Principles of Communication Systems

Chapter 2 (part 2): AM Variations

by
Nurulfadzilah Hasan
Faculty of Electrical & Electronics Engineering
nurulfadzilah@ump.edu.my

Chapter 2

2.4 Double side band, single side band and vestigial side band

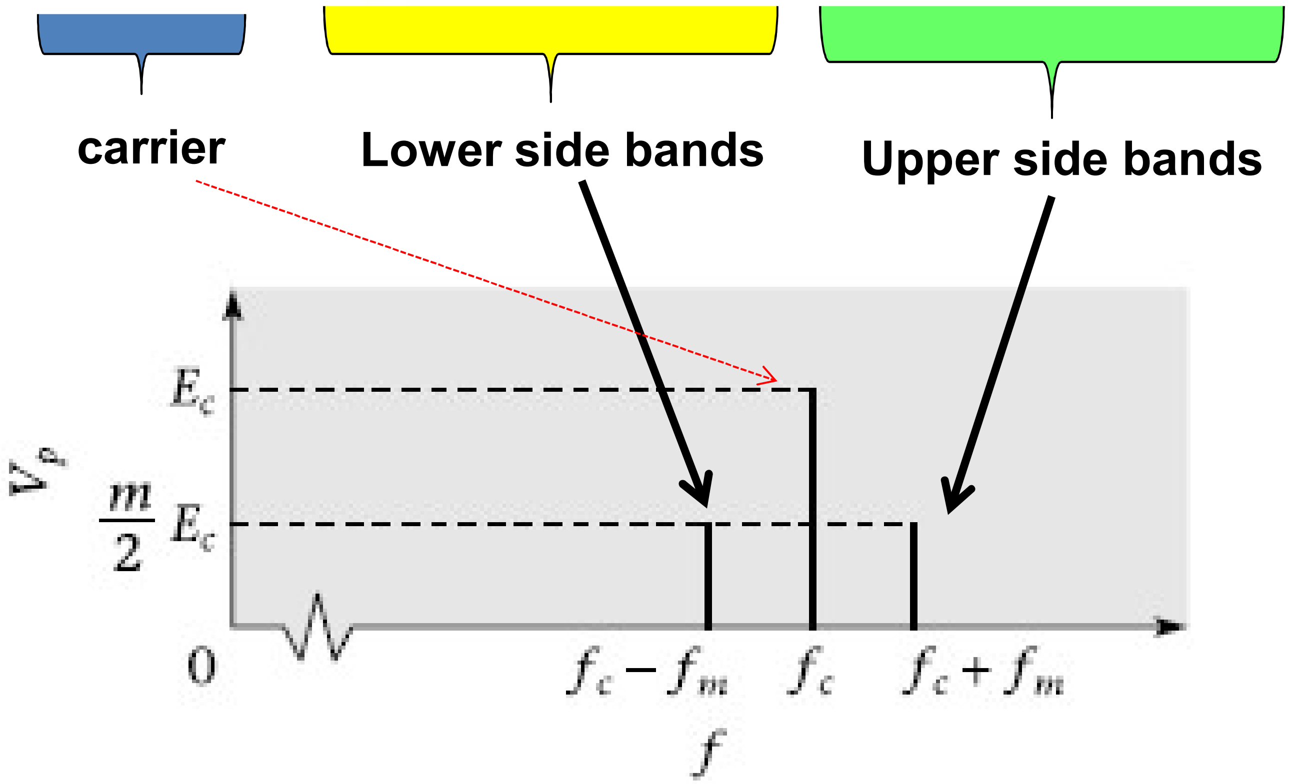
2.5 Suppressed carrier AM

Learning Outcomes

- By the end of this chapter, you should be able to:
  - Solve problems involving AM: SSB, DSB and VSB
  - Compare SSB transmission to conventional DSB

Full carrier AM: Frequency Domain

$$v(t) = E_c \sin \omega_c t + \frac{mE_c}{2}\cos(\omega_c - \omega_m)t - \frac{mE_c}{2}\cos(\omega_c + \omega_m)t$$



Power Relationship

$$P_T = P_c + P_{USB} + P_{LSB}$$

Transmission efficiency, *η* for AM:

$$\eta = \frac{P_{SB}}{P_T} \times 100\%$$

$$P_{SB} = P_{USB} + P_{LSB} = \frac{m^2}{4} P_c + \frac{m^2}{4} P_c = \frac{m^2}{2} P_c$$

$$\eta = \frac{\frac{m^2 P_c}{2}}{P_c\left(1 + \frac{m^2}{2}\right)} \times 100\% = \frac{m^2}{2 + m^2} \times 100\%$$

Power Relationship

If *m* = 1 (100% modulation),

- the average power, P_{SB} = 50% $P_c = P_c/2$
- *Transmission efficiency becomes:*

$$\eta = \frac{m^2}{2+m^2} \times 100\% = \frac{1}{2+1} \times 100\% = 33.33\%$$

AM power efficiency Problems:

- Information are contained in the sidebands, not in the carrier
- But carrier signal occupies 67% of total power: most of the power is wasted in the carrier signal
- Also, the upper and lower sidebands are mirror images of each other: carries exactly the same information.
- SOLUTION?
  - remove the carrier and/or one of its sidebands
    - Suppressed Carrier AM System
  - Remove one of the sidebands
    - Single sideband AM system

Variations of AM

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1) Double sideband full carrier (DSBFC)

- Contains USB, LSB and Carrier
- This is the most widely used type of AM modulation. In fact, all radio channels in the AM band use this type of modulation.

2) Double sideband suppressed carrier (DSBSC)

- Contains only USB & LSB
- A circuit that produces DSBSC is Balanced modulator

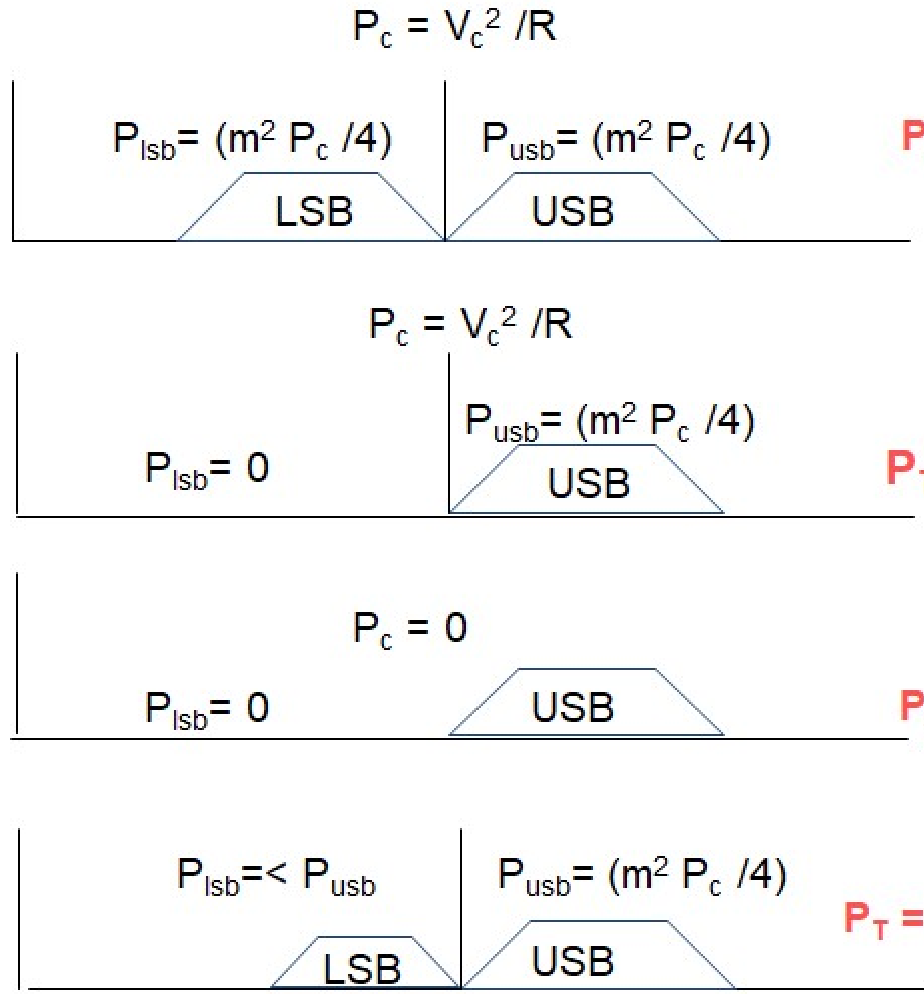
3) Single sideband (SSB)

- In this modulation, only half of the signal of the DSBSC is used
- Contains either LSB or USB
- Produce efficient system in term of power consumption and bandwidth

4) Vestigial Sideband (VSB):

- This is a modification of the SSB to ease the generation and reception of the signal.

Variations of AM



DSBFC AM — $P_T = P_c[1 + (m^2/2)]$

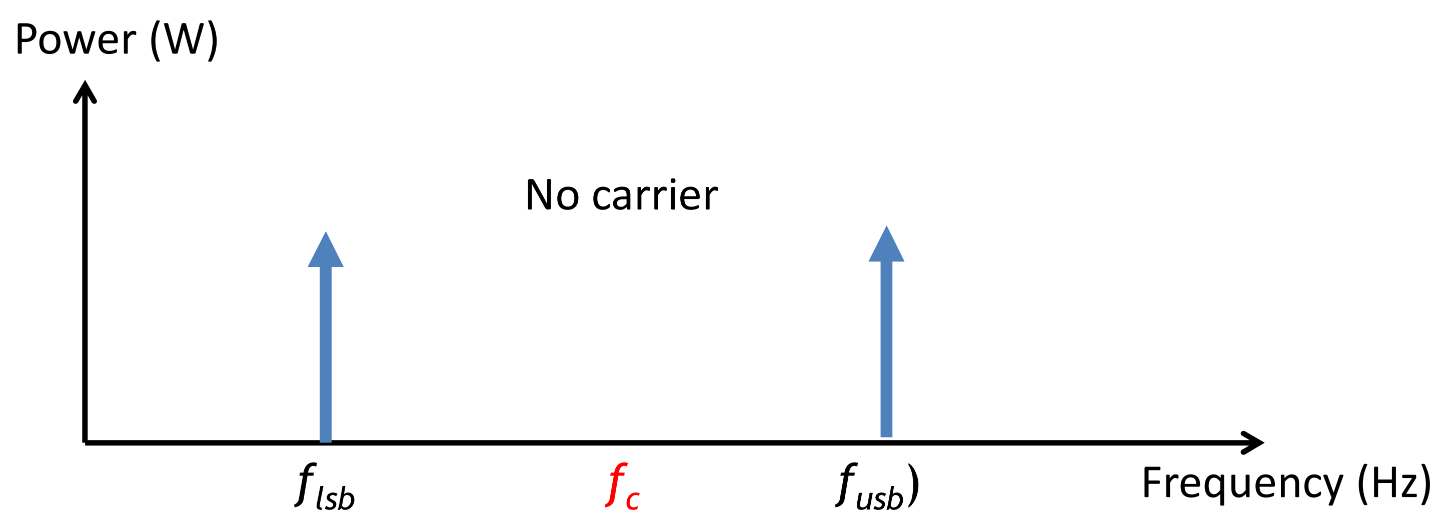
SSBFC AM — $P_T = P_c + (m^2 P_c/4)$

SSBSC AM — $P_{usb} = (m^2 P_c/8) = P_T$

VSB AM — $P_T = P_c + m^2 P_c/4 + P_{lsb}$

DSB Suppressed Carrier (DSBSC)

Generated by circuit called balanced modulator where it produces sum (f_{usb}) and difference (f_{lsb}) freq but cancel or balance out the carrier (f_c).

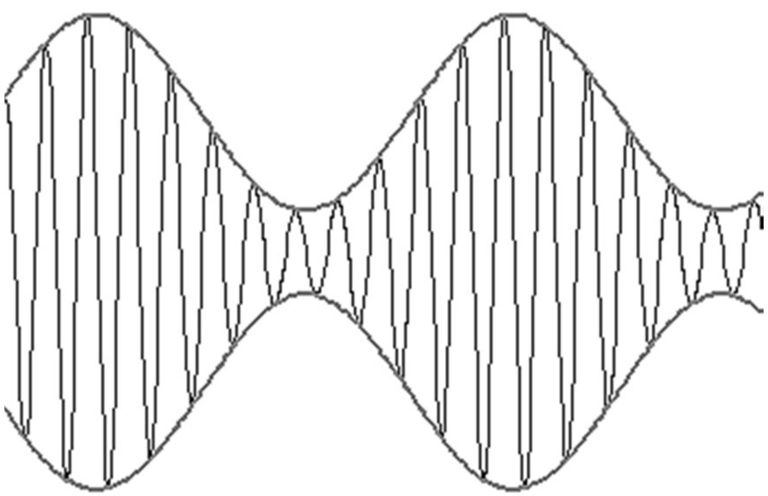


DSBSC helps in reducing power but bandwidth still the same as DSBFC.

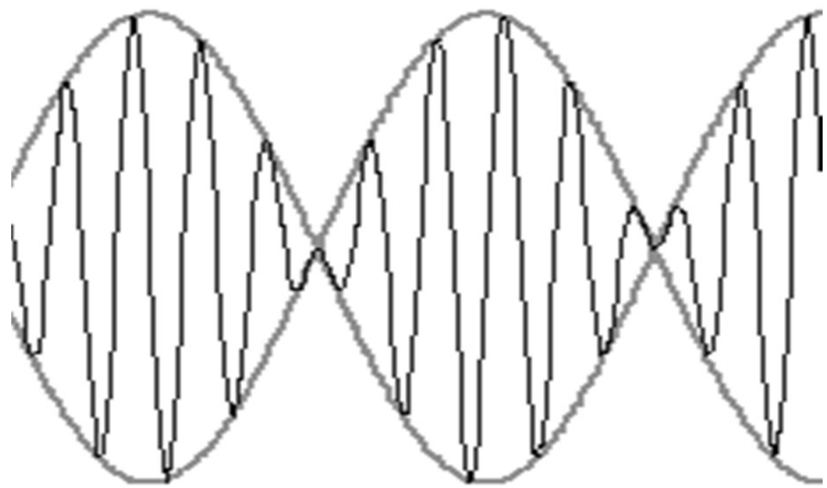
Suppressing the carrier

Double-sideband suppressed carrier (DSSC or DSB) envelope:

Full carrier AM signal



Suppressed carrier AM signal



AM DSBSC Equation:

From full AM equation:

$$v_{DSBSC}(t) = Ec\sin\omega_c t + \frac{mEc}{2}\cos(\omega_c - \omega_m)t + \frac{mE_c}{2}\cos(\omega_c + \omega_m)t$$

Remove the carrier signal, the equation becomes:

$$v_{DSBSC}(t) = \frac{mEc}{2}\cos(\omega_c - \omega_m)t + \frac{mE_c}{2}\cos(\omega_c + \omega_m)t$$

AM DSBSC Power distribution

$$P_T = P_{LSB} + P_{USB}$$

$$= \frac{V^2_{LSB_{rms}}}{R} + \frac{V^2_{USB_{rms}}}{R}$$

$$= \frac{\left(\frac{E_m}{2\sqrt{2}}\right)^2}{R} + \frac{\left(\frac{E_m}{2\sqrt{2}}\right)^2}{R}$$

$$= \frac{E^2_m}{8R} + \frac{E^2_m}{8R}$$

$$= \frac{E^2_m}{4R}$$

In DSBSC, all the power transmitted is sidebands power.

If R = 1 ohm.

$$P_T = \frac{E_m^2}{4}$$

$$P_T = P_{SB}$$

Therefore the efficiency, η = 100%

Single-Sideband Modulation

Single-sideband suppressed carrier (SSBSC): the carrier and one sideband is suppressed

All power is channeled into a single sideband, producing stronger signal

Bandwidth is narrower and noise in the signal is reduced.

But the signals are difficult to demodulate at the receiver.

A low power, **pilot carrier** is sometimes transmitted along with sidebands to help demodulation process at the receiver

AM SSBSC Equation:

From full AM equation:

$$v_{DSBSC}(t) = Ec\sin\omega_c t + \frac{mEc}{2}\cos(\omega_c - \omega_m)t + \frac{mE_c}{2}\cos(\omega_c + \omega_m)t$$

Remove the carrier signal, and one of the sideband, the equation becomes:

LSB:

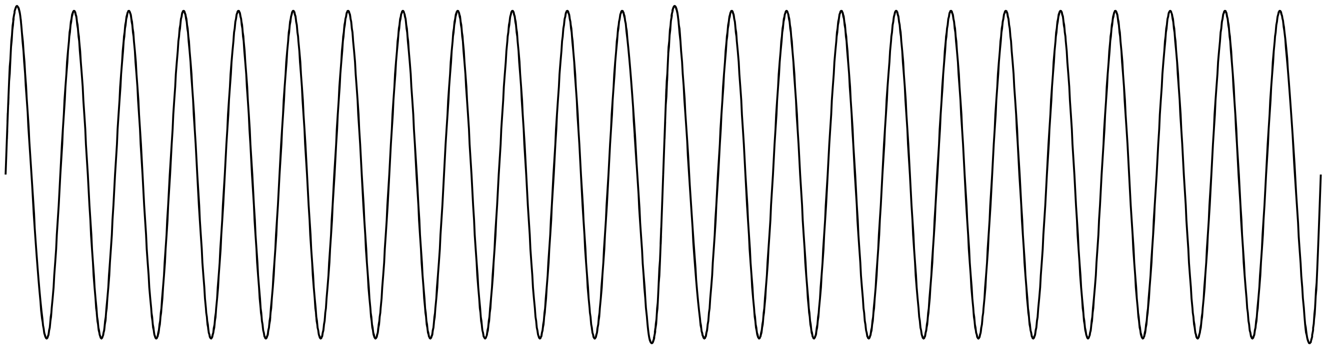
$$v_{LSB}(t) = \frac{mEc}{2}\cos(\omega_c - \omega_m)t$$

USB:

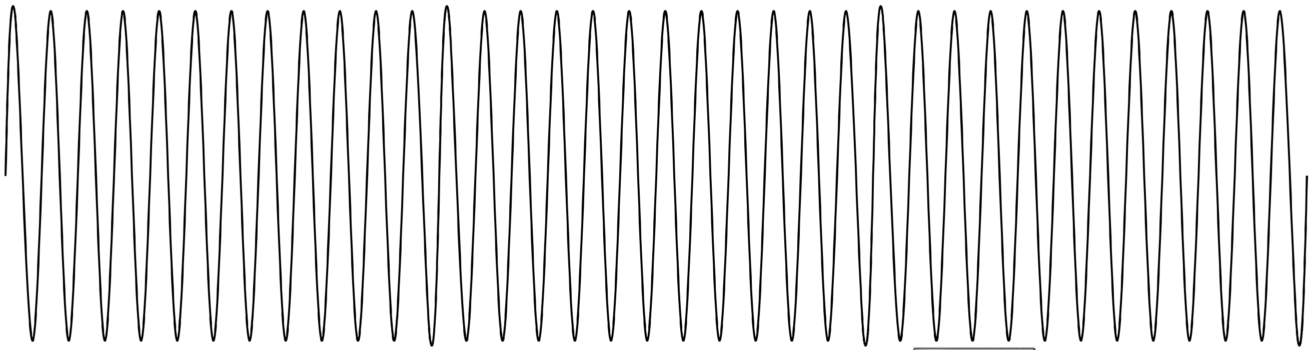
$$v_{USB}(t) = \frac{mE_c}{2}\cos(\omega_c + \omega_m)t$$

Time domain SSB signals

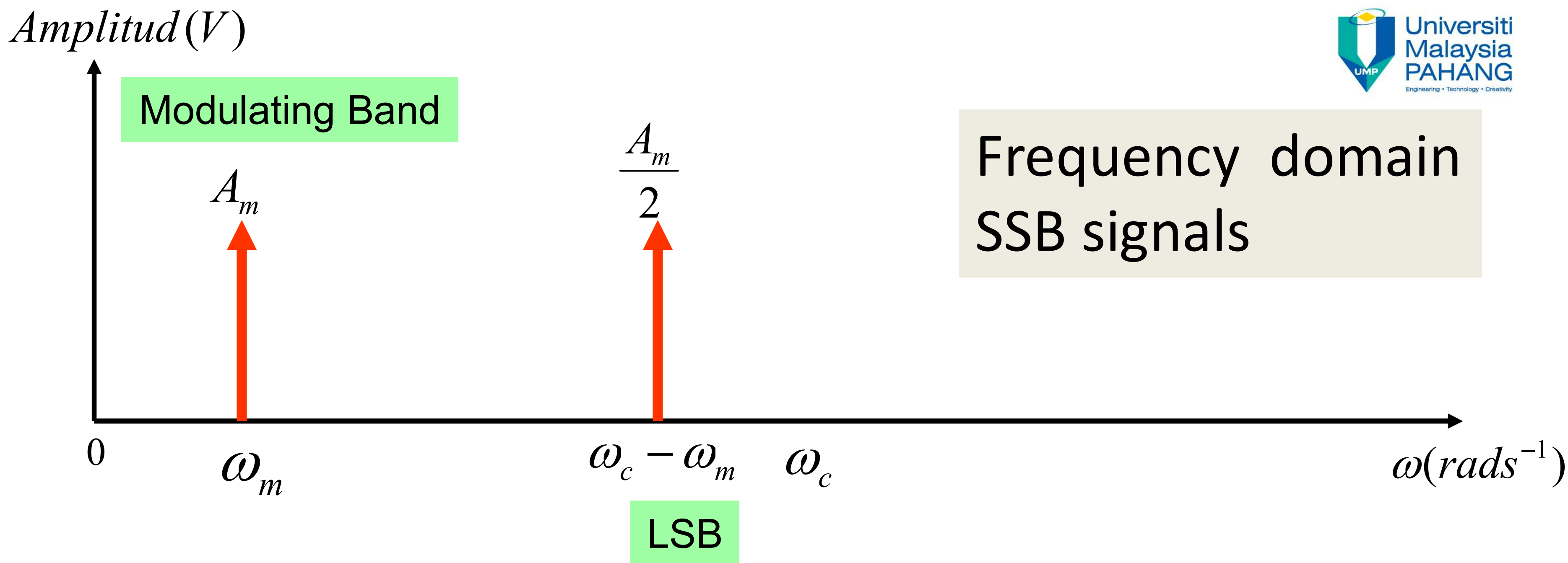
- AM SSB-LSB

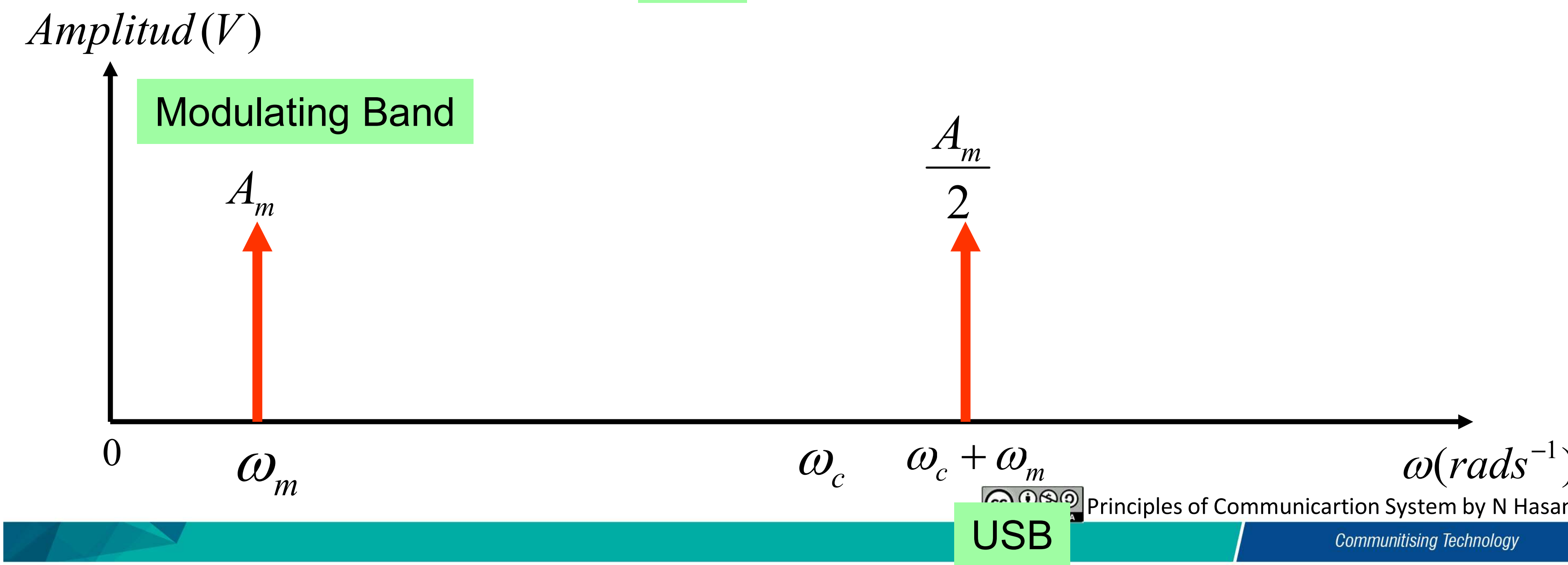


- AM SSB-USB



Frequency domain SSB signals





SSB: Signal Power Considerations

Theoretically,

$$P_T = P_{LSB} = \frac{\left(\frac{E_m}{2\sqrt{2}}\right)^2}{R} = \frac{E_m^2}{8R}$$

OR

$$P_T = P_{USB} = \frac{\left(\frac{E_m}{2\sqrt{2}}\right)^2}{R} = \frac{E_m^2}{8R}$$

Therefore the efficiency, η = 100%

SSB: Signal Power Considerations

- In SSB, the transmitter output is better expressed in terms of **peak envelope power (PEP), the** maximum power produced on voice amplitude peaks.

- Carrier power is useless as a measure of the power in a DSBSC or SSBSC signal

- Why? Because it carrier power is theoretically zero.

- Instead, the peak envelope power (PEP) is used

Peak Envelope Power

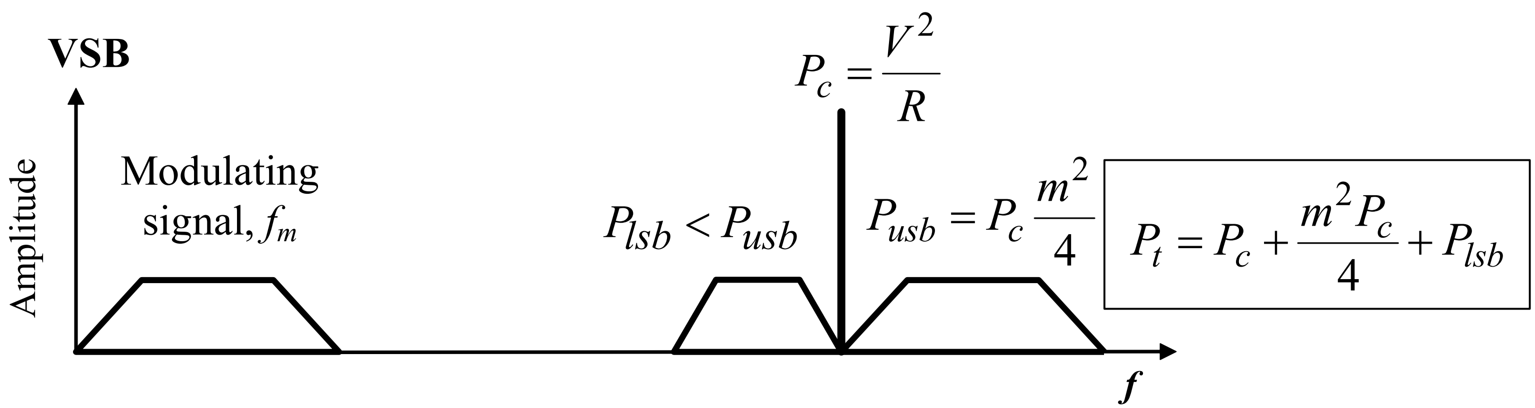
- It is simply the power at modulation peaks, calculated using RMS formula:

$$PEP = \frac{\left(V_p/\sqrt{2}\right)^2}{R_L} = \frac{V_{rms}^2}{R_L}$$

PEP = peak envelope power in Watts
V_p = peak signal voltage in volts
R_L = load resistance in ohms

Vestigial sideband (VSB) transmission

- **Vestigial sideband (VSB) transmission :** Modified AM transmission in which one sideband, the carrier, and only a portion of the other sideband are transmitted
- This kind of signal is used in TV transmission.
- The BW is typically 25% greater than that of SSBSC.



Collaborative authors:

Nurulfadzilah Binti Hasan
Noor Zirwatul Ahlam Binti Naharuddin
Norhadzfizah Binti Mohd Radi
Mohd Hisyam Bin Mohd Ariff

Faculty of Electrical & Electronics Engineering, UMP