

Multi-Antenna Interference Cancellation Techniques for Cognitive Radio Applications

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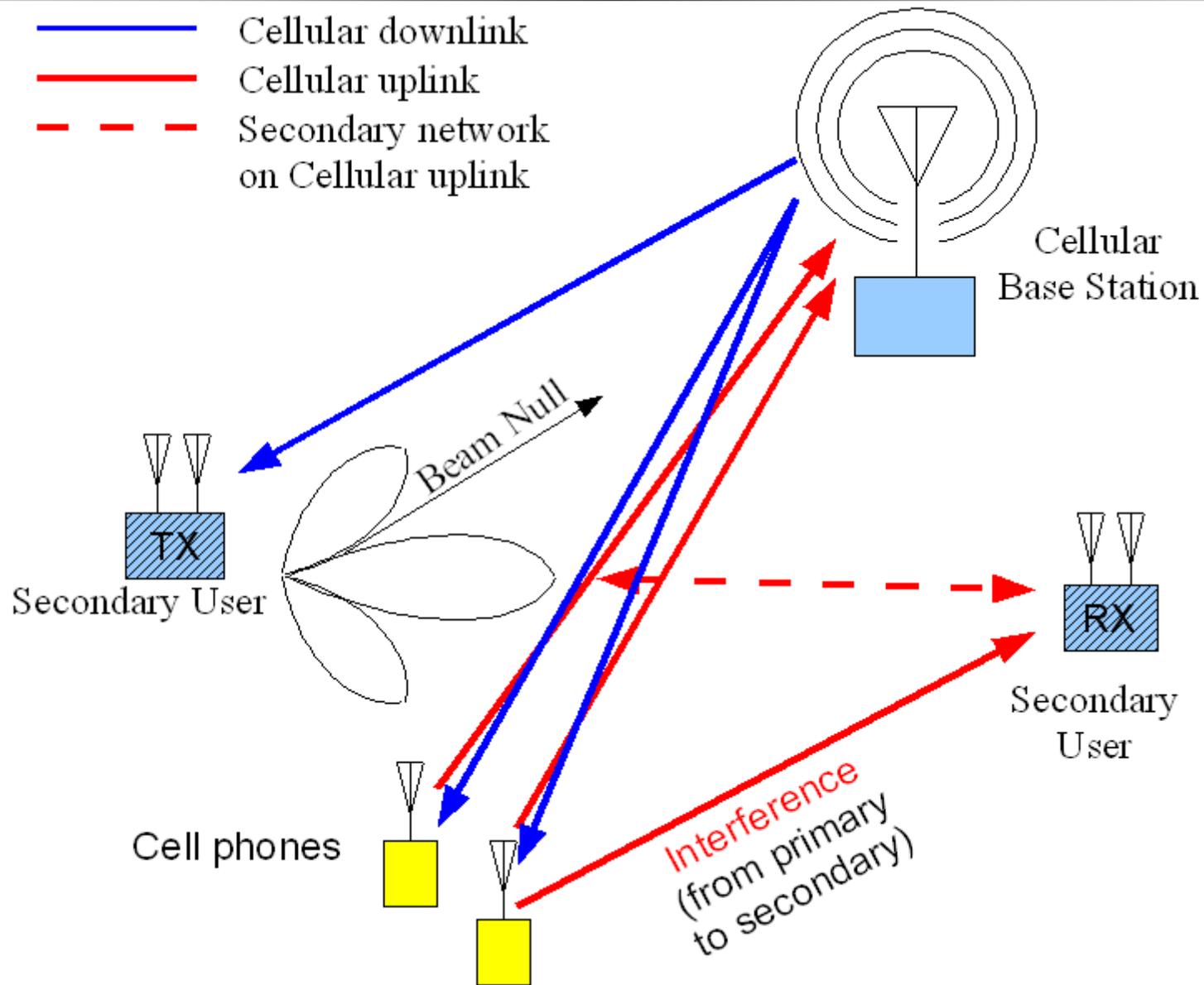
Kannan Ramchandran

Last Time

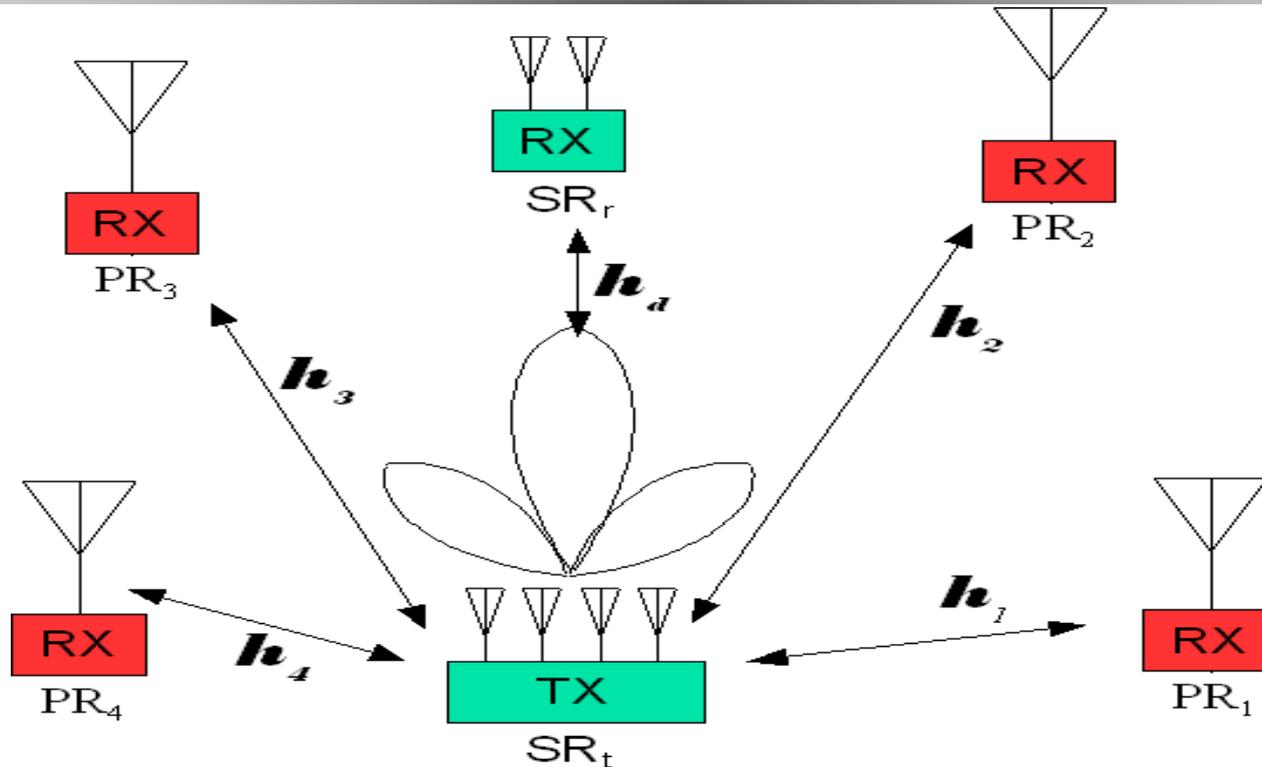
- Improving spectrum reuse using primary and secondary collaboration¹
- More effective spatial reuse using multiple antennas on the secondary
- Example: cellular uplink reuse
- Today: signal processing and array processing techniques to improve collaboration
- To appear in IEEE WCNC 2009

¹O. 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

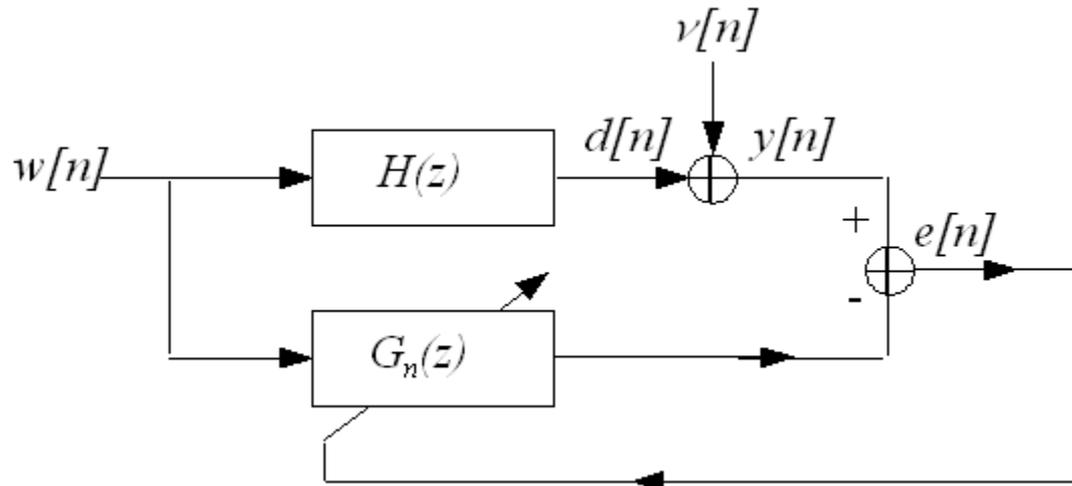


Collaborative framework for interference cancellation



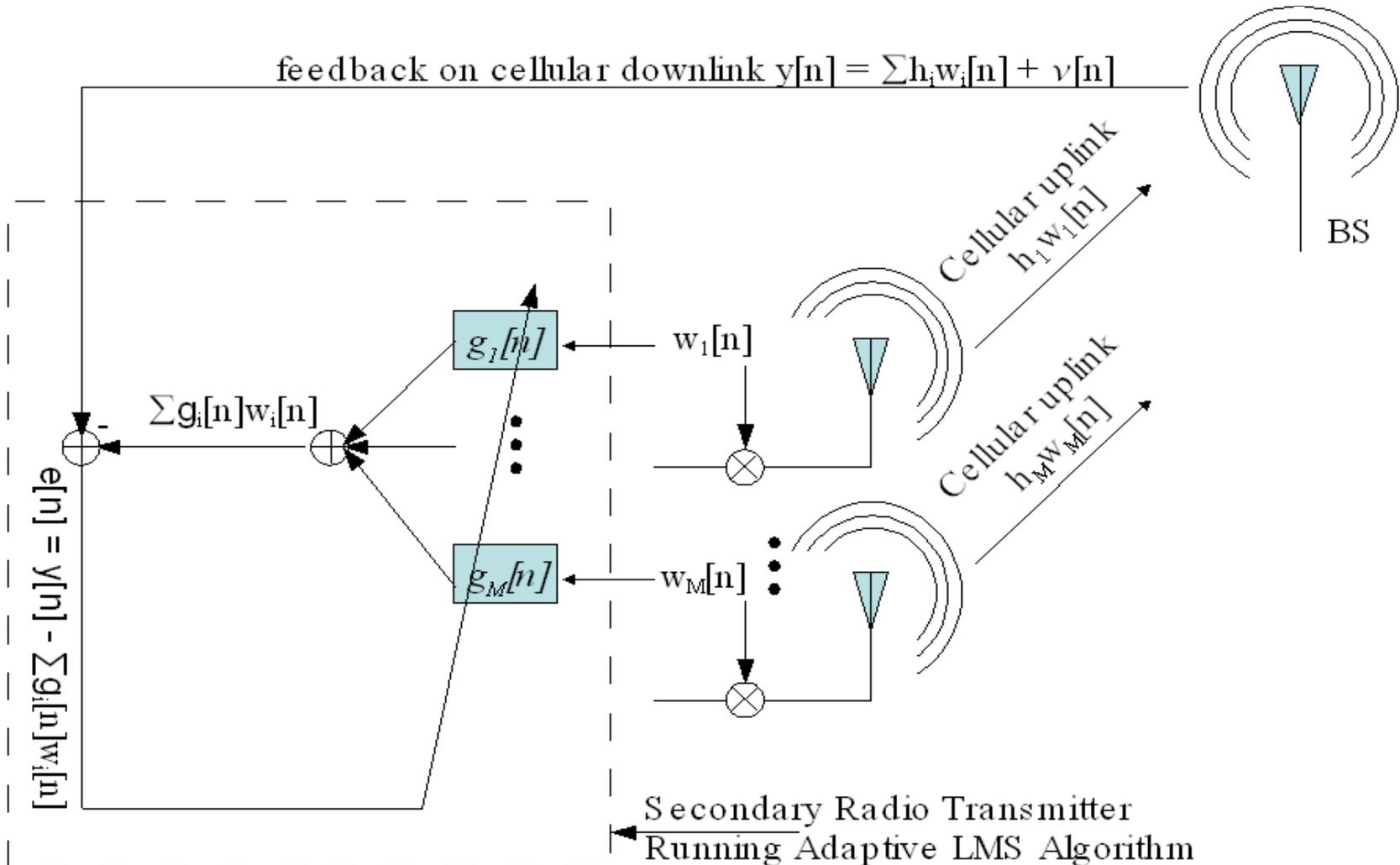
- \mathbf{h}_j for $0 < j < K+1$ are the channel responses from the secondary transmitter (\mathbf{SR}_t) to each of K primary users (base stations) respectively.
- \mathbf{h}_d is the channel response from \mathbf{SR}_t to \mathbf{SR}_r .
- Choose \mathbf{c} to be the component of \mathbf{h}_d that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

Estimation using adaptive filtering

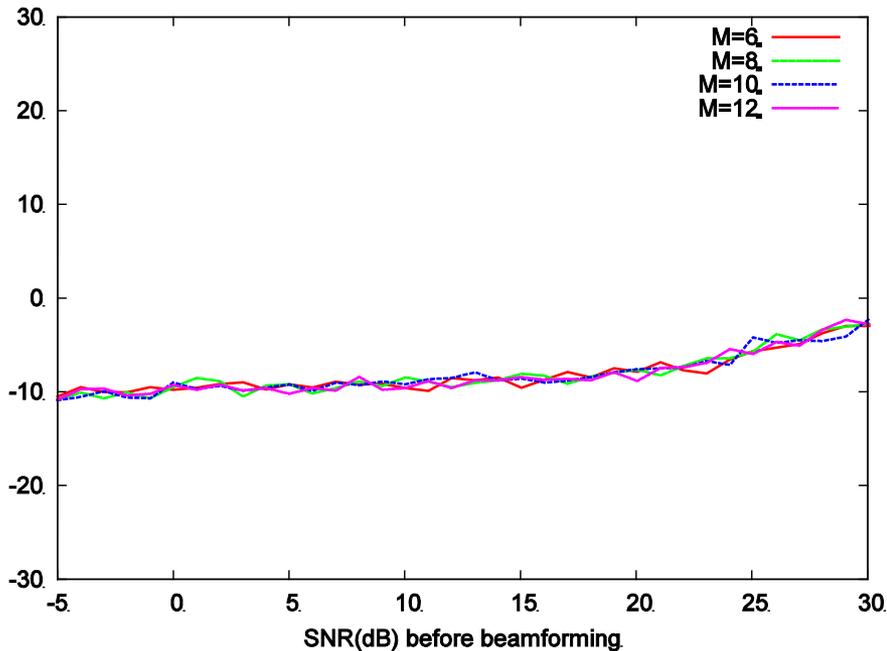


- Identifying an unknown filter (channel) $H(z)$ using an adaptive filter (e.g. Least Mean Square (LMS) algorithm)
- $w[n]$ is a known pseudo random sequence, $G_n(z)$ is the local estimate
- $G_n(z)$ will converge to a noisy estimate of $H(z)$ (due to the presence of noise)
- In the beamforming context,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

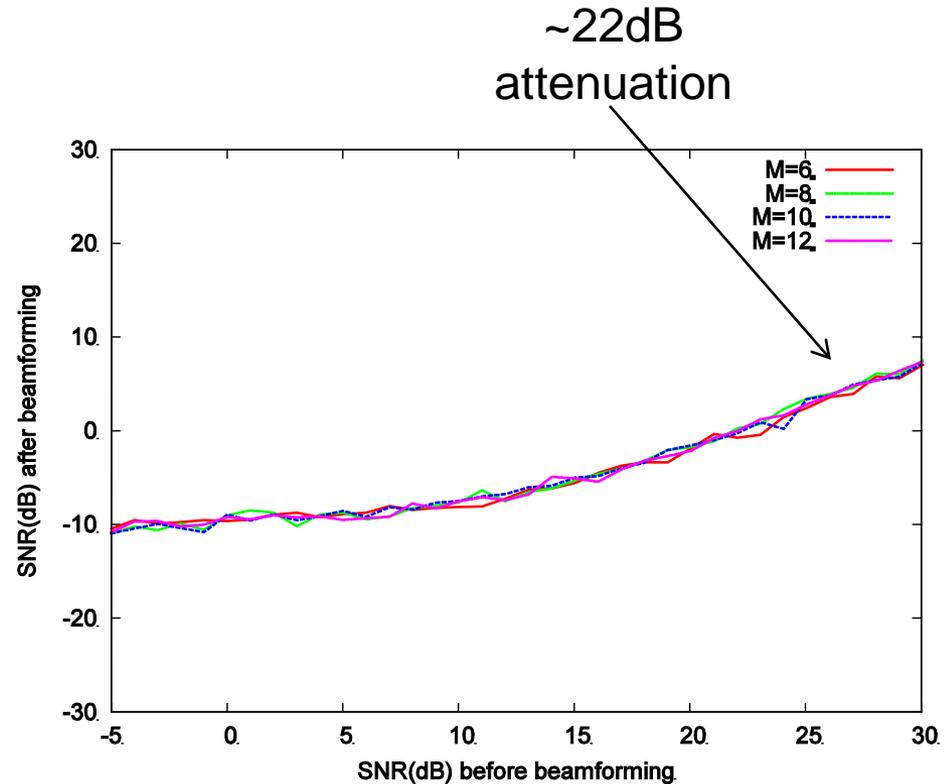
Beam-nulling using adaptive filtering



Simulated interference rejection



Infinite phase/amplitude resolution



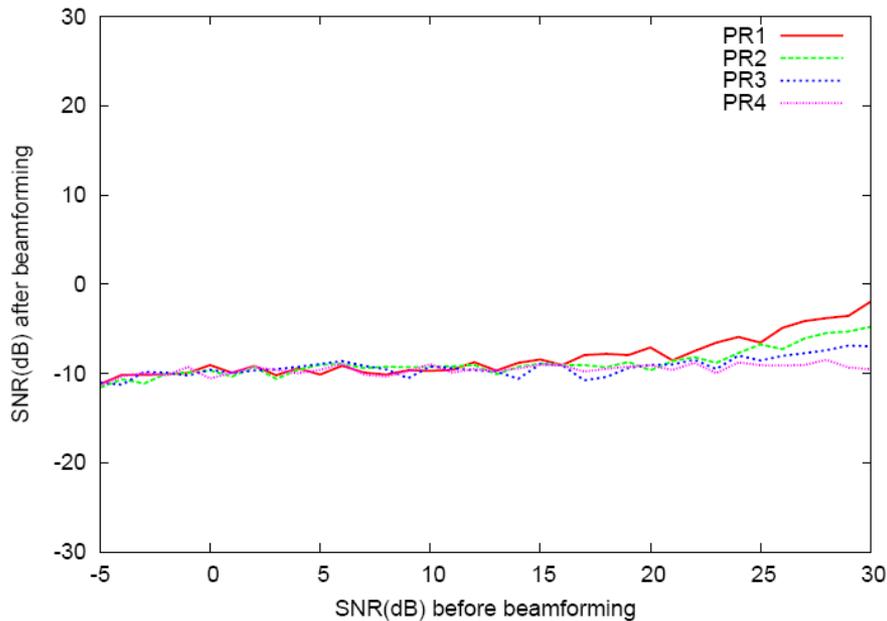
Finite phase/amplitude resolution

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

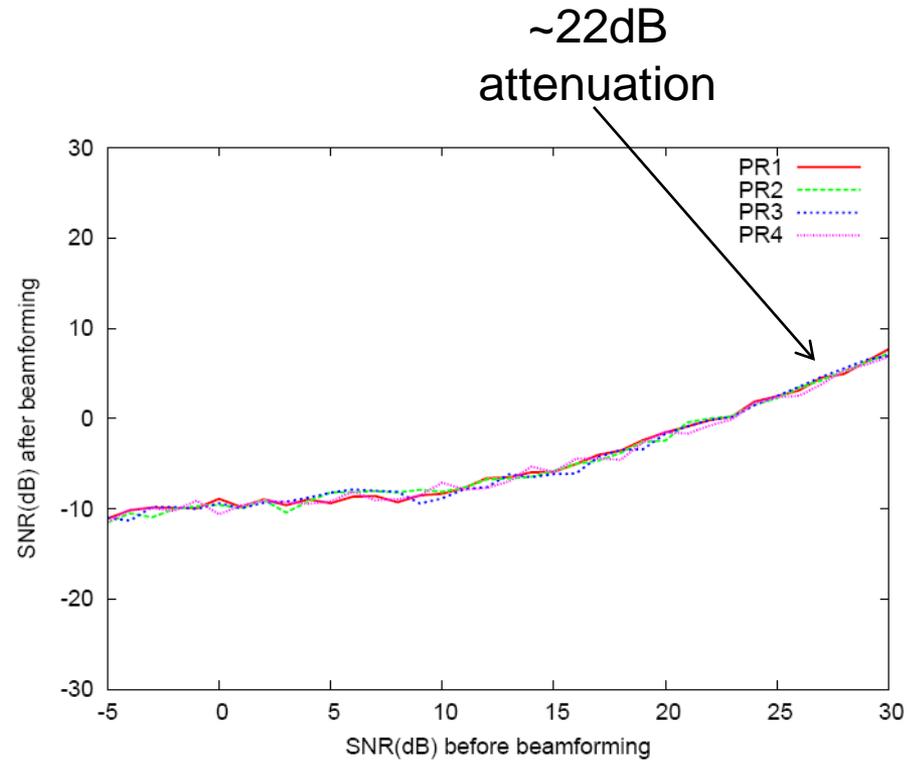
Iterative channel estimation

- Less coordination among primary users
- Better reuse of allocated channels
- Same adaptive algorithm, different choice of training sequence \mathbf{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 \mathbf{h}_1 , increase the power and choose \mathbf{w} orthogonal to \mathbf{h}_1
 - This will estimate the component of \mathbf{h}_2 orthogonal to \mathbf{h}_1
 - Increase the power, choose \mathbf{w} orthogonal to both $\mathbf{h}_1, \mathbf{h}_2$

Simulated interference rejection



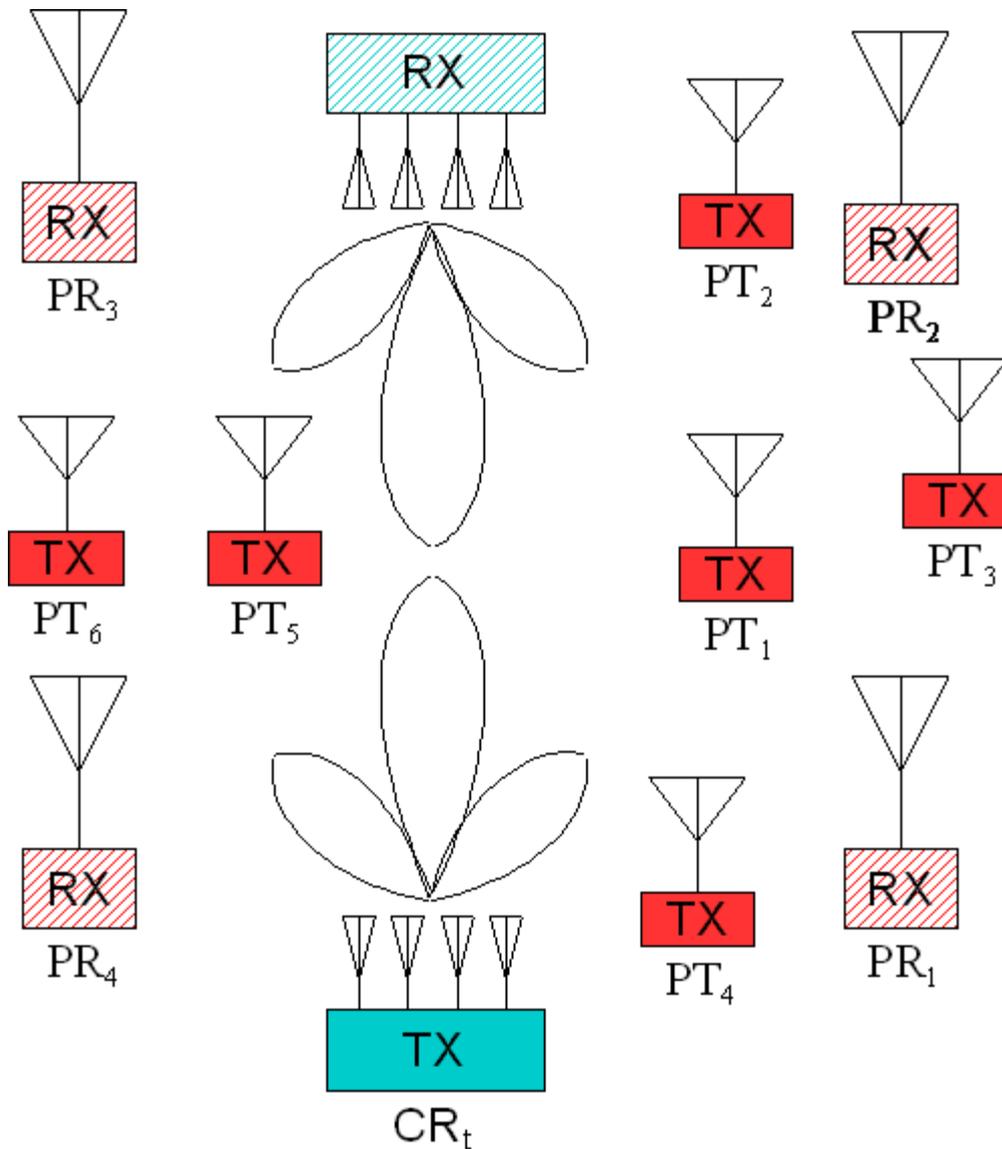
Infinite phase/amplitude resolution



Finite phase/amplitude resolution

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

What about the receiver



Interference suppression framework

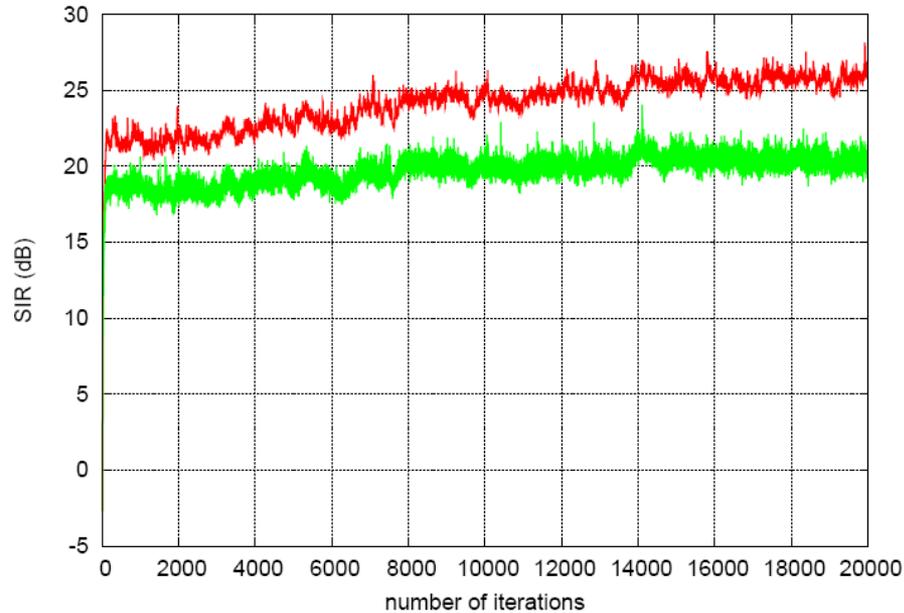
- Primary transmitters (cell phones) can cause interference to the secondary (cognitive radio) network
- At the secondary receiver:
 - $y[n] = \mathbf{h}_d \mathbf{d}[n] + \sum_i \mathbf{h}_i \mathbf{d}_i[n] + \mathbf{v}[n]$
- Choose beamforming (spatial filter) to maximize SINR
 - $\text{SINR}_{\text{out}}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

Differential MMSE Framework²

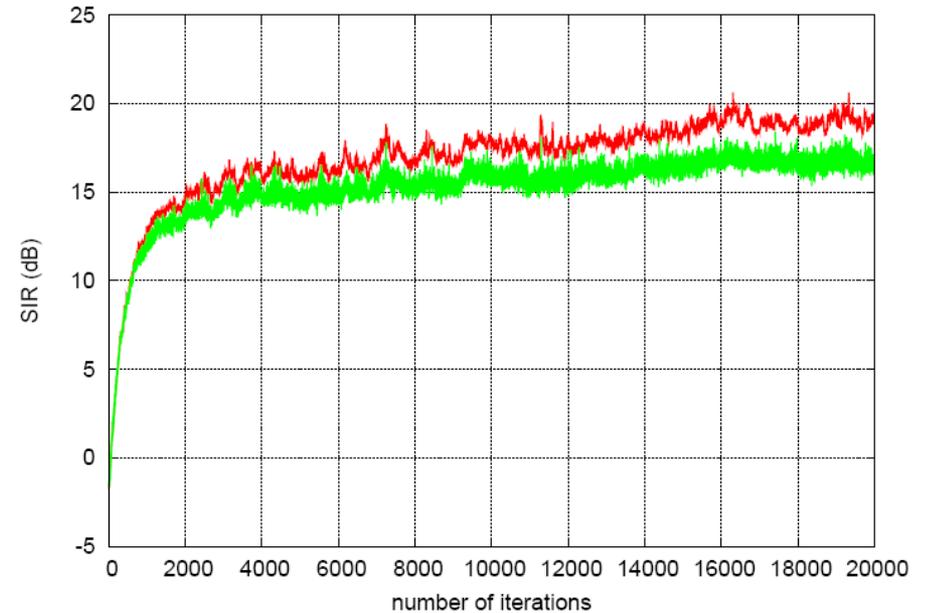
- Even in fast fading environments, channel remains relatively constant over successive symbols
- Avoid tracking channel variations by only looking at the difference (ratio) between symbols (similar to differential modulation)
- DMMSE criterion:
 - $\mathbf{c}_{DMMSE} = \arg \min_{\mathbf{c}} |\mathbf{c}^h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

²U. 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, $\text{SNR}_{\text{in}}=-20\text{dB}$, $\text{SIR}_{\text{in}}=-40\text{dB}$