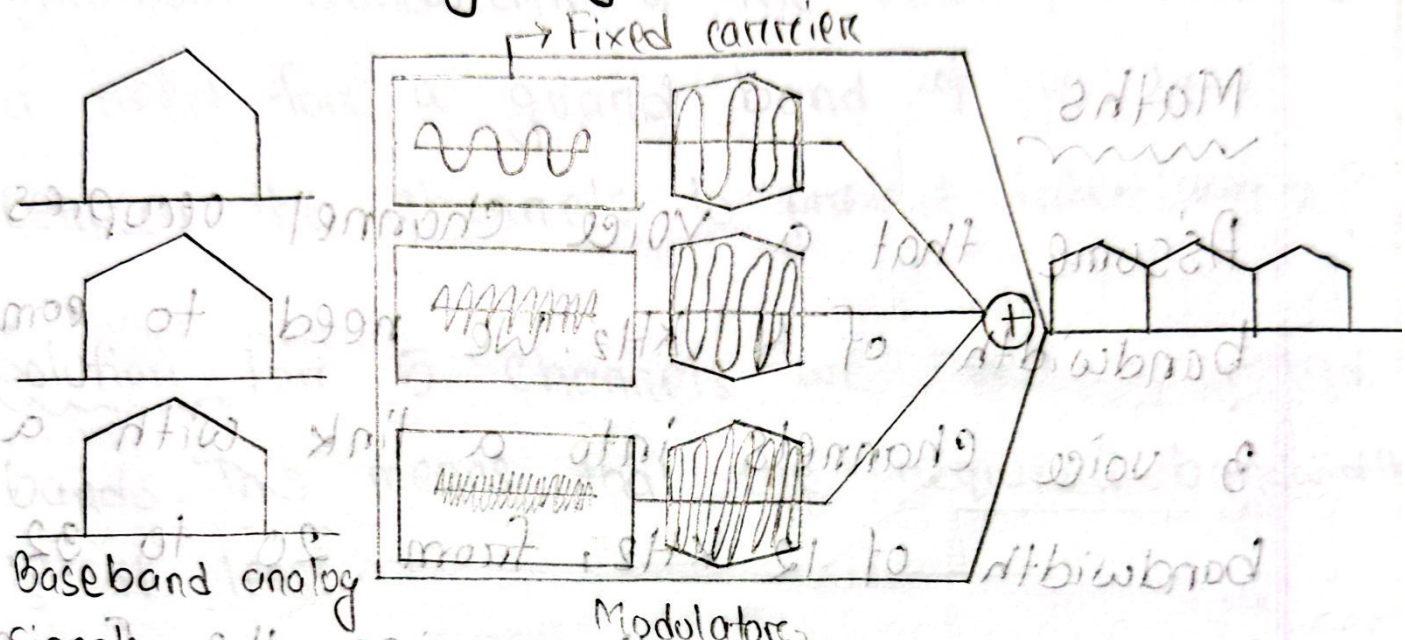


Multiplexing is of 3 types:

i) FDM = Frequency division multiplexing } analo
ii) WDM = Wavelength division multiplexing }
iii) TDM = Time division multiplexing (digital)

FDM

It is an analog multiplexing technique that combines analog signals.



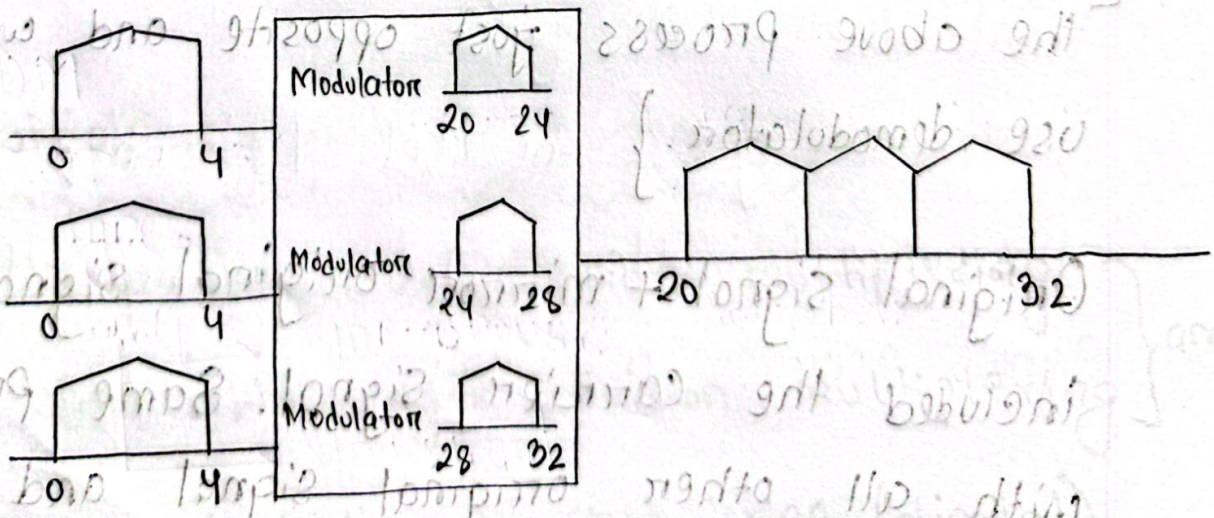
{In case of DEMUX (FDM) we will follow the above process just opposite and we will use demodulator.}

Original signal + mirror original signal + included the carrier signal. Same process with all other original signal and then adding all of them together as one bandwidth.

Fixed carrier frequency is used to keep the original signal as same. It acts as a bubble wrapping to a gift/fragile thing

Maths

Assume that a voice channel occupies a bandwidth of 4 kHz. We need to combine 3 voice channels into a link with a bandwidth of 12 kHz, from 20 to 32 kHz. Show, the configuration using the frequency domain. Assume there are no guard bands.

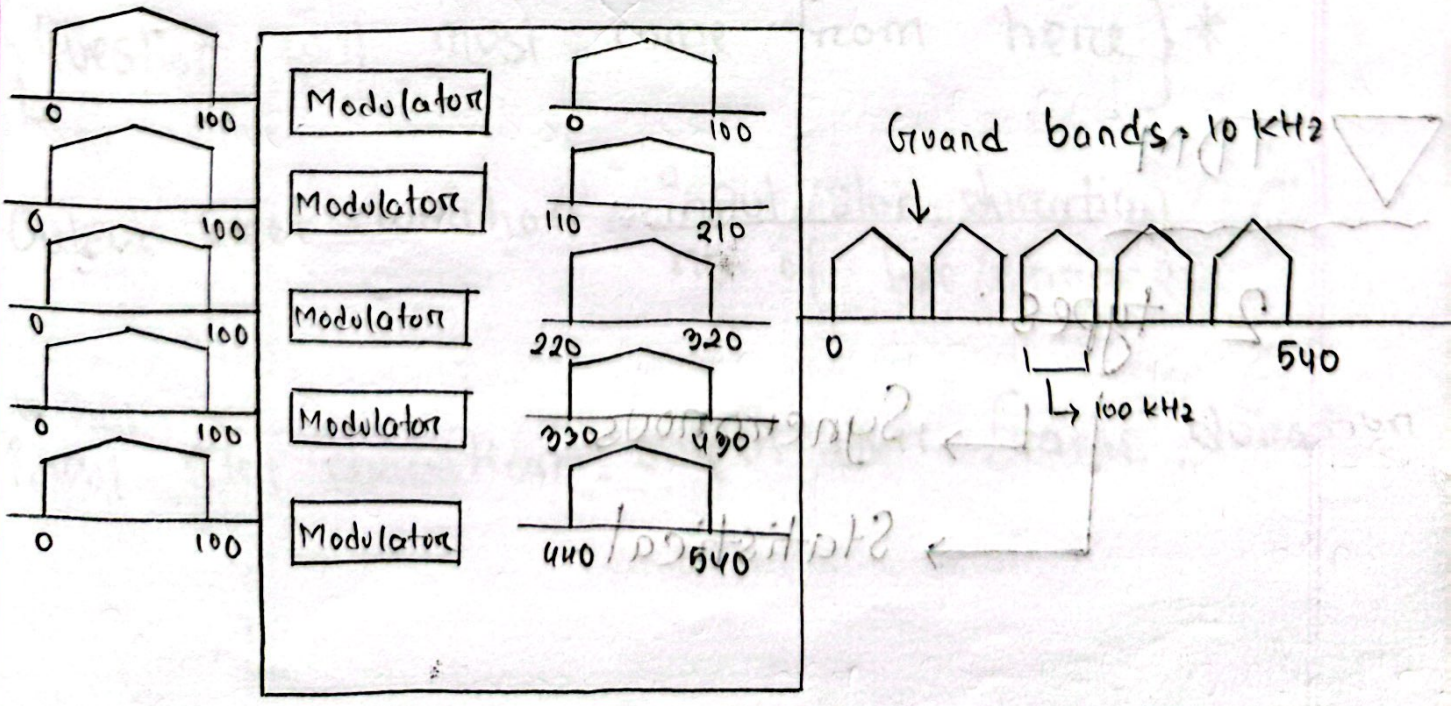


Maths

Five channels, each with a 100 kHz bandwidth are to be multiplexed together. What is the minimum bandwidth of the link if there is a need for a guard band of 10 kHz between the channels to prevent interference?

Solution: For 5 channels we need 4 guard bands. This means that the required bandwidth is at least.

$$\Rightarrow (5 \times 100) + (4 \times 10) = 500 + 40 = 540 \text{ kHz}.$$

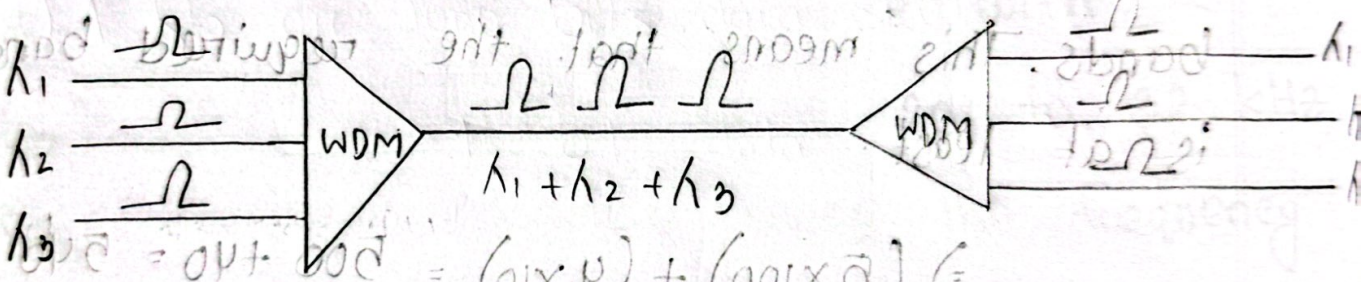


△ WDM

WDM is an analog multiplexing technique to combine optical signals.

Here, prism is used instead of modulator.

The use is same.

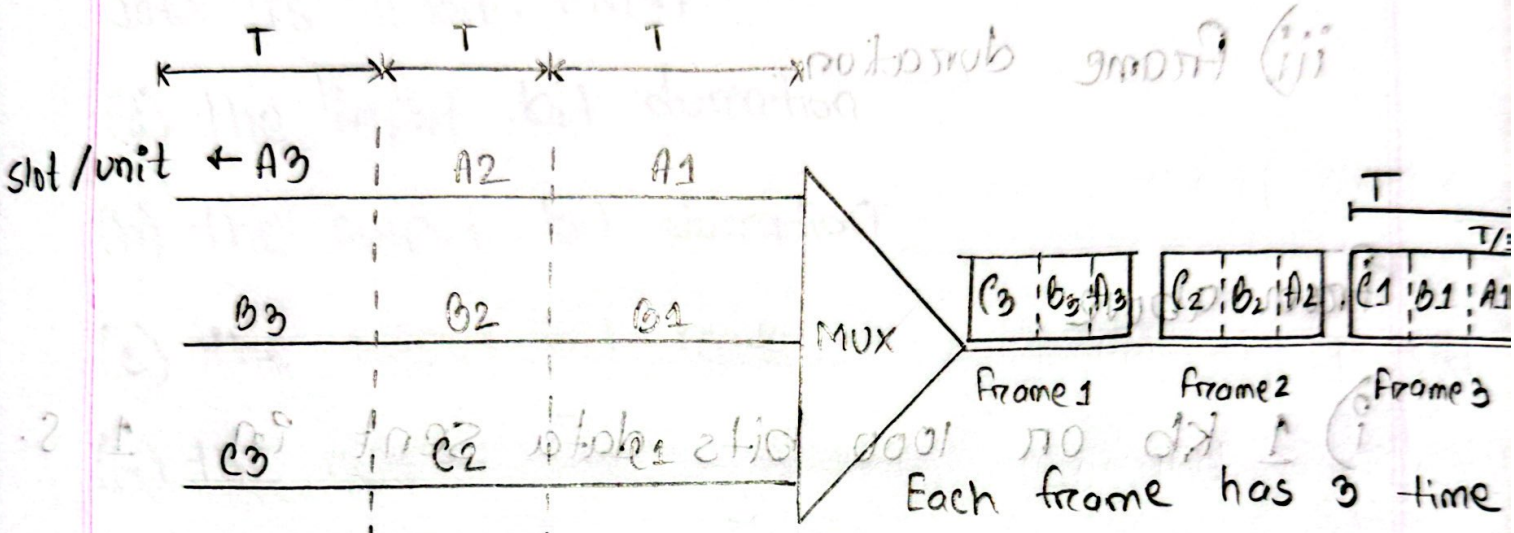


▽ TDM

2 types:

- Synchronous.
- Statistical.

It is a digital multiplexing technique for combining several low-rate digital channels into one high-rate one.



Each frame has 3 time slots.

Each time slot's duration is T/3 s.

{Question will must come from here}*

$$\text{Output slot duration} = \frac{\text{input slot duration}}{\text{no of line/channel.}}$$

input slot duration = output per frame duration.

(Ex) 6.5

Things that can be asked:-

i) Each input slot duration.

ii) Output slot duration

iii) Frame duration.

From above,

i) 1 kb or 1000 bits data sent in 1 s.

or, 1 bit data sent in $\frac{1}{1000}$

$= 1$ ms.

ii) Output slot duration $= \frac{1 \text{ ms}}{3} = 1/3$ ms

iii) Frame duration = input duration = 1 ms.

(Ans).

Ex: 6.6 Figure 6.14 shows synchronous TDM with 4 1Mbps data stream inputs and one data stream fore the output. The unit of data is 1 bit. Find,

(a) the input bit duration

(b) the output bit duration

(c) the output bit rate

(d) the output frame rate.

(a)

the input bit duration,

10^6 bit data send in 1 s.

∴ 1 bit data send in $1/10^6$

= 1 μs.

(b)

$$\text{Output bit duration} = \frac{\text{input slot duration}}{\text{no of line/channel}}$$

$= 1/4$ MS.

(c)

The output bit rate;

Is the output was 10^6 frame

if each frame contains 4 bit.

Output rate $= 4 \times 10^6$ Mbps.

(d)

Frame duration = 1 μs.

∴ The output frame rate,

1 μs or 10^{-6} s took to create 1 frame

1 s took to create $1/10^{-6}$

$= 10^6$ frames/s (Ans)

Ex:6.10 We have four sources, each creating 250 8-bit characters per second. If the interleaved unit is a character and 1 synchronizing bit is added to each frame, find

(a) the data rate of each source

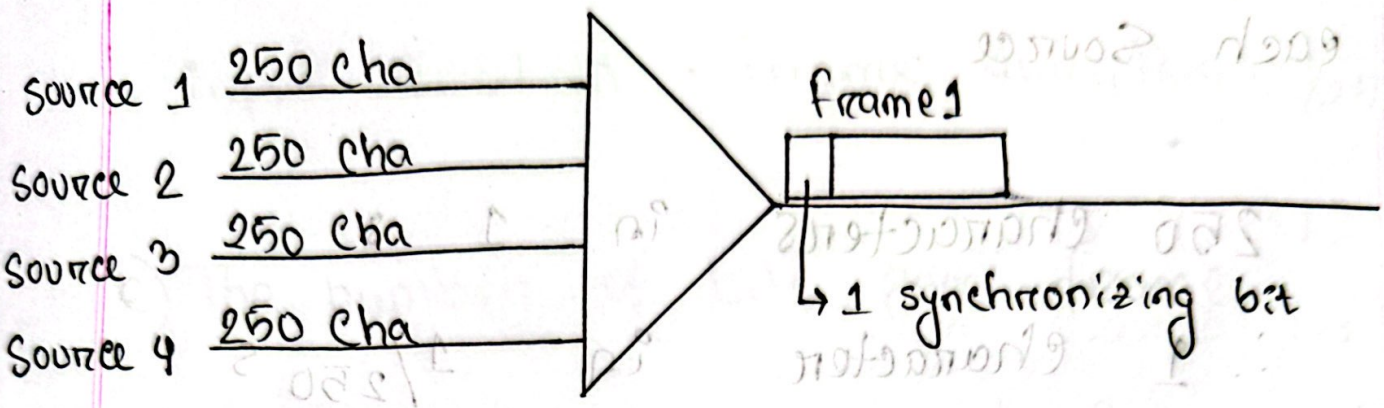
(b) the duration of each character in each source

(c) the frame rate

(d) the duration of each frame

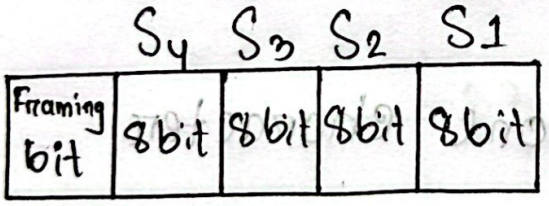
(e) the number of bits in each frame.

(f) the data rate of the link.



We know,

1 character = 8 bit



Frame

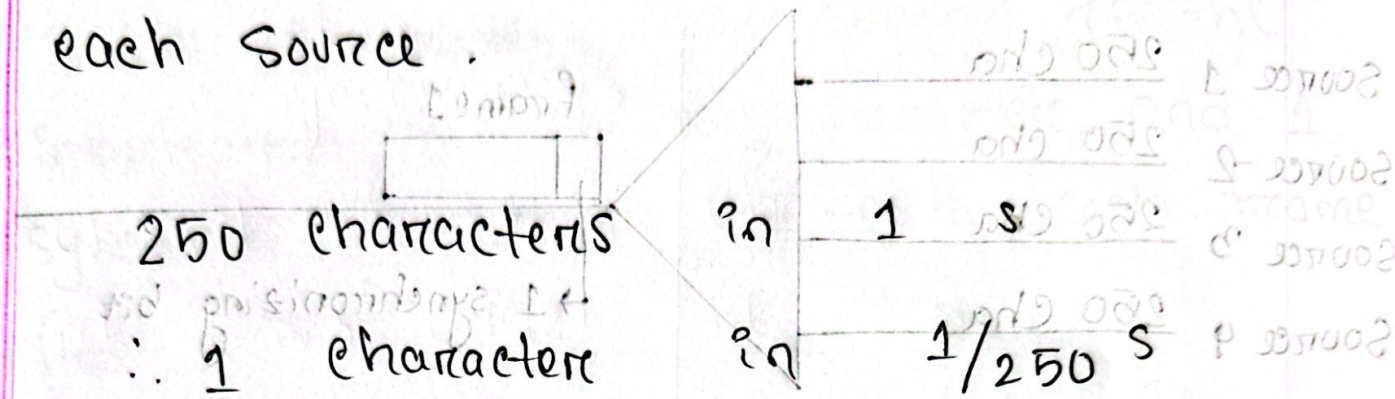
a) Data rate of each source.

= (250 x 8) bps

= 2000 bps.

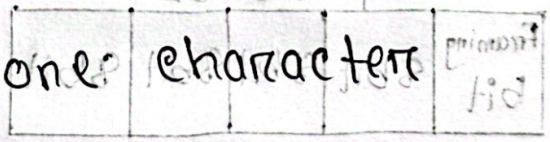
(Ans).

b) the duration of each character in each source.



$= 1/250$ s

c) The frame rate



250 characters send for 250 frame.

∴ frame rate 250 f/s

d) Frame duration

input duration = frame duration = $1/250$ s.

e) The number of bits per frame.

Frame bit 1	8 bit	8 bit	8 bit	8 bit

Frame.

∴ Bits per frame = $(4 \times 8) + 1$

= 33 bits per frame.

f) The data rate of the link.

250 frames per second.

data rate = (250×33)

= 8250 bits. per second

(Ans)

TDM Slot Comparision

Synchronous	Statistical
Channel data send না করলেও আমরা Frame এর মধ্যে empty slot হিসেবে রাখে দেই.	Channel data send না করলে আমরা frame এর মধ্যে empty slot রাখি না.
যেই সংখ্যা line/channel সেই সংখ্যা Division/ unit in frame.	Frame এ slot/unit কম থাকে, Data send হয়ে গেল, Data rate কমে যায়.
	Slot/unit of frame will be less than channels.
Diagram	Diagram এখানে frame এর মধ্যে channel এর slot লেখার আগে address 3 লিখতে হ

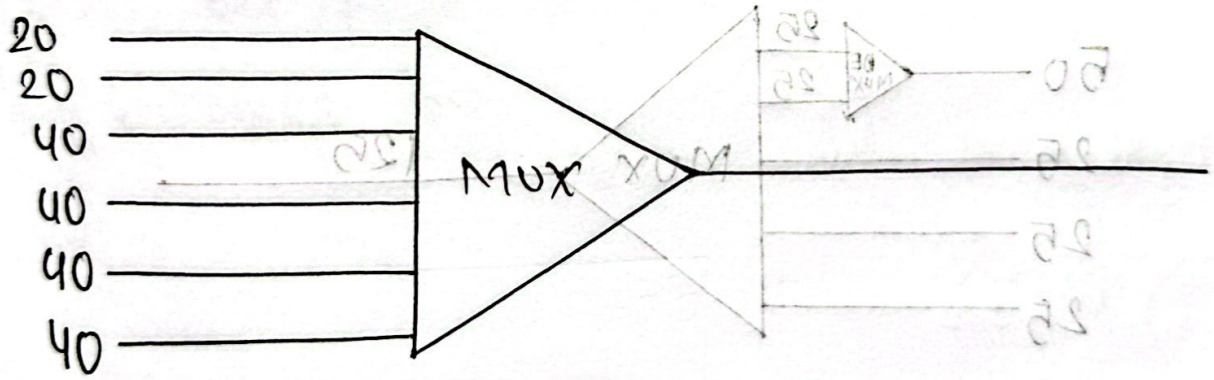
Data Rate Management:

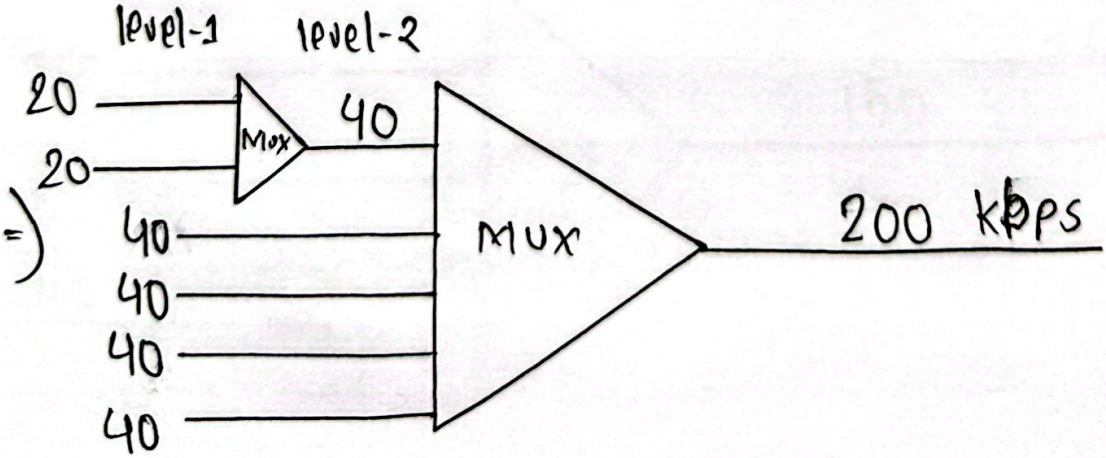
i) Multilevel Multiplexing

ii) Multiple-slot Allocating

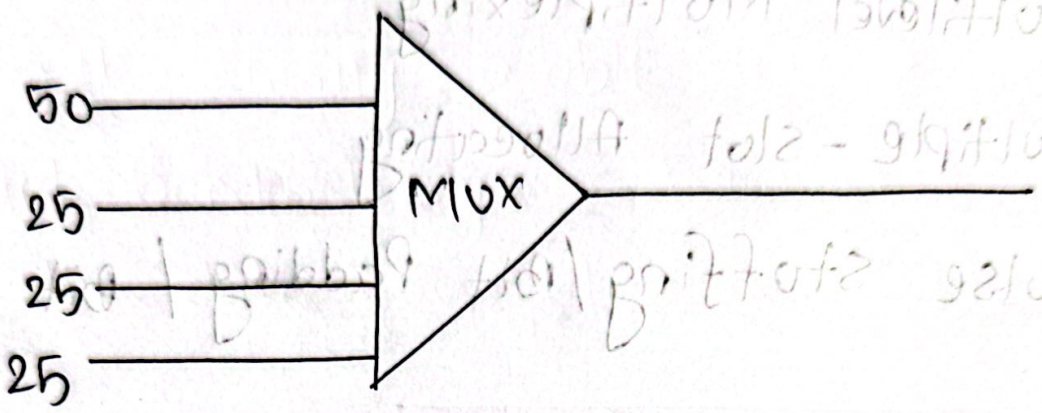
iii) Pulse stuffing / Bit Padding / Bit Stuffing

(i)

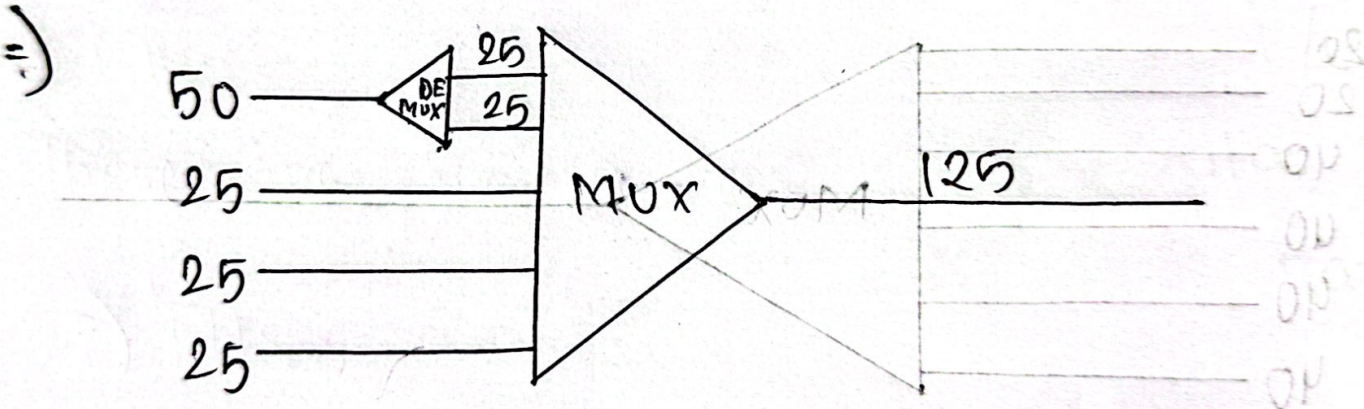




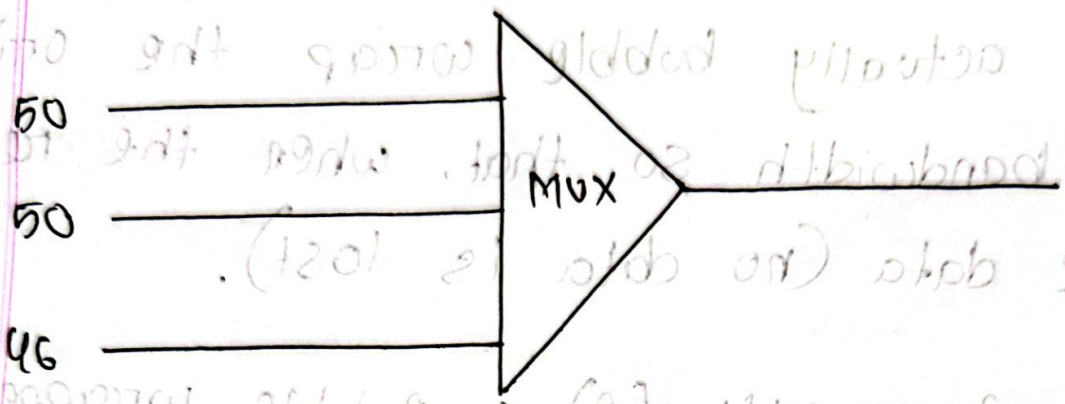
(ii)



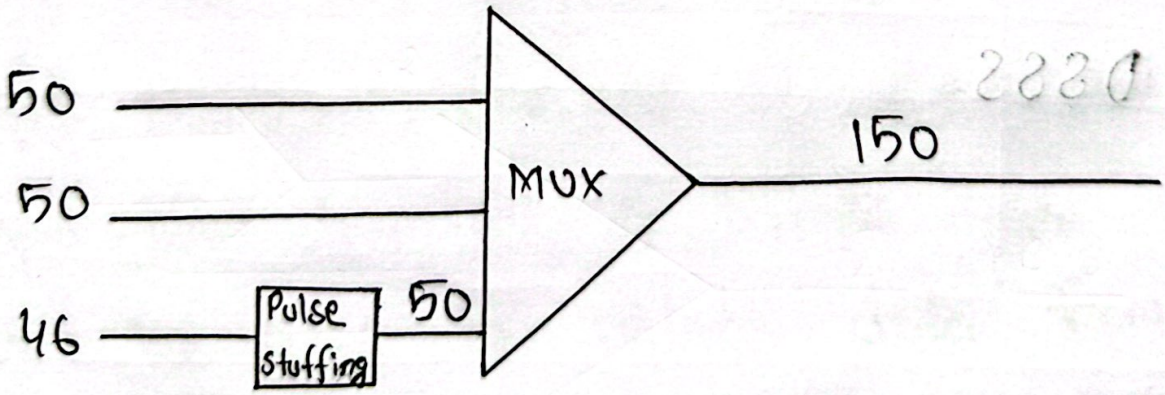
(i)



(iii)



↳ What we will do is, we will add some extra bit/pulse to the channel, so that it becomes 50.



Spread Spectrum:

We do this in the wireless medium.

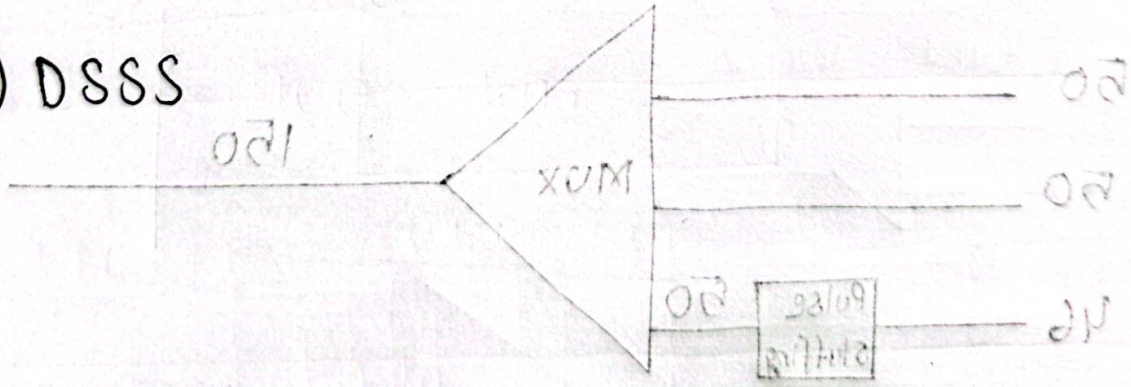
We will actually bubble wrap the original channel bandwidth so that, when the reciever gets the data (no data is lost).

Original Bandwidth (B) << Bubble wrapped Bandwidth (Bss).

There are two process:-

i) FHSS

ii) DSSS



Frequency Hopping Spread Spectrum: (FHSS)

$B << B_{FHSS}$.

M = number of divisions we will do to the given signal. Number of frequency.

K = it will give bit pattern of a digital signal.

001011101011 → Data code

In FHSS, if anyone doesn't know the bit pattern, number of frequencies again bit and number of hoppes then no one will be able to retrive data from the signal.

FHSS

k-bit pattern

k=3	101	111	001	000	010	110	011	100

k-bit	frequency
000	200 kHz
001	300 kHz
010	400 kHz
011	500 kHz
100	600 kHz
101	700 kHz → first hop frequency
110	800 kHz
111	900 kHz

n=8

এই table যেমন আকার and প্রতিটি সংখ্যার আমরা বুঝাতে পারি কোন bit এর against এ কত frequency

frequency table

Hopping period / Hopping frequency = M

Circle and Hopping are same.

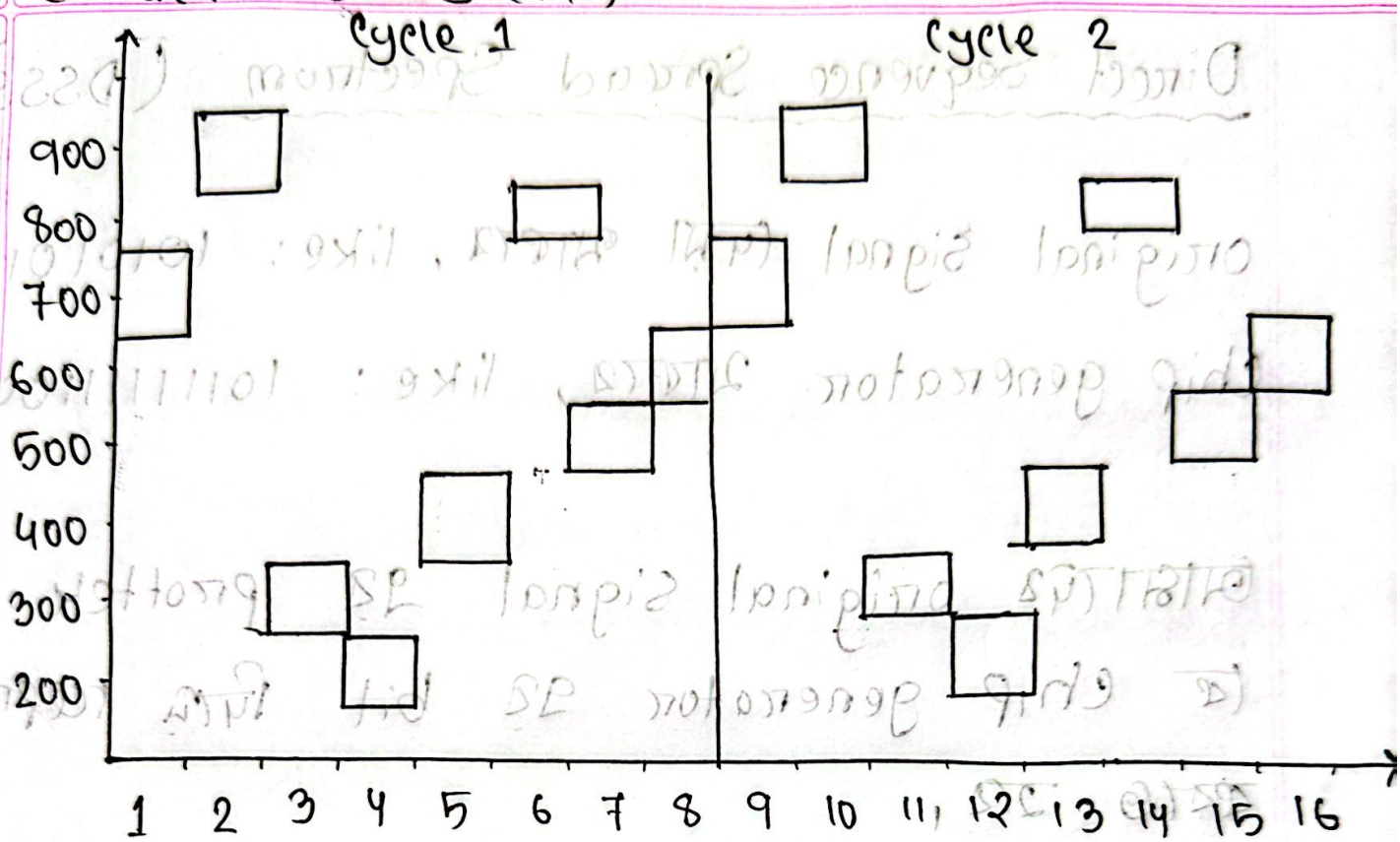
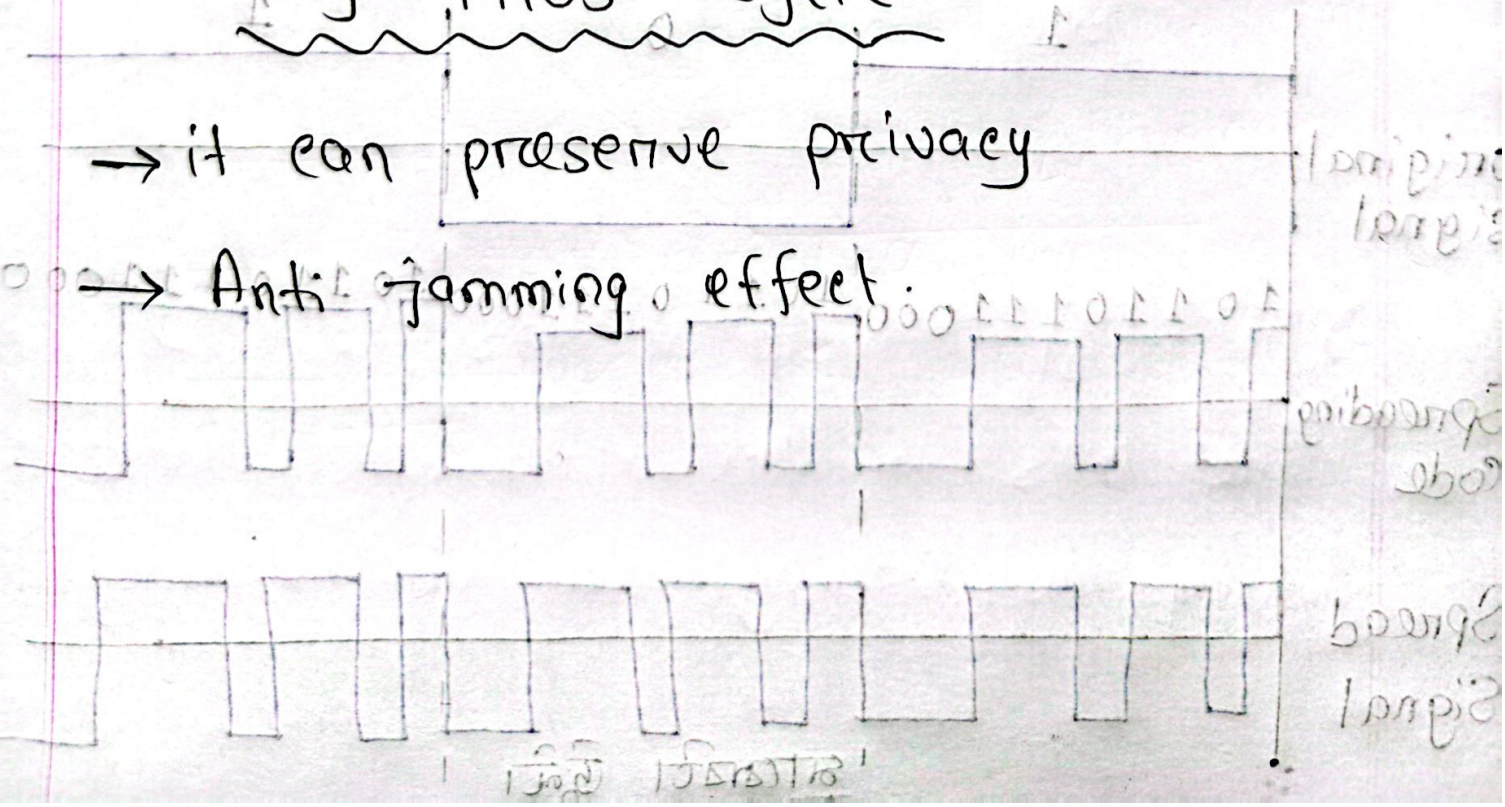


Fig : FHSS Cycle

→ it can preserve privacy

→ Anti-jamming effect.



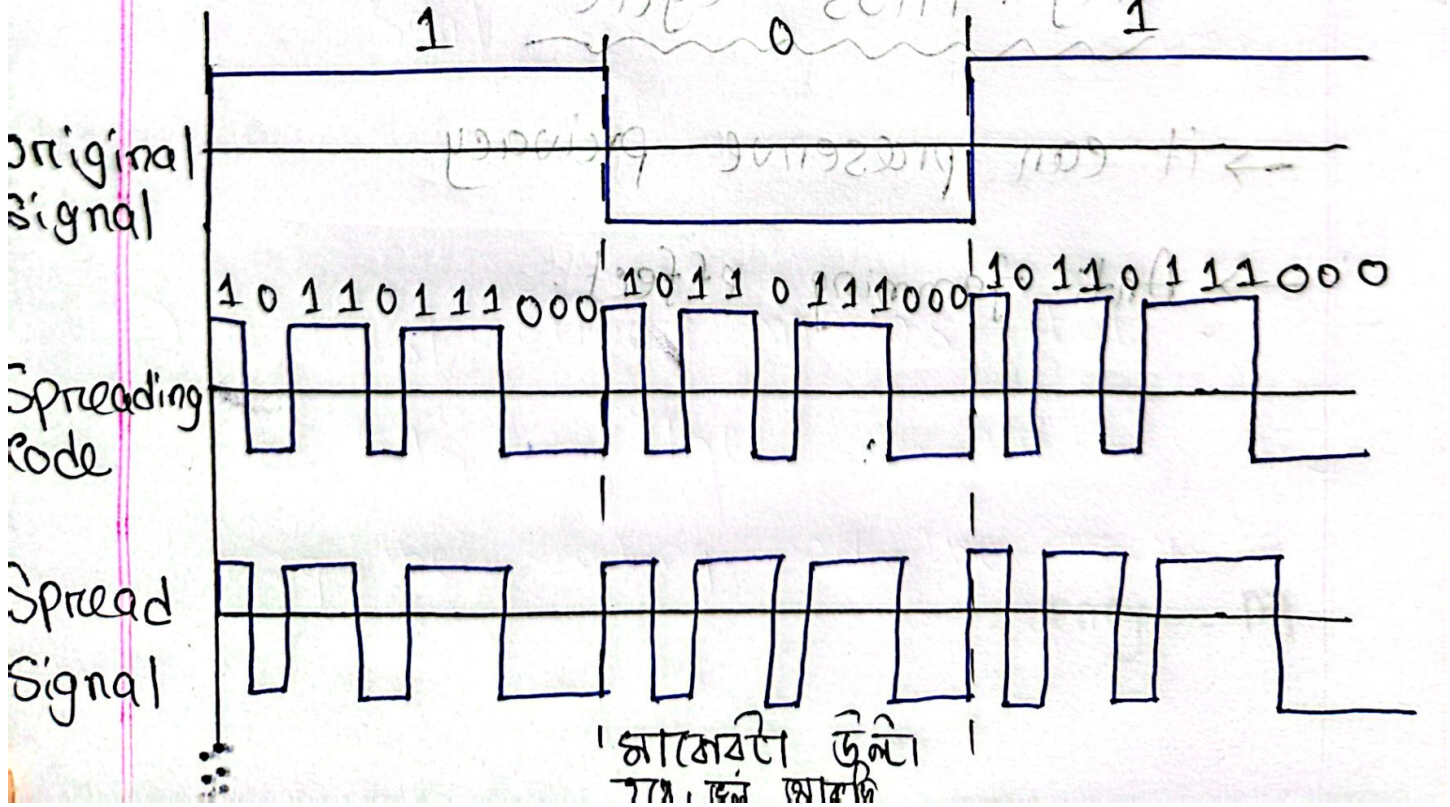
Direct Sequence Spread Spectrum (DSSS).

original signal যেমন আকার, like: 10101011

chip generator আকারে, like: 10111111100011

আমাদের original signal এর protitek bit কে chip generator এর bit দিয়ে represen করতে হবে।

original signal কে chip generator দিয়ে represent করলেই হয়ে যায় Spread Signa



Spread signal টা polar NRZ এর আগে কাজ করে, But kahini আগে সেটা হলো

polar NRZ এর concept হলো

1 → ⎍ positive

0 → ⎵ negative