mhby1g21

ELEC2220 Communications Coursework (2022/2023)

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1. Consider a message signal of $m(t)$ and a carrier of $c(t)$, as given by the following equations:

$$m(t) = -0.2 + 2\cos(2\omega_i t) + \cos(4\omega_i t) \text{ [V]} , \tag{1}$$

$$c(t) = 3\cos(\omega_c t) \text{ [V]} , \tag{2}$$

where their measurement units are in volts (V). The message signal $m(t)$ is used to modulate the carrier $c(t)$ using Frequency Modulation (FM), where $\omega_i = 10^3\pi$ and $\omega_c = 10^9\pi$. The frequency sensitivity factor is given by $k_f = 10$ kHz/V. Calculate:

   (a) the bandwidth of the message signal $m(t)$,

   (b) the approximate bandwidth of the FM signal in Hz, given that the maximum message signal amplitude is given by $|m(t)|_{\max} = 2.8$ V, and

   (c) the normalized power of the FM signal.

2. Draw and briefly explain the block diagrams of the modulation and demodulation for Quadrature Amplitude Modulation (QAM).

3. Sketch and briefly describe the block diagram for the creation of Quadrature Phase Shift Keying (QPSK) symbols, from bits to before transmission.

4. The baseband representation of a wireless radio communications link is shown in Figure 1. Explain which particular system components are modelled by the channel impulse response (CIR) $h[n]$. Similarly, comment on the various physical phenomena that may be modelled by the noise term $v[n]$.

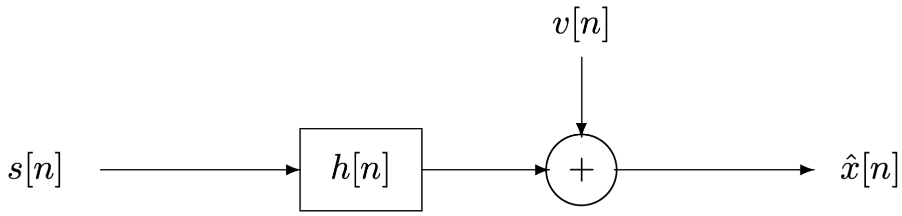

Figure 1: Baseband model.

See next page.

5. Consider a Binary Phase Shift Keying (BPSK) transmission, where a bit $b_1 = 1$ is mapped to symbol $s[n] = -d$ and a bit $b_0 = 0$ is mapped to symbol $s[n] = d$. The received signal is given by $r[n] = s[n] + w[n]$, where $w[n]$ is the additive White Gaussian noise having a variance of σ_w^2. The following probability density functions are valid, depending on whether b_1 or b_0 has been transmitted:

$$p(r|b_1) = \frac{1}{\sqrt{2\pi}\sigma_w} e^{-(r+d)^2/(2\sigma_w^2)} \quad ; \quad p(r|b_0) = \frac{1}{\sqrt{2\pi}\sigma_w} e^{-(r-d)^2/(2\sigma_w^2)} \quad .$$

(a) Find the value of d when the signal power (d^2) to noise power (σ_w^2) ratio (i.e. SNR) is given by 3dB and $\sigma_w = 1$.

(b) Assume that the binary symbol probabilities are $P(b_1) = \frac{1}{5}$ and $P(b_0) = \frac{4}{5}$, while the detection threshold is given by θ and the received signal is given by r. What is the probability of error when we have the following conditional probabilities: $P(r > \theta|b_1) = 0.05$ and $P(r < \theta|b_0) = 0.02$?

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(a) $\omega = 2\pi f$, $f = \frac{\omega}{2\pi}$, $B_M = \max\left(0, \frac{2\times10^3\pi}{2\pi}, \frac{4\times10^3\pi}{2\pi}\right) = 2$ kHz

(b) the approximate bandwidth of the FM signal in Hz, given that the maximum message signal amplitude is given by $|m(t)|_{\max} = 2.8$ V, and

(b) $B_{FM} = 2(B_m + f_d)$; frequency deviation, $f_d = k_f |m(t)|_{max}$

$\therefore B_{FM} = 2(2+28)\times10^3$ Hz $= 60$ kHz $\qquad = (10\times10^3)(2.8) = 2.8\times10^4$ Hz

(c) the normalized power of the FM signal.

$\rightarrow$ Amplitude of carrier

$P = \frac{A^2}{2} = \frac{3^2}{2} = \frac{9}{2} = 4.5$ W

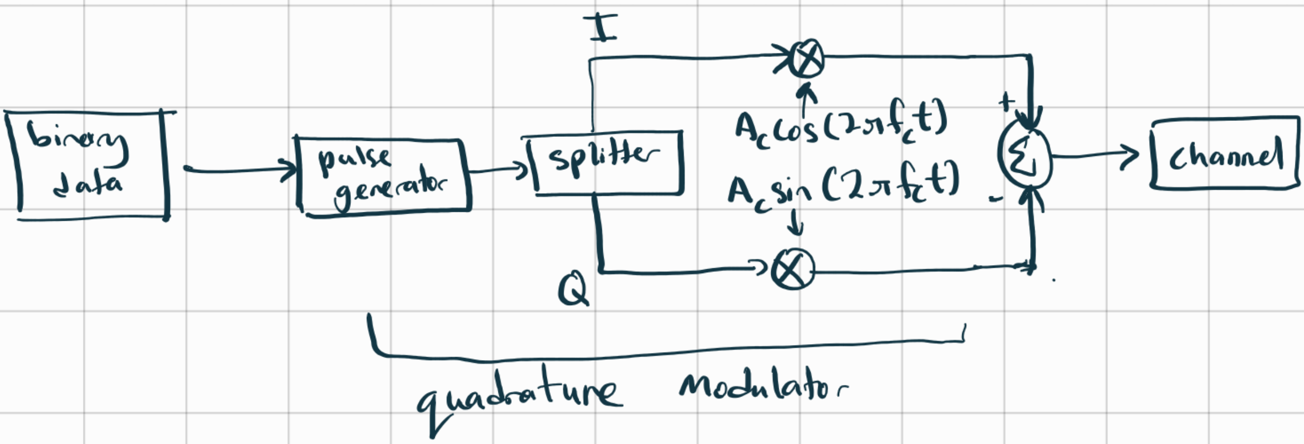
2. Draw and briefly explain the block diagrams of the modulation and demodulation for Quadrature Amplitude Modulation (QAM).

QAM is a type of digital modulation in which both phase and amplitude of a carrier signal are varied to transmit data. This signal is modulated using two seperate signals, known as I (in-phase) and Q (quadrature) signals. The data signal is passed through quadature modulator, which seperates it into the two components, I and Q.

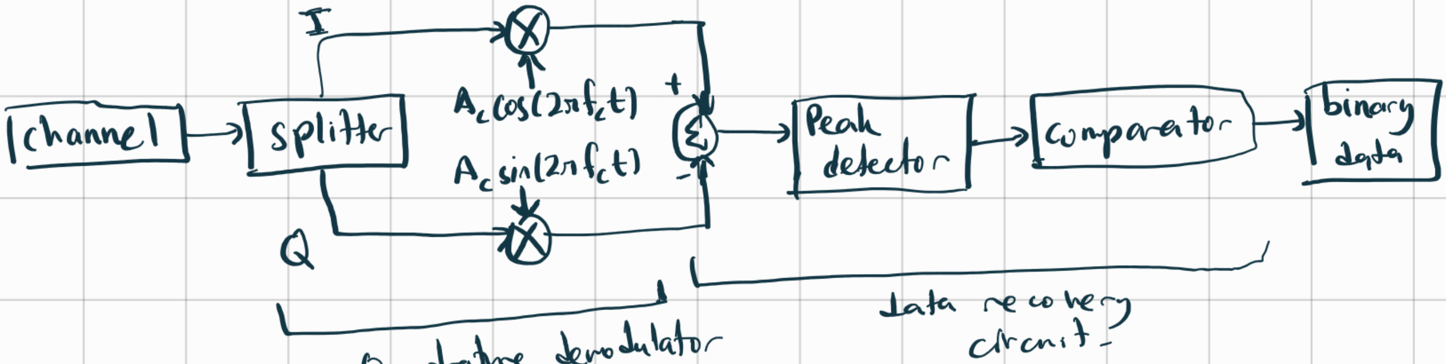
I signal is used to modulate amplitude of carrier signal using amplitude modulator. The Q signal is used to modulate the phase of carrier using phase modulator. The modulated carrier signal is the combination of both I and Q signal and carried through physical communication channel.

The received modulated carrier signals is passed through a quadrature demodulator, which separates the I and Q signals. The I and Q signal are used to recover the original data signal using a data recovery circuit.

modulation



demodulation



The symbol for the QAM is determined by how much bit data we want it to carry, the simplest being 4-bit, resulting into 16 symbols QAM, commonly known as 16-QAM.

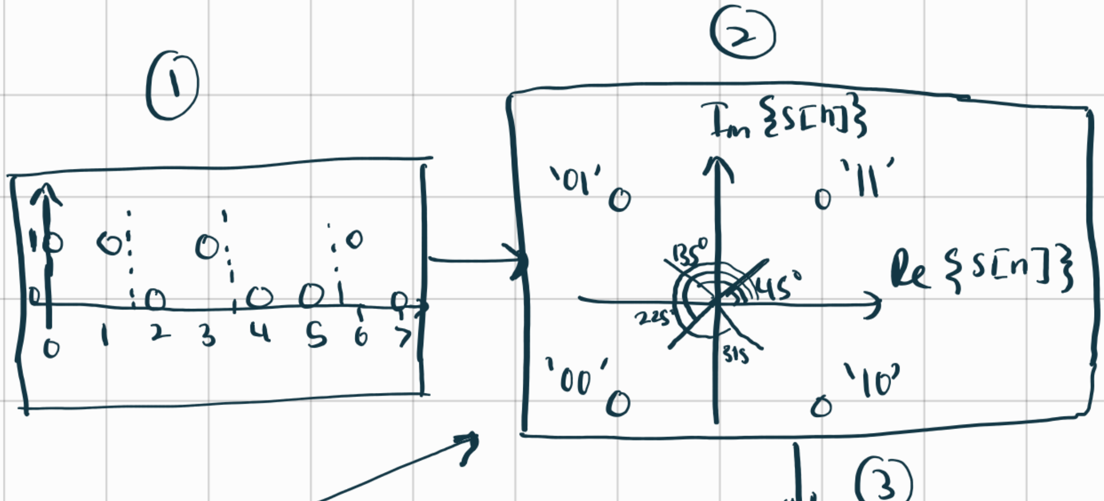
The symbols correlations to phase and amplitude can be modelled as constellation diagram.

3. Sketch and briefly describe the block diagram for the creation of Quadrature Phase Shift Keying (QPSK) symbols, from bits to before transmission.

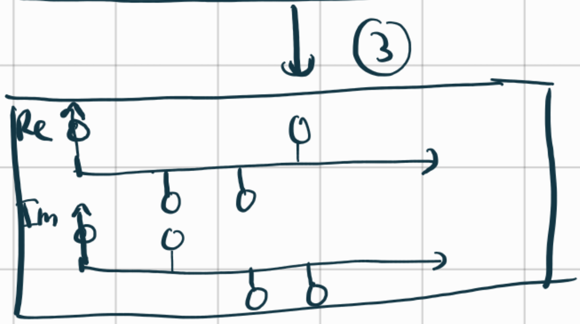
or 4-PSK.

QPSK is a special type of QAM, 4-QAM as it only encode 2 bits per symbol (00, 01, 10, or 11) through the following four phases 45°, 135°, 225°, 315°

1. Group data in 2 bits per group.
2. map it to constellation diagram.
3. corresponding real and Im value is the I and Q signal value



Each symbols also correspondong to specific phase shift relative to reference signal



4. The baseband representation of a wireless radio communications link is shown in Figure 1. Explain which particular system components are modelled by the channel impulse response (CIR) $h[n]$. Similarly, comment on the various physical phenomena that may be modelled by the noise term $v[n]$.

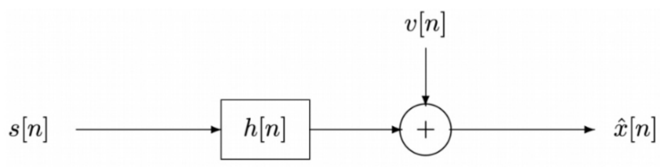


Figure 1: Baseband model.

(CIR) $h[n]$ models the response of wireless radio communication channels due to short pulse or impulse signal. This includes any time-varying nature of the channel such as time delays, attenuations and phase shift that signal experience as it propagates through channel.

Example of physical phenomena that can be modelled from noise term $v[n]$ are noise from surroundings such as temperature changes, vibrations and interferences from other electronic systems especially adjacent channel interference.

Together, both these terms can be used to form input-output relationship and determine the performance of system in terms of its signal-to-noise ratio (SNR) and error rate.

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5. (a) $\text{SNR} = \frac{d^2}{\sigma_w} = 3\text{ dB}$

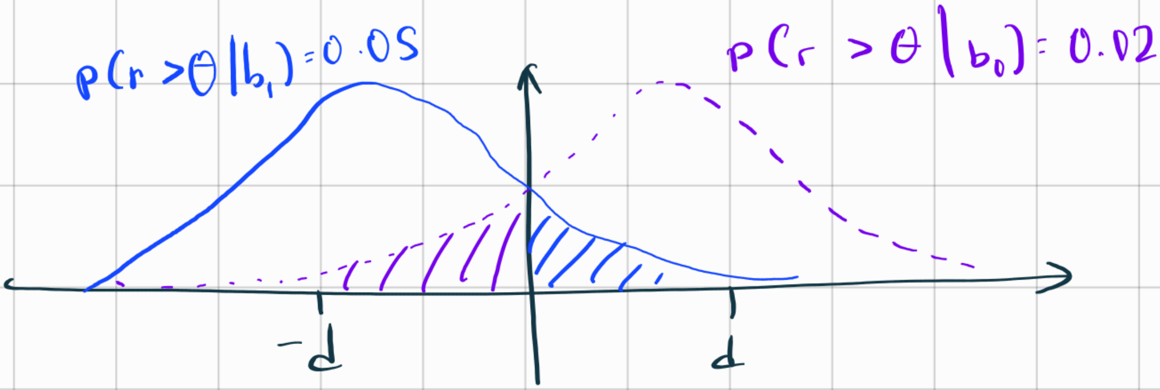
$\therefore 10\log_{10}\frac{d^2}{1} = 3$

$d^2 = 1.9953, \quad \therefore d = 1.41$

(b) $P(b_1) = \frac{1}{5}, \quad P(b_0) = \frac{4}{5}$

$r > \theta = -d, \; b_1 = 1, \quad r < \theta = d, \; b_0 = 0$

$\therefore P(r > \theta | b_1) = 0.05, \quad p(r < \theta | b_0) = 0.02$



$$P(\text{error}) = P(b_1) \times P(r > \theta | b_1) + P(b_0) \times P(r < \theta | b_0)$$

$$= 0.02 \times 0.8 + 0.05 \times 0.2$$

$$= 0.026$$