OFDM-based 802.16.3 sub-11 GHz BWA Air Interface Physical Layer proposal

IEEE 802.16 Presentation Submission Template (Rev. 8)

Document Number:

IEEE 802.16.3-00/30

Date Submitted:

2000-10-30

Source:

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Venue:

[Cite the specific meeting and any known agenda details.]

Base Document:

This presentation illustrates IEEE 802.16.3c-00/30, http://ieee802.org/16/tg1/contrib/802163c-00_30.pdf

Purpose:

To present an OFDM based PHY proposal for 802.16.3 TG3

OFDM-based PHY Initial Proposal for 802.16.3 PHY

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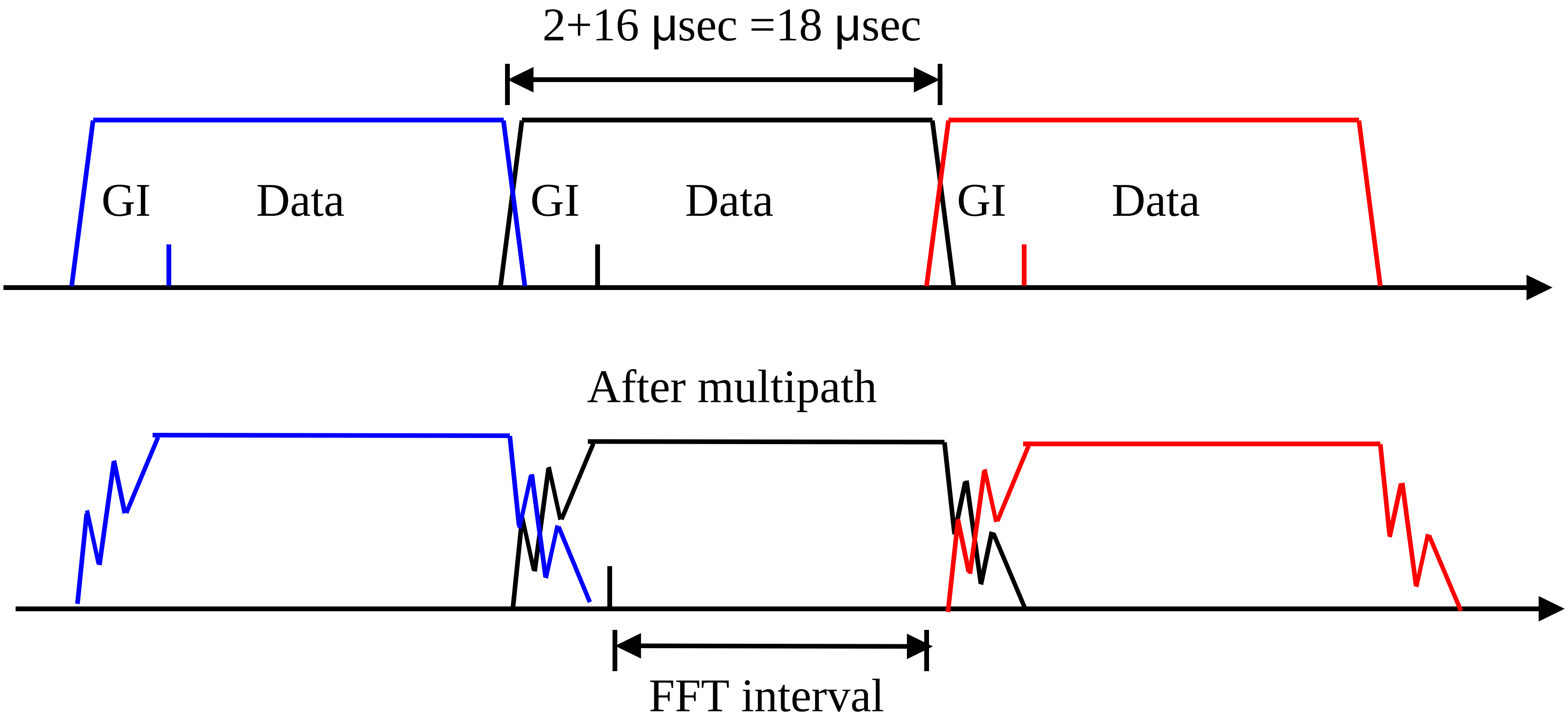
Why OFDM?

- Multipath robustness
- Incorporated in data-oriented standards
  - 802.11a: WLAN
  - HIPERLAN/2: WLAN with QoS
- Incorporated in broadcast standards
- Facilitates smart antenna techniques in multipath environment
- Enables fast parallel polling

Guard Interval and FFT Interval



FFT size tradeoffs

- GI is dictated by multipath duration
- Short FFT advantages
  - Shorter training sequences
  - Lower payload size granularity
  - Phase noise tolerance
- Long FFT advantages
  - Lower GI overhead and pilot symbol overhead
  - Steeper spectrum falloff
  - Facilitates OFDMA

Throughput vs. FFT size

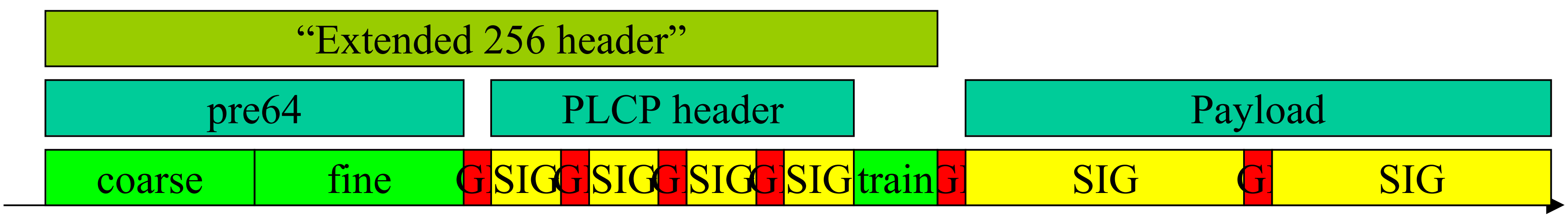
- 64 pt FFT mode
  - 48 data subcarriers, 4 pilot subcarriers
- 256 pt FFT mode (optional gear shift)
  - 208 data subcarriers, 8 pilot subcarriers
    - Faster spectral falloff is utilized to increase the fraction used.
- 16 pt Guard Interval in all modes (4 us @ 3.5 MHz)
  - Once the 64 pt FFT is used only in a small part of the packet, the incentive to decrease the GI reduces
- The 256 subcarrier mode provides
  - 27% rate improvement with 16 pt GI,
  - 18% rate improvement with 8 pt GI
- 1024 mode buys additional 6% or 3%, respectively

Which FFT size to use? Both!

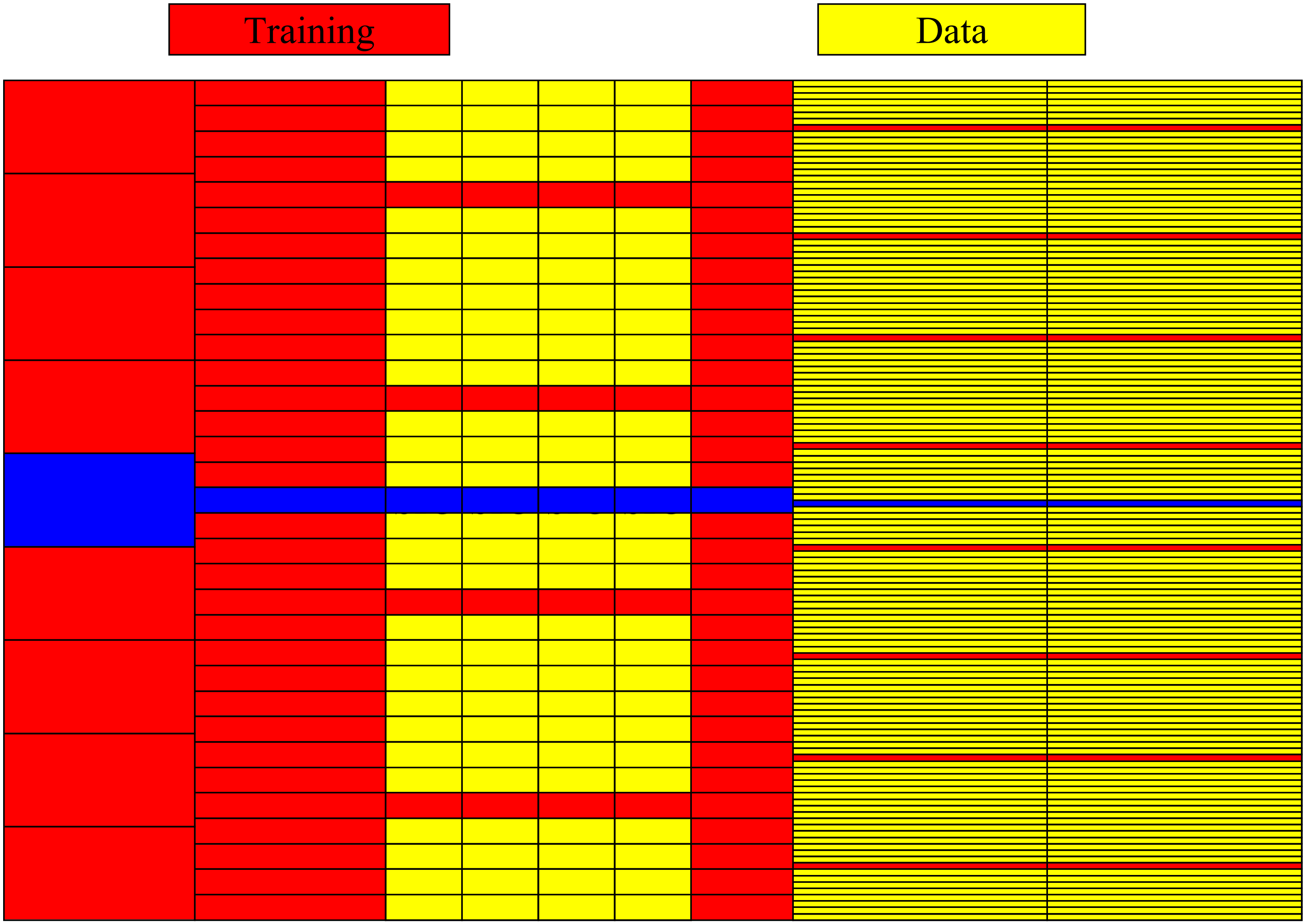
- 64 pt FFT is used in HIPERLAN and 802.11a
- Many proposals sympathize with longer FFT, mainly 256
  - Couple of proposals go higher- 512, 2048
- Pure 256 and beyond is not efficient due to preamble size
  - Unless radically new preambles designed
- Solution – a FFT size switchover

FFT size switchover solution

- Start with FFT size 64 preamble
  - similar to 802.11a and HIPERLAN/2
- Transmit the PHY header at FFT size 64
  - The receiver uses the header for refining the carrier tracking loop frequency estimate
- Send short sequence to retrain loops
- Transmit payloads at FFT size 256



Time-frequency view

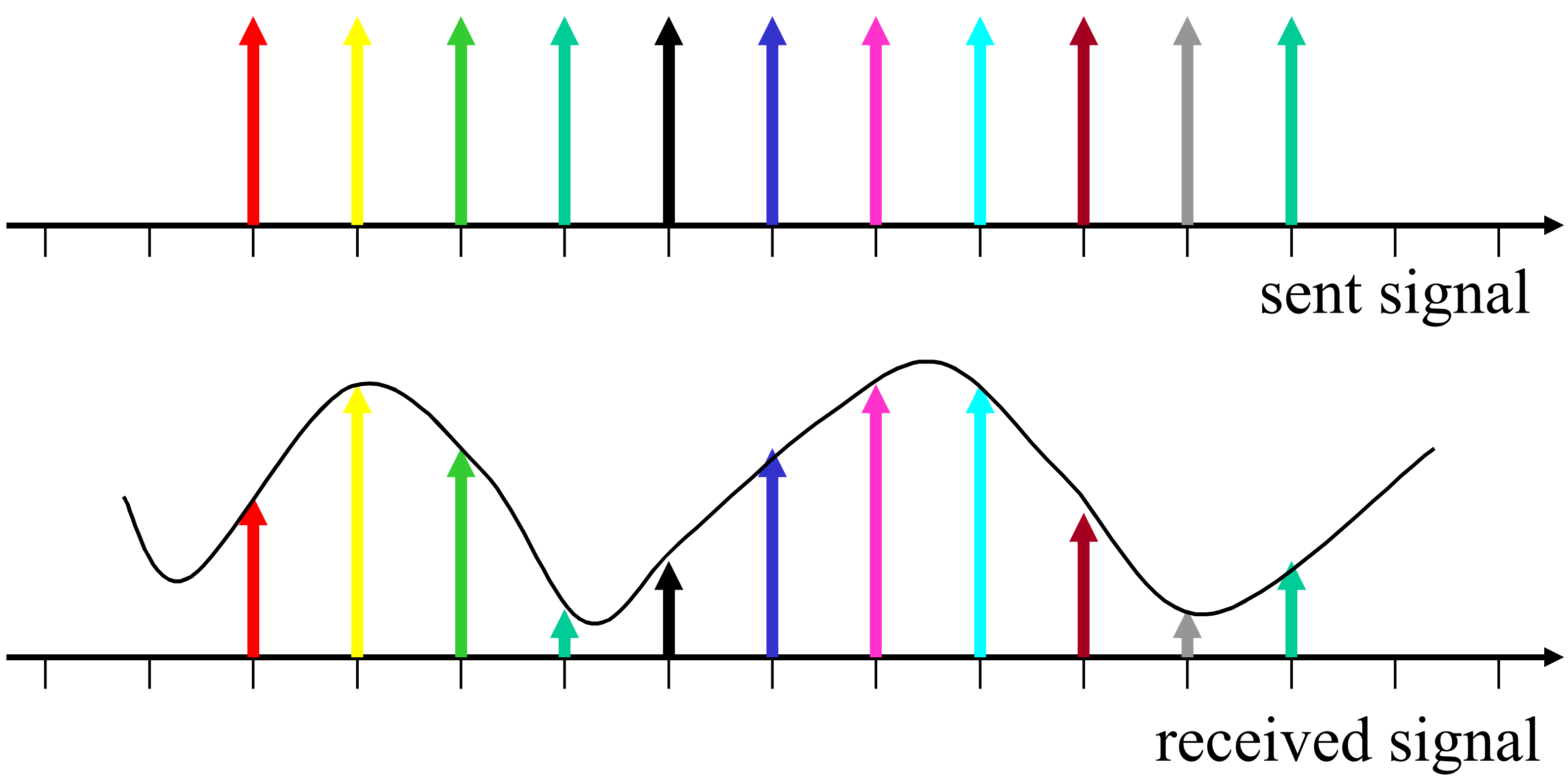


Modulation Constellations

- Use square QAM constellations only
  - Metrics extracted from I or Q separately
    - Significant implementation simplification
    - Not possible for 8PSK, 32QAM, 128QAM
  - ECC rate compensates for excess bits
- BPSK+4/16/64 QAM on downlink
  - 256 QAM optional
- BPSK+4/16 QAM on uplink
  - 64,256 QAM optional

Multipath effect on subcarriers

- Each subcarrier is scaled according to the channel, but they still do not interfere with each other



Error Correction Coding

- Convolutional code shall be used as a baseline mandatory mode.
  - K=7, R=1/2, 2/3, 3/4; terminated tail
    - Optional R=7/8
- Interleaver is needed to avoid adjacent faded bits
- Turbo Codes shall be used as an option with FFT-256 mode
  - One BTC block per one OFDM symbol
    - Possibly per integer number of OFDM symbols
  - BTC parameters chosen per constellation+rate

Modulation, ECC and Data Rates

3.5 MHz wide channels, 52 subcarriers, 12.5% guard interval

Modulation	Coding rate	Data Rate	Sensitivity
BPSK	R=1/2	1.33 Mbit/s	-94
BPSK	R=3/4	2.00 Mbit/s	-93
QPSK	R=1/2	2.67 Mbit/s	-91
QPSK	R=3/4	4.00 Mbit/s	-87
16QAM	R=1/2	5.33 Mbit/s	-86
16QAM	R=3/4	8.00 Mbit/s	-82
64QAM	R=2/3	10.67 Mbit/s	-78
64QAM	R=3/4	12.00 Mbit/s	-77
256QAM	R=2/3	14.22 Mbit/s	-73
256QAM	R=3/4	16.00 Mbit/s	-71

Sensitivity assumes NF=6 dB and 4 dB implementation loss

Data Rates with 256pt FFT

3.5 MHz wide channels, 216 subcarriers, 3.1% guard interval

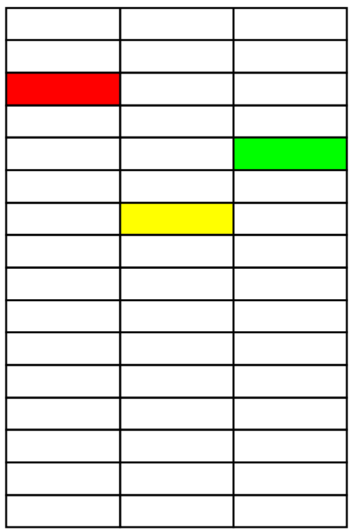
Modulation	Coding rate	Data Rate	Sensitivity
BPSK	R=1/2	1.62 Mbit/s	-94
BPSK	R=3/4	2.44 Mbit/s	-93
QPSK	R=1/2	3.25 Mbit/s	-91
QPSK	R=3/4	4.87 Mbit/s	-87
16QAM	R=1/2	6.50 Mbit/s	-86
16QAM	R=3/4	9.75 Mbit/s	-82
64QAM	R=2/3	13.00 Mbit/s	-78
64QAM	R=3/4	14.62 Mbit/s	-77
256QAM	R=2/3	17.33 Mbit/s	-73
256QAM	R=3/4	19.50 Mbit/s	-71

Sensitivity assumes NF=6 dB and 4 dB implementation loss

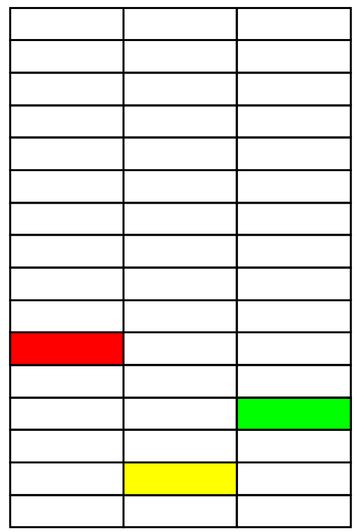
Subcarrier based parallel polling

- Fourier Transform allows simultaneous detection of multiple subcarriers sent by multiple users
  - Extreme case of OFDMA combined with On-Off Keying with 1 subcarrier per user.
- CDMA-like, but preserves orthogonality
- Concentrates power, allows higher SNR
- Permute frequencies in each superframe to avoid prolonged fades

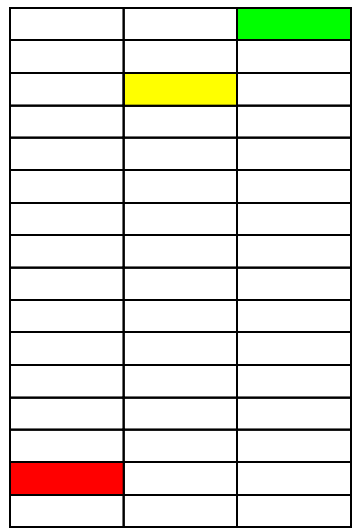
Subcarrier based polling



Frame 1



Frame 2

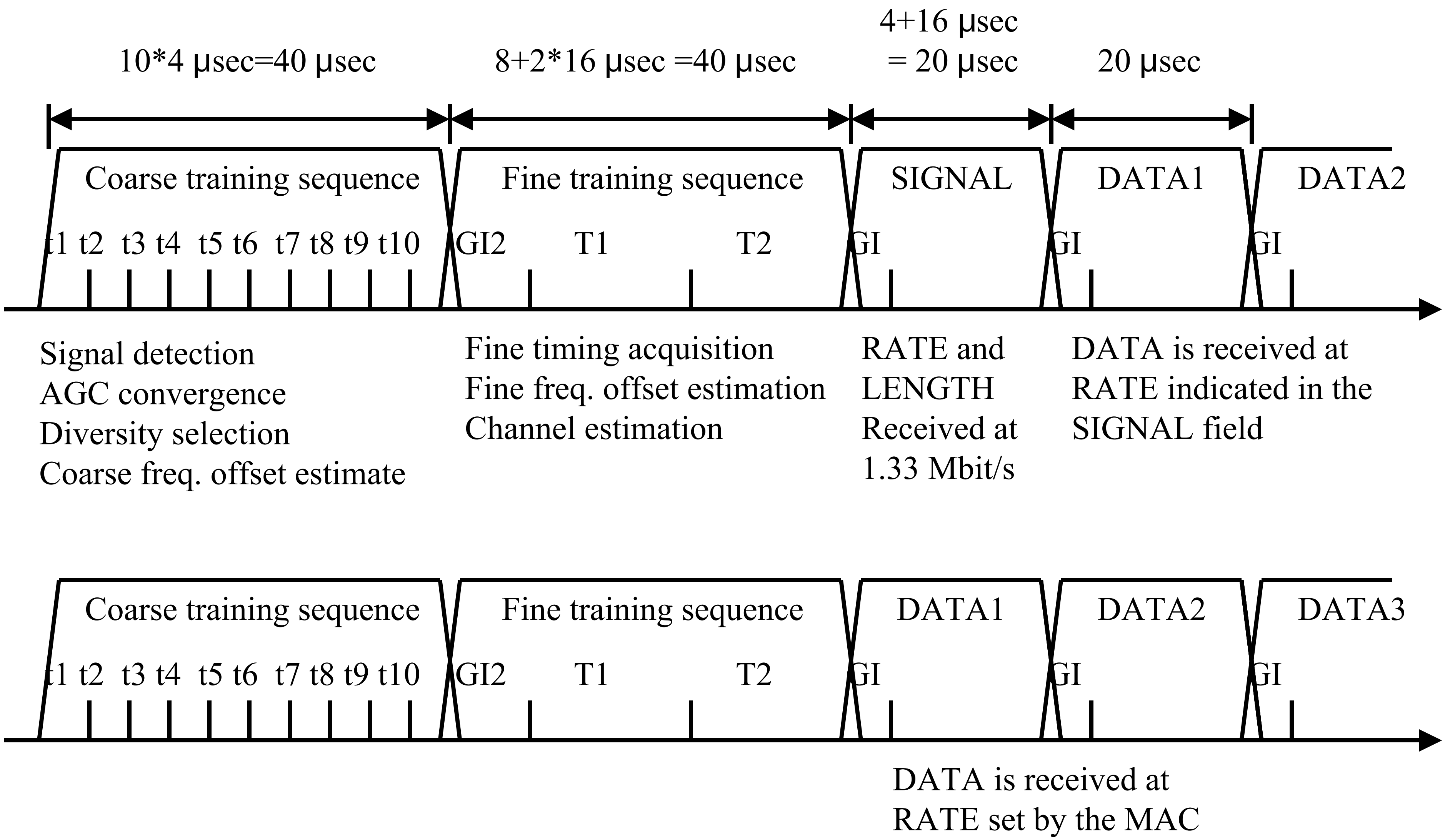


Frame 3

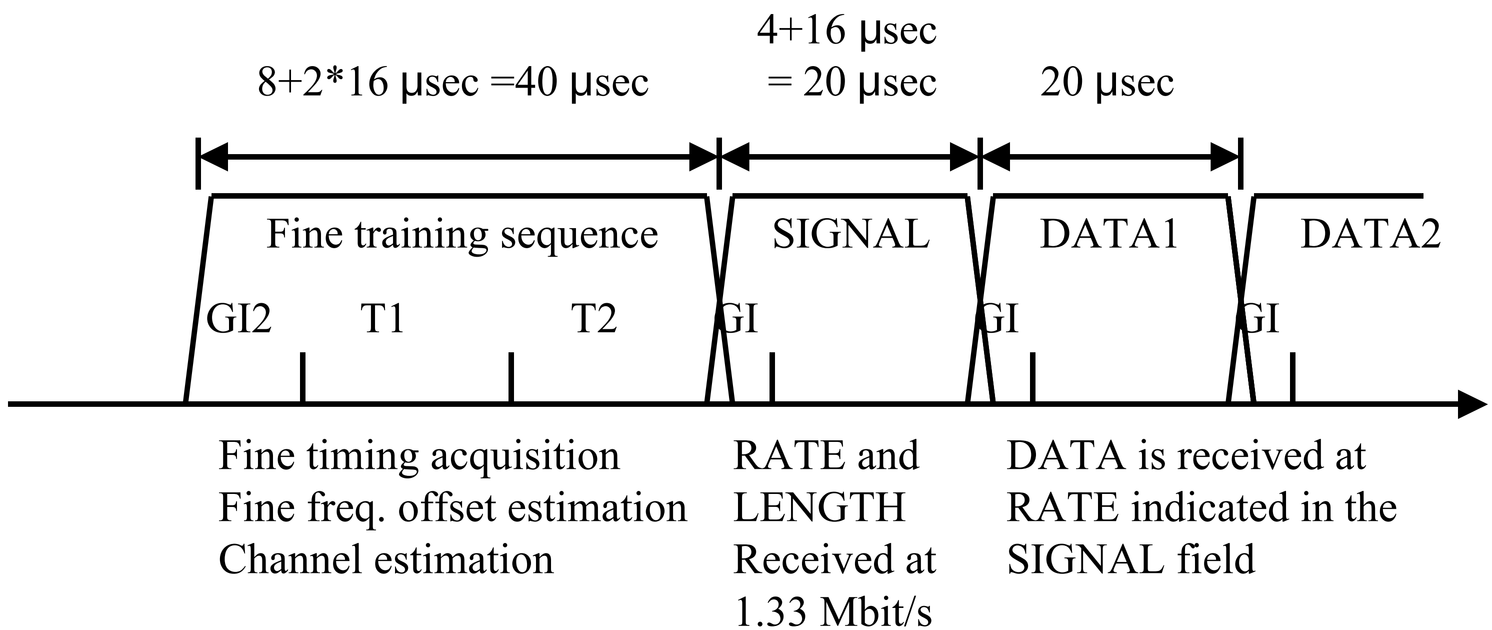
Preamble Structures

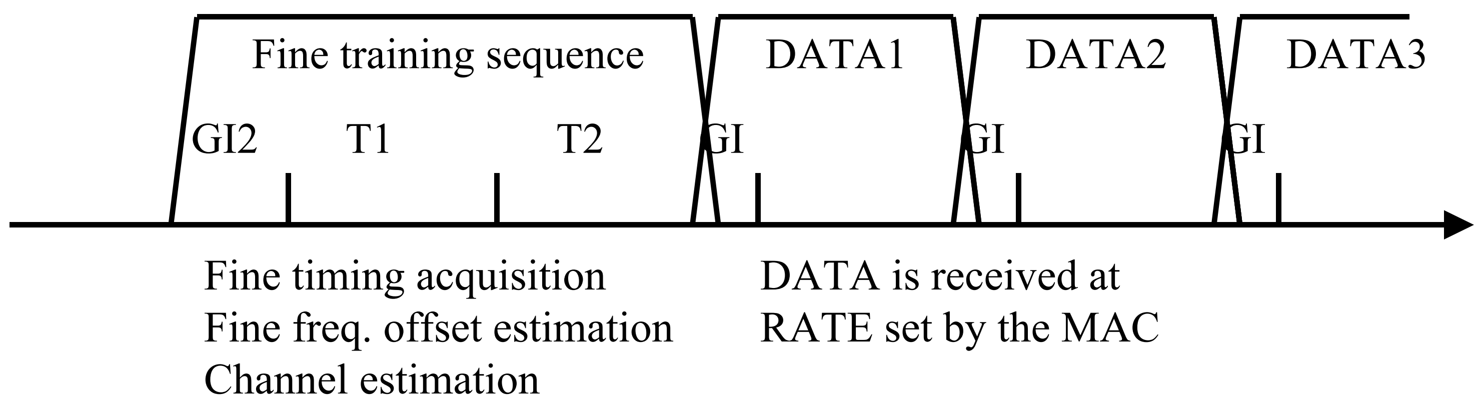
- The preamble is used to estimate
  - Antenna diversity selection and AGC convergence
  - Coarse, then fine **frequency** offset
  - Coarse, then fine **timing** offset
  - Channel response
- More prior knowledge allows shorter preambles
  - Gain preadjusted by transmit power control
  - Coarse frequency offset known from prior transmissions
  - Timing preadjusted by ranging and timing advance

Preamble for Initial Acquisition



Preamble for Re-Acquisition





Optional Advanced Techniques

- OFDMA
  - The OFDM preserves orthogonality between transmissions of different users
  - Allows survival at higher path loss
- Space-Time coding
  - The decoupling between equalization and coding plays important role in making those techniques practical
  - New preambles need to be designed for training of response from multiple antennas

Peak2Avg Problem- How bad?

- Worst case peaks are *kN* times the average
  - *N* is the number of subcarriers
  - *k* is constellation dependent, about 2-4 dB
  - 20 dB for *N*=52, 26 dB for *N*=216
- Central Limit Theorem (sum of many small contributions) → amplitude is Rayleigh
- Worst peak in a typical packet is +10 dB
- Some clipping can be tolerated!!
  - OFDM spreads clips over subcarriers
  - Error Correction Coding improves robustness
- Typical PA backoff – 7-9 dB
  - Depends on constellation and on regulatory masks

BRZE's OFDM proposal Summary

- Parameters draw on 802.11a+HIPERLAN/2 standards
  - Available technology
- Improved performance modes
  - Longer FFTs, improved ECCs
- Fast Parallel Polling for fast demand discovery
- Ready for advanced antenna and multiaccess techniques