Source: Motorola

Title: Performance Comparison of Rake and MMSE Equalizers

Document for: Discussion

1. SUMMARY

The performance gain of a linear MMSE equalizer over a Rake equalizer in resolvable multipath is presented. The linear MMSE equalizer is also compared to an upper bound on receiver performance in frequency selective channels. This is a follow up to a previous contribution where a linear MMSE receiver was recommended as a baseline for comparing various multi-antenna schemes [1].

2. DISCUSSION

Figure 1 shows the performance gain of a linear MMSE equalizer[1] over a Rake equalizer in the ITU Vehicular A multipath channel [2] for a single transmit antenna, single receive antenna link. In this example, the SINR at the output of the receiver filters is mapped directly to throughput using the Shannon bound. Mappings based on actual modulations and codes will produce similar trends. Note that this simulation assumes that all the codes and power are assigned to a single user with no overhead. The results show that the Rake equalizer experiences a throughput ceiling due to the loss of orthogonality among the Walsh codes in the frequency selective channel. In contrast, the MMSE equalizer does not experience a throughput ceiling. In high geometry locations, the MMSE equalizer can provide over 2.5 times the throughput of the Rake equalizer. The overall system-level benefit of MMSE varies depending on the details of the system, but it is clear from Figure 1 that the gain can be significant.

The upper bound shown in Figure 1 is based on [3] and represents the best possible capacity in a frequency selective channel. Its capacity is found from

$$C = \frac{1}{N}\sum_n \log_2(1+\gamma\beta_n\lambda_n)$$

where N is the number of transmitted symbols[2], γ is the average channel SNR, λ_n are the eigenvalues of $\mathbf{GG}^H$, $\mathbf{G}$ is the Toeplitz convolution matrix defining the channel, and β_n are powers allocated to each of the symbols according to the well-known waterfilling algorithm.

The upper bound is about 25% better than the MMSE equalizer over all SNRs. This implies that any non-linear equalizer implementation can improve performance by at most 25%. Achieving

[1] The MMSE filter length was set to roughly three times the length of the channel impulse response.

[2] The number of transmitted symbols in a block should be very large to reduce block overlap.

the upper bound requires perfect channel state information at the transmitter, which is impractical. A range of solutions exist, including linear and non-linear equalizers with and without partial channel state feedback. The linear MMSE equalizer, as shown in Figure 1 provides a reasonable baseline for comparing various technologies.

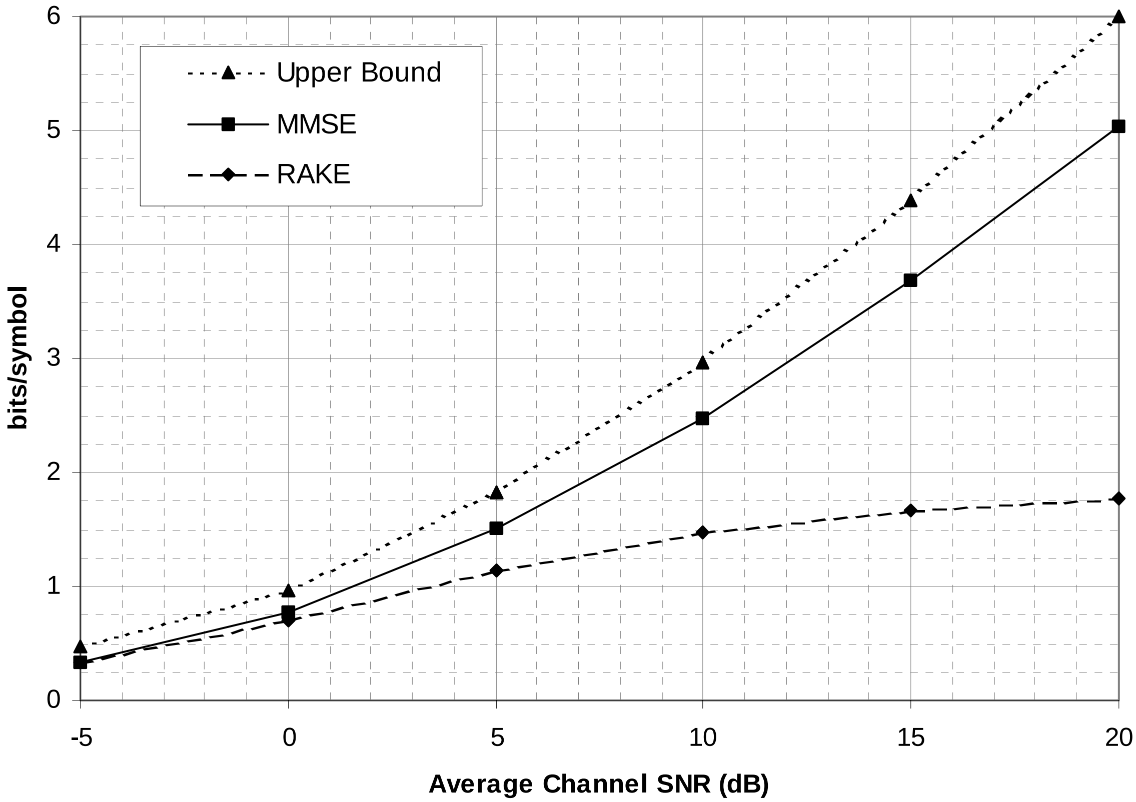

Figure 1. Rake vs. MMSE in Veh-A, 1 Tx / 1 Rx (Shannon Bound mapping).

3. CONCLUSIONS

Linear MMSE equalizers provide good performance in a cellular system along with reasonable complexity and are proposed as a baseline for system simulations.

4. REFERENCES

[1] Motorola, SCM-056, "A Proposed Receiver for System-Level Evaluations," September 17, 2002.

[2] Recommendation ITU-R M.1225, Guidelines for Evaluation of Radio Transmission Technologies for IMT 2000.

[3] G. Raleigh and J. Cioffi, "Spatio-Temporal Coding for Wireless Communications," Proc. of IEEE Globecom '96, pp. 1809-1814, 1996.