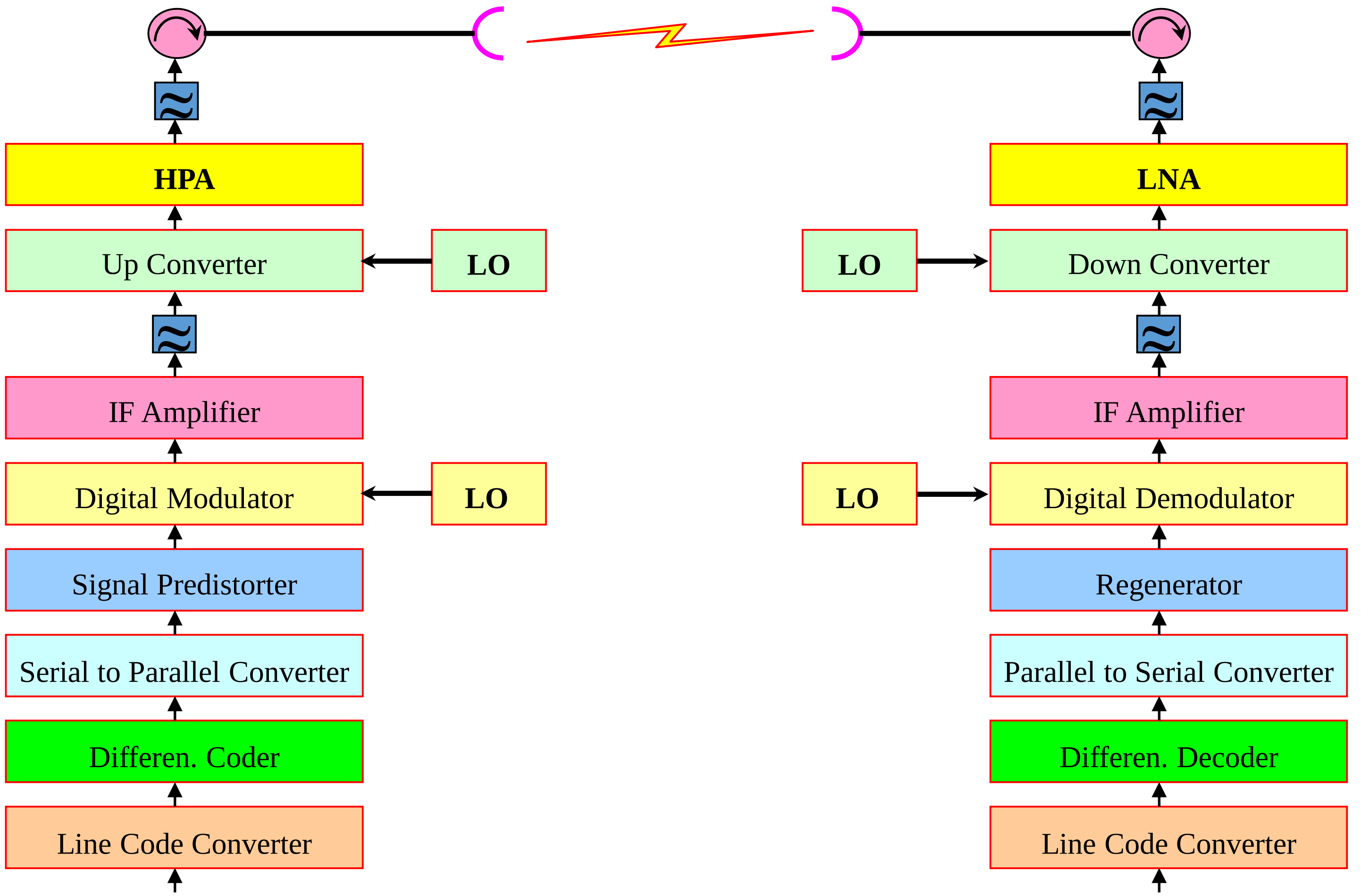
UNJUK KERJA

REF : FREEMAN

BLOK SISTEM KOMUNIKASI RADIO DIGITAL



Energy per bit per Noise density ratio Eb/No

Efisiensi pd siskom dijital yg bernoise dinyatakan dengan Eb/No yg diterima utk mendapatkan laju error yg ditentukan.

Eb : Energi per bit

$$E_{b(watt)} = \frac{RSL_{(watt)}}{R_{(bit/\det)}}$$

$$E_{b(dBw)} = RSL_{(dBw)} - 10\log R_{(bit/\det)}$$

No : aras noise pd penerima sempurna (dBw atau dBm) + noise figure perangkat (dB)

$$N_{o(dBw)} = -204_{(dBw)} + NF_{(dB)}$$

$$E_b/N_o = RSL_{(dBw)} - 10\log B_{(bit/\det)} + 204_{(dBw)} - NF_{(dB)}$$

Isu Regulasi - FCC

- Laju bit (bps) harus >= lebar pita (Hz) yg ditetapkan, kecuali lebar pita yg digunakan menghitung laju minimal tidak termasuk pita pengaman.
- Perangkat yg digunakan utk trans suara yg sudah beroperasi atau yg diaplikasikan sebelum 1 juni 1997:
  - di pita 2110 – 2130 MHz dan 2160 – 2180 MHz lebar pita yg dialokasikan harus mampu menyalurkan minimal 96 kanal.
  - di pita 3700 – 4200 MHz , 5925 – 6425 MHz (lebar pita 30 MHz), 10700 – 11700 MHz (lebar pita 30 dan 40 MHz) harus mampu menyalurkan 1152 kanal
- Kapasitas dan persyaratan pembebanan harus memenuhi perangkat yg digunakan dan beroperasi setelah 1 juni 1997 pada pita 3700 – 4200 MHz , 5925 – 6425 MHz dan 6525 – 6875 MHz (6GHz), 10550 – 10680 MHz (10 GHz) dan 10700 – 11700 MHz (11 GHz) seperti pd tabel berikut :

Nominal channel bandwidth (MHz)	Minimum payload capacity (Mbits/s)	Minimum traffic loading payload (as percent of payload capacity)	Typical utilization
0.400	1.54	N/A	1 DS-1
0.800	3.08	N/A	2 DS-1
1.25	3.08	N/A	2 DS-1
1.60	6.17	N/A	4 DS-1
2.50	6.17	N/A	4 DS-1
3.75	12.3	N/A	8 DS-1
5.0	18.5	N/A	12 DS-1
10.0	44.7	50[3]	1 DS-3/STS-1
20.0	89.4	50[3]	2 DS-3/STS-1
30.0 (11 GHz)	89.4	50[3]	2 DS-3/STS-1
30.0 (5 GHz)	134.1	50[3]	3 DS-3/STS-1
40	134.1	50[3]	3 DS-3/STS-1

Pembatasan Emisi - FCC

- Pd frek < 15 GHz, dlm setiap pita 4 KHz, frek tengah yg menyimpang dr frekuensi yg ditetapkan 50 % <Δf=< 250 % berlaku persamaan berikut tapi tidak boleh kurang dari 50 dB.

$$A = 35 + 0{,}8(P - 50) + 10\log_{10} B$$

  - Redaman > 80 dB atau daya absolut < -13 dBm/1MHz tidak diperlukan.
  - A : redaman (dB) dibawah aras daya keluaran rata-rata
  - P : prosen penyimpangan dr frek tengah lebar pita transmisi
  - B : lebar pita yg dialokasikan (MHz)
- Pd frek > 15 GHz, dlm setiap pita 1 MHz, frek tengah yg menyimpang dari frek yg dialokasikan 50 % <Δf=< 250 % dr lebar pita yg ditetapkan berlaku persamaan sbb, tetapi tidak kurang dr 11 dB.

$$A = 11 + 0{,}4(P - 50) + 10\log_{10} B$$

  - Redaman > 56 dB atau daya absolut < -13 dBm tidak diperlukan.

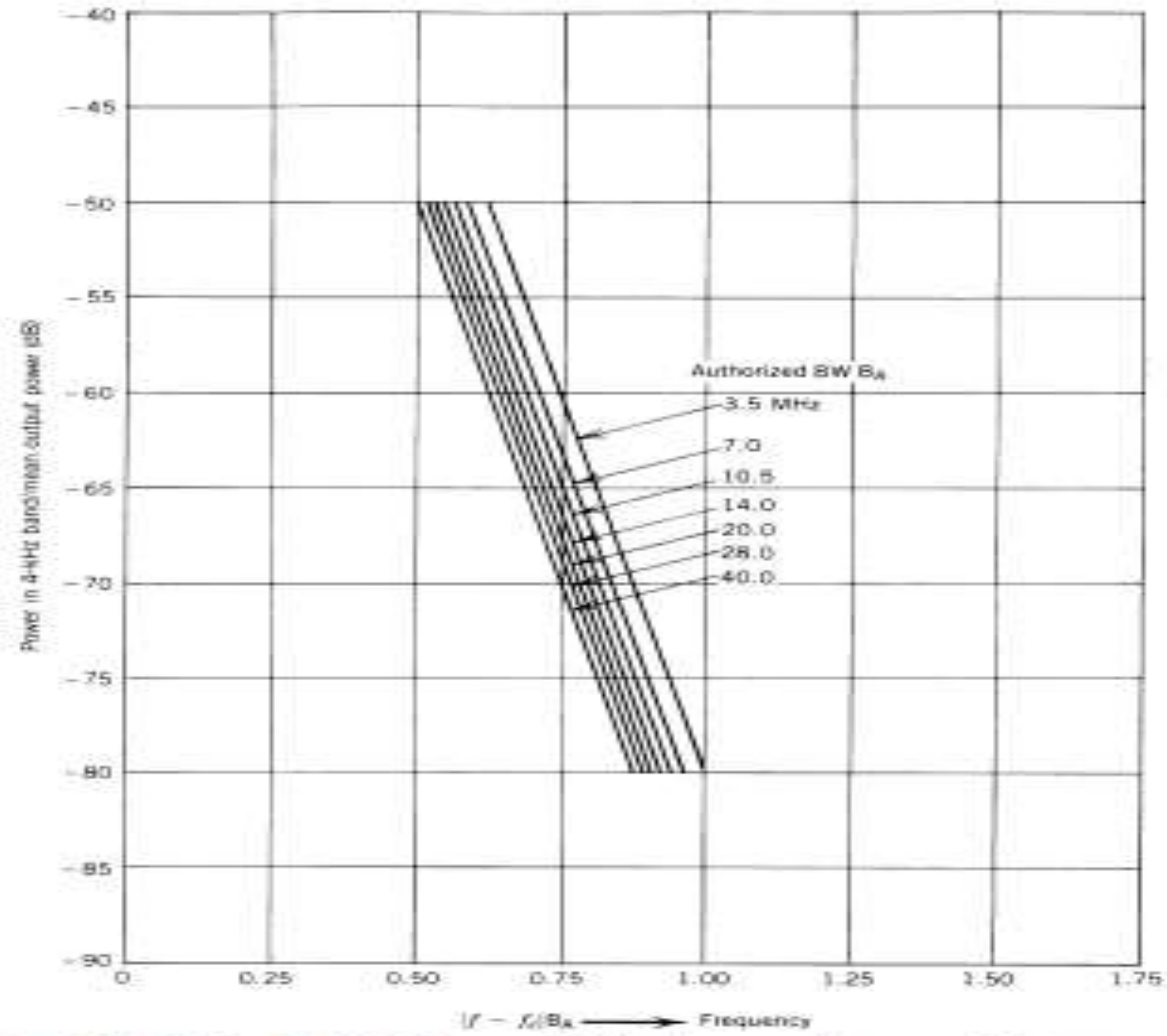


Figure 3.1. FCC Docket 19311 Spectrum Masks: f_c = center frequency; f = frequency of interest. (From Ref. 3.)

Bit Packing

- Kadang2 memperkirakan lebar pita yg diperlukan pd transmisi biner 1 bit/Hz,
- Pd BPSK, fasa pertama menyatakan binary 1 dan fasa kedua menyatakan binary 0, jarak keduanya 180o.
- Pd QPSK, terdapat 4 state fasa, yi 0o = 0,1; 90o = 0,0; 180o; 1,1 dan 270o = 1,0.
- Point penting : lebar pita fungsi dari transisi per detik atau perubahan state per detik
- Secara teori QPSK dapat menampung bit packing 2 bit/Hz.
- 8-PSK dapat menampung 3 bit/Hz
- 16-PSK dapat menampung 4 bit/Hz

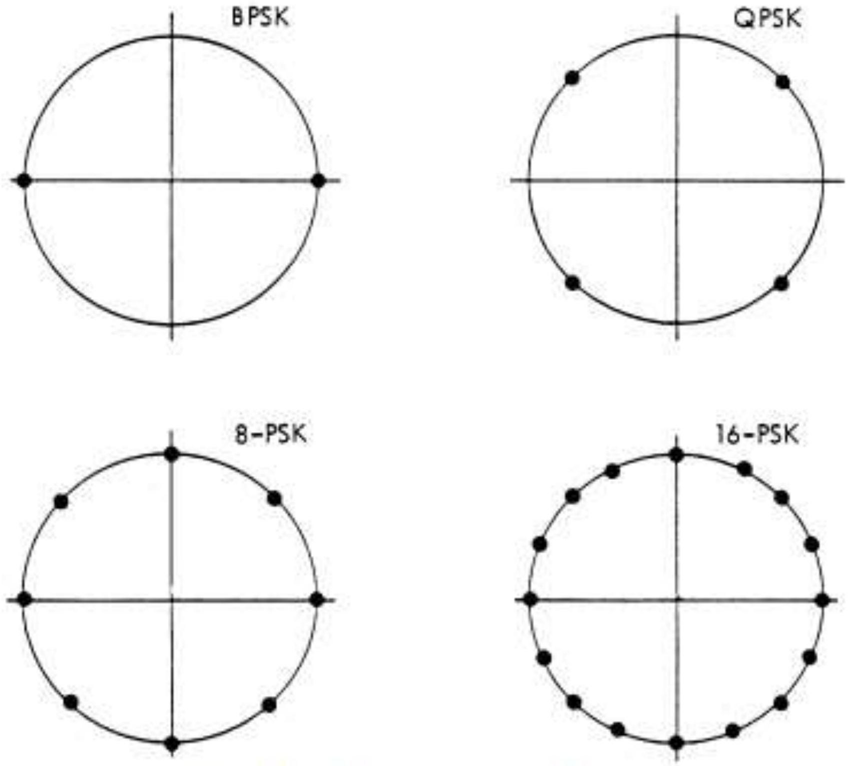


Figure 3.3. Signal state diagrams for PSK.

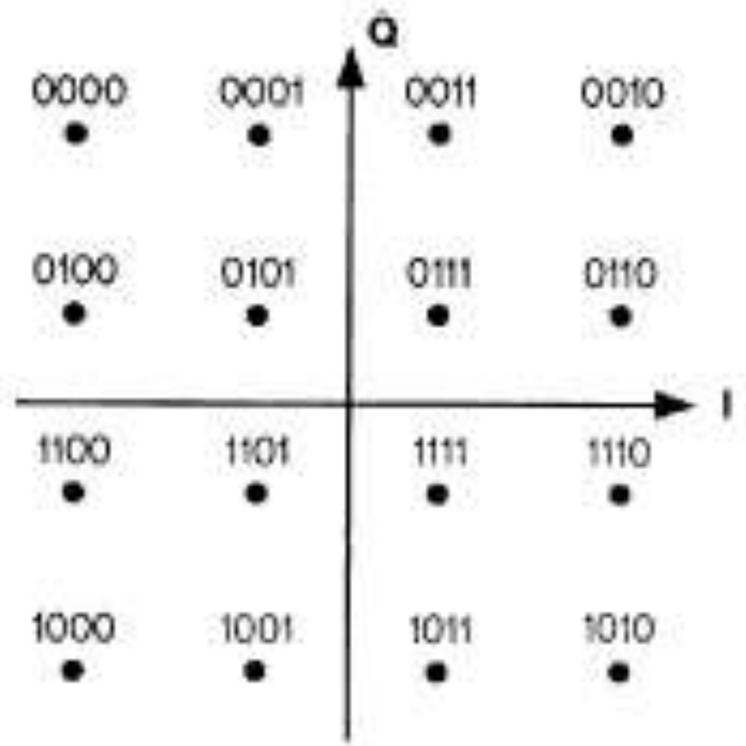


Figure 3.4. 16-QAM state diagram. I = in-phase, Q = quadrature.

Aras amplitudo +3, +1, -1, -3
Bit packing 16 QAM = 16-ary PSK = 4 bit/Hz

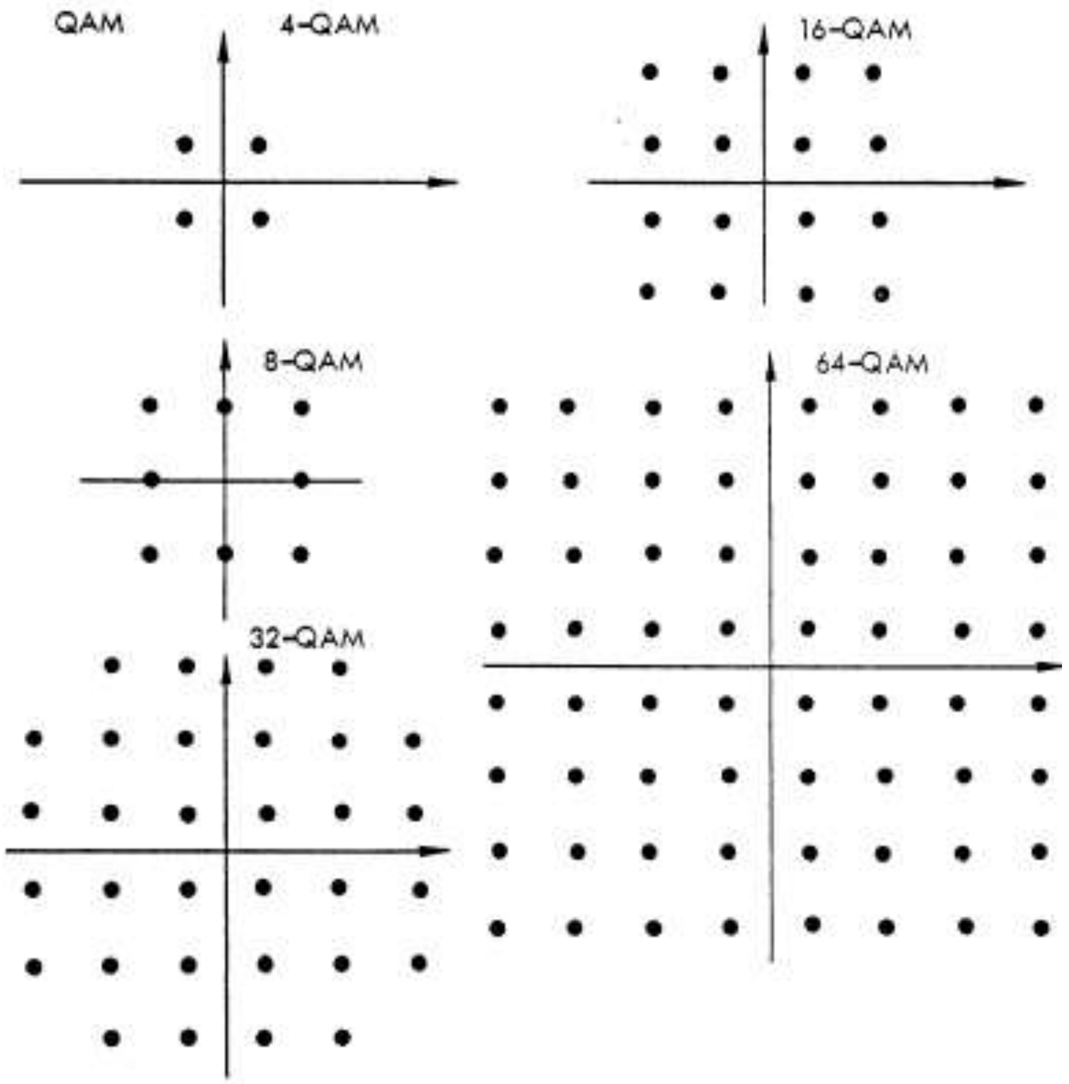


Figure 3.5. Signal state diagrams for 4-, 8-, 16-, 32-, and 64-QAM.

Efisiensi Spektral

Hubungan laju bit Rb dengan laju simbol (1/T) dan jumlah titik level modulasi M

$$R_{b(bps)} = \left(\frac{1}{T}\right)_{ps} \log_2 M$$

Efisiensi spektral η

$$\eta_{(bit/Hz)} = R_b/W = 1/WT \log_2 M$$

W : lebar pita RF

Tanpa interferensi kanal ➔WT dapat = 1

Lebar pita Nyquist ➔W = 1/T

Lebar pita Nyquist + lebar pita ekses W = (1+α)/T

α : cosine roll off factor, umumnya 0,5

Utk 1/T = ¾ W ➔

$$\eta_{(bit/Hz)} = 3/4 \log_2 M$$

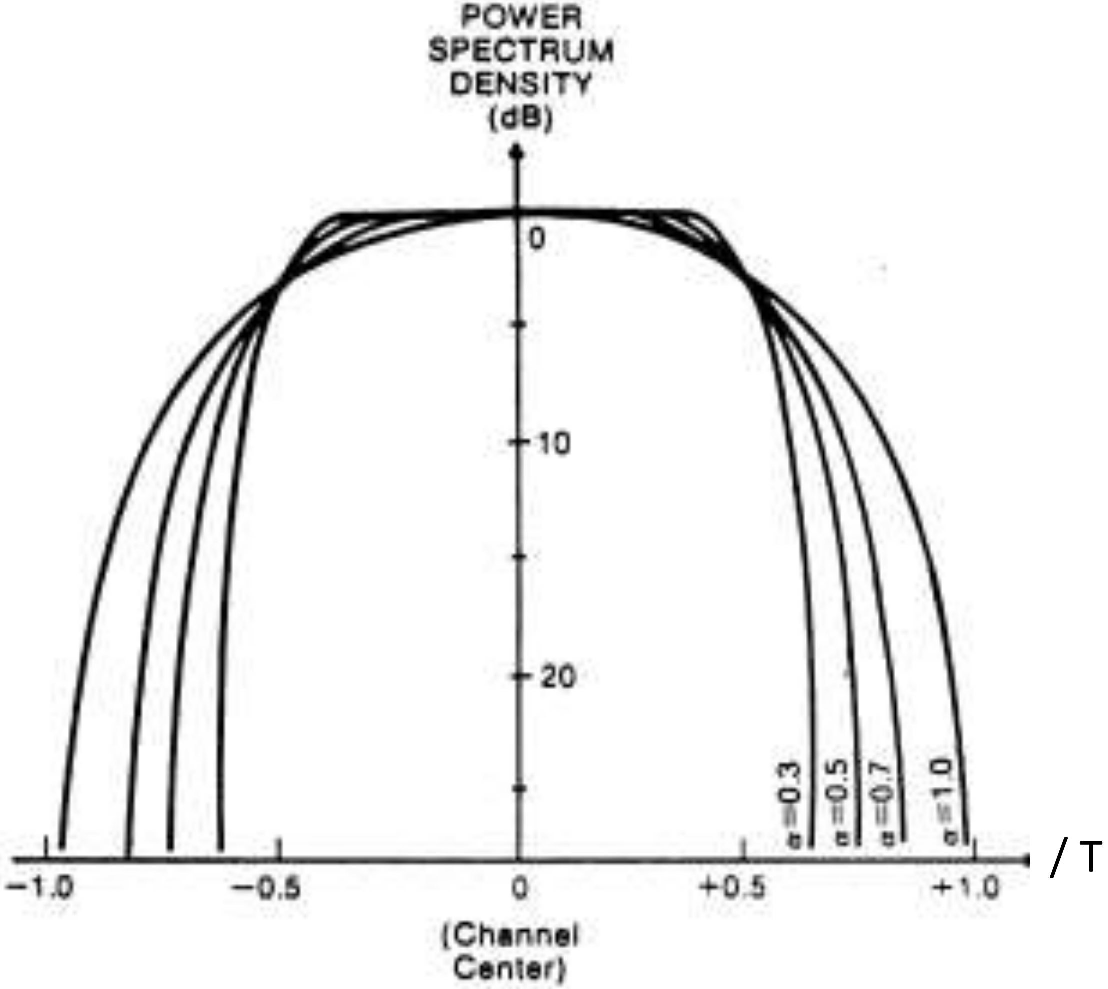


Figure 3.6. Transmitted spectra for typical cosine rolloff shaping. (From *IEEE Communications Magazine*, Oct. 1986, Figure 5, reprinted with permission; Ref. 4.)

Distorsi Penguat Daya

- Penguat daya pemancar gel mikro mrpk perangkat peak-power limited ➔ perangkat menjadi tidak linier jika mendekati saturasi ➔perlu diperhatikan distorsi secara serius utk gel M-QAM.
- Jika daya puncak berada pd daerah non linier ➔ distorsi non linier
- Pd penerima diperlukan daya rata2 utk mendapatkan BER tertentu.

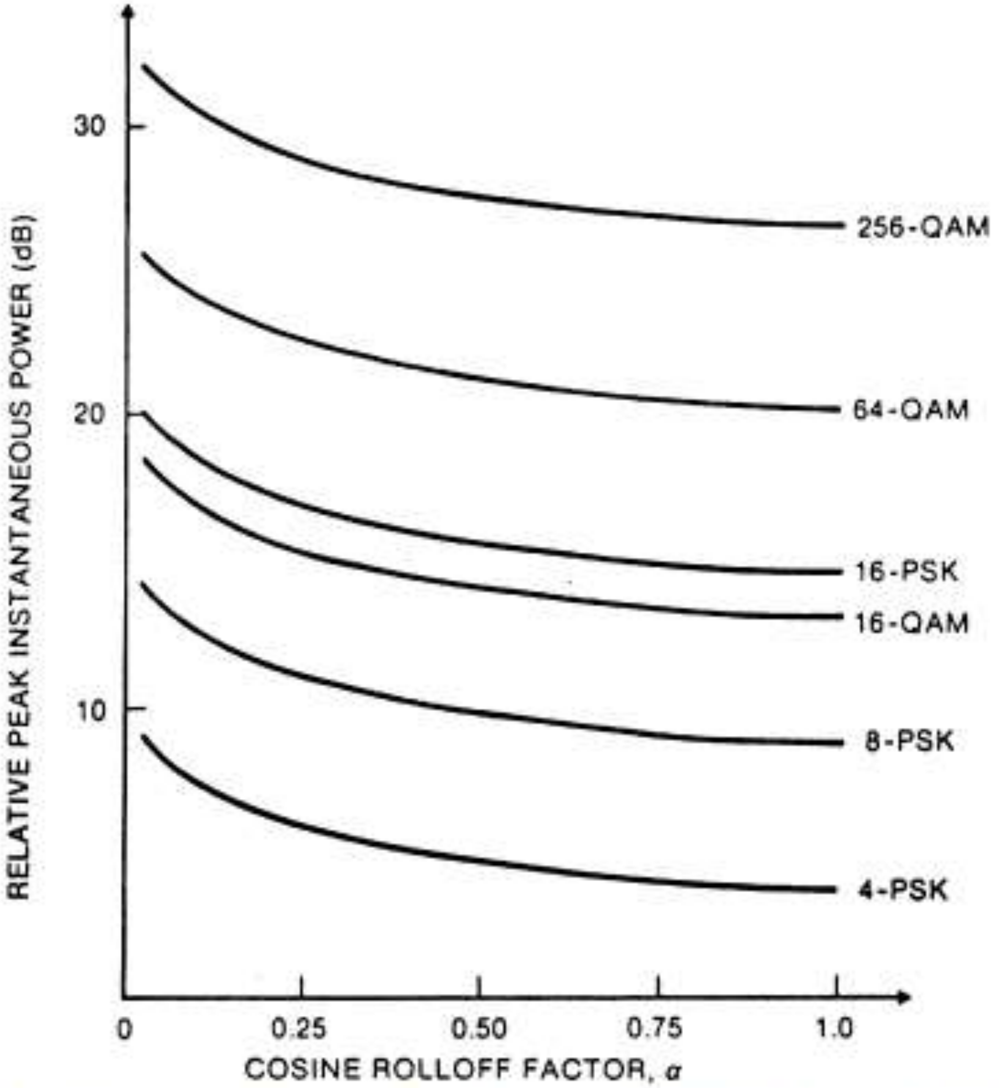


Figure 3.7. Peak instantaneous power (relative to QPSK with square pulses) for *M*-ary waveforms for several values of *M*. (From *IEEE Communications Magazine*, Oct. 1986, Figure 8, reprinted with permission; Ref. 4.)

Persyaratan dan sasaran unjuk kerja lintasan radio dijital

- BER : perbandingan jml bit error dgn jml bit diterima pd interval waktu
- RBER (Residual BER) : perbandingan bit error tanpa fading, termasuk error system inherent, lingkungan, efek usia dan interferensi jangka-panjang
- ES (Error Second) : perioda 1 detik terjadi 1 atau lebih bit error atau paling tidak terdeteksi 1 error
- SES (Severely Errored Second) : perioda 1 detik terjadi BER >= 1 x 10^3 atau paling tidak 1 rusak
- DM (degraded minute) : interval waktu m detik, 60 diantaranya tidak SES tetapi error ratio-nya lebih besar dr yg dispesifikasikan

TABLE 3.1 Comparison of Different Modulation Schemes[a]

System	Variants	$W(=E_b/N_0)$ (dB)	S/N (dB)	Nyquist Bandwidth (b_n)
	Basic Modulation Schemes			
FSK	2-state FSK with discriminator detection	13.4	13.4	B
	3-state FSK (duo-binary)	15.9	15.9	B
	4-state FSK	20.1	23.1	$B/2$
PSK	2-state PSK with coherent detection	10.5	10.5	B
	4-state PSK with coherent detection	10.5	13.5	$B/2$
	8-state PSK with coherent detection	14.0	18.8	$B/3$
	16-state PSK with coherent detection	18.4	24.4	$B/4$
QAM	16-QAM with coherent detection	17.0	20.5	$B/4$
	32-QAM with coherent detection	18.9	23.5	$B/5$
	64-QAM with coherent detection	22.5	26.5	$B/6$
	128-QAM with coherent detection	24.3	29.5	$B/7$
	256-QAM with coherent detection	27.8	32.6	$B/8$
	512-QAM with coherent detection	28.9	35.5	$B/9$
QPR[b]	9-QPR with coherent detection	13.5	16.5	$B/2$
	25-QPR with coherent detection	16.0	20.8	$B/3$
	49-QPR with coherent detection	17.5	23.5	$B/4$
	Basic Modulation Schemes with Forward Error Correction			
QAM with block codes[c]	16-QAM with coherent detection	13.9	17.6	$B/4 \times (1+r)$
	32-QAM with coherent detection	15.6	20.6	$B/5 \times (1+r)$
	64-QAM with coherent detection	19.4	23.8	$B/6 \times (1+r)$
	128-QAM with coherent detection	21.1	26.7	$B/7 \times (1+r)$
	256-QAM with coherent detection	24.7	29.8	$B/8 \times (1+r)$
	512-QAM with coherent detection	25.8	32.4	$B/9 \times (1+r)$

[a] Theoretical W and S/N values at 10^{-6} BER; calculated values may differ slightly due to different assumptions.

[b] QPR = quadrature partial response.

[c] As an example, BCH error correction with a redundancy of 6.7% ($r = 6.7\%$) is used for calculations in this table.

Source: Table 1a, p. 241, ITU-R Rec. F.1101, 1994 (Ref. 1).

$$RSL_{BER} = 10\log kT + 10\log b_n + NF_{(dB)} + \left(S/N\right)_{BER}$$

RSL_{BER} : aras sinyal terima
K : Konstanta Boltzman = 1,38 X 10^-23 J/oK
T : Suhu noise oK
b_n : laju symbol
NF : Noise Figure
$(SN)_{BER}$: perbandingan sinyal thd noise

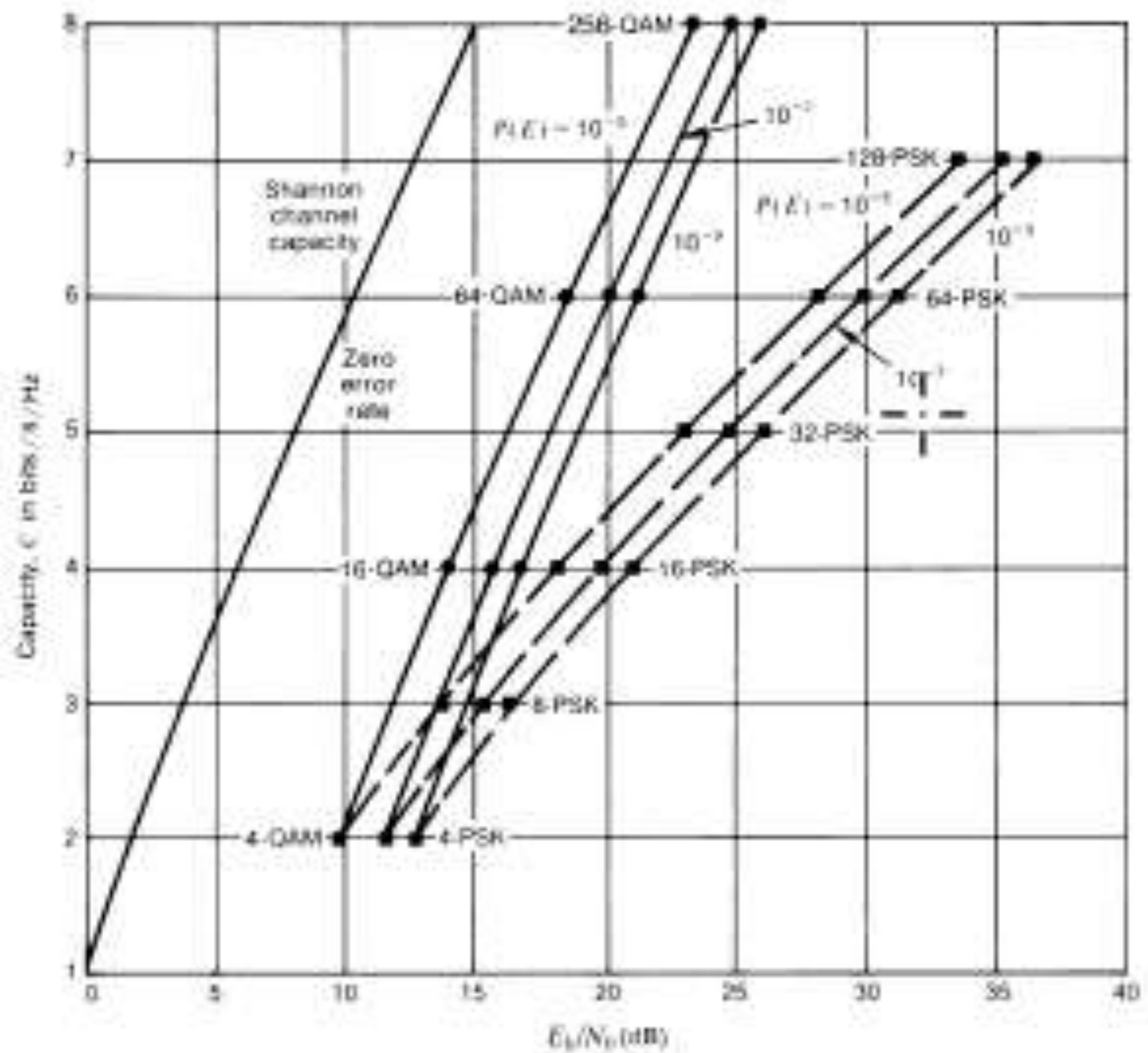


Figure 3.11. Channel capacity comparisons for ideal *M*-QAM and *M*-PSK systems (Ref. 8).

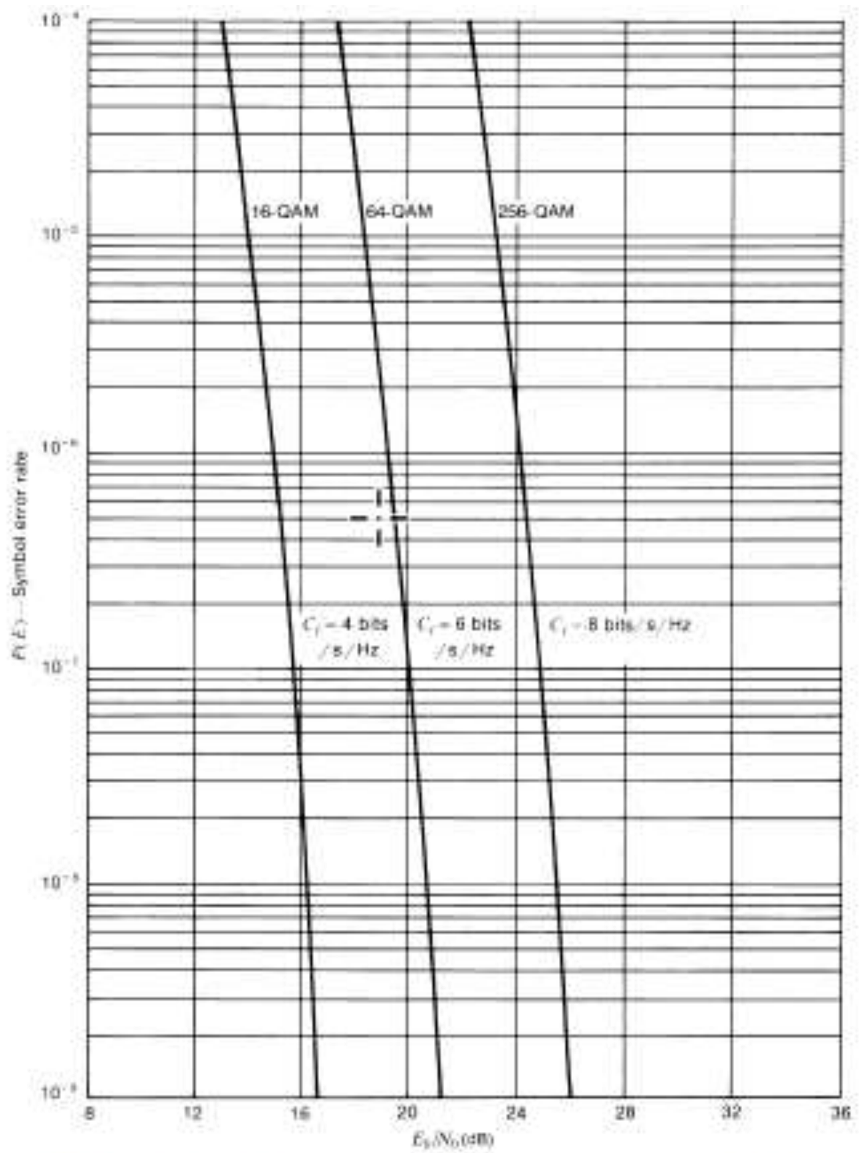


Figure 3.12. Ideal *M*-QAM performance. (From Ref. 8.) *Note:* Symbol error rate (SER) can be converted to bit error rate (BER) assuming Gray coded state assignment by:

$$\text{BER} = (1/\log M) \times \text{SER}$$