

Introduction to Analog and Digital

Communications

Introduction to Analog and Digital Communications
(A concise, structured overview for quick reference)

1. Fundamental Concepts

Concept	Definition	Typical Use
Signal	A physical quantity that conveys information (e.g., voltage, current, electromagnetic wave).	Both analog and digital systems.
Medium (Channel)	The physical path through which a signal travels (wired, wireless, optical fiber).	Determines bandwidth, attenuation, noise.
Modulation	Process of varying a carrier to embed information.	Essential for transmission over limited bandwidth channels.
Demodulation	Reverse of modulation; extracts the original information from the received carrier.	Performed at the receiver.
Noise	Unwanted random disturbances that corrupt the signal (thermal, shot, interference).	Impacts error rates and required SNR.

2. Analog Communication

2.1 What Is Analog?

- Continuous-time, continuous-amplitude representation.
- Information is encoded directly onto the amplitude, frequency, or phase of a carrier wave.

2.2 Key Analog Modulation Schemes

Scheme	Carrier Parameter Varied	Typical Bandwidth (relative to message)	Advantages	Disadvantages
Amplitude Modulation (AM)	Amplitude	2 × message bandwidth	Simple transmitter/receiver	Poor noise immunity

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Scheme	Carrier Parameter	Typical Bandwidth (relative to message)	Advantages	Disadvantages
Frequency Modulation (FM)	Frequency	$2 \times (f_m + f_m)$	Good noise resistance, capture effect	Larger bandwidth
Phase Modulation (PM)	Phase	Similar to FM	Efficient for digital data (see PSK)	Requires coherent detection

2.3 Analog System Block Diagram

Message (baseband) → Encoder (optional) → Modulator → Channel → Demodulator → Decoder → Recovered Message

2.4 Performance Metrics

- **Signal-to-Noise Ratio (SNR)** – ratio of signal power to noise power.
- **Carrier-to-Noise Ratio (C/N)** – used for carrier-based systems.
- **Bandwidth Efficiency (η)** – bits/s per Hz (low for pure analog).
- **Error Probability** – expressed as Bit Error Rate (BER) for analog-digital hybrid systems.

3. Digital Communication

3.1 What Is Digital?

- **Discrete-time, discrete-amplitude** representation (bits: 0/1).
- Information is first **quantized** and **encoded** before transmission.

3.2 Digital Modulation (Key Schemes)

Scheme	Symbol Set	Bits per Symbol	Typical Bandwidth	Notes
ASK (On-Off Keying)	{0, 1}	1	Same as baseband	Simple, vulnerable to amplitude noise

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Scheme	Symbol Set	Bits per Symbol	Typical Bandwidth	Notes
FSK (Frequency Shift Keying)	$\{f_1, f_2\}$	1	Slightly larger than baseband	Better noise immunity
PSK (Phase Shift Keying)	$\{0^\circ, 180^\circ \dots\}$	1–2 (BPSK, QPSK)	Efficient	Requires coherent detection
QAM (Quadrature Amplitude Modulation)	Constellation of amplitude/phase points	2–6+ (16-QAM, 64-QAM...)	High spectral efficiency	Sensitive to both amplitude & phase noise
OFDM (Orthogonal Frequency Division Multiplexing)	Multiple orthogonal sub			