Lectures 3 & 4

Topics

- DSB-WC: Modulation & Demodulation
- Spectrums of DSB-SC and DSB-WC
- QAM: Modulation & Demodulation

Problems with Synchronized Demodulation of DSB-SC

- Demodulation needs multiplication (but **multiplication is costly**!!)
- Multiplier has to be a **perfect match** in terms of frequency and phase

Alternative:

- Transmitter will send the carrier $A\cos\omega_c t$ alongside the modulated signal $m(t)\cos\omega_c t$
- Also known as **DSB-WC**

DSB-WC

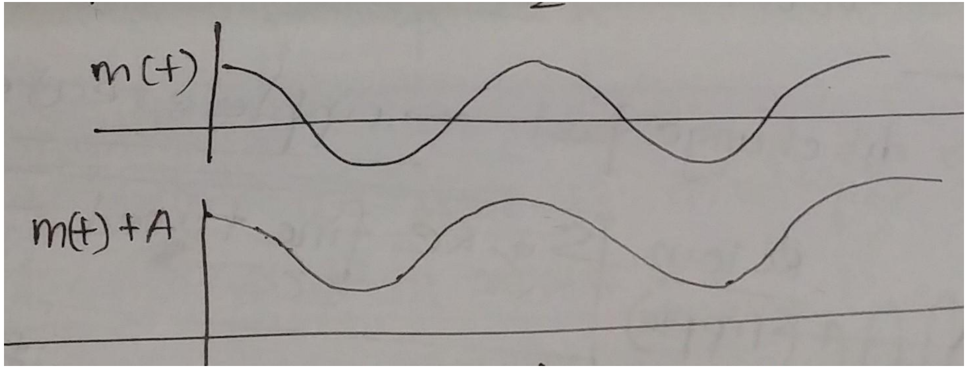
- Transmitter will send the carrier $A\cos\omega_c t$ alongside the modulated signal $m(t)\cos\omega_c t$
  - In this case, the transmitter has to transmit more power, which is costly
- In point-to-point communication, there is a single transmitter and a single receiver
  - Using a costly receiver is justified (DSB-SC)
- In a broadcast communication system with multiple receivers
  - Using a single high power transmitter and several simple receivers make more sense (DSB-WC)

DSB-WC

The transmitted signal:

$T = m(t)\cos\omega_c t + A\cos\omega_c t$

$= [m(t) + A]\cos\omega_c t$



DSB-WC

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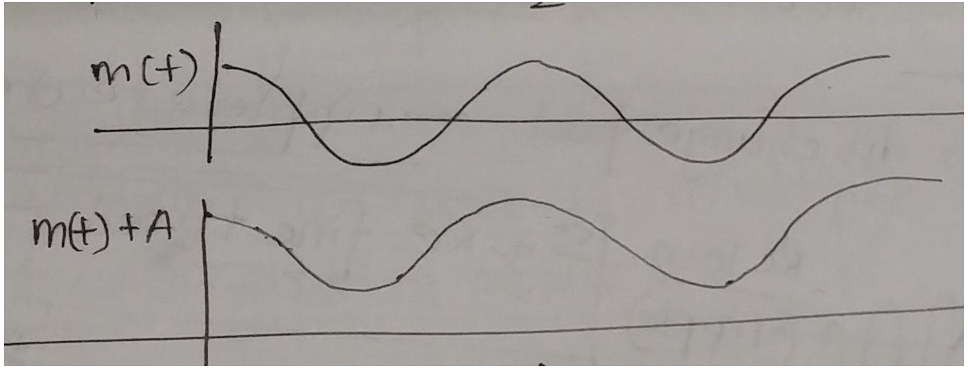


Tone Modulation

Tone: If the baseband signal is a sinusoid, it is called tone.

Tone Modulation: Modulation done to a tone is known as tone modulation

DSB-WC: Modulation

DSB-WC : Modulation

$$T = m(t)\cos\omega_c t + A\cos\omega_c t$$

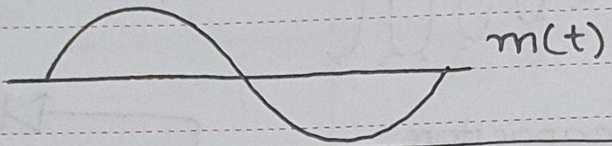
$$\therefore T(\omega) = \frac{1}{2}M(\omega+\omega_c) + \frac{1}{2}M(\omega-\omega_c)$$

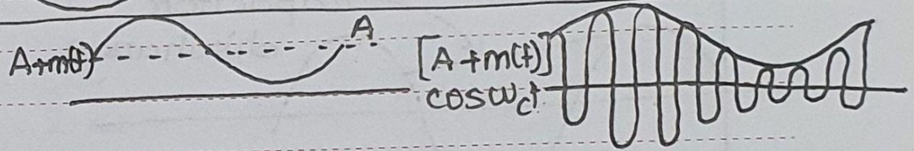
$$+ \frac{A}{2}\delta(\omega+\omega_c) + \frac{A}{2}\delta(\omega-\omega_c)$$

This is the same as DSB-SC, with two extra impulses at $\pm\omega_c$

DSB-WC: Envelope Detection

DSB-WC : Envelope Detection :





Case 1 : $A+m(t) > 0$
for all values of t

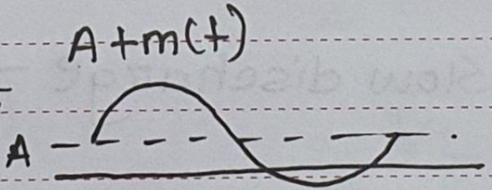
*** Envelope Detection is possible

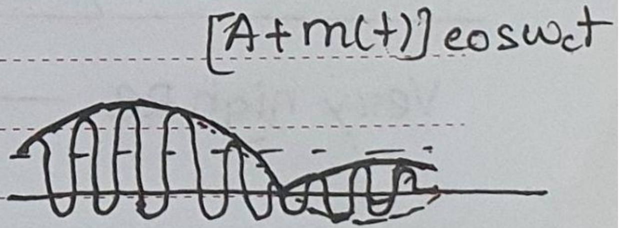
In this case, the Envelope (obtained by joining peak to peak) has the same shape as m(t) [riding on DC magnitude A]

DSB-WC: Envelope Detection

Case 2: $A + m(t) \ngtr 0$
for all values of t

*** Envelope Detection is not possible





In this case, some portion of the envelope is rectified

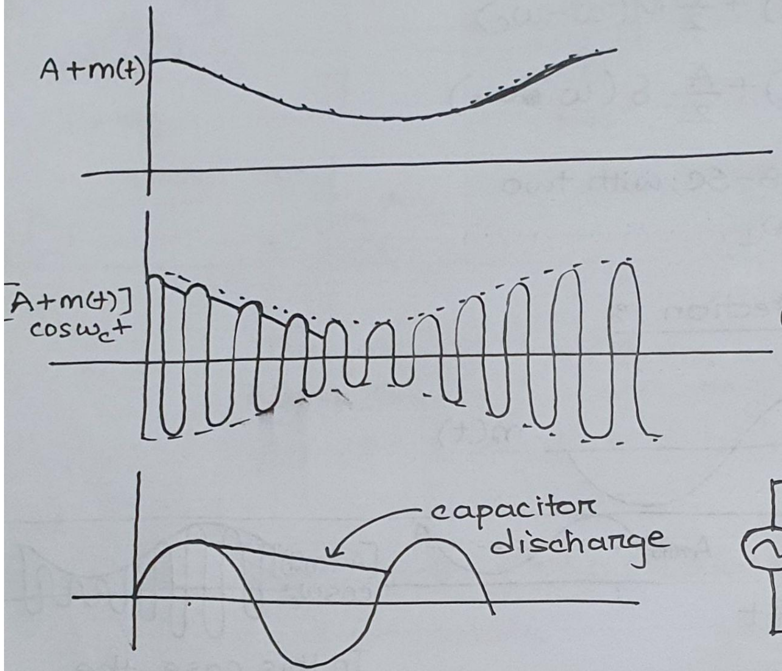
[cannot be $m(t)$ recovered]

DSB-WC: Envelope Detection

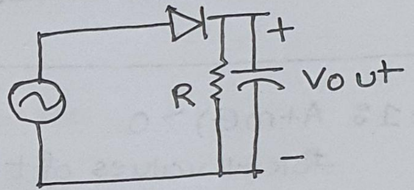
Envelope Detection: Cheaper + Easier!!

- DSB-WC demodulation is easier

DSB-WC: Envelope Detection (Value of RC)



For demodulation, we will consider the peaks and join them

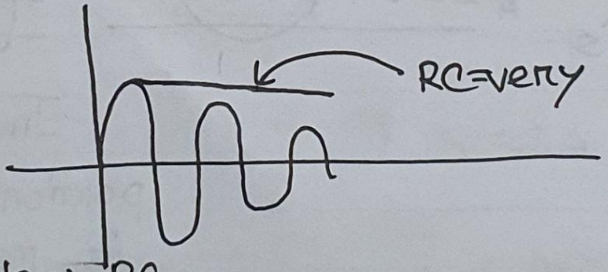


The value of RC needs to be perfectly tuned for envelope detection

DSB-WC: Envelope Detection (Value of RC)

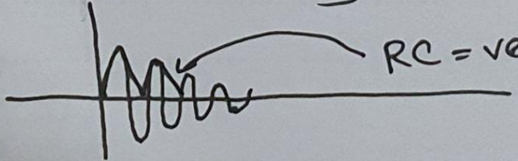
Case1: Very high RC

Very high RC → Slow discharge → Signal distortion



Case2: Very low RC

Very low RC → fast discharge → Ripple effect



DSB-WC: Envelope Detection (Value of RC)

RC has to be fine tuned!!

Solution :

1. Using the current value of RC to generate more accurate values of RC

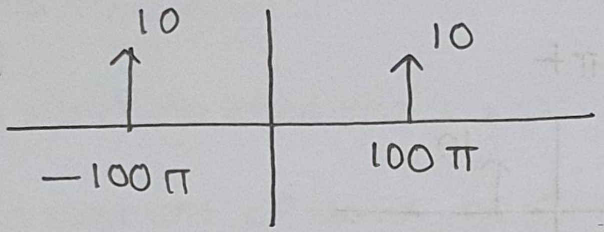
2. Using a capacitor

$$\frac{1}{\omega_c} << RC < \frac{1}{2\pi B}$$

(for ripple) (for distortion)

Spectrum Drawing

$\boxed{10\cos 100\pi t}$



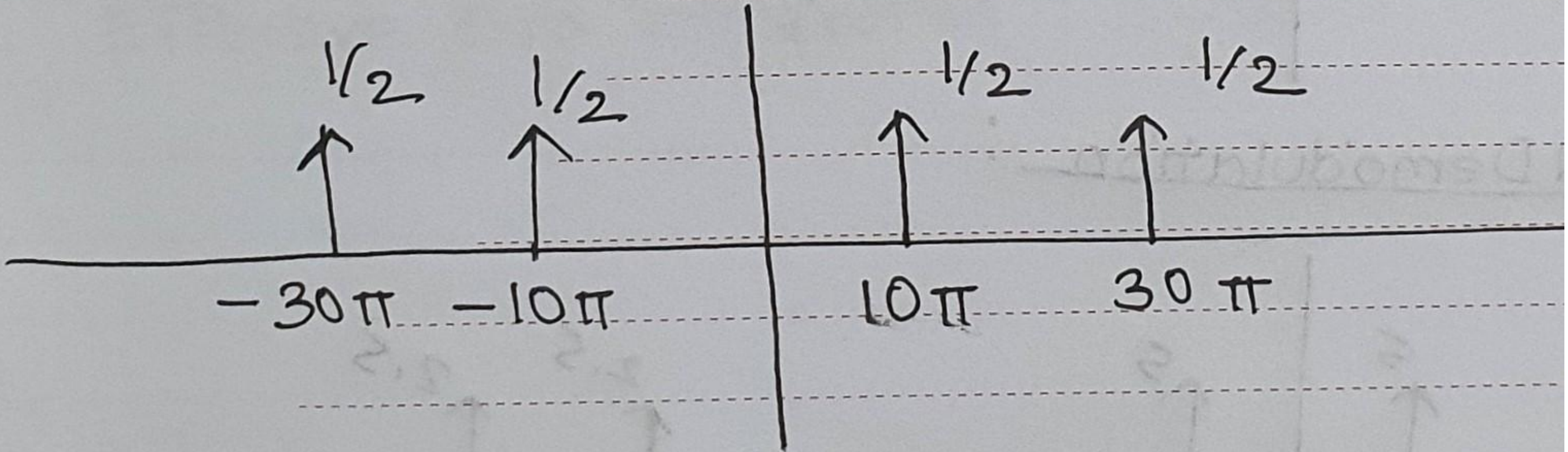
$$\boxed{\cos 10\pi t \cos 20\pi t} = \frac{1}{2}\cdot 2\cos 10\pi t \cos 20\pi t$$

$$= \frac{1}{2}\left[\cos(10+20)\pi t + \cos(20-10)\pi t\right]$$

$$= \frac{1}{2}\left[\cos 30\pi t + \cos 10\pi t\right]$$

$$= \frac{1}{2}\cos 30\pi t + \frac{1}{2}\cos 10\pi t$$

Spectrum Drawing



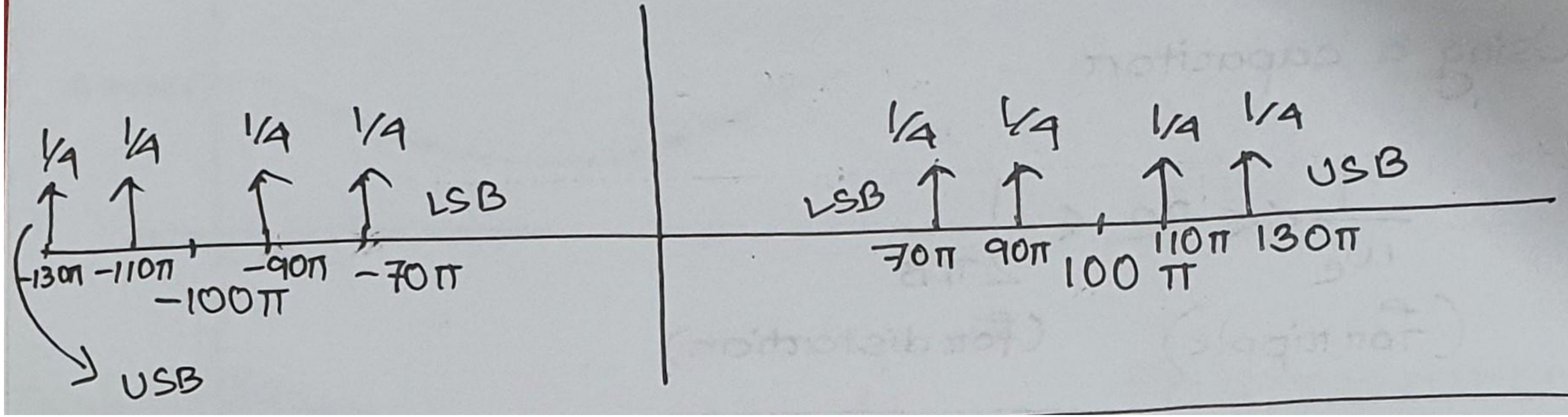
For Modulation: Multiply, then draw

For Demodulation: Multiply, then draw

Spectrum Drawing

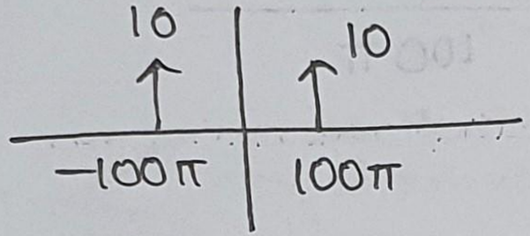
Let the carrier be : $\cos 100\pi t$

DSB-SC : $\frac{1}{2} M(\omega + \omega_c) + \frac{1}{2} M(\omega - \omega_c)$



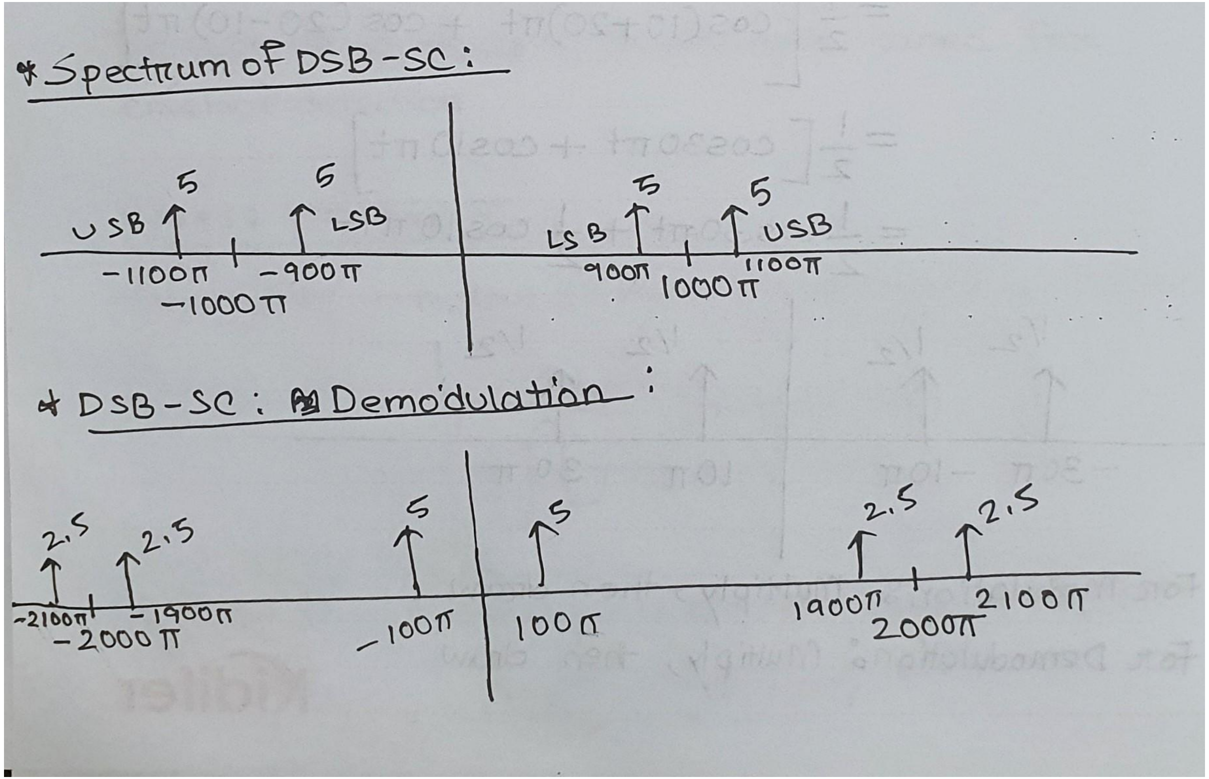
Spectrum Drawing

$$m(t) = 10\cos 100\pi t$$

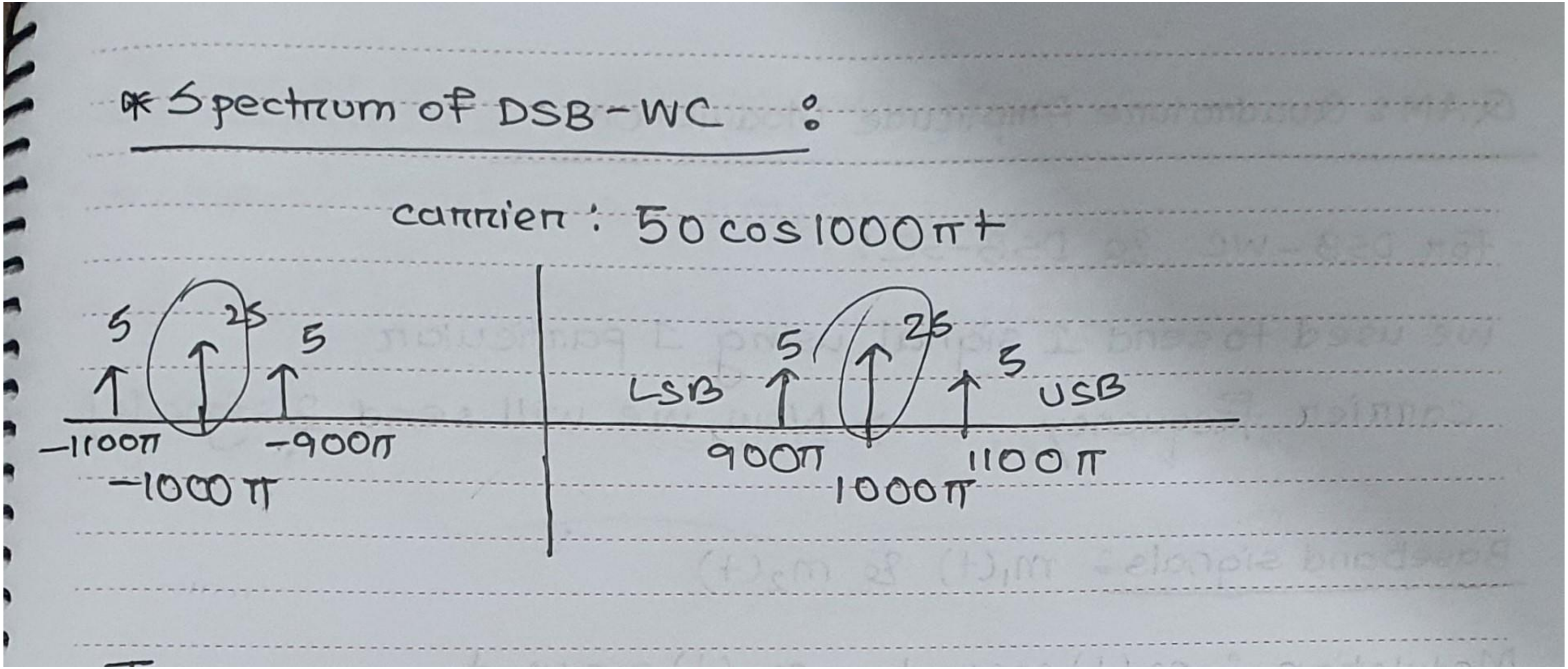


$$\text{carrier} = \cos 1000\pi t$$

Spectrum Drawing



Spectrum Drawing

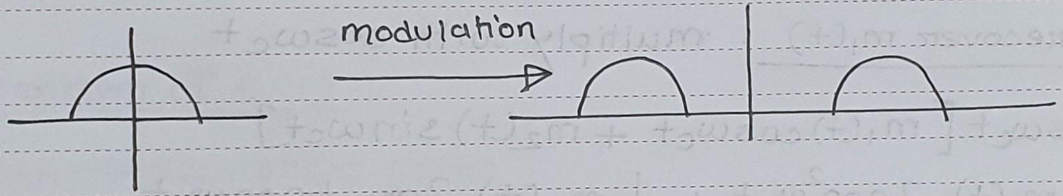


Bandwidth Requirement of DSB and QAM

In DSB-WC & DSB-SC:

Bandwidth used to send the signal : 2B (50% utilization)

To send B amount of data, we need 2B B/W



In QAM:

To send 2 signals, we need 2B B/W

Effective B/W utilization : 100%.

QAM: Modulation

QAM: Quadrature Amplitude Modulation

For DSB-WC & DSB-SC:

we used to send 1 signal using 1 particular carrier frequency → Now, we will send 2 signals!

Baseband signals: $m_1(t)$ & $m_2(t)$

Modulation : $m_1(t) \cos\omega_c t + m_2(t) \sin\omega_c t$

[at the same carrier frequency → 100% b/w utilization]

QAM: Demodulation

Demodulation : Coherent Detection :

To recover $m_1(t)$: multiply with $\cos\omega_c t$

$$* \quad \cos\omega_c t\left[m_1(t)\cos\omega_c t + m_2(t)\sin\omega_c t\right]$$

$$= \frac{1}{2} m_1(t) \cdot 2\cos^2\omega_c t + \frac{1}{2} m_2(t) \cdot 2\sin\omega_c t\cos\omega_c t$$

$$= \frac{1}{2} m_1(t)\left[1+\cos 2\omega_c t\right] + \frac{1}{2} m_2(t)\sin 2\omega_c t$$

$$= \frac{1}{2} m_1(t) + \underbrace{\frac{1}{2} m_1(t)\cos 2\omega_c t + \frac{1}{2} m_2(t)\sin 2\omega_c t}_{\text{Eliminate using a filter}}$$

QAM: Demodulation

To recover $m_2(t)$: multiply with $\sin \omega_c t$

$$* \sin\omega_c t\,[\,m_1(t)\cos\omega_c t + m_2(t)\sin\omega_c t\,]$$

$$= \frac{1}{2} m_2(t)\,[\,1 - \cos 2\omega_c t\,] + \frac{1}{2} m_1(t) \sin 2\omega_c t$$

$$= \frac{1}{2} m_2(t) - \underbrace{\frac{1}{2} m_2(t)\cos 2\omega_c t + \frac{1}{2} m_1(t)\sin 2\omega_c t}_{\text{Discard using a filter}}$$

* Here, we're using phase shift (cos & sin) $\longrightarrow$ phase shift can be done to send a maximum of 16 signals together

QAM: Problems with Demodulation

Problem of QAM :

- Very error prone
- Exact values of $\cos\omega_c t$ & $\sin\omega_c t$ are needed at the receiver end
- Even a tiny phase shift will result in a huge problem

QAM: Problems with Demodulation

Problem during Demodulation of QAM:

To recover $m_1(t)$:

Multiplying with $\cos(\omega_c t + \theta)$

phase shift

$$* \; 2\cos(\omega_c t + \theta)\left[m_1(t)\cos\omega_c t + m_2(t)\sin\omega_c t\right]$$

For ease of calculation

$$= 2m_1(t)\cos\omega_c t\cos(\omega_c t + \theta) + 2m_2(t)\sin\omega_c t\cos(\omega_c t + \theta)$$

$$= m_1(t)\left[\cos(2\omega_c t + \theta) + \cos\theta\right] + m_2(t)\left[\sin(2\omega_c t + \theta) - \sin\theta\right]$$

QAM: Problems with Demodulation

$$= m_1(t)\cos\theta - \underline{m_2(t)\sin\theta}$$

$$+ \underbrace{m_1(t)\cos(2\omega_c t+\theta) + m_2(t)\sin(2\omega_c t+\theta)}$$

These two components can be discarded using a filter

→ Not that big of a problem

→ This is the $\boxed{\text{main problem}}$

$m_2(t)$ is merging with $m_1(t)$

→ cannot recover $m_1(t)$