60 GHz:
What You Need to Know About 802.11ad and 802.11ay

Jason D. Hintersteiner, CWNE #171
Director of Business Development

WLPC 2019

LigoWave

60 GHz is NOT dead

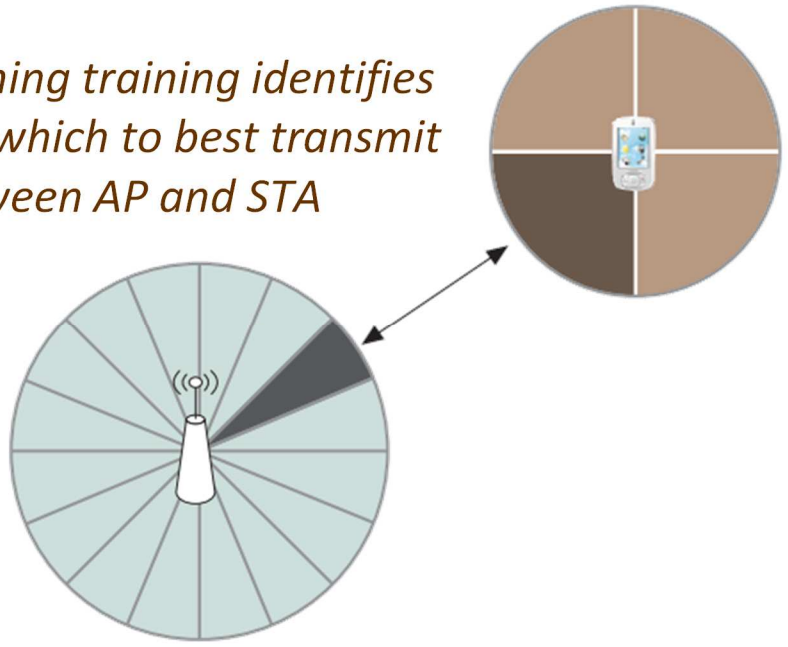
60 GHz

802.11ad Standards

LigoWave

- Key 802.11ad Applications
  - Point-to-(multi)point
  - Room-level Wi-Fi
- Key 802.11ad Specifications
  - DMG: **Directional** Multi-Gigabit PHY
  - Data rates: Up to 8 Gb/s
  - PHY Type: Single Carrier PHY (OFDM part of original standard but not implemented)
  - Phased antenna arrays for real-time beamforming with directional antennas
  - Single stream (SISO only, no MIMO or MU-MIMO)
  - Generally limited to one AP and up to 8 client devices (STA)

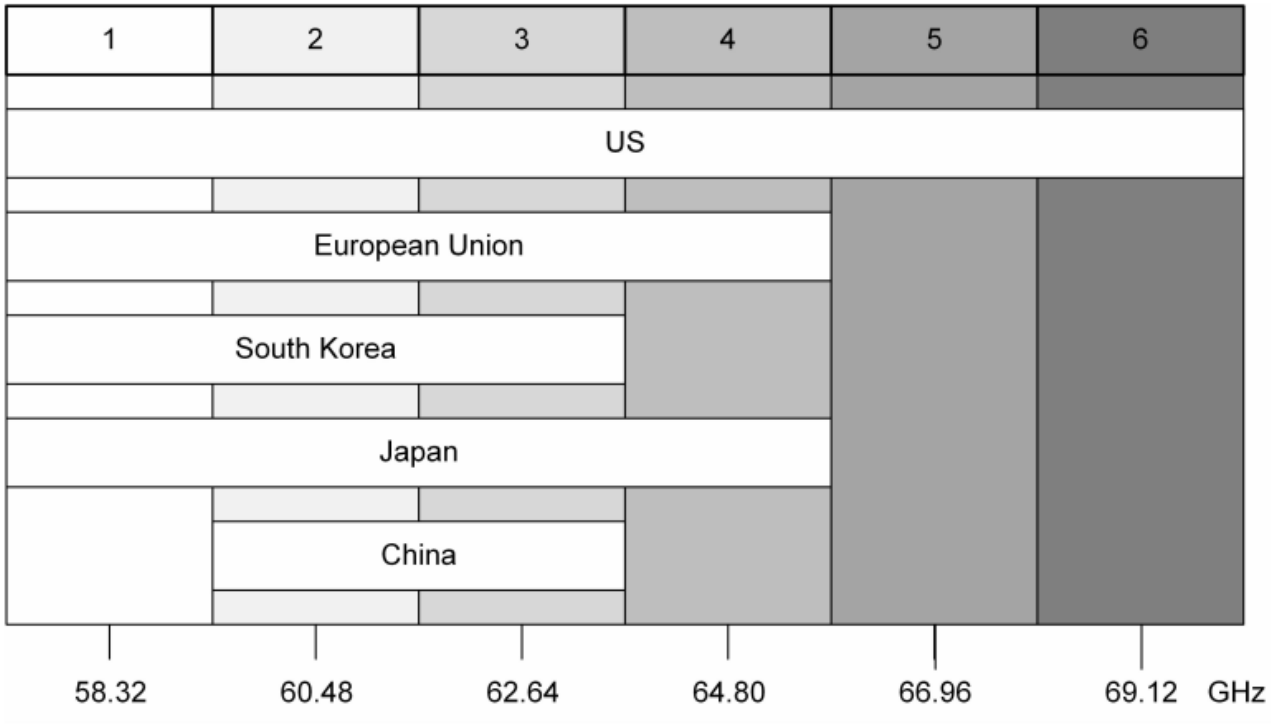
Beamforming training identifies sectors in which to best transmit between AP and STA



https://ieeexplore.ieee.org/document/6979964

60 GHz
Channels

- Original range: 57-66 GHz (4 channels of 2.16 GHz each)
- Extended range: 57-71 GHz (6 channels of 2.16 GHz / channel)
  - Only available in USA
  - May be opened up in Canada & EU in near future
- Only channels 2 & 3 (59.4 – 63.72 GHz) available worldwide

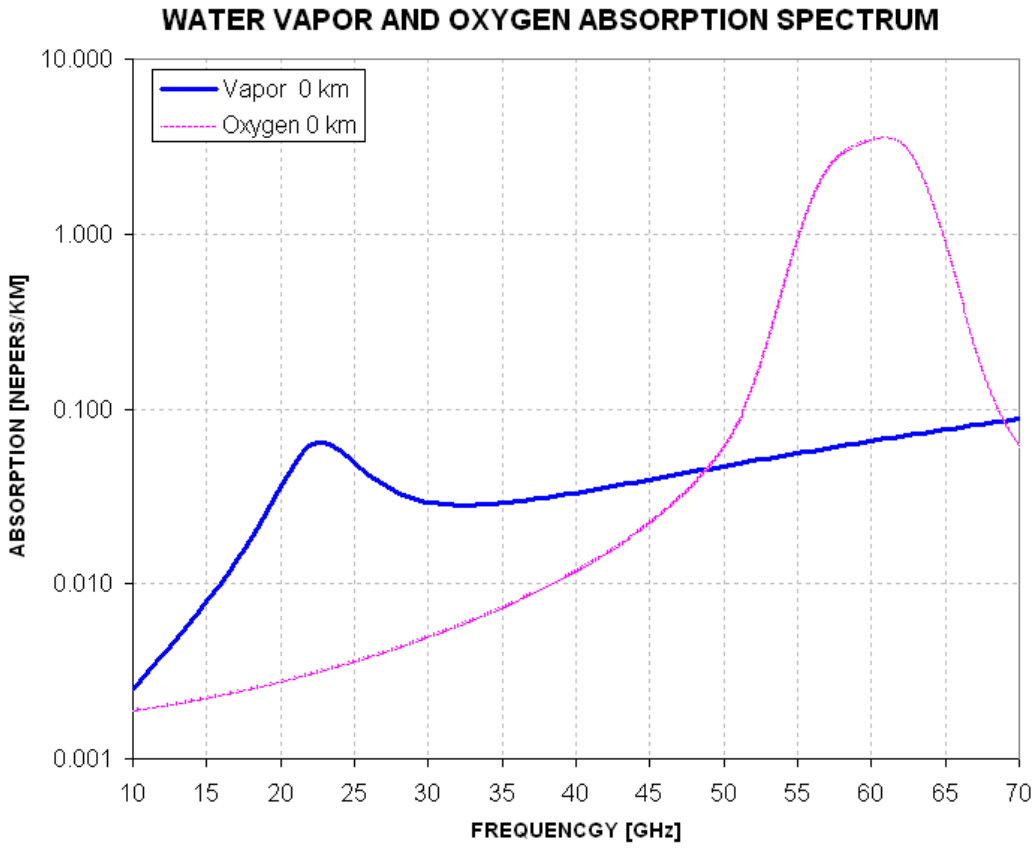


https://scdn.rohde-schwarz.com/ur/pws/dl_downloads/dl_application/application_notes/1ma220/1MA220_3e_WLAN_11ad_WP.pdf

60 GHz

Why is Range So Poor?

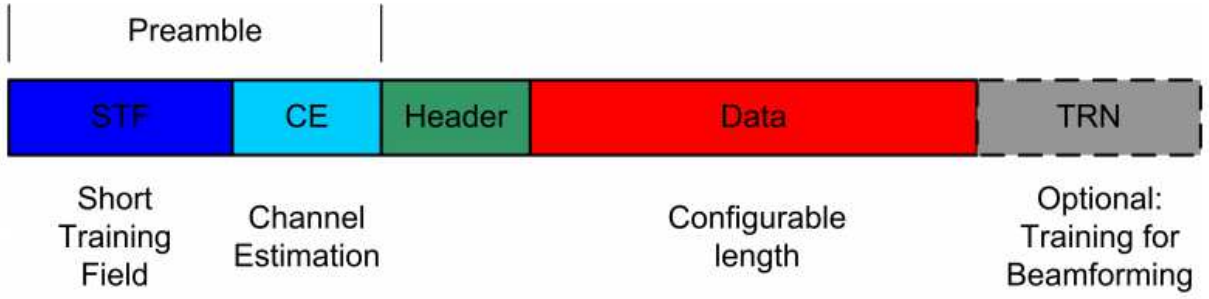
- Molecular oxygen absorbs significant amounts of energy in the 54 GHz – 66 GHz range
- Attenuation from water vapor increases as frequency increases
- Effects are negligible at <10 GHz; we are used to ignoring this in 2.4 GHz & 5 GHz
- Results for 60 GHz PTP/PTMP:
  - ***Significantly more limited range in air***
  - ***Large degradation in link performance from weather effects (e.g. rain, snow, fog)***



http://brucegary.net/MTP_tutorial/VaporAbs.png

60 GHz

802.11ad PHY



https://scdn.rohde-schwarz.com/ur/pws/dl_downloads/dl_application/application_notes/1ma220/1MA220_3e_WLAN_11ad_WP.pdf

- Preamble: Consists of short training field (STF) and channel estimation (CE) field for packet detection, automatic gain control, and frequency and timing offsets
- Header: Modulation and coding scheme for data, length of data field, checksum
- Data: Variable length field (1 to 262,143 octets) containing the Layer 2 payload
- TRN: Beamforming training field for transmitter or receiver

60 GHz

802.11ad MCS Rates

LigoWave

- Modulation Types
  - BPSK
  - QPSK
  - 16 QAM
- LDPC Coding
  - 1/2
  - 5/8
  - 3/4
  - 13/16
- Control PHY
  - Low SNR operation for beamforming training
- Single Carrier PHY
  - Intended for mobile client devices
  - Low complexity
  - Power efficient: maximizes battery life
  - Lower throughputs than OFDM

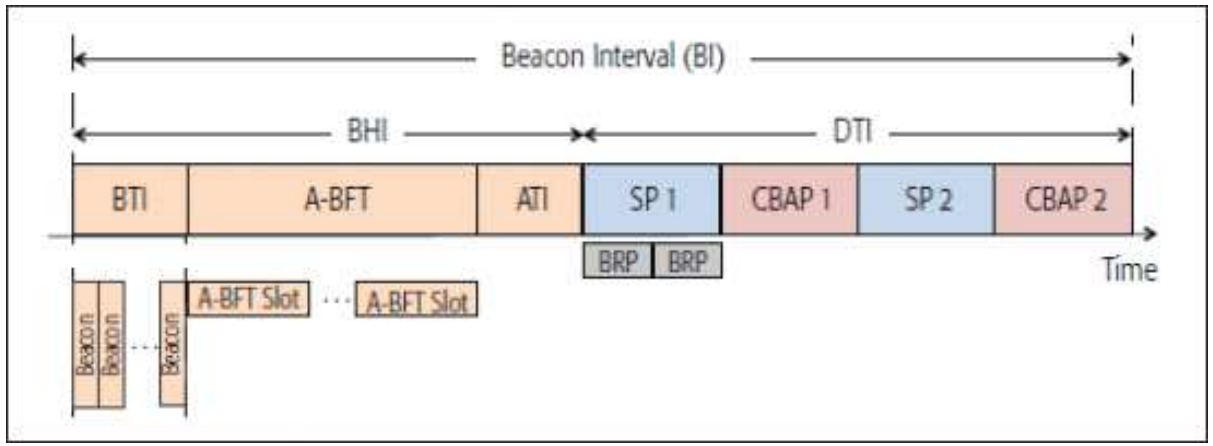
MCS Index	Modulation	Coding	Data Rate (Mbps)	Notes
MCS0	DBPSK	1/2	27.5	Control PHY
MCS1	π/2 BPSK	1/2	385	Single Carrier Phy 2 repeated frames
MCS2	π/2 BPSK	1/2	770	Single Carrier Phy
MCS3	π/2 BPSK	5/8	962.5	Single Carrier Phy
MCS4	π/2 BPSK	3/4	1155	Single Carrier Phy
MCS5	π/2 BPSK	13/16	1251.25	Single Carrier Phy
MCS6	π/2 QPSK	1/2	1540	Single Carrier Phy
MCS7	π/2 QPSK	5/8	1925	Single Carrier Phy
MCS8	π/2 QPSK	3/4	2310	Single Carrier Phy
MCS9	π/2 QPSK	13/16	2502.5	Single Carrier Phy
MCS10	π/2 16 QAM	1/2	3080	Single Carrier Phy
MCS11	π/2 16 QAM	5/8	3580	Single Carrier Phy
MCS12	π/2 16 QAM	3/4	4620	Single Carrier Phy

60 GHz

802.11ad PHY: Beacon Interval

LigoWave

- Beacon Header Interval (BHI) – all at MCS0
  - ***Replaces single beacon to transmit multiple beacons in different directions***
  - Beacon Transmission Interval (BTI): Series of directional beacon frames
  - Association Beamforming Training (A-BFT): Beamforming training for individual STA (8 slots in 802.11ad, 40 slots in 802.11ay)
  - Announcement Transmission Interval (ATI): Management frame exchange between AP and beam-trained STA (reduces BTI size so management info only transmitted to beamforming-trained stations)
- Data Transmission Interval (DTI)
  - Contention-based access periods (CBAP), consistent with standard 802.11 ECDA
  - Scheduled service periods (SP), such as TDMA or Polling (e.g. PCF)



https://ieeexplore.ieee.org/document/8088544

60 GHz

802.11ay Enhancements

LigoWave

EDMG: Enhanced Directional Multi-Gigabit PHY

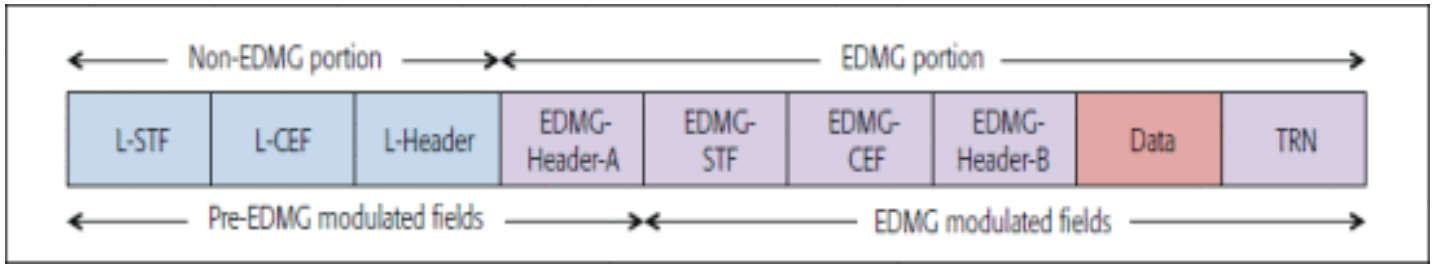
- Potential data rates: 20 – 40 Gbps (originally pitched as 100 Gbps)
- Channel bonding / aggregation
  - Up to 4 bonded channels (8.64 GHz channel)
  - Either adjacent (bonding) or non-adjacent (aggregation)
- MIMO and MU-MIMO (downstream)
- Up to eight spatial streams in spec (likely up to four in real chipsets)
- OFDM: 64 QAM and 256 QAM support
- Hybrid analog/digital beamforming
- Higher density client load (up to 40 clients w/ bonded channels)
- Backward compatible to 802.11ad
- Claimed Range: 300 – 500m (< 1 mile)

60 GHz

802.11ay PHY Structure

LigoWave

- Legacy Portion (non EDMG)
  - L-STF: Legacy Short Training Field
  - L-CEF: Legacy Channel Estimation Field
  - L- Header: Legacy Header (some re-definition of bits)
    (transmission duplicated on each bonded channel)
- EDMG Portion
  - EDMG Header A: Bandwidth, MCS, # bonded channels, # streams
    (transmission duplicated on each bonded channel)
  - EMMG-STF / CEF: utilized for MIMO / channel bonding
    (transmitted in bonded and/or MIMO mode)
  - EDMG Header B: MU-MIMO
    (transmitted in bonded and/or MIMO mode)
- TRN: Training Field for beamforming



https://ieeexplore.ieee.org/document/8088544

60 GHz

802.11ay MAC

LigoWave

- Modulation Types
  - BPSK
  - QPSK
  - 16 QAM
  - 64 QAM
  - 256 QAM
- LDPC Coding
  - 1/2
  - 5/8
  - 3/4
  - 13/16
  - 7/8 (added in 802.11ay)
- Other enhancements
  - Additional beamforming training slots in secondary channels to support higher density of clients
- Transmit Opportunities (TXOP)
  - Needed for MIMO and MU-MIMO operation
  - Binds channel with RTS or CTS-to-Self
- Beamforming training
  - MIMO / MU-MIMO
  - Asymmetric links

60 GHz

Takeaway: Benefits and Issues in PTP/PTMP

LigoWave

- Primary Benefits
  - Very high bandwidth from large channel sizes
  - Virtually no interference, even from nearby links, due to high directionality from phased antenna arrays
- Primary Issues: Limited Link Range and Link Stability
  - High attenuation due to oxygen absorption
  - Variable attenuation due to weather effects (can lose the link in bad weather)
  - Achieving and maintaining link alignment
    - Small, high gain antenna arrays
    - Very limited angular beamwidth
    - Real-time beamforming

Practical limit of link is ~ 1000 feet / 300 m. Good for high-bandwidth/short-distance or interference-free/short distance.