
# *Smarter WLAN Testing Strategy*

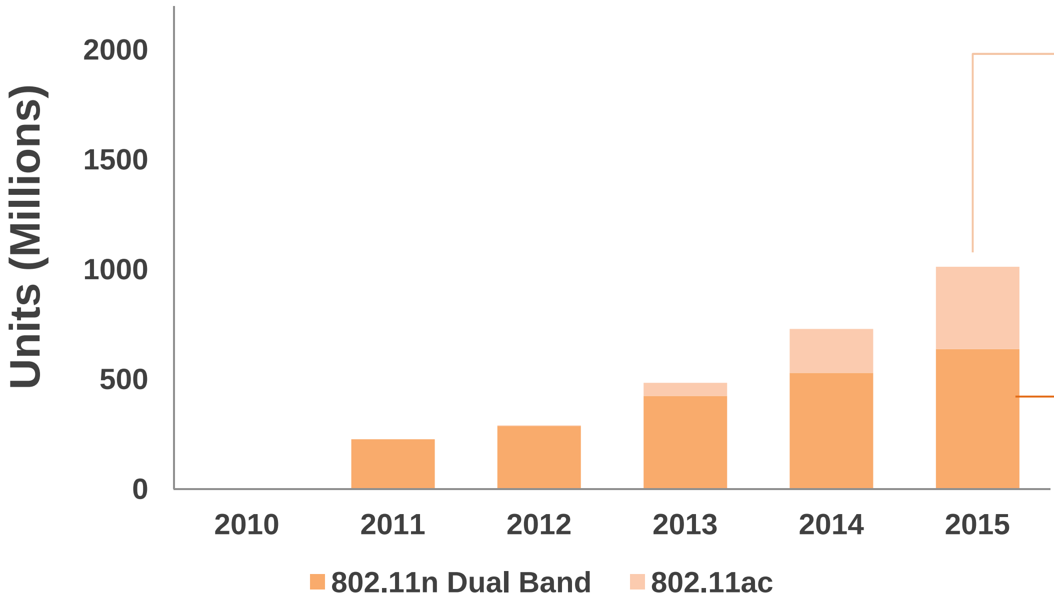
November 2012

# *Outline*

- Introduction
- Traditional Test Approach (Why)
- 5GHz is it the same
- What does 802.11ac Change
- A different Test Approach
- Summary

# *WLAN market trends*

Adoption of dual-band WiFi (2.4-GHz/5-GHz) is strong
2.4GHz is too crowded – 5GHz has many more channels
Access points with simultaneous dual band
Mobile device adopting dual band

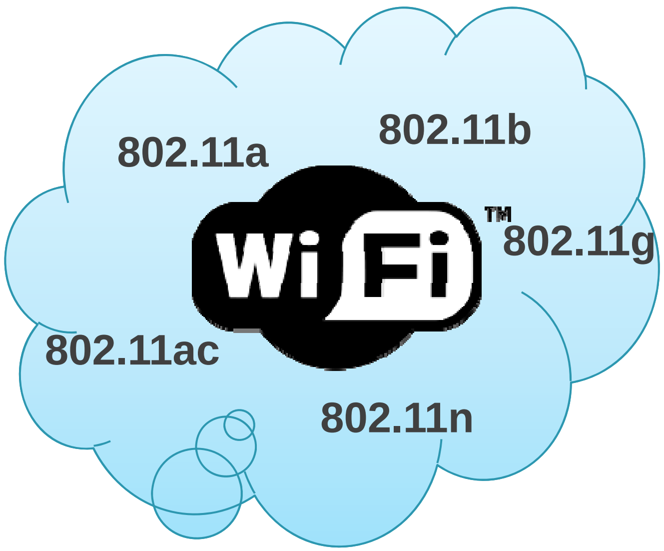


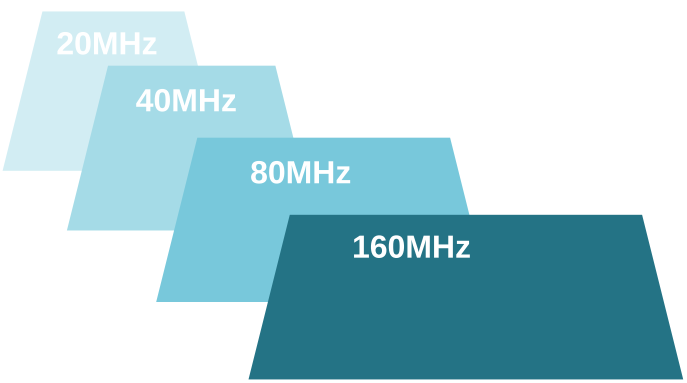

**802.11ac**

**802.11n Dual Band**

# *New challenges in WLAN testing*

## More Standards

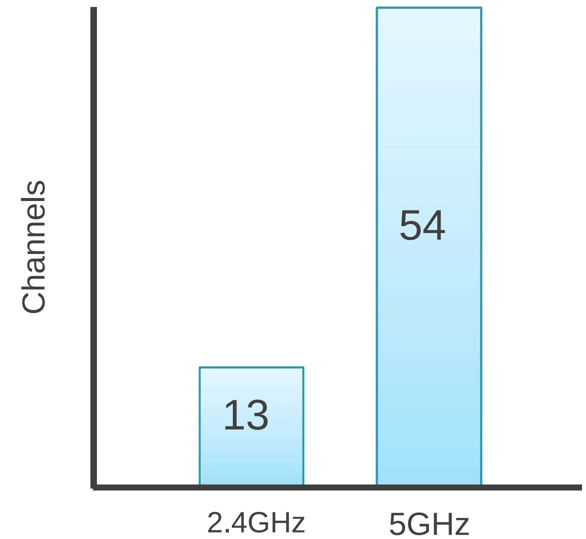


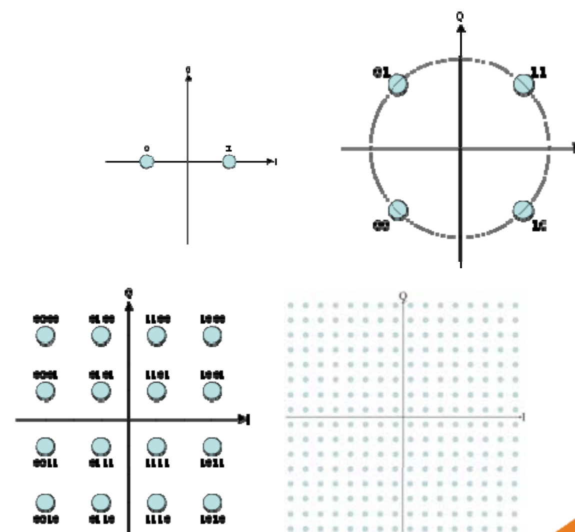




## More bandwidths

Time to Market

## More Channels



## More MCS

# *Traditional Test Approach*

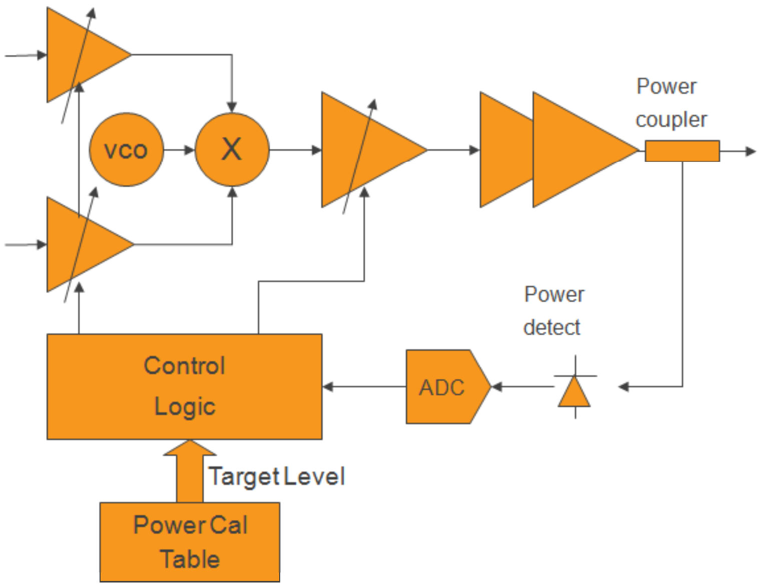
- Test performed at Low, Mid, High frequency of a frequency band
- Transmit performed at the test frequencies usually include:
  - EVM at the highest data rate

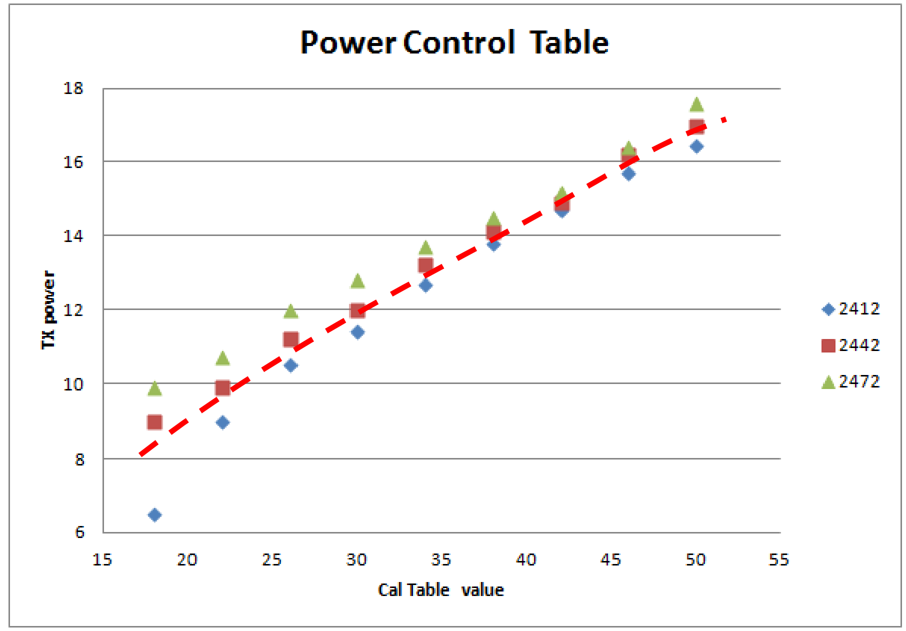
    11b – 11M, 11g – 54M, 11n – MCS7
  - Transmit Power
  - Mask measurement for 11b and possibly for OFDM
- Receive performed at the same 3 frequencies
  - PER test for highest data rate

    54M and/or MSC7, 11M
  - PER at the lowest input level

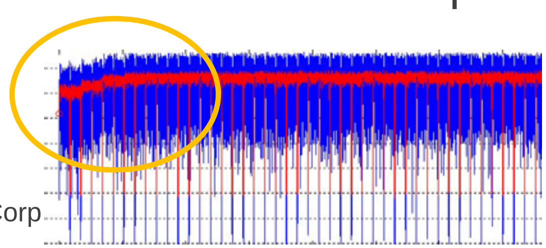
    6M or 1M
  - Some people add PER test at maximum input for 11M and 54M/MSC7

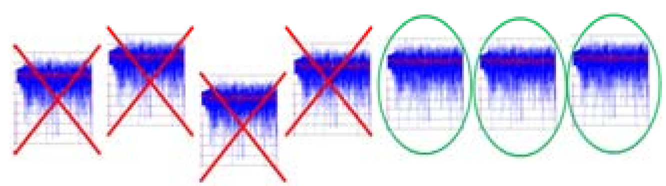
# *Why Low, Mid, High? – Transmitter*



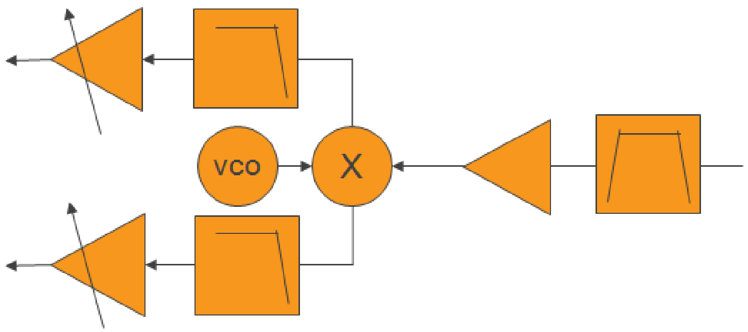



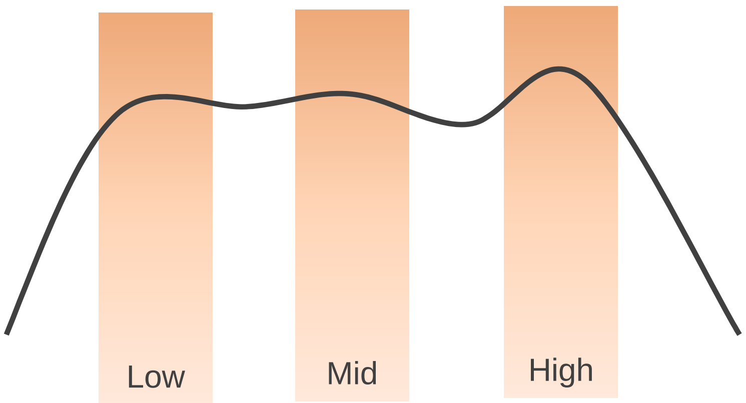

- One or more tables over given frequency range
  - One shared curve
  - Interpolation between multiple curves/points





# *Why Low, Mid, High? - Receiver*




- Noise Figure
  - Thermal noise (BB filter BW) + NF + SNR (Eb/No) for given PER = Sensitivity
  - Frontend loss adds directly to noise figure

- RF Filter normally shows ripple close to ends (low/high)

# *5GHz Changes the Picture*

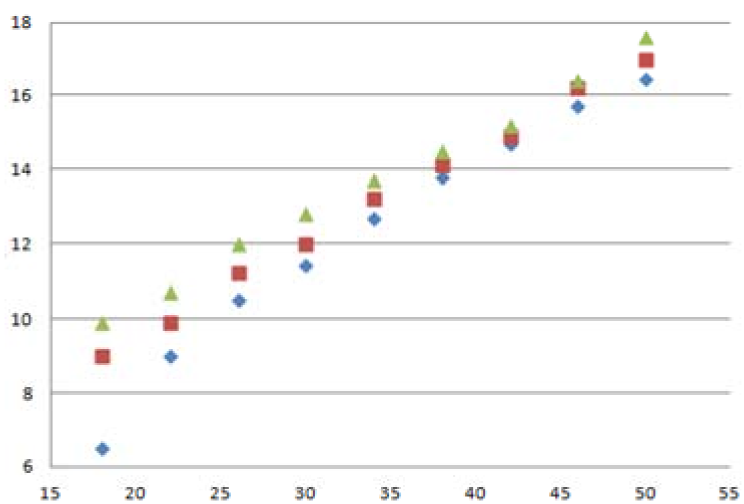
# 5GHz is Different

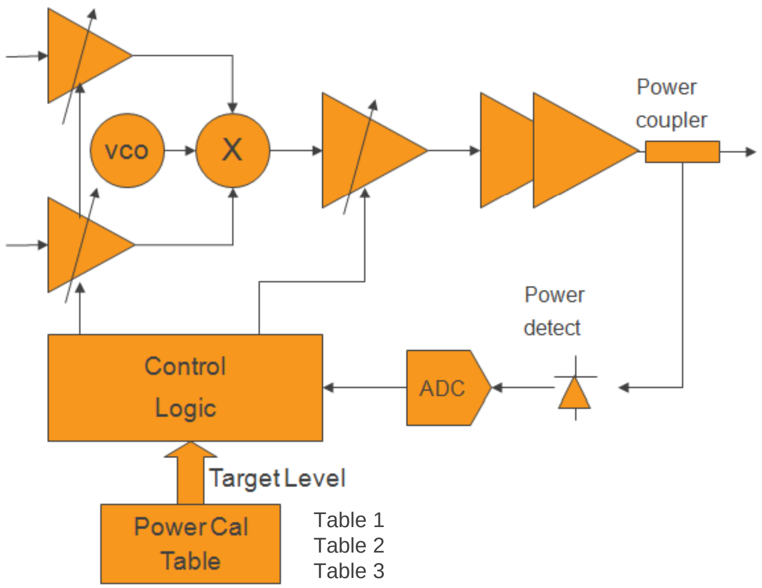

- Dual Band devices add many more channels
  - Less interference
- RF performance is more difficult @ 5GHz
  - Higher frequency
  - More phase noise
  - Much wider frequency range
- 802.11n HT20 and HT40
- 802.11ac
- No 802.11b

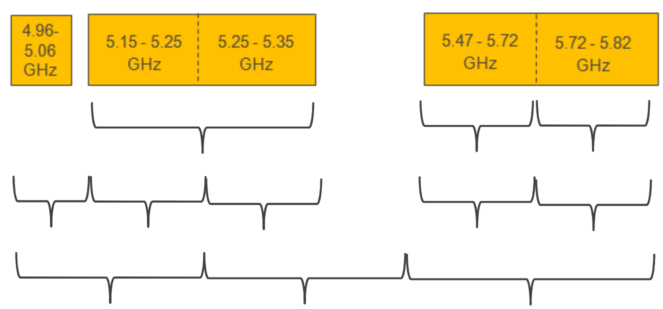
# 5GHz TX Operation

- 5GHz band separated into sub bands
  - Multiple Cal Tables used
  - RF performance drives the cal tables

- Basic idea remains the same

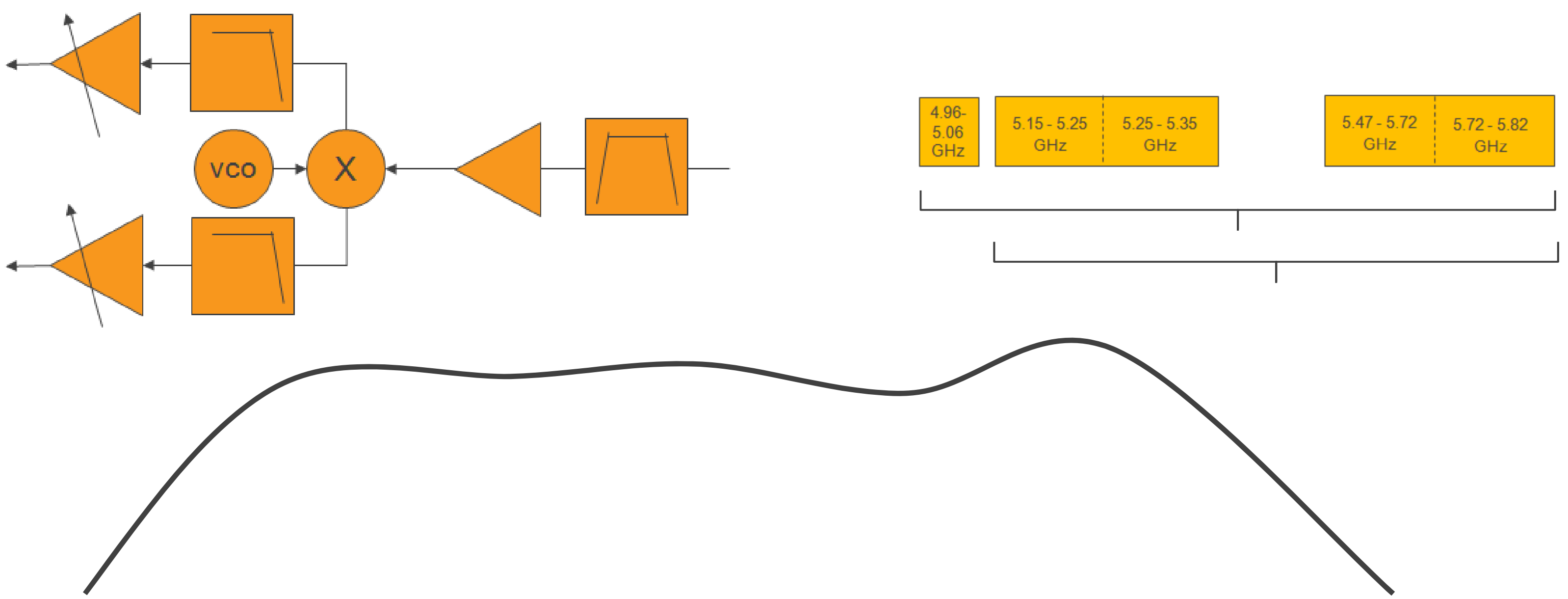


# 5GHz RX Operation

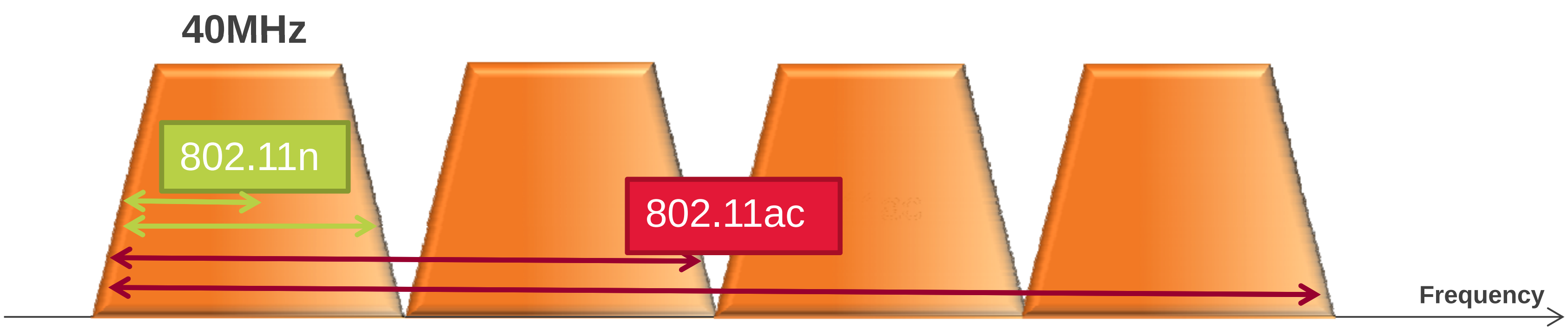
- Receive is typically not separated into sub bands
  - No Calibration so no need for sub-bands
  - RSSI typically not calibrated



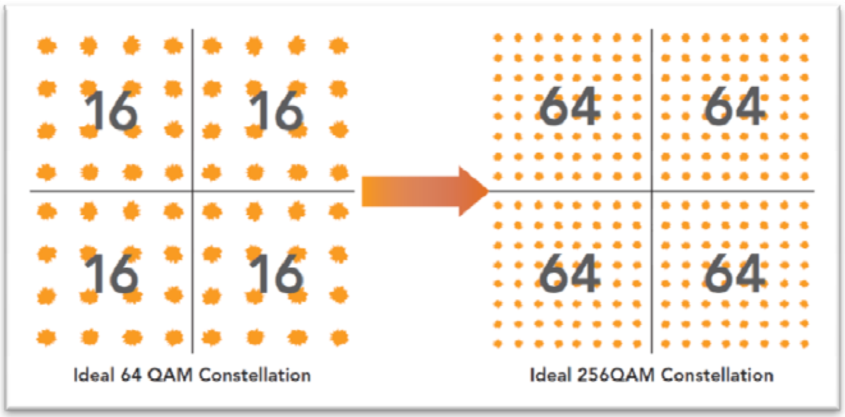
# *802.11ac is 5GHz only*

# 802.11ac PHY Layer Key Changes

- 80/160 MHz bandwidth channel




- 256QAM has 4X more symbols than 802.11n highest rate, driving tester SNR demands

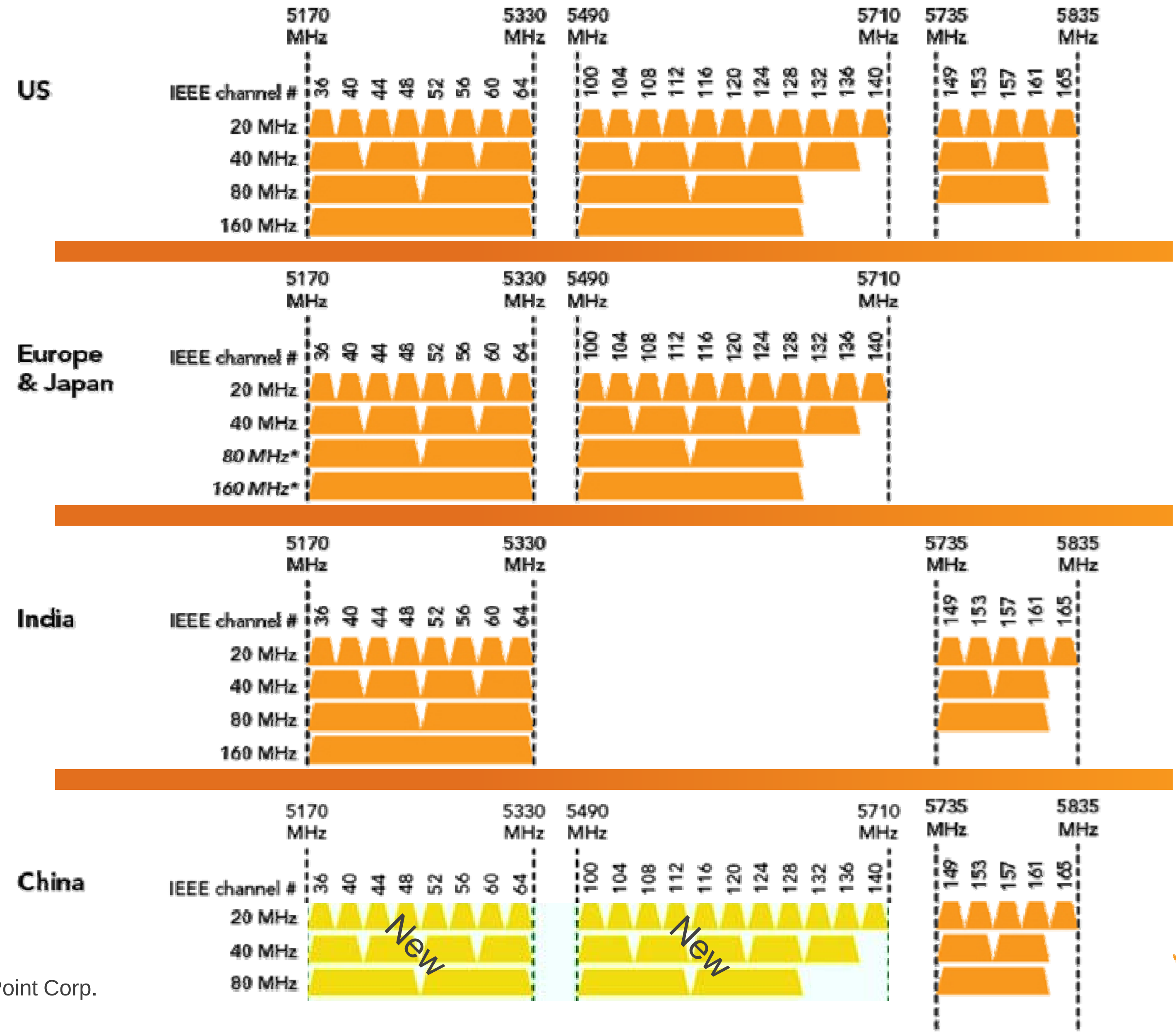


# *Modulation and Coding Scheme (MCS)*

- 802.11ac **mandatory** supports all the 802.11n modulation schemes
  - BPSK,QPSK,16QAM/64QAM
  - **Adds optional** 256QAM
  - 256QAM modulation scheme as tighter EVM requirement

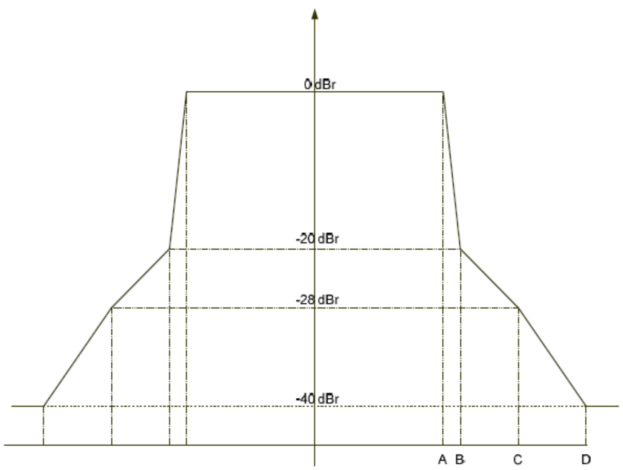
| Modulation | Coding rate | Relative constellation error (dB) |
|---|---|---|
| BPSK | 1/2 | -5 |
| QPSK | 1/2 | -10 |
| QPSK | 3/4 | -13 |
| 16-QAM | 1/2 | -16 |
| 16-QAM | 3/4 | -19 |
| 64-QAM | 2/3 | -22 |
| 64-QAM | 3/4 | -25 |
| 64-QAM | 5/6 | -28 |
| 256-QAM | 3/4 | -30 |
| 256-QAM | 5/6 | -32 |

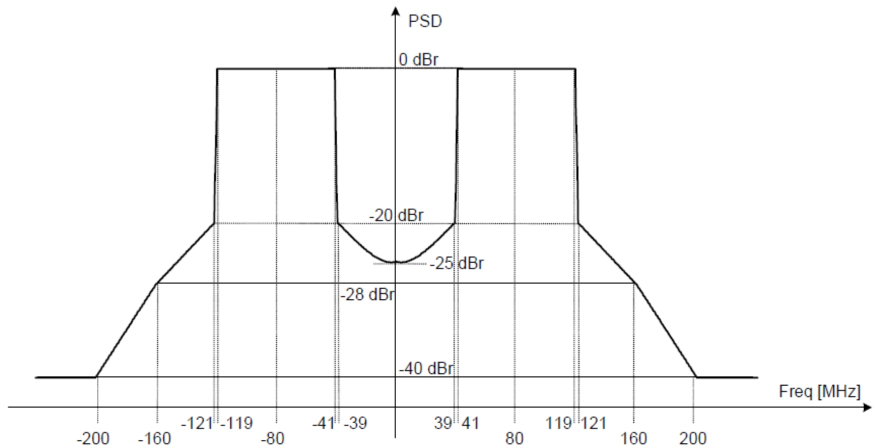
# 802.11ac Worldwide



# 802.11 ac Mask Measurements

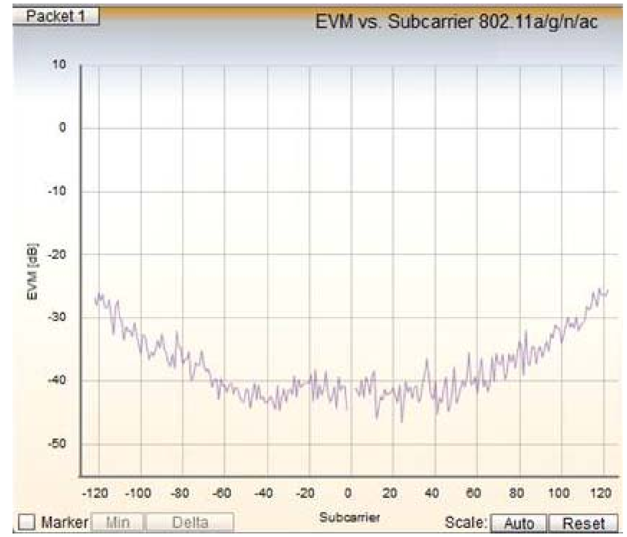
- Mask requirement in 5G band has changed recently (802.11 2012 release)
- Now masks are defined to -40dBr in 5G (Used to be -45dBr)
    - HT80 is worst case for 11ac spec
    - HT40 is tighter according to old spec
- 2.4GHz remains the original -45dBr




| Channel Size | A | B | C | D |
|---|---|---|---|---|
| 20 MHz | 9 MHz | 11 MHz | 20 MHz | 30 MHz |
| 40 MHz | 19 MHz | 21 MHz | 40 MHz | 60 MHz |
| 80 MHz | 39 MHz | 41 MHz | 80 MHz | 120 MHz |
| 160 MHz | 79 MHz | 81 MHz | 160 MHz | 240 MHz |

# *Transmitter Quality*




- IQ mismatch & group delay variations
  - BB Filter group delay
  - IQ mismatch accuracy over wide BW

- Phase noise

  Phase noise of synthesizer:

$$\text{Phase noise} \approx \frac{\text{Channel Frequency}}{\text{Reference Frequency}}$$

  Worst at highest channels

  EVM requirement for QAM256 restricts phase noise

- Compression
  - Much tighter EVM

- Insufficient SNR adds noise to constellation

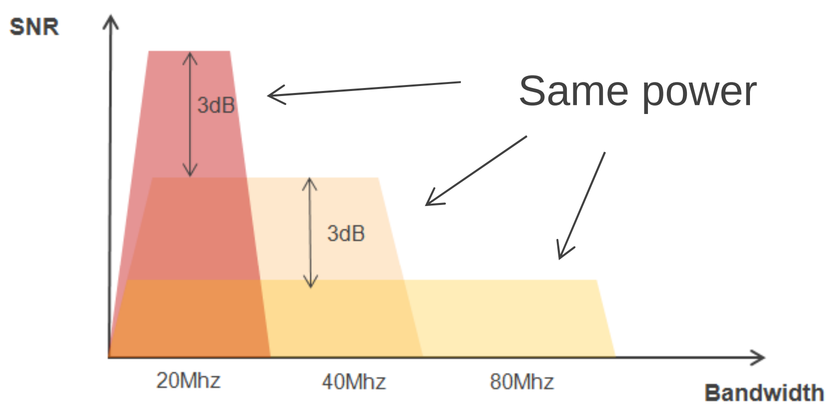
# *What to Test*


Zigbee
MIMO
WiFi
LTE
4G
FM
WAVE
Zigbee MIMO
WAVE MIMO
WiFi
GPS
WiMAX
4G WiFi Bluetooth Zigbee
WAVE
4G
WiMAX
FM

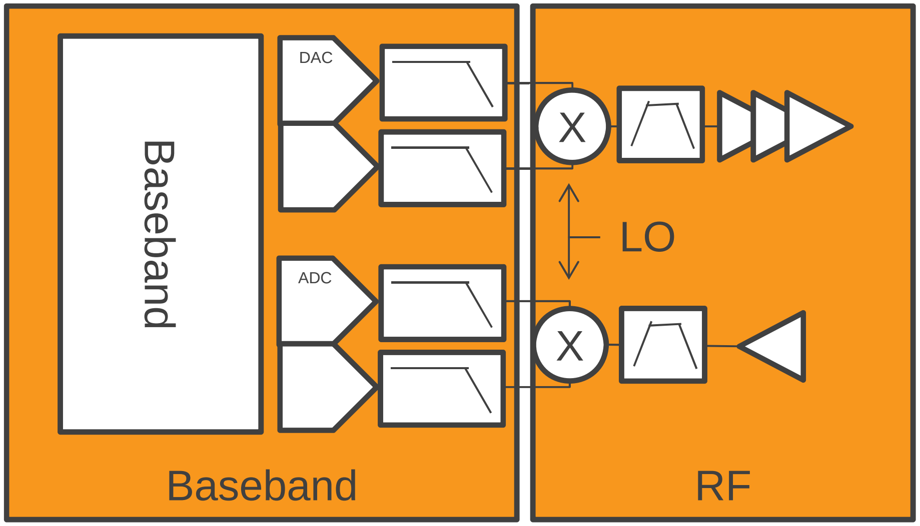
# What to Test

- HT20 vs. HT40 vs. HT80 (vs. HT160)
- Transmitting HT80 effectively has 6dB more stringent TX SNR requirement than HT20
  - Same power is transmitted over larger BW
    - Less power per carrier/MHz
  - Effects Mask and EVM
  - Typically other factors limit performance

- RX specification compensates for BW
  - RX is relaxed 3dB and 6dB for HT40/HT80



# *Understanding the Chip*

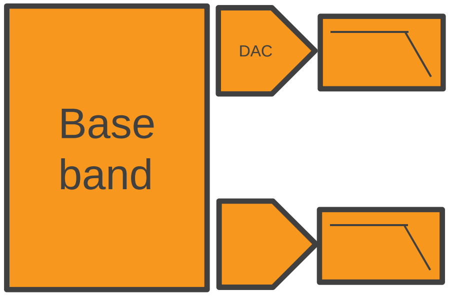



- Two functional blocks
  - Baseband
  - RF
- Baseband performs modulation and demodulation
  - Does not matter what frequency is used
- RF up-convert/down-convert the wireless signal
  - Does not matter what modulation is used

# What to Test - Transmitter

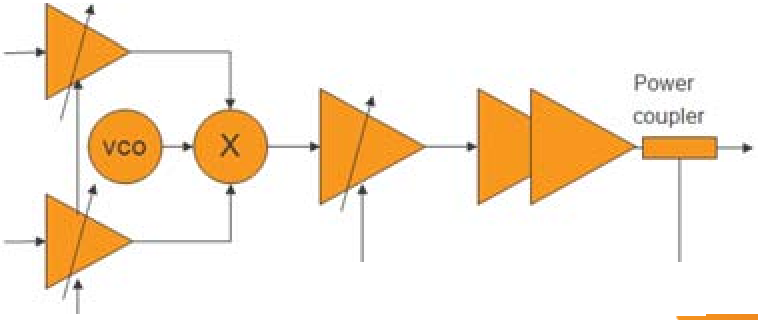
## Baseband

- Modulation
  - Different data rates
  - Fundamental rates
- Anti Alias Filter for different HT
  - Mask
  - Flatness (PA pre distortion)
  - Assume filter changes with TX BW




## RF

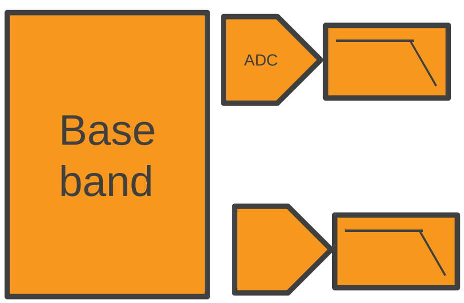
- Power accuracy
  - Calibration tables
  - Low, Mid, High
- EVM
  - IQ mismatch
  - Phase noise
  - Compression
- MASK
  - Compression
  - Noise floor
- Transmit flatness



# What to Test - Receiver

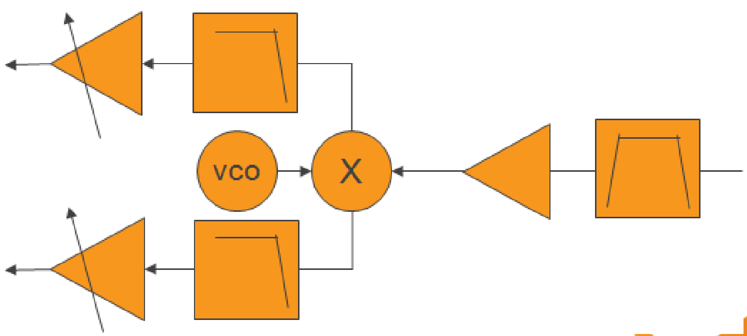
## Baseband

- Modulation
  - Different data rates demodulation
- Baseband RX filter over BW
  - 20MHz BW
  - 40MHz BW
  - 80MHZ BW



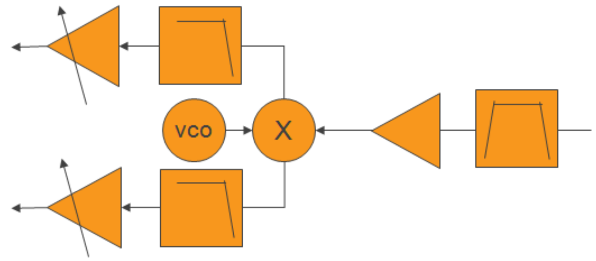

## RF

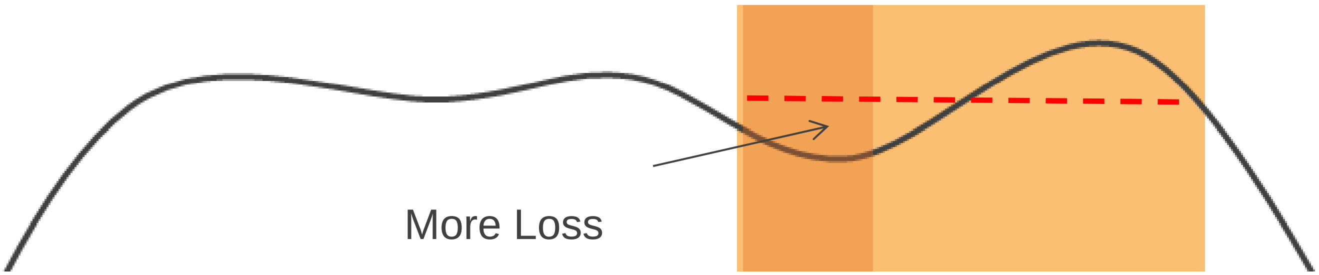
- Receive performance
- Noise Figure
- RF performance flatness
  - RF ripple
  - Testing with wide BW can mask ripple
- RX distortion
  - Max input compression
  - Phase noise
  - IQ mismatch



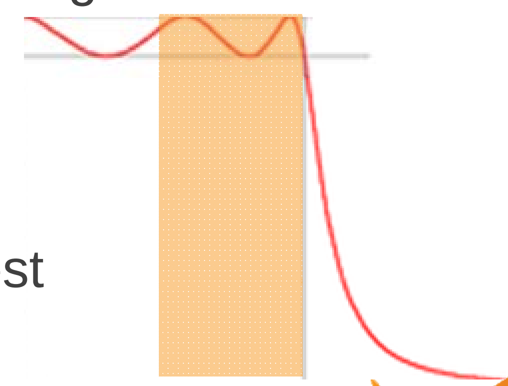
# *Narrow Band vs. Wide Band test*

- RF test covers RF filter ripple
  - RF ripple changes noise figure
  - Testing with wide BW can mask a narrow BW failure



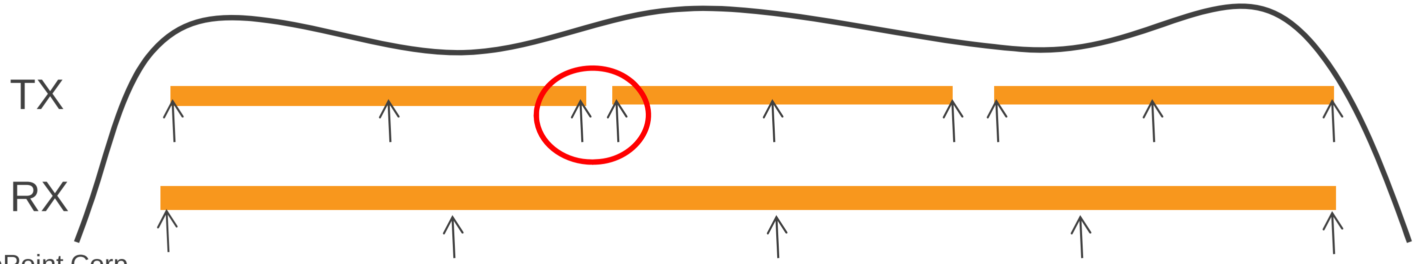

- Testing Wide BW baseband filter with narrow BW signal
  - 80MHz 11ac RX using 20MHz signal
  - Furthest from center

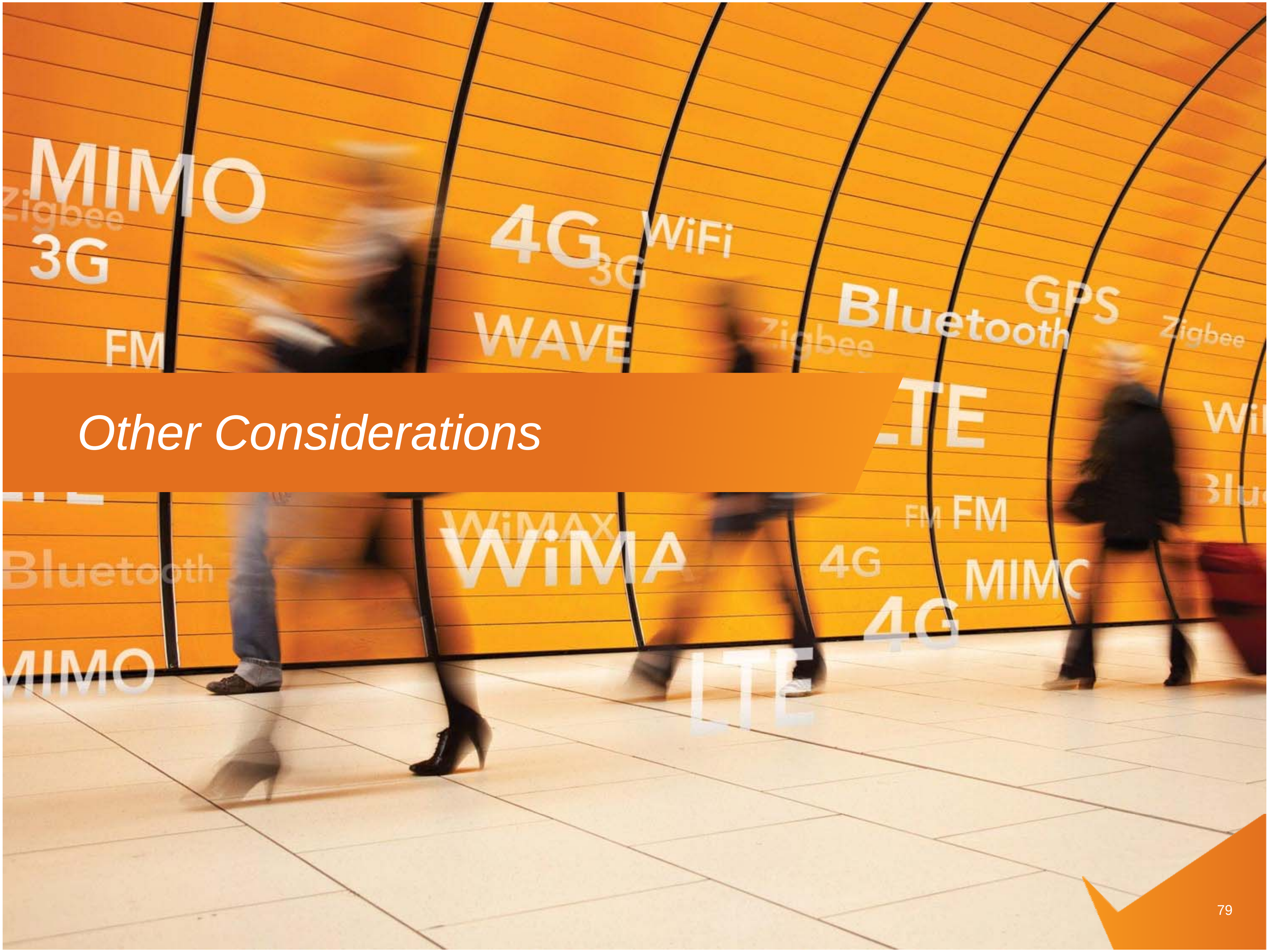


- TX test includes flatness so no need to narrow test

# *5GHz can be much more than 3x low, mid, high*

- Understand TX calibration approach
  - Need to validate **power** at Low, Mid, High for each sub-band
  - With 3 sub-bands **9** measurement points exist
  - Measurements to verify baseband function can be included
    - Power will be the same if using LTS
    - EVM is transmit quality so same for lower data rates
    - Test different BW over the 9 points where possible (HT20, HT40, HT80)
    - No need to repeat BB measurements already verified in 2.4GHz
  - Choose the worst case test scenario for critical measurements
    - Test phase noise via Max data rate at highest VCO frequency
- RX should **NOT** follow the TX points
  - High point of lower sub band is adjacent to next sub band low point
  - Spread the RX verification points over the full band

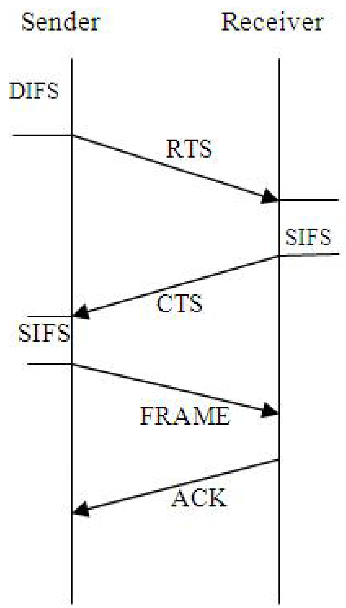





# *Other Considerations*

# *Looking beyond physical layer test*

- In actual transactions a transmitted packet is acknowledged from the recipient – The ACK
- The ACK packet is small basically only containing the MAC addresses of transmitter and receiver
- To make link asymmetrical the lowest data rate fitting the packet data, thus 24M will be used to ACK a 54M packet
  - 24M and 54M ack will have same duration
  - The lower rate is chosen to ensure high probability of the ACK being received when the received packet is good
  - Once data rate is lower, ACK will move to 6M




- If ACK is not working the DUT is not working
  - even if 54M packet is good

# *Simultaneous 2.4G & 5G Operation*

- Most modern High End APs support simultaneous dual band operation.
  - Ideally one should test this
- Receivers typically do not interfere
- Interference can occur if one channel is transmitting while the other is receiving
  - Transmitter wide band noise can enter the receiver
  - Noise from TX power supply current can couple to receiver
- Both TX simultaneous can effect quality from power supply
- No need to test differently (one band at a time)
  - Simply enable TX in the not tested band while testing in the other
  - When testing 5G one should test @ 2$^{nd}$ harmonic of 2.4G TX signal
- If 2.4G and 5G bands have separate RF connections (antenna connections) one can use fast switching
  - Testing both bands at the same time using the 2 RF ports of IQxel
  - Faster operation, but more complex to implement

# *Putting it all together*

# Example

Transmitter

| 2.4 GHz band | | |
|---|---|---|
| 11M EMP | 1M EMP | 54M EMP |
| | | |
| | | QAM 64 |
| | ACK | |
| | | |

| 5GHz Low band | | | 5GHz Mid band | | | 5GHz High band | | |
|---|---|---|---|---|---|---|---|---|
| 24M EMP | MSC6 HT80 EMP | MCS0 HT40 EMP | MSC8 HT40 EMP | MCS7 HT40 EPM | MCS4 HT20 EP | 6M EP | MSC2 HT40 EMP | MCS9 HT20 EMP |
| | | | | | | | | |
| QAM 16 | QAM 64 | BPSK | QAM 256 | QAM 64 | QAM 16 | BPSK | QPSK | QAM 256 |
| ACK | | ACK | | | ACK | ACK | | |
| | HT80 | HT40 | HT40 | HT40 | | | HT40 | HT20 |

Receiver

| 2.4 GHz band | | |
|---|---|---|
| 11M | 54M | 1M |
| | | |
| | | ACK |

| 5GHz band | | | | | | |
|---|---|---|---|---|---|---|
| 24M | MSC8 HT80 | MSC2 HT20 L | 6M | MSC7 HT40 | MSC4 HT20 H | MSC9 HT20 |
| | | | | | | |
| ACK | QAM 256 | QPSK | ACK BPSK | QAM 64 | ACK | QAM 256 |

## *Summary*

- Traditional low, mid, high test approach covers 2.4GHz well
  - Should add test for ACK operation
- 5GHz operation adds more required measurements
  - TX calibration tables should be verified
  - RX and TX do not need to be at same frequency
- Separate baseband and RF when designing test plan
  - Allows significant improvement in test coverage
  - TX follows cal tables
  - RX can be spread out over full band
  - Use different data rates to increase test coverage (baseband)
  - Use large BW for TX test (worst case SNR)
  - Use narrow BW when testing RX (wide can hide local issues)
- Simultaneous Dual Band devices should be tested with TX enabled
- Test planning is important for optimal test coverage and fast test time