# Multiple-input and multiple-output (MIMO)

MIMO is a wireless technology that multiplies the capacity of a radio link using multiple transmit and receive antennas.

* Uses the spatial dimension to increase link capacity
* Data rate speedup is roughly proportional to the number of transmitter and receiver antennas

**Spatial multiplexing:** MIMO starts with a high-rate data stream, which is de-multiplexed into multiple, lower-rate streams. Each stream is modulated and transmitted in parallel with different coding from the Tx antennas, with all streams in the same frequency channel. These co-channel, mutually interfering streams arrive at the Rx’s antenna array, each having a different spatial signature – gain-phase pattern at the Rx antennas. These distinct array signatures allow the Rx to separate the co-channel streams, demodulate them, and re-multiplex them to reconstruct the original high-rate data stream.

The key to MIMO is sufficient differences in the spatial signatures of the different streams to enable their separation. This is achieved through angle spread of the multipaths and sufficient spacing between antenna elements. In environments with rich multipath and high angle spread (like cellular and Wi-Fi), an antenna element spacing at each end (Tx and Rx) of just a few wavelengths can suffice. In other environments, larger element spacing (wider angle separation) is required at the Tx, Rx, or both ends.

## Mathematical description

# Channel models

Multipath – frequency-selective or flat, depending on the delay spread and the signal BW

The magnitude response of the channel in multipath is where is the delay spread. As increases, the spacing of the nulls in the magnitude response is compressed, and there is higher frequency selectivity. This results in ISI.