Layman's Guide to TxBF, MIMO and MU-MIMO

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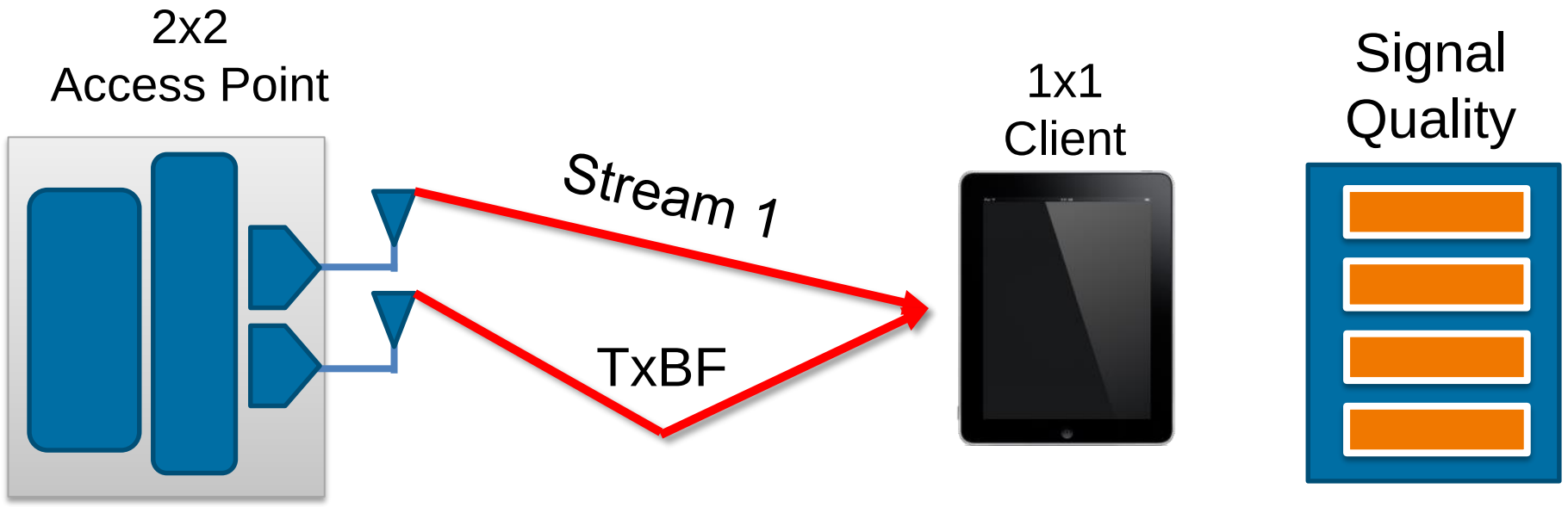
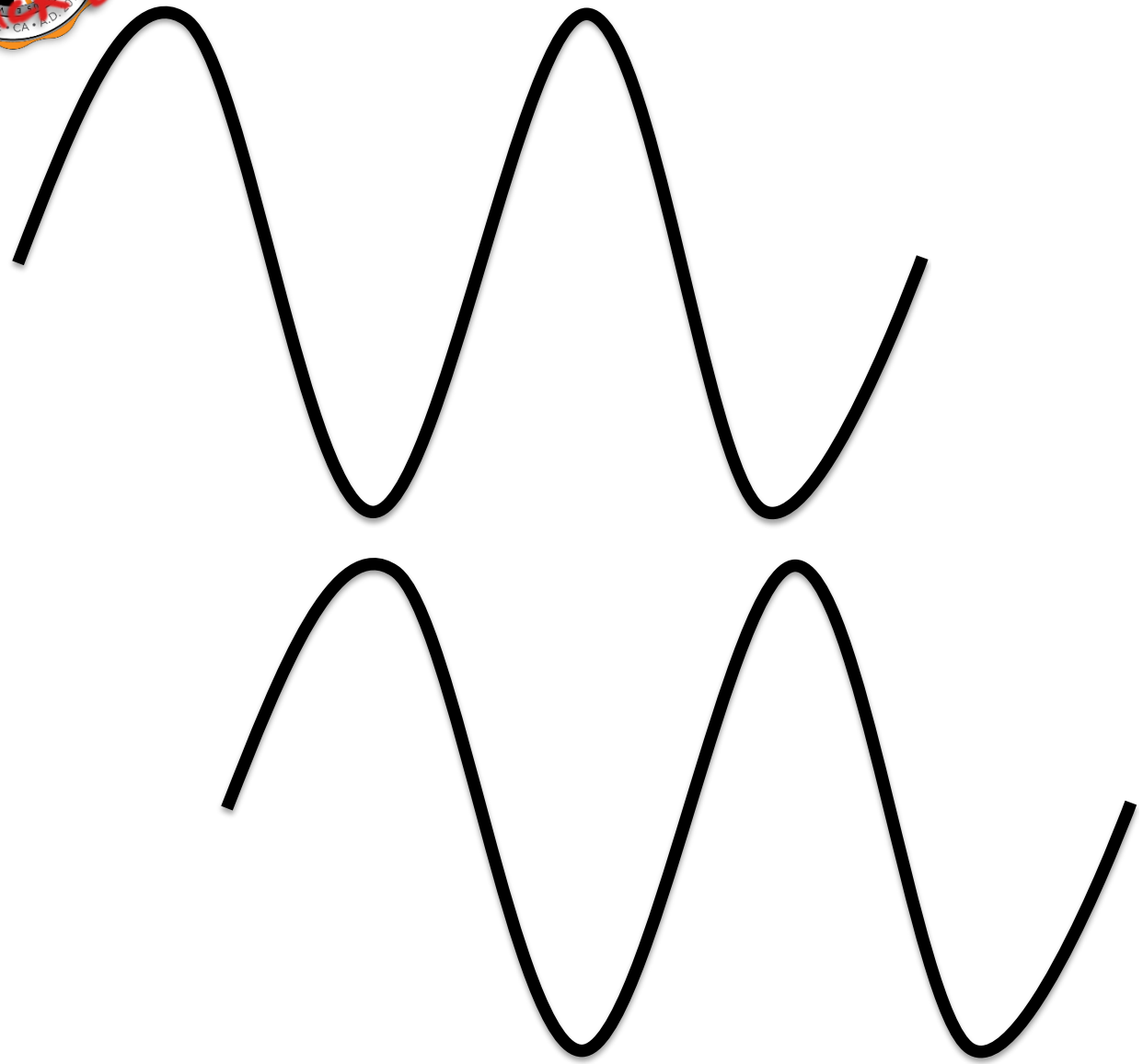
Transmit Beamforming

- Poor adoption with 802.11n
- 802.11ac focuses on one implementation
  - Universal industry focus
  - NDP Sounding with explicit immediate compressed feedback



Signals Out of Phase



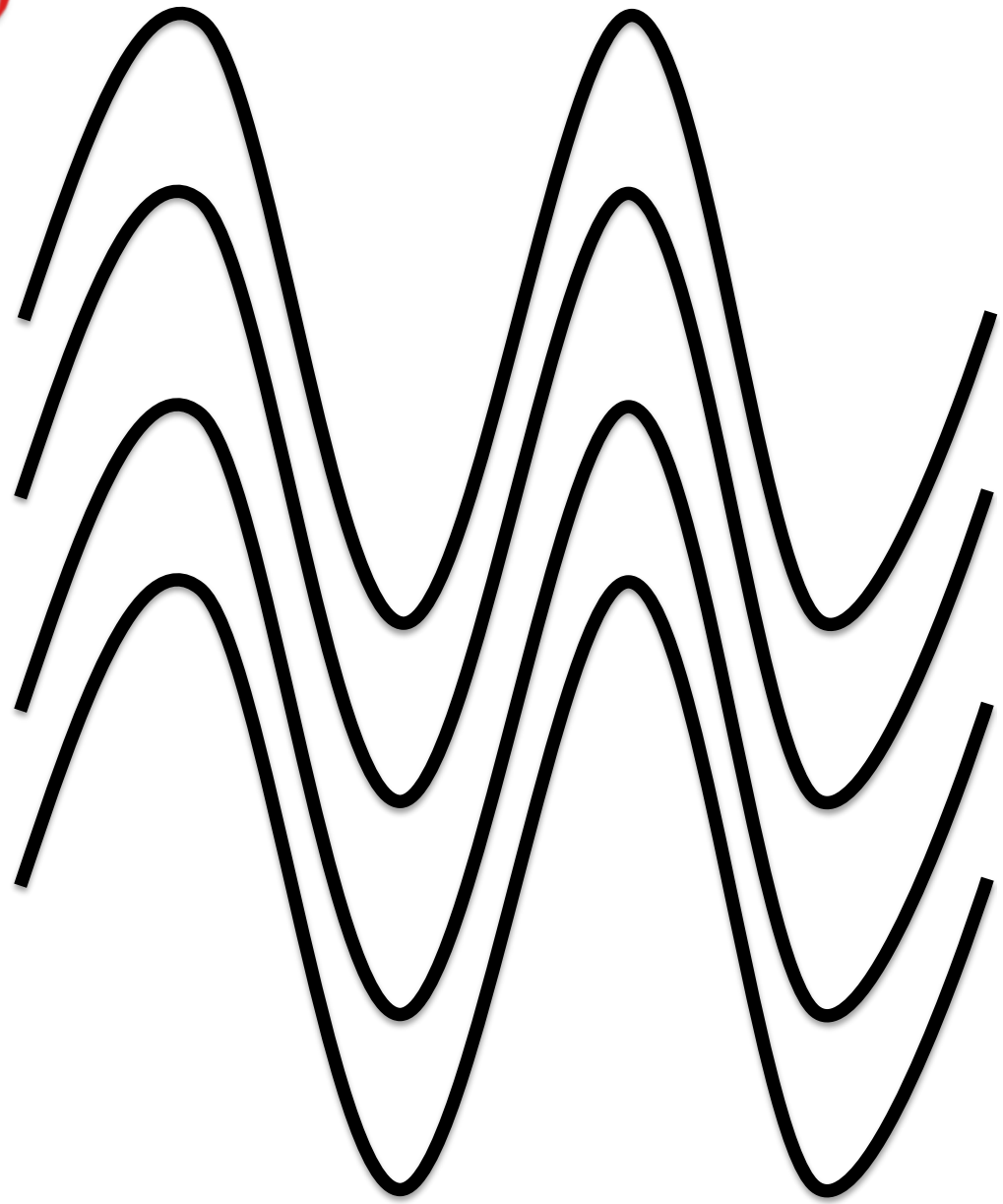
Signals in Phase

+3dB

Signals in Phase

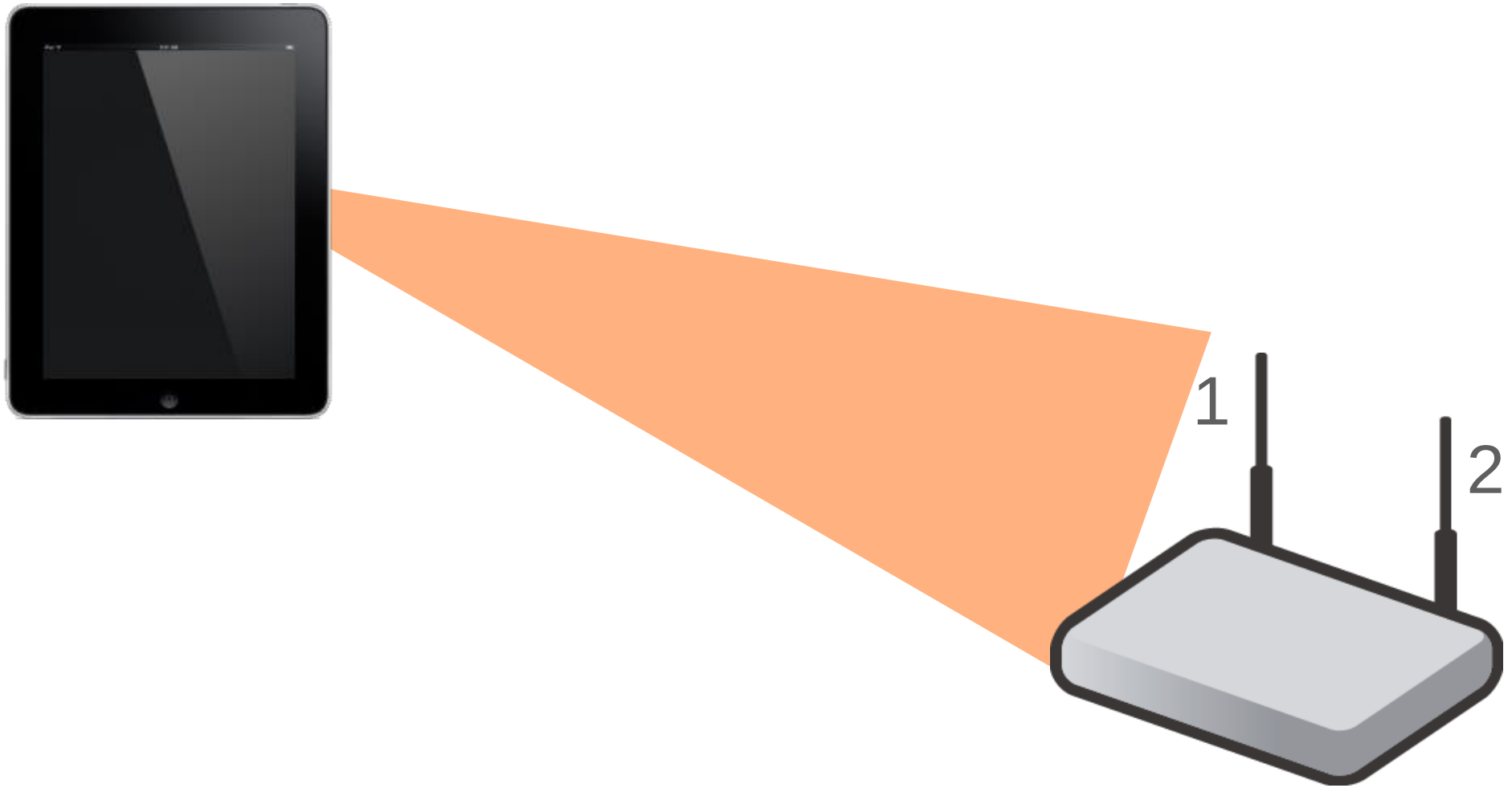
+4.7dB

Signals in Phase

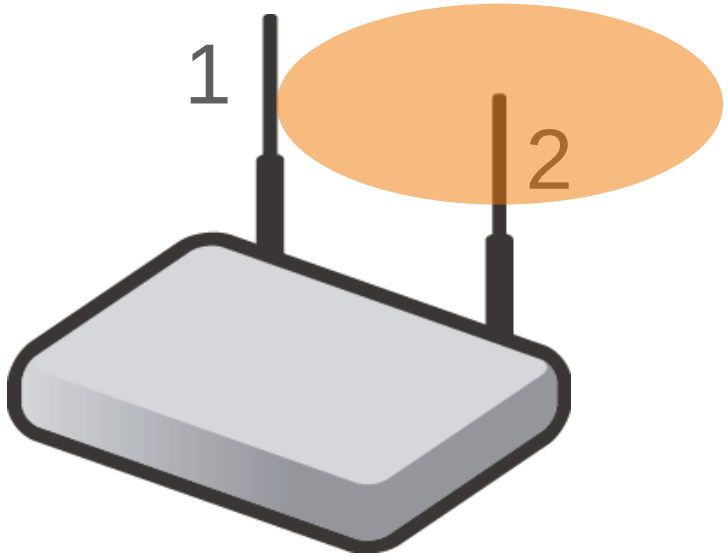


+6dB

Transmit Beamforming (TxBF)



Transmit Beamforming (TxBF)



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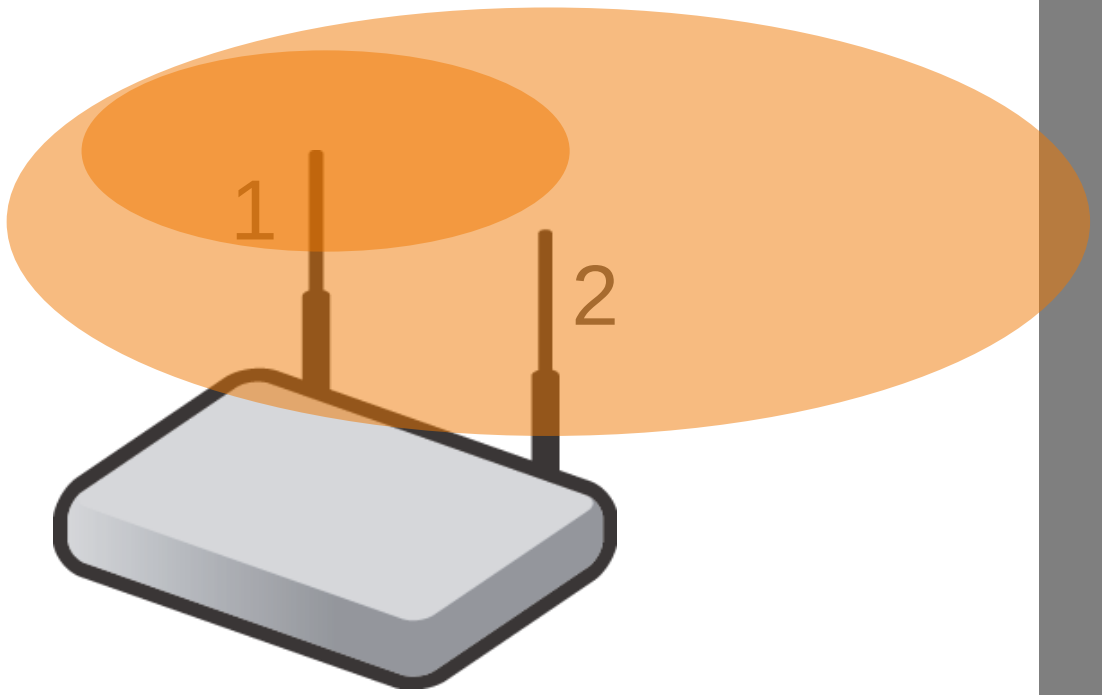
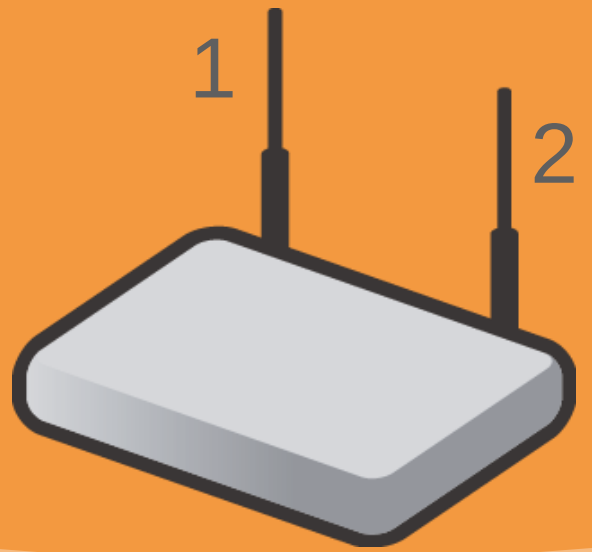
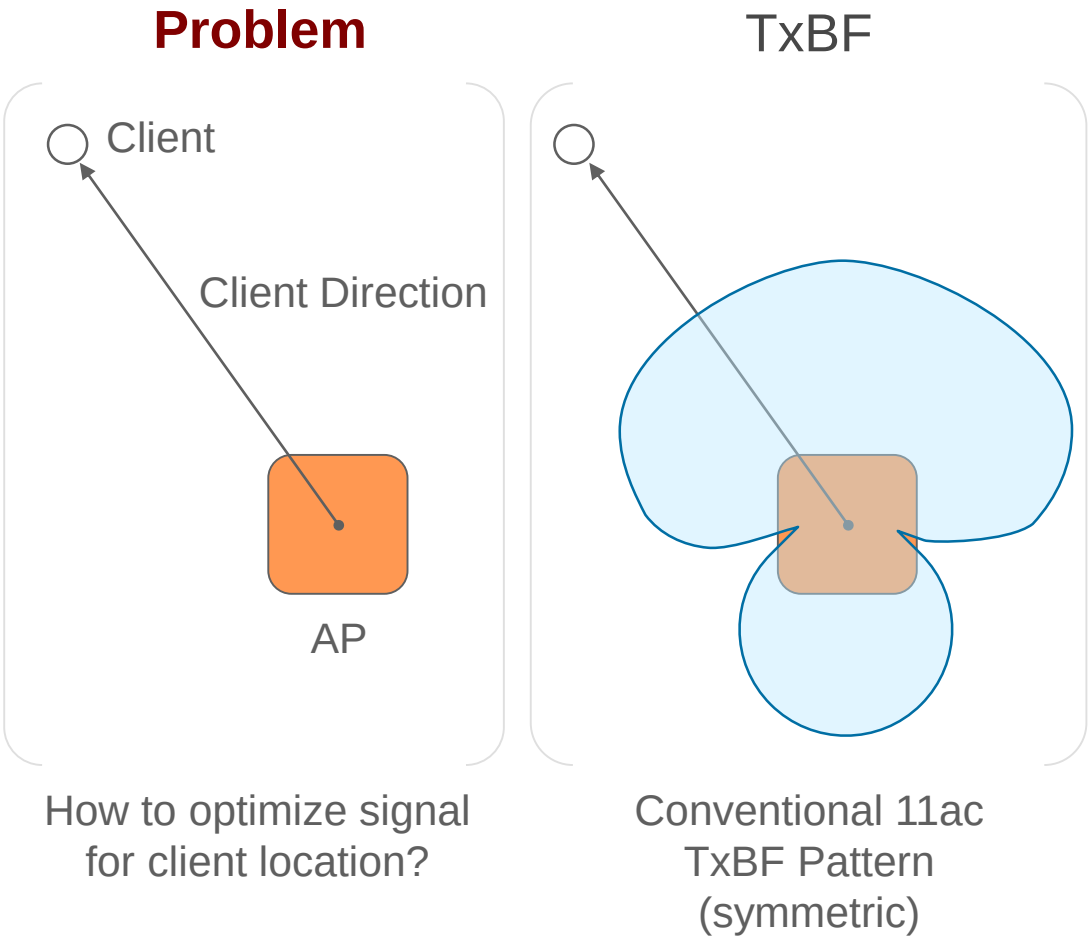


Transmit Beamforming (TxBF)



Transmit Beamforming

- 3 / 4.7 / 6 dB gain vs. additional spatial stream
  - Each antenna can either reinforce the signal (TxBF) or add more data (spatial multiplexing) but never both at the same time.
  - Each additional spatial stream adds significantly more speed
  - 3dB adds <10% more speed
- Requires client feedback
  - Does not work with 11a/b/g/n and only *some* 11ac clients



Can you hit this target?

1 Bit

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2 Bits

How about one of these?

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4 Bits

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6 Bits

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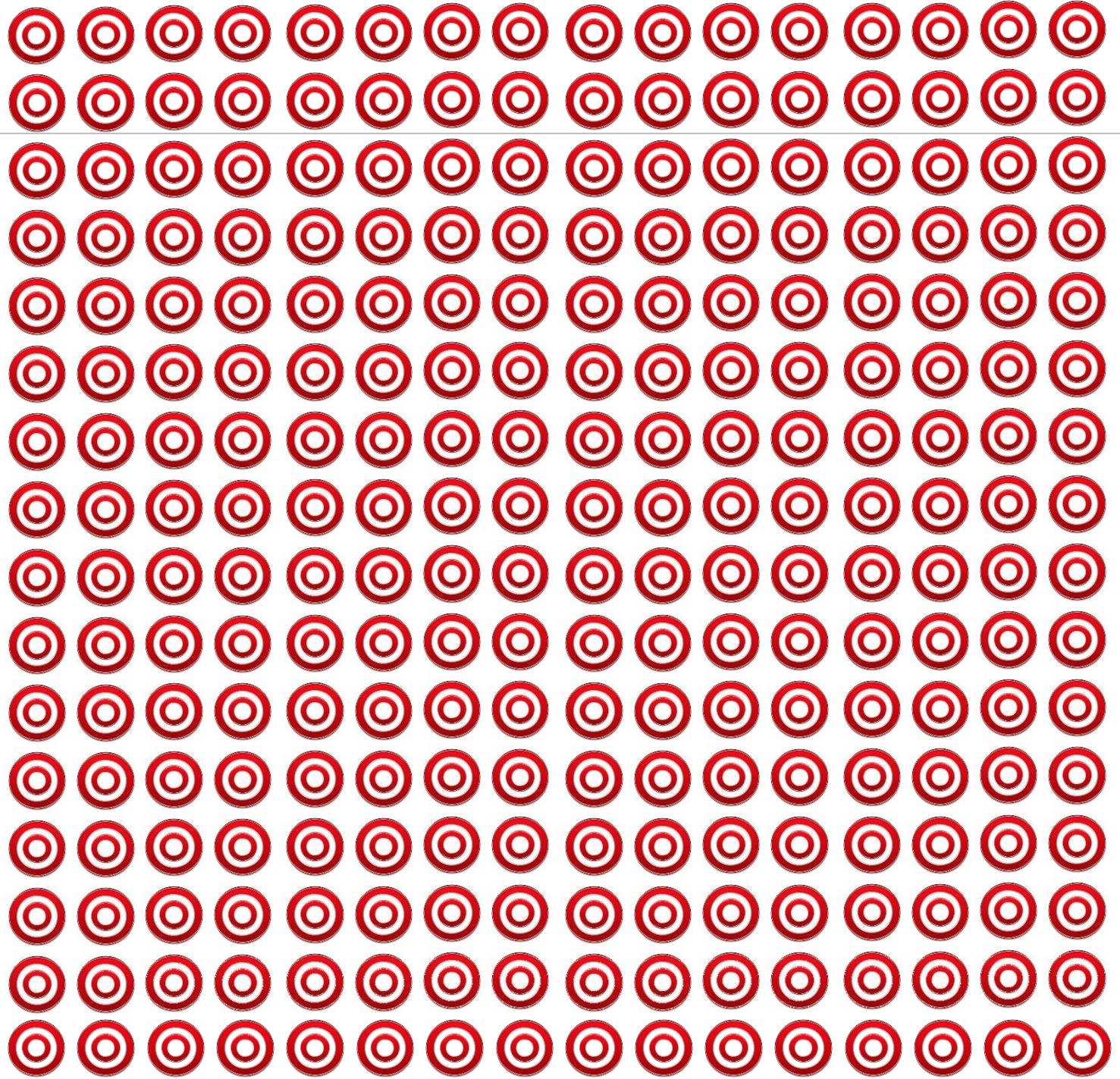
8 Bits



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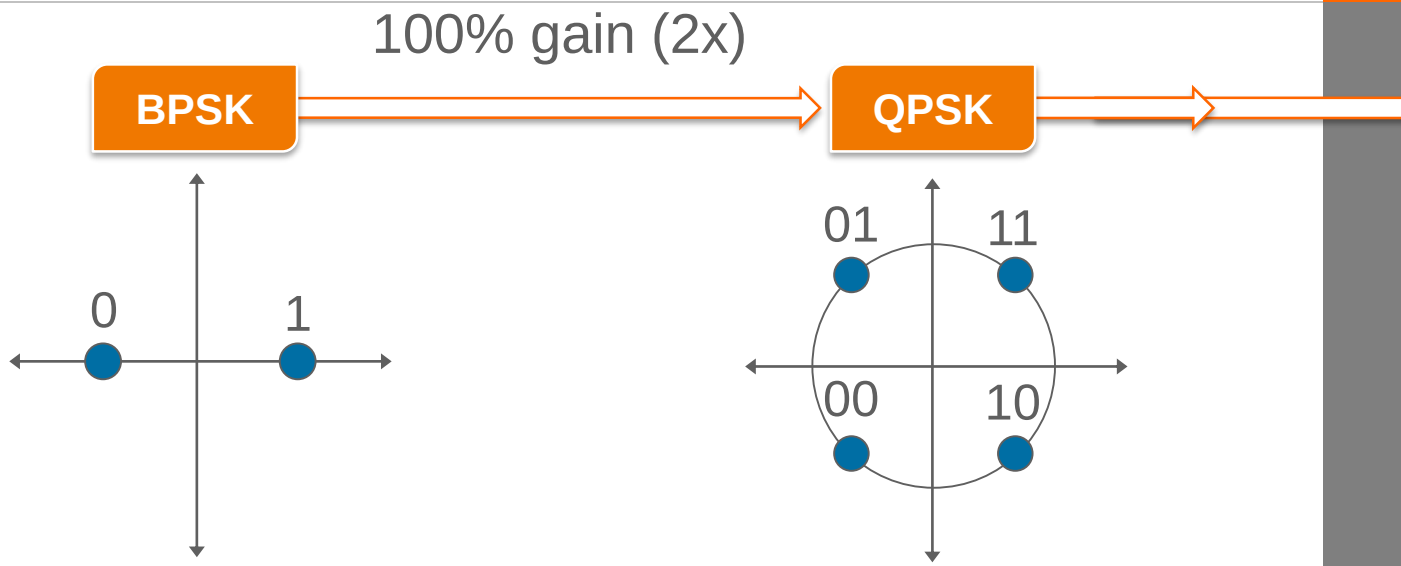
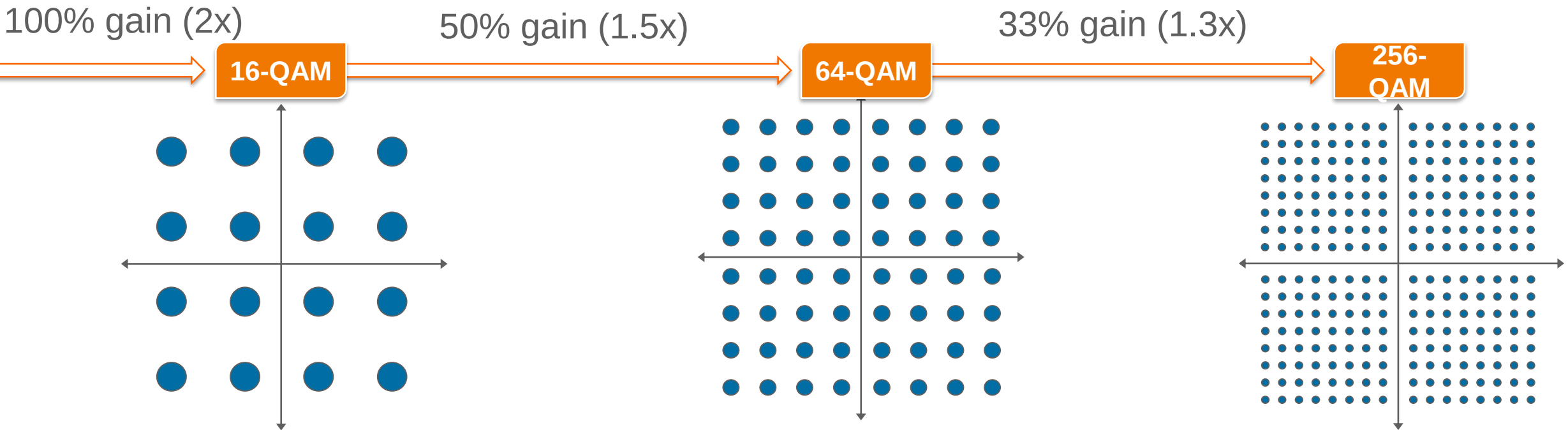
256-QAM

- Improves efficiency by 33%
- Adds complexity, requires higher SNR
- Efficiency gain from modulation does not increase linearly





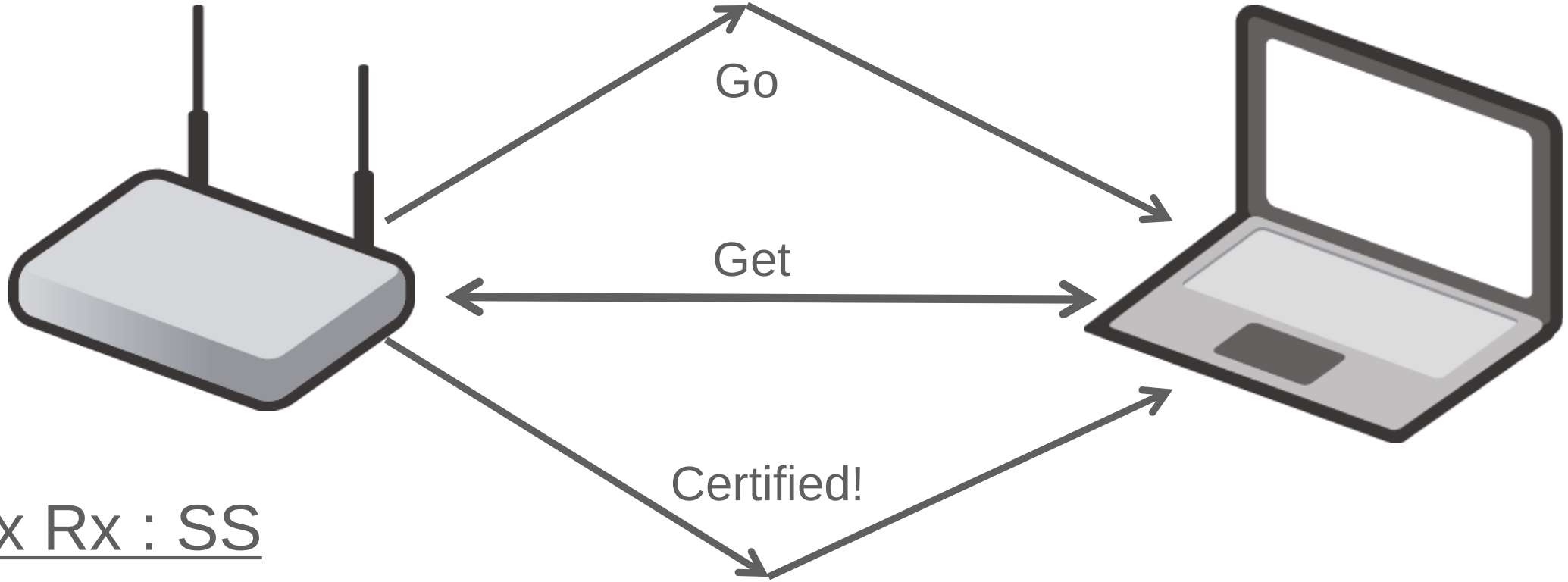
SISO (Diversity)

Uses only ONE antenna for transmit and receive

802.11a/b/g

MIMO – Spatial Multiplexing

Can use multiple antennas for transmit and receive



Tx Rx : SS

3 x 3 : 3

802.11n/ac

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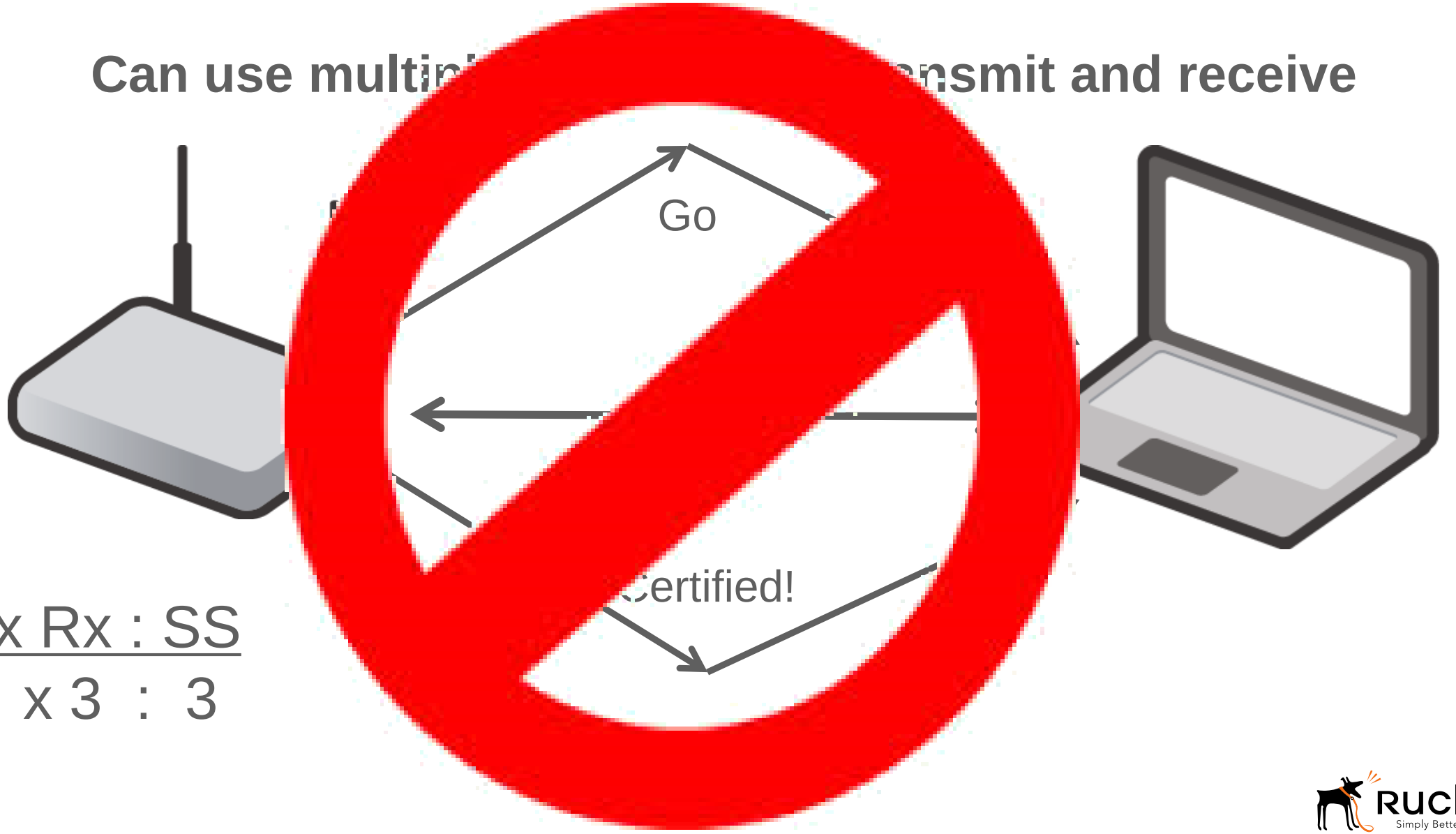
MIMO – Spatial Multiplexing

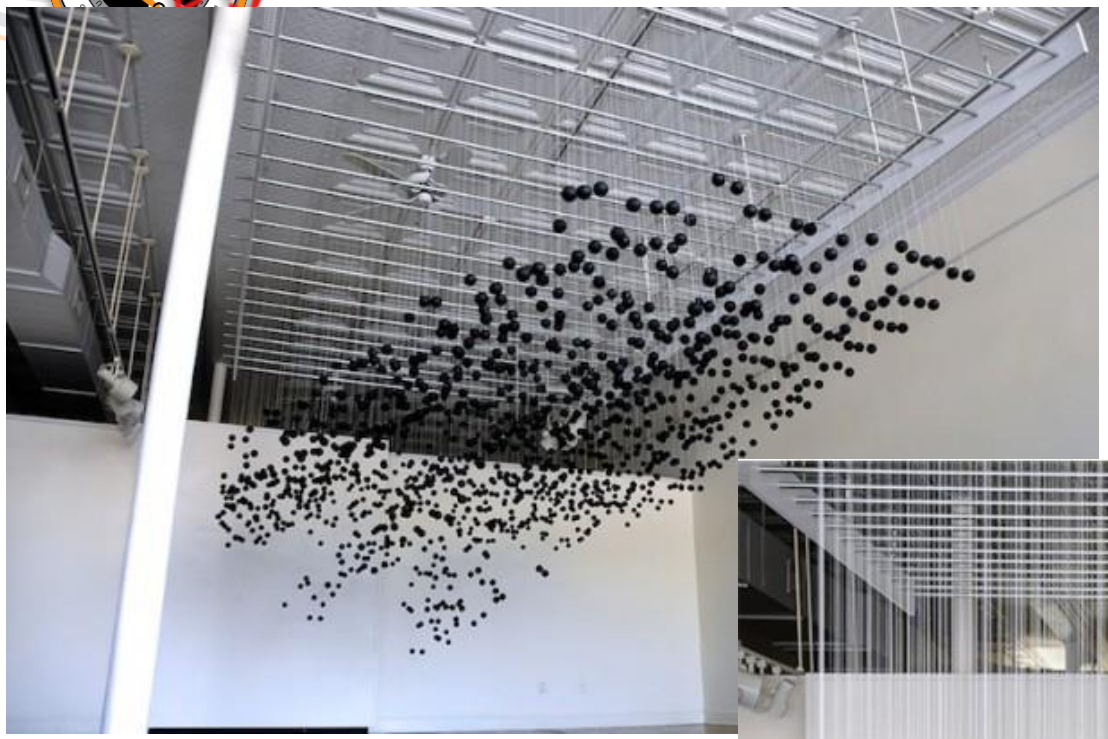
Can use multi[illegible] ansmit and receive

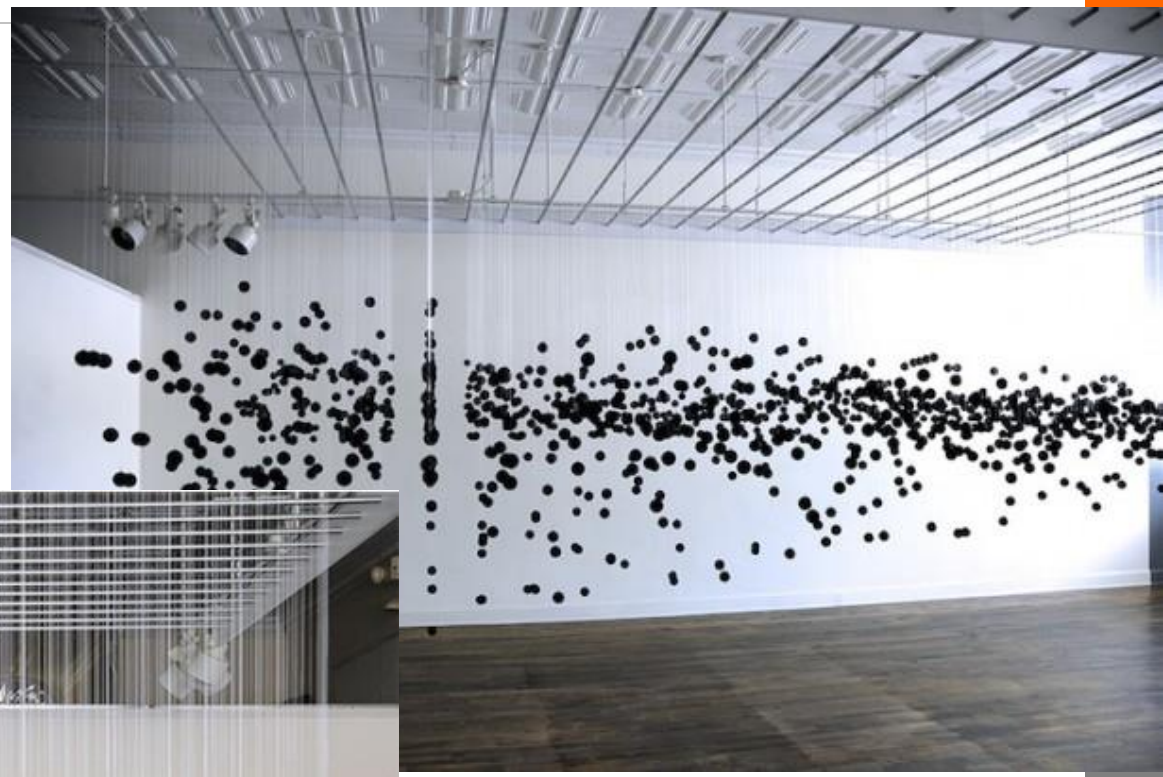


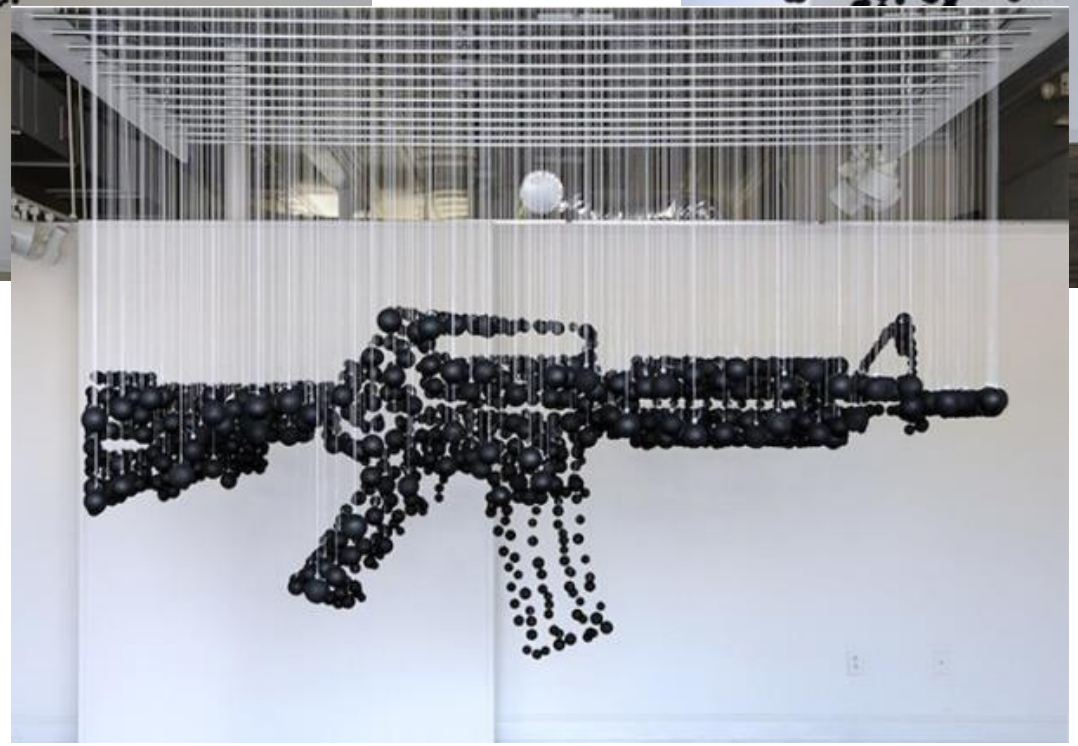
Tx Rx : SS

3 x 3 : 3

Artist Michael Murphy

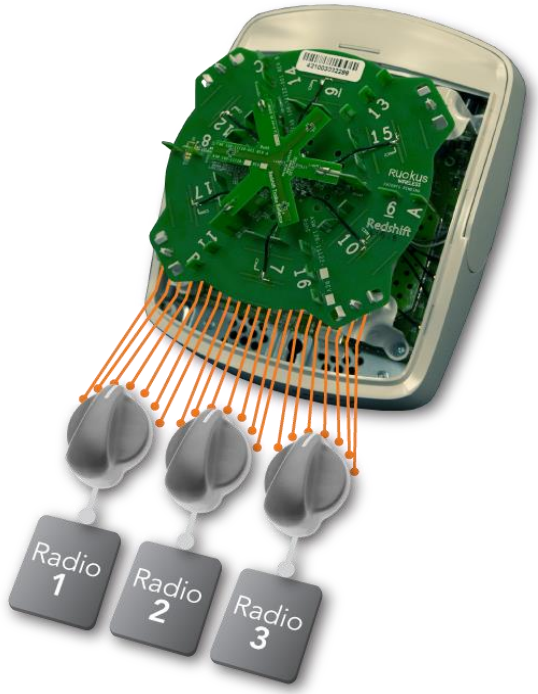


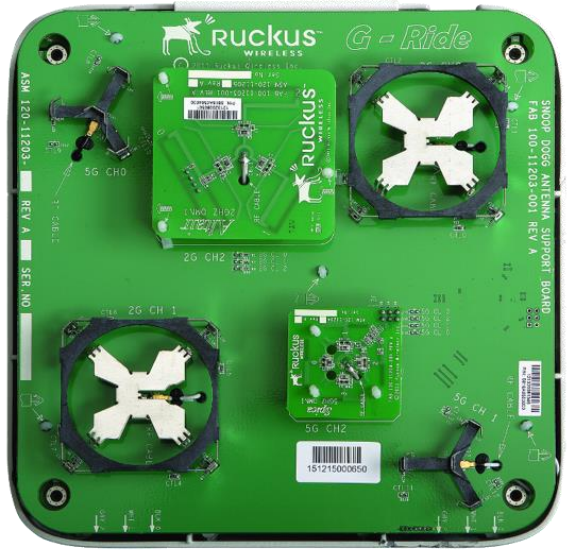




Decorrelation

- Increasing the difference in “perspective” between each stream
- Horizontal vs. vertical polarization
- Multipath





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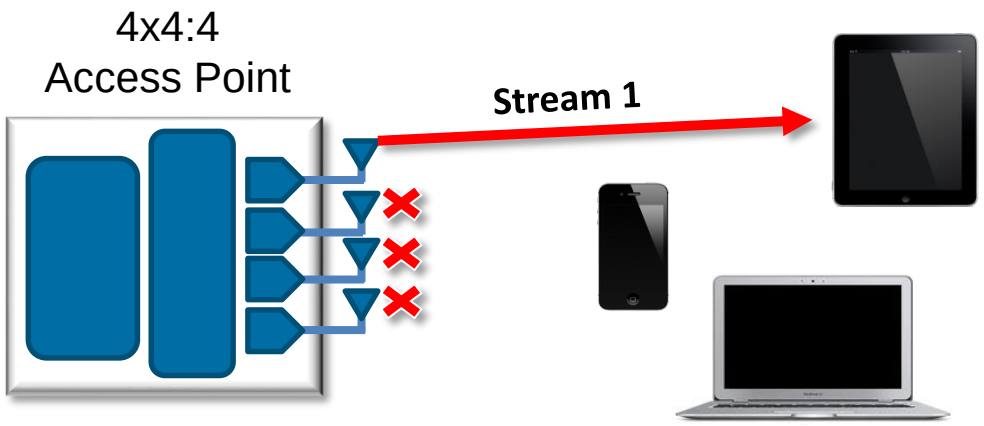
Multi-User MIMO (MU-MIMO)

- Requires 11ac client(s) with TxBF feedback/support
- Creates new challenges related to signal steering and isolation

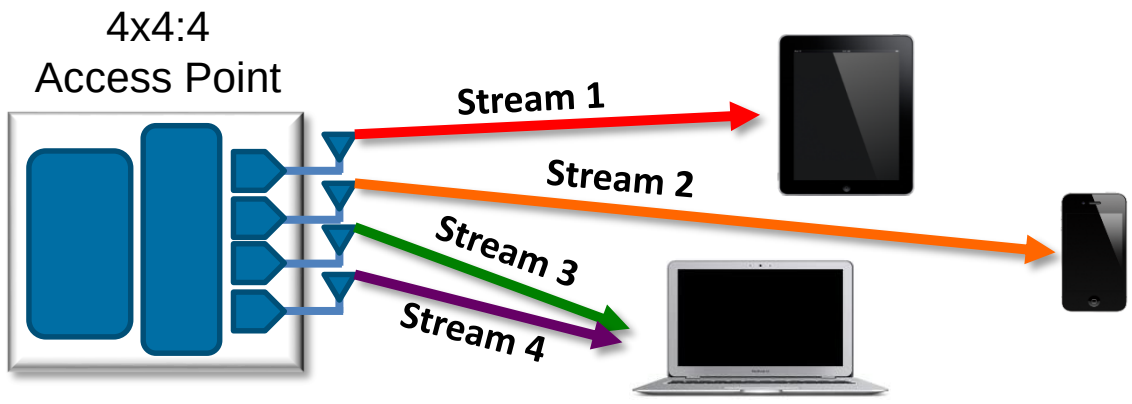
Single-User MIMO

one client at a time



Multi-User MIMO

multiple clients at the same time



Challenges with MU-MIMO

- Peak to Average Power Ratio
- Transmit power equalization
- Rate selection

MCS0	23 dBm
MCS1	23 dBm
MCS2	23 dBm
MCS3	23 dBm
MCS4	22 dBm
MCS5	20 dBm
MCS6	18 dBm
MCS7	17 dBm
MCS8	23 dBm
MCS9	23 dBm
MCS10	23 dBm
MCS11	23 dBm
MCS12	22 dBm
MCS13	20 dBm
MCS14	18 dBm
MCS15	17 dBm

Challenges with MU-MIMO

- Delayed Acknowledgment (block ack)
- Data Queuing
- Selecting MU groups
- Making the process efficient
  - Same size frames
  - Same data rate clients

Questions

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