# Adaptive Equalization for the downlink of a 3G W-CDMA system

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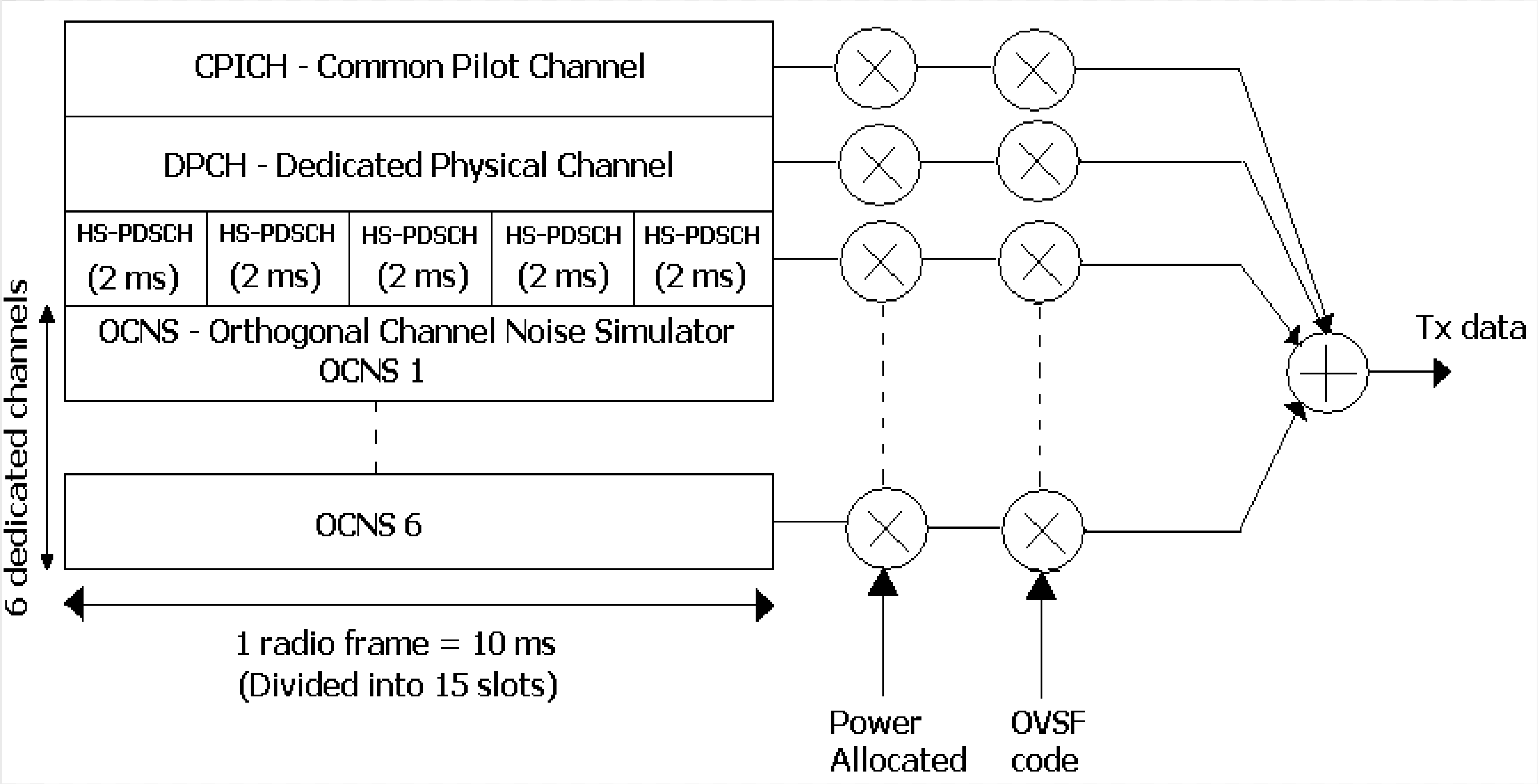
# 3G W-CDMA and HSDPA

- Wideband (5 MHz) Code Division Multiple Access: 3G cellular system.
- HSDPA (High Speed Downlink Packet Access)
  - A packet-based service in W-CDMA Release 5.
- Peak rate of 14.4 Mbps.
- Improved spectral efficiency.
  - Adaptive modulation and coding; faster scheduling; faster retransmissions.

# Downlink channel structure in W-CDMA




Each channel uses a unique OVSF code.

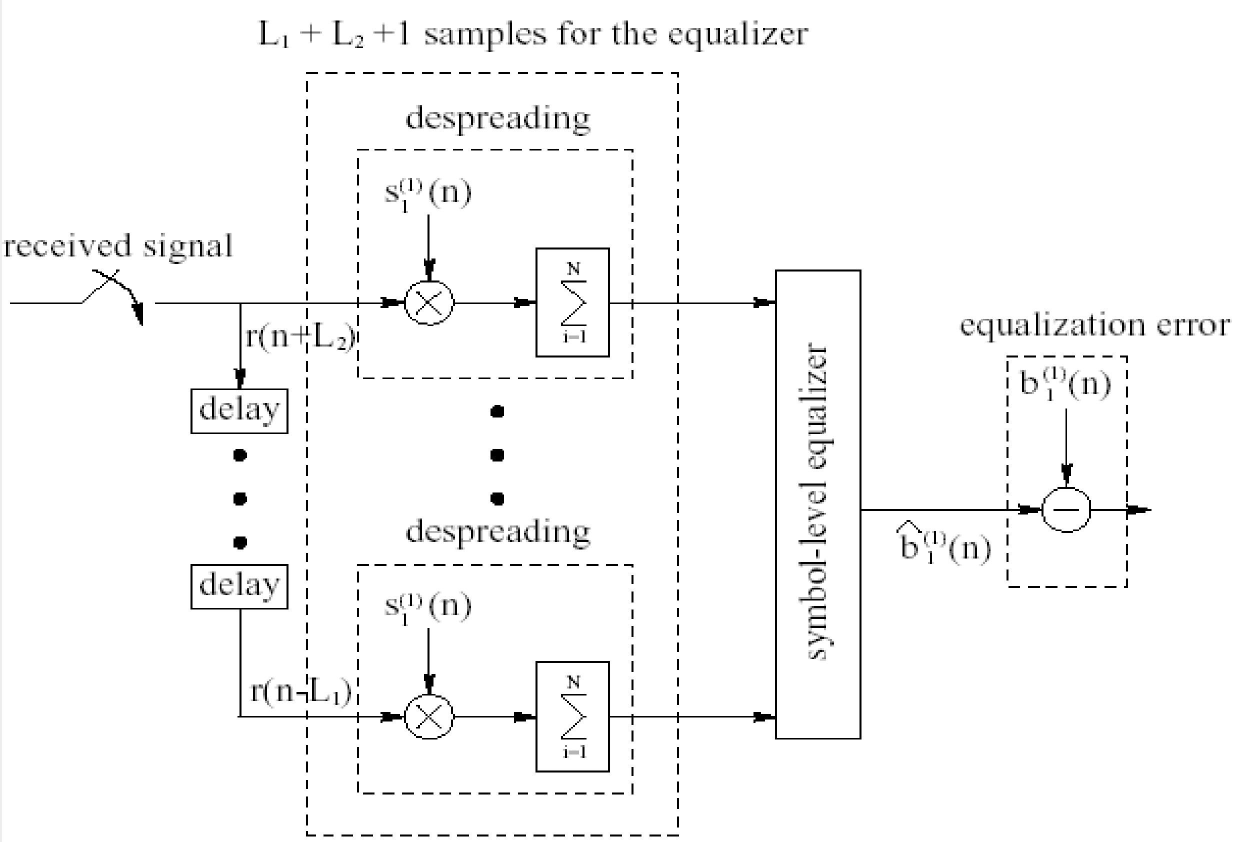
# Why Downlink Equalization ?

- ‘‘Near-far’’ problem.
- Interference due to multi-path propagation.
- Poor performance by matched-filter receivers (e.g. RAKE).
- Equalizers
  - mitigate interference, restore orthogonality.
  - robust against timing uncertainty.

# Equalization

- An equalizer is an FIR filter.
- Chip-level or symbol-level.
- Advantages of symbol-level over chip-level:
  - Works at a higher SNR.
  - Directly estimates users' symbols.
- Pre-despreading or post-despreading implementations.

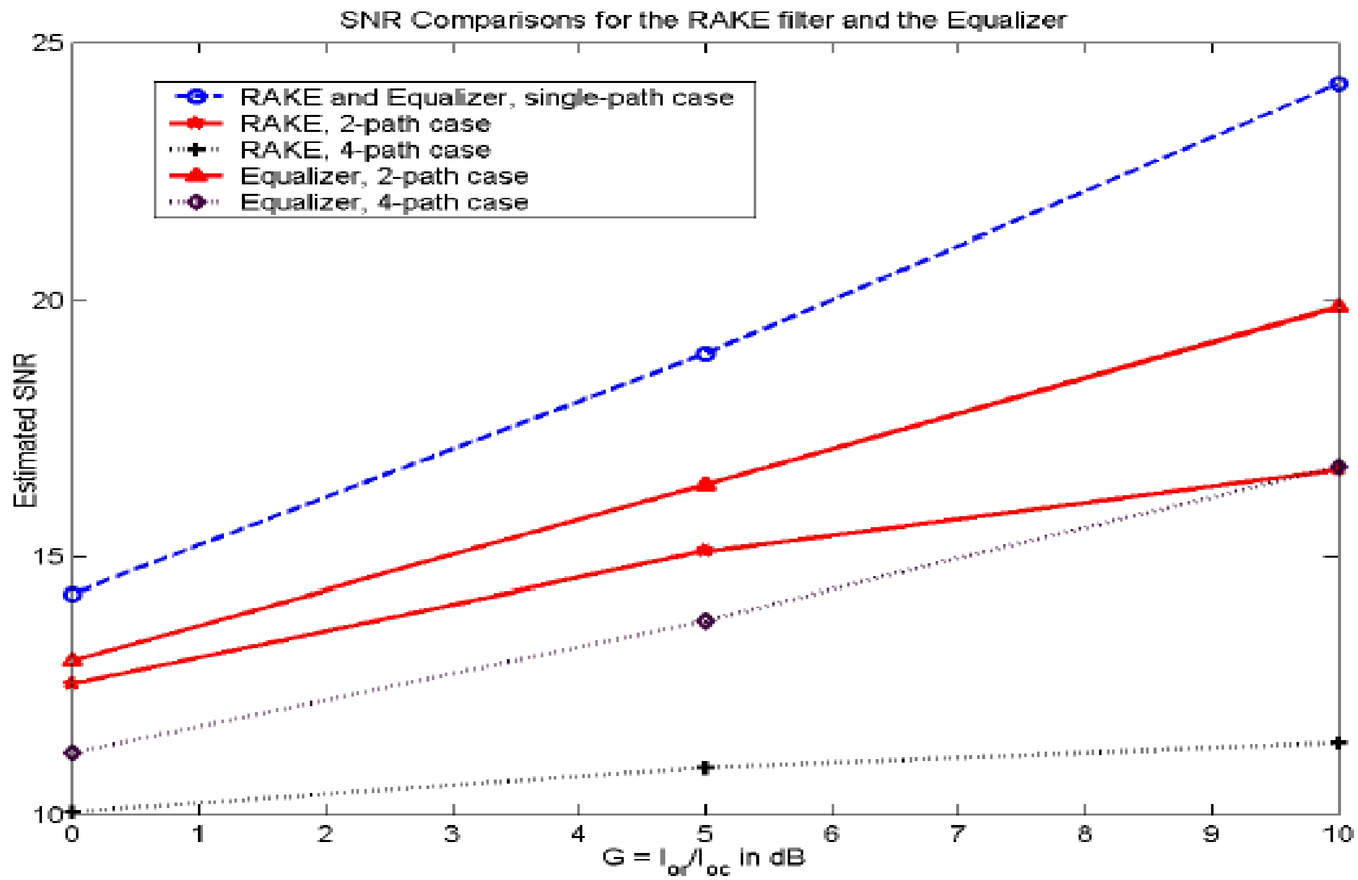
despreading implementation of the equalizer




Block diagram of the chip-spaced equalizer.

k, E. Visotsky, U. Madhow, "Adaptive Interference Suppression for the downlink of a DS-C
g Spreading Sequences", Proc.36th Annual conference on communications, control and co
, IL, Sep 1998.

# MMSE Equalizer (Analytical Computation)




Gain increases as in-cell interference increases.

# Adaptive Equalizers

- Time-varying channel => need for adaptation.
- Adaptation – based on pilot channel (CPICH).
- Two iterative algorithms –
  - Least Mean Square (LMS)
  - Recursive Least Squares (RLS).

# The LMS algorithm

- Recursive computation of Wiener filter.
- Memory efficient; computationally less complex.
- Convergence slow; susceptible to noise.
- LMS update equation for the equalizer:
- $$h_{i+1}(k) = h_i(k) + \mu \left[ \sum_{SF=m}^{m+256} u(m-k) \right] \cdot e^*(n); -L_2 \le k \le L_1$$ lated
  - Rate of convergence
  - Steady-state error

# The RLS algorithm

- Faster rate of convergence.
- Convergence in (2*number of taps) iterations.
- Higher memory – prior information taken into account.
- Computationally more complex than LMS.
- RLS update equation for the equalizer:

$$\hat{\mathbf{h}}(n) = \hat{\mathbf{h}}(n-1) + \mathbf{k}(n)\xi^{*}(n)$$

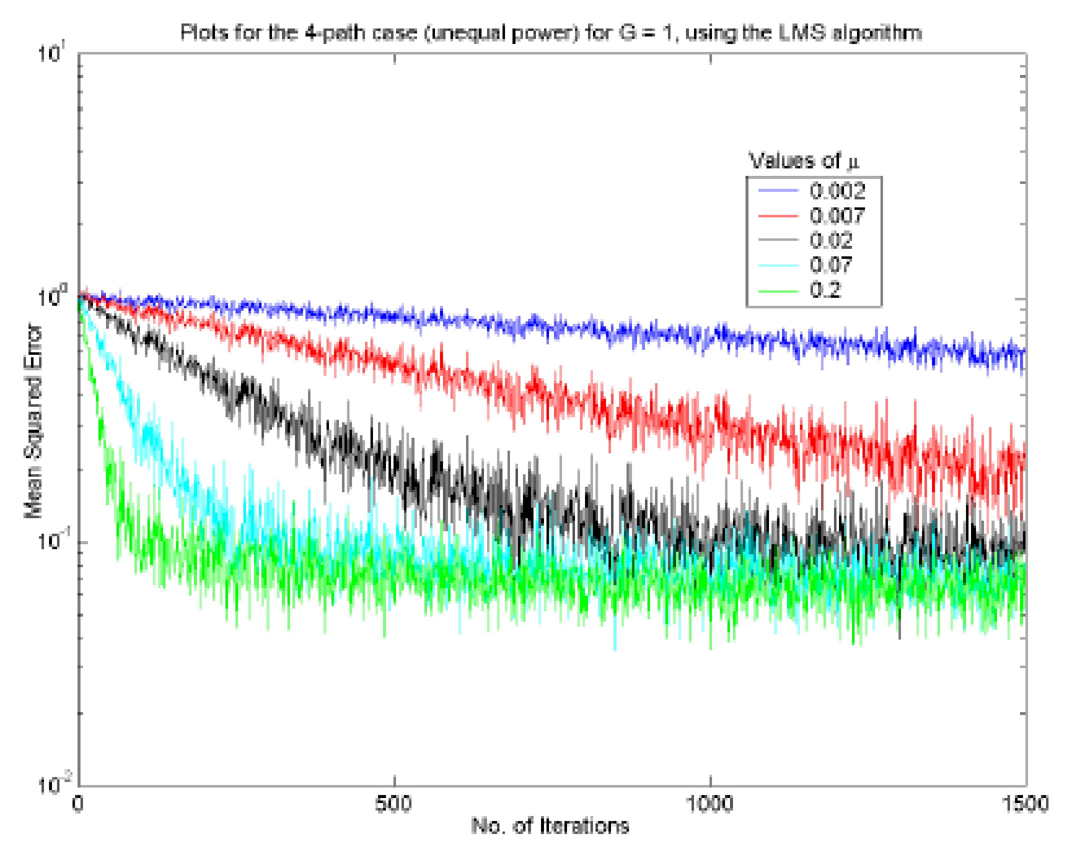
- λ is defined as the forgetting factor. 1/(1- λ) is the memory.

# Simulation parameters.

- 4-path channel assumed
  - Unequal power [0 -3 -6 -9] dB.
- Geometry (ratio of total power from own cell to total noise+out-of-cell interference power) = 0 and 10 dB.
- Mobile speed: 0, 10, 30 or 50 kmph.
- Jakes model – used for simulating the time-varying (fading) channel.
- Pilot power/Total transmit power = -10 dB.
- Length of equalizer = 14.

# MSE vs Time: Static channel

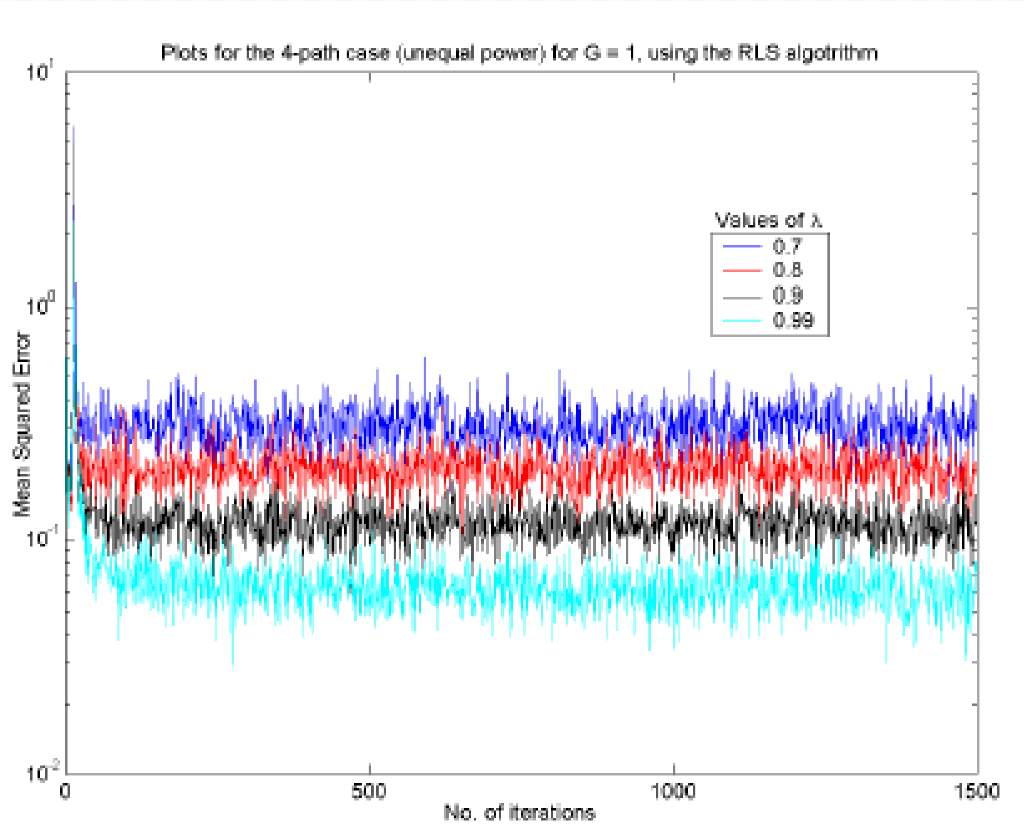
Geometry = 0 dB, LMS algorithm




Higher the μ, faster is the convergence.

# MSE vs Time: Static channel

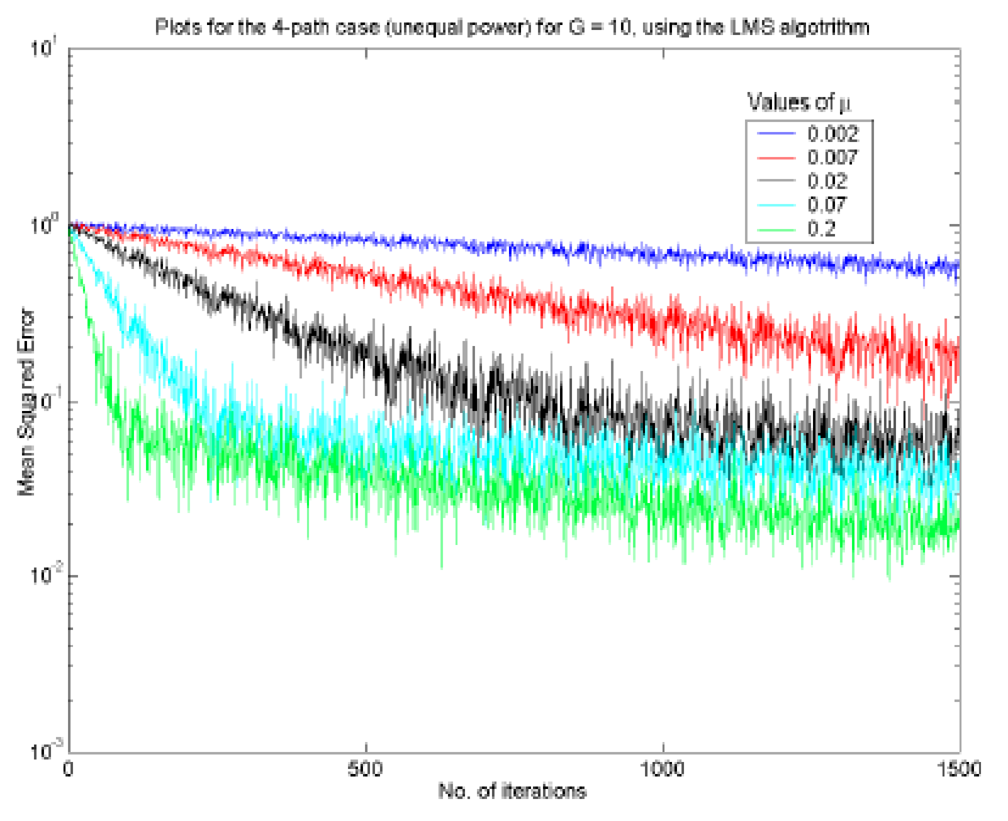
Geometry = 0 dB, RLS algorithm




Faster convergence compared to the LMS case.

# MSE vs Time: Static channel

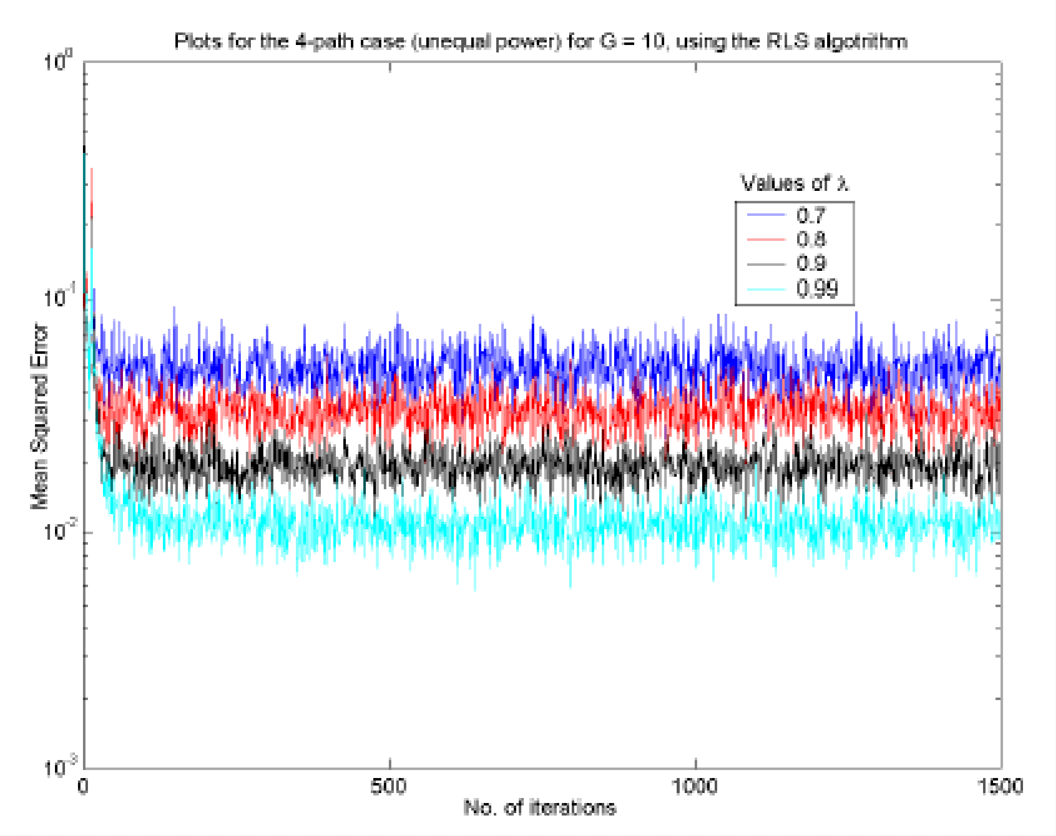
Geometry = 10 dB, LMS algorithm




Higher the Geometry, better the convergence.

# MSE vs Time: Static channel

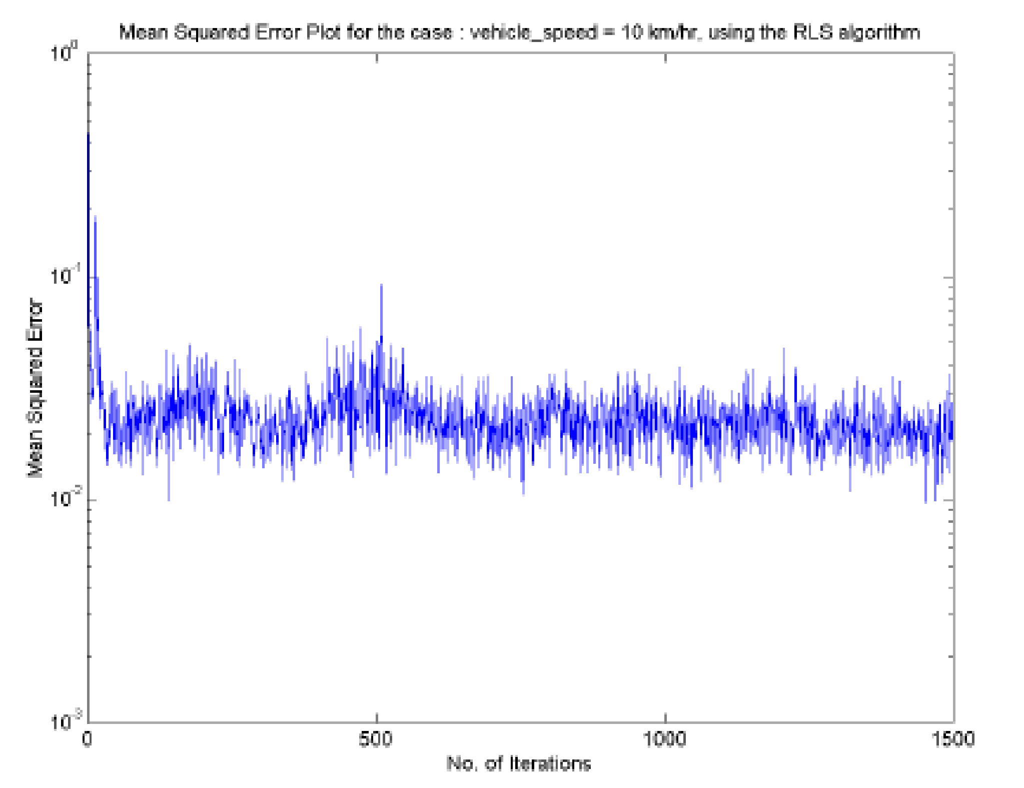
Geometry = 10 dB, RLS algorithm




Higher the Geometry, better the convergence.

# MSE vs Time: Fading channel

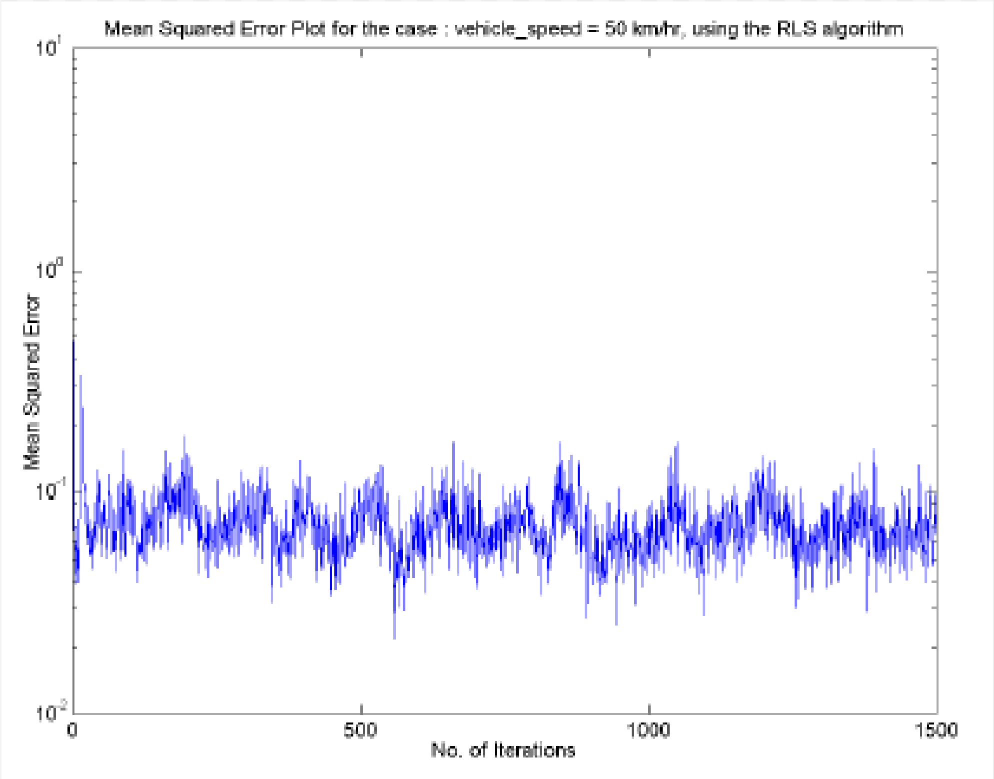
Vehicle speed = 10kmph




Very good convergence obtained at low vehicle speeds.

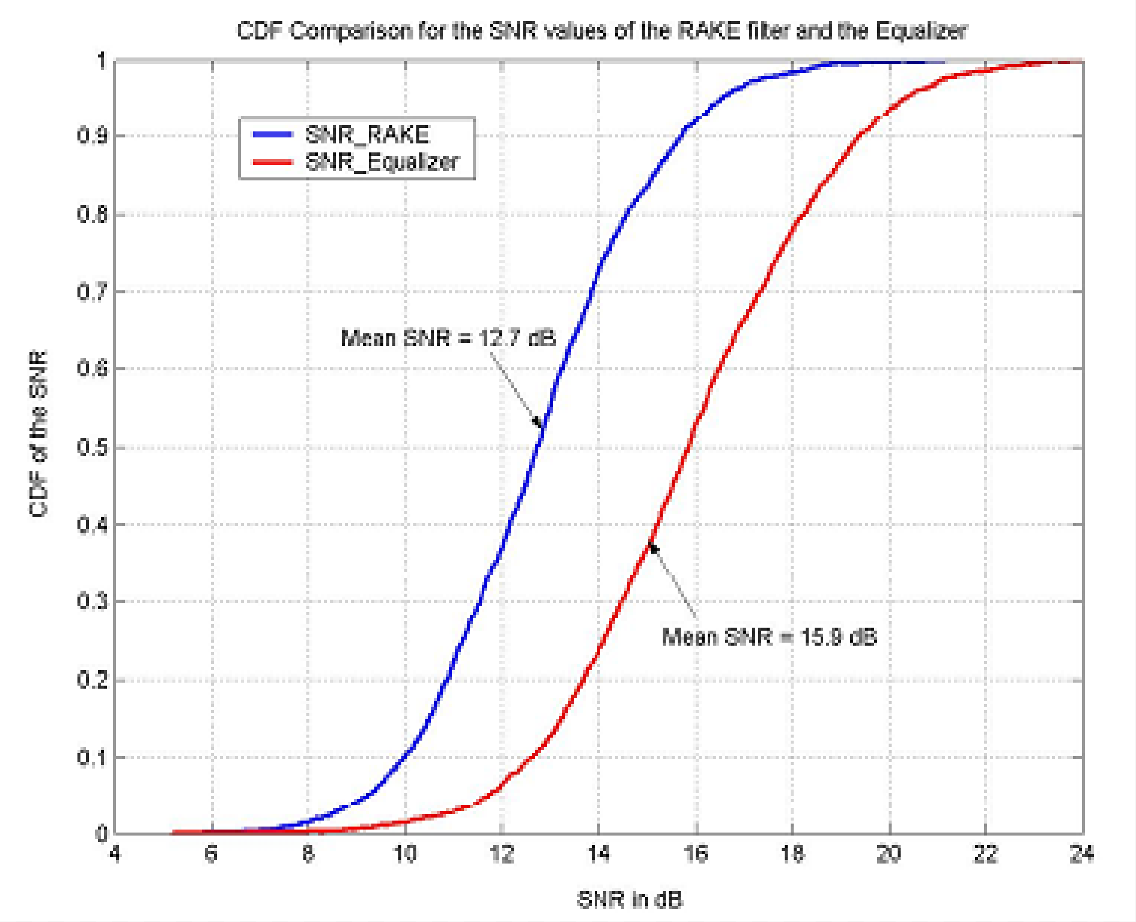
# MSE vs Time: Fading channel

Vehicle speed = 50 kmph




Even at speeds of 50 kmph, the MSE converges.

# SNR Improvement at the Receiver




Speed = 10 kmph, RLS-based Equalizer

# Conclusions

- Linear MMSE symbol-level equalizer performs better than RAKE receiver.
- For the static channel, LMS and RLS-based adaptive filters show a significant improvement in performance over the RAKE receiver.
- For the fading channel, RLS-based equalizer works well for speeds of up to 50 km/hr. However, LMS-based detector does not show any significant improvement in performance.