Amal

Indep.students
Alliance

بسم الله الرحمن الرحيم

TM355

- حِلف الطلاب العصاميين يقدم لكم النسخة الأولى من تجميعات الامتحانات النصفية محلولةً بالكامل.
- الشكر مُسدى لكل من صحَح وتعقَّب وراجع النسخ، ومَن جمع الملفات على مر السنين.
- نرجو ألا تكون هذه التجميعات محل اعتمادكم في المذاكرة، فشرائح المُقرر أولى وأكثر أهمية.
- يغلب على النماذج تكرار أفكار الأسئلة، لذا ننصح بالرجوع إليها والاهتمام بها.

وإنْ تَجِدْ عَيبًا فسُدَّ الخَلَلا فجَلَّ مَن لا عَيبَ فيهِ وعَلا

حرر في:
28/8/1445 – 09/03/2024

Question 1: **(6 Marks)**

For the waveforms shown in Fig.1 (a) and (b) below, draw the corresponding frequency domain representations given that the time period for both signals is **1ms**. You should show the corresponding values for the frequencies on the x-axis.

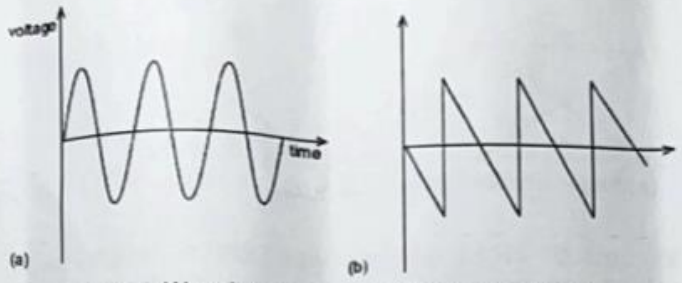


Figure 1. Waveforms corresponding to Question 1

Question 2: **(6 Marks)**

a) Discuss the difference in construction between a step-index fibre and a graded-index fibre. (2 marks)

b) Explain the multimode distortion. (2 marks)

c) Explain the advantage of a graded-index fibre over the corresponding step-index with respect to multimode distortion. (2 marks)

Question 3: **(6 Marks)**

a) For the rectangular pulse shown in Fig.2 below, draw the corresponding frequency domain representation showing the maximum value of the main lobe and the first pair of spectral nulls. (4 marks)

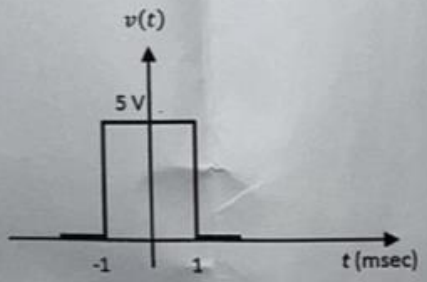


Figure. 2. A rectangular pulse – Question 3

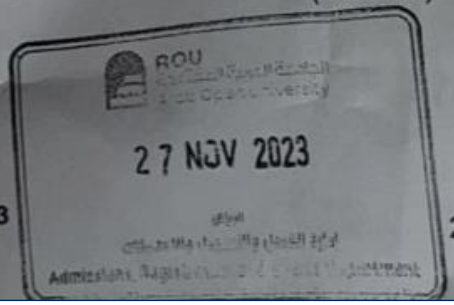
b) Sketch what the modulated waveforms for ASK and FSK might look like for the modulating signal 0 1 1 0 1. (2 marks)

Question 4: **(6 Marks)**

Suppose that we use a denary cyclic redundancy check with G = 888.

a) What is the code word if the message is 35353535? (3 marks)

b) The following code word is received at a decoder: 73310642111. Does it appear to contain errors? Justify your answer. (3 marks)



Question 5: **(6 Marks)**

a) Decide what the following sequences should be decoded to, assuming there is at most one error in each sequence. Use the trellis diagram shown in Fig. 3, starting from the upper branch. (4 marks)

i. 00 10 10 00

ii. 11 01 01 01

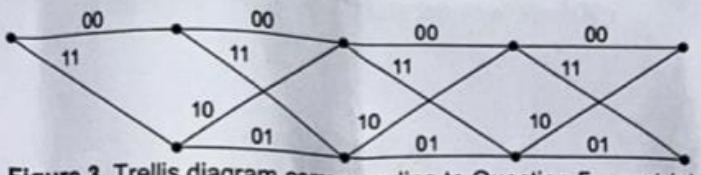


Figure 3. Trellis diagram corresponding to Question 5 – part (a)

b) Suppose the following sequence had been received: 01 01 10. Suppose further that you were exploring the paths on the trellis and looked at the two highlighted in Fig. 4 below. This means you would be comparing the received sequence against these two sequences:

i. 00 00 00

ii. 11 01 10.

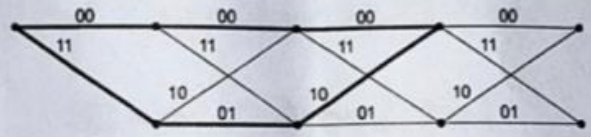


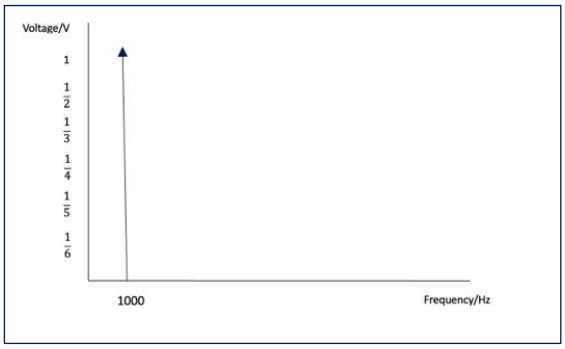
Figure 4. Trellis diagram corresponding to Question 5 – part (b)

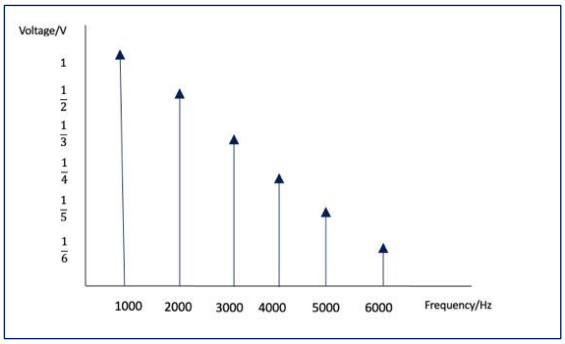
Which would be the best choice? Justify your answer. (2 marks)

End of Question

Question 1 Answers:

$$f = \frac{1}{T} \quad \rightarrow \quad \frac{1}{1 \times 10^{-3}} = 1000\text{Hz}$$





Question 2 Answers:

a. **step-index fibre:** the refractive index changes abruptly between core and cladding.

graded-index fiber: the refractive index varies smoothly from a maximum in the centre of the core to a minimum within the cladding.

b. **Multimode distortion**: two rays of light that set off at the same time may not reach the other end of the fibre exactly simultaneously as with attenuation, the effects are cumulative, *the longer the fibre, the worse it gets.*

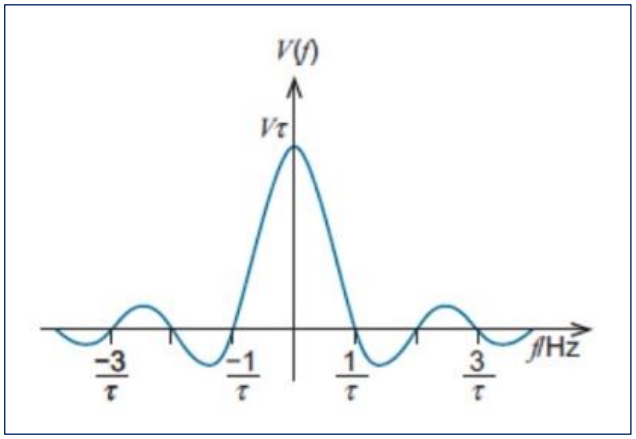
The signal transmitted is called a pulse, so the effect is known as pulse spreading.

One reason for pulse spreading in multimode fibres: different path lengths result in different timings for the trip through the fibre.

c. Waves that take slightly longer paths travel slightly faster, and so different waves setting off at the same time arrive nearly simultaneously at the other end of the fibre.

Question 3 Answers:

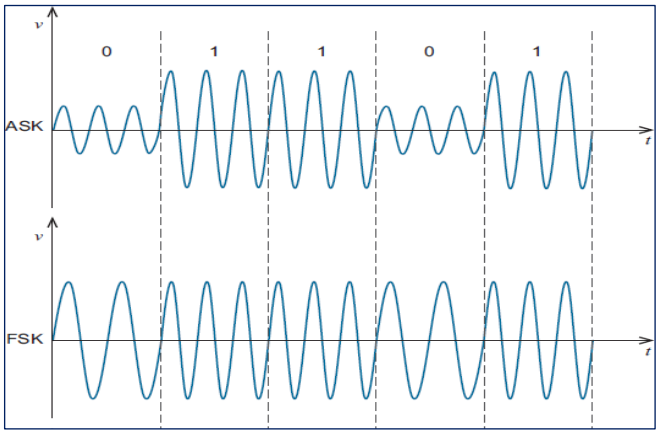
a.



Note:

The main lobe: 5V
First pair of spectral nulls: 1 and -1.

b.



Question 4 Answers:

a. 35 35 35 35 % 888 = 479 → check digits = 479
Code word = message + check digits = 35 35 35 35 479.

b. 73310642 % 888 = 026 → different from the received check digits "111", so there must have been errors.

Question 5 Answers:

a.

i. The sequence 00 10 10 00 does not correspond to any path through the decoder. However, assuming one error – in the fourth received bit – leads to the sequence 00 11 10 00, which corresponds to the sequence generated by the data 0100.

ii. 1111

b. The hamming distance are 3 for (i) and 1 for (iii) so the best choice would be sequence (iii) which is 11 01 10.

Question 1: **(6 Marks)**

a) From your study of communication systems and signals, explain what is meant by the term 'signal'. (2 marks)

b) Discuss the benefits of transmitting signals in digital form. (4 marks)

Question 2: **(6 Marks)**

a) From your study of optical fibres, what keeps light guided along its path in an optical fibre? Why does the light not just stop when it comes to the first bend? (3 marks)

b) In a certain type of optical fibre, half the power supplied to the fibre at the source is lost after the light signal has travelled a distance of 10 km. Assuming that the source (input) power is 10 mW, and by treating the fibre as a series of 10 km sections, calculate:
   i. The fraction of the power that will be left after 20 km. (1.5 marks)
   ii. The value of the power after 20 km. (1.5 marks)

Question 3: **(6 Marks)**

a) For the modulating and carrier signals shown in Fig. 1(a), draw a rough sketch for the resulted amplitude modulated signal. (3 marks)

b) If the frequency spectrum of the modulating signal is shown in Fig. 1(b), draw the corresponding frequency spectrum of the amplitude modulated signal. (3 marks)

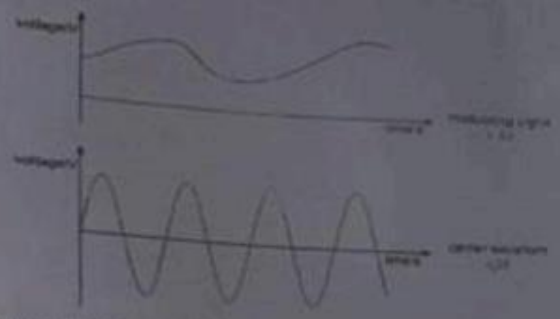


Figure. 1(a). Modulating and carrier signals

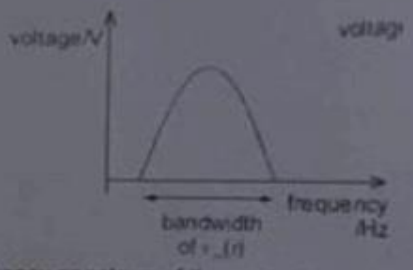


Figure. 1(b). Frequency spectrum of the modulating signal

Question 4:

a) A mobile device is being used by someone sitting on a high-speed train moving at 300 km/h and the transmitter frequency is nominally 2.1 GHz. Calculate the Doppler shift, in Hz, for the case where the mobile is moving directly towards the fixed transmitter from which it is receiving a signal. (Take the speed of light, c, to be 3×10^8 m/s.) **(6 Marks)** (3 marks)

b) With the noise power density shown in Fig. 2, what noise power falls within the shaded channel? (3 marks)

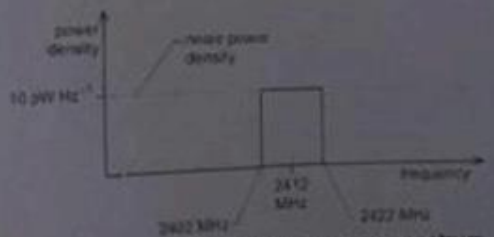


Figure 2. Noise power spectrum

Question 5: (6 Marks)

Fig. 3 below represents a **message** of 35 bits arranged as shown.

0	0	0	1	0	1	0
1	0	0	1	1	1	1
1	1	0	0	1	1	1
0	1	0	0	1	0	0
1	0	1	1	0	1	1

Figure 3. Corresponds to Question 6 – Parts (a-d)

a) Construct a **rectangular code** word for this message. (3 marks)
b) Calculate the code rate and the redundancy rate for this code. (1 mark)
c) Fig. 4 below represents a rectangular **code word** that was detected by a receiver. Check whether the received code is correct or not. If it is not correct, identify which digit is in error (if possible). (2 marks)

0	0	0	1	0	1	0	0
1	0	0	1	1	1	1	1
1	1	0	0	1	1	1	1
0	1	0	0	1	0	0	1
1	0	1	1	0	1	1	1
1	0	1	0	1	0	1	0

Figure 4. Corresponds to Question 6 – Part (e)

End of Question

Question 1 Answer:

a. Signal describes the form in which a message is sent along a communications channel.

b.

- Whenever a signal is sent along a communications channel, it gets smaller and distorted.
- It is possible to compensate for attenuation by amplifying the received signal.
- With digital signals we can get rid of the distortion entirely by the process of regeneration (threshold detection).
- voice, music and video can all be handled by the same techniques as computer data if they are first converted to a digital form.

Question 2 Answer:

a. Optical fibres work because the refractive index is not the same all the way across the fibre, but is higher in the central core than it is in the cladding around the core.

if light is directed from one medium towards another with a lower refractive index, and it hits the boundary at a sufficiently small angle, it is not refracted but reflected back into the first medium.

Thus in an optical fibre it will continue all the way along the fibre, relying on total internal reflection to keep it on course.

b.

i.

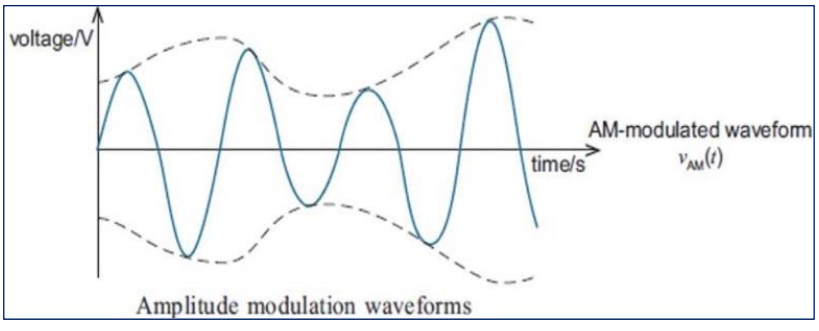
after 10 km = 0.5 original powers.

after 20 km $= \frac{0.5}{2} = 0.25$ original power.

ii. $10\ mW \times \left(\frac{1}{4}\right) = 2.5\ mW$

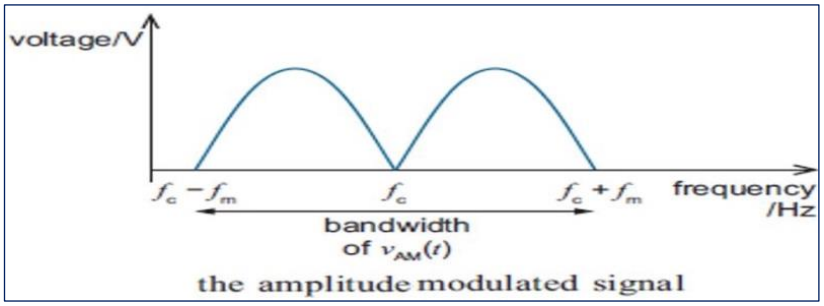
Question 3 Answers:

a.



Amplitude modulation waveforms

b.



the amplitude modulated signal

Question 4 Answers:

a.

$$f_r - f_t = \left(\frac{f_t \times v}{c}\right)$$

$$v = \frac{300 \times 10^3}{60 \times 60} = 83.33 ms^{-1}$$

$$f_r - f_t = \left(\frac{2.1 \times 10^9 \text{Hz} \times 83.33 ms^{-1}}{3 \times 10^8 \text{ m s}^{-1}}\right) \approx 583\text{Hz}.$$

b.

Noise power = noise power density × Bandwidth
noise power density = $10 \times 10^{-12}\text{w/Hz}$
Bandwidth = $2422\text{MHz} - 2402 \text{ MHz} = 20 \text{ MHz} = 20 \times 10^6$ Hz
Noise power = $(10 \times 10^{-12}\text{w/Hz}) \times (20 \times 10^6\text{Hz}) = 200 \times 10^{-6} = 200\mu\text{W}$

Question 5 Answers:

a.

0	0	0	1	0	1	0	0
1	0	0	1	1	1	1	1
1	1	0	0	1	1	1	1
0	1	0	0	1	0	0	0
1	0	1	1	0	1	1	1
1	0	1	1	1	0	1	1

b. Code rate: $\frac{35}{48} = 0.73 = 73\%$ and Redundancy rate: $\frac{13}{48} = 0.27 = 27\%$

c.

0	0	0	1	0	1	0	0
1	0	0	1	1	1	1	1
1	1	0	0	1	1	1	1
0	1	0	**0**	1	0	0	1
1	0	1	1	0	1	1	1
1	0	1	0	1	0	1	0

This represents rectangular code word, so it's contained the message and the parity check, by checking the parity check we find that we have an odd number at the highlighted digits which led to an error. So, we have an error in the intersection so the 0 will be convert to 1.

Question 1:

a) In a certain type of optical fibre, half the power supplied to the fibre at the source is lost after the light signal has travelled a distance of 10 km. By treating the fibre as a series of 10 km sections, calculate what fraction of the power will be left after 20 km and 50 km. **(6 Marks)** (4 marks)

b) A signal is transmitted along a cable 100 m long. The signal consists of a series of pulses each 25 ns long. How far does the signal travel along the cable in the time between a pulse starting and ending? Assume that the speed of the signal is 2×10^8 m/s. (2 marks)

Question 2: **(6 Marks)**

Figure 1 shows an example of a saw-tooth signal. Because a sawtooth signal is periodic, it can be represented by a Fourier series. If the first four components of the Fourier series of a saw-tooth signal are as follows:

$v(t) = \cos(\omega t + \pi/2) + (1/2)\cos(2\omega t + \pi/2) + (1/3)\cos(3\omega t + \pi/2) + (1/4)\cos(4\omega t + \pi/2) + \ldots$,

Sketch the frequency domain (amplitude only) of this signal for the **first three components**, if **the signal period is 1ms**. Your sketch should clearly indicate the values of amplitudes and the frequencies.

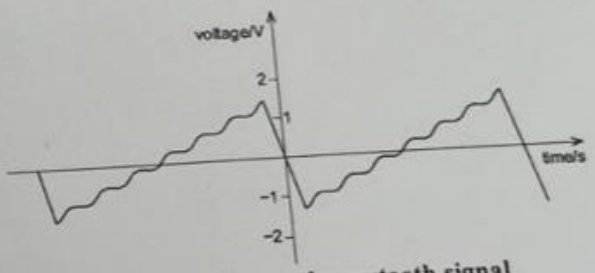


Figure 1. Example sawtooth signal

Question 3: **(6 Marks)**

a) A radio signal has a centre frequency of 101.1 MHz and a bandwidth of 150 kHz. What are the highest and lowest frequencies in the signal spectrum? State your answer in MHz. (3 marks)

b) With the noise power density shown in Figure 2, what noise power falls within the shaded channel? (3 marks)

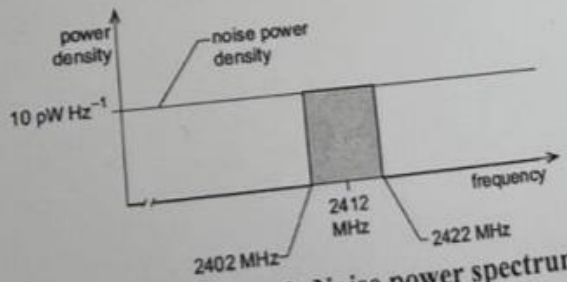


Figure 2. Noise power spectrum

Question 4:

Suppose that we use a denary cyclic redundancy check with G = 999. **(6 Marks)**

a) What is the code word if the message is 45454545? (3 marks)

b) The following code word is received at a decoder: 52310642002. Does it appear to contain errors? Justify your answer. (3 marks)

Question 5: **(6 Marks)**

a) Digital modulation has many advantages over analogue modulation. Mention three of them. (3 marks)

b) Orthogonality is an important concept in communications systems. From your study, explain briefly this concept and mention its importance. (3 marks)

End of Questions

Question 1 Answers:

a.

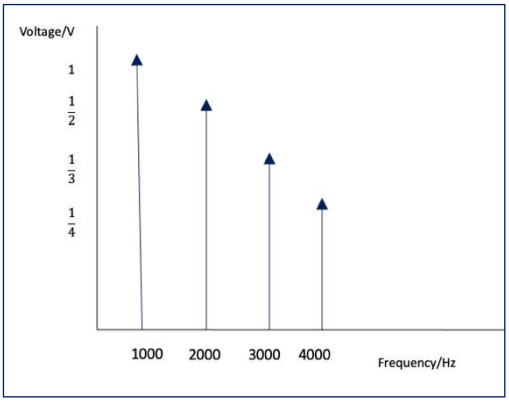
after 10 km = 0.5 original power.

after 20 km = $\frac{0.5}{2} = 0.25$ original power

after 50 km = $\frac{0.25}{8} = 0.03125$ original power.

b. $D = (25 \times 10^{-9}\text{s}) \times (2 \times 10^{8}\text{m/s}) = 5\text{m}$

Question 2 Answers:



Question 3 Answers:

a.

$$f_{max} = f_c + \frac{\text{bandwidth}}{2} \rightarrow 101.1\ \text{MHz} + \frac{150 \times 10^{-3}\text{MHz}}{2} = 101.175\text{MHz}$$

$$f_{max} = f_c - \frac{\text{bandwidth}}{2} \rightarrow 101.1\ \text{MHz} - \frac{150 \times 10^{-3}\text{MHz}}{2} = 101.025\text{MHz}$$

b.

Noise power = noise power density × Bandwidth
noise power density = $10 \times 10^{-12}\text{w/Hz}$
Bandwidth = $2422\text{MHz} - 2402\ \text{MHz} = 20\ \text{MHz} = 20\ \times\ 10^{6}$ Hz
Noise power = $(10 \times 10^{-12}\text{w/Hz}) \times (20\ \times\ 10^{6}\text{Hz}) = 200\ \times 10^{-6} =\ 200\ \mu\text{W}$

Question 4 Answers:

a.

45 454 545 % 999 = 45 → check digits = 045
Code word = message + check digits = 45454545045.

b. 52310642%999 = 005 → different from the received check digits “002”, so there must have been errors.

Question 5 Answers:

a.

- Has a greater immunity to noise and other types of interference.
- Enables techniques to be used such as error control coding, which enables the performance to be improved.
- Encryption for securing transmissions.

b.

“Orthogonal” in the context of two orthogonal lines, in which it means they are “at right angles” or perpendicular to each other. It can also mean “statistically independent” or uncorrelated”.

Its importance: If two signals are orthogonal: when they are transmitted simultaneously, one can be completely recovered at the receiver without any interference from the second, and vice versa.

Question 1:

Various effects distort signals in optical fibres by smearing out sharp transitions between light and dark sections of the signal. This phenomenon is called pulse spreading. **(6 Marks)**

a) What is the effect of this phenomenon? (2 marks)
b) Draw a simple sketch to illustrate the problem. (2 marks)
c) What is the main reason for pulse spreading in multimode fibres? Draw a sketch representing this effect. (2 marks)

Question 2:

a) Suppose a 1000 W kettle takes six minutes to boil. Calculate the energy in (kilowatt-hours) **(6 Marks)**

b) A light wave has a wavelength of 500 nm. What is its frequency and its period? (3 marks)

Question 3:

a) For the modulating and carrier signals shown in Fig. 1, draw a rough sketch for the resulted amplitude modulated signal. **(6 Marks)**

b) If the frequency spectrum of the modulating signal is shown in Fig. 2, draw the corresponding frequency spectrum of the amplitude modulated signal. (3 marks) (3 marks)

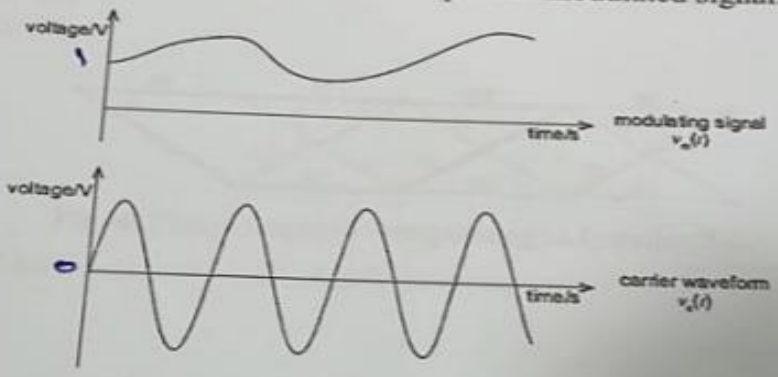


Fig. 1. Modulating and carrier signals

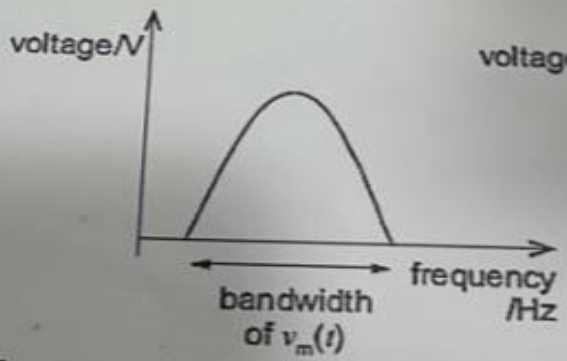


Fig. 2. Frequency spectrum of the modulating signal

Question 4:

The performance of signal reception can be improved by using different techniques, among which are the beam steering and the MIMO. Briefly explain these techniques. **(6 Marks)**

Question 5:

a) Decide what the following sequences should be decoded to, assuming there is at most one error in each sequence. Use the trellis shown in Fig. 3 by starting from the upper left node. **(6 Marks)**

i. 00 10 10 00 (3 marks)

ii. 11 01 01 01

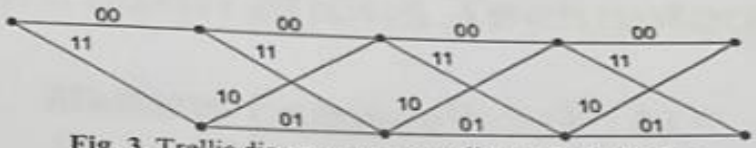


Fig. 3. Trellis diagram corresponding to Question 5-a.

b) Suppose the following sequence had been received: 01 01 10. Suppose further that you were exploring the paths on the trellis and looked at the two highlighted in Fig. 4 below. This means you would be comparing the received sequence against these two sequences:

i. 00 00 00

ii. 11 01 10.

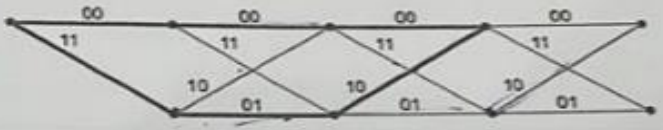


Fig. 4. Trellis diagram corresponding to Question 5-b.

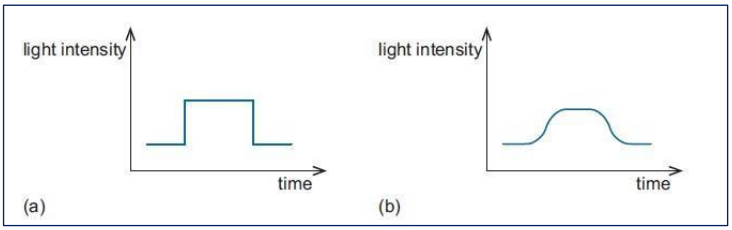
Which would be the best choice? Justify your answer. (3 marks)

End of question

Question 1 Answers:

a. This effectively limits the data rate that can be obtained over a length of fibre, because parts of the signal start to merge into each other. The effects are cumulative; the longer the fibre, the worse it gets.

b.



c. Different path lengths result in different timings for the trip through the fibre.

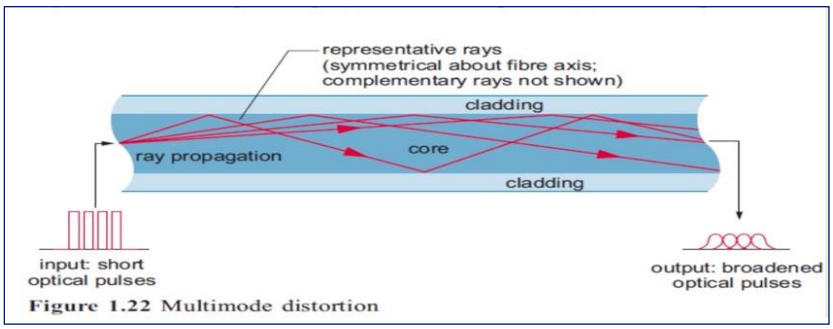


Figure 1.22 Multimode distortion

Question 2 Answers:

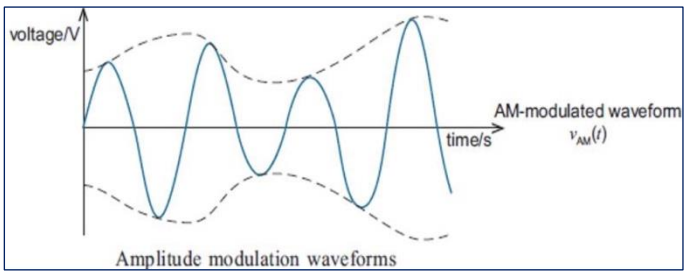
a. Energy: Power (W) × Time (h)
Energy: 1000W × $\left(\frac{6}{60}\ h\right)$ = 100wh → $\frac{100}{1000} = 0.1\ kwh$

b. $f = \frac{c}{\lambda} \rightarrow f = \frac{3\times10^{8}}{500\times10^{-9}} = 6\times\ 10^{14}\text{Hz}$

$T = \frac{1}{f} \rightarrow T = \frac{1}{6\times\ 10^{14}} = 1.6\ \times 10^{-15}\text{sec}$

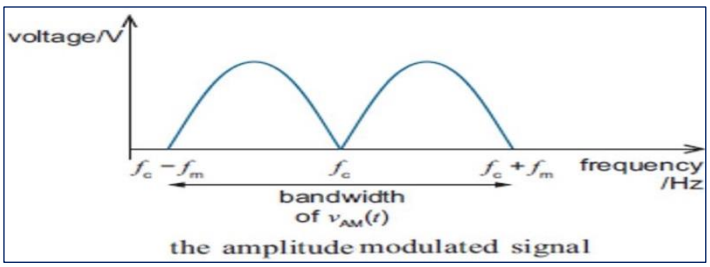
Question 3 Answers:

a.



Amplitude modulation waveforms

b.



the amplitude modulated signal

Question 4 Answers:

Beam steering: also called beamforming, is a technique that uses multiple transmitter antennas. It is used when communicating with a single receiver, and its purpose is to improve reception at this target device.

In this technique, the relative amplitudes and phases of the signals from each antenna are adjusted so that when they arrive at the target receiver, they add together constructively. This increases the strength of the received signal and provides some resistance to fading.

MIMO: uses multiple antennas at both the transmitter and the receiver.

Question 5 Answers:

i. The sequence 00 10 10 00 does not correspond to any path through the decoder. However, assuming one error – in the fourth received bit – leads to the sequence 00 11 10 00, which corresponds to the sequence generated by the data 0100.

ii. 1111

Question 6 Answers:

The hamming distance are 3 for (i) and 1 for (iii) so the best choice would be sequence (iii) which is 11 01 10.

Question 1:

a- Mention the difference between a **step-index fiber** and a **graded-index fibre**

b- Some of the main causes of pulse spreading in fibre are dispersion and polarization mode distortion.
Give a brief definition for each of these two terms.

Question 2:

a) A communication system uses 20 Km of fibre that has a 1.25 dB/Km loss characteristics. Find theoutput power (P_2) if the input power (P_1) is 800 mW.

Question 3:

Draw the frequency -domain representation or spectrum (amplitude versus frequency only) of each of thefollowing wave forms:

b) $a(t) = 10 \sin (40 \pi t)$

c) $b(t) = 2 \cos (12000 \pi t - \pi/4)$

Question 4:

a- A particular FM radio system uses a modulation index of 5 and the modulating signal has a spectrum that extends from 30 KHz to 60 KHz. What is the approximate bandwidth of the FM-modulated signal?

b- If AM were used instead, what should be the bandwidth of the modulated signal?

Question 5:

a) Find the Hamming distance between the two codes: 1100110 and 0000111

b) For codes that have a Hamming distance equals to the value found in part (a) above, answer thefollowing questions:
   i. How many errors can be detected without correcting them?
   ii. How many errors can be corrected?

Question 6:

The question is about a system using seven-digit hamming code (refer to figure below for hint.)

a) What would the coded messages be if the original messages were the following?
   i. 0100
   ii. 1110

b) Check for the following code word that has been received if there is any error occurred during the transmission (1110000) and extract the decoded message.

Question 1 Answers:

a. **step-index fibre:** the refractive index changes abruptly between core and cladding.

graded-index fiber: the refractive index varies smoothly from a maximum in the centre of the core to a minimum within the cladding.

b. **Dispersion:** caused by light of different wavelengths travelling at different speeds.

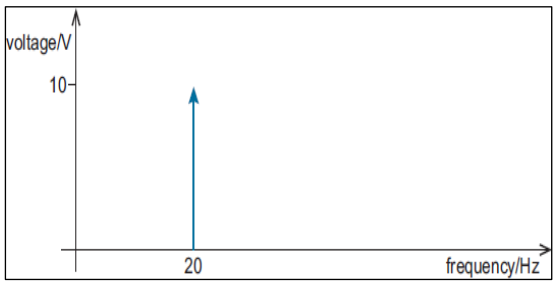
Polarization: affects single-mode fibres and is caused by another variation in the speed of light.

Question 2 Answer:

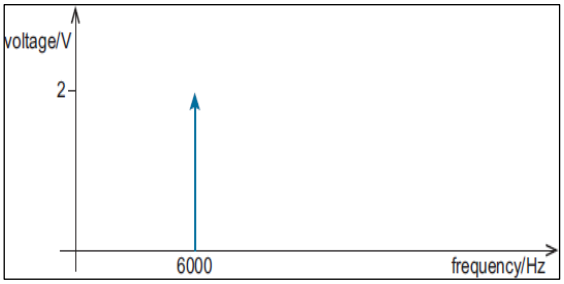
$$G = 10\log\left(\frac{p2}{p1}\right) \quad \rightarrow \quad p_2 = p_1 \times 10^{\frac{loss\ dB}{10}}$$
$$loss\ dB = 20km \times -1.25\ dB = -25\ dB$$
$$p_2 = 800mW \times 10^{\frac{-25dB}{10}} = 2.53mW$$

Question 3 Answers:

a.



b.



Question 4 Answers:

a.

$\beta = 5, F_m = 60kHz - 30kHz = 30\ kHz$

$B_{FM} = 2(1 + \beta) \times FM \quad \rightarrow \quad B_{FM} = 2(1 + 5) \times 30 = 360kHz$

b.

$2F_m = 2 \times 30\ kHz = 60\ kHz$

Question 5 Answers:

a. Hamming distance: 3

b.

i. $(3 - 1) = 2$

ii. $\frac{(3-1)}{2} = 1 \rightarrow$ a single error in any one code word.

Question 6 Answers:

a.

i. Parity 1 (1,3,5,7): 1010
Parity 2 (2,3,6,7): 0000
Parity 3 (4,5,6,7): 1100
Code word: 1001100

ii. Parity 1 (1,3,5,7): 0110
Parity 2 (2,3,6,7): 0110
Parity 3 (4,5,6,7): 0110
Code word: 0010110

b. Parity 1 (1,3,5,7): 1100 → Syndrome → Correct → 0
Parity 2 (2,3,6,7): 1100 → Syndrome → Correct → 0
Parity 3 (4,5,6,7): 0000 → Syndrome → Correct → 0
Syndrome: $(000)_2 \rightarrow (0)_{10}$ → correct codeword
Message (3,5,6,7) = 1000

Question 1: **(6 Marks)**

a) Mention the difference between a step-index fibre and a graded-index fibre. (2 marks)

b) Some of the main causes of pulse spreading in fibres are **dispersion** and **polarization** mode distortion. Give a brief definition for each of these two terms. (4 marks)

Question 2: **(4 Marks)**

A communication system uses 20 km of fibre that has a 1.25 dB/km loss characteristics. Find the output power (P_2) if the input power (P_1) is 800 mW.

Question 3: **(4 Marks)**

Draw the frequency-domain representation or spectrum (amplitude versus frequency only) for each of the following two waveforms:

i. $a(t) = 10 \sin(40\pi t)$ (2 marks)

ii. $b(t) = 2 \cos(12000\pi t - \pi/4)$. (2 marks)

Question 4: **(4 Marks)**

a) A particular FM radio system uses a modulation index of 5 and the modulating signal has a spectrum that extends from 30 kHz to 60 kHz. What is the approximate bandwidth of the FM-modulated signal? (2 marks)

b) If AM were used instead, what would be the bandwidth of the modulated signal? (2 marks)

Question 5: **(6 Marks)**

a) Find the Hamming distance between the two codes: 1100110 and 0000111 (2 marks)

b) For codes that have a Hamming distance equals to the value found in part (a) above, answer the following questions:

i. How many errors can be detected without correcting them? (2 marks)

ii. How many errors can be corrected? (2 marks)

Question 6: **(6 Marks)**

This question is about a system using the seven-digit Hamming code (Refer to Fig. 1 for hint.)

(a) What would the coded messages be if the original messages were the following?

(*i*) 0100 (1 mark)

(*ii*) 1110 (1 mark)

(b) If the code **1110000** is received, state whether there have been any errors, and give the decoded output. (Assume that the probability of there being more than one error in a received code word is negligible.) (4 marks)

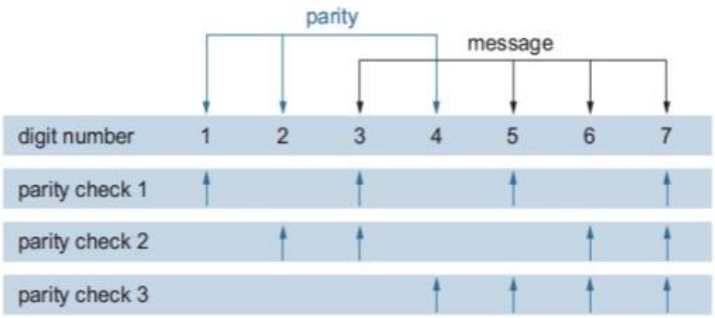


Figure 1. Parity-check for a seven-digit Hamming code

End of Questions

Question 1 Answers:

a. step-index fibre: the refractive index changes abruptly between core and cladding.

graded-index fiber: the refractive index varies smoothly from a maximum in the centre of the core to a minimum within the cladding.

b. Dispersion: caused by light of different wavelengths travelling at different speeds.

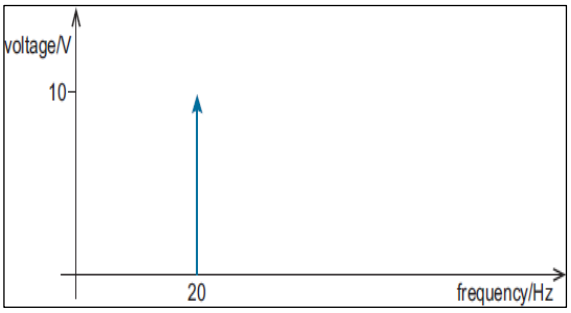
Polarization: affects single-mode fibres and is caused by another variation in the speed of light.

Question 2 Answer:

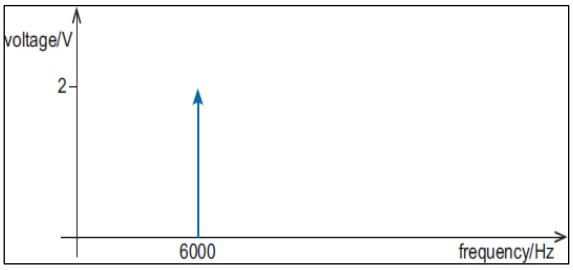
$$G = 10\log\left(\frac{p2}{p1}\right) \rightarrow p_2 = p_1 \times 10^{\frac{loss\ dB}{10}}$$
$$loss\ dB = 20km \times -1.25\ dB = -25\ dB$$
$$p_2 = 800mW \times 10^{\frac{-25dB}{10}} = 2.53mW$$

Question 3 Answers:

a.



b.



Question 4 Answers:

a.

$\beta = 5, F_m = 60kHz - 30kHz = 30\ kHz$

$B_{FM} = 2(1 + \beta) \times FM \rightarrow B_{FM} = 2(1 + 5) \times 30 = 360kHz$

b.

$2F_m = 2 \times 30\ kHz = 60\ kHz$

Question 5 Answers:

a. Hamming distance: 3

b.

i. $(3 - 1) = 2$

ii. $\frac{(3-1)}{2} = 1 \rightarrow$ a single error in any one code word.

Question 6 Answers:

a.

i. Parity 1 (1,3,5,7): 1010
Parity 2 (2,3,6,7): 0000
Parity 3 (4,5,6,7): 1100
Code word: 1001100

ii. Parity 1 (1,3,5,7): 0110
Parity 2 (2,3,6,7): 0110
Parity 3 (4,5,6,7): 0110
Code word: 0010110

b. Parity 1 (1,3,5,7): 1100 → Syndrome → Correct → 0
Parity 2 (2,3,6,7): 1100 → Syndrome → Correct → 0
Parity 3 (4,5,6,7): 0000 → Syndrome → Correct → 0
Syndrome: $(000)_2 \rightarrow (0)_{10}$ → correct codeword
Message (3,5,6,7) = 1000

Question 1:

A communication system uses 10km of fiber that has a 2.5 dB/km loss charachteristics. Find the outputpower (P_2) if the input power (P_1) is 400 mW

Question 2:

a) Mention the difference between a step-index fiber and a graded-index fiber

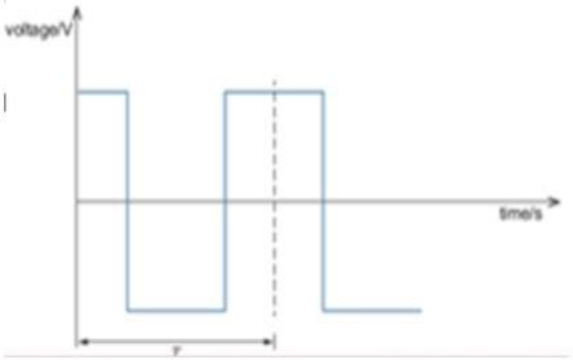
b) What is multimode distortion?

c) What is the advantage of a graded-index fiber over the corresponding step-index with respect to multimode distortion?

Question 3:

If the Fourier series for the periodic square waveform shown below is represented by:

$$v(t) = \frac{4V}{\pi}\left[\cos(\omega t) + \frac{1}{3}\cos(3\omega t + \pi) + \frac{1}{5}\cos(5\omega t) + \frac{1}{7}\cos(7\omega t + \pi) + \ldots\right]$$



Draw the corresponding frequency-domain representing showing the first four harmonics.

Question 4:

a) What is the maximum data rate, in kilo-bit per second, in a noise-free channel with bandwidth of20000 Hz and a set of 128 symbols?

b) If the channel described in part (a) above was noisy channel that has a signal-to-noise ratio of 1000,what would be the corresponding data rate in kilo-bit per second?

Question 5:

Table 1 below should give the length (n), the number of message (k), and the code rate of Hamming code words fornumbers of parity digits (m). Fill in the table for all the Hamming codes and show the relation between parity digits and code word size.

Number of Parity digits	Hamming code word length, n	Number of message digits, k	Code rate
m	$n= 2^m - 1$	K= n-m	Code rate = k/n
2			
4			
6			
8			

Question 6:

Check whether the following EAN-13 code is a valid code or not : 978-0521625575. Show the details ofyour calculation.

Question 1 Answer:

$$G = 10\log\left(\frac{p2}{p1}\right) \rightarrow p_2 = p_1 \times 10^{\frac{loss\ dB}{10}}$$
$$loss\ dB = 10km \times -2.5\ dB = -25\ dB$$
$$p_2 = 400mW \times 10^{\frac{-25dB}{10}} = 1.26mW$$

Question 2 Answers:

a. step-index fibre: the refractive index changes abruptly between core and cladding.

graded-index fiber: the refractive index varies smoothly from a maximum in the centre of the core to a minimum within the cladding.

b. Multimode distortion: two rays of light that set off at the same time may not reach the other end of the fibre exactly simultaneously as with attenuation, the effects are cumulative, *the longer the fibre, the worse it gets.*

The signal transmitted is called a pulse, so the effect is known as pulse spreading.

One reason for pulse spreading in multimode fibres: different path lengths result in different timings for the trip through the fibre.

c. Waves that take slightly longer paths travel slightly faster, and so different waves setting off at the same time arrive nearly simultaneously at the other end of the fibre.

Question 3 Answer:

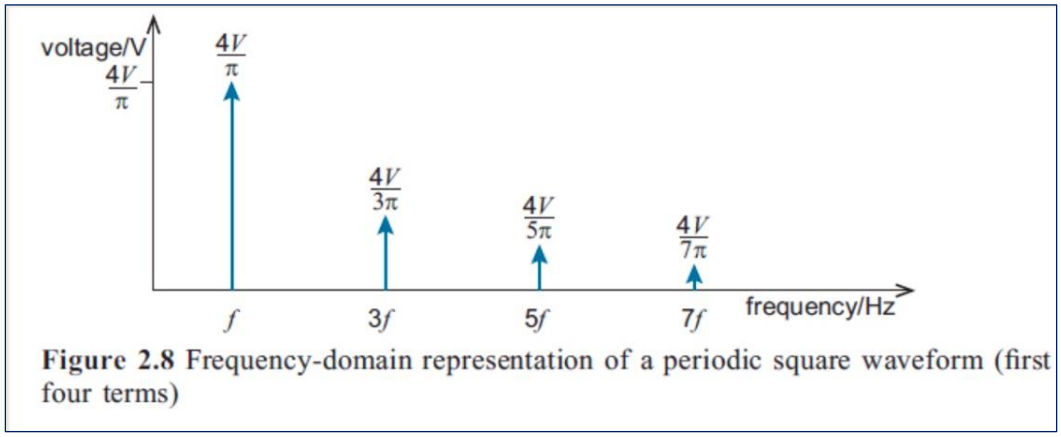


Figure 2.8 Frequency-domain representation of a periodic square waveform (first four terms)

Question 4 Answers:

a. $\boldsymbol{D = 2B\ log_2 M}$

D = 2(20 kHz) $\boldsymbol{log_2}128$

D = (40 kHz) $\boldsymbol{log_2}2^7$

D = (40 kHz) 7

D = 280 k bit/s

b. $C = W\log_2(1 + S/N)$

$C = 20\ \text{kHz}\ \log_2(1 + 1000)$

$C = 200$ kbit/s

Question 5 Answer:

Number of Parity digits	Hamming code word length, n	Number of message digits, k	Code rate
$\boldsymbol{m}$	$n = 2^m - 1$	$\boldsymbol{K = n - m}$	$\boldsymbol{Code\ rate = k/n}$
2	3	1	$\frac{1}{3} = 0.33$
4	15	11	$\frac{11}{15} = 0.73$
6	63	57	$\frac{57}{63} = 0.90$
8	255	247	$\frac{247}{255} = 0.96$

Question 6 Answer:

Sum of odd positions: $9 + 8 + 5 + 1 + 2 + 5 = 30$
Sum of even positions: $7 + 0 + 2 + 6 + 5 + 7 = 27$
Sum of even positions $\times$ 3: $27 \times 3 = 81$
Sum of odd positions + (Sum of even positions $\times$ 3): 30 + 81 = 111
111%10 = 1 → 10 – 1 = 9 → invalid.

Question 1: **(5 Marks)**

From your study of optical fibre, explain the "**graded-index fibre**" briefly.

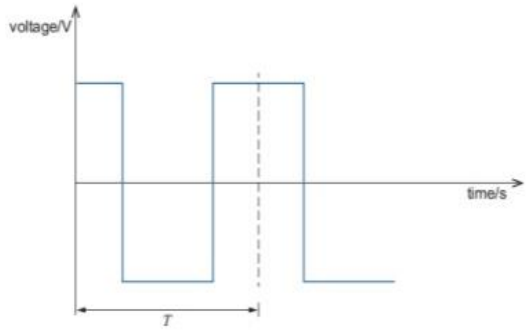
Question 2: **(5 Marks)**

From your study of antennas, explain the concept of "**Beam Steering**".

Question 3: **(5 Marks)**

If the Fourier series for the periodic square waveform shown below is represented by:

$$v(t) = \frac{4V}{\pi}\left[\cos(\omega t) + \frac{1}{3}\cos(3\omega t + \pi) + \frac{1}{5}\cos(5\omega t) + \frac{1}{7}\cos(7\omega t + \pi) + \ldots\right]$$



Draw the corresponding frequency-domain representation showing the first four harmonics.

Question 4: **(5 Marks)**

Which of the following might be valid code words using even parity?

(a) 11000111

(b) 10101010

Question 5: **(5 Marks)**

This question is about a system using the seven-digit Hamming code (Refer to Figure below for hint.) If the code **1101011** is received, state whether there have been any errors, and give the decoded output. (Assume that the probability of there being more than one error in a received code word is negligible.)

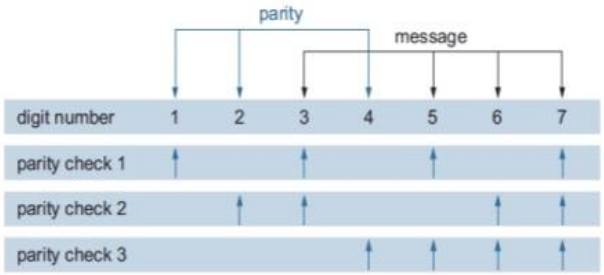


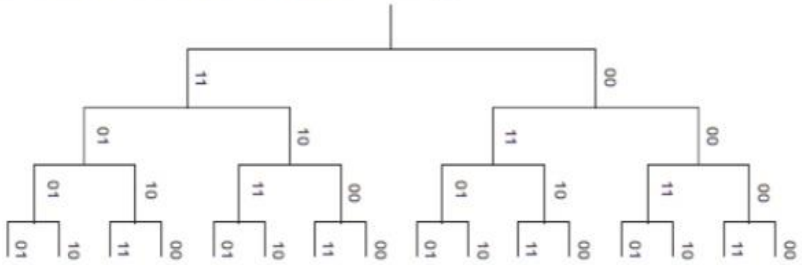
Fig. Parity-check for a seven-digit Hamming code

Question 6: **(5 Marks)**

In a convolutional coding system, suppose a decoder of the code with the tree shown below receives the following sequences:

a) 00 00 00 00
b) 00 10 00 00

Decide what each sequence should be decoded to by looking at possible paths through the tree (Assume the smallest number of errors, if necessary).



End of Questions

Question 1 Answer:

graded-index fiber: the refractive index varies smoothly from a maximum in the centre of the core to a minimum within the cladding.

Question 2 Answer:

Beam steering: also called beamforming, is a technique that uses multiple transmitter antennas. It is used when communicating with a single receiver, and its purpose is to improve reception at this target device.

In this technique, the relative amplitudes and phases of the signals from each antenna are adjusted so that when they arrive at the target receiver, they add together constructively. This increases the strength of the received signal and provides some resistance to fading.

Question 3 Answer:

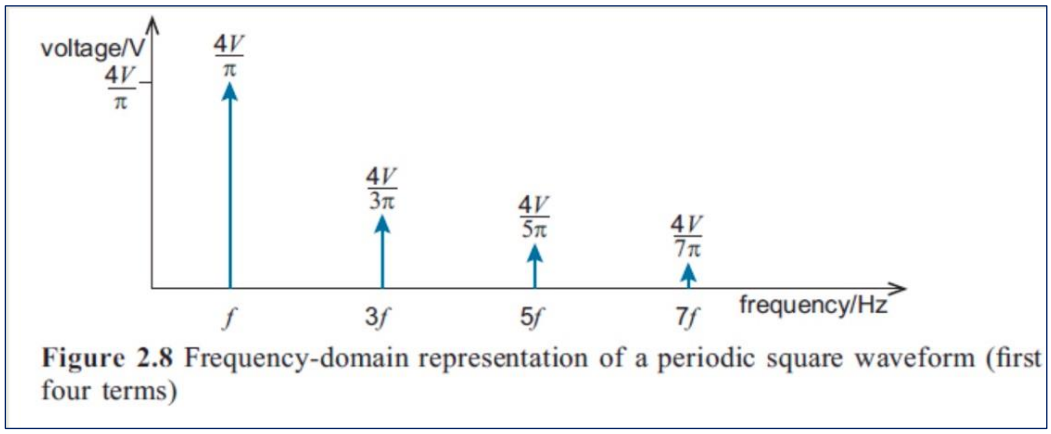


Figure 2.8 Frequency-domain representation of a periodic square waveform (first four terms)

Question 4 Answer:

a. Invalid
b. Valid

Question 5 Answer:

Parity 1 (1,3,5,7): 1001 → Syndrome → Correct → 0
Parity 2 (2,3,6,7): 1011 → Syndrome → incorrect → 1
Parity 3 (4,5,6,7): 1011 → Syndrome → incorrect → 1
Syndrome: $(110)_2$ → $(6)_{10}$ → correct codeword: 1101001
Message (3,5,6,7) = 0001

Question 6 Answer:

a. 0000

b. There is no path through the decoder that would result in this output stream, So, there must have been one or more errors. However, if we assume that the third bit in the stream is in error, and should be a 0 rather than a 1, then we are back to 00 0000 00, which should be decoded to 0000.

Question 1: **(5 Marks)**

What is the speed of light in glass with a refractive index of 1.5? (Take $c = 3\times10^8$ m/s.)

Question 2: **(5 Marks)**

For the waveforms shown in Fig.1 (a) and (b) below, draw the corresponding frequency domain representations given that the time period for both signals is equal to 1ms.

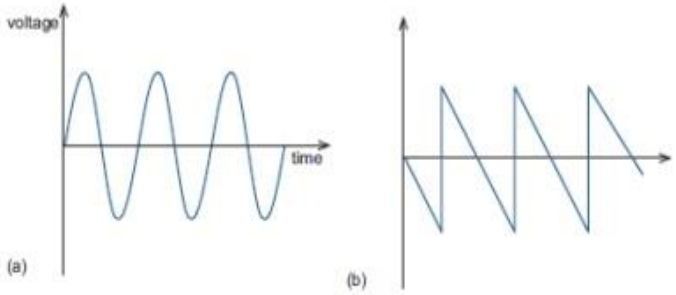


Figure 1. Corresponding to Question 2.

Question 3: **(5 Marks)**

a) For the modulating and carrier signals shown in Fig. 2(a), draw a rough sketch for the resulted amplitude modulated signal.

b) If the frequency spectrum of the modulating signal is shown in Fig. 2(b), draw the corresponding frequency spectrum of the amplitude modulated signal.

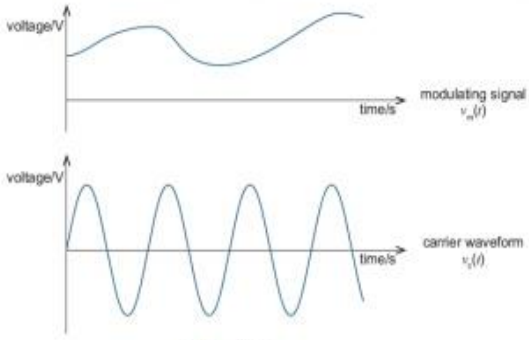


Fig. 2(a)

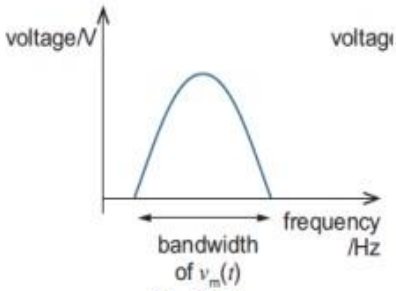


Fig. 2(b)

Question 4: **(5 Marks)**

(a) If a communications system uses 64 symbols, how many bits does each symbol represent?

(b) If the same system has a symbol rate of 16000 baud, what is the data rate?

Question 5: **(5 Marks)**

From your study of spectrum management, mention three technical issues that should be considered when allocating services to different parts of the spectrum.

Question 6: **(5 Marks)**

Suppose that we use a denary cyclic redundancy check, with G = 999.

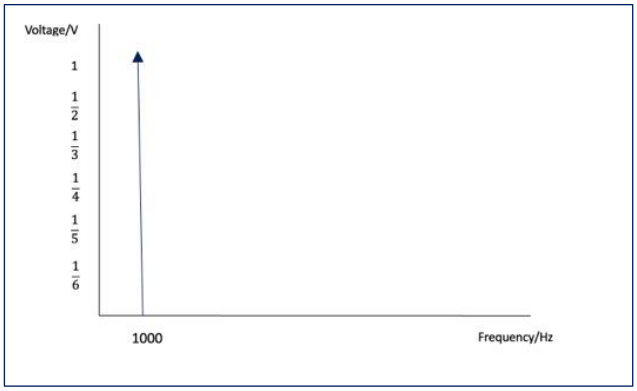
a) What is the code word if the message is 45454545?
b) If the code word 52310642002 is received at a decoder. What is the message digit? Does it appear to contain errors?

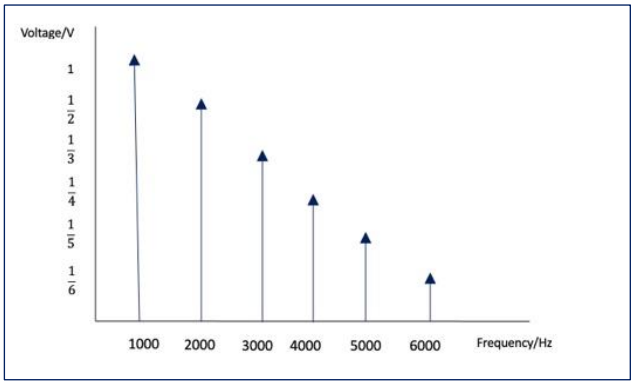
End of Questions

Question 1 Answer:

$$v = \frac{c}{n} \rightarrow \frac{3 \times 10^8 \text{ m s}^{-1}}{1.5} = 2 \times 10^8$$

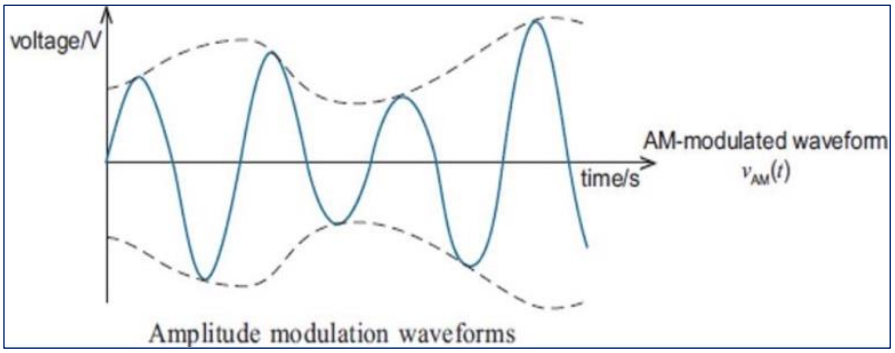
Question 2 Answer:



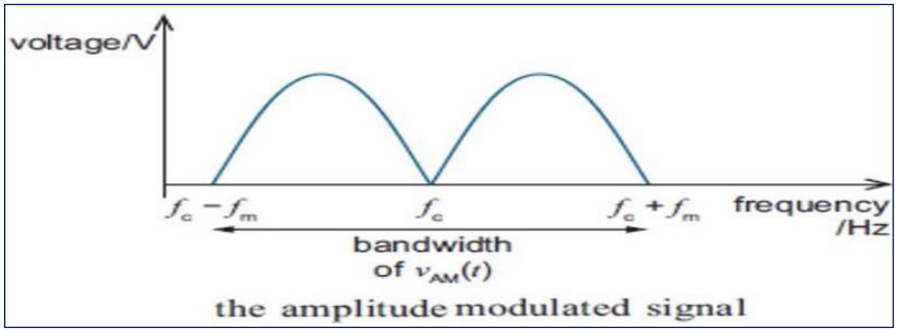


Question 3 Answers:

a.



b.



Question 4 Answers:

a. n = log_2(M) = log_2(64) = 6 bits/symbol
b. $16000 \times 6 = 96\ k\ bits/s$

Question 5 Answers:

- Line-of-sight.
- Long-distance
- It is not possible to accommodate wide bandwidths in low- frequency bands.
- Communication between a satellite and the ground requires a window through the atmosphere where absorption is low.
- Transmitters and receivers for the highest frequencies present significant engineering challenges.

Question 6 Answers:

a. 45 454 545 % 999 = 45 → check digits = 045
Code word = message + check digits = 45454545045.

b. Message = 52310642. 52310642%999 = 005 → different from the received check digits "002", so there must have been errors.

Question 1: **(5 Marks)**
List five examples of noise or interference.

Question 2: **(5 Marks)**
A mobile device is being used by someone sitting on a high-speed train moving at 300 km/h and the transmitter frequency is nominally 2.1 GHz. Calculate the Doppler shift, in Hz, for the case where the mobile is moving directly towards the fixed transmitter from which it is receiving a signal. (Take the speed of light, c, to be 3×10^8 m/s.)

Question 3: **(5 Marks)**
In a certain type of optical fibre, half the power supplied to the fibre at the source is lost after the light signal has travelled a distance of 10 km. By treating the fibre as a series of 10 km sections, calculate what fraction of the power will be left after 20 km, 30 km and 50 km.

Question 4: **(5 Marks)**
Sketch what the modulated waveforms for ASK, FSK and PSK might look like for the modulating signal 0 1 1 0 1.

Question 5: **(5 Marks)**
Which of the following might be valid code words using even parity?
(a) 01101010
(b) 01001100

Question 6: **(5 Marks)**
This question is about a system using the seven-digit Hamming code (Refer to Figure 1 for hint.) If the code **1110000** is received, state whether there have been any errors, and give the decoded output. (Assume that the probability of there being more than one error in a received code word is negligible.)

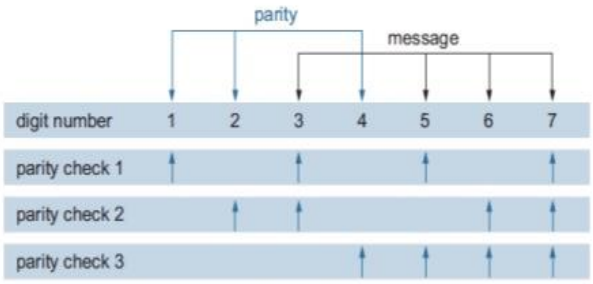


Figure 1. Parity-check for a seven-digit Hamming code

End of Questions

Question 1 Answers:

- Interference from unwanted stations on AM or FM radio.
- Mobile phones can interfere with unrelated equipment radio transmitter.
- Domestic appliances or power tools.
- Natural sources of noise include electrical storms and the effects of the sun.
- Another important noise source is noise generated within the receiver.

Question 2 Answers:

$$f_r - f_t = (\frac{f_t \times v}{c})$$

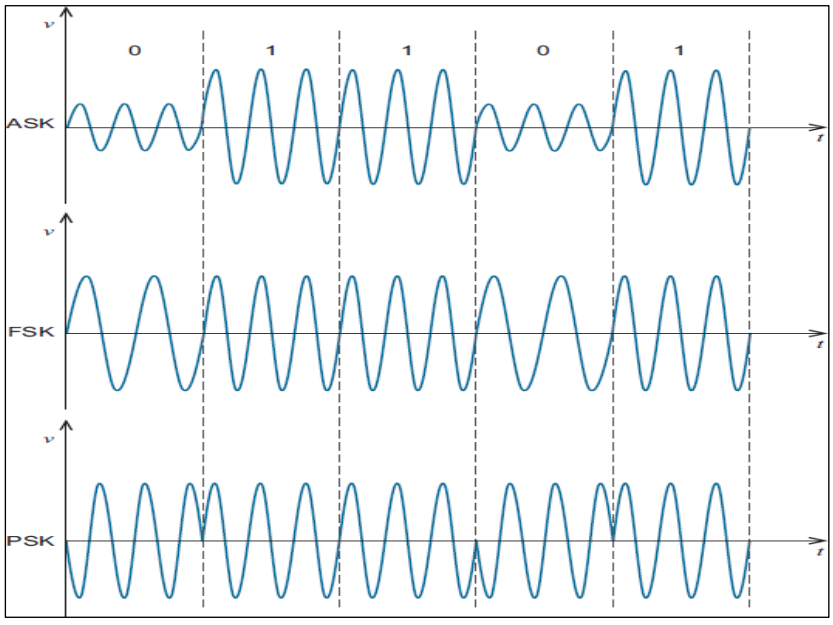
$$v = \frac{300 \times 10^3}{60 \times 60} = 83.33ms^{-1}$$

$$f_r - f_t = \left(\frac{2.1 \times 10^9 \text{Hz} \times 83.33ms^{-1}}{3 \times 10^8 \text{ m s}^{-1}}\right) \approx 583\text{Hz}.$$

Question 3 Answers:

after 10 km = 0.5 original powers.
after 20 km $= \frac{0.5}{2} = 0.25$ original power
after 30 km $= \frac{0.25}{2} = 0.125$ original power.
after 50 km $= \frac{0.5}{4} = 0.03125$ original power.

Question 4 Answers:



Question 5 Answers:

i. Valid
ii. Invalid

Question 6 Answers:

Parity 1 (1,3,5,7): 1100 → Syndrome → Correct → 0
Parity 2 (2,3,6,7): 1100 → Syndrome → Correct → 0
Parity 3 (4,5,6,7): 0000 → Syndrome → Correct → 0
Syndrome: $(000)_2$ → $(0)_{10}$ → correct codeword
Message (3,5,6,7) = 1000

Question 1: **(5 Marks)**

Resolutions of seven bits and eight bits have been found by telecommunications operators to be adequate for telephone speech. Suppose a 7-bit converter takes 8000 samples per second. How many different quantisation levels are there? How many bits of data are produced every second?

Question 2: **(5 Marks)**

A periodic signal can be represented as the sum of five sine waves with frequencies of 150, 300, 450, 600 and 750 MHz. What is the bandwidth of the signal?

Question 3: **(5 Marks)**

In a certain type of optical fibre, half the power supplied to the fibre at the source is lost after the light signal has travelled a distance of 10 km. By treating the fibre as a series of 10 km sections, calculate what fraction of the power will be left after 20 km, 30 km and 50 km.

Question 4: **(5 Marks)**

A signal is transmitted along a cable 100 m long. The signal consists of a series of pulses each 25 ns long. How far does the signal travel along the cable in the time between a pulse starting and ending? Assume that the speed of the signal is 2×108 m s−1

Question 5: **(5 Marks)**

With the noise power density shown in Fig. 1, what noise power falls within the shaded channel?

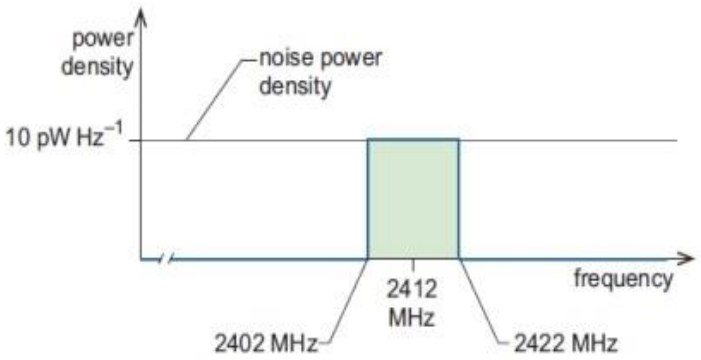


Fig. 1

Question 6: **(10 Marks)**

For the modulating signal $v_m(t)$ shown in Fig. 2(a) and the carrier signal $v_c(t)$ shown in Fig. 2(b):

a) How can we find the resulting time-domain modulated signal?
b) Draw the corresponding time domain modulated signal.
c) Draw the spectrum of the modulating, carrier, and modulated signals.

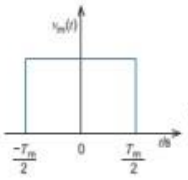


Fig. 2 (a)

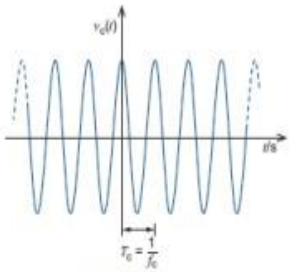


Fig. 2 (b)

Question 7: **(10 Marks)**

Check whether the following EAN-13 code is valid or not: 978–0521425575. Show the details of your calculations.

Question 8: **(15 Marks)**

a) Use the trellis of Fig. 3 to find the coding of the following input data: 1010. Assume we start from the top left node, and we take the upper branch if an input bit is a 0 and the lower branch if the input is a 1.
b) Suppose a decoder of the code with the tree shown in Fig.3 receives the following sequences. Decide what each sequence should be decoded to, assuming that there is at most one error in each sequence.
   i. 00 10 10 00
   ii. 11 01 01 01

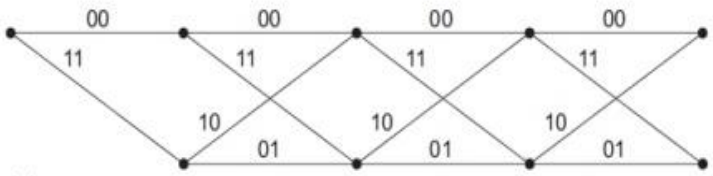


Fig.3.

End of Questions

Question 1 Answers:

Quantization levels = $2^n \rightarrow 2^7 = 128$ different quantization levels.
Data rate = number of samples $\times$ number of bits = $8000 \times 7 = 56000$

Question 2 Answers:

highest frequency - lowest frequency
750 MHz − 150 MHz = 600 MHz.

Question 3 Answers:

after 10 km = 0.5 original powers.
after 20 km $= \frac{0.5}{2} = 0.25$ original power
after 30 km $= \frac{0.25}{2} = 0.125$ original power.
after 50 km $= \frac{0.5}{4} = 0.03125$ original power.

Question 4 Answers:

$\mathrm{D} = (25 \times 10^{-9}\mathrm{s}) \times (2 \times 10^{8}\mathrm{m/s}) = 5\mathrm{m}$

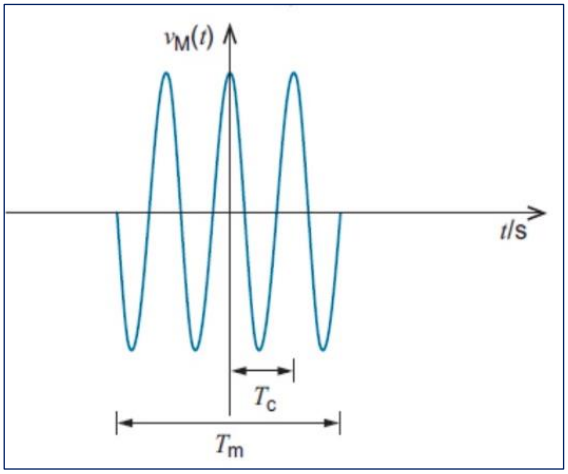
Question 5 Answers:

Noise power = noise power density × Bandwidth
noise power density = $10 \times 10^{-12}\mathrm{w/Hz}$
Bandwidth = $2422\mathrm{MHz} - 2402\ \mathrm{MHz} = 20\ \mathrm{MHz} = 20 \times 10^{6}$ Hz
Noise power = $(10 \times 10^{-12}\mathrm{w/Hz}) \times (20 \times 10^{6}\mathrm{Hz})$ = $200 \times 10^{-6} = 200\mu\mathrm{W}$

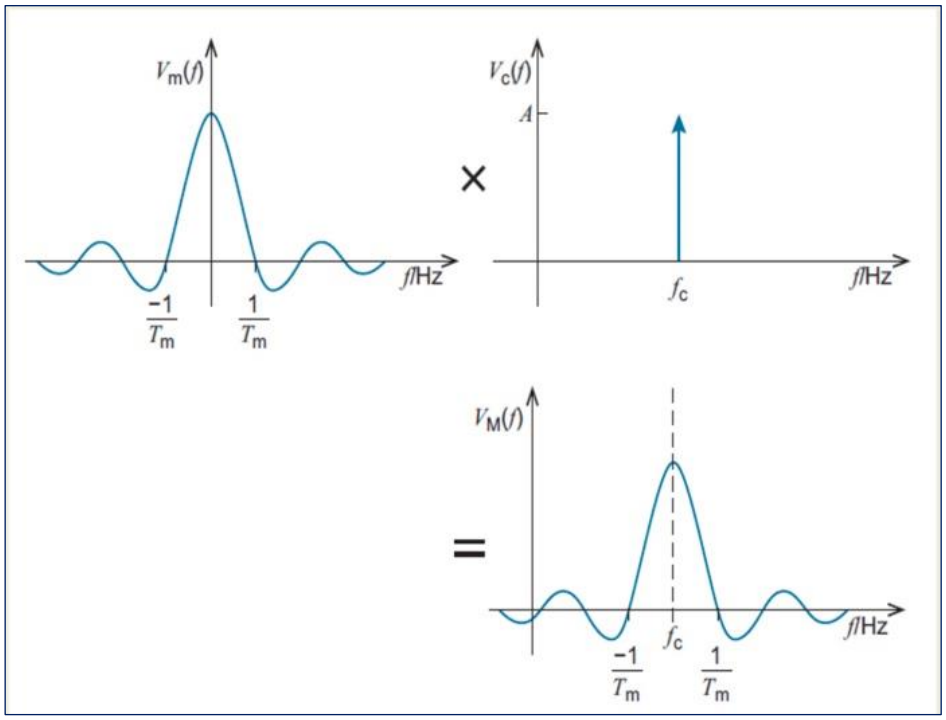
Question 6 Answers:

a. The modulated signal is created by multiplying the modulating signal and the carrier signal together.

b.



c.



Question 7 Answers:

Sum of odd positions: 9 + 8 + 5 + 1 + 2 + 5 = 30
Sum of even positions: 7 + 0 + 2 + 4 + 5 + 7 = 25
Sum of even positions × 3: 25 × 3 = 75
Sum of odd positions + (Sum of even positions × 3): 30 + 75 = 105
105%10 = 5 → 10 – 5 = 5 → valid.

Question 8 Answers:

a. 11 10 11 10

b.

i. The sequence 00 10 10 00 does not correspond to any path through the decoder. However, assumingone error – in the fourth received bit – leads to the sequence 00 11 10 00, which corresponds to the sequence generated by the data 0100.

ii. 1111

Mock Exams

Question 1:
Suppose a 6 kW kettle takes one minutes to boil. Calculate the energy in (kilowatt-hours).

Question 2:
The power sent along a fibre link by the transmitter is 5 mW, and the receiver sensitivity is 20 μW. The attenuation of the fibre is 0.2 dB km−1. A margin of 2 dB is required to allow for other losses and penalties. What is the maximum length of the link?

Question 3:
Sketch the graphical representations (wave form) for the following mathematical representations:

i. $v(t) = A\cos(\omega t)$
ii. $v(t) = A\cos(\omega t - \pi/2)$

Question 4:
How much would the difference in path lengths have to change for the received signal to go from maximum to minimum strength? What is this distance if the frequency is 2 GHz? (Take the speed of light to be 3×10^8 m s^{-1}.)

Question 5:
A mobile device is being used by someone sitting on a high-speed train moving at 400 km/h and the transmitter frequency is nominally 2.5 GHz. Calculate the Doppler shift, in Hz, for the case where the mobile is moving directly towards the fixed transmitter from which it is receiving a signal. (Take the speed of light, c, to be 3×10^8 m/s.)

Question 6:
Which of the following might be valid code words using even parity?

a) 01011010
b) 01000000

Question 7:
Suppose that we use a denary cyclic redundancy check with G = 999. What is the code word if the message is 8787878787?

Question 8:
Various effects distort signals in optical fibres by smearing out sharp transitions between light and dark sections of the signal. This phenomenon is called pulse spreading. What is the main reason for pulse spreading in multimode fibres?

End of Questions

Question 1 Answers:

Energy: Power (W) × Time (h)
Energy: 6kW × $\left(\frac{1}{60}\ h\right)$ = 100wh = 0.1 kwh

Question 2 Answers:

$$G = 10\log\left(\frac{p1}{p2}\right) = \rightarrow\ 10\log\left(\frac{5\times10^{-3}\text{W}}{20\times10^{-6}\text{W}}\right) = 24dB.$$

$$24dB - 2dB = 22dB$$

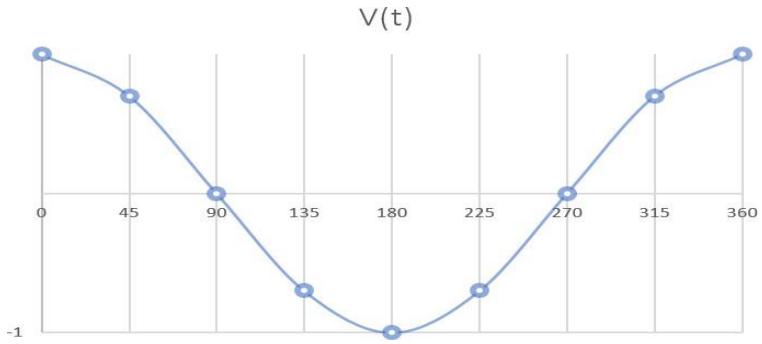
$$\frac{22dB}{0.2} = 110Km.$$

Question 3 Answers:

i.

WT	V(t)
0	1
45	0.7
90	0
135	-0.7
180	-1
225	-0.7
270	0
315	0.7
360	1

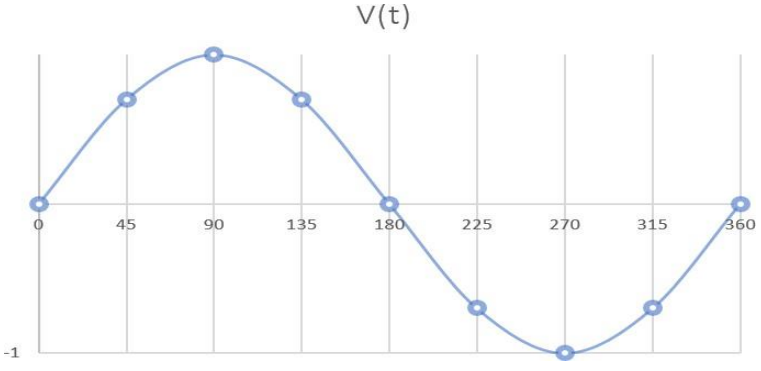
V(t) = A cos (ωt)



ii.

WT	V(t)
0	0
45	0.7
90	1
135	0.7
180	0
225	-0.7
270	-1
315	-0.7
360	0

V(t) = A cos ($\omega t - \frac{\pi}{2}$)



Question 4 Answers:

The maximum occurs when the radio waves are completely “in phase”, when they line up together, and the minimum occurs when they are completely “out of phase”. The difference between these two conditions amounts to half a wavelength.

$$\boldsymbol{\lambda} = \frac{C}{f}$$

$$\frac{3 \times 10^{8}\ \mathrm{m\,s^{-1}}}{2 \times 10^{9}\ \mathrm{Hz}} = \frac{3}{20} m = 0.15m$$

→ Half wavelength = $0.075m$ or $75mm$

Question 5 Answers:

$$f_r - f_t = \left(\frac{f_t \times v}{c}\right)$$

$$v = \frac{400 \times 10^{3}}{60 \times 60} = 111.11 ms^{-1}$$

$$f_r - f_t = \left(\frac{2.5 \times 10^{9}\mathrm{Hz} \times 111.11 ms^{-1}}{3 \times 10^{8}\ \mathrm{m\,s^{-1}}}\right) \approx 926\mathrm{Hz}.$$

Question 6 Answers:

a. Valid
b. Invalid

Question 7 Answers:

8787878787 % 999 = 462 → check digits = 462
Code word = message + check digits = 8787878787462.

Question 7 Answers:

different path lengths result in different timings for the trip through the fibre.

MTA Mock 2019 Fall

Question 1:

(6 Marks)

a) From your study of optical fibers, what keeps light guided along its path in an optical fiber? Why does the light not just stop when it comes to the first bend? (3 marks)

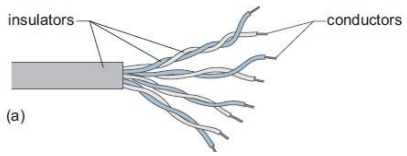
b) Of the many types of cable that are used for transmitting digital data and other high-frequency signals, you have been introduced to two important ones: the unshielded twisted pair (UTP) and the coaxial cable. Briefly describe their construction and give a simple sketch for them. (3 marks)

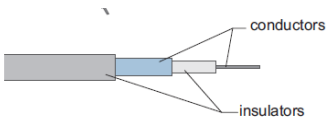
Solution:

a) Optical fibers work because the refractive index is not the same all the way across the fiber but is higher in the central core than it is in the cladding around the core **(1 mark).** If light is directed from one medium towards another with a lower refractive index, and it hits the boundary at a sufficiently small angle **(1 mark)**, it is not refractedbut reflected back into the first medium. Thus, in an optical fiber it will continue all theway along the fiber, relying on total internal reflection to keep it on course **(1 mark).**

b)

- Unshielded twisted pair (UTP) **cable**: a pair of conductors that is twisted togetheralong its length **(1 mark).**
- **Coaxial cable**: the two conductors take the form of a center conductor with a conducting shield around it **(1 mark).**





(1 mark).

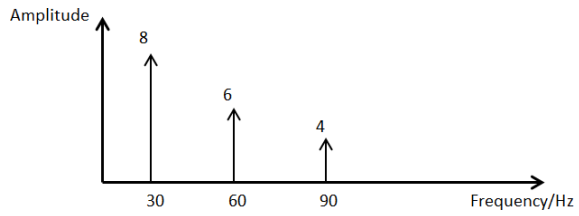
Question 2: **(4 Marks)**

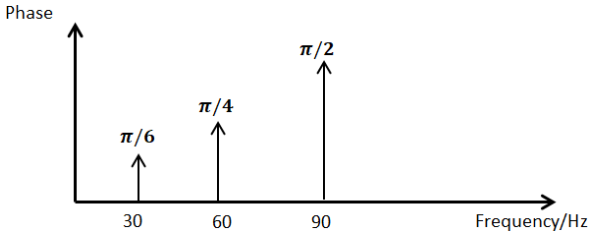
For a signal that is presumably represented by the following Fourier series:

$$v(t) = 8\cos(60\pi t + \pi/6) + 6\cos(120\pi t + \pi/4) + 4\cos(180\pi t + \pi/2)$$

where the frequencies are given in Hertz and the phases are given in (rad). Draw its frequency-domain representation showing both the amplitude component and the phase component.

Solution:





Question 3: **(4 Marks)**

The performance of signal reception can be improved by using different techniques, among which are the beam steering and the MIMO. Briefly explain these techniques.

Solution:

- **Beam steering**: also called beamforming, is a technique that uses multiple transmitter antennas. It is used when communicating with a single receiver **(1 mark).** In this technique, the relative amplitudes and phases of the signals from each antenna are adjusted so that when they arrive at the target receiver, they add together constructively **(1 mark).**

- **Multiple Input Multiple Output (MIMO)**: uses multiple antennas at both the transmitter and the receiver **(2 marks).**

Question 4: **(6 Marks)**

Suppose that we use a denary cyclic redundancy check with G = 888.

(a) What is the code word if the message is 35353535? (3 marks)

(b) The following code word is received at a decoder: 73310642111. Does it appear to contain errors? Justify your answer. (3 marks)

Solution:

(a) The check digits are given by the remainder of 35353535 divided by 888 ➔
35353535/888 = 39812.539 (to 3 d.p.), meaning the remainder is:
35353535 – 39812 × 888 = 479.

So the transmitted sequence is 35353535479. **(3 Marks)**

(b) For 73310642111, the data is 73310642 and the received check digits are 111. Calculating the check digits (from 73310642 divided by 888) gives 026. This is different from the receivedcheck digits, so there must have been errors. **(3 Marks)**

Question 5: **(6 Marks)**

A repetition code has just two code words: one for a data 0 (which repeats 0) and one for a data 1 (which repeats 1).

a) Repeating three times gives a code with two code words: 000 and 111. What is the Hamming distance of this code? Explain. (1 mark)
b) How many errors can it correct in each code word? Justify your answer. (1 mark)
c) Describe the code using the (*n*, *k*) notation. (1 mark)
d) What is the code rate? (1 mark)
e) Answer the same questions as in parts (a-d) for a code that repeats five times. (2 marks)

Solution:

a) The Hamming distance is 3, because 000 differs from 111 in three places. **(1 mark)**
b) It can correct a single error in any one code word, since the hamming distance is odd and hence it can correct up to (*d*-1)/2 ➔ (3-1)/2 =1. **(1 mark)**
c) It is a (3, 1) code. **(1 mark)**
d) The code rate is 1/3. **(1 mark)**
e) The Hamming distance is 5 **(0.5 mark)**, because 00000 differs from 11111 in five places. It can correct two errors in any one code word ((*d*-1)/2 ➔ (5-1)/2 =2) **(0.5 mark)**, and it is a (5, 1) code **(0.5 mark)**. The code rate is 1/5 **(0.5 mark)**.

Question 6: **(4 Marks)**

a) Decide what the following sequences should be decoded to, assuming there is at most one error in each sequence. Use the trellis shown in Fig. 1, if needed. (2 marks)
   i. 00 10 10 00
   ii. 11 01 01 01

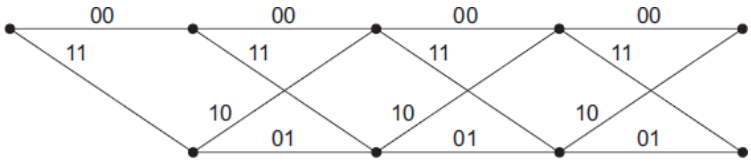


Figure 1.

b) Suppose the following sequence had been received: 01 01 10. Suppose further that you were exploring the paths on the trellis and looked at the two highlighted in Fig. 2 below. This means you would be comparing the received sequence against these two sequences:
   i. 00 00 00
   ii. 11 01 10.

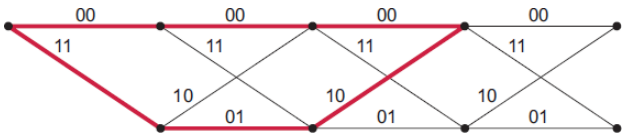


Figure 2.

Which would be the best choice? Justify your answer. (2 marks)

Solution:

a)

i. The sequence 00 10 10 00 does not correspond to any path through the decoder. However, assuming one error – in the fourth received bit – leads to the sequence 00 11 10 00, which corresponds to the sequence generated by the data **0100**.

(1 mark)

ii. The sequence 11 01 01 01 corresponds to the sequence generated by the data **1111**, without any errors. **(1 mark)**

b) Since the Hamming distances are **3** for (*b-i*) **(0.5 mark)** and **1** for (*b-ii*) **(0.5 mark)**, the best choice would therefore be sequence (*ii*): 11 01 10 **(1 mark)**.

End of Questions

MTA Mock 2019 Spring

Question 1: **(6 Marks)**

a) One of the major challenges facing amplitude modulation (AM) systems is their susceptibility to noise. Why is this less of a problem in frequency modulation (FM) and phase modulation (PM) systems? (2 marks)

b) A particular FM radio system uses a modulation index of 4 and the modulating signal has a spectrum that extends from 10 kHz to 20 kHz.

i. What is the frequency deviation? (2 marks)

ii. What is the approximate bandwidth of the FM-modulated signal? How does this compare to the modulated bandwidth if AM were used instead? (2 marks)

Solution:

a) This is a problem in AM because when noise is added to the modulated signal, it affects the signal's envelope **(1 mark)**. The noise is therefore processed at the receiver in the same way as the information in the signal **(0.5 mark)**. However, in FM and PM the information is not carried in the envelope of the modulated signal **(0.5 mark).**

b)

i. If $\beta = 4$ and $f_m = 20 - 10 = 10$ kHz **(1 mark)**➔ $\Delta f = \beta \times f_m = 4 \times 10 = 40\ kHz$. **(1 mark)**

ii. The bandwidth of the FM-modulated signal is given by:

$B_{FM} = 2(\Delta f + f_m) = 2(40 + 10) = 100\ kHz.$ **(1 mark)**

For the AM: $B_{AM} = 2f_m = 2 \times 10 = 20\ kHz$. So, FM uses much more spectrum. **(1 mark)**

Question 2: **(4 Marks)**

Some of the main causes of pulse spreading in fibers are **dispersion** and **polarization** mode distortion. Give a brief definition for each of these two terms.

Solution:

- Dispersion is caused by light of different wavelengths travelling at different speeds. (2 marks)
- Polarization mode distortion is caused by variation in the speed of light with the orientationof the light wave in the fiber. (2 marks)

Question 3: **(6 Marks)**

Fig. 1 below shows three examples of digitally modulated waveforms. For each example, decide which modulation scheme has been used and, work out what binary data each of these represents.

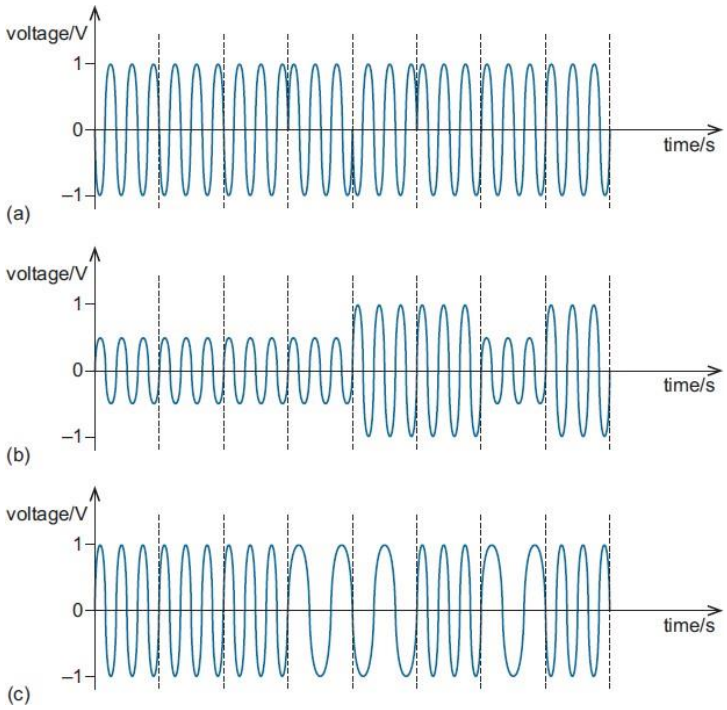


Figure 1. Three digitally modulated waveforms

Solution:

Waveform (a) is an example of a **BPSK**-modulated waveform representing the data:

0 0 0 1 0 1 1 1. (1+1=2 marks)

Waveform (b) is an example of a **BASK**-modulated waveform representing the data:

0 0 0 0 1 1 0 1. (1+1=2 marks)

Waveform (c) is an example of a **BFSK**-modulated waveform representing the data:

1 1 1 0 0 1 0 1. (1+1=2 marks)

Question 4: **(4 Marks)**

a) Urban environments present particular difficulties in radio propagation at VHF and above, due to the large number of obstructions and reflecting surfaces. In this regard, there are two types of fading that are commonly distinguished: **slow fading** and **fast fading**. For each of these fading, mention the type of distribution that can be used to model the variation in power. (2 marks)

b) A mobile device is being used by someone sitting on a high-speed train moving at 300 km/h and the transmitter frequency is nominally 2.1 GHz. Calculate the Doppler shift, in Hz, for the case where the mobile is moving directly towards the fixed transmitter from which it is receiving a signal. (Take the speed of light, c, to be 3×10^8 m/s.)

(2 marks)

Solution:

a) The variation in power in slow fading can be modelled by **a log-normal distribution.** (**1 mark**) Whereas in case of fast fading, it is the **Rayleigh distribution** or **Rician distribution** (**1 mark**) (*It is enough to mention one distribution for the case of fast fading*).

b) The speed of the train in m/s is given by: $\frac{300\,000}{3600}$ = 83.33 m/s (**0.5 mark**). Then the Doppler shift = $f_r - f_t = \frac{f_t v}{c}$ (**0.5 mark**) = $\frac{2.1\times10^9\times83.33}{3\times10^8}$ = 583 Hz (**1 mark**)

Question 5: **(4 Marks)**

A system uses the seven-digit Hamming code, as described in Fig. 2 below.

a) Describe the code in the form (*n*, *k*) (1 mark)
b) Write down the code rate. (1 mark)
c) What would the coded messages be if the original message was: **0101** (2 marks)

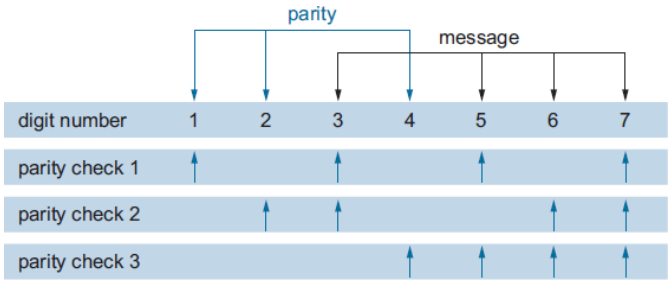


Figure 2. Parity-check for a seven-digit Hamming code

Solution:

Each message has 4 bits and each code word 7 bits, so *n* = 7 and *k* = 4 ➔

a) It is a (7, 4) code. (**1 mark**)
b) The code rate = *k*/*n* = 4/7 = 0.57 (**1 mark**)
c) The coded message is **0100101.** (**2 mark**)

Question 6: **(6 Marks)**

Assume that a standard for some system specifies the use of CRCs with the following generator polynomial: $x^8 + x^4 + x^3 + x^2 + 1$.

a) What binary number does this represent? (2 marks)
b) What is the code capability of detecting **odd** numbers of errors? (1 mark)
c) What is the code capability of detecting bursts of length 8 bits or shorter? (1 mark)
d) What is the probability that a burst longer than 9 bits escapes detection, assuming that all error patterns within the burst are equally probable? (1 mark)
e) What is the probability that a burst of 9 bits escapes detection, assuming that all error patterns within the burst are equally probable? (1 mark)

Solution:

a) The polynomial represents: 100011101. (**2 mark**)
b) The code is capable of detecting **all** odd numbers of errors. (**1 mark**)
c) It is capable of detecting **all** bursts of length 8 bits or shorter. (**1 mark**)
d) The probability of any burst longer than 9 bits escaping detection is $1/2^8 = 0.0039$. (**1 mark**)
e) The probability of a burst 9 bits long escaping detection is $1/2^7 = 0.0078$. (**1 mark**)

Question 1: **(4 Marks)**

From your study of electric and magnetic fields, write down **four** short sentences about these fields and how they relate to electrical signals in conductors.

Solution: (1 mark each)

- An electromagnetic wave consists of electric and magnetic fields at right angles to each other.
- They are linked by mathematical relationships (Maxwell's equations).
- Electric and magnetic fields can store and release energy.
- Conductors carrying electrical signals are surrounded by electric and magnetic fields.

Question 2: **(4 Marks)**

Optical transmitters are classified into two main types, the light-emitting diode (LED) and the laser diode (LD). Compare between these two types considering the following criteria: cost (expensive or inexpensive), power emission (high or low), cone of radiation (aligned or broad), and the data rate that can be obtained (low or high). **Use the below table to present your answer.**

	Cost	**Power emission**	**Cone of radiation**	**Data rate**
LED				
LD				

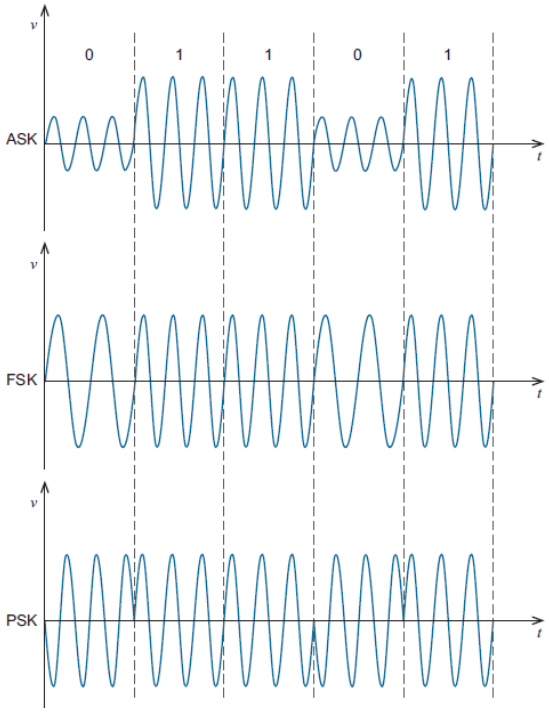
Solution: (0.5 mark for each cell)

	Cost	**Power emission**	**Cone of radiation**	**Data rate**
LED	Inexpensive	Low	Broad	Low
LD	Expensive	High	Aligned	High

Question 3: **(6 Marks)**

Sketch what the modulated waveforms for ASK, FSK and PSK might look like for the modulating signal: 0 1 1 0 1.

Solution: (2 marks for each)



Question 4: **(6 Marks)**

Calculate the signal power and noise power for receivers B and C in Fig. 1 below, and hence calculate the S/N ratio in each case.

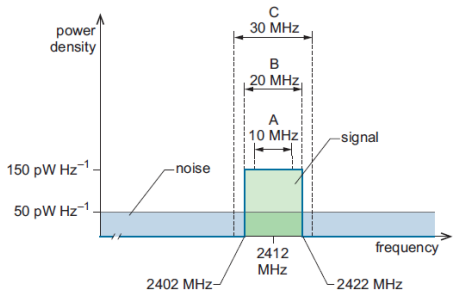


Figure 1. Power densities of a signal and noise, with passbands of different receivers

Solution:

For receiver **B**, the signal power is:

150 pW/Hz × 20 MHz (0.5 mark)

$= 150\times10^{-12} \times 20\times10^{6} = 3000\times10^{-6}$ W = 3 mW (0.5 mark)

The noise power is:

50 pW/Hz × 20 MHz (0.5 mark)

$= 50\times10^{-12} \times 20\times10^{6} = 1000\times10^{-6}$ W = 1 mW (0.5 mark)

Hence, S/N = 3/1 = 3. (1 mark)

For receiver **C**, the signal bandwidth remains the same, so the signal power is again 3 mW.

(1 mark)

The noise power is:

50 pW/Hz × 30 MHz (0.5 mark)

$= 50\times10^{-12} \times 30\times10^{6} = 1500\times10^{-6}$ W = 1.5 mW (0.5 mark)

Hence, S/N = 3/1.5 = 2. (1 mark)

(*Note: Student can express his answer in W or mW. Both units are correct.*)

Question 5: **(6 Marks)**

Fig. 2 below represents a message of 12 bits arranged as shown.

a) For the message shown, construct a rectangular code word. Assume even parity check. (2 marks)
b) How many parity digits are used per code word to check for errors? (1 mark)
c) Describe this code using the (*n*, *k*) notation. (1 mark)
d) Calculate the code rate of this code. (1 mark)
e) Calculate the redundancy of this code, expressed as a percentage. (1 mark)

1 0 1
0 1 0
0 1 0
1 1 1

Figure 2. 12-bit message arrangement for Question 5

Solution:

a) (0.25 mark for each correct parity)

1	0	1	**0**
0	1	0	**1**
0	1	0	**1**
1	1	1	**1**
0	**1**	**0**	**1**

b) **Eight parity digits** are used to check for errors, out of 20 digits in total. (1 mark)
c) *n* is the total number of bits in the code, 20, and *k* is the number of bits in the message, which is 12. The code is therefore a **(20, 12)** code. (1 mark)
d) The code rate is *k*/*n*, which is 12/20 (0.5 mark) = 3/5 = 0.6 = 60%. (0.5 mark)
e) The redundancy (*n*-*k*)/*n* = (20-12)/20 (0.5 mark) = 8/20 = 0.4 = 40%. (0.5 mark)

Question 6: **(4 Marks)**

Fig. 3 below is a trellis used for a convolutional code. Decide what the following sequences should be decoded to, assuming that there is at most one error in each sequence.

a) 00 10 10 00 (2 marks)
b) 11 01 01 01 (2 marks)

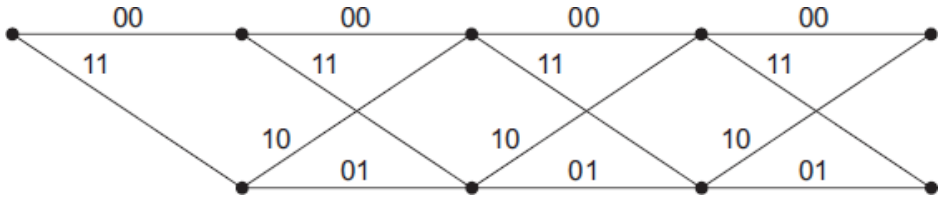


Figure 3. A trellis used for a convolutional code

Solution:

a) The sequence 00 10 10 00 does not correspond to any path through the decoder. However, assuming one error – in the fourth received bit (1 mark) – leads to the sequence 00 11 10 00, which corresponds to the sequence generated by the data **0100**. (1 mark)
b) The sequence 11 01 01 01 corresponds to the sequence generated by the data **1111,** (1 mark) **without any errors**. (1 mark)

End of Questions

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