EE 4301 - Communication Systems 1

Lecture 14

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FM Spectrum for varying amplitude and frequency of sinusoidal modulating wave

- Number of sidebands produced in FM spectrum is increased with β.

$$\beta = \frac{\Delta f}{f_m} = \frac{k_f A_m}{f_m}$$

- When the frequency of the modulating wave is fixed, but it's amplitude is varied
  - variation occurred in the frequency deviation Δf

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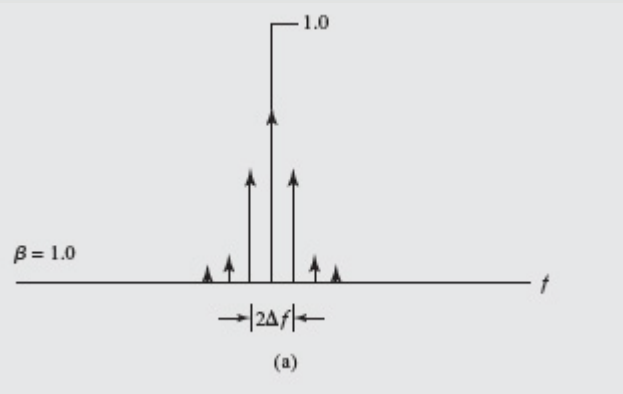

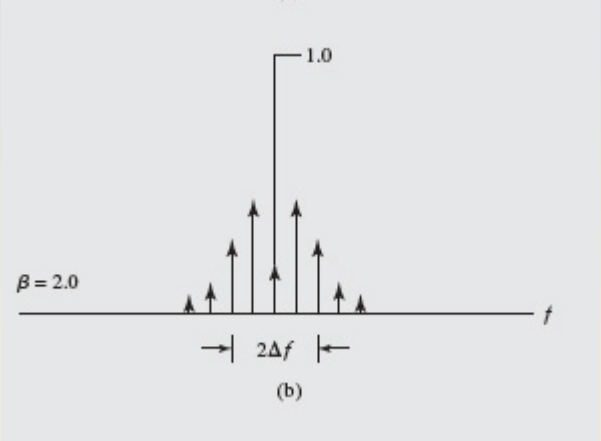

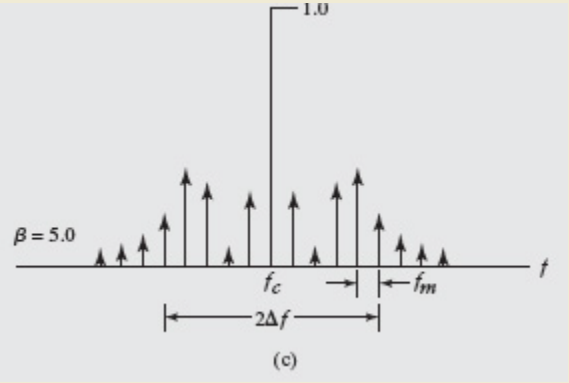

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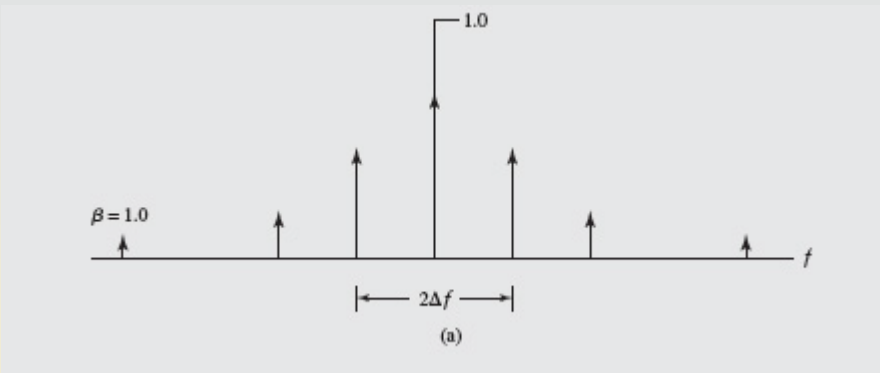
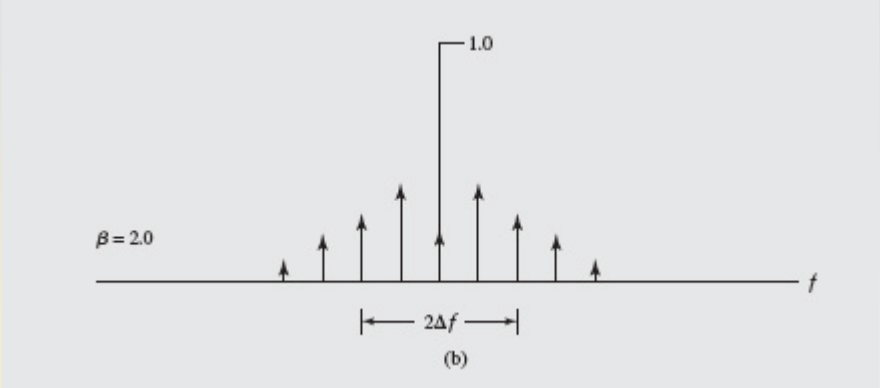
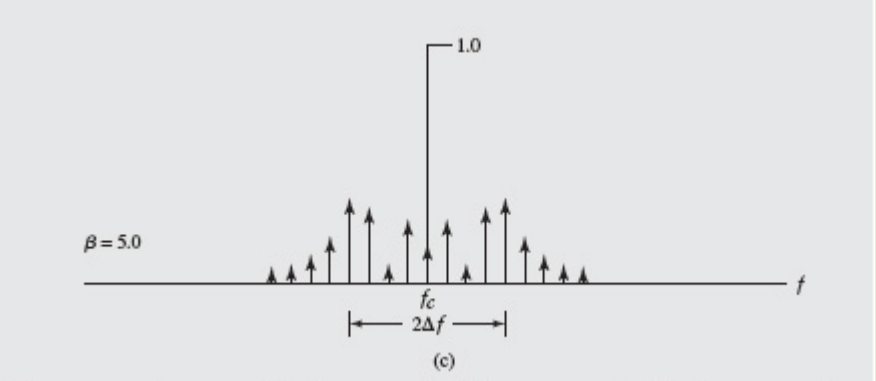






Transmission bandwidth of FM wave

- CARSON's RULE : the FM wave is effectively limited to a finite number of significant side frequencies with specified amount of distortion.
  - For large values of β, bandwidth approaches to slightly greater than Δf
  - For small values of β, bandwidth approaches to $2f_m$

$$B_T = 2(\Delta f + f_m) = 2\Delta f\left(1 + \frac{1}{\beta}\right) \qquad where\ \beta = \frac{\Delta f}{f_m}$$

Transmission bandwidth of FM wave

- Alternative assessment method: based on retaining the maximum number of significant side frequencies whose amplitude all are greater than some selected value.
- This value is 1 percent of unmodulated carrier amplitude.

$$B_T = 2n_{max}f_m$$

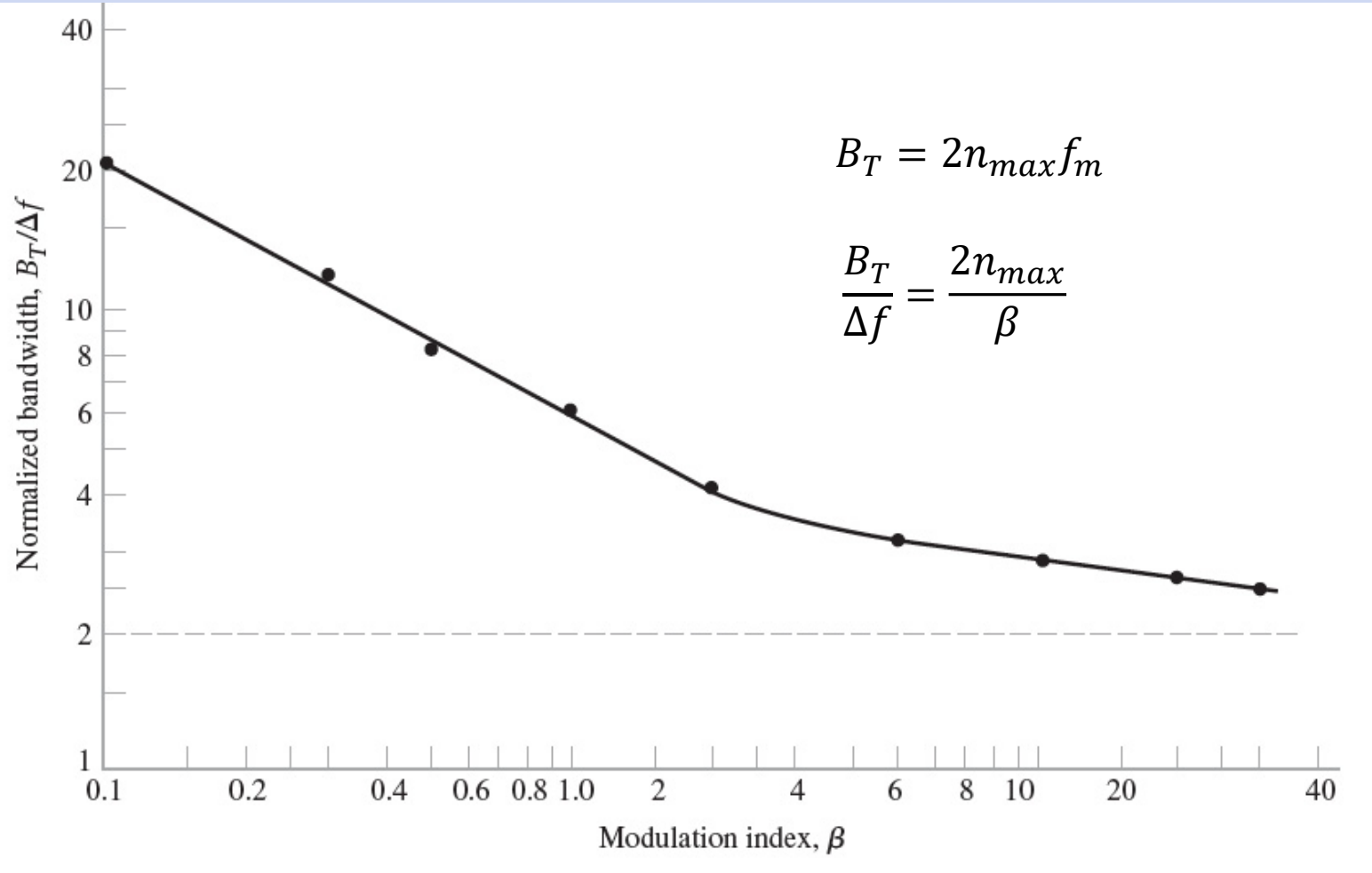
- B_T transmission bandwidth
- f_m modulating frequency
- n_{max} is the largest value of the integer n that satisfies the $|J_n(\beta)| > 0.01$

Transmission bandwidth of FM wave

Number of Significant Side-Frequencies of a Wide-Band FM Signal for Varying Modulation Index

Modulation Index β	*Number of Significant Side-Frequencies* $2n_{max}$
0.1	2
0.3	4
0.5	4
1.0	6
2.0	8
5.0	16
10.0	28
20.0	50
30.0	70

Transmission bandwidth of FM wave



$$B_T = 2n_{max}f_m$$

$$\frac{B_T}{\Delta f} = \frac{2n_{max}}{\beta}$$

Universal curve for evaluating 1 percent bandwidth of FM wave

Transmission bandwidth of FM wave

- Bandwidth requirement for arbitrary modulating waveform (maximum frequency W) is estimated by

$$B_T = 2(D + 1)W$$

- Deviation ratio

$$D = \frac{\Delta f}{W}$$

  - Δf is the maximum frequency deviation
  - W is the highest modulation frequency