Wi-Fi Technology Fundamentals

WI-FI TECHNOLOGY
FUNDAMENTALS COURSE

Module-2

WLAN Physical Layer

Session-2b

Modulation and Coding/ MIMO Basics

Last Session Recap……

Module-2

WLAN Physical Layer

Session-2a

Frequency Allocation and Modulation Basics

- ✓Frequency Spectrum
- ✓Wi-Fi Frequencies
- ✓Basics of Signals and Modulation
- ✓Spread Spectrum Techniques

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Module-2
WLAN Physical Layer
Session-2b
Modulation and Coding/ MIMO Basics

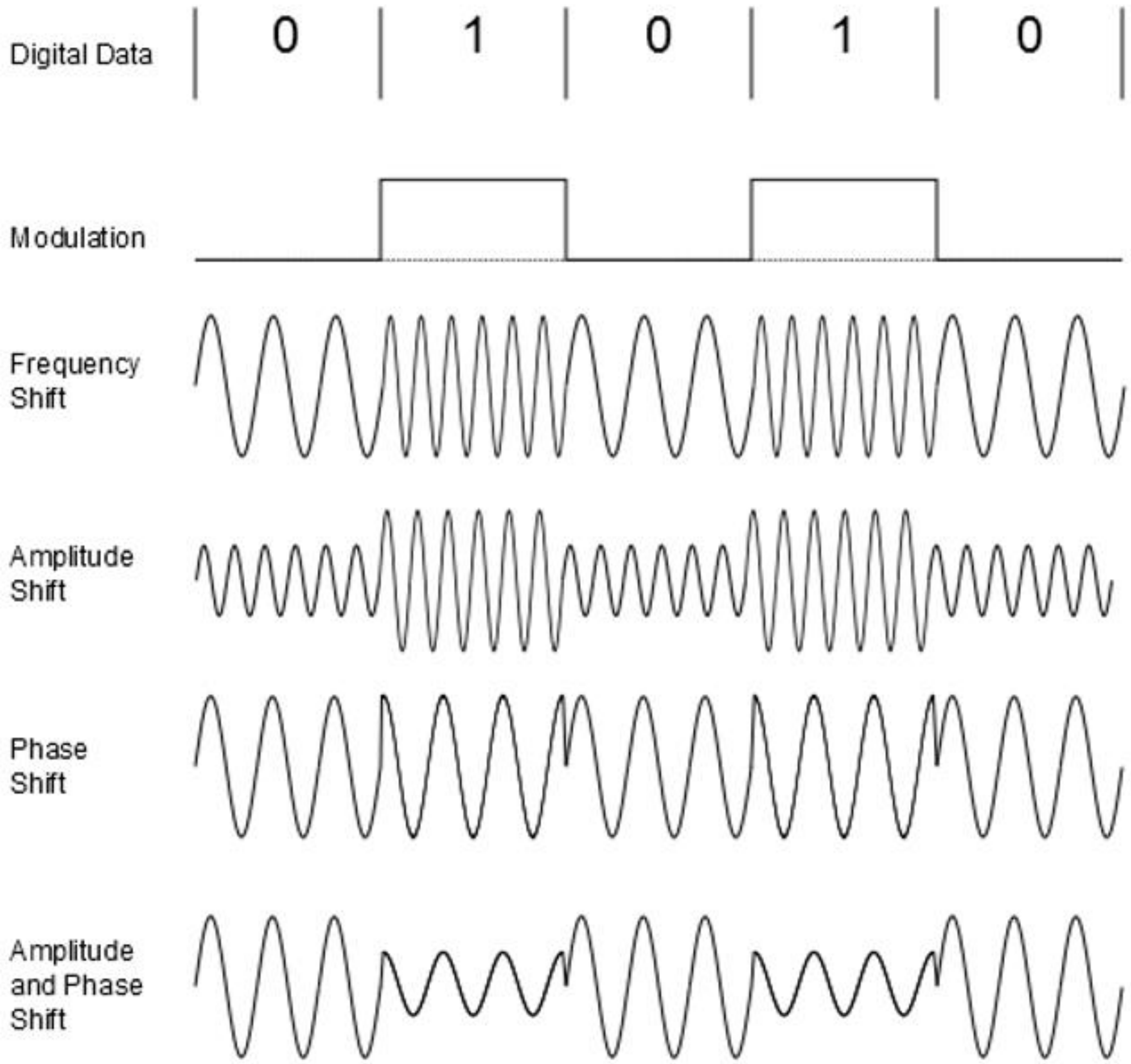
Modulation

Modulation, is the process of varying one or properties of a periodic waveform called a carrier wave in order to carry information.

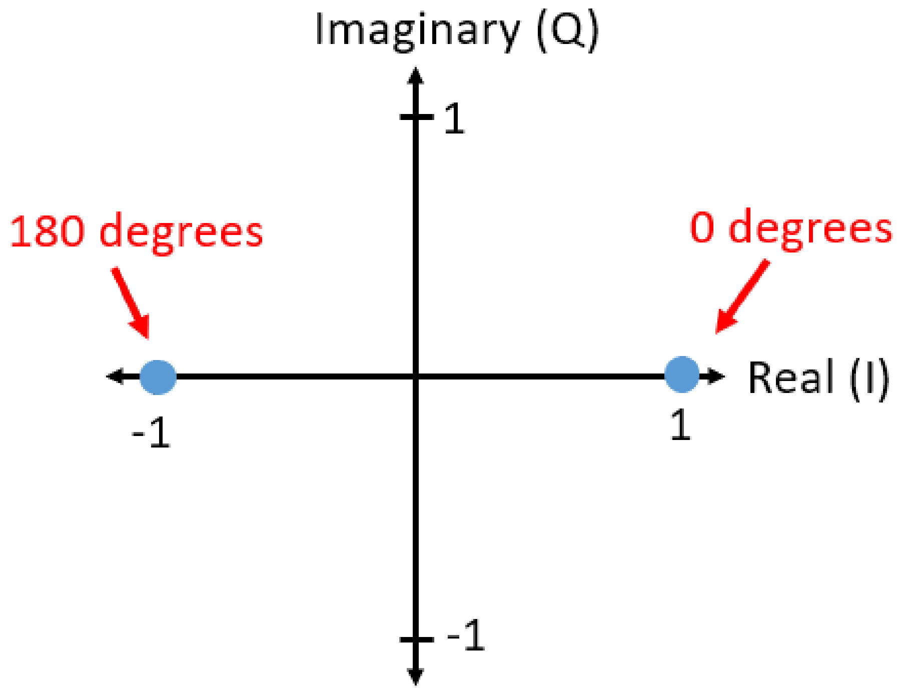
There are various forms of modulation, each designed to alter a particular characteristic of the carrier wave. The most commonly altered characteristics include amplitude, frequency, phase, pulse sequence, and pulse duration.

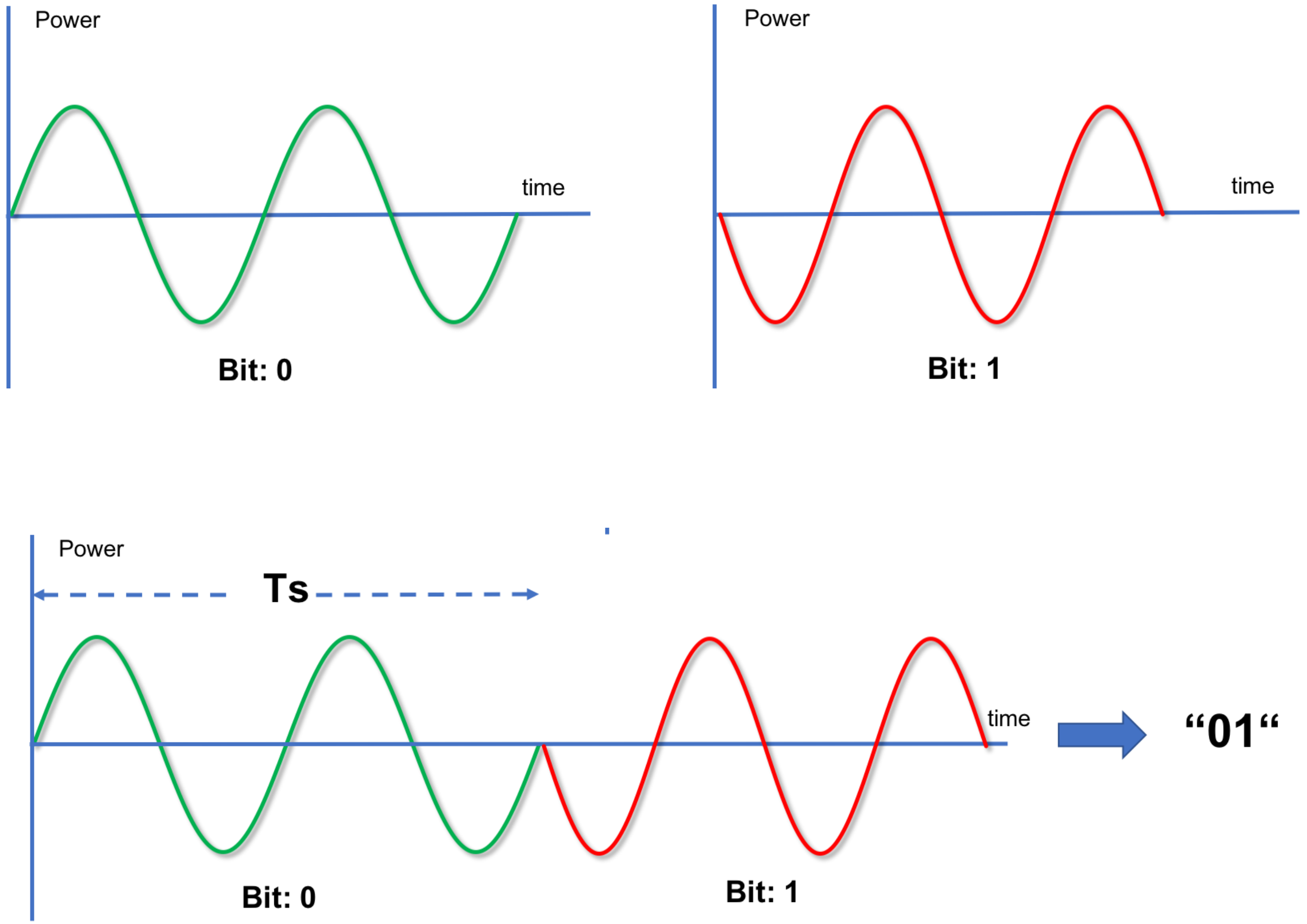
- FSK: Frequency of the carrier signal is varied to represent binary 1 and 0
- ASK: Amplitude of the carrier signal is varied to represent binary 1 and 0
- PSK: Phase of the carrier signal is varied to represent binary 1 and 0
- QAM: Amplitude and Phase of the carrier signal is varied to represent binary 1 and 0

Parameter	FSK	ASK	PSK	QAM
Bandwidth Needed	Higher	Low	Low	Lowest
Noise Immunity	Higher	Low	Higher	Lowest
Complexity	Low	Low	Higher	Highest
Data Rates	Low	Higher	Higher	Highest

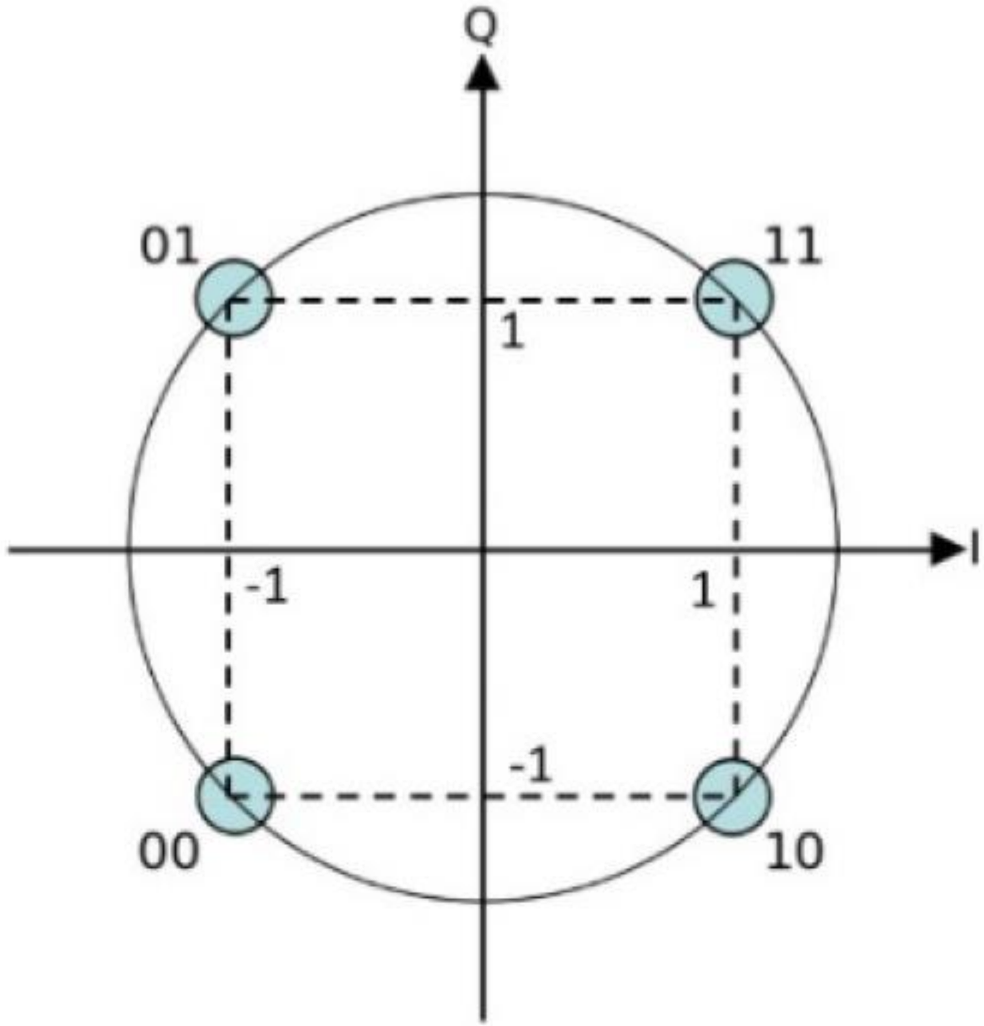


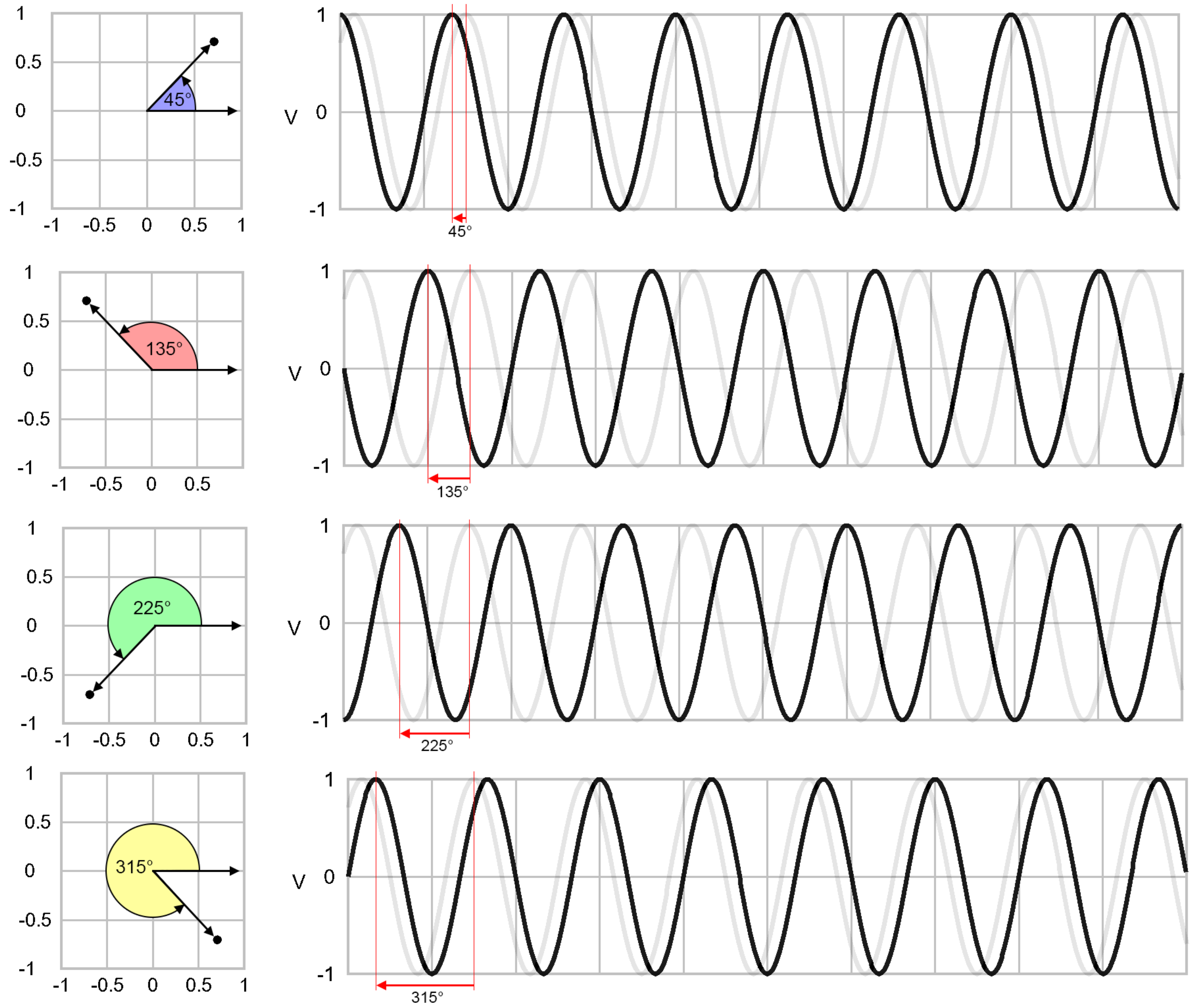
Example : BPSK Modulation



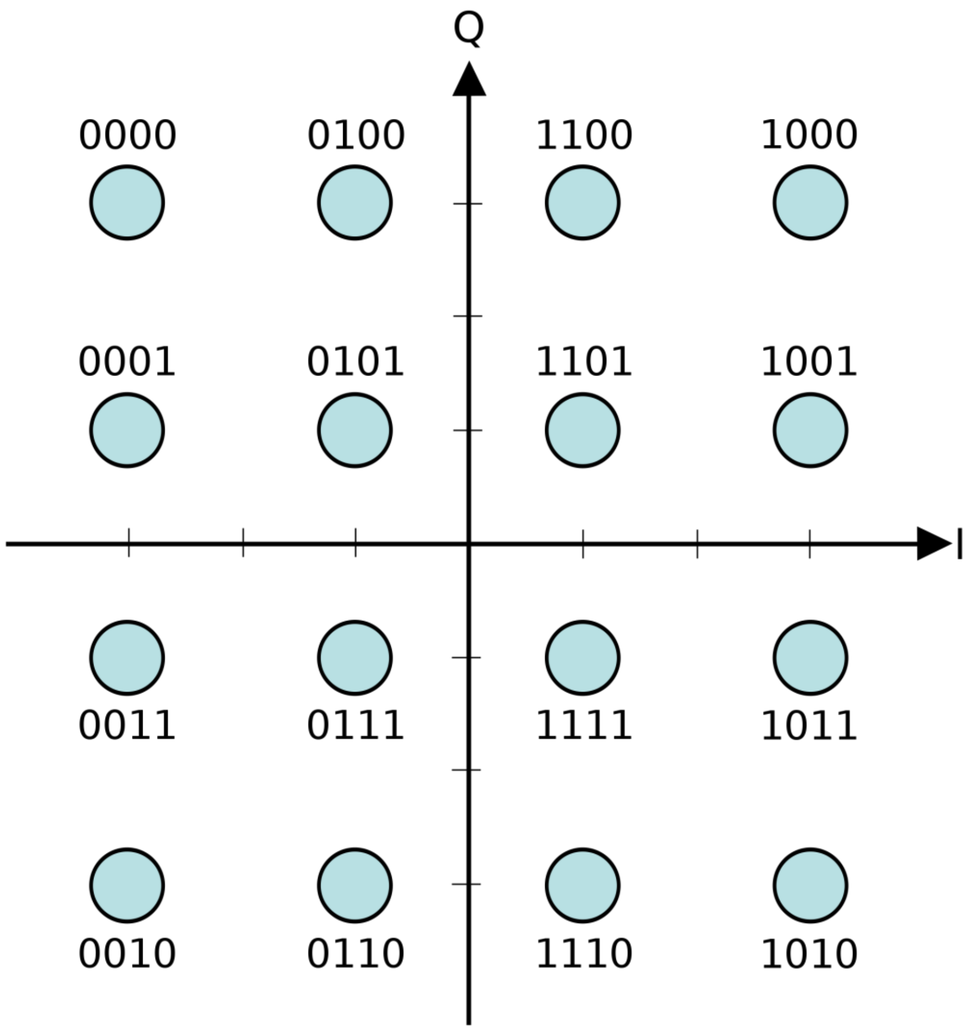


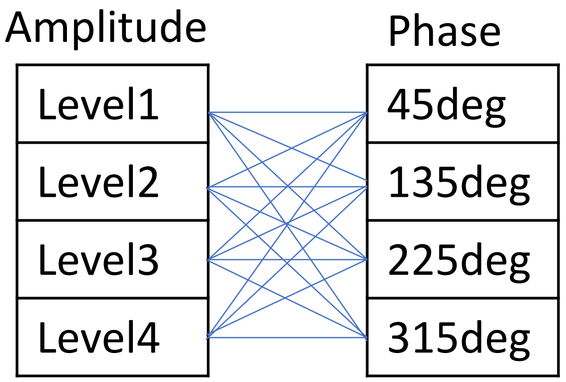
Example : QPSK Modulation



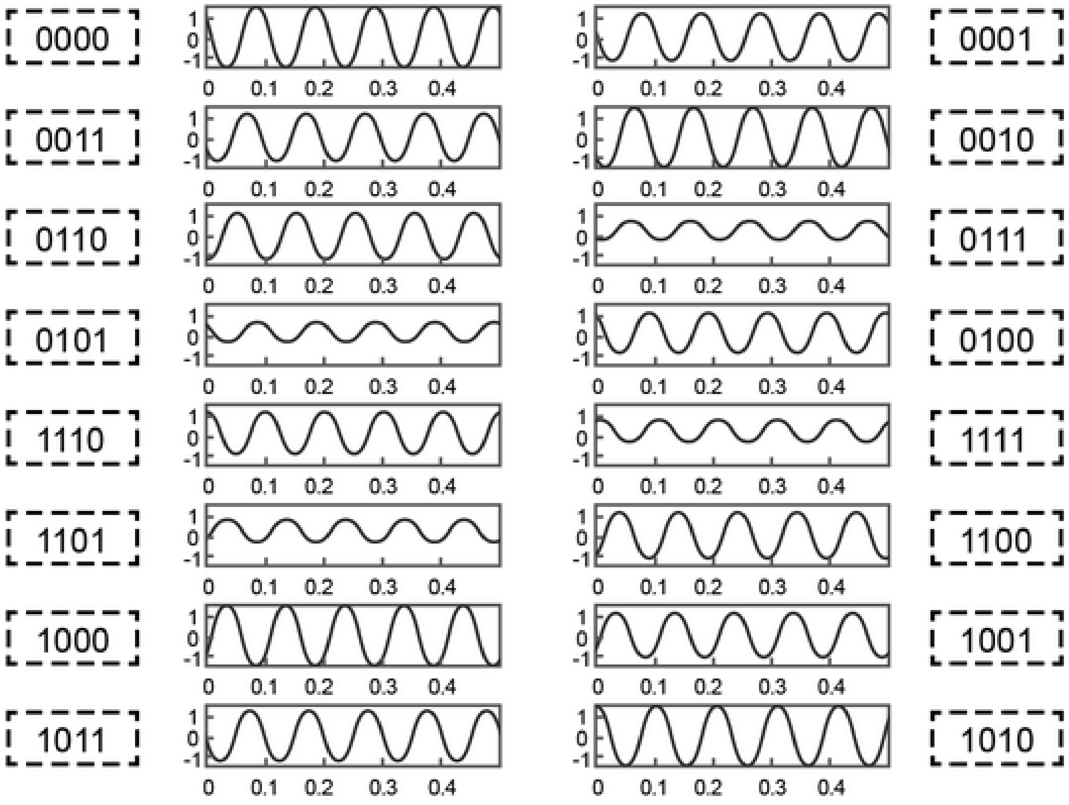


Example: 16QAM Modulation

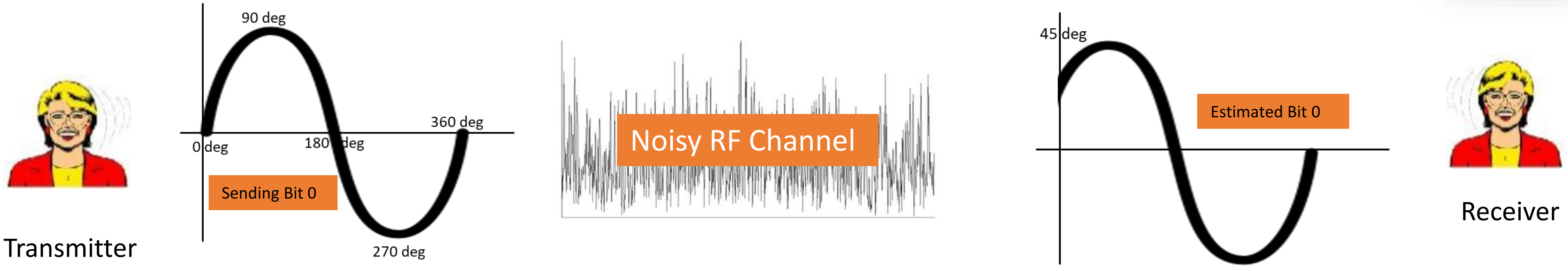


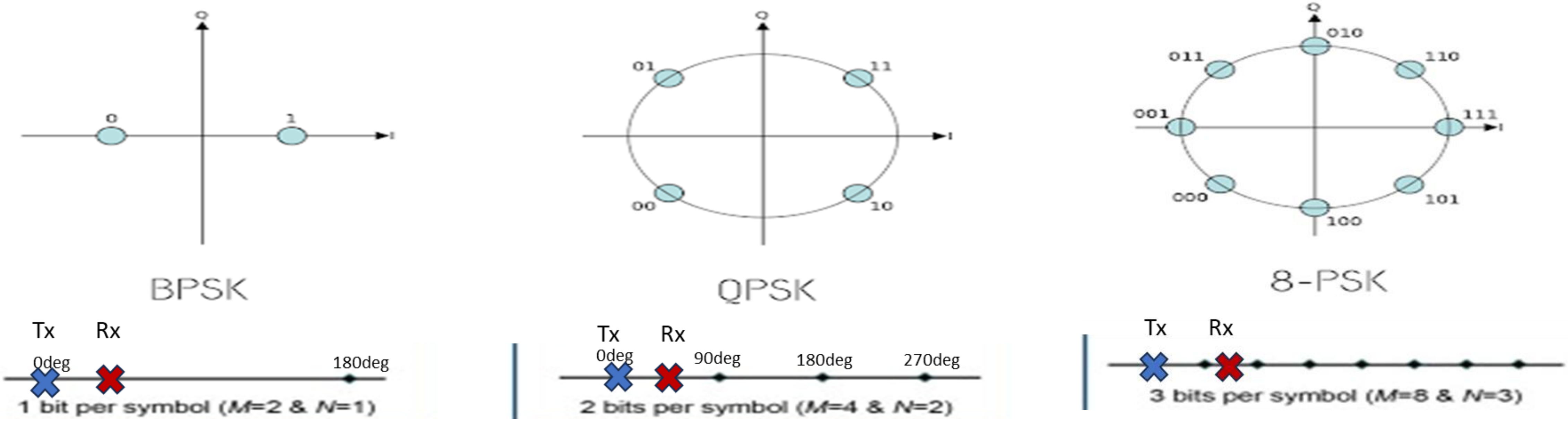


= 16 combinations
(4bits)

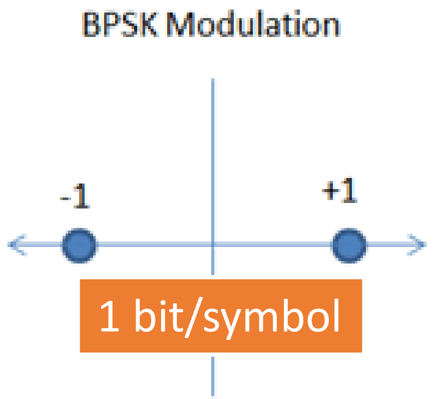


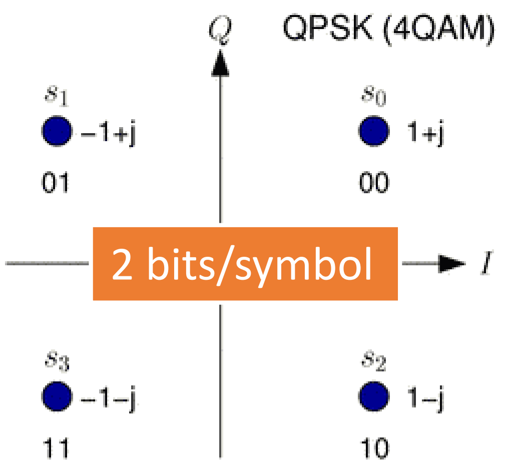
The Throughput/Reliability Tradeoff

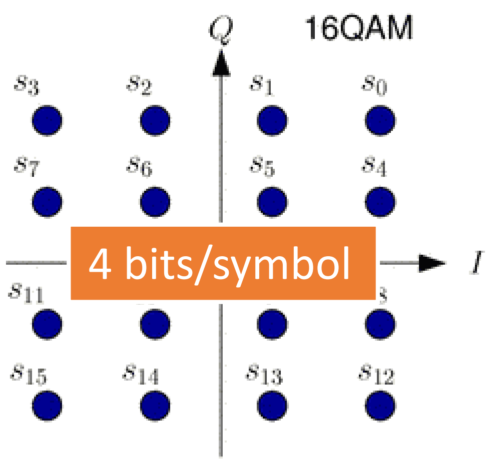


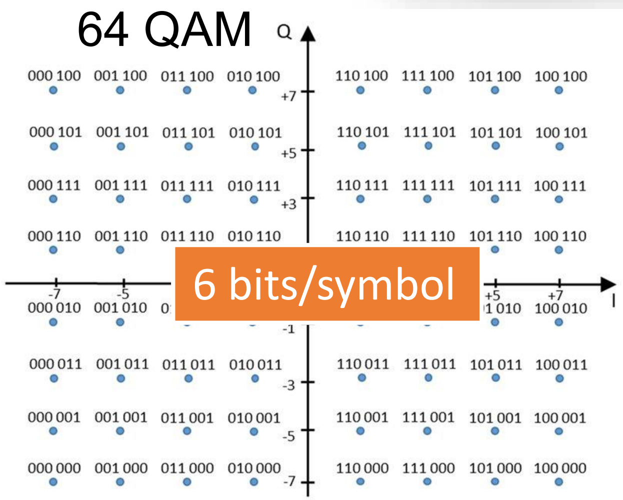


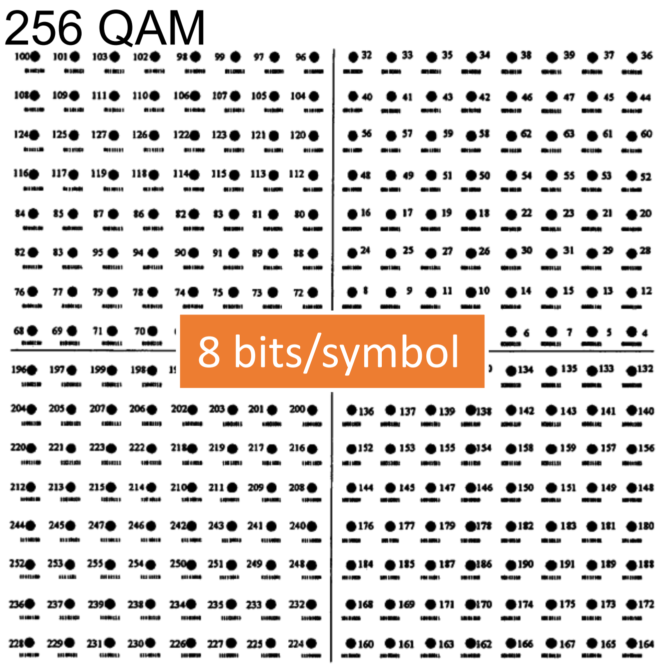
Wi-Fi QAM Rates

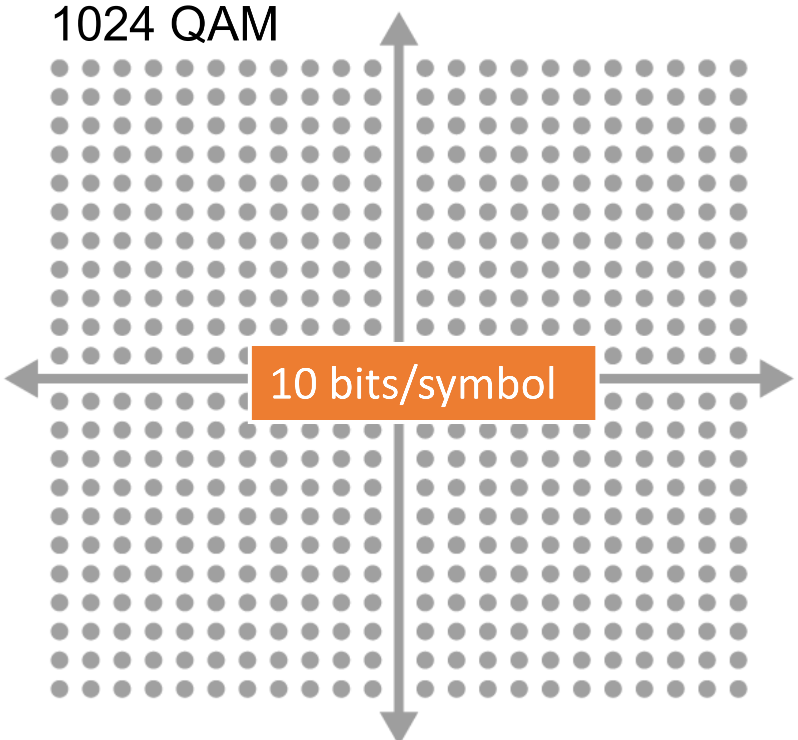


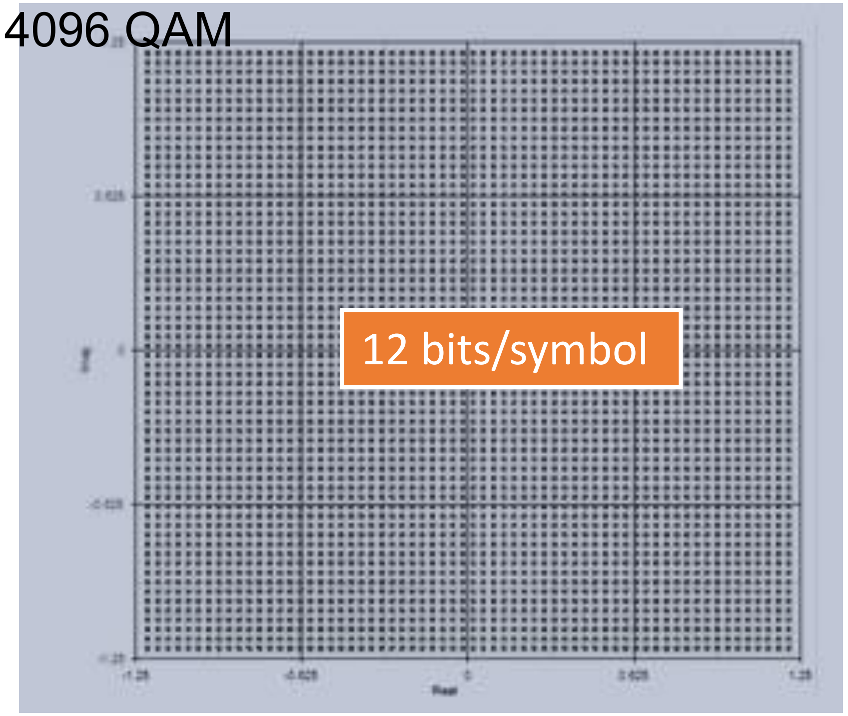






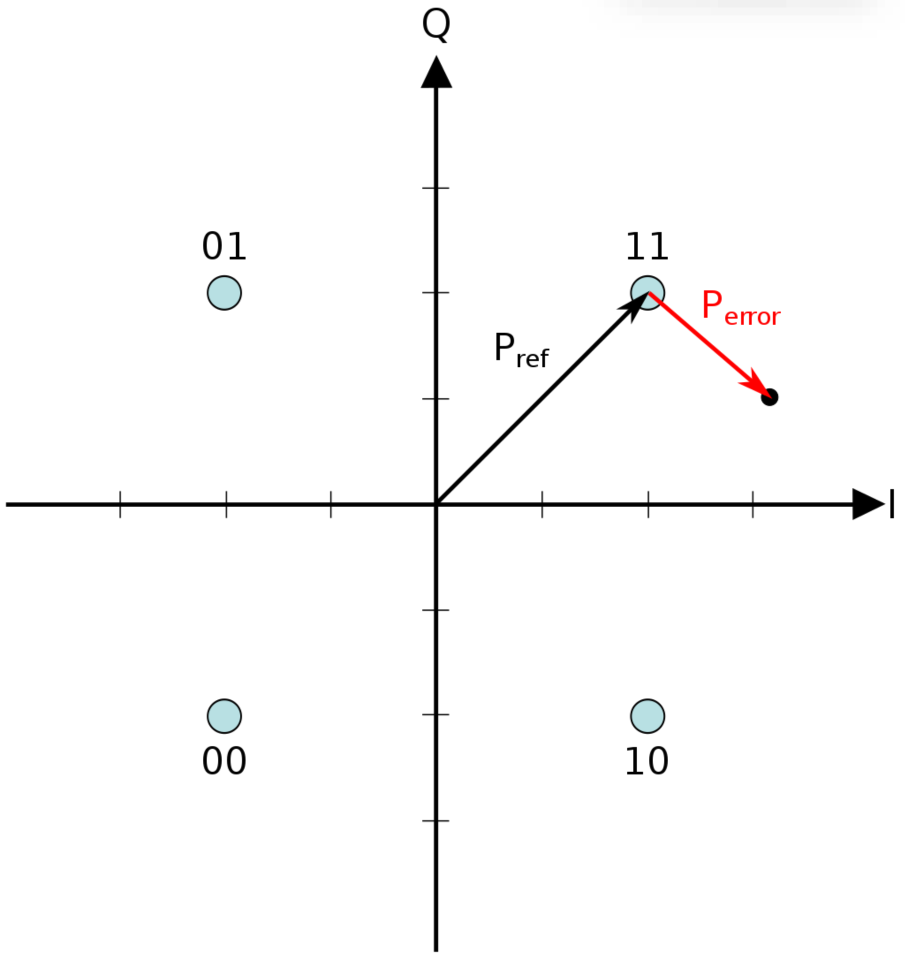




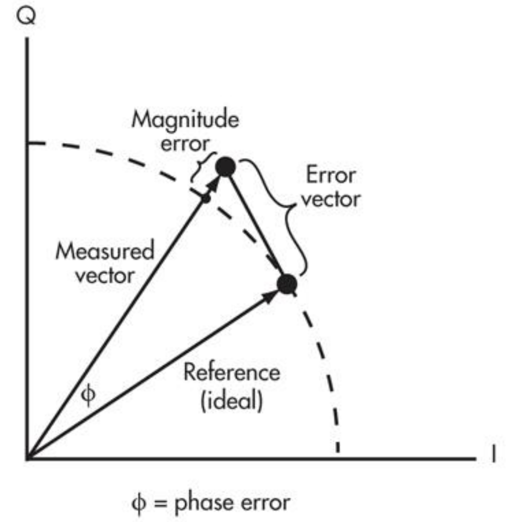


Error Vector Magnitude (EVM)

The error vector magnitude or EVM is a measure used to quantify the performance of a digital radio transmitter or receiver. A signal sent by an ideal transmitter or received by a receiver would have all constellation points precisely at the ideal locations, however various imperfections in the implementation (such as carrier leakage, low image rejection ratio, phase noise etc.) cause the actual constellation points to deviate from the ideal locations. Informally, EVM is a measure of how far the points are from the ideal locations.

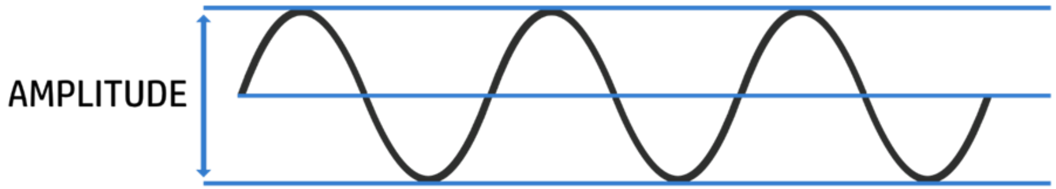


Modulation scheme	Code rate	EVM limit (802.11ac)
BPSK	1/2	−5 dB
QPSK	1/2	−10 dB
QPSK	3/4	−13 dB
16 QAM	1/2	−16 dB
16 QAM	3/4	−19 dB
64 QAM	2/3	−22 dB
64 QAM	3/4	−25 dB
64 QAM	5/6	−27 dB
256 QAM	3/4	−30 dB
256 QAM	5/6	−32 dB

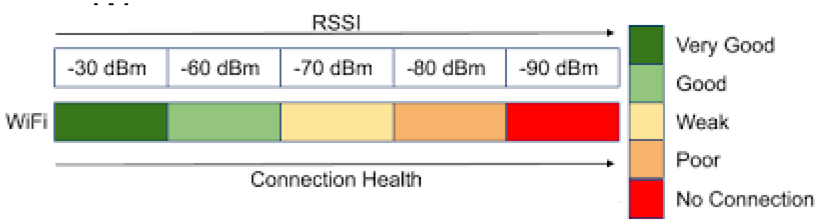


RF Power and Units

The RF signal strength can be measured in Watts (W) using the amplitude or the signal waveform's top peak to the bottom peak height. Decibel (dB) conversion is used for exponential values.



Received Signal Strength Indication (RSSI) is a measurement of the power present in a received radio signal. It is also measured in dBm



Milliwatts and Decibels

Absolute Power

POWER CONVERSION FROM WATTS TO dBm	
Power (W)	Power (dB)
100 W	+50 dBm
10 W	+40 dBm
1 W	+30 dBm
500 mW	+27 dBm
100 mW	+20 dBm
10 mW	+10 dBm
2 mW	+3 dBm
1 mW	0 dBm
0.5 mW	-3 dBm
0.1 mW	-10 dBm
0.01 mW	-20 dBm

Relative Power

Decibel (dB) Laws

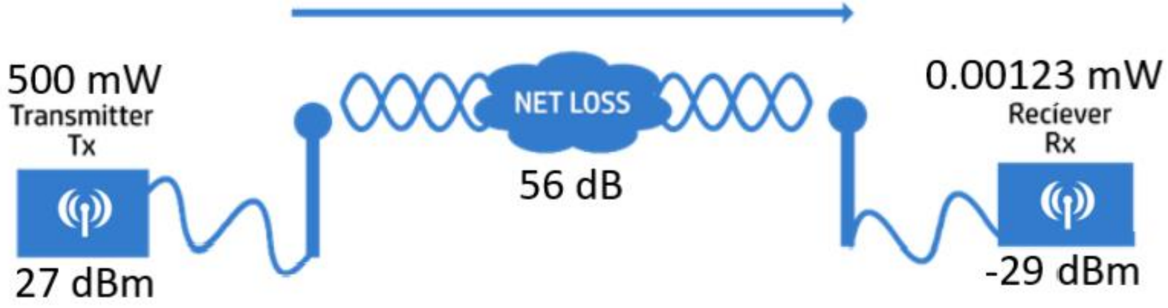
There are three dB laws, which are based on dB changes of 0, 3, and 10:

1.Law of Zero – A value of 0 dB indicates that the absolute power values of the source P2 and the reference value P1 are the same

2.Law of 3s – A value of 3 dB indicates that the power value of P2 is twice P1

3.Law of 10s – A value of 10 dB indicates that the power value of P2 is 10 times that of P1

POWER CHANGE	dB VALUE
=	0 dB
X 2	+3 dB
/ 2	-3 dB
X 10	+10 dB
/ 10	-10 dB

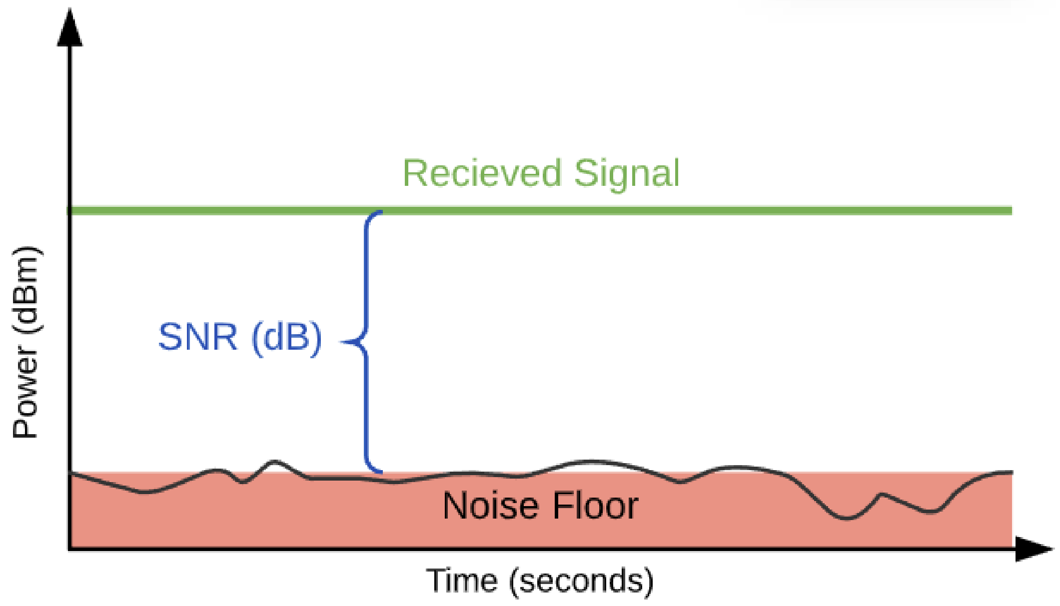


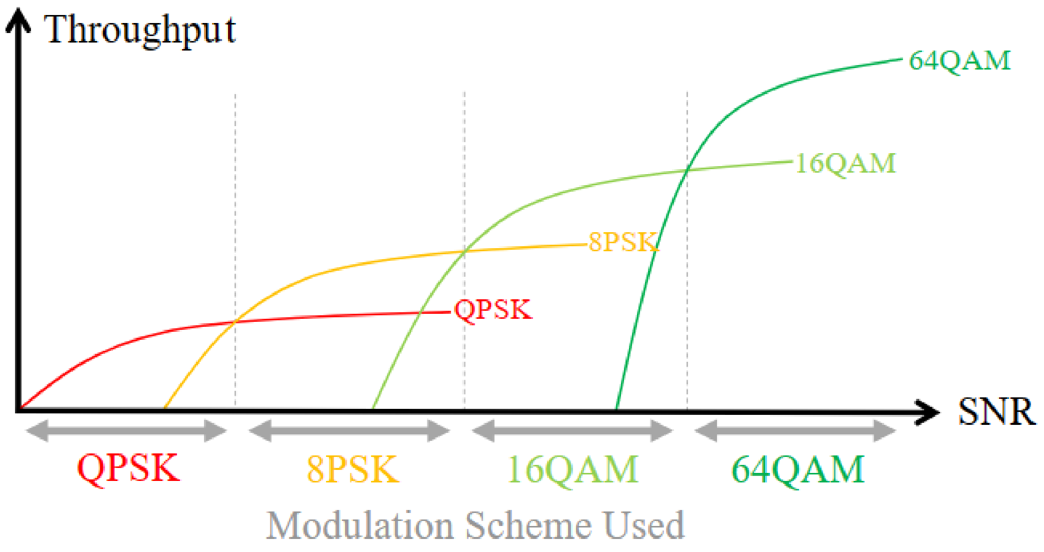
Source: https://study-ccnp.com/understanding-rf-power-db-conversion/

Signal to Noise Ratio (SNR)

Signal-to-noise ratio (SNR or S/N) is a measure used in science and engineering that compares the level of a desired signal to the level of background noise. SNR is defined as the ratio of signal power to noise power, often expressed in decibels. A ratio higher than 1:1 (greater than 0 dB) indicates more signal than noise.

Modulation	Code rate	N_{DBPS}	Spectral efficiency (bps/Hz)	Required SNR (dB)
BPSK	1/2	26	0.5	−3.83
QPSK	1/2	52	1	0
QPSK	3/4	78	1.5	2.62
16-QAM	1/2	104	2	4.77
16-QAM	3/4	156	3	8.45
64-QAM	2/3	208	4	11.67
64-QAM	3/4	234	4.5	13.35
64-QAM	5/6	260	5	14.91
256-QAM	3/4	312	6	17.99



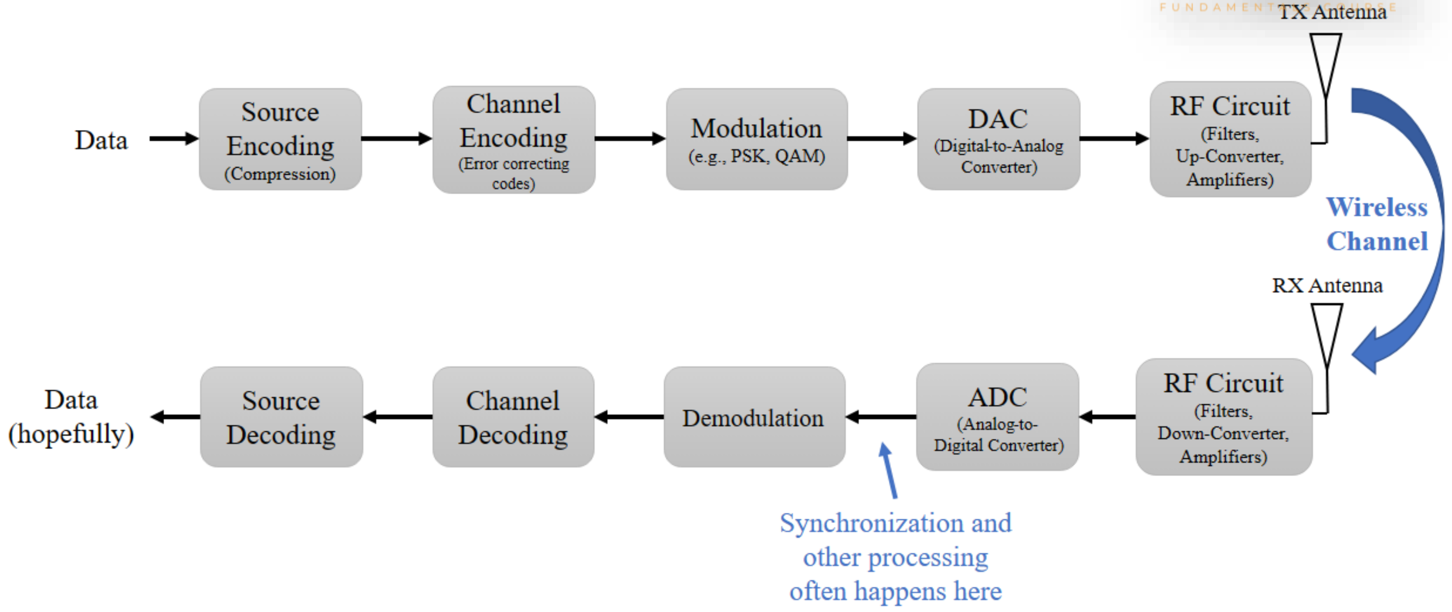


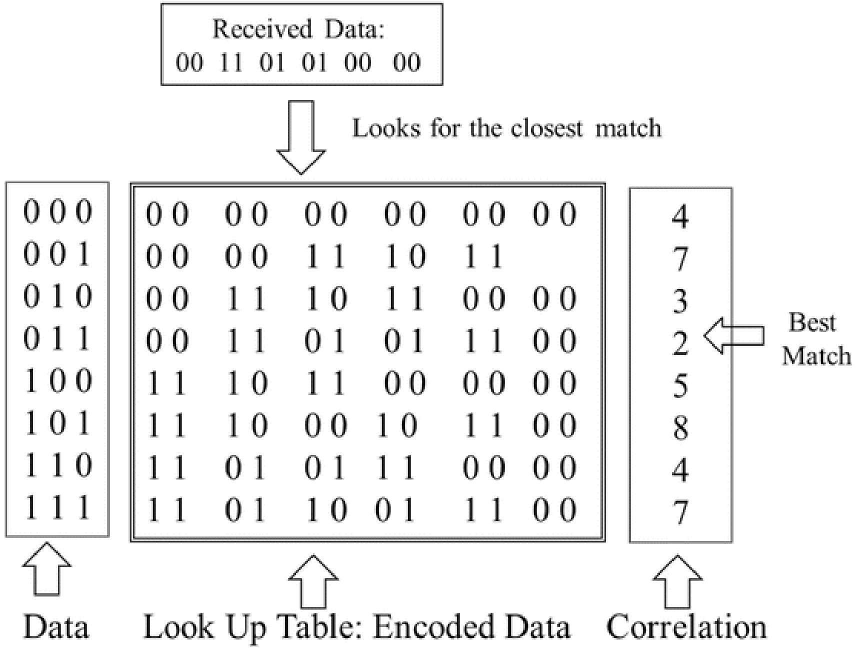
Coding Basics

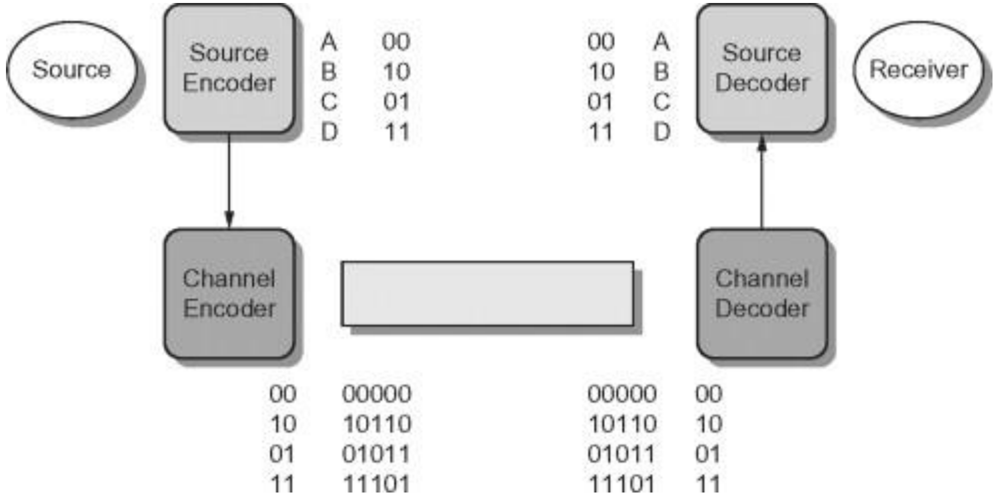
Source Coding – uses compression techniques to reduce the size of the data transmitted.

Channel Coding – Adds redundancy to the transmitted data so as to recover the original data in case of bad channel conditions.

For example ¾ coding rate will mean, for every 3 bits of data , the transmitter will send a total of 4 bits by adding 25% information redundancy.







RF Performance Table (AP Datasheet)

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DATA SHEET
ARUBA 570 SERIES WIRELESS ACCESS POINTS

RF PERFORMANCE TABLE

	Maximum transmit power (dBm) per transmit chain	Receiver sensitivity (dBm) per receive chain
2.4GHz, 802.11b		
1 Mbps	22	-97
11 Mbps	22	-89
2.4GHz, 802.11g		
6 Mbps	22	-94
54 Mbps	20	-76
2.4GHz, 802.11n/ac HT20		
MCS0	22	-93
MCS8	19	-72
2.4GHz, 802.11ax HE20		
MCS0	22	-93
MCS11	17	-62
5GHz, 802.11a		
6 Mbps	22	-95
54 Mbps	20	-76
5GHz, 802.11n/ac HT20/VHT20		
MCS0	22	-94
MCS8	19	-72
5GHz, 802.11n/ac HT40/VHT40		
MCS0	22	-92
MCS9	19	-68
5GHz, 802.11ac VHT80		
MCS0	22	-90
MCS9	19	-65
5GHz, 802.11ac VHT160		
MCS0	22	-84
MCS9	19	-59
5GHz, 802.11ax HE20		
MCS0	22	-94
MCS11	17	-62
5GHz, 802.11ax HE40		
MCS0	22	-91
MCS11	17	-60
5GHz, 802.11ax HE80		
MCS0	22	-87
MCS11	17	-57
5GHz, 802.11ax HE160		
MCS0	22	-85
MCS11	17	-53

Throughput/Range for various QAM Rates

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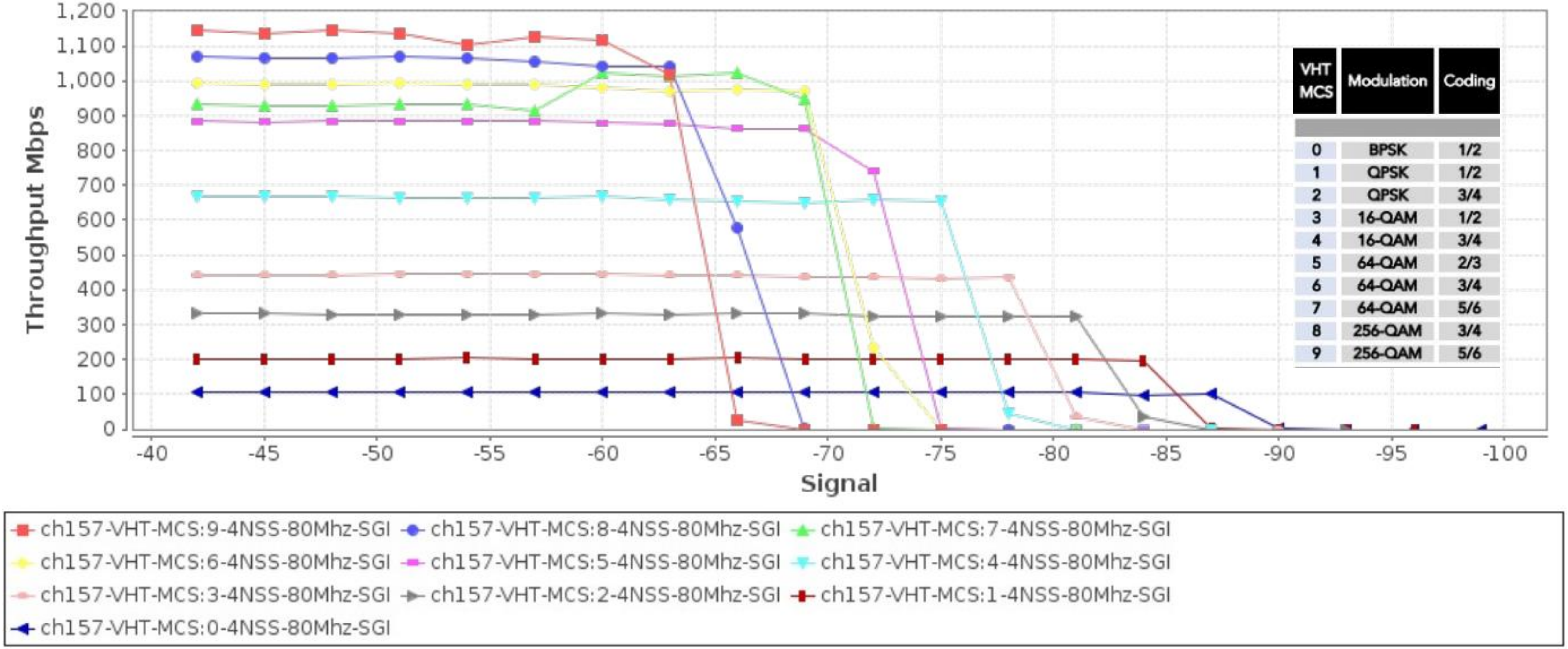
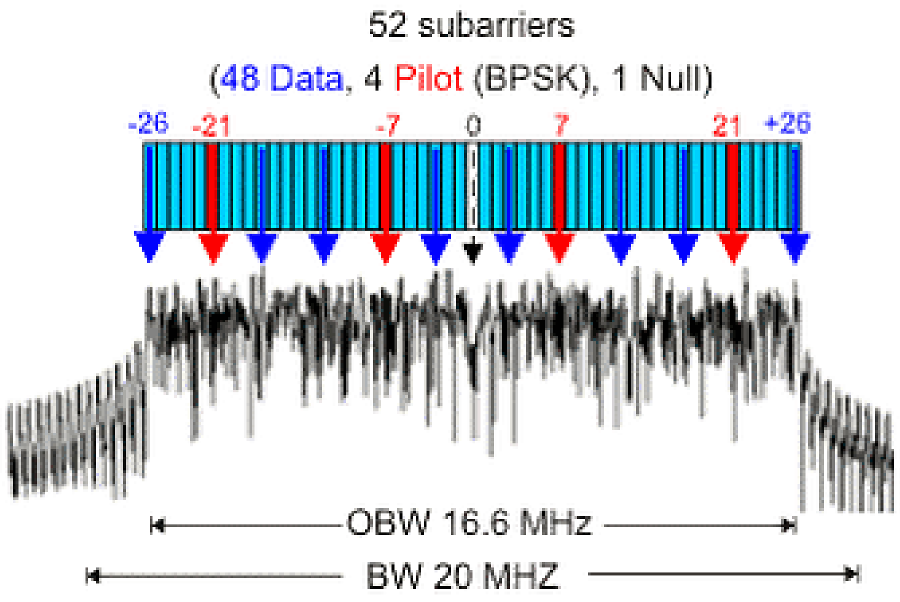


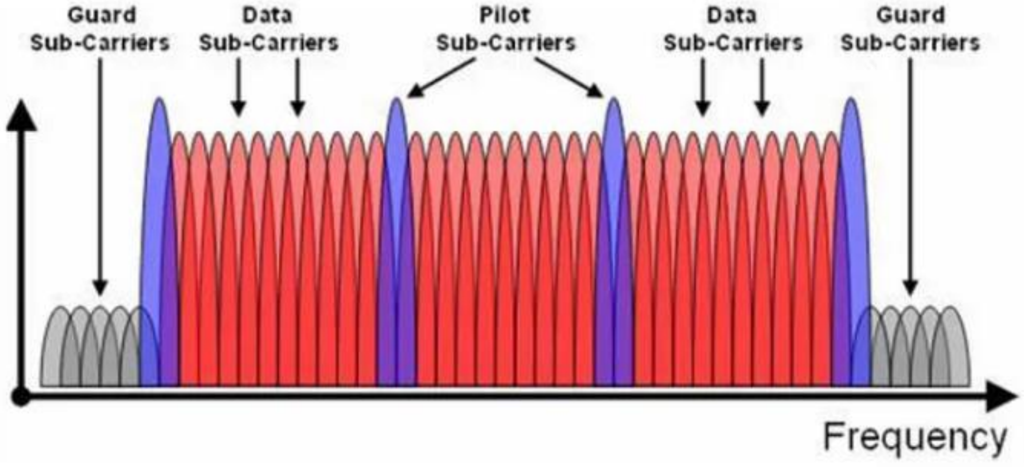
VHT MCS	Modulation	Coding
0	BPSK	1/2
1	QPSK	1/2
2	QPSK	3/4
3	16-QAM	1/2
4	16-QAM	3/4
5	64-QAM	2/3
6	64-QAM	3/4
7	64-QAM	5/6
8	256-QAM	3/4
9	256-QAM	5/6

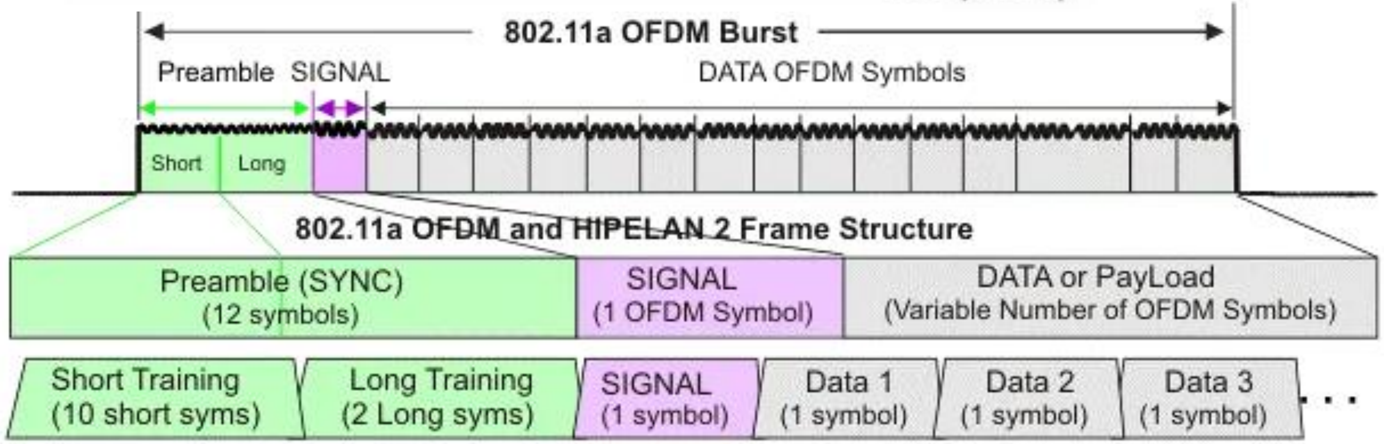
OFDM Example



One Subcarrier	= 1 constellation point
1 OFDM symbol	= 52 subcarriers
1 OFDM Burst	= one or more OFDM symbols

802.11a OFDM PHY Parameters	
BW	20 MHZ
OBW	16.6 MHZ
Subcarrer Spacing	312.5 Khz (20MHz/64 Pt FFT)
Information Rate	**6**/9/**12**/18/**24**/36/48/54 Mbits/s
Modulation	BPSK, QPSK, 16QAM, 64QAM
Coding Rate	1/2, 2/3, 3/4
Total Subcarriers	52 (Freq Index -26 to +26)
Data Subcarriers	48
Pilot Subcarriers*	4 (-21, -7, +7, +21) *Always BPSK
DC Subcarrier	Null (0 subcarrier)





Short Training Seq.
8 us length
12 subcarriers - every 4th subcarrier
equal Magnitude
signal detect
AGC Diversity Sel
timing sync
coarse freq offset est.

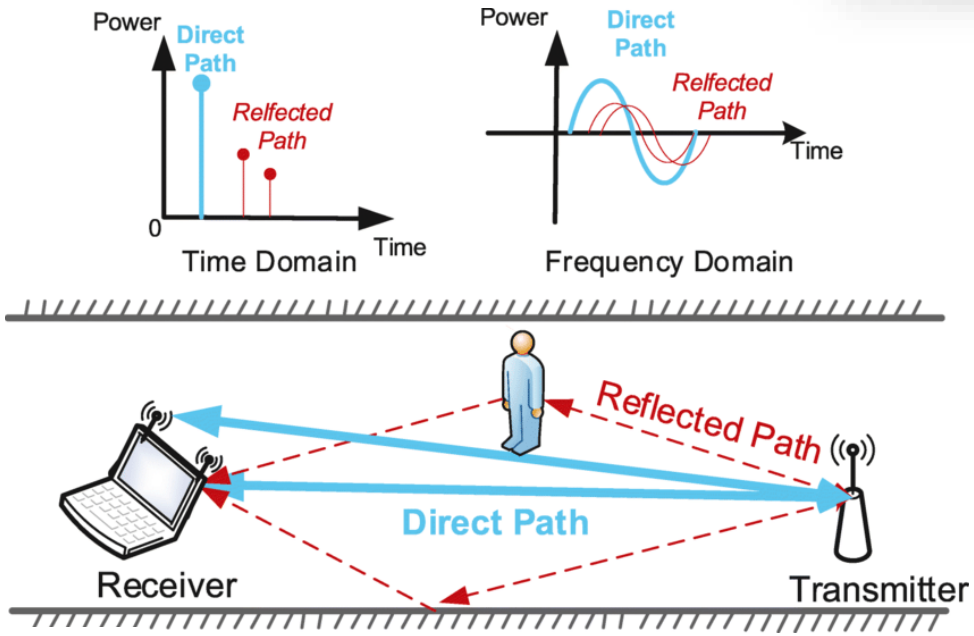
Long Training Seq.
8 us duration
all 52 subcarriers
equal mag/phase
channel estimation
chan equalization
fine freq offset est

SIGNAL symbol
4 us duration
always BPSK
Rate info
Length info
*SIGNAL 802.11a only

Data symbols
4 us duration
1 IFFT per symbol
52 subcarriers per symbol
48 data, 4 pilots & zero Null sub.
data: same mod fmt per burst
(BPSK,QPSK,16QAM,64QAM)
pilots: BPSK only
Max 4096 bits per frame

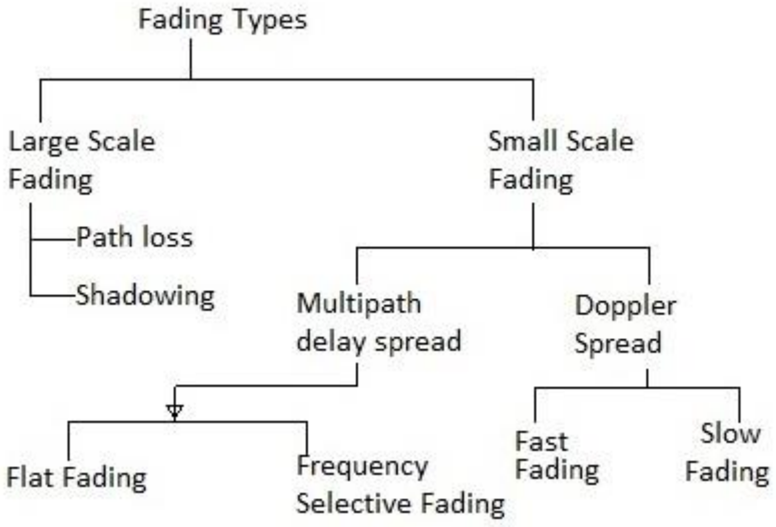
Multipath Basics

Multipath is created by the returned reflections of the original signal that are combined at the receiver. These reflections occur when the signal bounces from the various surfaces within the indoor environment.

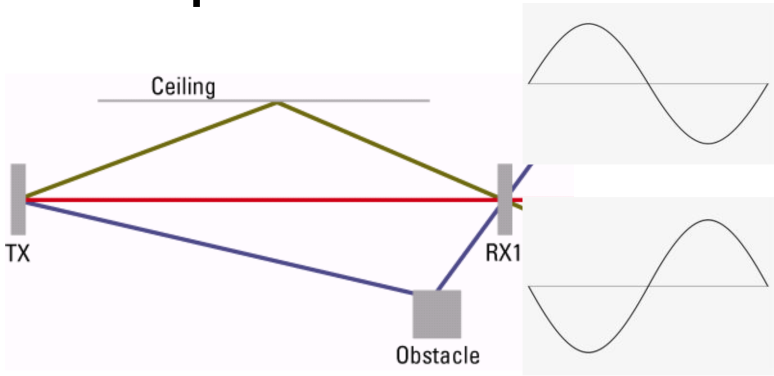


Delay spread is generally defined as the difference between the time of arrival of the earliest component (e.g., the line-of-sight wave if there exists) and the time of arrival of the latest multipath component

Fading : In wireless communication, fading is a phenomenon in which the strength and quality of a radio signal fluctuate over time and distance. Fading is caused by a variety of factors, including multipath propagation, atmospheric conditions, and the movement of objects in the transmission path



Nulls due to Multipath

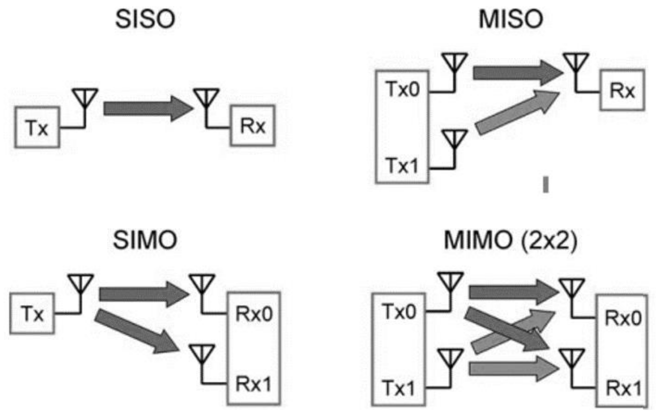


MIMO Basics

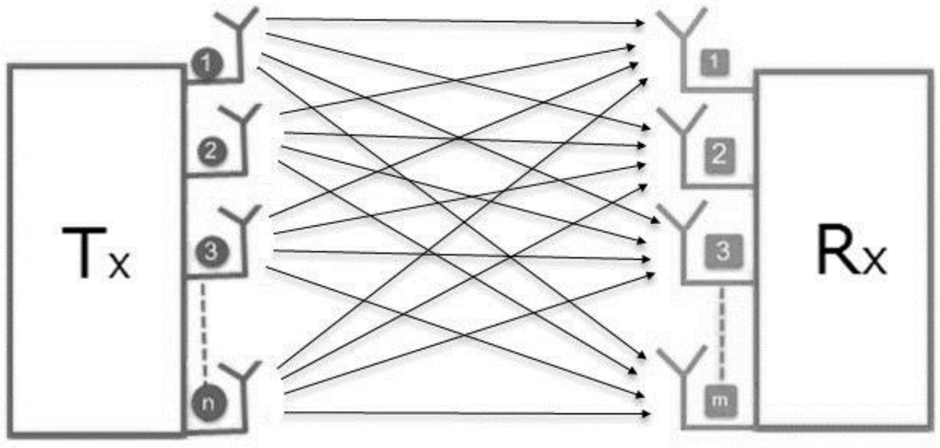
A **radio chain** is defined as a single radio and all of its supporting architecture, including mixers, amplifiers, and analog/ digital converters.

A MIMO system consists of multiple radio chains, with each radio chain having its own antenna.

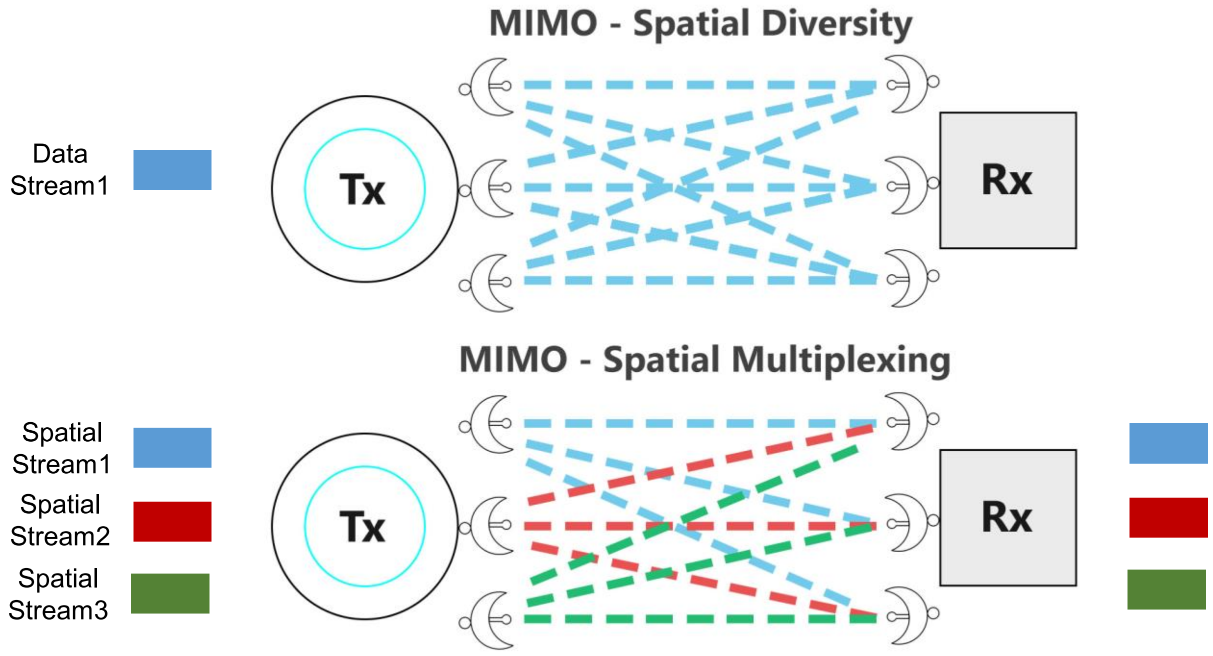
A MIMO system is characterized by the number of transmitters and receivers used by the multiple radio chains.



Spatial streaming(Nss) is a transmission technique used in MIMO wireless communication to transmit independent and separately coded data signals, from each of the multiple transmit antennas.



Basic Structure of a MIMO System



References

Basics of Modulation Techniques
https://en.wikipedia.org/wiki/Modulation

Understanding Error Vector Magnitude
https://www.youtube.com/watch?v=rMVAQsUudSs

OFDM Overview
https://rfmw.em.keysight.com/wireless/helpfiles/89600b/webhelp/subsystems/wlan-ofdm/content/ofdm_80211-overview.htm

Multipath Basics
https://www.cisco.com/c/en/us/support/docs/wireless-mobility/wireless-lan-wlan/27147-multipath.html

MIMO Introduction
https://www.youtube.com/watch?v=T7NyrG4_RSI

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QUIZ!
TIME

Quiz 2a Results

Number of participants - 193

Winner

Umeshraja N