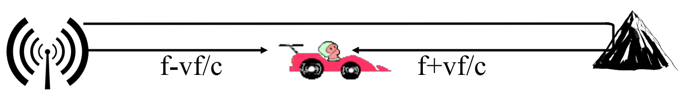
Doppler Spread and Coherence Time



- Two rays will be received (*original+reflection*)
- **Doppler Spread** = 2vf/c = 2 × Doppler shift
- They will add or cancel-out each other as the receiver moves
- **Coherence time**: Time during which the channel response is constant = 1/Doppler spread = $c/2vf = \lambda/2v$

Example

- What is the *coherence time* for a 2.4 GHz wifi link connecting a car travelling at 72 km/hr?

V=(72 x 1000)/3600 = 20 m/s
Doppler spread = $2vf/c$ = $(2\text{x}20\text{x}2.4\text{x}10^9)/(3\text{x}10^8)$ = 320 Hz
Coherence time = 1/320 = 0.003125 s = 3.125 ms

Duplexing

- Duplex = Bi-Directional Communication
- Frequency division duplexing (FDD) (Full-Duplex)

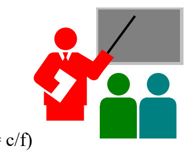
Base —— Frequency 1 → / ← Frequency 2 —— Subscriber

- Time division duplex (TDD): Half-duplex

Base → ← → ← → Subscriber

- Many LTE deployments will use TDD.
  - Allows more flexible sharing of DL/UL data rate
  - Does not require paired spectrum
  - Easy channel estimation ⇒ Simpler transceiver design
  - Con: All neighboring BS should time synchronize

Summary



1. Electric, Radio, Light, X-Rays, are all electromagnetic waves
2. Wavelength and frequency are inversely proportional (wavelength = c/f)
3. Historically, wireless communications mostly used frequencies below 6 GHz, but beyond 6 GHz is actively explored in modern wireless networks.
4. Hertz and bit rate are related by Nyquist and Shannon's Theorems
5. Nyquist's theorem explains capacity for noiseless channels
6. Shannon's capacity takes SNR into consideration
7. By spreading the original signal bandwidth over a much wider band, spread spectrum can provide better immunity against interference and jamming as well allowing multiple parties to communicate over the same frequency at the same time.
8. FHSS and DSSS are two fundamental methods of realizing spread spectrum
9. Doppler effect explains the shift in frequency experienced by mobile objects
10. Doppler spread is twice the Doppler shift
11. Channel coherence time is inversely proportional to doppler spread
12. FDD and TDD are two fundamental methods of resource allocation between the transmitter and the receiver so they both can exchange information with each other

PHY FUNDAMENTALS II

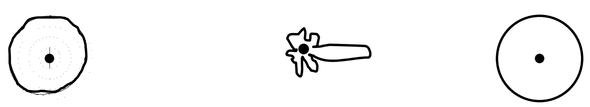
Wireless Signal Propagation

Overview

1. Antenna
2. Reflection, Diffraction, Scattering
3. Fading, Shadowing, Multipath
4. Inter-symbol Interference
5. Path loss model (Frii's, 2-ray)
6. MIMO (Diversity, Multiplexing, Beamforming)
7. Orthogonal Frequency Division Multiplexing (OFDM)
8. Orthogonal Frequency Division Multiple Access (OFDMA)
9. Effect of Frequency

Antenna

- Transmitter converts electrical energy to electromagnetic waves
- Receiver converts electromagnetic waves to electrical energy
- Same antenna is used for transmission and reception
- Omni-Directional: Power radiated in all directions
- Directional: Most power in the desired direction
- Isotropic antenna: Radiates in all directions *equally*
- Antenna Gain = Power at particular point/Power with Isotropic Expressed in dBi ("decibel relative to isotropic")



Omni-Directional   Directional   Isotropic

Example

Question: How much stronger a 17 dBi antenna effectively receives (transmits) the signal compared to the isotropic antenna?

Solution
Let
Power of isotropic antenna = P_{iso}
Power of 17 dBi antenna = P
We have
$17 = 10\log_{10}(P/P_{iso})$
Thus $P/P_{iso} = 10^{1.7} = 50.12$, i.e., the 17 dBi antenna will *effectively* receive (transmit) the signal 50.12 times stronger than the isotropic antenna albeit using the same *actual* transmit power.

Relationship between antenna size and frequency

- Antennas are designed to transmit or receive a specific frequency band
  - Cannot use a TV antenna for wireless router, or vice-versa (why?)
- End-to-end antenna length = ½ wavelength
  - So that electrons can travel back and forth the antenna in one cycle
- If dipole (two rods), each rod is ¼ wavelength