Channel estimation issues for TDD and FDD OFDM

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Purpose:

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

Channel estimation issues for TDD and FDD OFDM

- Carl Scarpa

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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

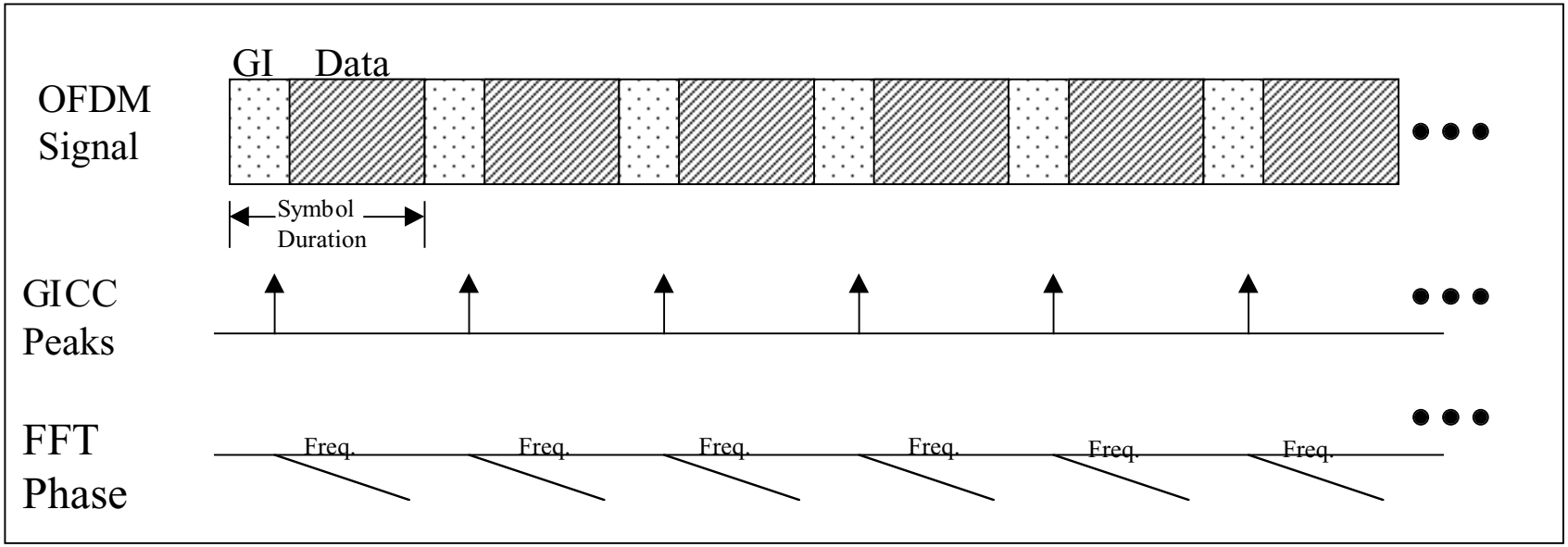
Importance of Channel Estimation

- 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!

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 with +/- _ 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

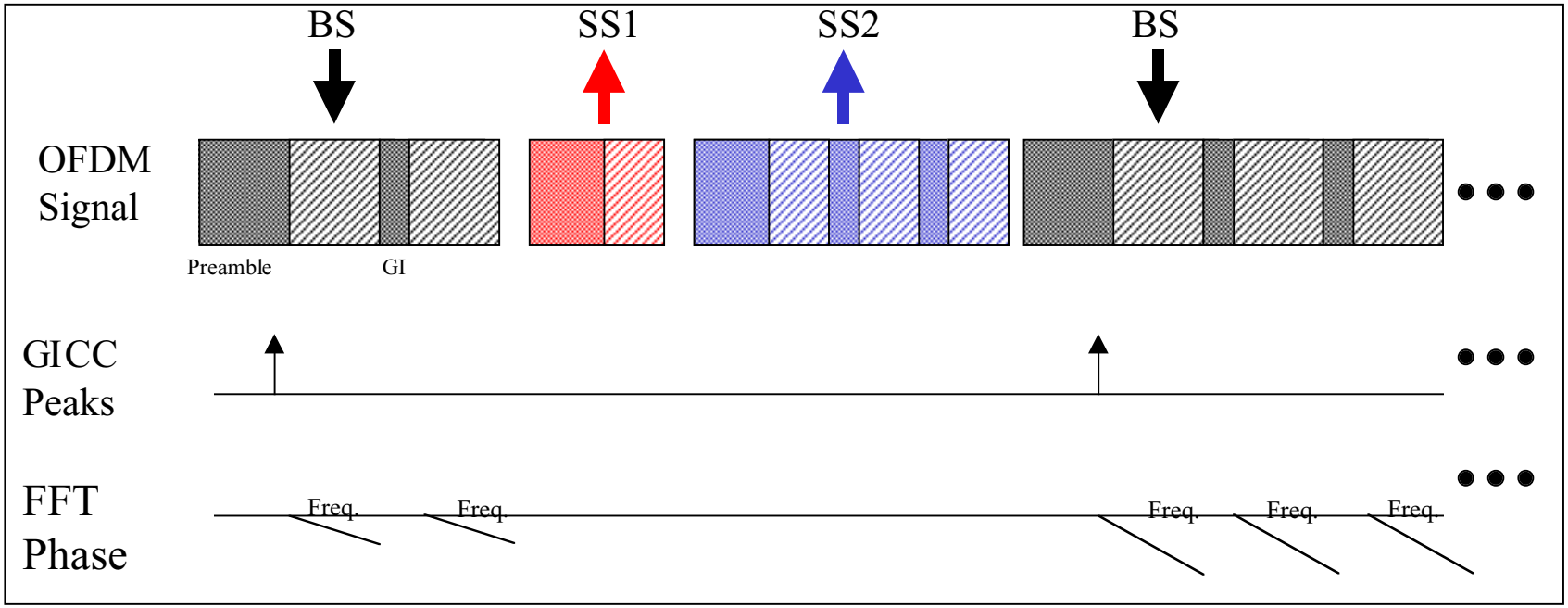
FDD OFDM

- 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 <u>good</u> 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