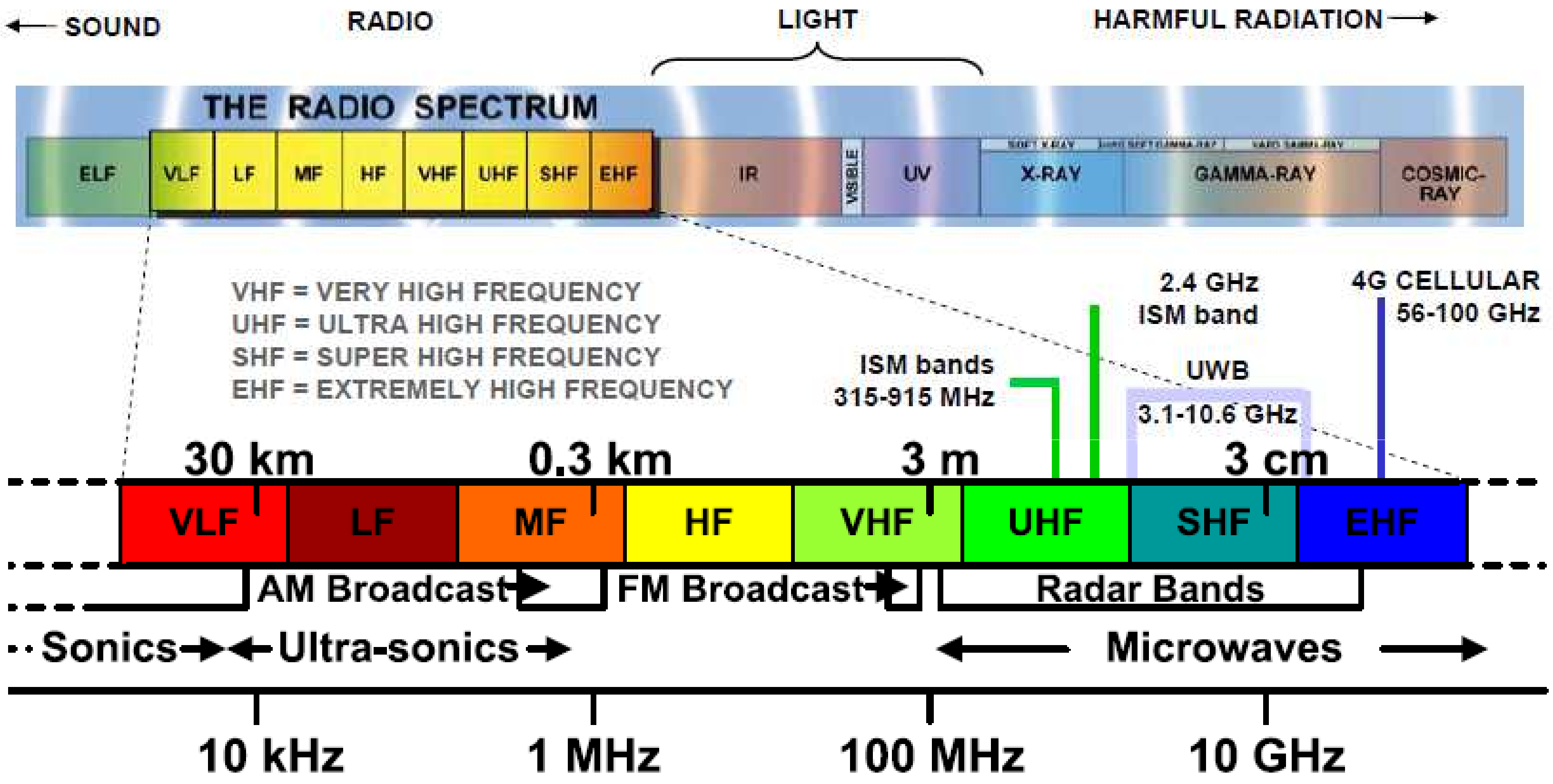
Background

Electromagnetic Spectrum



Frequency Spectrum Allocation

- **Unlicensed ISM/SRD bands:**
- **USA/Canada:**
  - 260 – 470 MHz (FCC Part 15.231; 15.205)
  - 902 – 928 MHz (FCC Part 15.247; 15.249)
  - 2400 – 2483.5 MHz (FCC Part 15.247; 15.249)
- **Europe:**
  - 433.050 – 434.790 MHz (ETSI EN 300 220)
  - 863.0 – 870.0 MHz (ETSI EN 300 220)
  - 2400 – 2483.5 MHz (ETSI EN 300 440 or ETSI EN 300 328)
- **Japan:**
  - 315 MHz (Ultra low power applications)
  - 426-430, 449, 469 MHz (ARIB STD-T67)
  - 2400 – 2483.5 MHz (ARIB STD-T66)
  - 2471 – 2497 MHz (ARIB RCR STD-33)

  - ISM = Industrial, Scientific and Medical

ISM/SRD License-Free Frequency Bands

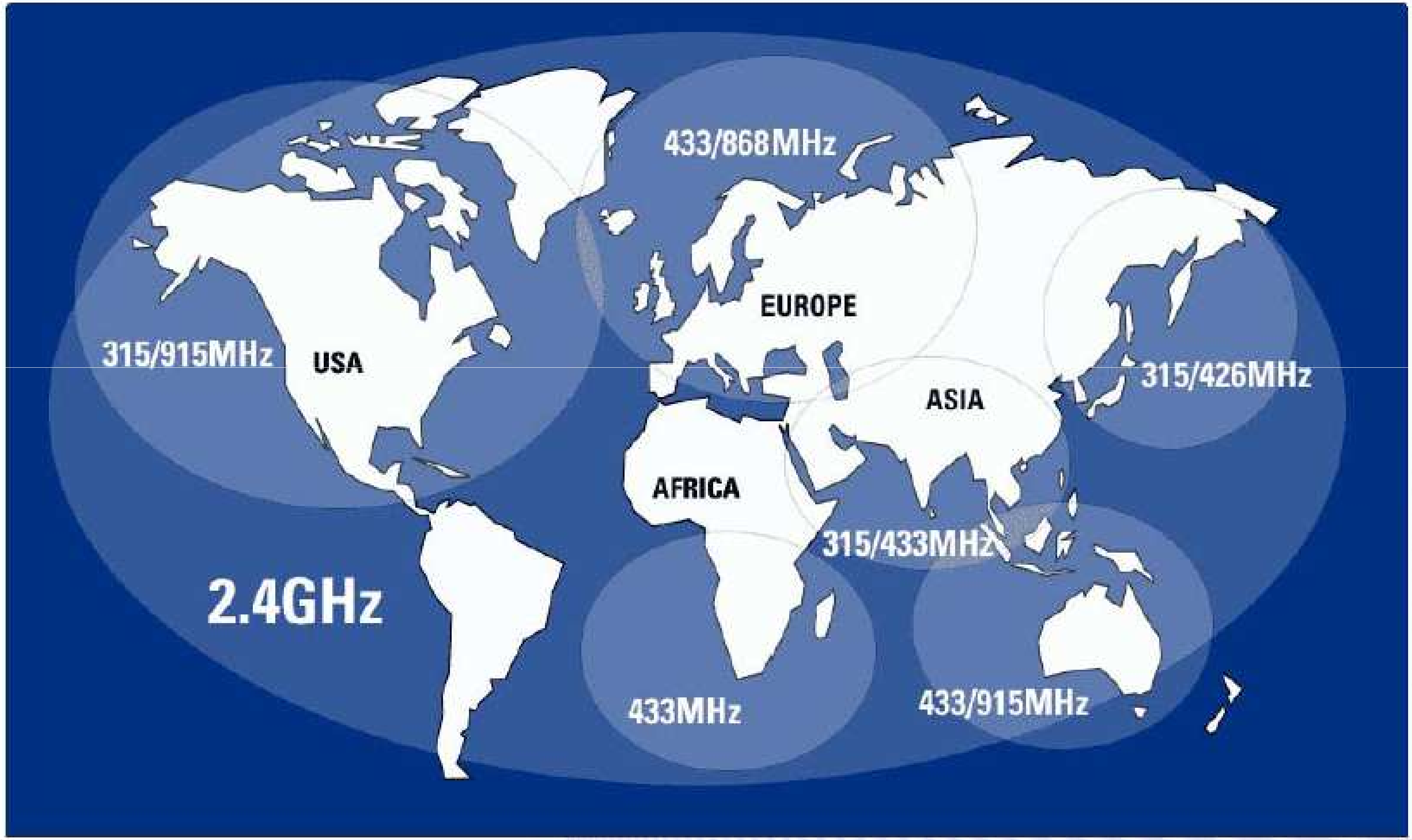
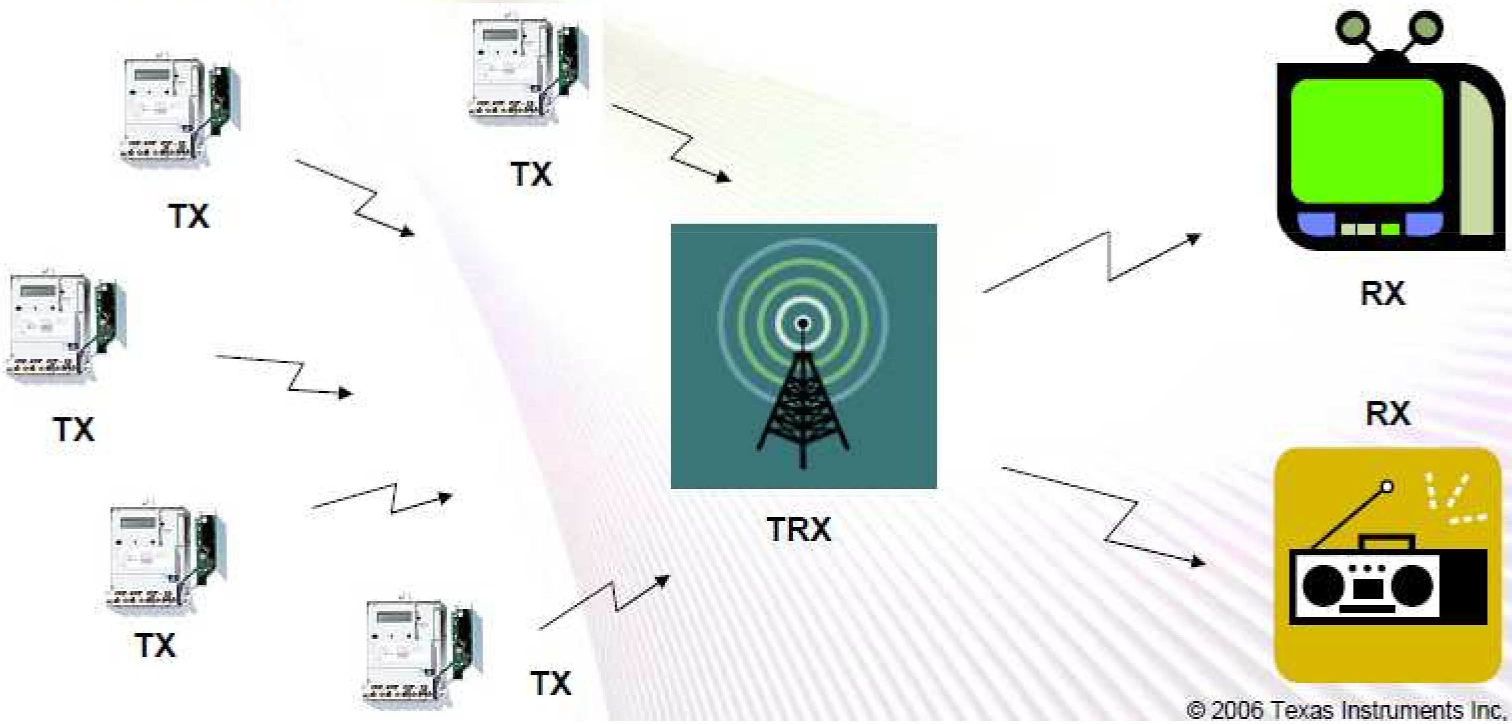


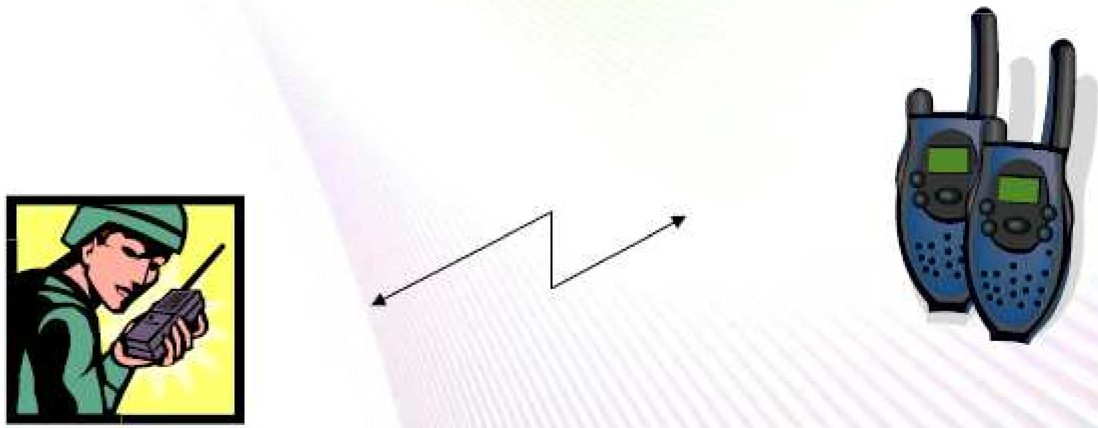
Table 2.4 IEEE 802.11b Channels for Both DS-SS and FH-SS WLAN Standards

Country	Frequency Range Available	DSSS Channels Available	FHSS Channels Available
United States	2.4 to 2.4835 GHz	1 through 11	2 through 80
Canada	2.4 to 2.4835 GHz	1 through 11	2 through 80
Japan	2.4 to 2.497 GHz	1 through 14	2 through 95
France	2.4465 to 2.4835 GHz	10 through 13	48 through 82
Spain	2.445 to 2.4835 GHz	10 through 11	47 through 73
Remainder of Europe	2.4 to 2.4835	1 through 13	2 through 80

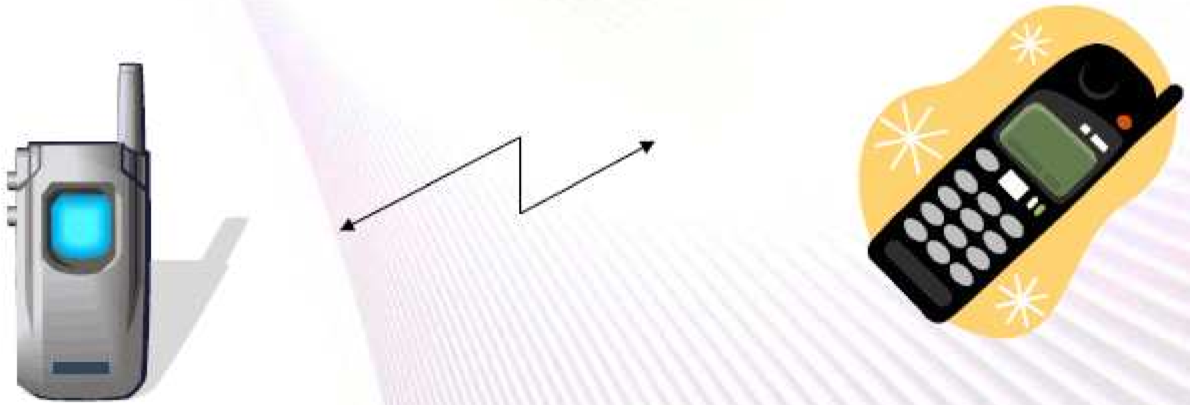
- **Simplex RF System**
  - A radio technology that allows only one-way communication from a transmitter to a receiver
  - Examples: FM radio, Pagers, TV, One-way AMR systems



- **Half-duplex RF Systems**
  - Operation mode of a radio communication system in which each end can transmit and receive, but not simultaneously.
  - **Note:** The communication is bidirectional over the same frequency, but unidirectional for the duration of a message. The devices need to be transceivers. Applies to most TDD and TDMA systems.
  - Examples: Walkie-talkie, wireless keyboard mouse



- **Full-duplex RF Systems**
  - Radio systems in which each end can transmit and receive simultaneously
  - Typically two frequencies are used to set up the communication channel. Each frequency is used solely for either transmitting or receiving. Applies to Frequency Division Duplex (FDD) systems.
  - Example: Cellular phones, satellite communication



Unidades

- **dBm** ou **dBmW** (decibel miliwatt) é uma unidade de medida utilizada principalmente em telecomunicações para expressar a frequencia absoluta mediante uma relação logaritimica. Define-se como o nível de potência em decibéis em relação ao nível de referência de um 1 mW

- P(dBM) = 10 log10 (Power in mW)

- The **decibel watt** or **dBW** is a unit for the measurement of the strength of a signal expressed in decibels relative to one watt.

- P(dBM) = 10 log10 (Power in W)

Exemplo

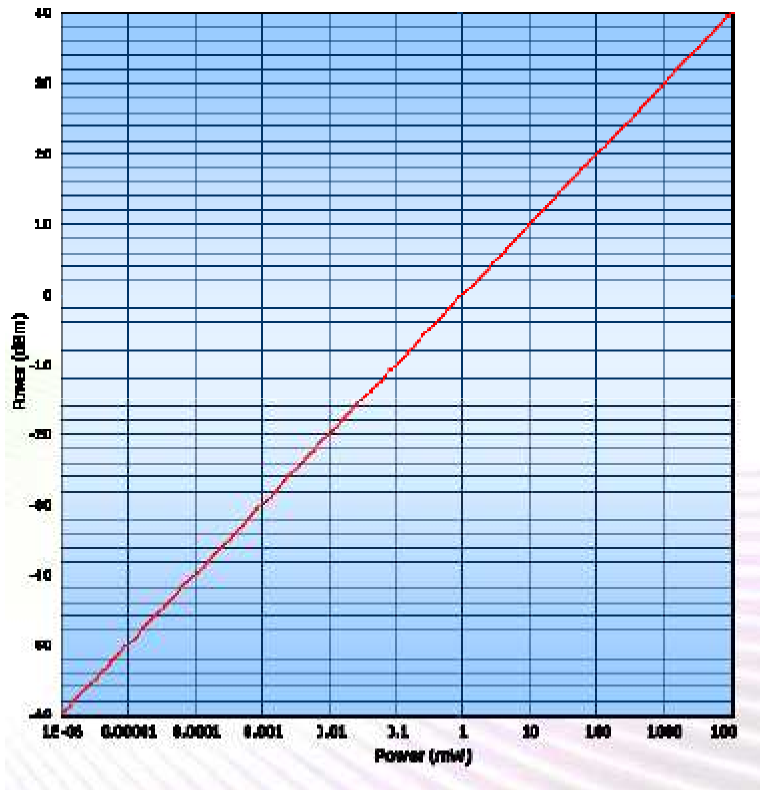
- Potência de transmissão Pt = 50W
- (a)dBm
- (b)dBW

- Pt (dBm) = 10 log[50×10^3] = 47,0 dBm
- Pt (dBM) = 10 log[50] = 17,0 dBW

Unidades

Definitions

- dBm – relative to 1 mW
- dBc – relative to carrier
- 10mW = 10dBm, 0dBm = 1mW
- -110dBm = 1E-11mW = 0.00001nW



Rule of thumb:

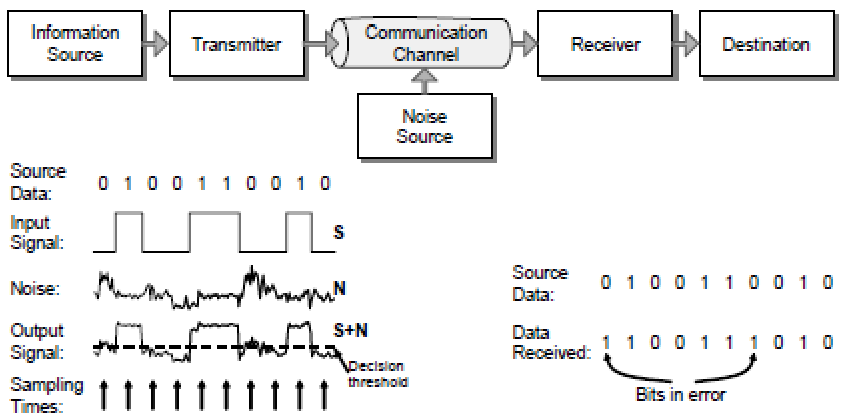
- Double the power = 3 dB increase
- Half the power = 3 dB decrease

dBm to Watt

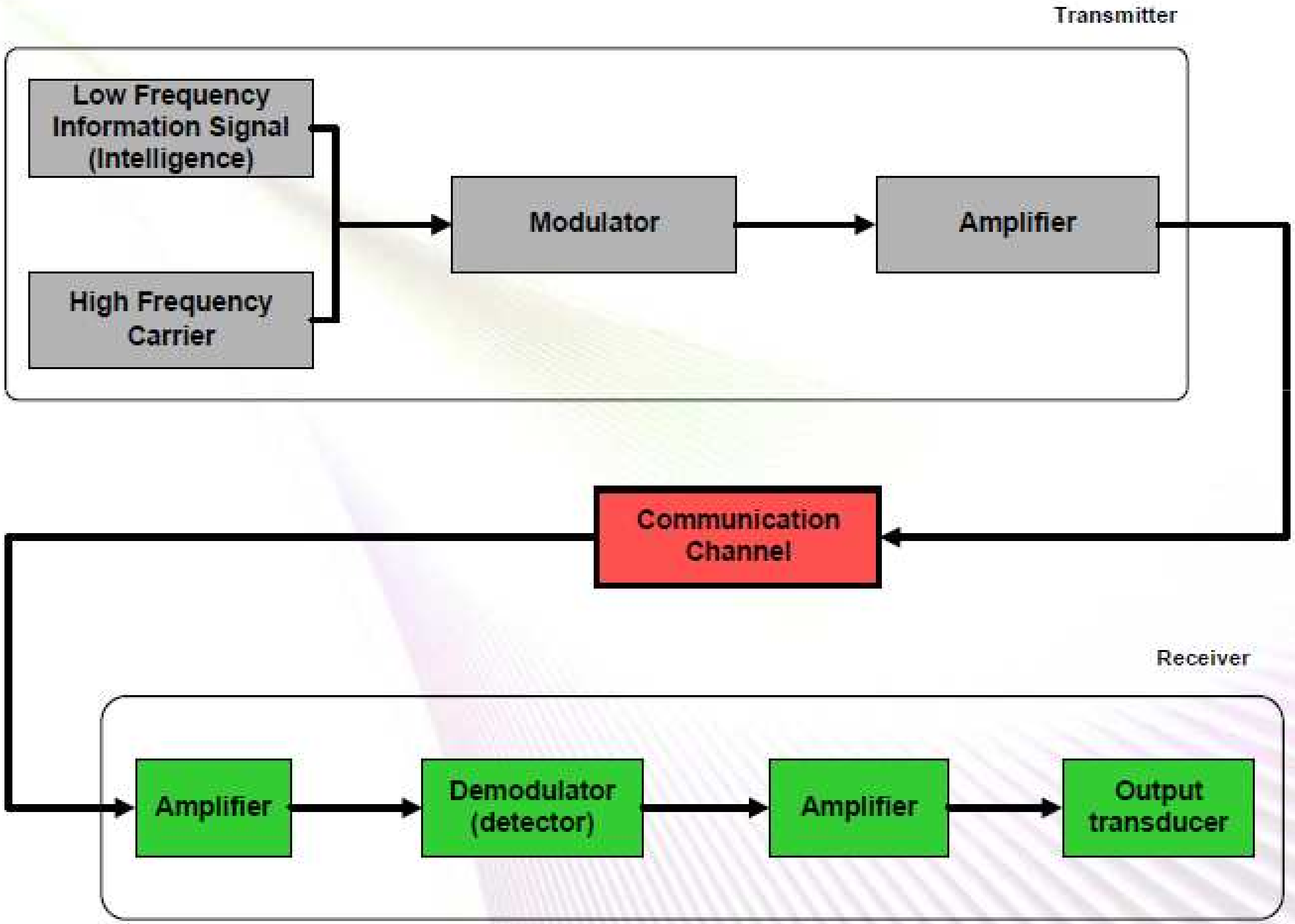
- **About dBm and W**

▪ Voltage Ratio	aV = 20 log (P2/P1)	[aV] = dB
▪ Power Ratio	aP = 10 log (P2/P1)	[aP] = dB
▪ Voltage Level	V‘ = 20 log (V/1µV)	[V‘] = dBµV
▪ Power Level	P‘ = 10 log (P/1mW)	[P‘] = dBm

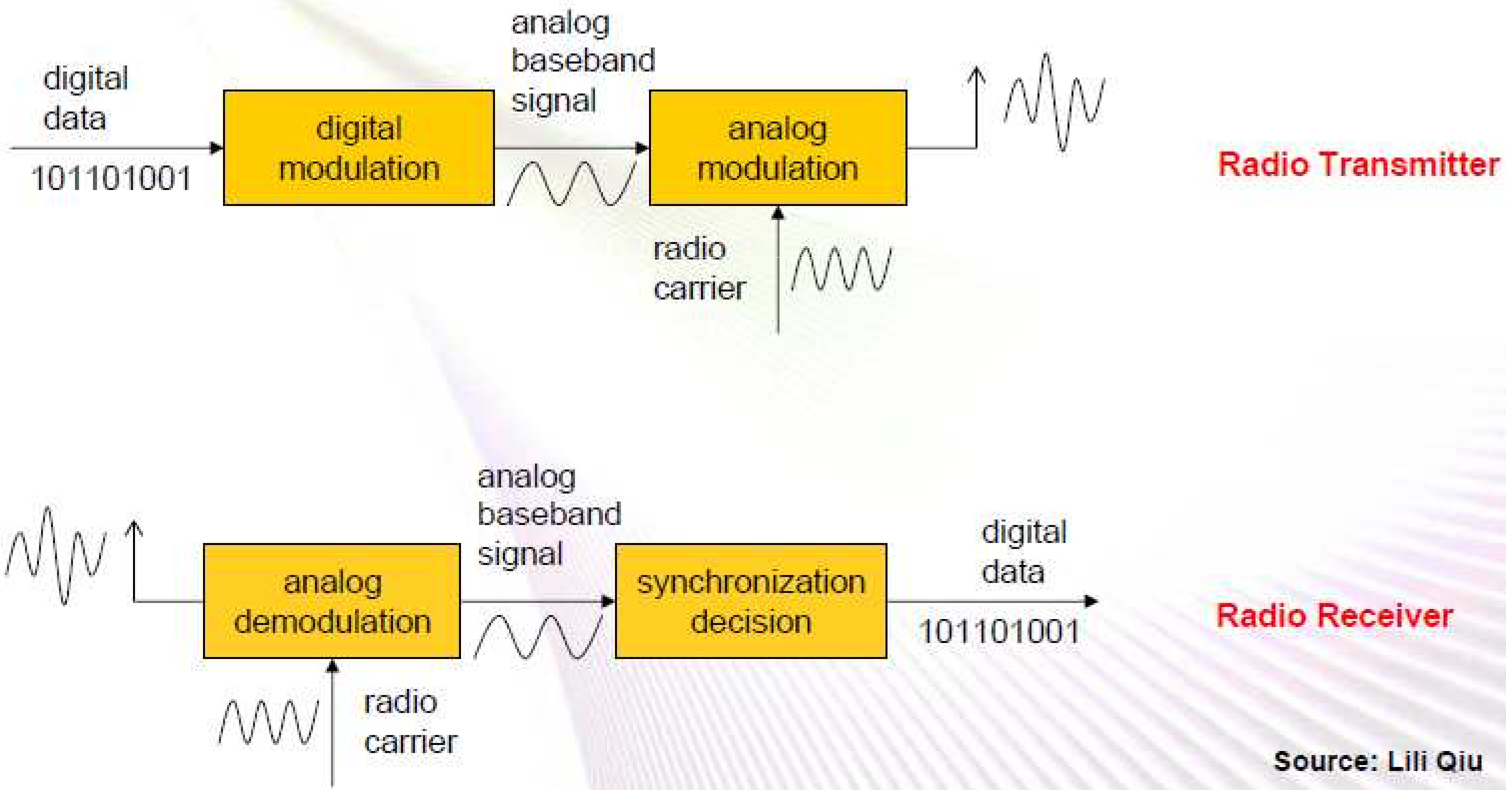
Communication process



Wireless Communication Systems



Modulation and Demodulation



Source: Lili Qiu

Modulation Methods

- **Starting point:**
  we have a low frequency signal and want to send it at a high frequency

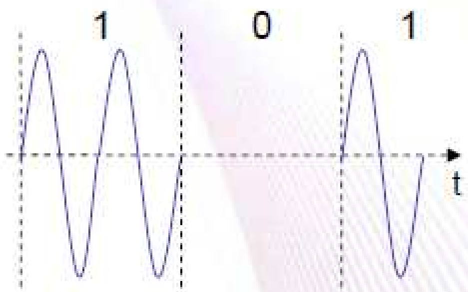
- **Modulation:** The process of superimposing a low frequency signal onto a high frequency signal

- **Three modulation schemes available:**
  1. **Amplitude Modulation (AM):** the amplitude of the carrier varies in accordance to the information signal
  2. **Frequency Modulation (FM):** the frequency of the carrier varies in accordance to the information signal
  3. **Phase Modulation (PM):** the phase of the carrier varies in accordance to the information signal

Digital Modulation

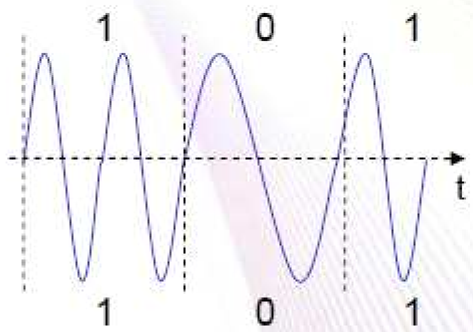
- **Modulation of digital signals is known as Shift Keying**

- **Amplitude Shift Keying (ASK):**
  - Pros: simple
  - Cons: susceptible to noise
  - Example: Many legacy wireless systems, e.g. AMR



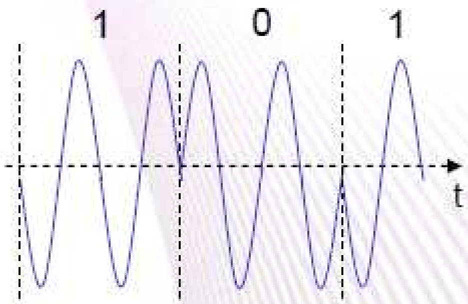
Digital Modulation

- **Frequency Shift Keying (FSK):**
  - Pros: less susceptible to noise
  - Cons: theoretically requires larger bandwidth/bit than ASK
  - Popular in modern systems
  - Gaussian FSK (GFSK), e.g. used in Bluetooth, has better spectral density than 2-FSK modulation, i.e. more bandwidth efficient



Digital Modulation

- **Phase Shift Keying (PSK):**
  - Pros:
    - Less susceptible to noise
    - Bandwidth efficient
  - Cons:
    - Require synchronization in frequency and phase ➔ complicates receivers and transmitter
  - Example: IEEE 802.15.4 / ZigBee



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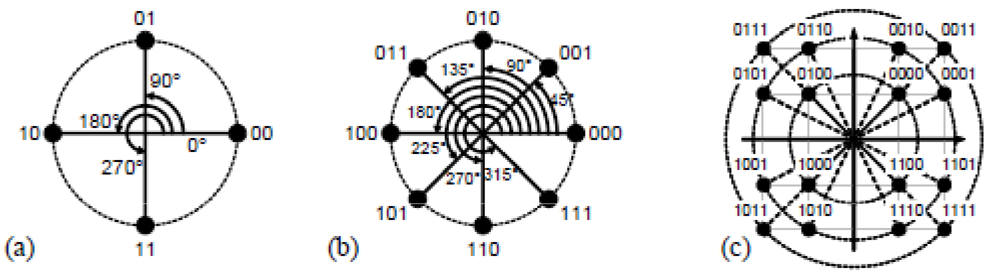
Constelação



(a) (b) (c)

Figure 2-6. Representation of the phase and amplitude relationship by a constellation of symbols, or phase-state diagram, for QPSK (a) and 8-PSK (b). (c) Constellation diagram of an *M*-ary QAM (*M*=16, 3 amplitudes + 12 phases) signal set. [Note that there are other possible 16-QAM constellations].