

Introduction to Wireless Communication

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Key concepts, components, and fundamentals for a solid start in the field.

1. What Is Wireless Communication?

- **Definition:** Transfer of information (voice, data, video, etc.) between two or more points without physical conductors (cables).
 - **Medium:** Electromagnetic waves traveling through air, vacuum, or space.
 - **Typical Uses:** Mobile phones, Wi-Fi, satellite links, Bluetooth, RFID, IoT devices, broadcast TV/radio.
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2. Basic Terminology

Term	Meaning
Transmitter	Generates and radiates the RF (radio frequency) signal.
Receiver	Captures the RF signal and converts it back to the original information.
Antenna	Converts electrical signals to/from electromagnetic waves.
Frequency (f)	Number of cycles per second (Hz). Determines wavelength ($\lambda = c/f$).
Bandwidth	Range of frequencies a system can use; directly linked to data rate.
Modulation	Process of embedding information onto a carrier wave (e.g., AM, FM, QAM).
Multiplexing	Sharing a single channel among multiple signals (e.g., FDMA, TDMA, CDMA, OFDM).
Path Loss	Reduction of signal strength with distance and obstacles.
Noise	Unwanted random signals that degrade quality (thermal, atmospheric, interference).
SNR (Signal-to-Noise Ratio)	Ratio of signal power to noise power; higher SNR = better performance.

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3. Electromagnetic Spectrum Overview

Band	Frequency Range	Typical Applications
VLF/LF	3 kHz – 300 kHz	Submarine communication
MF	300 kHz – 3 MHz	AM broadcast
HF	3 MHz – 30 MHz	Short-wave radio, HF data links
VHF	30 MHz – 300 MHz	FM radio, TV channels 2–13, air-traffic control
UHF	300 MHz – 3 GHz	TV channels 14–69, cellular 2G/3G, Wi-Fi (2.4 GHz)
SHF	3 GHz – 30 GHz	Radar, satellite, Wi-Fi (5 GHz), 5G mmWave
EHF	30 GHz – 300 GHz	Millimeter-wave 5G, experimental high-capacity links

Note: The usable portion for most commercial wireless systems lies between 300 MHz and 30 GHz.

4. Core Components of a Wireless System

1. Transceiver (Tx/Rx)

- RF front-end (amplifiers, mixers, filters)
- Baseband processor (digital signal processing)

2. Antenna System

- Types: dipole, monopole, patch, Yagi, phased-array, parabolic.
- Parameters: gain, radiation pattern, polarization, impedance.

3. Channel

- Physical medium; characterized by path loss, fading, multipath, Doppler shift.

4. Medium Access Control (MAC)

- Governs how multiple users share the channel (e.g., CSMA/CA for Wi-Fi, TDMA for GSM).

5. Network Layer

- Routing