

# Channel estimation issues for TDD and FDD OFDM

Document Number:

IEEE 802.16.3p-00/57

Date Submitted:

2000-11-27

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Venue:

IEEE 802.16 Session #11, Ottawa Canada

Base Document:

None

Purpose:

Bring to attention the importance of channel estimation in OFDM systems, Particularly how TDD and FDD technology affected such measurements.

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# Channel estimation issues for TDD and FDD OFDM

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# Position

- Talk not intended to encourage/discourage.
  - Single carrier /Multi carrier
  - TDD /FDD

—Virtually any combination of technologies can work for 802.16
- OFDM has been designed for TDD and FDD.
- OFDM performance is highly dependent on Channel estimation accuracy.
- FDD provides for excellent channel estimate due to long time averaging
- TDD OFDM should have pilot training within the payload to improve channel estimates

# Required OFDM Receiver Processing

- Carrier recovery
  - Ensures carriers remain orthogonal to each other
- Sampling rate timing recovery
  - Synchronous sampling rate ensures carriers remain orthogonal to each other
- FFT symbol period starting location
  - Ensures we avoid multipath-corrupted signaling section
- **Channel estimation**
  - Determine channel impulse response (in frequency domain)
- Channel equalization/Compensation
  - Recovers all carriers back to their original format (in amp and phase)
  - Need to perform a non-linear operation of  $1/x$
- FEC decoding

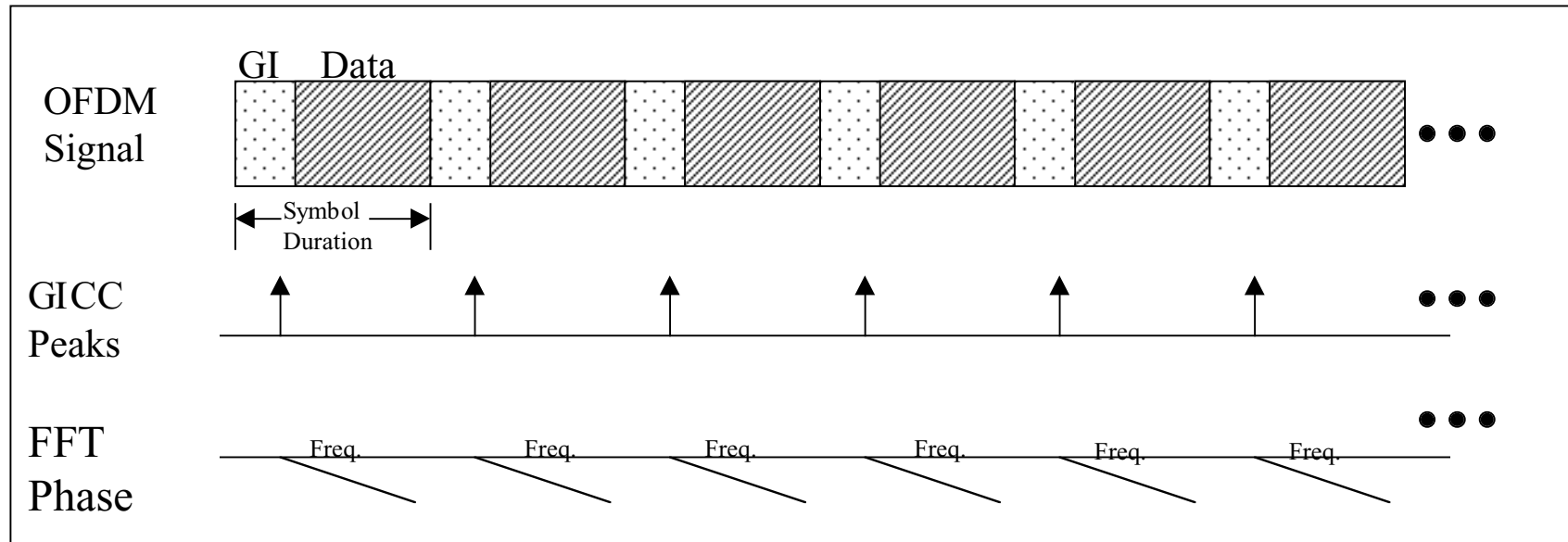
# Importance of Channel Estimation

- Needed to compensate for amplitude and phase correction.
- Pilots used with known amplitude and Phase.
- Can be part of the preamble (a la 802.11a) or
- Distributed in the frequency domain (a la DVB-T)
- **Must be accurate**
  - Ultimately a  $(1/x)$  operation is performed:
    - Inverts the channel for multipath compensation
    - Can create non linear  $1/x$  noise enhancement if estimate is noisy
    - Problem is more critical as SNR drops and/or constellation density increases
- **Averaging** is used to get good channel estimates! 5

# Guard Interval (GI) Processing.

- Almost all FDD OFDM systems exploit GI for synchronization (other techniques are possible)
- Compute Complex GI cross-correlation (GICC).
- GICC resulting peaks are used to:
  - Derive a synchronous sampling clock
  - Calculate frequency offset to within  $\pm$  FFT bin spacing
  - Determine end of GI and beginning of FFT data
- Peak location is not critical since GI is long
  - BUT: Will affect each FFT bin phase

# FFT phase Relationships between OFDM symbols (FDD)



- Amount of induced FFT bin phase rotation will depend on the peak location (delay) where data is extracted for FFT processing

# FDD OFDM

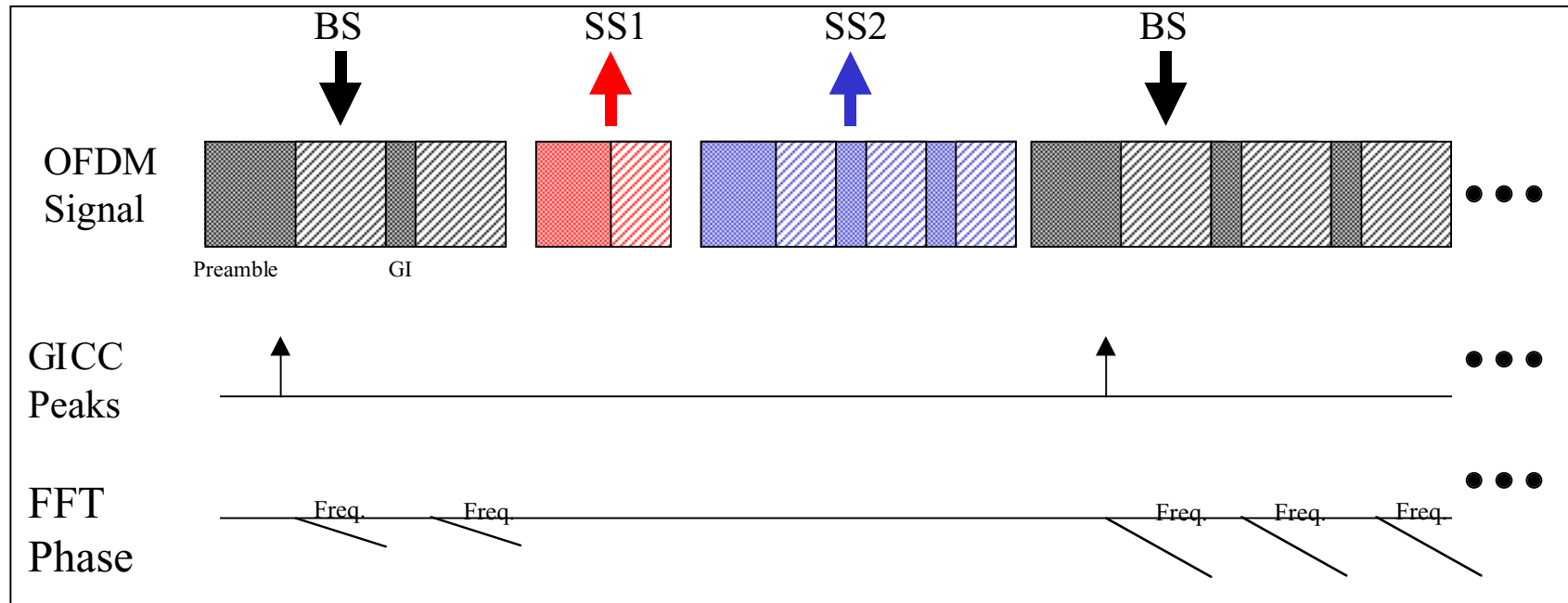
- Continuous OFDM allows for **Freq/phase locking** to the signal, providing:
  - Continuous tracking of offsets (carrier, sampling rate etc)
  - Consistent starting point (W.R.T. the guard interval) to extract data for FFT processing
  - Consistent phase rotation across FFT bins for each OFDM symbol.
  - Consistent phase rotation from one OFDM symbol to the next allows for time averaging of the I/Q pilot data.**
  - Time averaging provides for good channel estimates, allowing high spectral efficiency.**



# Preamble Processing

- Burst TDD OFDM requires a preamble for Synchronization
- Preamble structure allows for fast and complete reacquisition
  - Signal detection, carrier offset, sampling offsets etc.
  - Channel estimate done at start of packet with all bins filled with pilots!
- Need to reacquire signal due to carrier drifts, sampling drifts, channel dynamics etc. for each burst.
  - Channel estimate for each burst may look different
  - Difficult to get good channel estimates since one can't do much averaging (ex: 2 OFDM symbols in 802.11a)

# FFT phase Relationships between OFDM symbols (TDD)



Each downstream burst will have a different phase relationship due to required reacquisition (from channel dynamics, carrier drifts, timing drifts etc).

# TDD OFDM

- Acquisition from burst to burst can have significantly different channel estimate
- Averaging channel estimates from burst to burst may not be possible
- Poor estimates possible due to
  - Channel dynamics
  - From limited averaging
  - Limited training data in the preamble
- A poor channel estimate will result in lower throughput
- Should contain pilot training data within the payload data

# Summary

- Talk only addressed channel estimation problem
  - Ignored other pros and cons of TDD and FDD technology!!!
- Good channel estimation is critical
  - Due to  $1/x$  operation
- FDD OFDM allows for :
  - Time averaging of pilot training data to reduce noise errors
  - Better channel estimates provide high throughput
- TDD burst forces reacquisition from burst to burst
  - Harder to get reliable channel estimates with noise.
  - Highly Impacts constellation density and throughput
  - Should have pilot training data within the payload