Principles of Communication (BEC-28)

Unit-2

Angle Modulation

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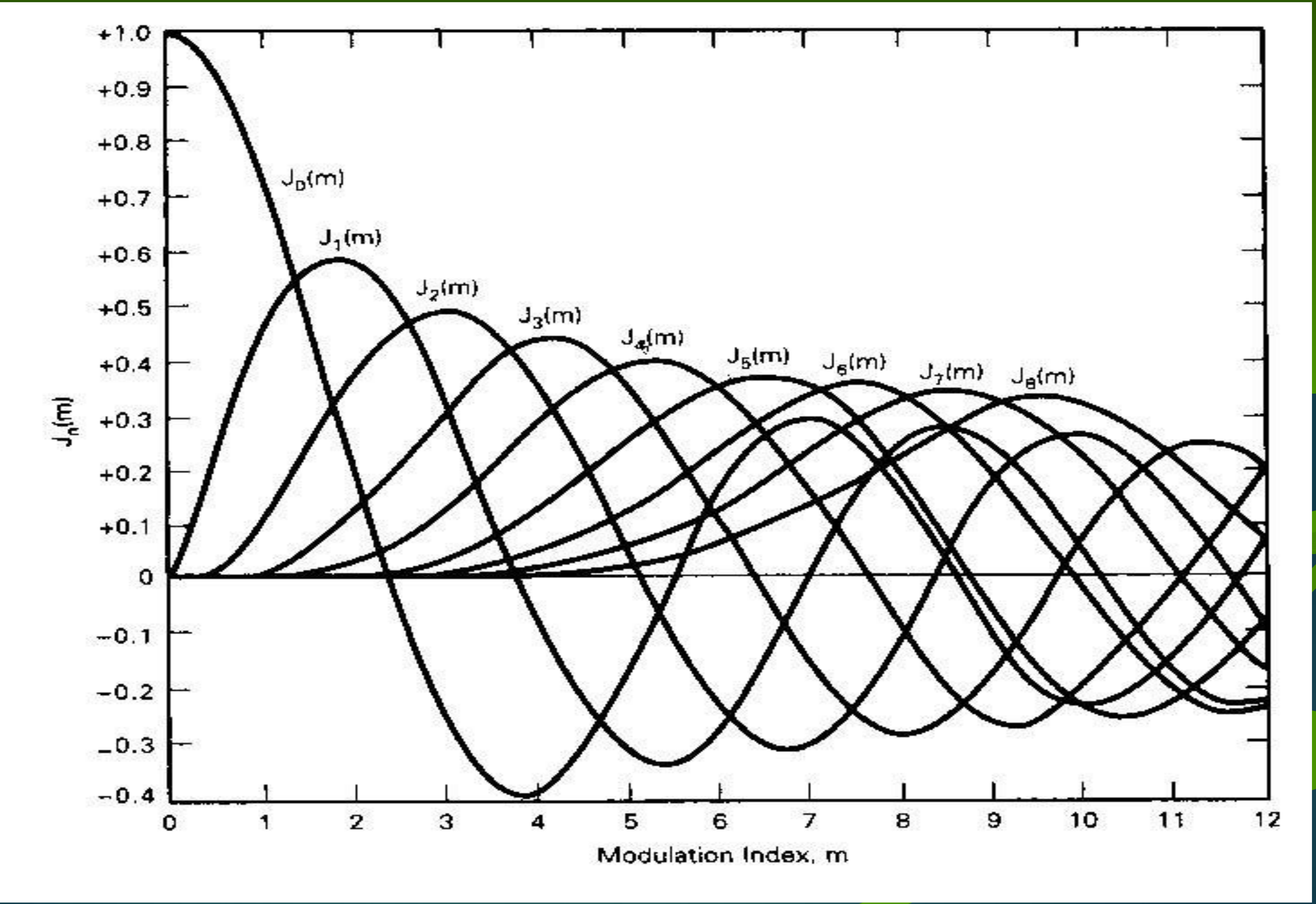
FREQUENCY ANALYSIS OF FM **WAVES**

BESSEL TABLE

Modulation index	Carrier J_0	Sidebands J_1	J_2	J_3	J_4	J_5	J_6	J_7	J_8	J_9	J_{10}
0.0	1.00	—	—	—	—	—	—	—	—	—	—
0.25	0.98	0.12	—	—	—	—	—	—	—	—	—
0.5	0.94	0.24	0.03	—	—	—	—	—	—	—	—
1.0	0.77	0.44	0.11	0.02	—	—	—	—	—	—	—
1.5	0.51	0.56	0.23	0.06	0.01	—	—	—	—	—	—
2.0	0.22	0.58	0.35	0.13	0.03	—	—	—	—	—	—
2.5	−0.05	0.50	0.45	0.22	0.07	0.02	—	—	—	—	—
3.0	−0.26	0.34	0.49	0.31	0.13	0.04	0.01	—	—	—	—
4.0	−0.40	−0.07	0.36	0.43	0.28	0.13	0.05	0.02	—	—	—
5.0	−0.18	−0.33	0.05	0.36	0.39	0.26	0.13	0.06	0.02	—	—
6.0	0.15	−0.28	−0.24	0.11	0.36	0.36	0.25	0.13	0.06	0.02	—
7.0	0.30	0.00	−0.30	−0.17	0.16	0.35	0.34	0.23	0.13	0.06	0.02
8.0	0.17	0.23	−0.11	−0.29	0.10	0.19	0.34	0.32	0.22	0.13	0.06

Tabulated value for Bessel Function for the first kind of the n^{th} order

- The first column gives the modulation , while the first row gives the Bessel function.
- The remaining columns indicate the amplitudes of the carrier and the various pairs of sidebands.
- Sidebands with relative magnitude of less than 0.001 have been eliminated.
- Some of the carrier and sideband amplitudes have negative signs. This means that the signal represented by that amplitude is simply shifted in phase 180° (phase inversion).
- The spectrum of a FM signal varies considerably in bandwidth depending upon the value of the modulation index. The higher the modulation index, the wider the bandwidth of the FM signal.
- With the increase in the modulation index, the carrier amplitude decreases while the amplitude of the various sidebands increases. With some values of modulation index, the carrier can disappear completely.



Bessel Function, $J_n(m)$ vs m

PROPERTIES OF BESSEL FUNCTION

- **Property - 1:**

For n even,

we have $J_n(\beta) = J_{-n}(\beta)$

For n odd,

we have $J_n(\beta) = (-1)\, J_{-n}(\beta)$

Thus,

$$J_n(\beta) = (-1)^n J_{-n}(\beta)$$

- **Property - 2:**

For small values of the modulation index β, we have

$J_0(\beta) \cong 1$

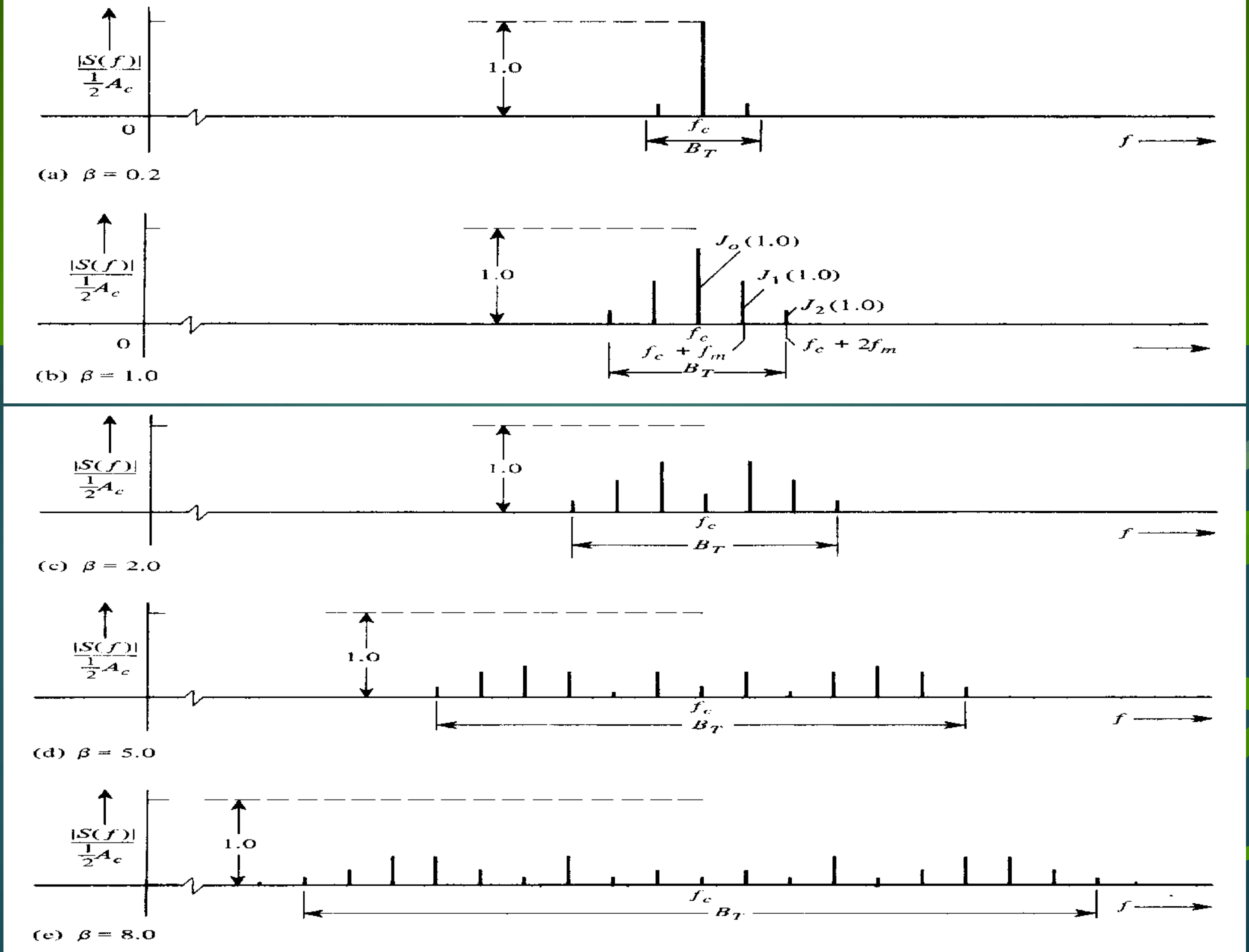
$J_1(\beta) \cong \beta/2$

$J_3(\beta) \cong 0 \quad$ for $n > 2$

Property - 3:

$$\sum_{n=-\infty}^{\infty} J_n^2(\beta) = 1$$

AMPLITUDE SPECTRUM



Amplitude spectrum of different value of β

FM BANDWIDTH

- The total BW of an FM signal can be determined by knowing the modulation index and Bessel function.

$$BW = 2 f_m N$$

N = number of significant sidebands

f_m = modulating signal frequency (Hz)

- Another way to determine the BW is use Carson's rule
- This rule recognizes only the power in the most significant sidebands with amplitude greater than 2% of the carrier.

Example 3

Calculate the bandwidth occupied by a FM signal with a modulation index of 2 and a highest modulating frequency of 2.5 kHz. Determine bandwidth with table of Bessel functions.

Referring to the table, this produces 4 significant pairs of sidebands.

$$BW = 2 \times 4 \times 2.5$$

$$= 20\text{kHz}$$

CARSON'S RULE

$$BW = 2[f_{d\,(\max)} + f_{m(\max)}]$$

$f_{d\,(\max)}$ = max. frequency deviation

$f_{m\,(\max)}$ = max. modulating frequency

- Carson's rule always give a lower BW calculated with the formula BW = $2f_mN$.
- Consider only the power in the most significant sidebands whose amplitudes are greater than 1% of the carrier.
- Rule for the transmission bandwidth of an FM signal generated by a single of frequency f_m as follows:

$$B_T = BW \cong 2\Delta f + 2f_m = 2\Delta f\,(1 + \frac{1}{\beta})$$

$$\text{or} \qquad = 2f_m(1 + \beta)$$


Thank You