EEN 1043/EE452 Wireless and Mobile Communication

The Wireless Channel

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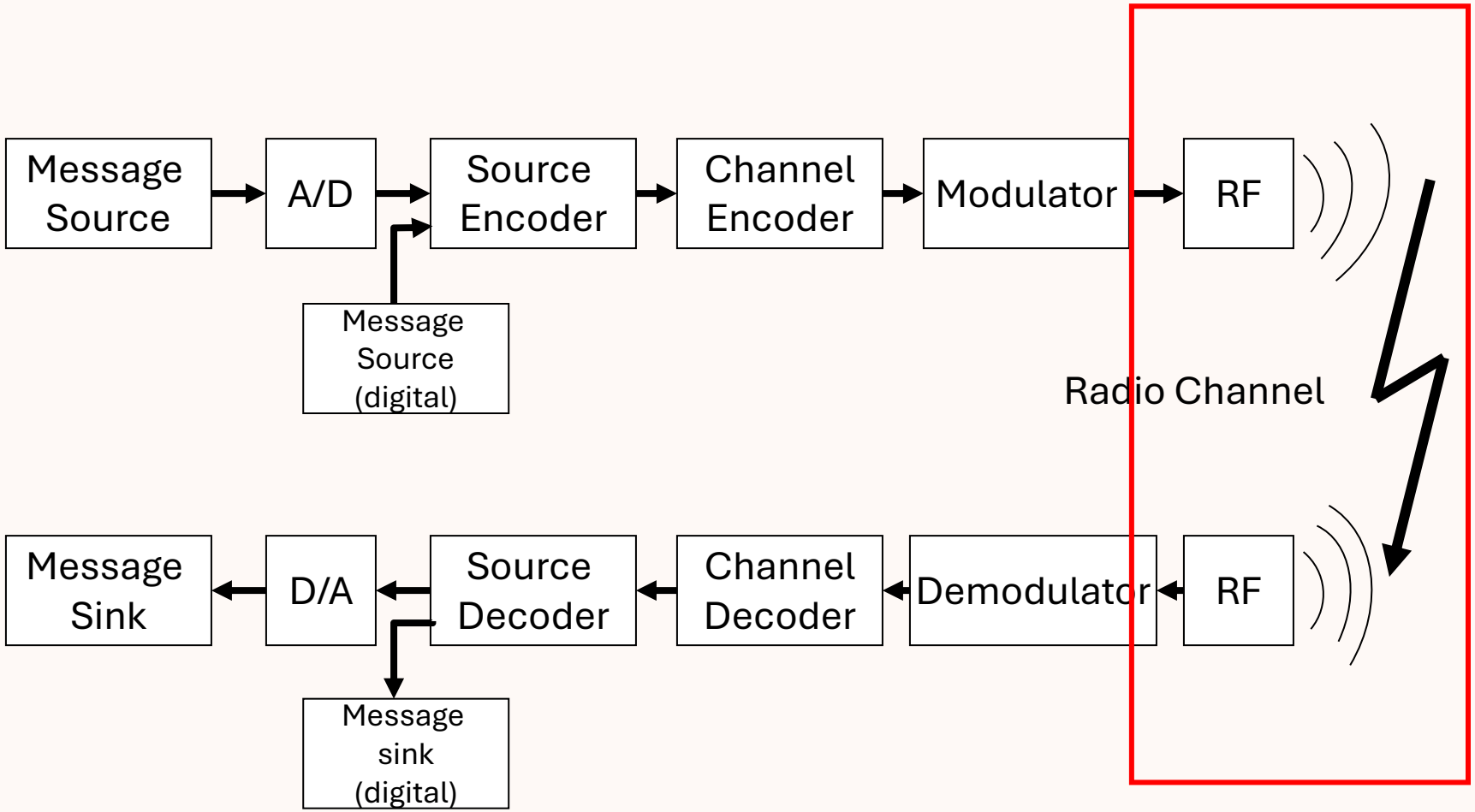
Radio Link


Message Source
A/D
Source Encoder
Channel Encoder
Modulator
RF
Message Source (digital)
Radio Channel
Message Sink
D/A
Source Decoder
Channel Decoder
Demodulator
RF
Message sink (digital)

Outline

- Antennas
  - Types
  - Directionality
- Propagation
  - Large-scale fading
    - Free space loss
    - Noise
    - Multipath
    - Loss Models
  - Small scale fading
    - Multipath
    - Mobility

Components of Wireless Channel

- Transmit Antenna
- Wireless Signal Propagation
- Receive Antenna

The three of them determine the signal quality

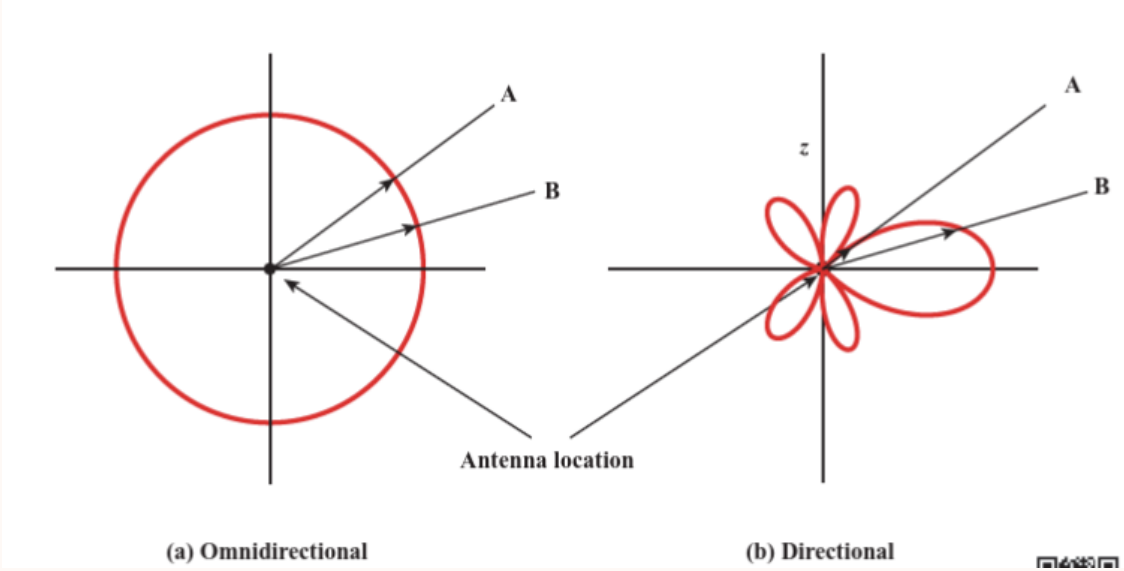
Antennas

- An antenna is an electrical conductor or system of conductors, used for
  - Transmission: radio-frequency electrical energy from the transmitter is converted into electromagnetic energy and radiated into the surrounding environment (atmosphere, space, water)
  - Reception: electromagnetic energy from environment is collected and converted into radio-frequency electrical energy which is fed to the receiver

- In two-way communication, the same antenna can be used for transmission and reception
  - Antenna characteristics are essentially the same for TX and RX

Antennas: Radiation Patterns

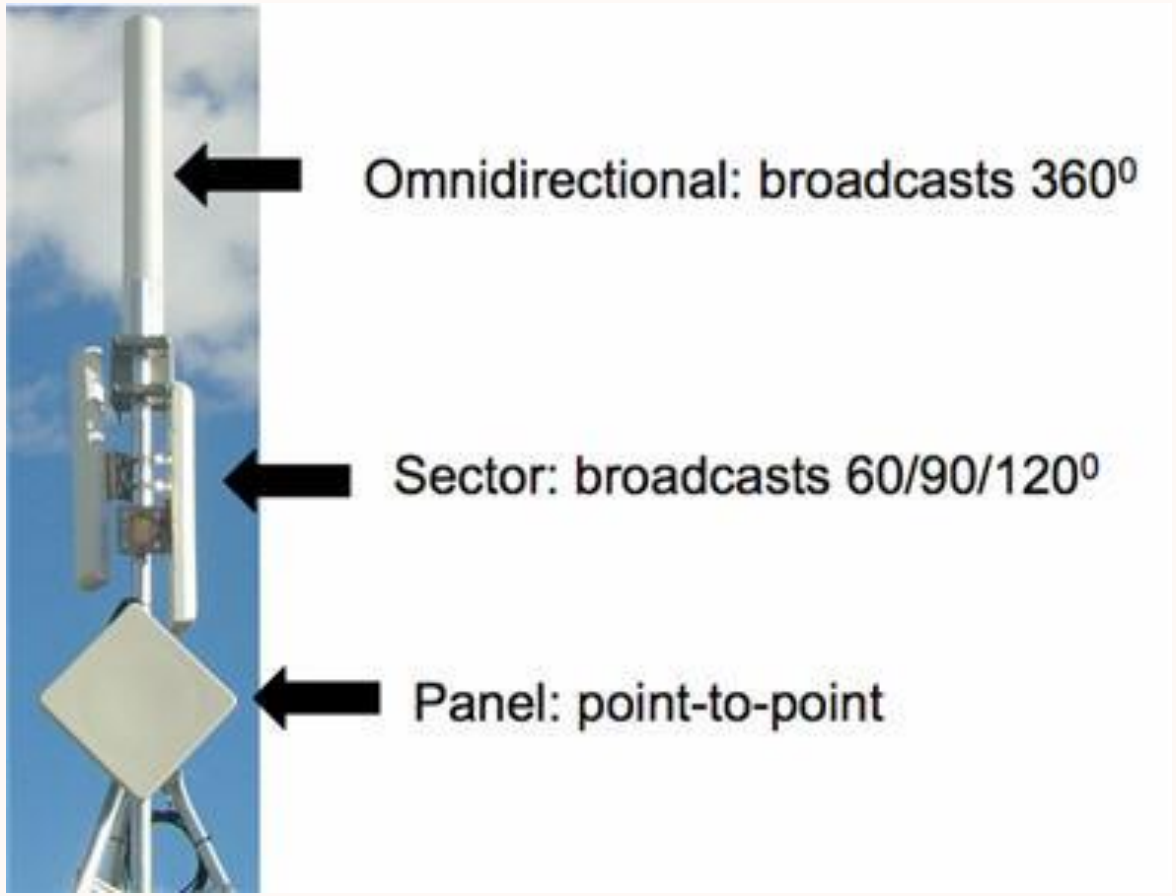
- Radiation pattern
  - Graphical representation of radiation properties of an antenna as a function of space coordinates
  - Depicted as a 2-D cross section of actual 3-D pattern



Antennas: Radiation Patterns

- Beam width (or half-power beam width)
  - Measure of ***directivity*** of an antenna
  - The angle within which the power radiated by the antenna is at least half of what it is in the most preferred direction
- Reception pattern
  - Receiving antenna's equivalent to radiation pattern

Antenna Types



Microstrip patch antenna

Iphone internal antennas

Antennas: Gain

- Antenna gain: a measure of the **directionality** of an antenna
  - Power output ***in a particular direction*** compared to that produced in any direction by a perfect omnidirectional antenna (i.e. isotropic antenna)
  - e.g. 3dB gain means the antenna improves on the isotropic antenna in that direction by 3dB (factor of 2 improvement)
  - Increased power radiated in one direction means reduced power radiated in other directions

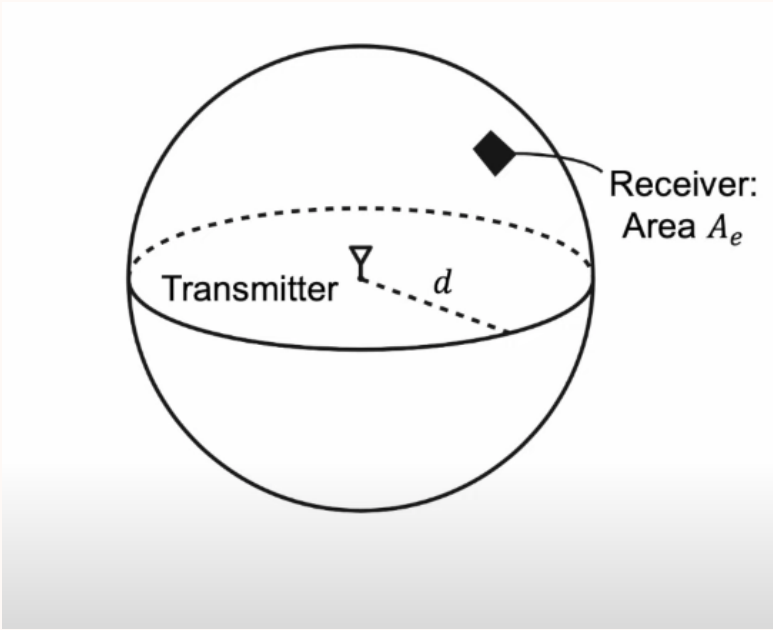
- Effective area
  - Related to physical size and shape of antenna

Antennas: Gain and effective area

- Relationship between antenna gain and effective area:

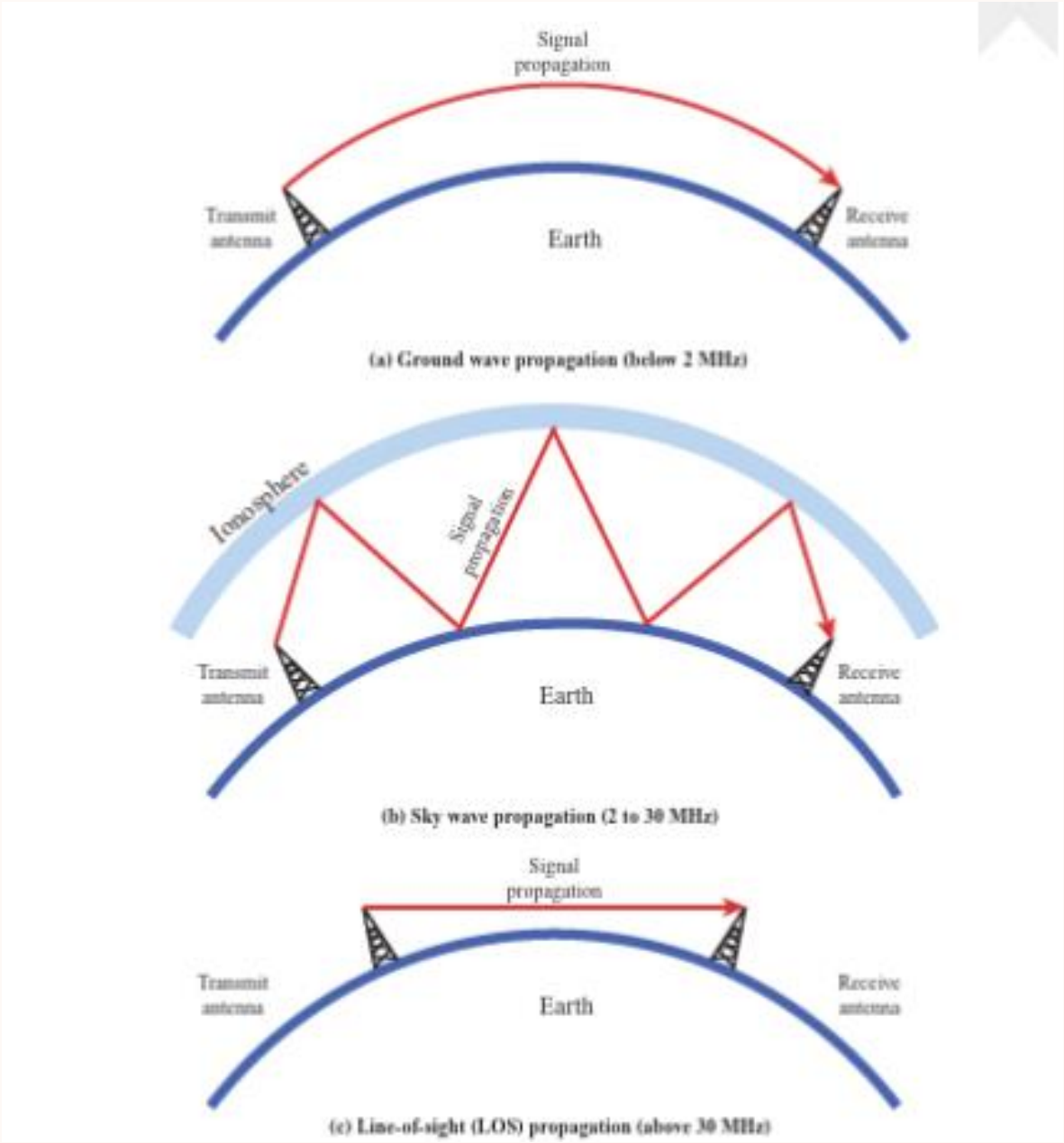
$$G = \frac{4\pi A_e}{\lambda^2} = \frac{4\pi f^2 A_e}{c^2}$$

  - G = antenna gain
  - A_e = effective area
  - f = carrier frequency
  - c = speed of light ($\approx 3 \times 10^8$ m/s)
  - λ = carrier wavelength



Propagation Modes

- Signals travel along one of three routes
  - Ground wave: follows the contour of the earth.
    - Frequency <2MHz.
    - E.g. AM radio
    - Main advantage is distance.
  - Sky wave: bounces between earth's surface and ionosphere.
    - Amateur radios, CB radios, international broadcasts.
    - Potentially very large range
  - Line-of-Sight (LOS)
    - Only mode above 30MHz.
    - Factors such as refraction affect the actual Line of Sight.

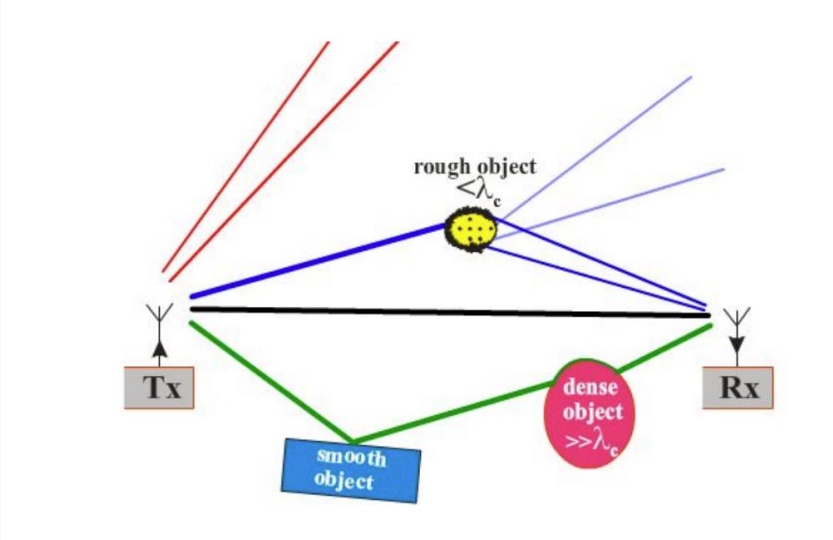

Signal
propagation
Transmit
antenna
Earth
Receive
antenna
(a) Ground wave propagation (below 2 MHz)
Ionosphere
Signal
propagation
Transmit
antenna
Earth
Receive
antenna
(b) Sky wave propagation (2 to 30 MHz)
Signal
propagation
Transmit
antenna
Earth
Receive
antenna
(c) Line-of-sight (LOS) propagation (above 30 MHz)

Line-of-Sight Transmission

- Various factors affect the signal in LOS wireless transmission, including:
  - Free space loss
  - Atmospheric absorption
  - Multipath
  - Mobility
- These factors will affect the power needed to send a signal and the amount of data which can be transmitted.
- Prediction of channel behavior requires relatively complex models, often based on empirical data.

Wireless Channels

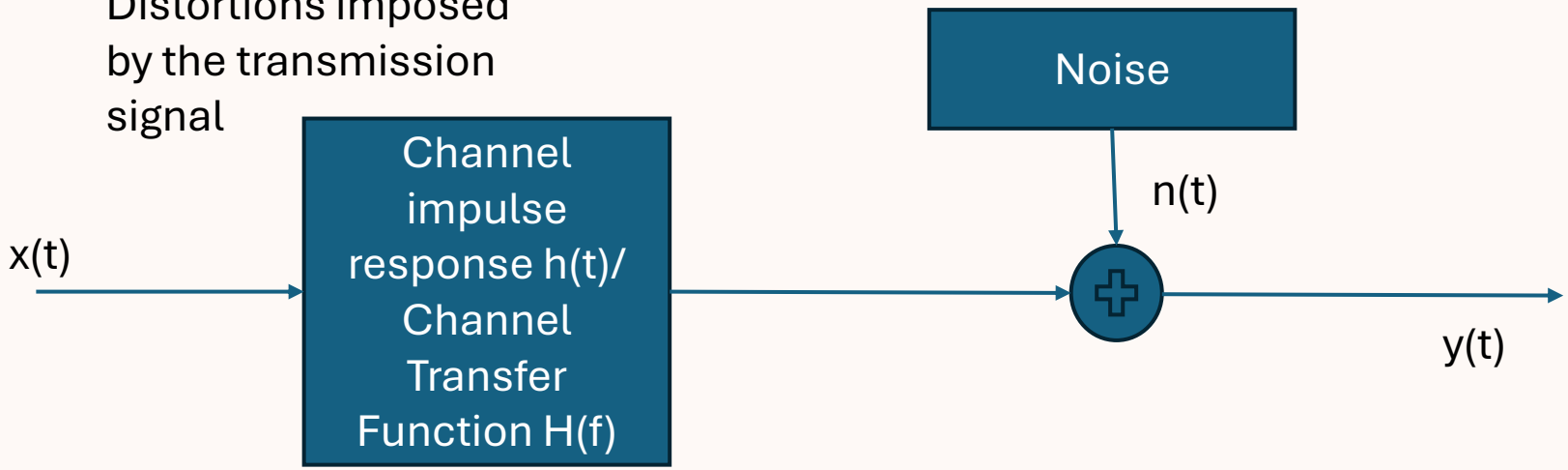
- Noise (thermal, sky, etc..)
- Unintentional interference from other Tx (multiple access interference)
- Intentional (hostile) interference (from Jammers)
- Multipaths
  - Reflection
  - Diffraction
  - Refraction
  - Scattering



Wireless Channel Model

The unwanted signal that is inserted somewhere between transmission and reception

Distortions imposed by the transmission signal



$$y(t) = h(t) * x(t) + n(t)$$