

# Effects and Mitigation of Timing Errors in MRC techniques over Rayleigh Channels

**Abstract:** The effects of imperfect timing on Pulse-Amplitude Modulation is approximated using a Gram-Charlier series and the Symbol Error Rates using MRC techniques over a Rayleigh channel is analysed. These results are justified through numerical simulation. Numerical simulation indicates sub-optimum performance using tradition Decision Region Boundaries. A method of detecting the optimum Decision Region Boundaries for given timing error statistics is presented, and these are found to result in a significant reduction in Symbol Error Rate.

## Summary

- Timing Errors have been found to be Tikhonov-distributed.
- The effects of Tikhonov-distributed timing errors on MRC receivers have been treated in [Yin et al. 03]. However these results dealt with BPSK signalling and assumed rectangular signalling.
- Assuming a Root-Raised Cosine response, the effects of a known timing error on the received signal can be treated as a deterministic attenuation.
- The received signal PDF can be approximated using a Gram-Charlier series.
- Using both analytical methods and simulation, the performance of PAM receivers using MRC techniques are found to degrade significantly with increasing timing error variance.
- A optimum variance-dependent decision region boundaries have been determined through simulation. Using these values, performance was found to increase by 7-38%.
- Further performance increases could be possible through determining optimum channel gain- & variance-dependent decision region boundaries.

## Conclusion

The effect of imperfect symbol timing has been analyzed in MRC techniques over Rayleigh fading channels. PAM modulation with coherent demodulation has been considered. Timing errors on different diversity branches have been assumed to be i.i.d. according to a Tikhonov distribution. The effects of timing errors have been theoretically analyzed and justified by computer simulation. Optimum timing variance-dependent decision region boundaries have been calculated, and performance with traditional and optimum boundaries examined. It has been numerically demonstrated that timing errors result in greatly reduced performance using MRC techniques, and a significant performance gain has been observed using optimum boundaries.