EEEN 462 – ANALOGUE COMMUNICATION

INTRODUCTION TO ANALOGUE COMMUNICATION – TEST YOUR KNOWLEDGE

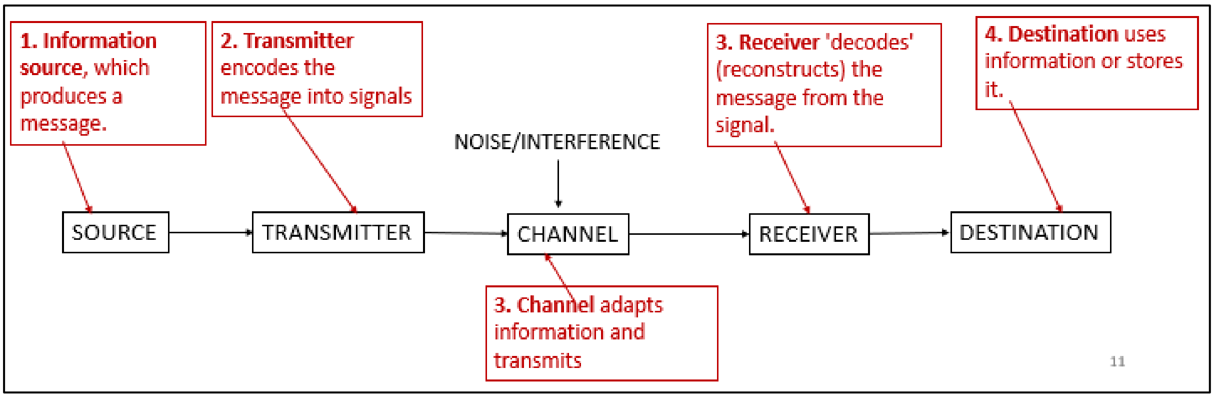
1(a) What is the primary objective of a communication system?

(b) Draw and label a simplified block diagram of a generic communication system.

Model Answer

(a)The primary objective of a communication system is to transmit information (voice, data, image, video) from a source to a destination with minimum distortion and maximum efficiency.

(b)



- **Information Source:** Creates the message (e.g., voice, data, video).
- **Transmitter:** Processes and converts the message into a form suitable for transmission over the channel (e.g., modulation, amplification).
- **Channel:** The physical medium that carries the signal from transmitter to receiver (e.g., free space, coaxial cable, optical fiber). It introduces noise, attenuation, and distortion.
- **Receiver:** Extracts the desired message from the received signal amidst noise and distortion (e.g., demodulation, amplification, filtering).
- **Destination:** The intended recipient of the message.

2. Differentiate between analogue and digital communication.

Model Answer

Analogue communication transmits continuous signals (e.g., AM/FM radio), while digital communication transmits discrete signals (e.g., mobile data, Wi-Fi, Bluetooth).

3. Explain the fundamental need for modulation in a communication system. List three key reasons.

Model Answer

Modulation is the process of impressing a low-frequency information signal onto a high-frequency carrier wave. It is essential for:

1. **Practical Antenna Size:** For efficient radiation, the antenna size must be on the order of the signal's wavelength (λ = c/f). Modulating a high-frequency carrier allows the use of reasonably sized antennas.
2. **Frequency Division Multiplexing (FDM):** It allows multiple signals to be translated to different frequency bands and transmitted simultaneously over the same channel without interference.
3. **Efficient Signal Propagation:** High-frequency carrier waves can travel long distances via specific propagation methods (e.g., skywaves) that are not possible with baseband signals.

4. Differentiate between Baseband and Passband transmission. Provide an example of each.

Model Answer

- **Baseband Transmission:** Information signal is transmitted in its original frequency band without shifting its spectrum. It is typically used for short-distance communication. Example of baseband transmission is Ethernet (LAN cables), PCM audio in a wired telephone.
- **Passband Transmission:** Information signal is modulated onto a high-frequency carrier wave, shifting its spectrum to a higher frequency band. It is used for long-distance wireless and wired communication. Example of passband transmission is FM Radio broadcast, Satellite communication.

5. In the context of noise, define Signal-to-Noise Ratio (SNR). Why is SNR a critical performance metric?

Model Answer

Signal-to-Noise Ratio (SNR) is the ratio of the power of the desired signal to the power of the unwanted noise at a given point in the system. It is usually expressed in decibels (dB).

$$SNR(dB) = 10log_{10}\left(\frac{P_{signal}}{P_{noise}}\right)$$

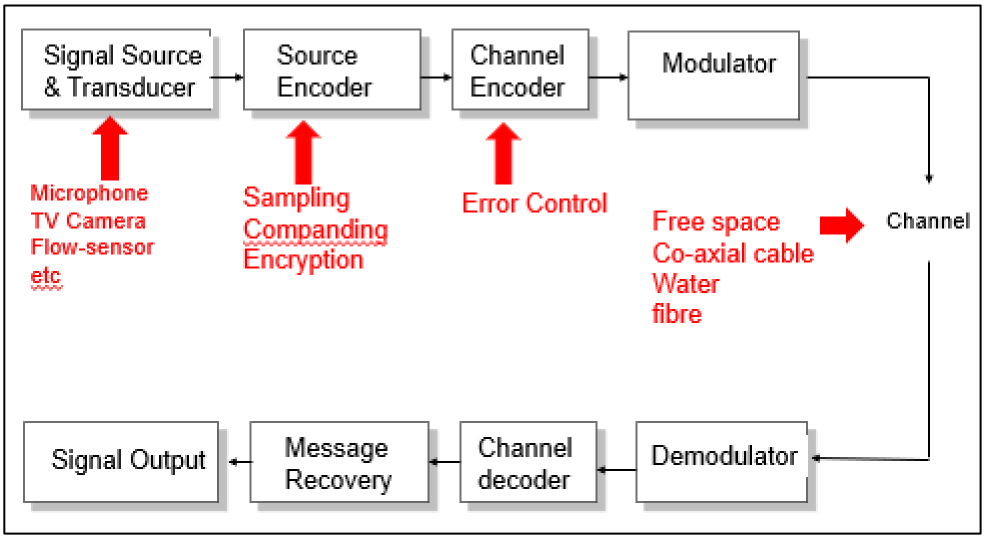
where P_{signal} is the power of the signal and P_{noise} is the power of noise.

SNR is a critical metric because it directly correlates with the quality and fidelity of the received signal. A higher SNR means the signal is stronger relative to the noise, resulting in clearer audio, fewer errors in data, and a sharper video image.

6. Draw a basic block diagram of a Digital Communication System, highlighting the key differences from an analogue system.

Model Answer

The key difference is the conversion of the analogue information into a digital bitstream and the addition of error control coding.



Source Encoder: Removes redundancy from the data (compression).

Channel Encoder: Adds structured redundancy (error control coding, e.g., parity bits) to protect the data from channel errors.

Digital Modulator: Maps the digital bitstream onto analog waveforms (e.g., using ASK, FSK, PSK, QAM).

Digital Demodulator & Decoders: Perform the reverse operations, including detecting and correcting errors.

7. What is the Shannon-Hartley Theorem? State its formula and explain its significance.

Model Answer

The **Shannon-Hartley Theorem** defines the maximum possible channel capacity (C) in bits/sec for a communication channel with a given bandwidth (B) and Signal-to-Noise Ratio (SNR).

Formula: $C = B * \log_2(1 + SNR)$ bits per second

Significance: It provides a fundamental limit on the maximum error-free data rate for a given channel. It shows the trade-offs between bandwidth and SNR. For example, you can compensate for a low SNR by increasing the channel bandwidth, and vice-versa.

8. A voice-grade telephone channel has a bandwidth of 3.1 kHz and a signal-to-noise ratio (SNR) of 30 dB.

a) Calculate the channel capacity.

b) If the SNR is improved to 45 dB (e.g., by using a better amplifier), what is the new capacity?

c) Comment on the results: why isn't the capacity doubled when the SNR is increased by 15 dB?

MODEL ANSWER

a) We convert SNR from dB to a linear ratio:

$$SNR_{linear} = 10^{30/10} = 10^{3} = 1000$$

Then we apply Shannon's formula:

$\text{Channel Capacity, C} = \text{B}\log_2(1 + \text{SNR}) = 3100\log_2(1 + 1000) = 3100 \times 9.97 = 30{,}907 \text{ Bits/Sec}$

b) We convert SNR from dB to a linear ratio:

$$SNR_{linear} = 10^{45/10} = 10^{4.5} = 31623$$

Then we apply Shannon's formula:

$\text{Channel Capacity, C} = \text{B}\log_2(1 + \text{SNR}) = 3100\log_2(1 + 31623) = 3100 \times 14.5 = 46{,}300 \text{ Bits/Sec}$

c) The relationship between capacity and SNR is logarithmic, not linear. A 15 dB increase in SNR represents a massive 31,622x linear increase in signal power relative to noise. However, the $\log_2(1+SNR)$ term means that capacity increases very slowly for high SNR values. Doubling the capacity would require squaring the linear SNR, which is an enormous and often impractical increase in power.

9. List THREE practical applications of communication systems and identify the typical frequency band or medium used for each.

Model Answer:

1. **Cellular Mobile Communication (2G/3G/4G/5G)** used for voice and high-speed data transmission for mobile phones. Cellular communication operates in various UHF and microwave bands (e.g., 900 MHz, 1800 MHz, 2.1 GHz) over a wireless radio channel.
2. **Satellite Communication** (e.g., satellite telephony, Satellite TV) used for telephony, broadcasting, long-distance relaying. Satellite communication uses specific microwave bands (e.g., C-band: 4-8 GHz, Ku-band: 12-18 GHz). The medium is free space between the satellite and ground stations.
3. **Fiber-Optic Communication** used for high-speed internet backbone, cable TV, telephony. Uses pulses of light in the infrared spectrum (e.g., 1550 nm wavelength). The medium is a glass or plastic optical fibre cable.

10 (a) Define the term "frequency band" in the context of wireless communications.

(b) What is the primary physical characteristic that most significantly changes as you move from Low Frequency (LF) bands to Extremely High Frequency (EHF) bands?

(c) (i) How is the wavelength (λ) of a signal related to its frequency (f) and the speed of light (c)?
(ii) Calculate the wavelength of a signal in the 2.4 GHz Wi-Fi band.

Model Answer

(a) A **frequency band** is a specific, contiguous range of frequencies in the electromagnetic spectrum that is allocated for a particular communication service or type of technology. These bands are defined by international agreement to prevent interference between different services (e.g., radio broadcasting, satellite, cellular).

(b) The most significant change is the **propagation characteristics**.

i. **Low Frequencies (LF):** Propagate via ground waves for long distances, can bend around obstacles (diffraction), and penetrate water and soil well.
ii. **High Frequencies (HF):** Can reflect off the ionosphere (skywave propagation), enabling intercontinental communication.
iii. **Microwave Frequencies (UHF/SHF/EHF):** Propagate primarily line-of-sight (LOS). They are prone to attenuation by rain, atmospheric gases, and obstacles but can carry vast amounts of data.

(c) (i) The wavelength (λ) of a signal related to its frequency (f) and the speed of light (c) by the equation:

$$\lambda = \frac{c}{f}$$

(ii) Calculate the wavelength of a signal in the 2.4 GHz is given by

$$\lambda = \frac{3\times10^8}{2.4\times10^9} = 1.25 \times 10^{-1}\text{m} = 12.5\text{ cm}$$

11. The following table lists common frequency bands but is missing their names, common applications, and a key advantage/disadvantage. Complete the table.

Frequency Range	**Band Name**	**Common Applications**	**Key Propagation Characteristic**
3 - 30 kHz			
300 - 3000 MHz			
3 - 30 GHz			

Model Answer

Frequency Range	**Band Name**	**Common Applications**	**Key Propagation Characteristic**
3 - 30 kHz	Very Low Frequency (VLF)	Submarine communication, navigation (LORAN), time signals	Extremely long-range ground-wave; penetrates seawater well.
300 - 3000 MHz	Ultra High Frequency (UHF)	TV broadcasting, GPS, 4G/5G mobile phones, Wi-Fi (2.4/5.8 GHz), Bluetooth	Line-of-sight; good balance between range and data capacity; building penetration.

3 - 30 GHz	Super High Frequency (SHF)	Radar, satellite communication, point-to-point microwave links, 5G mmWave, WiGig	

12(a) What is the role of the International Telecommunication Union (ITU) in managing frequency bands?

(b) Explain the difference between a licensed frequency band and an unlicensed frequency band. Provide one common example of each.

(c) Why are unlicensed bands, like the 2.4 GHz Industry Scientific and Medical (ISM) band, often more susceptible to interference?

Model Answer

(a) ITU (International Telecommunication Union) is a specialized United Nations agency responsible for global radio spectrum management, telecommunication equipment standards and satellite slot allocation. Its key role is to coordinate international agreements on the allocation of different frequency bands to specific services (e.g., fixed, mobile, satellite, radio astronomy) to prevent harmful interference between systems and countries.

(b) Licensed Band: A band where exclusive rights to transmit are granted by a national regulator (like the Communication Authority in the Kenya) to a specific entity (e.g., a mobile network operator). This guarantees no interference from other users. **Example:** The 900 MHz band used by cellular operators (Safaricom, Airtel and Telkom).

Unlicensed Band: A band where anyone can operate a transmitter without an individual license, provided their device complies with technical rules (e.g., power limits). There is no protection from interference. **Example:** The **2.4 GHz and 5.8 GHz ISM bands** used for Wi-Fi, Bluetooth, and microwave ovens.

(c) Unlicensed bands are more susceptible to interference precisely **because they are unlicensed**. Many different technologies and users (Wi-Fi routers, Bluetooth headsets, wireless cameras, microwave ovens) all share the same spectrum without any centralized coordination. This creates a "commons" where devices must compete for airtime and can easily disrupt each other's signals.