Wireless Sensor Network (BCO056A)

By:-
Yogesh Bhardwaj
Assistant Professor
CSE Department

Unit-II

Topics:-

- Introduction to Physical Layer
- wireless channel and communication fundamentals
- frequency allocation, modulation and demodulation Applications
- wave propagation effects and noise
- quality of wireless channels and measures for improvement

Topics Cont..

Topics:-

- physical layer and transceiver design consideration in wsn
- Energy usage profile
- choice of modulation

Physical layer Introduction

- Physical layer: the functions and components of a sensor node that mediate between the transmission and reception of wireless signals and the processing of data, including the higher – level protocol processing;
- The physical layer is concerned with modulation and demodulation of digital data; this is carried by the transceivers;
- In Sensor networks, the challenge is to find modulation schemes and transceiver architectures that are simple, low cost, but still robust enough to provide the desired service;
- Also deals in the important concepts regarding wireless channels and digital communications (over wireless channels); its main purpose is to explain the tasks involved in transmission and reception over wireless channels.

Wireless channel and communication fundamentals

JECRC UNIVERSITY

BUILD YOUR WORLD

- In WSN, electromagnetic waves propagate in free space between a transmitter and a receiver.

- Wireless channels are an unguided medium, meaning that signal propagation is not restricted to well-defined locations.

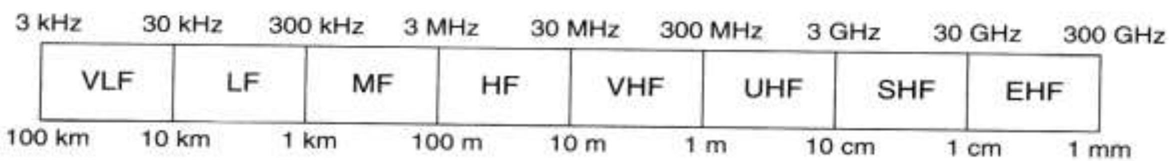
- Wireless Communication can be of three types:
- (i)Radio frequency based communication
- (ii)Optical Communication
- (iii) Infra Red communication

Cont…

- The infrared spectrum is between wavelengths of 1 mm to 2.5 μm (300 GHz to 120 THz) ;
- The optical spectrum ends at 780 nm (≈ 385 THz);
- Generally RF based systems work at frequencies below 6 GHz are used for WSN the allocation of radio frequencies is governed by regulations to avoid unwanted interference.

Frequency allocation

- In RF based systems, the carrier frequency has to be carefully chosen;
- the carrier frequency determines the propagation characteristics, like how well are obstacles penetrated , about capacity.
- Frequency Band: Since a single frequency does not provide any capacity, so always a finite portion of the electromagnetic spectrum, called a **frequency band.**



VLF = Very low frequency
LF = Low frequency
MF = Medium frequency
HF = High frequency
VHF = Very high frequency
UHF = Ultrahigh frequency
SHF = Super high frequency
EHF = Extremely high frequency

ISM Band

- **ISM Band (**Industrial, Scientific, and Medical (ISM) band)
- The **industrial, scientific and medical** (ISM) radio bands are radio bands (portions of the radio spectrum) reserved internationally for the use of radio frequency (RF) energy for **industrial, scientific and medical** purposes other than telecommunications
- ISM is a licensefree bands means that one can just go to a shop, buy equipment, and start to transmit data without requiring any permission from the government/frequency allocation body.
- Now a days ISM bands have also been shared with (non-ISM) license-free error-tolerant communications applications such as wireless sensor networks in the 915 MHz and 2.450 GHz bands.

JECRC UNIVERSITY
BUILD YOUR WORLD

- There are also license free bands, the ISM bands:

Frequency	Comment
13.553–13.567 MHz	
26.957–27.283 MHz	
40.66–40.70 MHz	
433–464 MHz	Europe
902–928 MHz	Only in the Americas
2.4–2.5 GHz	Used by WLAN/WPAN technologies
5.725–5.875 GHz	Used by WLAN technologies
24–24.25 GHz	

- In the public ISM bands, any system has to coexist with other systems, meaning they have to be robust against interferences. Requesting allocation of some exclusive spectrum is time consuming;
- An important parameter in a transmission system is the antenna efficiency, defined as the ratio of the radiated power to the total input of the antenna; the remaining power is dissipated as heat;
- Small dimensions are required in case of sensors but this is difficult even at high frequencies;

Antenna efficiency

- It is the ratio of the radiated power to the total input power to the antenna; the remaining power is dissipated as heat.
- The small form factor of wireless sensor nodes allows only small antennas.
- For example, radio waves at 2.4 GHz have a wave length of 12.5 cm, much longer than the intended dimensions of many sensor nodes. In general, it be comes more difficult to construct efficient antennas .

Modulation and demodulation

- Groups of symbols (data) are mapped to one of a finite number of waveforms of the same finite length. Modulation can be a binary modulation or a m – ary modulation;
- The mapping from a received waveform to symbols is called demodulation;
- The most common form of modulation is the bandpass modulation:
  - The information signal is modulated onto a periodic carrier wave of comparably high frequency;
  - The spectrum used is typically described by a center frequency f_c and a bandwidth B and most of the signal energy can be found in the frequency range: $[f_c – B/2, f_c + B/2]$;

- In the process of modulation, (groups of) symbols from the channel alphabet are mapped to one of a finite number of waveforms of the same finite length; this length is called the symbol duration.
- **Symbol rate:** The symbol rate is the inverse of the symbol duration; for binary modulation, it is also called bit rate.
- **Data rate :**The data rate is the rate in bit per second that a user can transmit binary data. For binary modulation, bit rate and data rate are the same and often the term **bit rate** is (sloppily) used to denote the data rate. For *m-ary modulation, the data rate is actually given as the symbol rate times the number of bits* encoded in a single waveform. For example, in 8-ary modulation, eight possible groups of three bits and thus the bit rate is three times the symbol rate.
- Modulation is carried out at the transmitter. The receiver ultimately wants to recover the transmitted symbols from a received waveform. The mapping from a received waveform to symbols is called **demodulation.**

Modulation Types

The carrier is typically represented as a cosine wave, uniquely determined by amplitude, frequency and phase shift; As a consequence modulated signal s(t) can be represented as:

$$s(t) = A(t)\cos(\omega(t) + \Phi(t))$$

where *A(t) is the time-dependent amplitude, ω(t) is the time-dependent frequency, and φ(t) is the* phase shift.

- Accordingly, there are 3 fundamental modulation types: Amplitude Shift Keying (ASK), Phase Shift Keying (PSK) and Frequency Shift Keying (FSK)

ASK (Amplitude shift keying)

- *ASK* refers to a type of amplitude modulation that assigns bit values to discrete amplitude levels. The carrier signal is then modulated among the members of a set of discrete values to transmit information. The amplitude of the resultant output depends upon the input data whether it should be a zero level or a variation of positive and negative, depending upon the carrier frequency.
- **Amplitude Shift Keying (ASK)** is a type of Amplitude Modulation which represents the binary data in the form of variations in the amplitude of a signal.
- In ASK, the waveforms *si (·) for the different symbols are chosen as:*

$$s_i(t) = \sqrt{\frac{2E_i(t)}{T}} \cdot \cos\left[\omega_0 t + \phi\right],$$

- where *ω0 is the center frequency, φ is an arbitrary constant initial phase, and Ei (t) is constant* over the symbol duration *and assumes one of m different levels.*

ASK

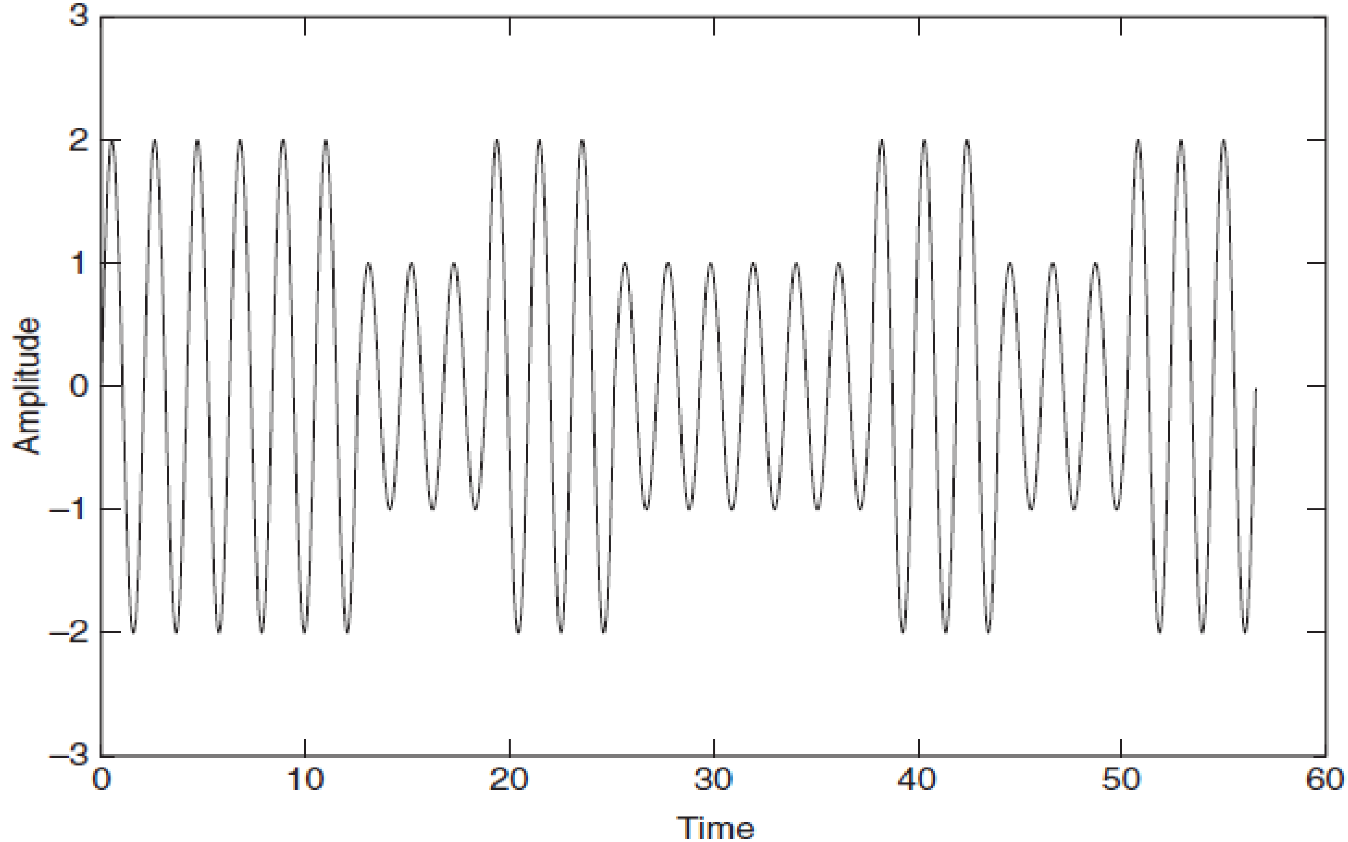


Figure 4.2 Amplitude shift keying (ASK) example

PSK

- The phase of the output signal gets shifted depending upon the input. These are mainly of two types, namely BPSK and QPSK, according to the number of phase shifts. The other one is DPSK which changes the phase according to the previous value.
- **Phase Shift Keying (PSK)** is the digital modulation technique in which the phase of the carrier signal is changed by varying the sine and cosine inputs at a particular time. Modulated signal s(t) as below

In PSK, we have:

$$s_i(t) = \sqrt{\frac{2E}{T}} \cdot \cos\left[\omega_0 t + \phi_i(t)\right],$$

where ω_0 is the center frequency, E is the symbol energy, and $\phi_i(t)$ is one of m different constant values describing the phase shifts. The same binary data as in the ASK example is shown using

PSK Example

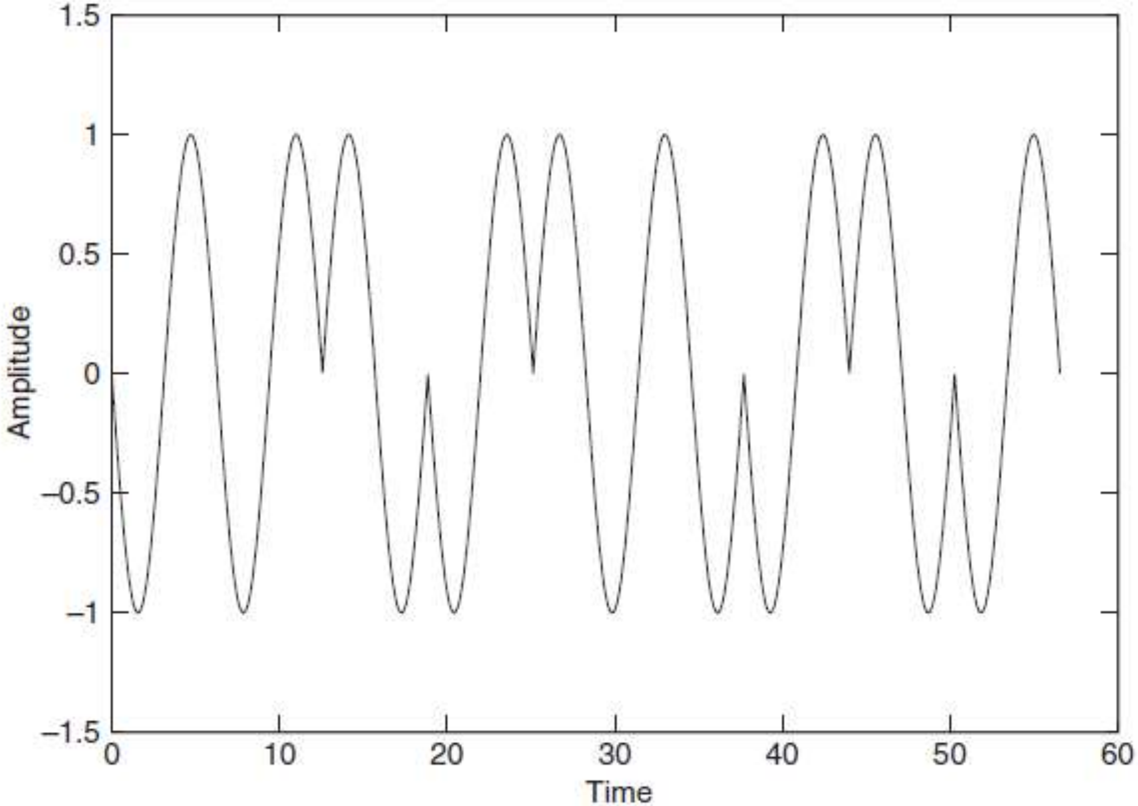


Figure 4.3 Phase shift keying (PSK) example

FSK

- The frequency of the output signal will be either high or low, depending upon the input data applied.
- **Frequency Shift Keying (FSK)** is the digital modulation technique in which the frequency of the carrier signal varies according to the discrete digital changes. FSK is a scheme of frequency modulation.

In FSK, we have:

$$s_i(t) = \sqrt{\frac{2E}{T}} \cdot \cos\left[\omega_i(t) \cdot t + \phi\right],$$

where $\omega_i(t)$ is one of n different frequencies, E is the symbol energy, and ϕ is some constant

FSK Example

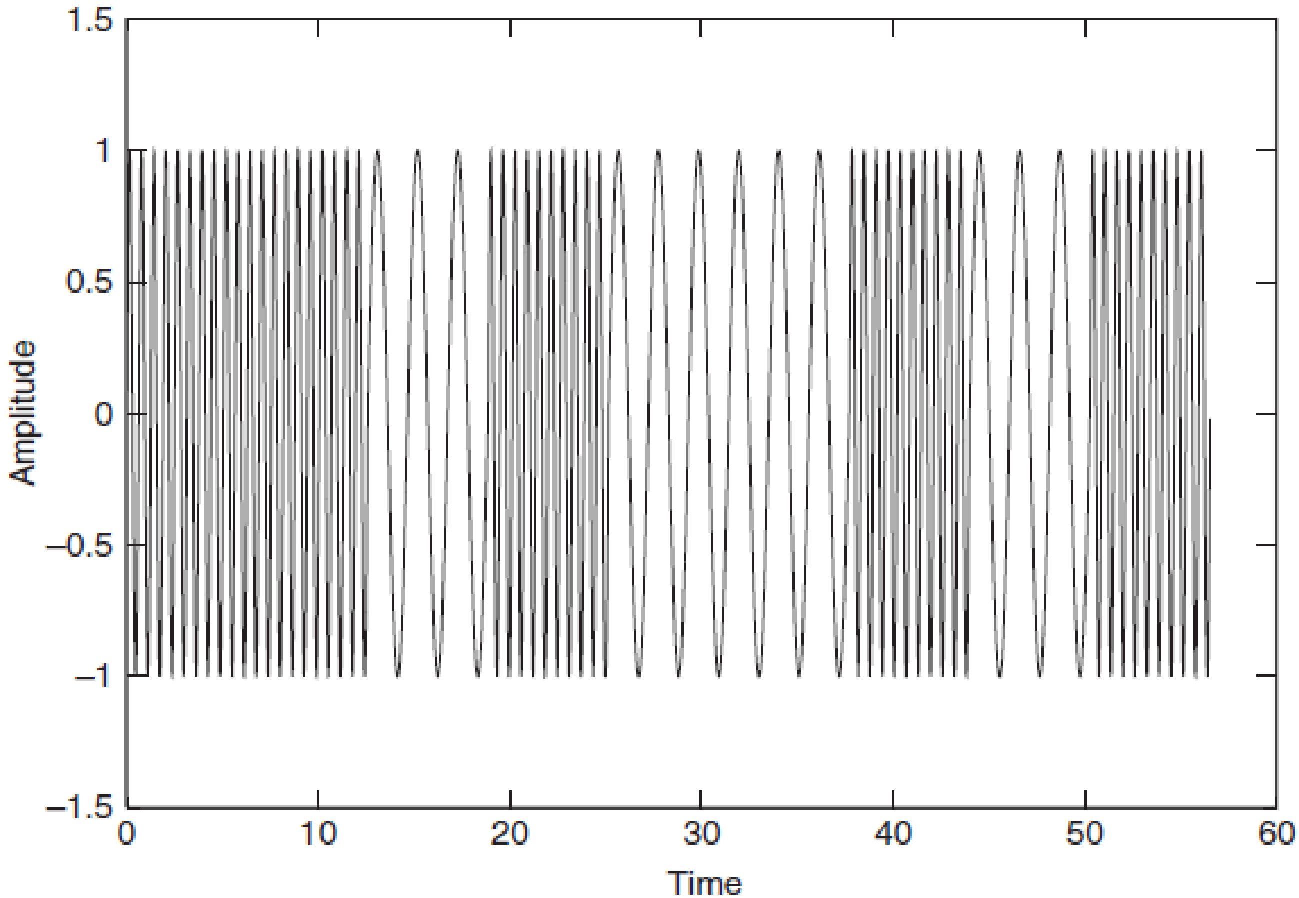
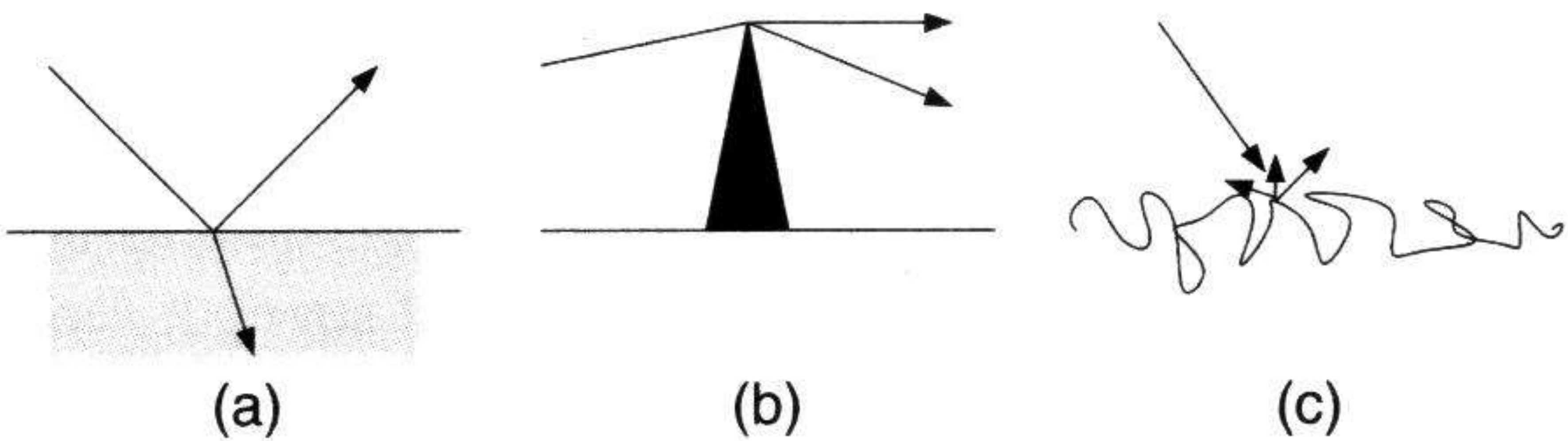


Figure 4.4 Frequency shift keying (FSK) example

Wave propagation effects and noise

- Waveforms transmitted over wireless channels are subject to several physical phenomena that distort the waveform; this introduces bit errors at the receiver;
- The basic wave propagation phenomena are:
  - (a)**Reflection:** when a waveform propagating in medium A hits the boundary to another medium B and the boundary layer is smooth, one part of the waveform is reflected back into medium A, another one is transmitted into medium B and the rest is absorbed;
  - (b)**Diffraction:** all points on a wavefront can be considered as sources of a new wavefront; if a waveform hits a sharp edge, it can be propagated into another region;
  - (c)**Scattering:** when a waveform hits a rough surface, it can be reflected multiple times and diffused into many directions.

(d)**Doppler fading:** when a transmitter and a receiver move relative to each other, the waveforms experience a shift in frequency, according to the Doppler effect; if the shift is important, this can cause the receiver to sample signals at wrong frequencies;



Physical layer and transceiver design considerations in WSNs

- Some of the most crucial points influencing PHY design in WSNs are:
  - Low power consumption;
    - Consequence 1: small transmit power and thus a small transmission range;
    - Consequence 2: low duty cycle; most hardware should be switched off or operated in a low power standby mode most of the time;
  - Low data rates (tens to hundreds kb/s);
  - Low implementation complexity and costs;
  - Low degree of mobility;
  - A small form factor for the overall node;
  - Low cost.

Energy usage profile

- The radiated energy is small but the overall transceiver consumes much more energy than is actually radiated;
- For small transmit powers the transmit and receive modes consume more or less the same power; therefore it is important to put the transceiver into sleep state instead of idle state;
- This rises the problem of startup energy/ startup time which a transceiver has to spend upon waking up from sleep mode. during this startup time, no transfer of data is possible. therefore, going into sleep mode is unfavorable when the next wakeup comes fast;
- Computation is cheaper than communication: the ratio is hundreds to thousands of instructions/ 1 transmitted bit;

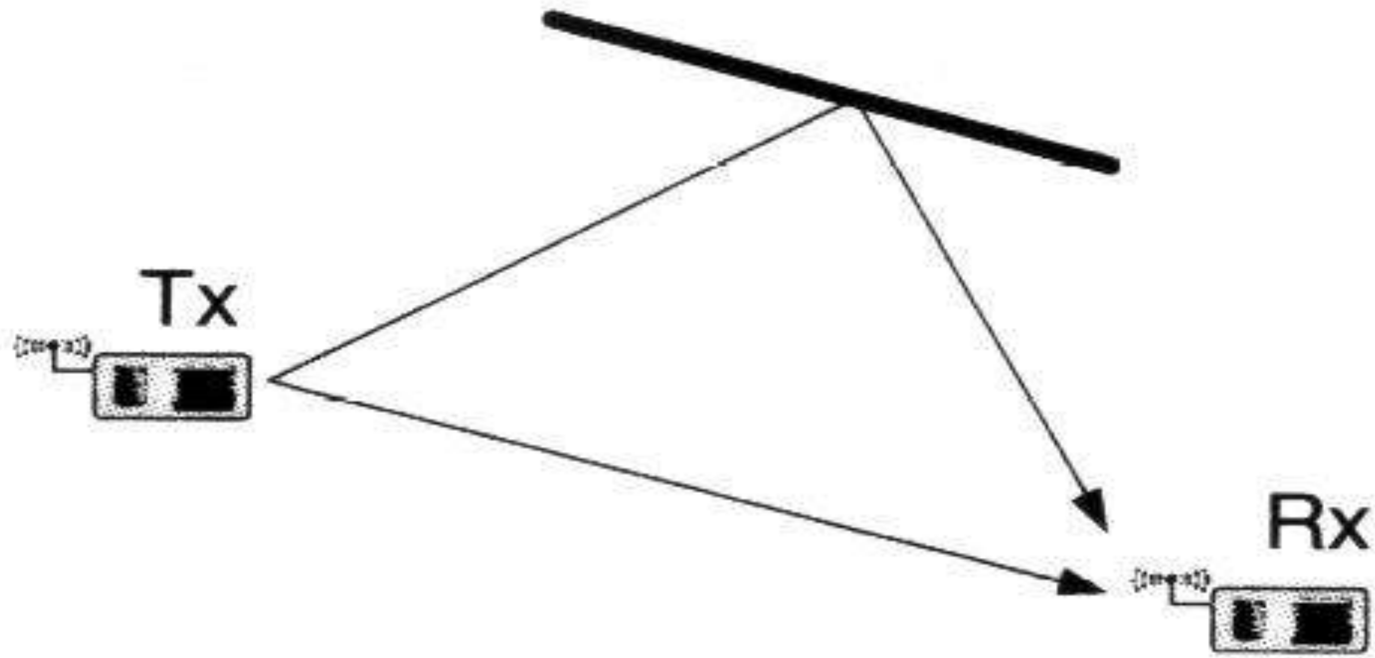
Choice of modulation scheme

- The choice of modulation scheme depends on several aspects, including technological factors, packet size, target error rate and channel error model;
- The power consumption of a modulation scheme depends much more on the symbol rate than on the data rate; it leads to desire of high data rates at low symbol rates which ends to m – ary modulation schemes; trade – offs:
  - M – ary modulation schemes require more hardware than 2 – ary schemes;
  - M – ary modulation schemes require for increasing m an increased E_b/N_0 ratio;
  - Generally, in WSN applications most packets are short; for them, the startup time dominates overall energy consumption making the other efforts irrelevant;

- Dynamic modulation scaling is necessary;

Types of anteena

- **omnidirectional :**Radio antennas radiate their signal into all directions at (nearly) the same strength.
- **directed antennas:** Radio antennas radiate their signal into a preferred direction characterized by a beam.
- **Noise and attenuation:** We know that only a single but multiple copies of the same signal would reach the receiver over different paths with different path lengths and attenuation where a direct path or Line Of Sight (LOS) path and a reflected, or Non line Of Sight (NLOS) path are shown.
- In either case, it is likely that not only a single but multiple copies of the same signal would reach the receiver over different paths with different path lengths and attenuation


Tx
Rx

Thank You!