OFDM, HT and VHT PHY reference sheet in the 5GHz-band

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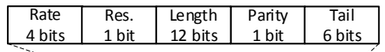
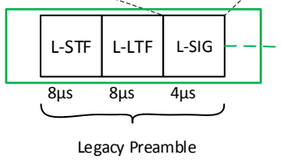
Start of a frame, common for all PHY-types

Legacy Signal Field (24 bits, 4µs)
48 coded bits on 48 subcarrier
24 batabits, BPSK, ½ binary convolution code (BCC)
48 subcarriers for coded bits
4 subcarriers for pilot
3,2µs OFDM-symbol + 0,8µs cyclic prefix

Databits
- Rate, 4 bits, 8 levels
---data rate (6,9,12,18,24,36,48,54),
---modulation (BPSK,QPSK,16-QAM, 64-QAM
---coding (½, ¾,2/3)
Reserved bit for future use, 1 bit
Length, 12 bits, amount of data in octets
Parity, 1 bit, to give even parity over the first 17 bit
Tail, 6 bits, all zeros, used to flush the encoder/ decoder





Legacy Preamble

Legacy Short Training Field (8µs)
10 reps of 0,8µs symbol
12 of 52 subcarriers
(-24,-20,-16,-12,-8,-4,4,8,12,16,20,24)
Start-of-packet detection
AGC (automatic gain control)
Initial frequency offset estimation
Initial time synchronization

Legacy Long Training Field (8µs)
Two 3,2µs long training symbols prepended by a 1,6µs cyclic prefix
52 subcarriers (-26 to 26, except 0)
Channel estimation
More accurate frequency offset estimation and time synchronization

Legacy Preamble on several transmit chains
Legacy preamble is transmitted as single stream on all antennas/chains. If no cyclic shift on several antenna -> large variation between power of the L-STF and Data field. Therefore: legacy preamble is cyclic shifted between the antenna chains, uptil 200ns

OFDM datafield. This field are common for all PHY-types

Data Field
Service Field:
- first 7 bits scrambler initialization bit, all zeros
- last 9 bits are reserved and all zeros
Data Field (data bits) MSDU
Tail bit, 6 bits, all zeros
Pad bits, all zeros, to fill up last data symbol
3,2µs OFDM-symbol + 0,8µs cyclic prefix
4 subcarriers: pilots used for phase/freq tracking and training (-/ +21, -/+7)
48 subcarriers for databits(-26 to 26 except pilots)

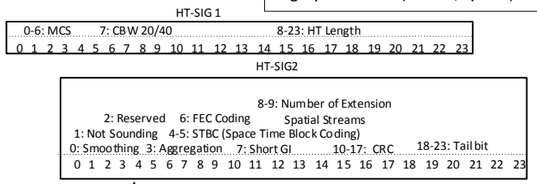
How to differentiate the first symbol after L-SIG
The next symbol after L-SIG is either legacy OFDM-data (a/g), HT-SIG1(n) or VHT-SIG-A1(ac)
Basic: compute a metric based of power on the real part of the subcarriers averaged over the 48 subcarriers minus the power of the imaginary part of the same subcarrier.

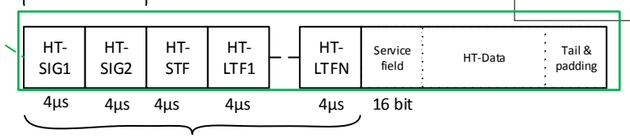
OFDM (803.11a)
- This is the start of the data, the Servicefield and the MAC-header
- The metric gives a large positive number for BPSK to 0 for QAM
HT (803.11n)
- First symbol is the HT-SIG1 and the HT-SIG1 is rotated 90° (QBPSK) and it gives will give a large negative number.
- No real power and a lot imaginary power
VHT (803.11ac)
- First symbol is the VHT-SIG-A1, then the VHT-SIG-A2
- VHT-SIG-A1 is ordinary BPSK (the same as legacy OFDM at 6Mb/s)
- VHT-SIG-A2 is rotated 90° (QBPSK), so BPSK+QBPSK indicate i VHT preamble
So
- If it detects QPSK or QAM the symbol and packet is legacy OFDM (11a), 803.11a data
- If it detects QBPSK the symbol and packet is HT preamble
- If it detects BPSK at the first symbol and OBPSK at the second symbol it is VHT preamble

HT preamble and the datafield

HT-SIG 1 and HT-SIG2
Legacy 6Mb/s
BCC encoded, BPSK, coding ½
QBPSK(BPSK rotated 90°relative to L-SIG)
Legacy subcarrier (48data/4pilots)

HT-SIG1 and HT-SIG2
MCS: 0-76 (modulation, coding and spatial streams)
CBw 20/40: Indicate 20 or 40MHz transmission
HT Length: 0-65.535 bytes
Smoothing: for TxB
Not sounding. For TxB, 0-sounding packet
Reserved: always set to 1
Aggregation: 0= single MPDU 1= A-MPDU
STBC: 0= no STBC, 3=reserved, 1 or 2= STBC
FEC Coding: 0=binary convolutional coding (BCC), 1= LDPC coding
Short GI: 0=800ns, 1=400ns
CRC: protect 33 bit (HT-Sig1 and bit 0-9 of HT-SIG2)

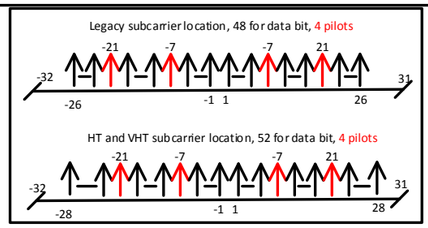




HT Preamble

HT-STF
More accurate power estimates for AGC
Cyclic shift up til 600ns depended of number of spatial streams
Same subcarriers as L-STF

HT-LTF (HT-LTFn)
4µs long training symbol (lts) for each spatial stream (3ss=4lts)
Same cyclic shifts as HT-STF
56 subcarriers are filled with LTS (both 52 data and 4 pilot) -> not able to perform phase tracking during HT-LTF
First time with 52 subcarrier at 20MHz



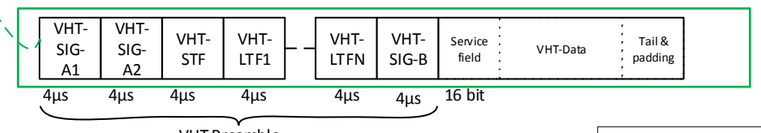
L-SIG Length
Legacy OFDM: amount of data been transmitted
HT: rate is set to 6mbs and length set so that legacy devices defer transmission for at least the duration of the HT-packet. More accurate HT-Length is set in HT-SIG1 where Length represent the amount of bytes. HT could ignore Length in L-SIG
VHT???

VHT preamble and the datafield

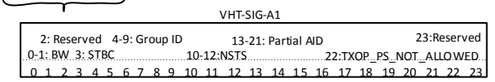
VHT-STF
Switch to VHT waveform
More accurate power estimates for AGC
Cyclic shift depended of number of spatial streams, 1-4ss same as HT
12 subcarriers between -28,28 at 20MHz
4µs symbol and 800ns GI (cyclic prefix)

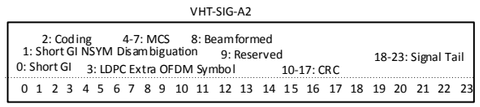
VHT-LTF (VHT-LTFn)
4µs long training symbol (LTS) for each spatial stream (uptil 8)
With pilot subcarrier for phase tracking. (not in HT-LTF)
Channel estimation during first VHT-LTF, then during subsequent LTS pilot subcarriers are equalized and the phase rotation is tracked and corrected

VHT-SIG-B
Primary usage for signaling user specific information for MU-packets. For SU-packet the VHT-SIG-B is still included in all packets. Receiver not required to process this field in SU-packet
BPSK, BCC ½ modulation over 52 subcarriers



VHT Preamble





VHT-SIG-A1 and VHT-SIG-A2
Legacy 6Mb/s
BCC encoded, coding ½
Symbol VHT-SIG-A1 : BPSK
Symbol VHT-SIG-A2:QBPSK (BPSK with 90° rotation
Legacy subcarrier (48data/4pilots)

VHT-SIG-A1 and VHT-SIG-A2
BW: 0=20MHz, 1=40MHz, 2=80MHz, 4=160MHz or 80+80MHz
Reserved: set to 1
STBC: 0=no STBC, 1= STBC
Group ID: mainly for MU packets, SU-packet to AP=0, other SU-packet=63
NSTS: number of space-time streams 0=1 space-time stream or spatial steam
Partial ID: for SU packet, the AID from MAC sublayer. For power save
TXOP...: a new VHT TXOP power save, not widely supported
Short GI: 0=800ns, 1=400ns
Short GI NSYM Disambiguation: used together with short GI
Coding: 0=BCC, 1=LDPC
LDPC Extra OFDM Symbol: used together with LDPC-coding
MCS: 0-9 (modulation and coding, not spatial streams)
Beamformed: 1=beamforming steering matrix, otherwise =0
Reserved: set to 1
CRC: protect 33 bit (VHT-SIG-A1 and bit 0-9 in VHT-SIG-A2)
Signal tail: to make VHT-SIG-A1 and VHT-SIG-A2 = 48 bit