# Wireless Fundamentals

University of Southern Queensland

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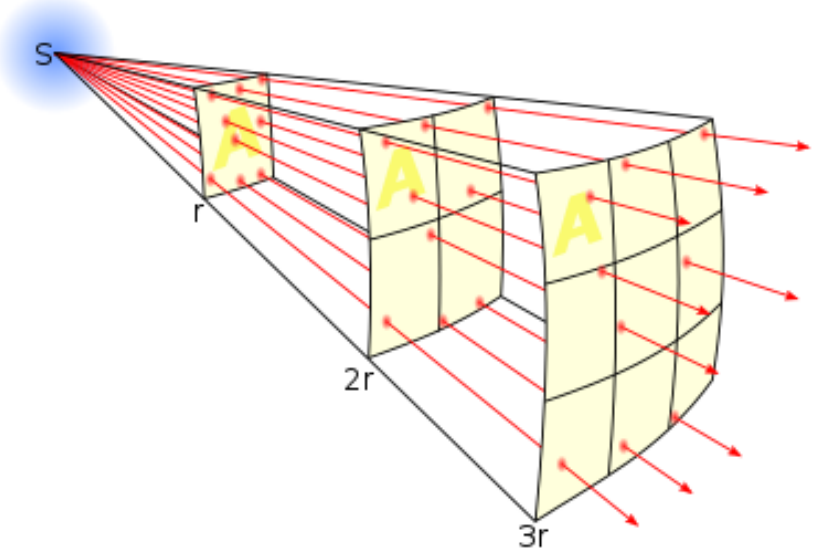
# RF Fundamentals

- Wireless Signal Characteristics
- Antenna Design and Choice
- The Shannon-Hartley law
- System Gain
- Reflection and Refraction

# Wireless Signal Characteristics

- Power vs distance
- Power vs Frequency
- Noise and interference

# Power vs distance




The power of an electromagnetic signal reduces over distance.

$$P_d = \frac{1}{d^2} P_1, \quad (1)$$

# Power vs Frequency

The atmosphere is not transparent. Some frequencies are absorbed more than others.

Higher frequencies are more likely to be absorbed.

This introduces additional loss.

This additional "gain" will be $d^{-a}$ for some $a > 0$ (a gain less than 1 is really a loss), where $d$ is the distance through the atmosphere.

# Noise and interference

Supposing the noise has power level $N$, and the signal has power $S$. The formula of Hartley and Shannon gives the maximum capacity, $C$, as:

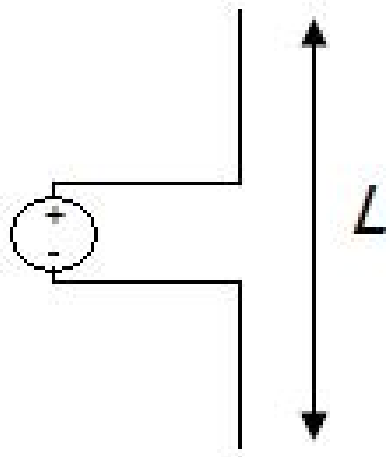
$$C = B \log_2(1 + S/N).$$

where $B$ is the bandwidth, in Hz.

# Antenna Design and Choice

- Dipole antennas
- Frequency dependence
- Reciprocity
- MIMO

# Dipole antennas




- current causes a time-varying magnetic field
- which propagates as light
- $L < \lambda/2$
- Signal strength $\sim L$ (so long as $L < \lambda/2$)

# Frequency dependence

The physical dimensions of an antenna depends on the frequencies transmitted, or received

An antenna for frequency $f$, used for frequency $2f$, will perform badly.

# Reciprocity

*Reciprocity is one of the most useful (and fortunate) property of antennas. Reciprocity states that the receive and transmit properties of an antenna are identical. Hence, antennas do not have distinct transmit and receive radiation patterns - if you know the radiation pattern in the transmit mode then you also know the pattern in the receive mode. This makes things much simpler, as you can imagine. [1]*

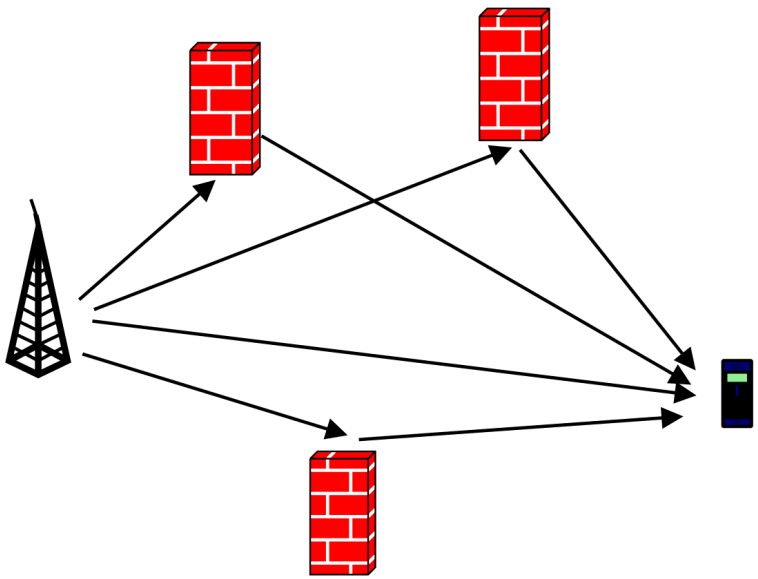
# MIMO

An antenna larger than 1/4-1/2 wavelength needs to use multiple antennas, each with the 1/4-1/2 wavelength length. The signals from each antennas have to be combined by complex coefficients, determined from the channel frequency response.

This is important for high frequences because no single antenna will receive sufficient power.

# System Gain

# Reflection and Refraction



Wireless signals pass along multiple paths of different gain, and delay. Some paths can also be refracted.

This is the multipath problem.

# OFDM

- OFDM solves the multipath problem.
  - Divide spectrum up into bands
  - Relative to a frame, bands are *orthogonal*
  - Estimate the complex gain of each frequency
  - This overcomes multipath interference
  - Transmit over all frequencies at once
  - Each frame must include a cyclic continuation

The OFDM concept was fully proved by Australia's CSIRO and introduced from 802.11a. 802.11b was the last non-OFDM wifi.

# References


antennatheory.com.

antennatheory.com, 2022.

https://www.antenna-theory.com/definitions/reciprocity.php#:~:text=Reciprocity%20states%20that%20the%20receive,pattern%20in%20the%20receive%20mode.