Wi-Fi Performances: Under the Hood of Wireless Clients

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#wifitrek

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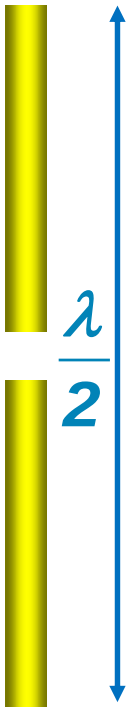
Agenda

- Physical performances: how different hardware impact Rx/Tx performances
- Software performances: how rate adaptation algorithms change performances
- Conclusion: can you really design a cell without a client?

Physical Specs and Performances

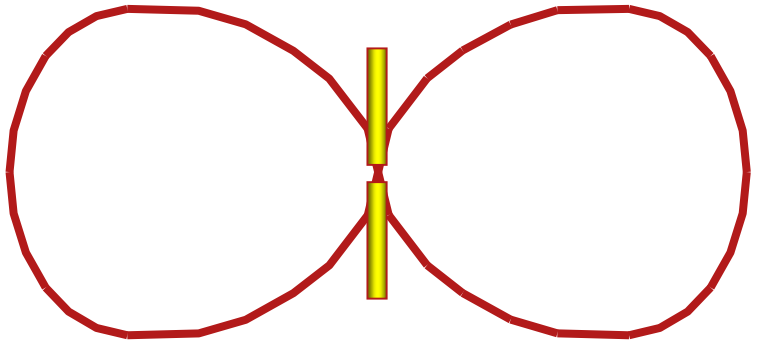
RF Schoolbook Antenna Design

- Basic antenna size = half wavelength
  - 2.4 GHz: 12 cm (4.7 inches)
  - 5 GHz: 5.5 cm (2.1 inches)

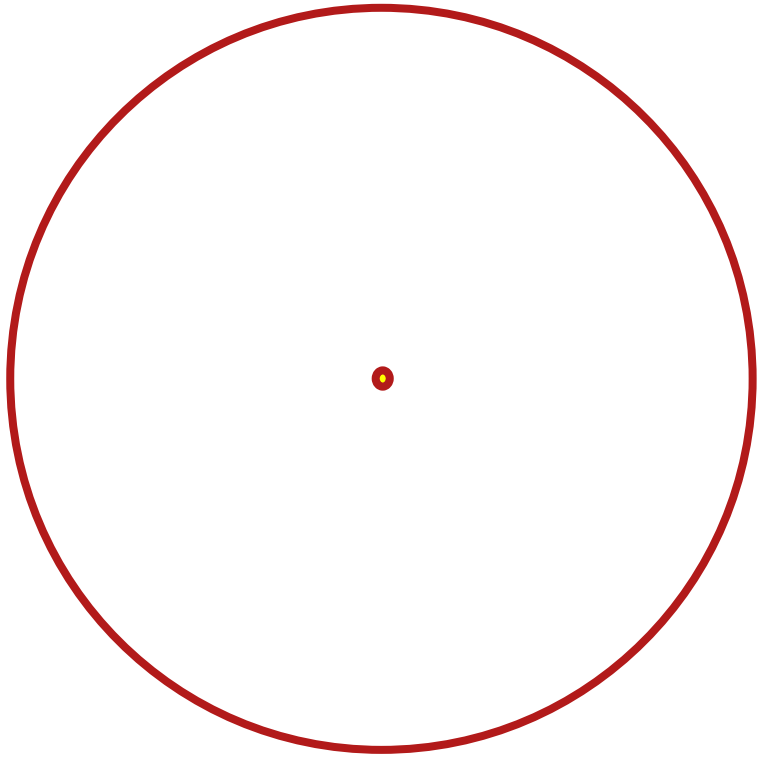


RF Schoolbook Antenna Design

- Signal radiates all around



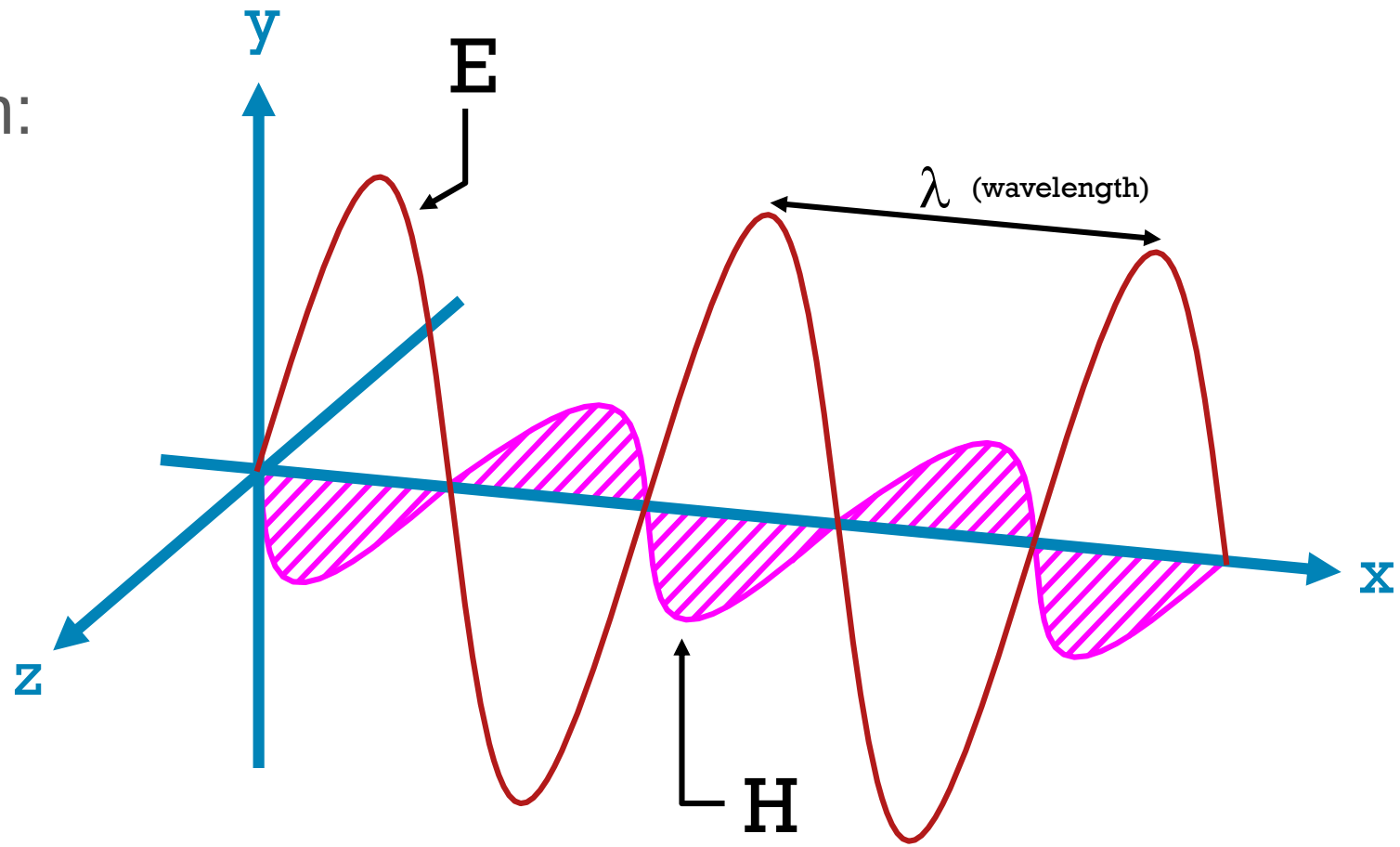
Elevation



Azimuth

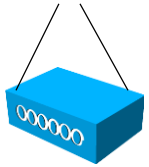
RF Schoolbook Antenna Design

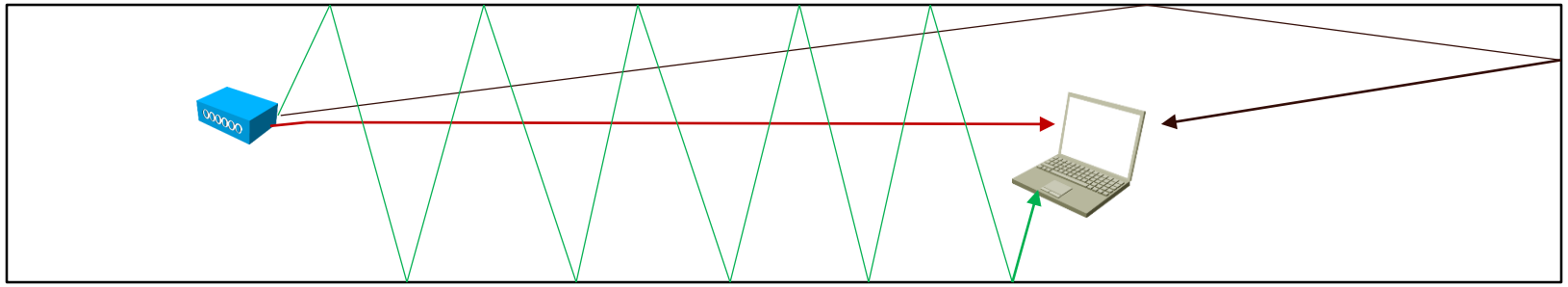
- Po – la – ri – za – tion:



RF Schoolbook Antenna Design

- Po – la – ri – za – tion:
  - Multipath is the enemy

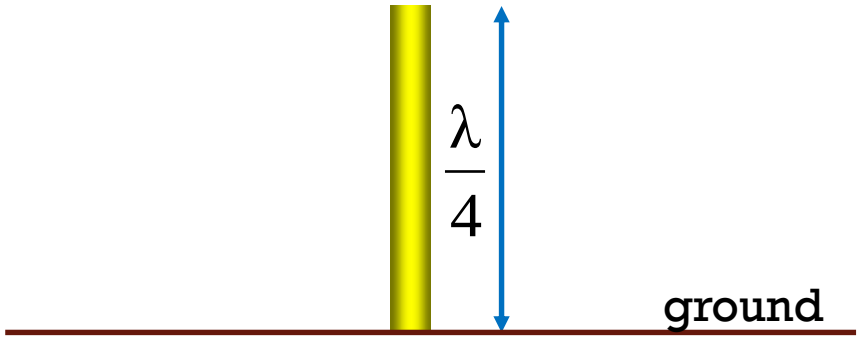


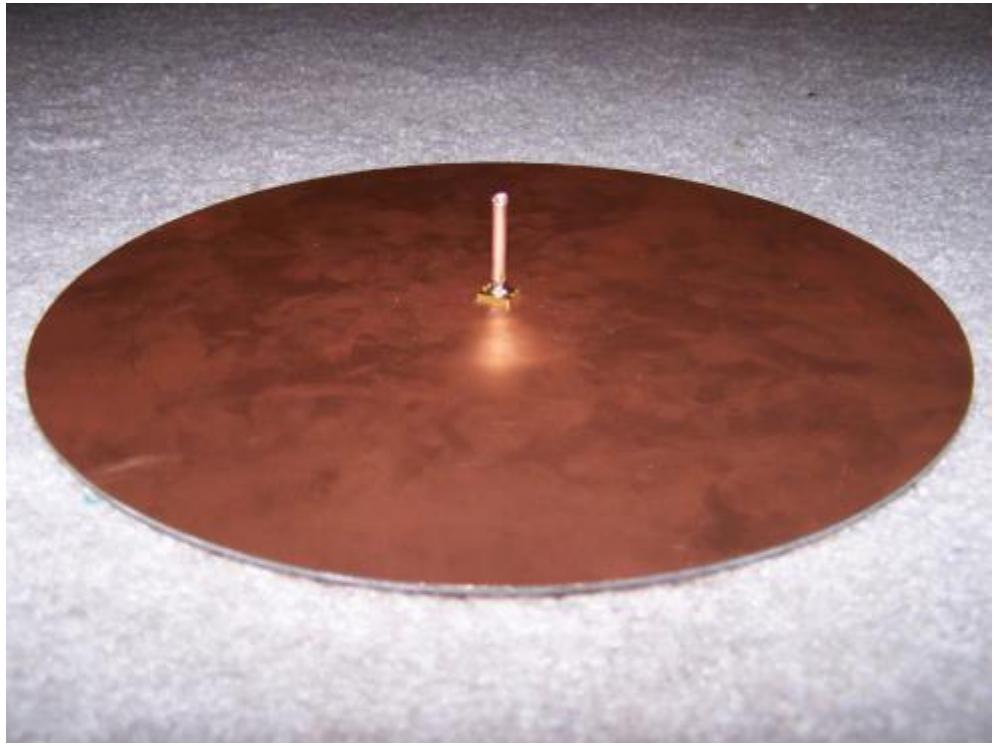


Schoolbook vs Real World

Antenna Size Reduction Options

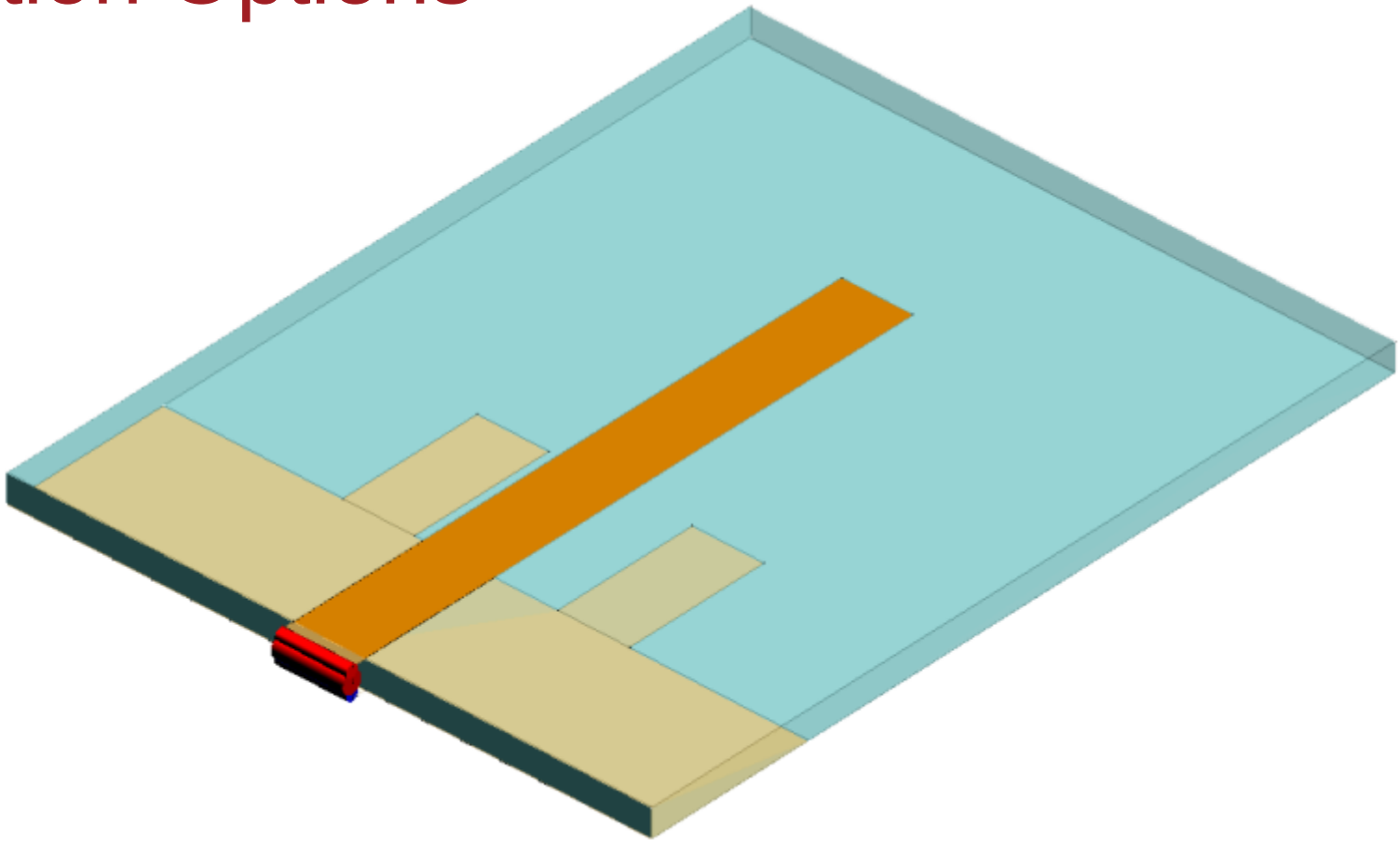
- Use a monopole





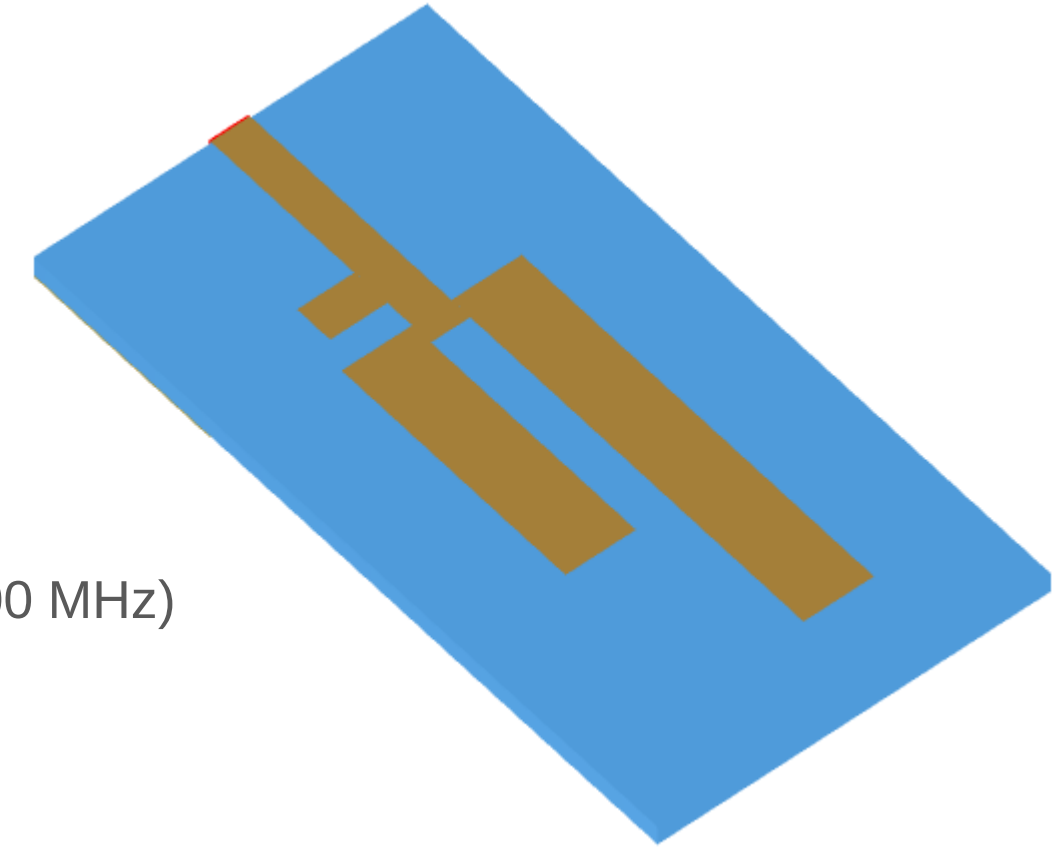
Antenna Size Reduction Options

- Use a monopole
- Fold it
  - Congratulations, you just invented the planar antenna
  - Wait… are you expecting this antenna to support 2.4 GHz, 5 GHz, but also cellular (700 MHz, 900 MHz etc)?



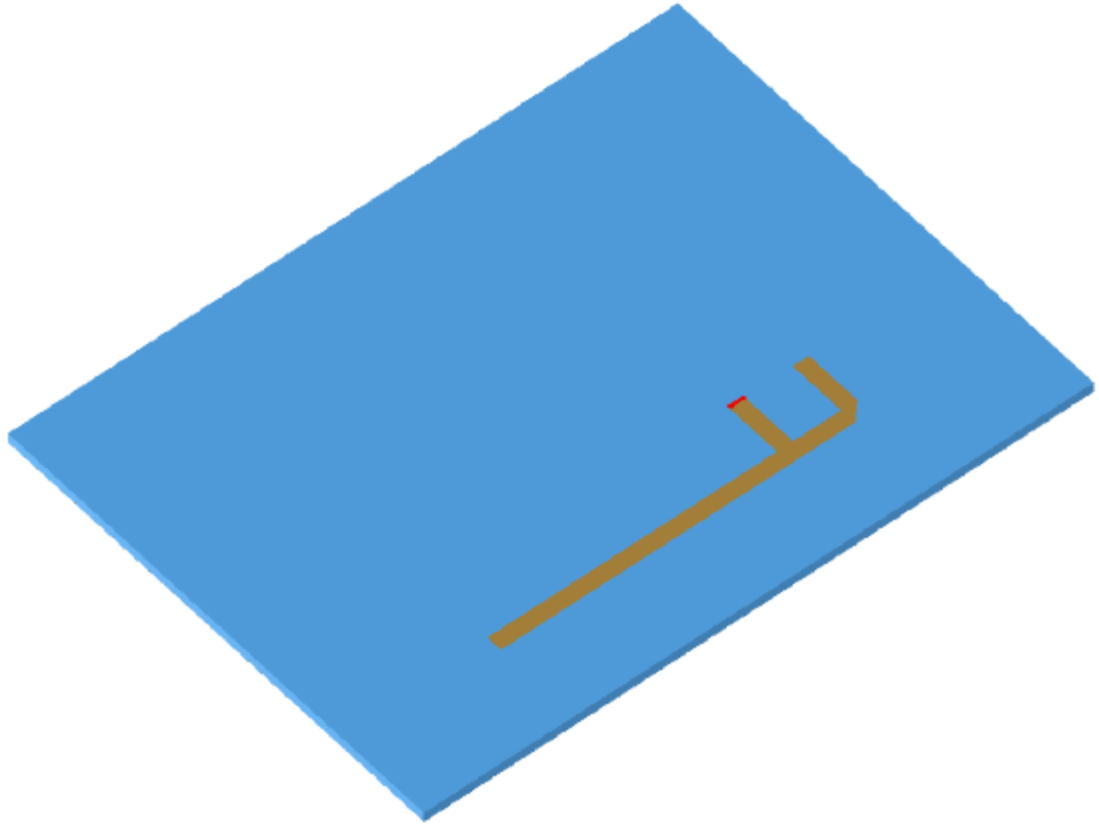
Antenna Size Reduction Options

- You could use more antennas
  - This is a planar dual-band monopole antenna
  - You probably sense that this is not perfect (one antenna per band)
    - Iphone 6: (850, 900, 1700/2100, 1900, 2100 MHz) 802.11a/b/g/n/ac
  - Also… for 2.4 GHz, this is still 3 cm… too long



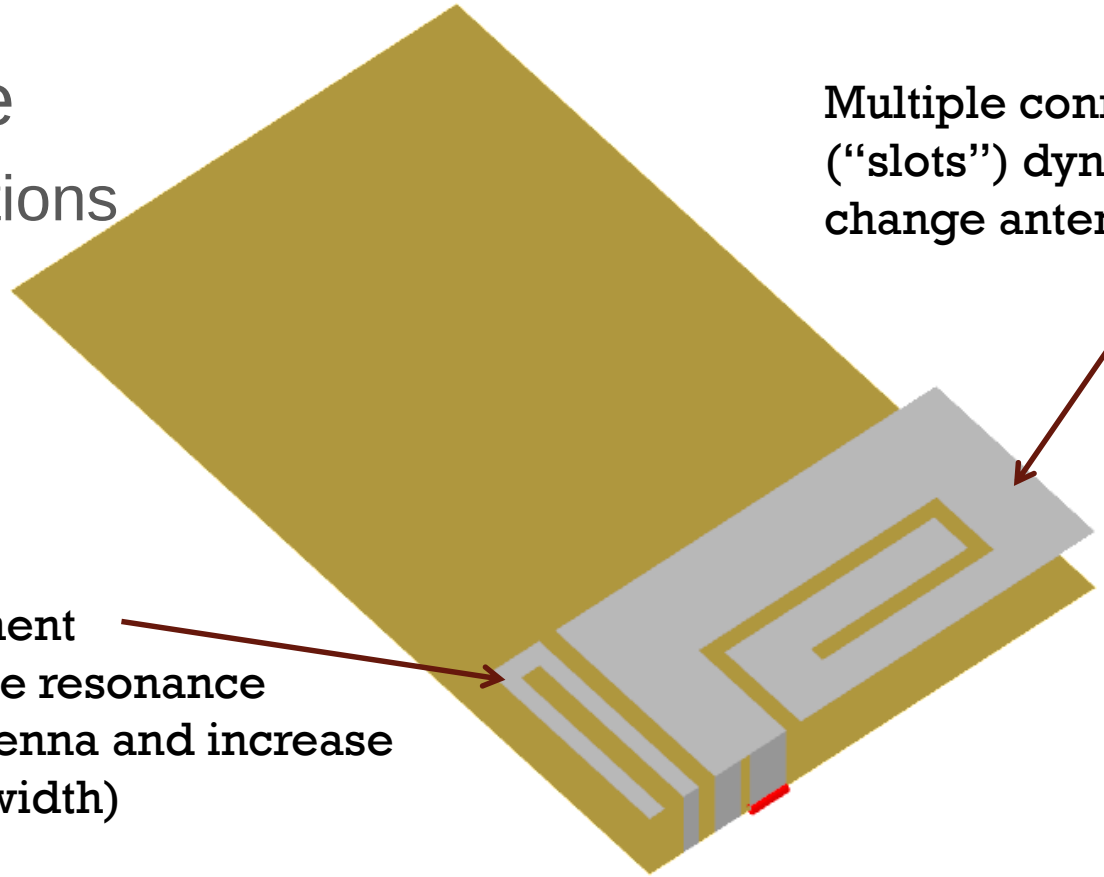
Antenna Size Reduction Options

- Fold the antenna more
  - This is the planar inverted F antenna (AKA PIFA)



Antenna Size Reduction Options

- Fold the antenna more
  - There are multiple variations
    - More complex PIFA



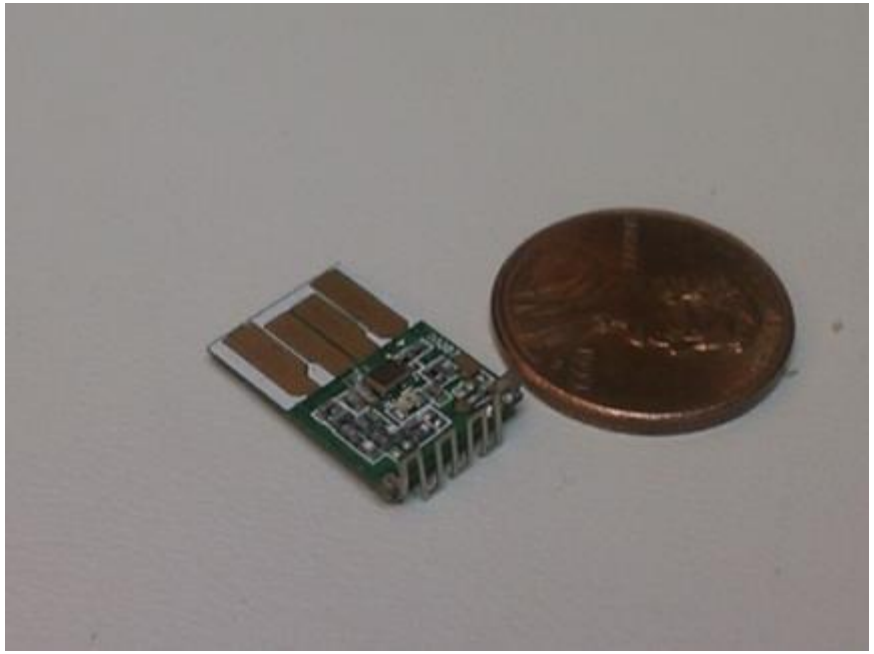
Multiple connection points to board ("slots") dynamically activated to change antenna length

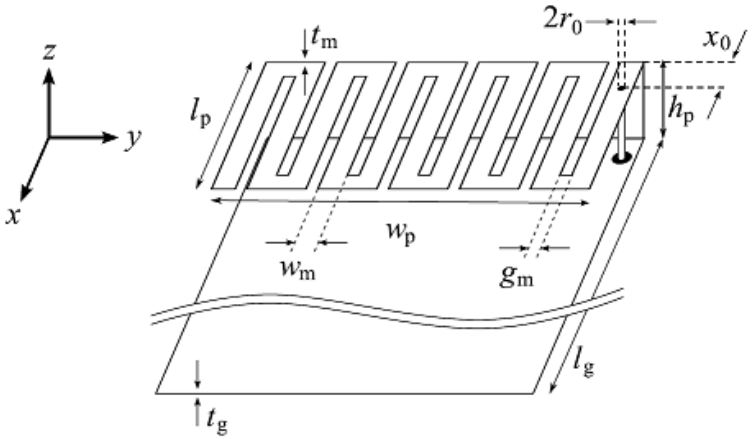
Parasitic element (used to create resonance with main antenna and increase gain or bandwidth)

Antenna Size Reduction Options

- Fold the antenna more
  - As many variations as there are form-factor use cases

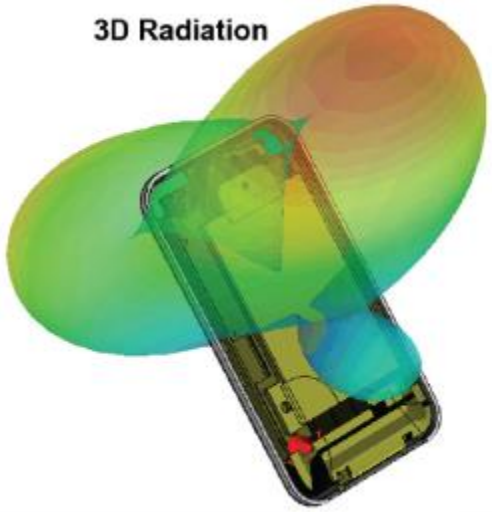
Compact Meandered Planar Inverted-F Antenna (please call me MIFA):

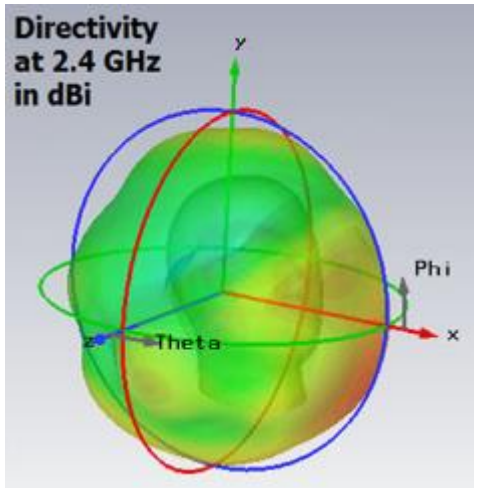




How is that thing radiating anyway?

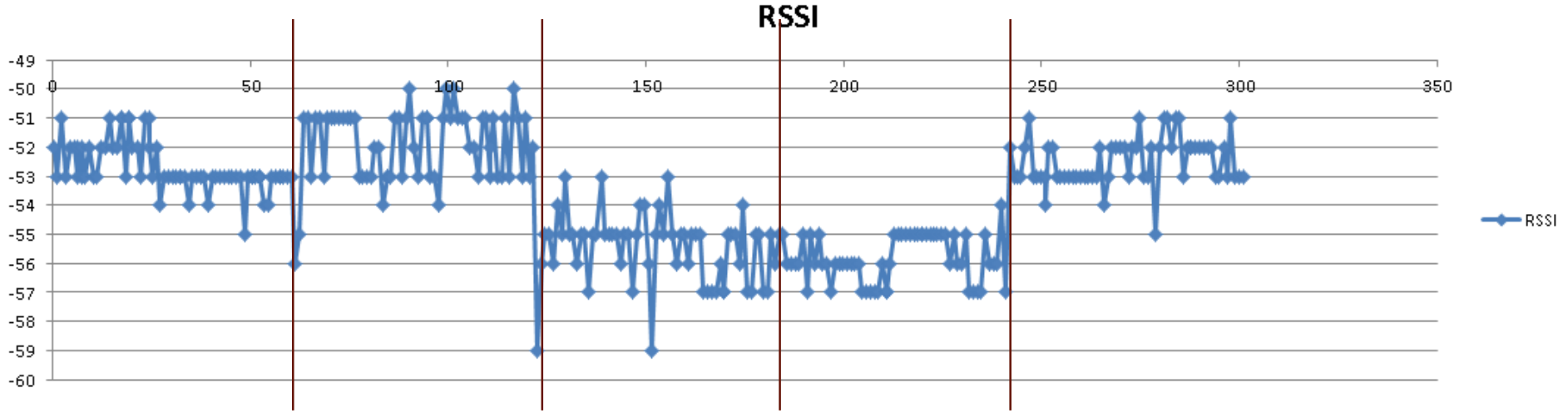
- These more complex antennas are often “pseudo-omni”
  - there is no predominant direction of radiation in most cases - radiate in both orthogonal polarizations, depending on the direction.





PIFA and Polarization

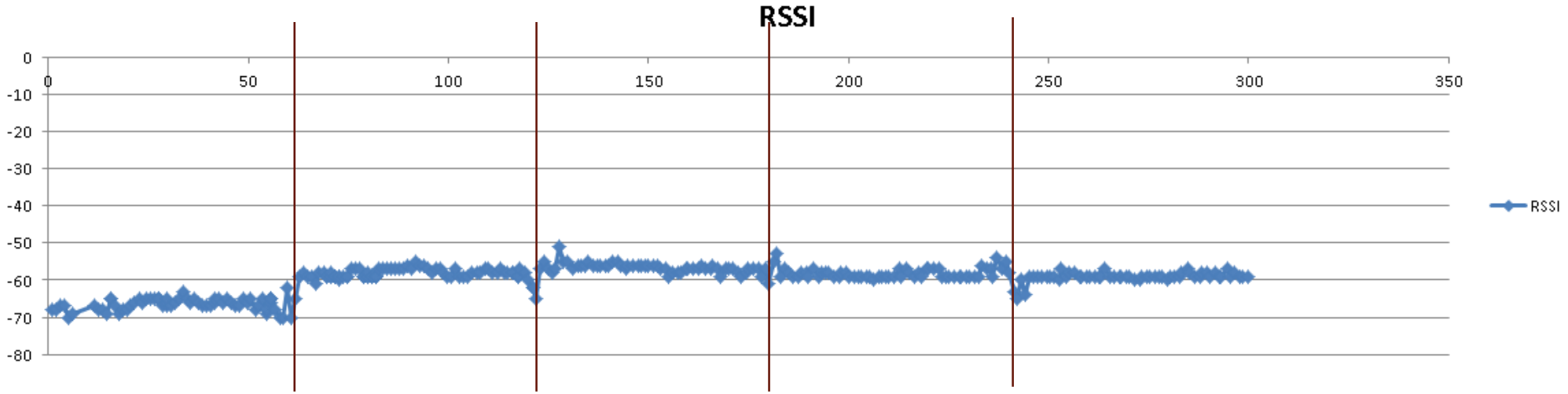
- BYOD was rotated (by a human!) every minute. Capture was taken next to AP



- Phone typical behavior (displayed Samsung Alpha; tested Iphone 5, 5S, 6, Samsung S4, S5, Alpha, HTC One, Nokia 635)
- Phone does not like to be upside down. Best position:

PIFA and Polarization

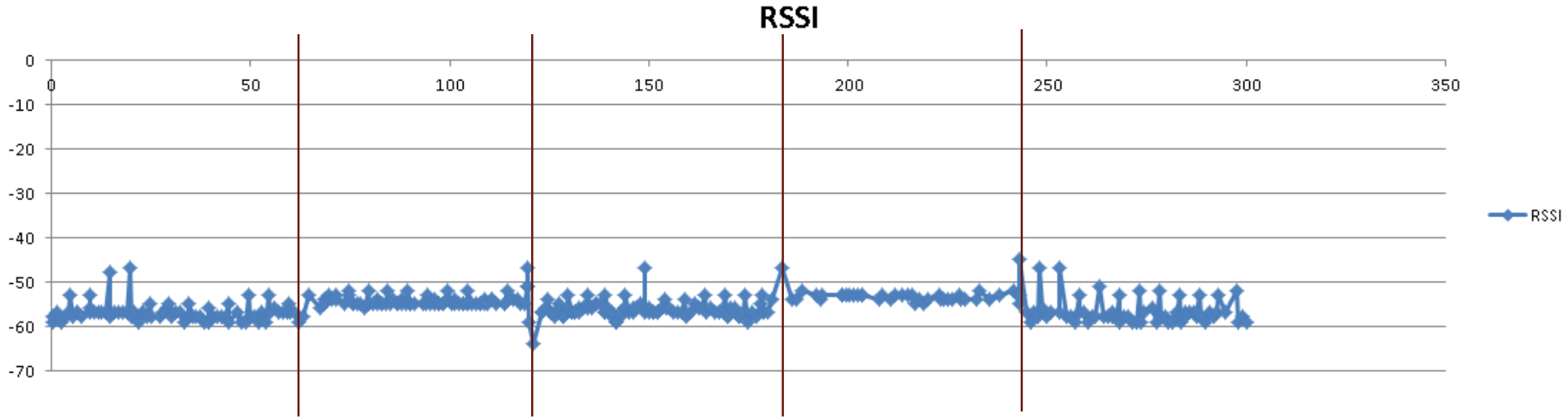
- BYOD was rotated (by a human!) every minute. Capture was taken next to AP



- Tablet typical behavior (displayed Samsung tab 4 7inch; tested Samsung tab 4 7, Ipad mini)
- Turning the tablet has little influence… okay, multipath or dual polarized antenna?

PIFA and Polarization

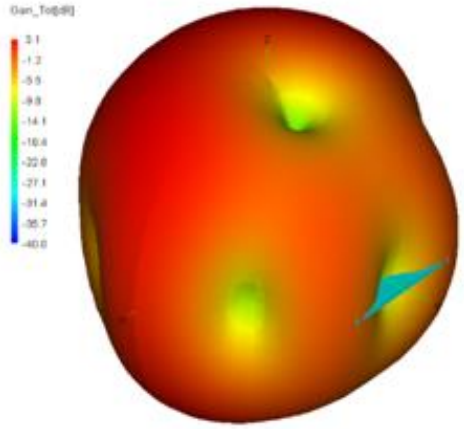
- BYOD was rotated (by a human!) every minute. Capture was taken next to AP



- Larger tablet typical behavior (displayed Surface Pro 3; tested Surface Pro 3, Ipad 3, Ipad 4)
- Turning the tablet has little influence

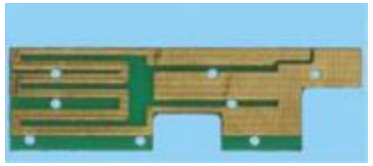
And How much, in dBi?

- Form factor often is privileged over RF efficiency

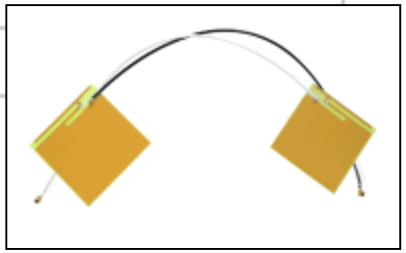


Red = 2.1 dBi
Green = -14 dBi

Frequency (GHz)	Gain (dBi) Type: Pifa
2.400-2.480	-1.4
5.150-5.250	0.14
5.250-5.350	-1.66
5.47-5.725	-0.83
5725-5850	-2.85



Specifications:	
Antenna Type	PIFA, Main/AUX 2x2 design
Frequency Range	• 2.4 ~ 2.5GHz (802.11b/g) • 4.9 ~ 5.875GHz (802.11a)
Average Gain	• -4.5dBi on 2.4 ~ 2.5GHz • -5dBi on 4.9 ~ 5.875GHz
Peak Gain	• 3dBi on 2.4 ~ 2.5GHz • 6dBi on 4.9 ~ 5.875GHz
Polarization	liner, vertical




-67 dBm
-83 dBm
-63 dBm
-67 dBm
-65 dBm
SAMSUNG
Network Signal Info
Used Servers & More
Refurbished IT equipment. Inspected, tested and guaranteed!
Zscaler Internet Security
he.net - Network Tools
htc

Rate Adaptation Algorithms and Performances

Rate Adaptation Algorithm Labyrinths

- Channel estimation mechanisms
  - Evaluate the signal received from the AP (RSSI and/or SNR), to decide on what data rate to use to send the next frame to that AP
- Open-loop mechanisms
  - Rely on previous frames transmission successes or failures (ACK received or not) to downshift or upshift

Rate Adaptation Algorithm Labyrinths

- Some names you will hear

Algorithm	Family	Behavior
Auto Rate Fallback (ARF)	Open loop	2 missed ACKs -> downshift, 10 successful ACKs - > upshift
Channel-aware rate selection algorithm (CHARM)	Channel Estimation	Base rate on received frames RSSI/SNR and minimum performance tables (with padding)
protocol for opportunistic retransmission (PRO)	Open loop	Feeds CHARM padding based on past successes or failures

Rate Adaptation Algorithm Labyrinths

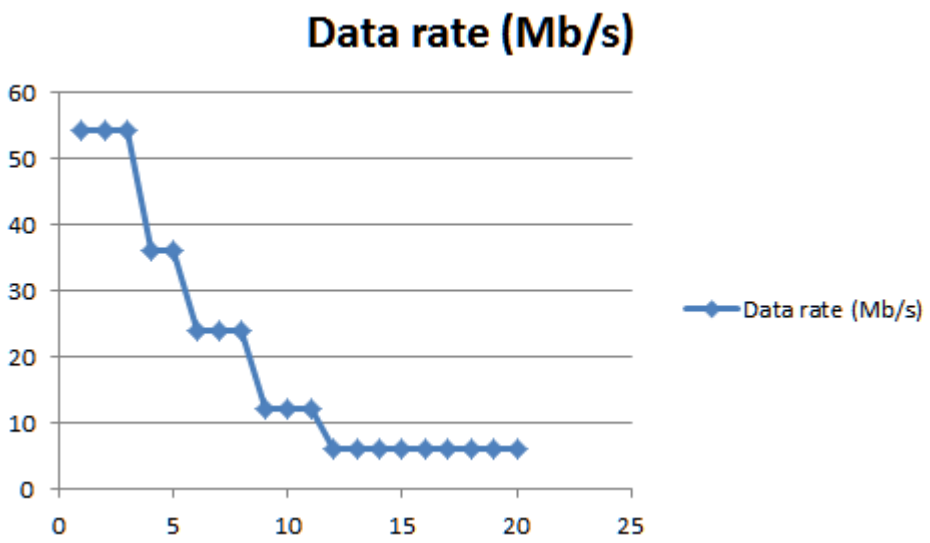
- More advanced/hybrid algorithms: minstrel
  - Lists descending rates and attempt counts (r0/c0, r1/c1 etc.).
  - Tries first rate (r0) based on channel estimation, ‘c0’ times
  - If fails, after ‘c0’ attempts, use r1 rate for c1 attempts, etc. (then discard frame)
  - Every 100 ms, take random samples of past 100 ms transmissions, measure transmission successes (for r0, r1 etc)
  - Modify list of rates (r0,r1) etc. by applying “success chances” weight to each rate in the list
  - E.g: old list: 54/3, 48/2, 36/3, 24/3. New list: 54/2, 36/2, 24/3.

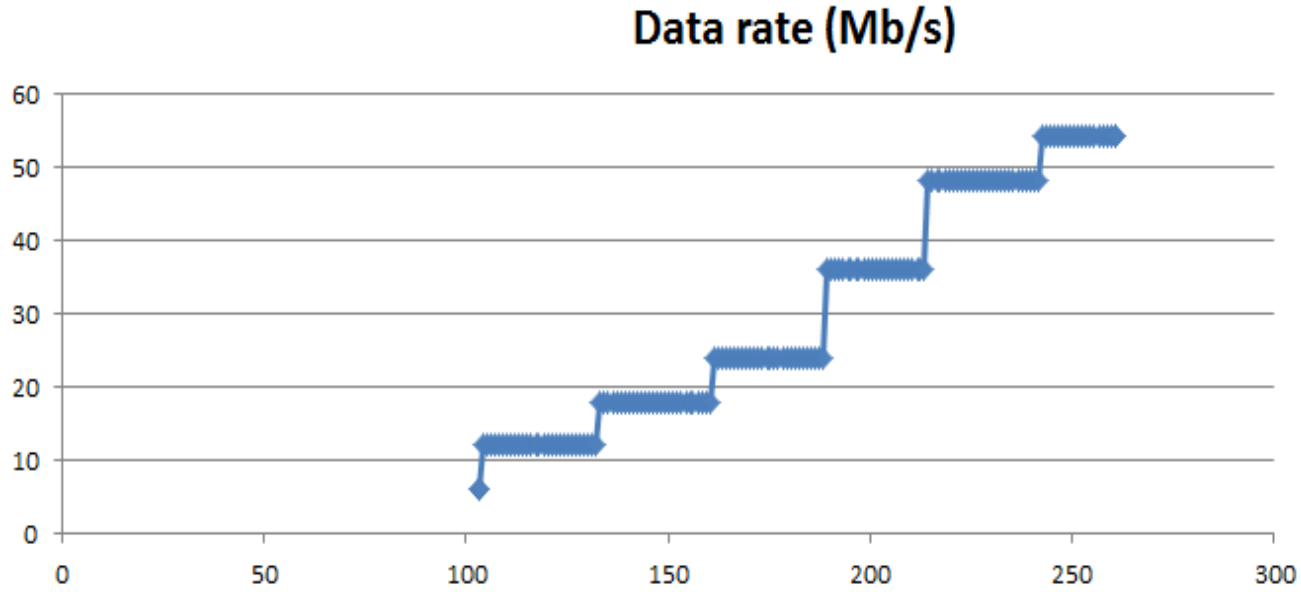
Rate Adaptation Algorithm Labyrinths

- More advanced/hybrid algorithms: SampleRate
  - Take all rates, start with highest (e.g. 54 Mbps)
  - Look at rate in list that has lowest transmission time (i.e. fastest rate, but also with lowest retry history over sampling period, e.g. 100 ms)
  - If 4 retries, go down one rate, and remove failed rate from “eligible list”
  - If 10 consecutive successes on “best” [lowest transmission time], move up one rate

SampleRate Example

- Iphone 6 (IOS8.x), close to SampleRate ‘pure form’:





What Rate for What Signal?

- 802.11ac Min Rx Sensitivity (1 SS, 800 ns GI, 4096 byte PSDU, PER less than 10%

MCS	20 Mhz	40 Mhz	80 Mhz	160 Mhz
0	-82	-79	-76	-73
1	-79	-76	-73	-70
2	-77	-74	-71	-68
3	-74	-71	-68	-65
4	-70	-67	-64	-61
5	-66	-63	-60	-57
6	-65	-62	-59	-56
7	-64	-61	-58	-55
8	-59	-56	-53	-50
9	-57	-54	-51	-48

What Rate for What Signal?

- 802.11ac Min Rx Sensitivity (1 SS, 800 ns GI, 4096 byte PSDU, PER less than 10%, for a well known card vendor

MCS	20 Mhz	40 Mhz	80 Mhz	160 Mhz
0	-91	-85.5	-82	n/a
1	-90	-84.5	-81	n/a
2	-88	-84	-80	n/a
3	-86	-82	-79	n/a
4	-84.5	-81	-78	n/a
5	-79.5	-76.5	-75.5	n/a
6	-77.5	-75	-73.5	n/a
7	-76.5	-74.5	-71.5	n/a
8	-74	-74	-68.5	n/a
9	n/a	-72	-65.5	n/a

What Rate for What Signal?

- 802.11ac Min Rx Sensitivity (1 SS, 800 ns GI, 4096 byte PSDU, PER less than 10%, for a well known card vendor
- In green, how much better the vendor is, compared to IEEE minimums
- Conclusion: you can't rely on IEEE values to estimate a client perfs

MCS	20 Mhz	40 Mhz	80 Mhz	160 Mhz
0	9	6.5	6	n/a
1	11	8.5	8	n/a
2	11	10	9	n/a
3	12	11	11	n/a
4	14.5	14	14	n/a
5	13.5	13.5	15.5	n/a
6	12.5	13	14.5	n/a
7	12.5	13.5	13.5	n/a
8	15	18	15.5	n/a
9	n/a	18	14.5	n/a

Conclusion

- You cannot predict performances based on “canned” (calculated) models
- Measure your target device, design for the poorest
- Factor adaptation behavior – cannot be guessed, has to be measured