Cochannel Signal Separation In Fading Channels Using A Modified Constant Modulus Array

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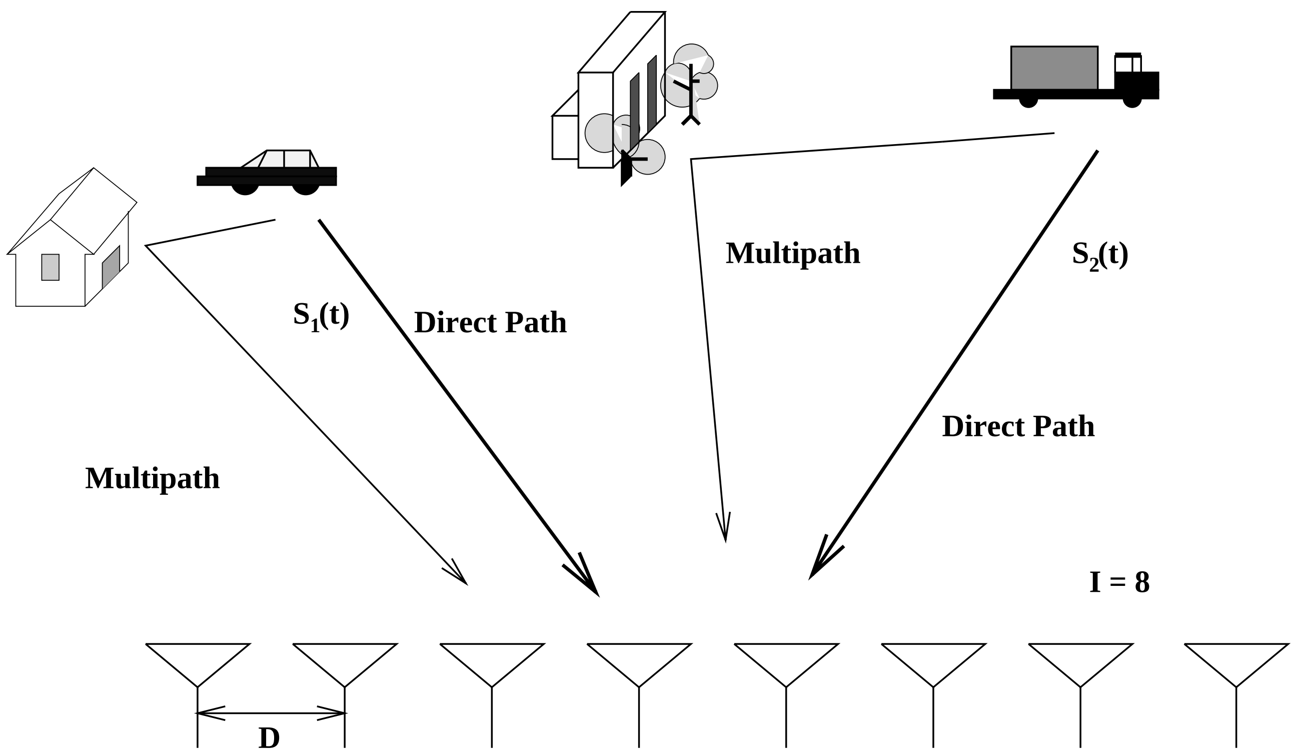
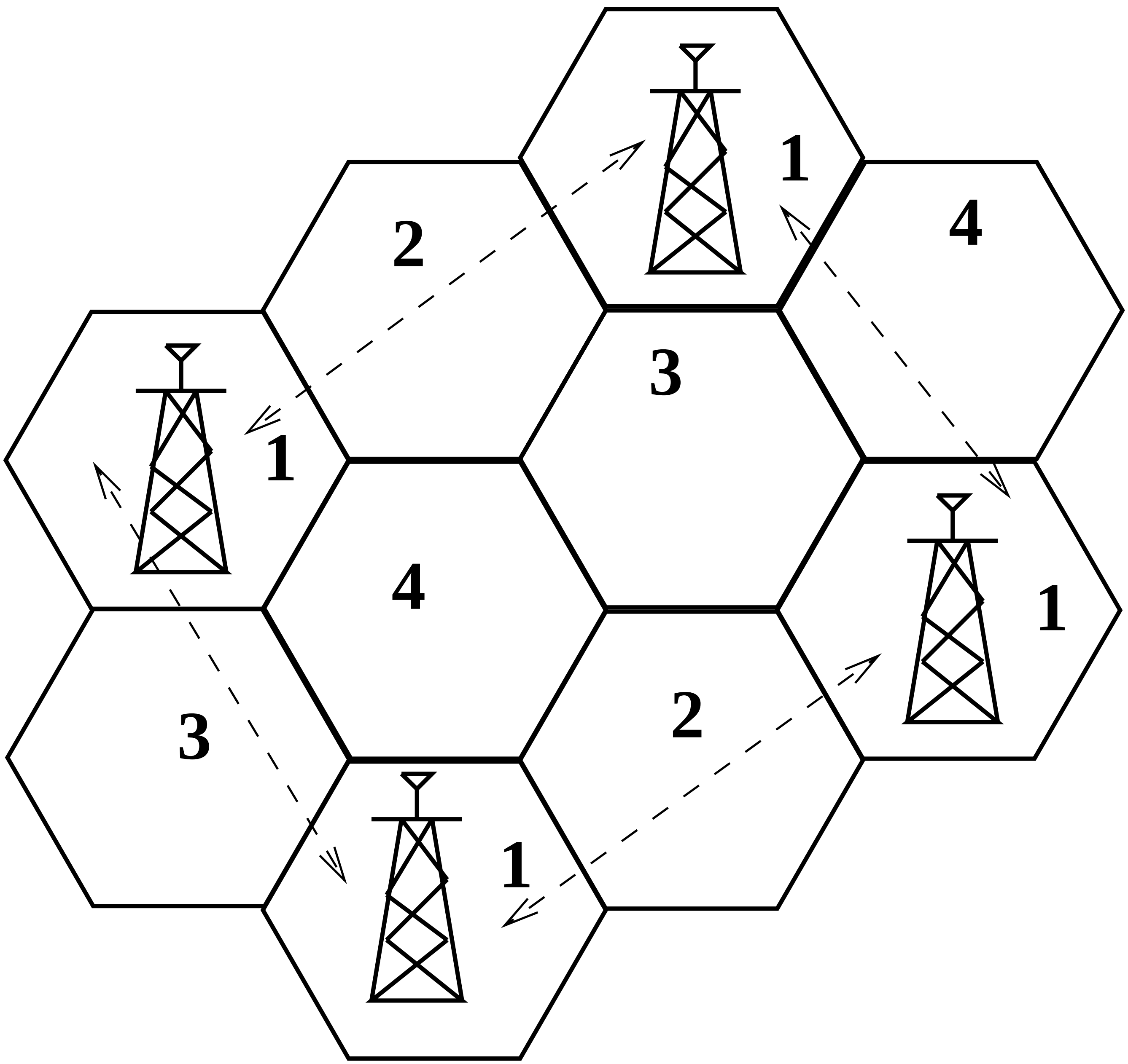
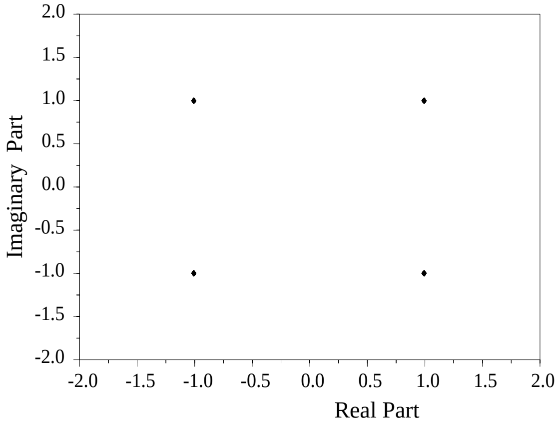
Multipath



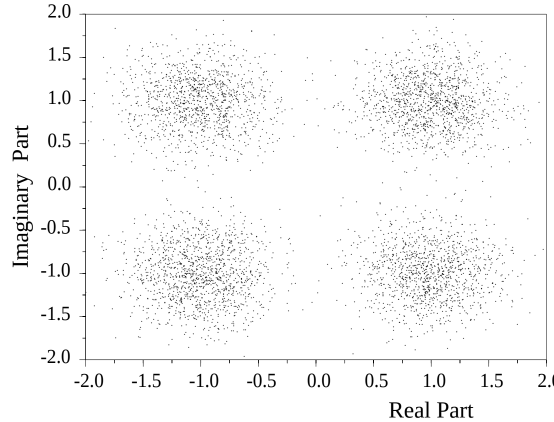
Cochannel Interference



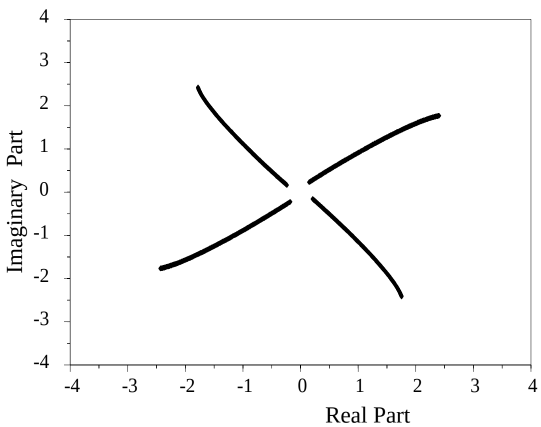
Need for Smart Antennas



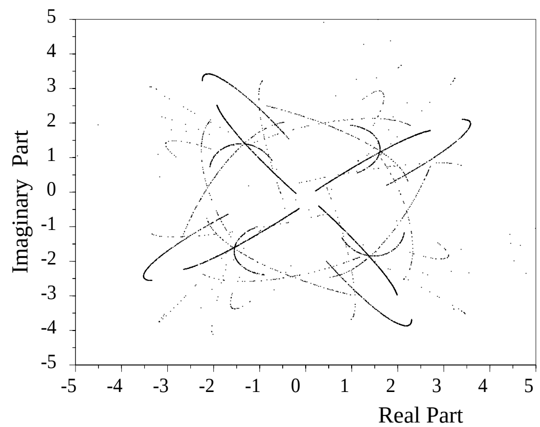
Transmitted Signal



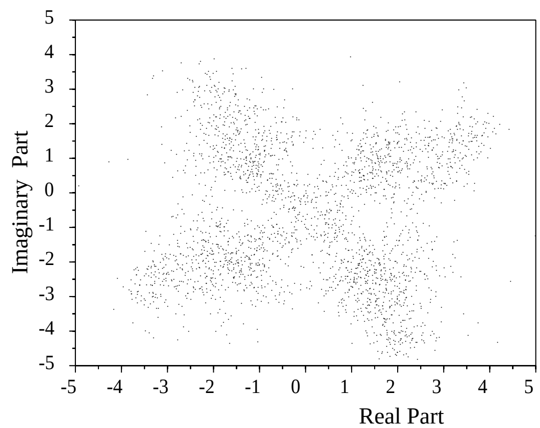
Only Noise (SNR = 10 dB)



Rayleigh Fading

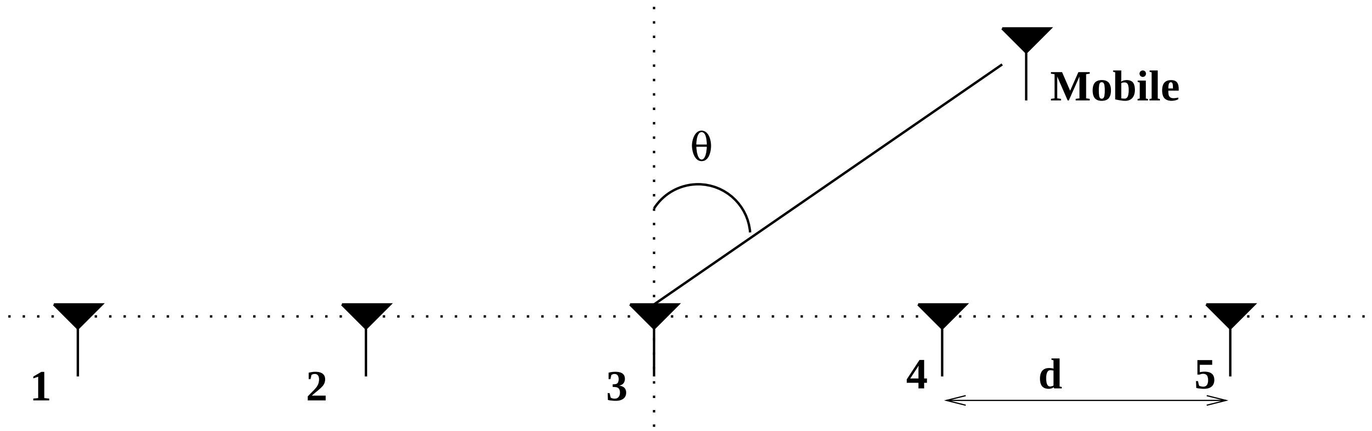


Rayleigh Fading and Multipath



Rayleigh Fading, Multipath and Noise (SNR = 10 dB)

Problem Statement



The received signal $\mathbf{r}(k)$ at the antenna array

$$\mathbf{r}(k) = [r_1(k)\ r_2(k) \cdots\ r_I(k)]$$

$r_i(k)$ is the signal at i^{th} antenna element

$$r_i(k) = \sum_{l=1}^{L} \sum_{m=0}^{M_l - 1} \alpha_{ilm}(k)\ s_l(k-m)$$

k	discrete-time index
i	spatial sampling
$s_l(k)$	the l^{th} transmitted signal
L	the total number of signals
I	number of array elements ($I > L$)
M_l	number of multipaths of the l^{th} signal
$\alpha_{ilm}(k)$	coefficient of the m^{th} multipath of the l^{th} signal at the i^{th} antenna element

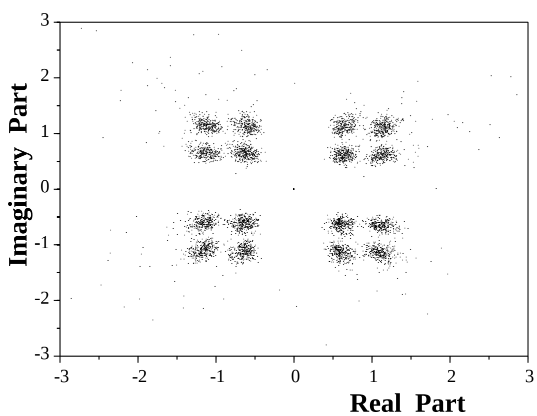
Assumptions

- Statistically independent cochannel signals
- Transmitted signal has constant modulus (QPSK, FSK, QAM)
- Rayleigh fading channel (urban setting)
- Shortest delay path has maximum energy
- Narrowband
- Far field — plane wave propagation

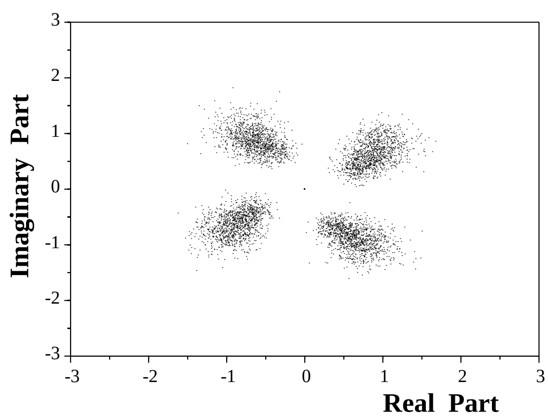
Aim

- Real-time, robust separation of **all** cochannel signals using adaptive equalization

- Output of a cochannel signal separator separating 2 cochannel signals

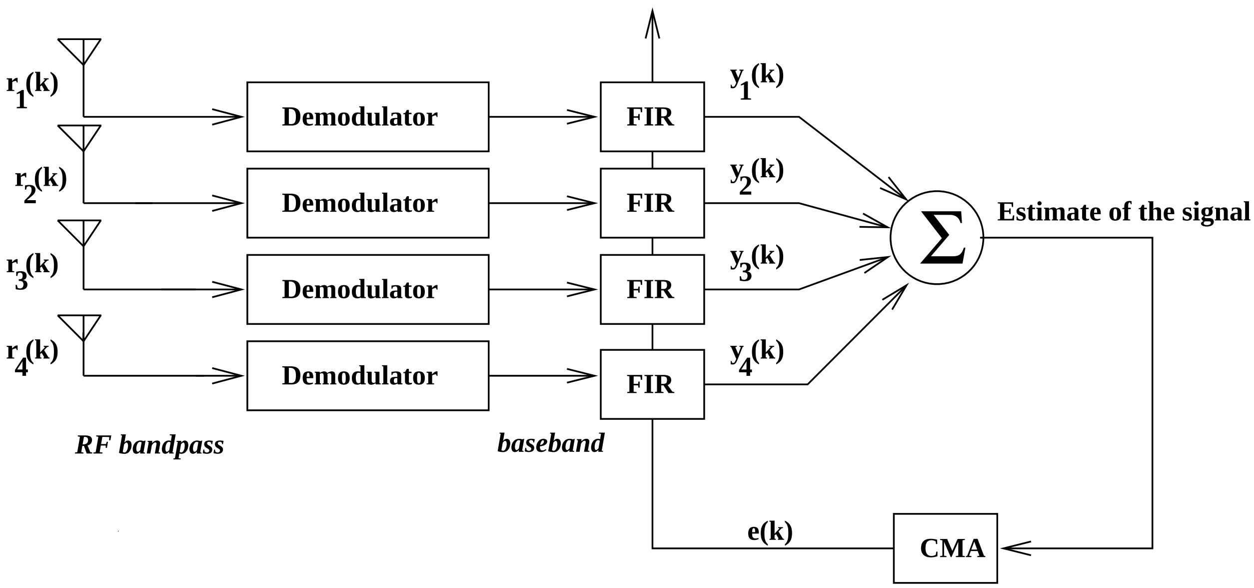


First Signal



Second Signal

Constant Modulus Beamformer



Weight and sum beamformer adapted by Constant Modulus Algorithm (CMA)

- Captures signal having maximum power
- One common error updates coefficients
- Insensitive to phase shifts in the channel

Constant Modulus Algorithm

- Beamformer output

$$y(k) = \sum_{i=1}^{I} \mathbf{x}_i^H(k)\, \mathbf{w}_i(k)$$

Dropping antenna subscript i, data vector

$$\mathbf{x}(k) = [x(k)\ x(k-1)\ \cdots\ x(k-N+1)]^H$$

$\mathbf{w}(k)$ vector of adjustable FIR coefficients.

$$\mathbf{w}(k) = [w_0(k)\ w_1(k)\ \cdots\ w_{N-1}(k)]^H$$

- Cost function of p^{th}-order CM Algorithm

$$J_p(k) = \frac{1}{2p}(|\ y(k)\ |^p - 1)^2$$

$$\mathbf{w}(k+1) = \mathbf{w}(k) - \mu_{cma}\, \mathbf{x}^*(k)\ \frac{y(k)\ (|\ y(k)\ |^p - 1)}{|\ y(k)\ |^{2-p}}$$

Constant Modulus Algorithm

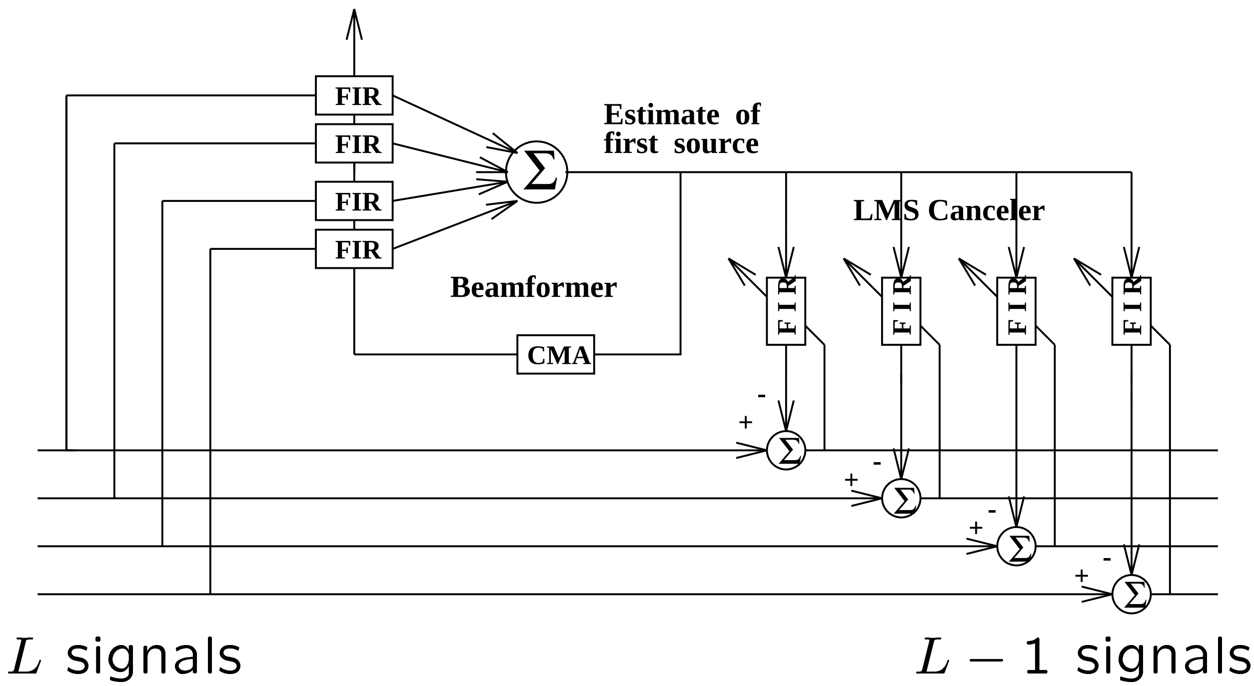
- Use first-order CM algorithm

$$J_1(k) = \frac{1}{2}(|\ y(k)\ | - 1)^2$$

$$\mathbf{w}(k+1) = \mathbf{w}(k) - \mu_{cma}\ \mathbf{x}^*(k)\ (y(k) - \frac{y(k)}{|\ y(k)\ |})$$

- Blind equalization (*no training required*)
- Similar to LMS — $e(k) = d(k) - y(k)$
- $\frac{y(k)}{|\ y(k)\ |}$ acts as the "desired response"
- Can be implemented in real time

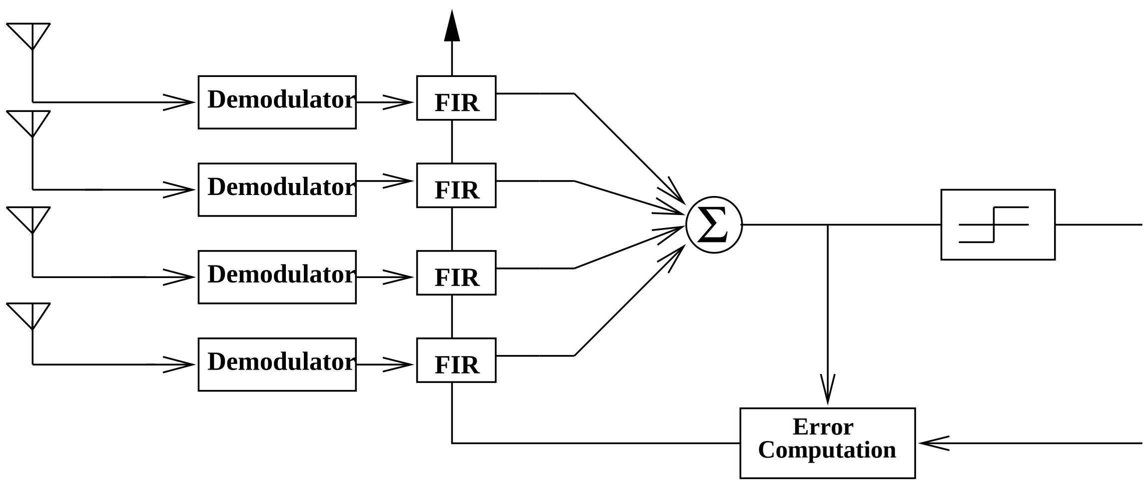
LMS Canceler



First stage of a multistage CM array: beamformer followed by a canceler

- Canceler removes captured signal
- Adapted using the LMS algorithm
- Weights estimate columns of array response matrix
- Canceler error signals are never zero

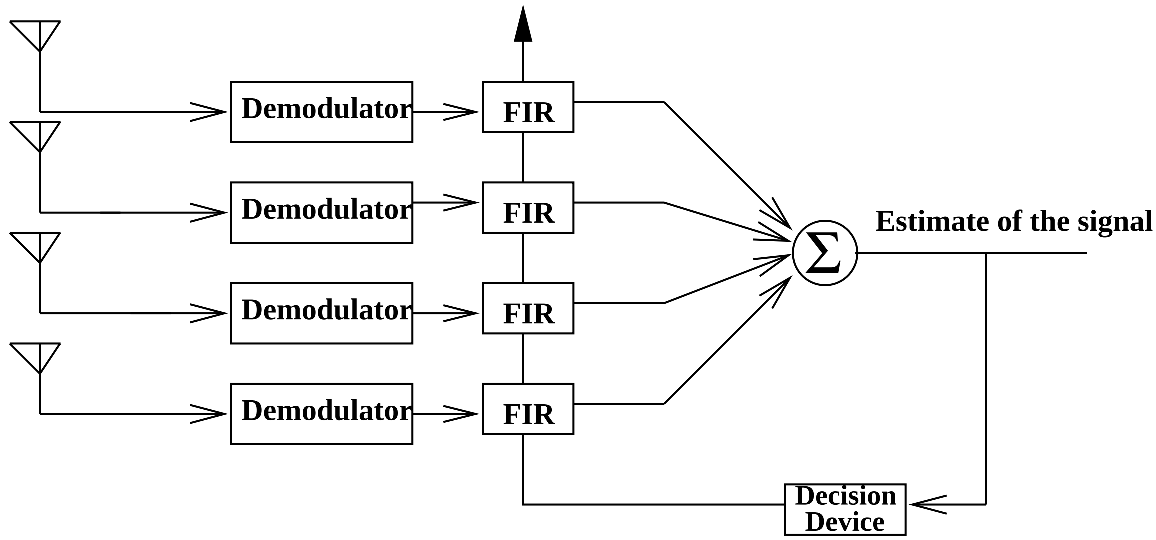
Decision Directed Approach



Receiver when it uses decision directed mode

- Output may be used as "desired" response for adaptive equalization
- Can only be used if the output were the correct transmitted sequence
- Any decision error will be propagated

Modified Error Criterion



Modify error signal $e(k)$ as

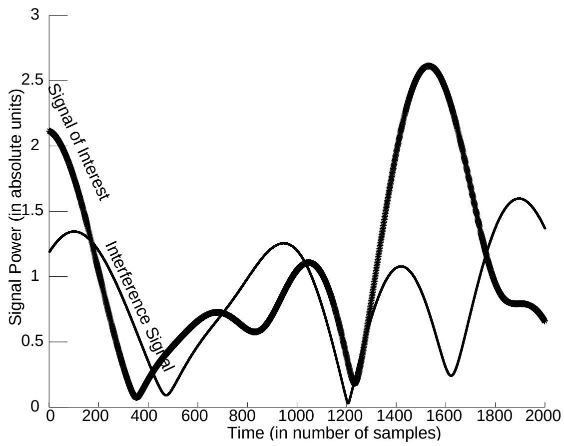
$$\alpha_{cma}\ e_{cma}(k) + \alpha_{dd}\ e_{dd}(k)$$

$0 \leq \alpha_{cma} \leq 1$
$\alpha_{dd} = 1 - \alpha_{cma}$
$e_{cma}(k)$ is the CM error
$e_{dd}(k)$ is the DD error

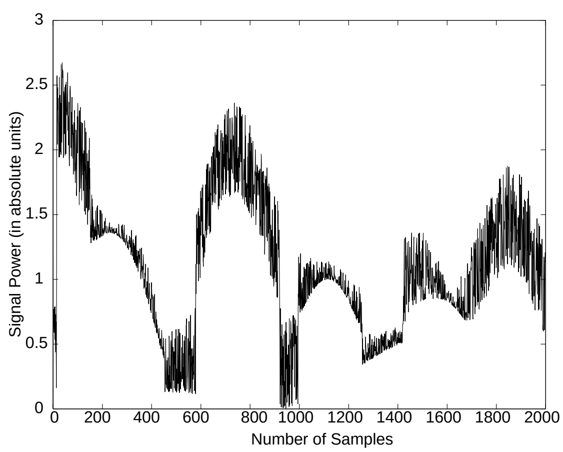
Improves symbol error rate:

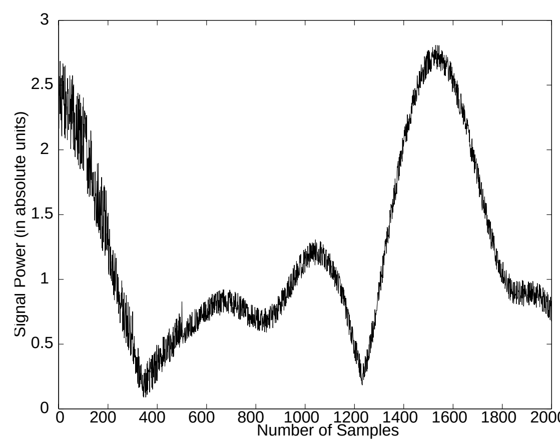
- reduces frequency and phase offset
- latches onto a captured signal

Simulation Results



Amplitude of fading signals





Traditional CM Beamformer

Modified CM Beamformer

Output power of the first stage.

Conclusion

- Modified error $\rightarrow$ weighted sum of constant modulus and decision directed error
- Adds phase sensitivity to the beamformer
- Latches onto captured signal
- Insignificant increase in complexity compared to original constant modulus array

Open Issues

- Step size of beamformer and canceler
- When to switch from constant modulus mode to decision directed mode
- Poor performance at low SNR