Multi-Antenna Interference Cancellation Techniques for Cognitive Radio Applications

Omar Bakr

Ben Wild

Mark Johnson

Raghuraman Mudumbai (UCSB)

Kannan Ramchandran

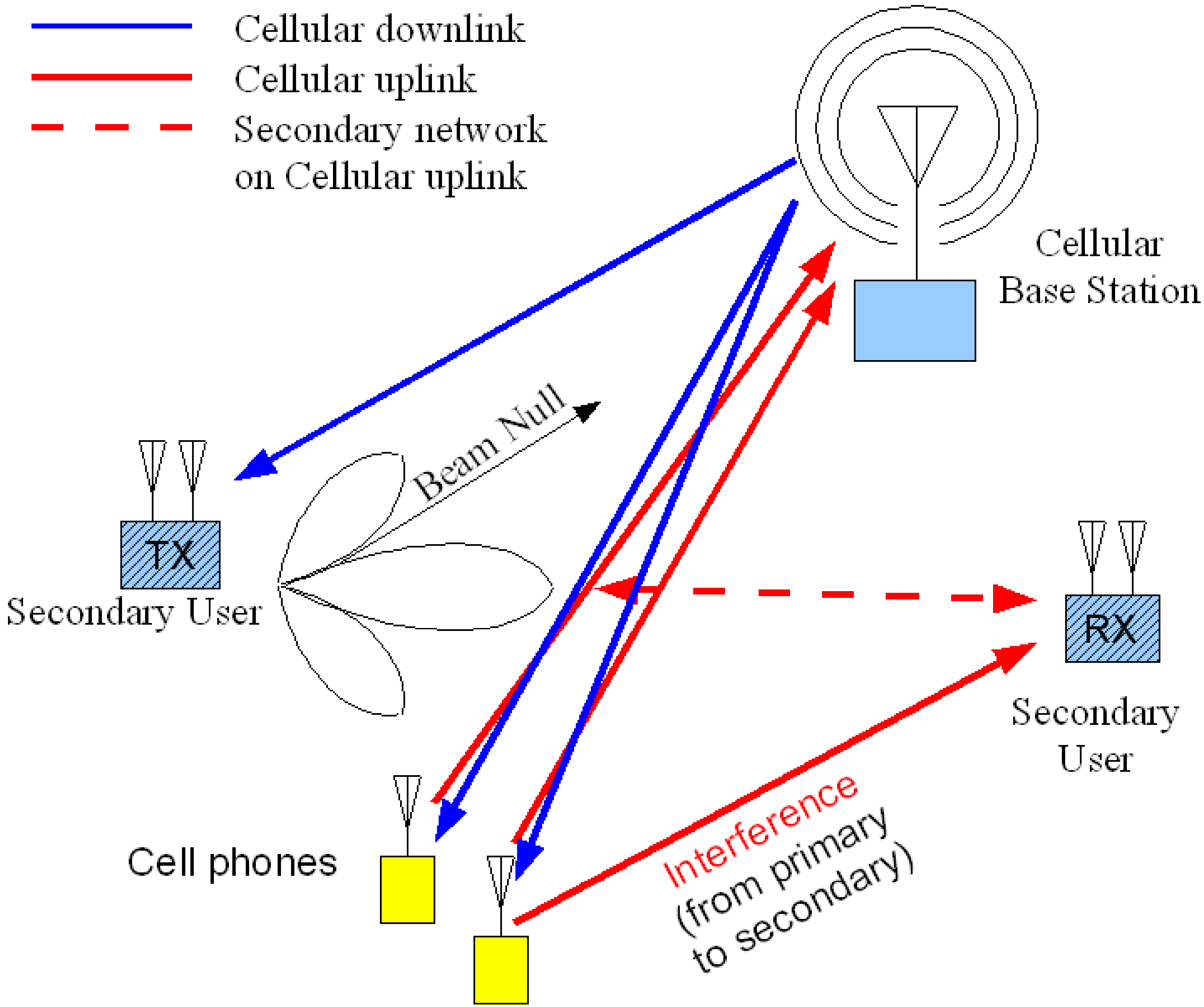
Berkeley Wireless Research Center

Last Time

- Improving spectrum reuse using primary and secondary collaboration[1]
- More effective spatial reuse using multiple antennas on the secondary
- Example: cellular uplink reuse
- Today: signal processing and array processing techniques to improve collaboration
- To appear in IEEE WCNC 2009

[1] O. Bakr, M. Johnson, B. Wild, and K. Ramchandran, “A multi-antenna framework for spectrum reuse based on primary-secondary cooperation,” in *IEEE Symposium on New Frontiers in Dynamic Spectrum Access Networks (DySPAN), October 2008.*

Cellular uplink reuse framework



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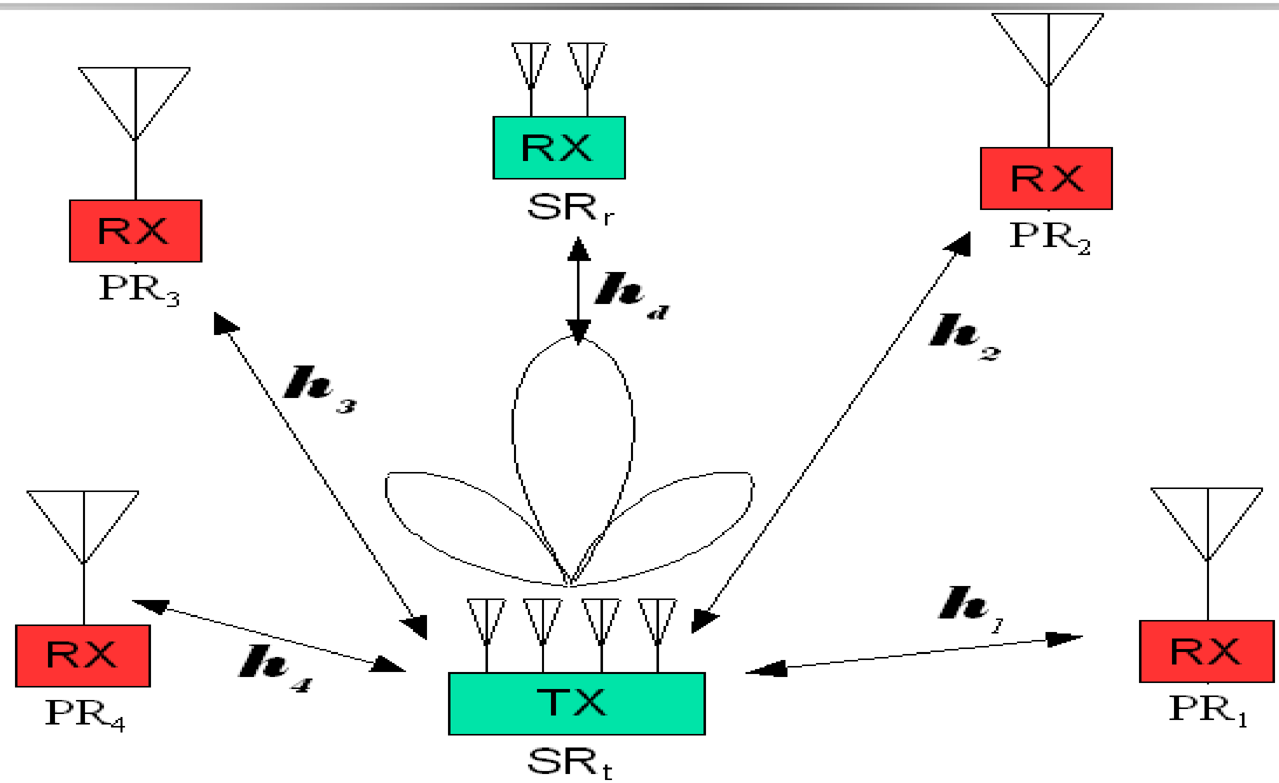
Collaborative framework for interference cancellation



- $\boldsymbol{h}_j$ for $0<j<K+1$ are the channel responses from the secondary transmitter ($\boldsymbol{SR}_t$) to each of K primary users (base stations) respectively.
- $\boldsymbol{h}_d$ is the channel response from $\boldsymbol{SR}_t$ to $\boldsymbol{SR}_r$.
- Choose $\boldsymbol{c}$ to be the component of $\boldsymbol{h}_d$ that is orthogonal to $\boldsymbol{h}_j$ for $0<j<K+1$ (projection)
- Channels unknown apriori? Need to estimate.

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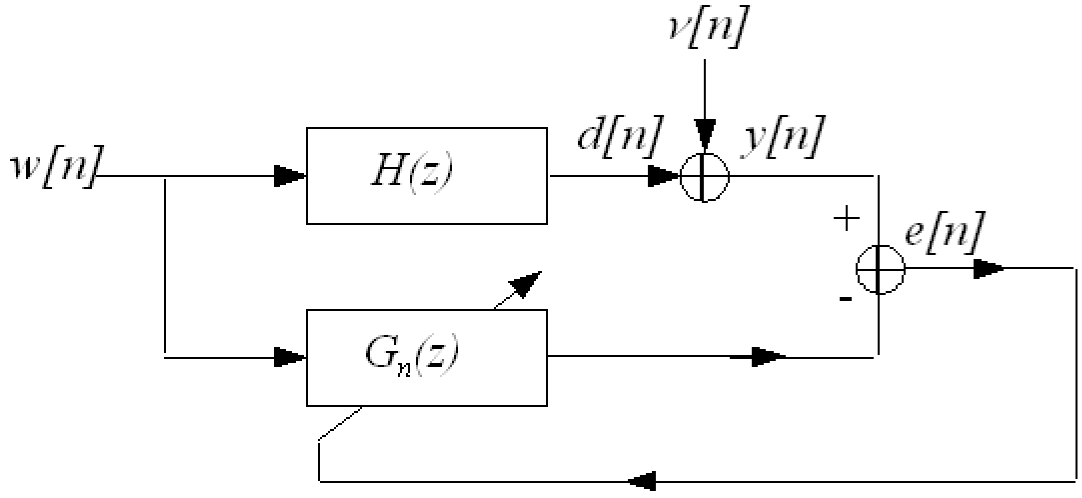
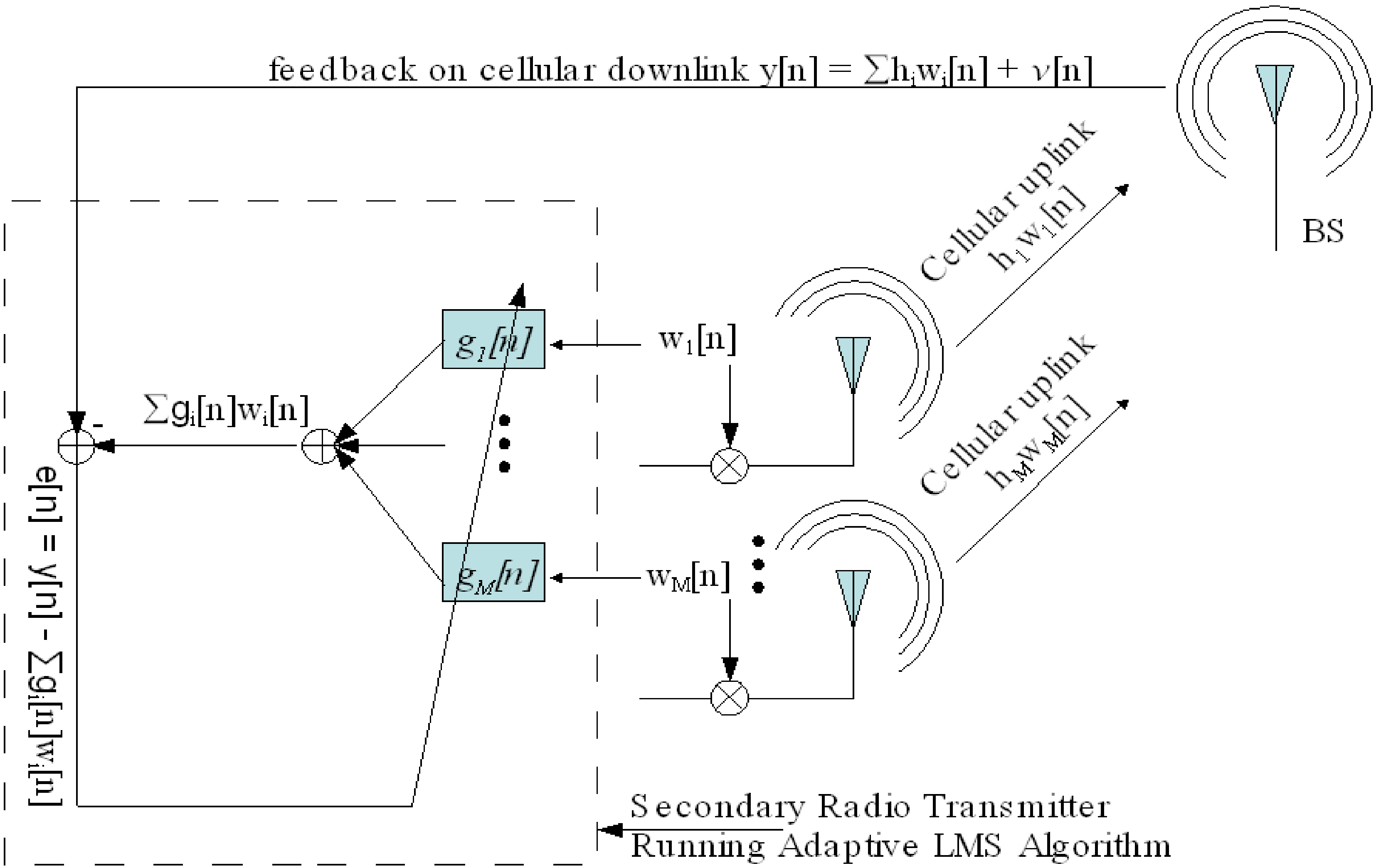
Estimation using adaptive filtering



•Identifying an unknown filter (channel) *H(z)* using an adaptive filter (e.g. Least Mean Square (LMS) algorithm)
•w[n] is a known pseudo random sequence, $G_n(z)$ is the local estimate
•$G_n(z)$ will converge to a noisy estimate of *H(z)* (due to the presence of noise)
•In the beamforming context, the taps of *H(z)* are the complex responses from each antenna element on the secondary radio towards a primary radio

Beam-nulling using adaptive filtering



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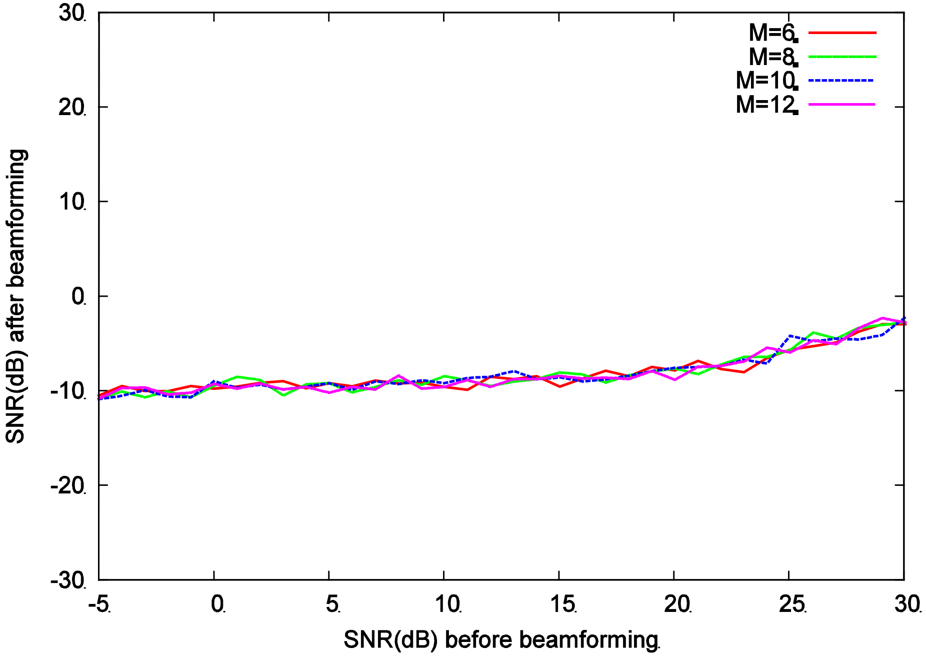
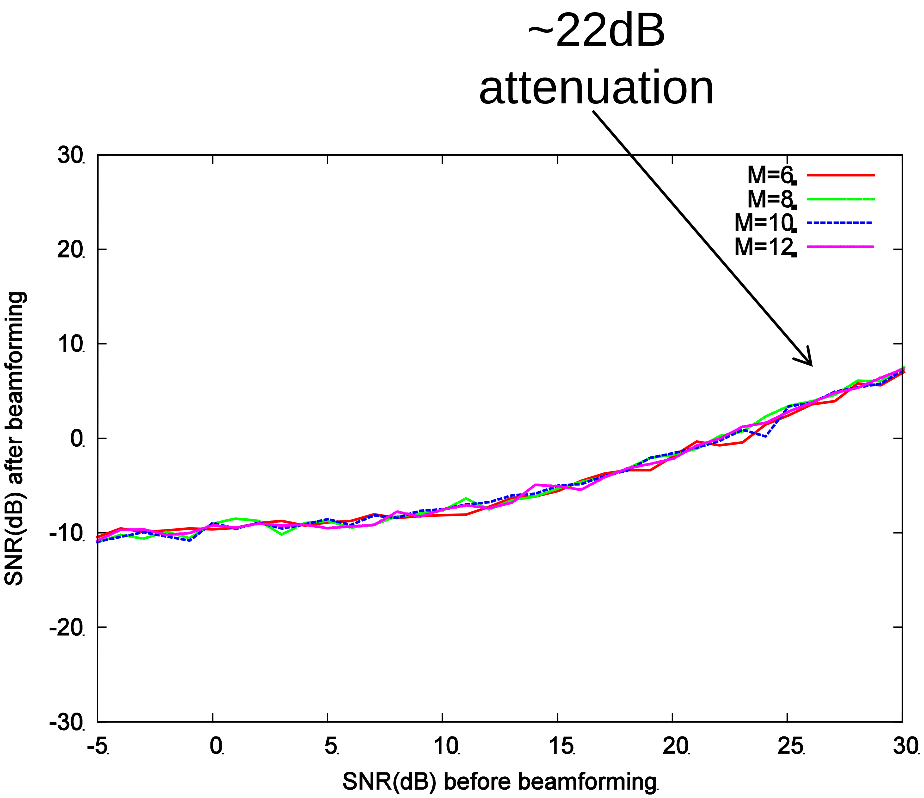
Simulated interference rejection



Infinite phase/amplitude resolution



Finite phase/amplitude resolution

4 primary users (base stations), cognitive radio has M antennas

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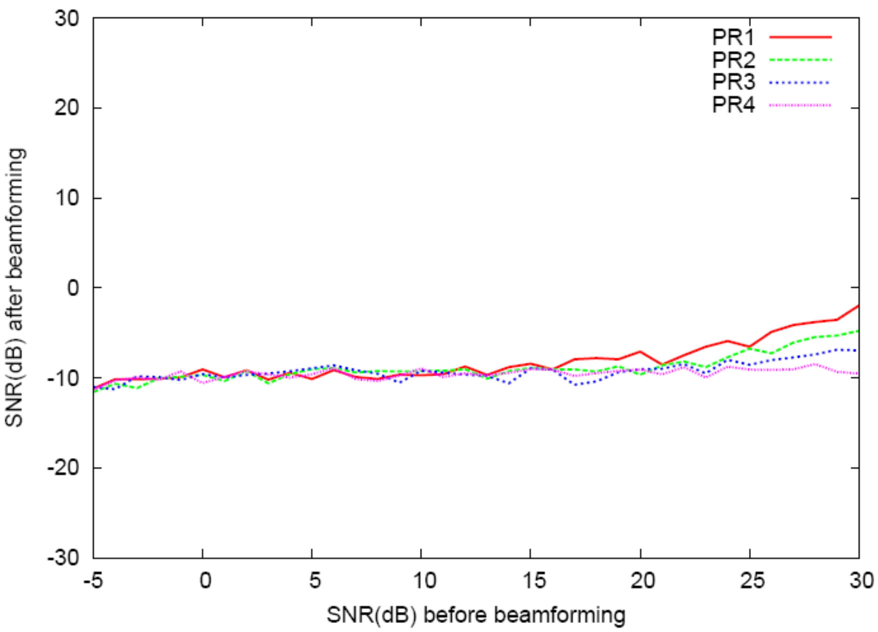
Iterative channel estimation

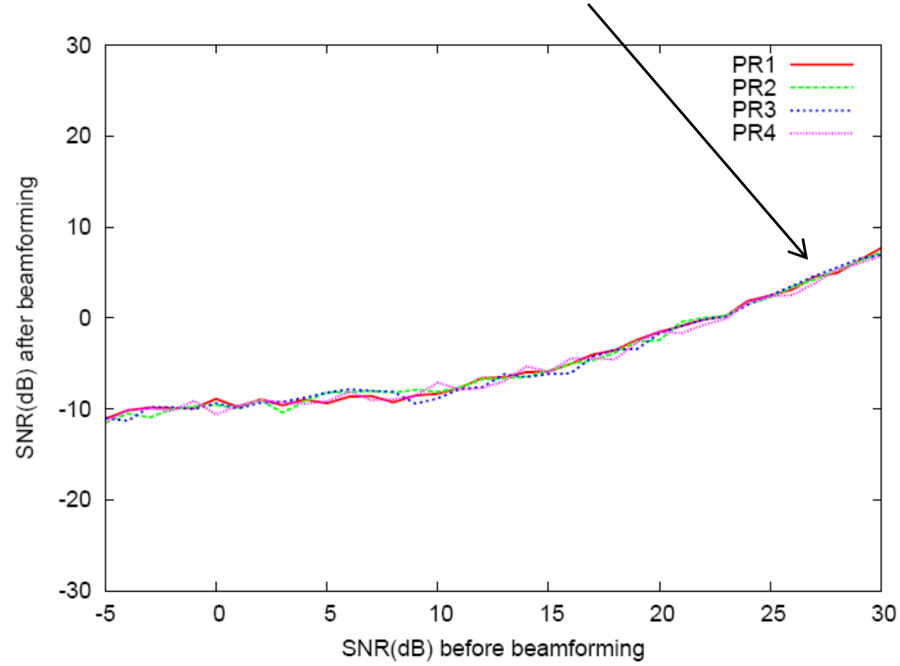
- Less coordination among primary users
- Better reuse of allocated channels
- Same adaptive algorithm, different choice of training sequence $\boldsymbol{w}$
- Adaptively perform a Gram-Schmidt orthogonalization
  - Start with the closest node (e.g. PR1)
  - Run LMS at low power (no interference to other nodes)
  - After estimating $\boldsymbol{h}_1$, increase the power and choose $\boldsymbol{w}$ orthogonal to $\boldsymbol{h}_1$
  - This will estimate the component of $\boldsymbol{h}_2$ orthogonal to $\boldsymbol{h}_1$
  - Increase the power, choose w orthogonal to both $\boldsymbol{h}_1$, $\boldsymbol{h}_2$

Simulated interference rejection



Infinite phase/amplitude resolution

~22dB attenuation



Finite phase/amplitude resolution

4 primary users (base stations), cognitive radio has 12 antennas

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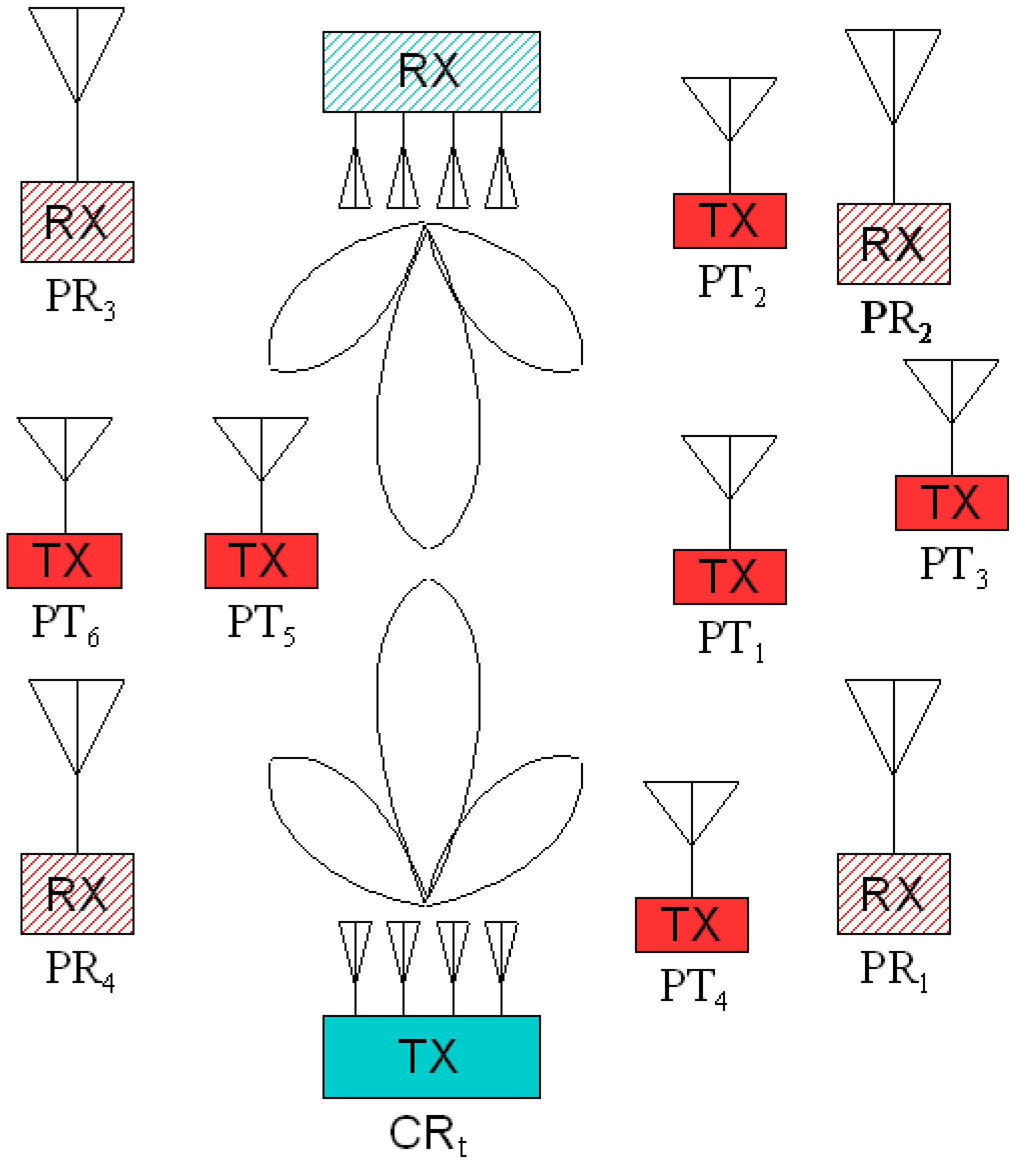
What about the receiver



Interference suppression framework

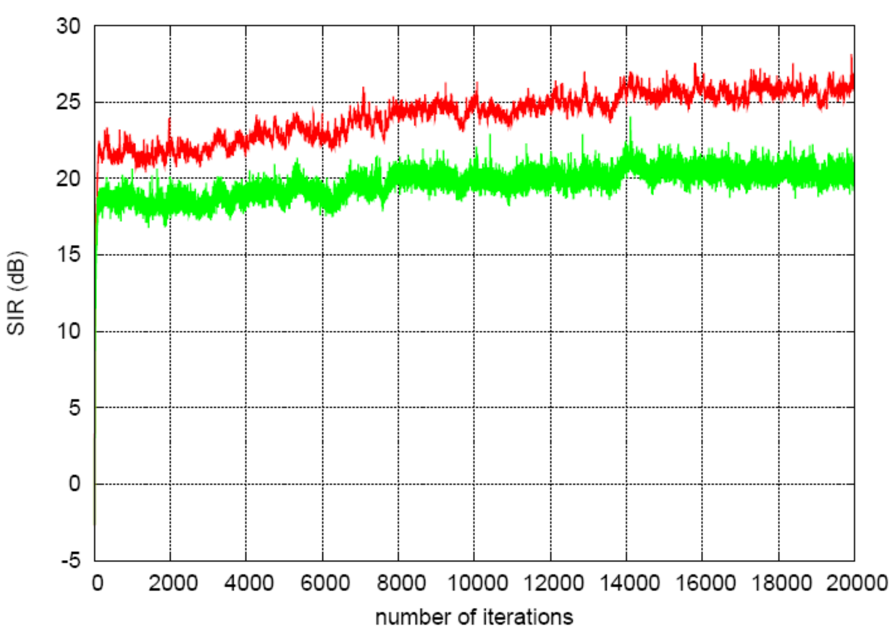
- Primary transmitters (cell phones) can cause interference to the secondary (cognitive radio) network
- At the secondary receiver:
  - $\boldsymbol{y}[\mathrm{n}] = \boldsymbol{h}_d \boldsymbol{d}[n] + \sum_{\mathrm{i}} \boldsymbol{h}_i \boldsymbol{d}_i[n] + \boldsymbol{v}[n]$
- Choose beamforming (spatial filter) to maximize SINR
  - $\mathrm{SINR}_{\mathrm{out}} = |\boldsymbol{c}^h \boldsymbol{h}_d|^2 / (\sum_{\mathrm{i}} |\boldsymbol{c}^h \boldsymbol{h}_d|^2 + N_v)$
- MMSE criterion:
  - $\boldsymbol{c}_{MMSE} = \arg\min_{\mathrm{c}} |e[n]|^2 = \arg\min_{\mathrm{c}} |\boldsymbol{c}^h \boldsymbol{y}[n] - d[n]|^2$
- Good rejection in slow fading channels
- Doppler/frequency offsets can create problems

Differential MMSE Framework[2]

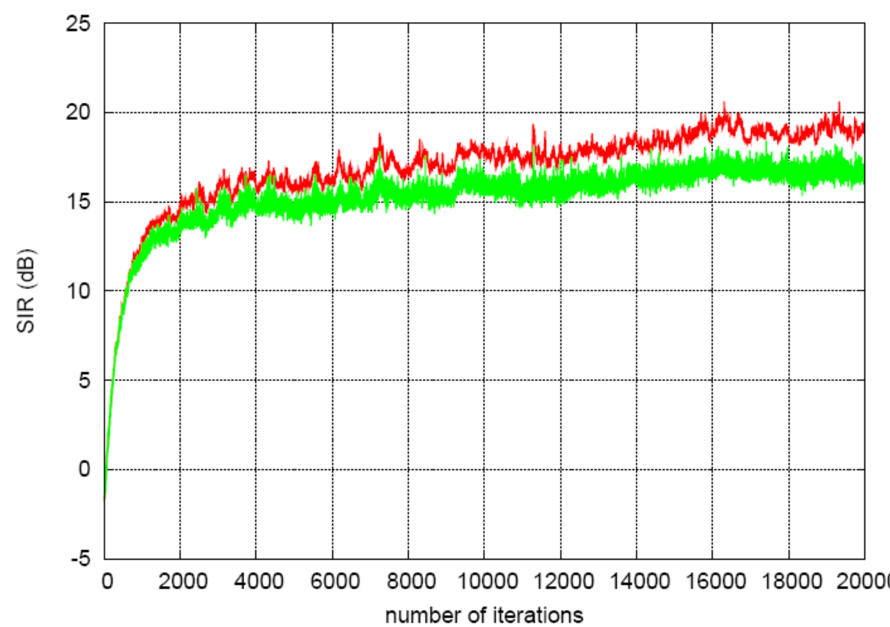
- Even in fast fading environments, channel remains relatively constant over successive symbols
- Avoid tracking channel variations by only looking at the difference (ratio) between symbols (similar to differential modulation)
- DMMSE criterion:
  - $\boldsymbol{c}_{DMMSE} = \arg\min_{c} |\boldsymbol{c}^h\boldsymbol{y}[n-1]d[n] - \boldsymbol{c}^h\boldsymbol{y}[n]d[n-1]|^2$
  - Subject to $E[|\boldsymbol{c}^h\boldsymbol{y}[n]|^2]=1$

[2]U. Madhow, K. Bruvold, and L. J. Zhu, "Differential MMSE: A framework for robust adaptive interference suppression for ds-cdma over fading channels," *IEEE Transactions on Communications, vol. 53, no. 8,* pp. 1377–1390, Aug. 2005.

Simulated interference rejection



DMMSE, offset=10% symbol rate



NLMS, offset=1% symbol rate

8 antennas, 6 interferers, SNR_{in}=-20dB, SIR_{in}=-40dB