0.1 Transmitting information

$$C = 2B \log_2 M \tag{1}$$

C
: channel capacity

B
: bandwith

2B
: baudrate in symbol/s or baud

M
: levels used to encode information

0.2 Types of modulations

- Binary signal
- Amplitude modulation
- Frequency modulation
- Phase modulation
- Quadrature Amplitude Modulation (M - QAM)

0.3 Shannon's Law

The maximum theoretical capacity of a channel (bit/s) is given by the following expressions:

$$SNR = \frac{P_r}{N_0 B_c} \tag{2}$$

$$C = B_c \log_2(1 + SNR) \tag{3}$$

SNR
: signal to noise ratio

B_c
: bandwidth of the channel (Hz)

P_r
: signal power as seen by receiver (W)

N_0
: White noise; noise power per unit bandwidth (W/Hz)

0.4 Free space loss

$$\frac{P_t}{P_r} = \frac{(4\lambda f d)^2}{c^2} \tag{4}$$

P_t
: signal power at transmitting antenna

P_r
: signal power at receiving antenna

λ
: carrier wavelength

d
: propagation distance between antennas

c
: speed of light $3 * 10^8$ m/s

0.5 Solved Exam Problems

2018R - 1

- 16 QAM
- bitrate (C) = 8kbit/s
- baudrate (2B) = ?

$$C = 2B \log_2 M$$
$$8 = 2B \log_2 16$$
$$8 = 2B * 4$$
$$2B = 2$$

2018N - 1

- 8PSK
- baudrate (2B) = 250 kbaud
- bitrate (C) = ?

$$C = 2B \log_2 M$$
$$C = 250 \log_2 8$$
$$C = 250 * 3$$
$$C = 750$$

2017N - 2

- baudrate (2B) = 100 kbaud
- bitrate (C) = 300 kbit/s
- phase modulation
- nº of phases = ?

$$C = 2B\log_2 M$$

$$300 = 100\log_2 M$$

$$3 = log_2 M$$

$$M = 2^3 = 8$$

2017N - 3

$$\frac{P_t}{P_r} = \frac{(4\lambda fd)^2}{c^2}$$

$$P_r = \frac{P_t}{\frac{(4\lambda fd)^2}{c^2}}$$

$$P_r = \frac{P_t c^2}{(4\lambda fd)^2}$$

$$SNR = \frac{P_r}{N_0 B}$$

Quanto maior d, menor P_r, e quanto menor P_r, menor SNR. Quanto maior B, menor SNR, logo menor a eficiência.

2016R - 1

- baudrate (2B) = 80 kbaud
- bitrate (C) = 320 kbit/s
- phase modulation
- nº of phases = ?

$$C = 2B\log_2 M$$

$$320 = 80\log_2 M$$

$$4 = log_2 M$$

$$M = 2^4 = 16$$

2016N - 2

- 16 QAM
- bitrate (C) = 100kbit/s
- baudrate (2B) = ?

$$C = 2B \log_2 M$$

$$100 = 2B \log_2 16$$

$$100 = 2B * 4$$

$$2B = 25$$

2016N - 3 Canal rádio com propagação em espaço livre.

$$\frac{P_t}{P_r} = \frac{(4\lambda f d)^2}{c^2}$$

$$P_r = \frac{P_t}{\frac{(4\lambda f d)^2}{c^2}}$$

$$P_r = \frac{P_t c^2}{(4\lambda f d)^2}$$

$$SNR = \frac{P_r}{N_0 B}$$

$$C = B_c \log_2(1 + SNR)$$

Quanto menor a distância e frequência, maior P_r. Quanto maior P_r, maior SNR, logo maior a capacidade.

2015 - 2

- 2 ligações sem fios
- Pt1 = Pt2 (potência transmitida pelo emissor)
- B1 = B2 (largura de banda do canal)
- d1 < d2 (distância entre o emissor e o recetor)
- relação entre P e C das ligações?

$$\frac{P_t}{P_r} = \frac{(4\lambda f d)^2}{c^2}$$

$$P_t = P_r \frac{(4\lambda f d)^2}{c^2}$$

De Pt1 = Pt2,

$$P_r 1 * (4\lambda f d_1)^2 = P_r 2 * (4\lambda f d_2)^2$$

Como d1 < d2, P_r1 > P_r2, então C1 > C2

$$C_1 = B_1 \log_2(1 + \frac{P_r 1}{N_0 B_1})$$

$$C_2 = B_1 \log_2(1 + \frac{P_r 2}{N_0 B_1})$$

2014N - 1

- baudrate (2B) = 8 kbaud
- bitrate (C) = 32 kbit/s
- bandwith (B) = 4 kHz
- M = ?

$$C = 2B \log_2 M$$

$$32 = 8 \log_2 M$$

$$4 = \log_2 M$$

$$M = 16$$

2013N - 1

- bandwith (B) = 1 MHz
- baudrate (2B) = 2 MHz
- SNR = 40 dB
- 8 level impulses => M = 8
- bitrate (C) = ?

$$C = 2B \log_2 M$$

$$C = 2 \log_2 8$$

$$C = 2 * 3 = 6$$

2012N - 1

- 4 QAM
- baudrate (2B) = 100 kbaud
- bitrate (C) = ?

$$C = 100 \log_2 4$$

$$C = 100 * 2$$

$$C = 200$$

2011N - 2 Num canal sem fios, potência recebida é tanto maior quanto menor for a distância emissor-recetor e o comprimento de onda da portadora.

$$\frac{P_t}{P_r} = \frac{(4\lambda f d)^2}{c^2}$$

$$P_r = \frac{P_t}{\frac{(4\lambda f d)^2}{c^2}}$$

$$P_r = \frac{P_t c^2}{(4\lambda f d)^2}$$