Narrowband Interference Mitigation in SC-FDMA Using Bayesian Sparse Recovery

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SC-FDMA and Narrowband Interference (NBI)

Why SC-FDMA?
- Performance comparable to OFDMA
- Additional Advantage of low PAPR
- Used in LTE uplink [1]

NBI Sources
- Coexisting systems in unlicensed bands
- Garage door openers
- Cordless phones etc.

NBI’s Sparse Nature and Impact on SC-FDMA

- NBI is sparse in frequency-domain
- In SC-FDMA data is encoded in time-domain

Single strong interference can completely destroy the data in SC-FDMA.
Sparse Bayesian NBI Recovery

Sparse Signal Recovery

- Exploit NBI sparsity
- Reserve few data-points and solve an under-determined system for NBI recovery [2]

Sparse Signal Recovery Schemes

- Greedy (fast)
  - OMP
  - CoSaMP
  - StOMP

- Bayesian (utilize prior statistics)
  - FBMP
  - SBL

- Convex optimization (robust)
  - BP
  - BPDN
  - LASSO


Support Agnostic Bayesian Matching Pursuit (SABMP)?

- **Acknowledges** Gaussianity of the Noise
- **Agnostic** to the distribution of the *active elements* of the signal
  
  Essential for NBI mitigation

- Multiple Measurement vector SABMP[4]

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Grid Offset precludes direct CS

Model

Solution

Traditional – Windowing [5]

Spectrally contain the spread signal

Proposed – Haar Transform

Not Sparse in Fourier Basis, Expand in Haar Basis

Unitary unlike Windowing (desirable for CS)

Numerical Observation: Better Sparsification

Simulation Results (No Grid Offset)

Performance as good as any other reconstruction scheme

Computational complexity lower than or equal to any other reconstruction scheme

Simulation Parameters:

Subcarriers N=512  Users U=2  Delay Spread N_c=N/4  Modulation 16 QAM

SIR=10 dB  NBI sources 1-4  Reserved data-points 25%

MATLAB codes available from the website of T. Y. Al-Naffouri
Simulation Results (Sparsification)

Gini Index [6]

\[ GI(I') = 1 - 2 \sum_{k=0}^{N-1} \frac{|I'(k)|}{\|I'\|_{\ell_1}} \left( \frac{N-k-\frac{1}{2}}{N} \right) \]

1. Normalized Measure of Sparsity
2. Higher GI -> More Sparse Signal

Observations:

- Fewer NBI Sources: Haar > Windowing
- Plentiful NBI Sources: Windowing > Haar

Simulation Parameters:

- Subcarriers N=512
- Ind. Grid Offsets
- Experiments=1000
- NBI sources 1-6

Simulation Results (Grid Offset)

Simulation Parameters:

- Subcarriers $N=512$
- Users $U=2$
- Delay Spread $N_c=N/4$
- Modulation 16 QAM
- SIR = 10 dB
- NBI sources 1-4

Reserved data-points 25%

$E_b/N_0$ 17.5 dB

70 % to 78%: Relative Increase 11 %
Improving Spectral Efficiency

Four Step Data-Aided Procedure

1. Reserve Few Tones
2. Estimate and compensate for NBI
3. Find Reliable Data Points
4. Estimate NBI using Rel. Data + Res. Points

- Residual not strong
- Most data-points in correct decision regions
- Find a subset of most reliable ones [7]

Simulation Results (Spectral Efficiency)

Simulation Parameters:

- Subcarriers $N=512$
- Users $U=2$
- Delay Spread $N_c=N/4$
- Modulation 16 QAM
- SIR=10 dB
- NBI sources 1-4
- Reliable data-points 12.5%
- Reserved data-points 12.5%

Grid Offset

No Grid Offset

- $E_b/N_0$ (dB) vs. BER
- BER improves by 6 dB with grid offset
- BER improves by 2.5 dB without grid offset
Wider NBI sources

NBI Width > Subcarrier Spacing

- Interleaved sub-carrier assignment
- At basestation: Joint NBI support recovery using MMV-SABMP [4]
- Individual magnitude recovery

Simulation Results (Wider NBI)

Simulation Parameters:
- Subcarriers $N=512$
- Users $U=2$
- Delay Spread $N_c = N/4$
- Modulation 16 QAM
- SIR=10 dB
- NBI sources 1-4
- Reserved data-points 8%
- No Grid Offset

BER vs $E_b/N_0$ (dB) graph with different line types and markers for NBI Impaired, SMV-Recovered, MMV-Recovered, and NBI Free conditions.
Summary

- Interference has a dire impact on SC-FDMA systems
- Compressed sensing can be used to mitigate interference
- SABMP has good performance and low computational complexity
- The grid offset issue can be overcome by using the Haar transform
- The spectral efficiency can be improved by using data-aided approach
- Other structure can be exploited, offered e.g., by wider NBI sources and SIMO systems
Thank you for your attention!

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