
Peer reviewed version

Link to published version (if available):
10.1109/VETECS.2006.1683186

Link to publication record in Explore Bristol Research
PDF-document
Robust Synchronisation for OFDM

Dr Chris Williams
Prof. Mark Beach
University of Bristol

Prof. Steve McLaughlin
University of Edinburgh
Overview

- Motivation
- Robust timing synchronisation in multipath and single frequency networks
  - Performance of timing estimators
  - Timing variance reduction
- Multiple antennas for synchronisation
  - Enhanced mobility
- Conclusions
Motivation

Interworking of networks for efficient service delivery
- Broadcast and cellular

Synchronisation for OFDM (multimode)
- Pre-FFT processing to reduce complexity
- Robust in multipath environments and single frequency networks

Need for enhanced mobility
- Particularly for current broadcast standards
Basic Correlation Technique

MLF derived for AWGN channel by Beek

DVB-T : N=2048, G=512

Focus on timing estimate error

![Graphs showing MLF and MLE for AWGN and multipath scenarios]

- **AWGN**
  - Multipath
  - $A=0.4$

- **Multipath**
  - $A=1.5$
Derivative Based Methods

Other techniques too dependent on the actual channel characteristics

Derivative of MLE is maximum near first peak, and has edge shortly after (or negative going zero crossing of 2^{nd}-Derivative)
Simulation Parameters

DVB-T System, 2k mode
Pilot structure & coding (RS & convolutional)

Short cyclic prefix:
- 64 samples (1/32 useful symbol)
- Model (LOS) proposed by Bug
  - Less impact of the equaliser
- Two multipath clusters (2 SFN Tx)
- Estimate filters: 15pt median, 16 pt averaging FIR
Performance - SFN delay

SFN relative power = 0dB, $E_b/N_0=20$dB

Maximum multipath delay exceeds guard interval
Improving Performance
Mobility Limitations

Problem:
- Equalisation fails for higher mobility
- Limit mobility or need more pilots (lower capacity)

Approach:
- Exploit spatial clustering of multipath clusters
- Separate clusters and apply individual synchronisation to each (time and frequency)
- Compresses the effective channel in both domains
  - Reduced Doppler spread
    - Better mobility
  - Reduced delay spread
    - Reduced intersymbol interference
    - Improved performance by reducing the work of the equaliser
    - Tolerate higher transmit oscillator offsets in SFNs
Signal Frequency Network (SFN)

Doppler Spectrum (single antenna)

- Spread for Tx1
- Spread for Tx2

Combined spread

Doppler Spectrum

- Combined spread (after removing individual shifts)
System design

- Integrate synchronisation (time and frequency) into antenna processing
- Antenna processing to separate received signal into clusters (insufficient resolution in time or frequency domain)
- Synchronisation estimation on each derived cluster
- Frequency correction applied per cluster
- Timing correction:
  - Per cluster (pre-combining, pre-CTC)
  - Earliest timing estimate applied to all (post-CTC)
Simulation Parameters

DVB-T System, 2k mode
Pilot structure & coding (RS & convolutional)

Short cyclic prefix:
- 64 samples (1/32 useful symbol)
- NLOS (UN2) multipath model proposed by Bug
  - 8 path, max. delay 3.3\(\mu\)s
- Two multipath clusters (2 SFN Tx)
  - Equal power
  - 3\(\mu\)s delay (27 samples)

Correlation derivative timing estimator
- Estimate filters: 15pt median, 16 pt averaging FIR
- Rules processing enabled
Sectors – 2 cluster model

Cluster (i) path distribution

Doppler shift (j) = \( F_{d,max} \cdot \cos(\phi(j)) \)

Doppler spread (i) = \( F_{d,max} \cdot \left(\theta(i)/360\right) \)

Path (j)

\(-F_{d,max}\) \hspace{1cm} \(F_{d,max}\)

\( \theta(i) \)

\( \phi(j) \)

Angle sweep (700Hz)

Angle (°)

BER

Sectors, fixed cluster at 20°, 700Hz Doppler

A=1

A=2, pre-CTC

A=2, post-CTC

A=4, Pre-CTC

A=4, Post-CTC

Doppler sweep (20° /180°)

Doppler frequency (Hz.)

BER

Sectors, clusters at 20° and 180°

A=1

A=2, pre-CTC

A=2, post-CTC

A=4, Pre-CTC

A=4, Post-CTC
Sectors – measured channels (2GHz)

Sectors, urban channel, 100Hz Doppler

Sectors, urban channel, 700Hz Doppler

Sectors, urban channel, 700Hz Doppler
Summary of results

- Proposed a robust synchronisation method for OFDM for SFN networks with severe multipath
  - Derivative method
  - Low additional complexity
- Performance enhancement
  - Reduction of Spurious errors
  - See rules given in paper
- Application of sectorised antenna in DVB-T terminal
  - Performance gains
  - Analysis with real channel data