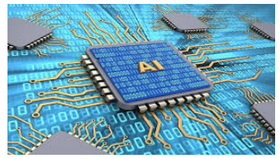


Other trends
New developments

- AI (artificial intelligence) in mobile networking
- Sensor-aided mobile networking
- Drone-aided mobile networking
- Programmable wireless environment
- Simultaneous wireless information and power transfer
- Terahertz wireless networking
- Nanoscale wireless sensor networking
- …

Summary: wireless and mobile trends

1. WiFi has grown worldwide in just 15 years and continues to develop in capacity with innovations in PHY and data link layer
2. Bluetooth has reached the 5 billion milestone in 2020
3. 5th generation of cellular technology is already here in 2020 with massive capacity and new features
4. Wireless speed growth is following Moore's Law
5. Mobile subscriptions are approaching world population
6. Many innovative new technologies are being developed to meet the unabated demand in wireless and mobile communications

PHY FUNDAMENTALS I

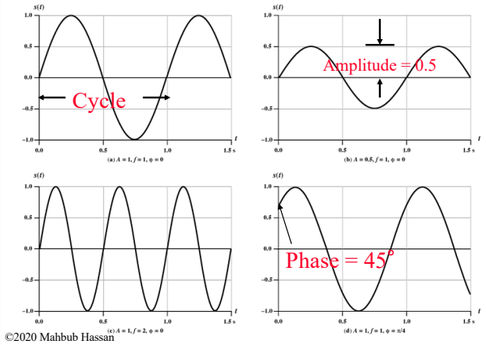
Coding and Modulation

Overview

1. Frequency, Wavelength, Amplitude, and Phase
2. Electromagnetic Spectrum
3. Time and Frequency Domains
4. Decibels
5. Coding and modulation
6. Channel Capacity (Nyquist's and Shannon's Theorems)
7. Hamming Distance and Error Correction
8. Multiple Access Methods (TDMA, FDMA, CDMA)
9. Spread Spectrum (Frequency Hopping and Direct Sequence)
10. Doppler Shift, Doppler Spread, Coherence Time
11. Duplexing

Frequency, Period, and Phase

- A Sin(2pft + ⏀), A = Amplitude, f=Frequency, ⏀ = Phase, Period T = 1/f,
  Frequency is measured in Cycles/sec or **Hertz**

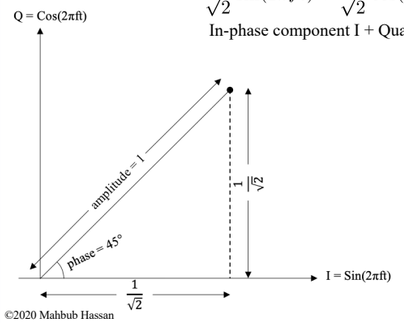


Phase and Amplitude: 2D Representation

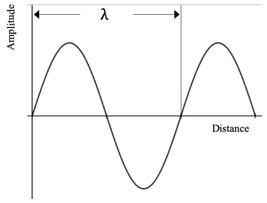
- Sine wave with a phase of 45°

$$\sin(2\pi ft + \frac{\pi}{4}) = \sin(2\pi ft)\cos(\frac{\pi}{4}) + \cos(2\pi ft)\sin(\frac{\pi}{4})$$
$$= \frac{1}{\sqrt{2}}\sin(2\pi ft) + \frac{1}{\sqrt{2}}\cos(2\pi ft)$$

In-phase component I + Quadrature component Q



Wavelength



- Distance occupied by one cycle
- Distance between two points of corresponding phase in two consecutive cycles
- Wavelength = λ
- Assuming signal velocity *v*
  - $\lambda = vT$
  - $\lambda f = v$
  - c = 3 × 10^8 m/s (speed of light in free space) = *300 m/μs*

Example: converting frequency to wavelength

- Frequency = 2.5 GHz

$$\text{Wavelength } = \lambda = \frac{c}{f}$$
$$= \frac{300 \text{ m}/\mu\text{s}}{2.5 \times 10^9}$$
$$= 120 \times 10^{-3} = 120 \text{ mm} = 12 \text{ cm}$$

Example: converting wavelength to frequency

- Wavelength = λ = 5 mm

Frequency = f = c/λ
= (3 x 10^8 m/s) / (5 x 10^{-3} m)
= (300 x 10^9) / 5 = 60 GHz