Adaptive Modulation for Transmitter Antenna Diversity Mobile Radio Systems[1]

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Abstract – **Adaptive transmission techniques such as adaptive modulation and transmitter antenna diversity have been proposed for mobile wireless systems to satisfy high data-rate service requirements. In rapidly time variant channels, these methods need the knowledge of future fading conditions and therefore require accurate long range fading prediction. We investigate three combined adaptive modulation and transmitter diversity schemes in conjunction with our previously proposed long-range fading channel prediction (LRP) algorithm. It is demonstrated that the novel combined schemes achieve significantly higher data rates than conventional adaptive modulation methods when aided by the LRP. Performance–complexity trade-off for several combined adaptive methods is examined. In addition to utilizing the Jakes fading model to test the proposed methods, we validate the LRP for antenna diversity systems using a novel realistic fading channel model.**

I. SUMMARY

We investigate *combined adaptive modulation and transmitter antenna diversity*. This study is motivated by results in [1] where it was demonstrated that diversity yields large capacity gains for adaptive transmission methods. The combined adaptive modulation and transmitter diversity methods depend on accurate channel state information (CSI), but the rapid variation of the fading channel makes feedback of the current channel estimate insufficient. To realize the potential of adaptive transmission methods, these channel variations have to be *reliably predicted* at least several milliseconds ahead. Recently, we have investigated a *novel adaptive long range fading channel prediction algorithm* (LRP) [2]. The superior performance of this algorithm relative to conventional methods is due to its *longer memory span* that permits prediction much further into the future. Given *fixed model order*, the long memory span is achieved by using *low sampling rate* (on the order of twice the maximum Doppler shift, which is much lower than the data rate).

We previously applied the long-range prediction in adaptive modulation and in transmitter diversity schemes for Wideband Code Division Multiple Access (WCDMA) systems. It was demonstrated that *LRP enables these adaptive transmission techniques* for high vehicle speeds and realistic feedback delays.

In this paper and [3], we extend the application of long range channel prediction to our proposed combined adaptive modulation and transmitter diversity schemes. We concentrate on the study of the following three combined schemes: combined adaptive modulation (AM) + Selective Transmitter Diversity (STD); (2) combined adaptive modulation (AM) + Transmit Adaptive Array (TxAA); and (3) adaptive space-time modulation (AM + STTD). (Here we only consider Alamouti space-time code [4].) We analyze performance of these techniques for perfect CSI and demonstrate that the LRP enables their performance for rapid vehicle speeds using the Jakes fading channel model. In addition, we describe a realistic physical model that captures variation of channel parameters associated with the reflectors that contribute to the channel for an antenna array system. Performance of selective diversity with LRP is investigated for this model.

II. RESULTS AND CONCLUSIONS.

We consider the case of two transmitter antennas and one receiver antenna. The same analytical approach can be extended to the case of any number of transmitter antennas. Modulation level-controlled adaptive modulation (AM) scheme is employed [5]. We restrict the constellation size M of square Quadrature Amplitude Modulation (M-QAM) to 0, 2, 4, 16 and 64, and choose the target Bit Error Rate (BER) as 10^{-3}. The channels from the two antennas to the mobile are modeled as i.i.d. Rayleigh fading with fading gains $\alpha_1(t)$ and $\alpha_2(t)$, respectively. The transmitter antennas are combined according to the chosen diversity scheme. The modulation level selection rule and the performance depends on the transmission diversity scheme and fading channel conditions for both antennas. Thus, we can find a function of $\alpha_1(t)$ and $\alpha_2(t)$ for each combining scheme, say $g(\alpha_1, \alpha_2)$, so that the modulation size is selected based on $g(\alpha_1, \alpha_2)$, using the thresholds calculated as in [5]. Using this approach, we derived the data rates, the BER and the outage probabilities for the three adaptive transmission schemes (TxAA, STD and STTD) assuming the perfect CSI is available at the transmitter [3]. *We found that all combined methods achieve higher data rates that AM only*. When three transmitter diversity methods under investigation are combined with AM, *Tx AA has the best performance and the highest complexity, whereas STTD is the simplest to implement and has the lowest data rate*. We also examined combined schemes aided by long range prediction through simulations and showed that *accurate prediction is necessary to realize these adaptive transmission methods* for mobile radio channels. Finally, we employed *a novel realistic physical model to validate performance of LRP* in transmitter diversity techniques.

REFERENCES

[1] M. S. Alouini, and A. J. Goldsmith, "Capacity of Rayleigh Fading Channels Under Different Adaptive Transmission and Diversity-Combining Techniques," *IEEE Trans. Veh. Technol.*, Vol. 48, No. 4, July 1999, pp. 1165 – 1181.

[2] A. Duel-Hallen, S. Hu, H. Hallen, "Long-range Prediction of Fading Signals: Enabling Adaptive Transmission for Mobile Radio Channels", *IEEE Signal Processing Magazine*, Vol. 17, No.3, May 2000, pp.62-75.

[3] S. Hu, A. Duel-Hallen, "Combined Adaptive Modulation and Transmitter Diversity Using Long Range Prediction for Flat Fading Mobile Radio Channels," Proc. of IEEE Globecom'01.

[4] S. M. Alamouti, "A Simple Transmit Diversity Technique for Wireless Communications," *IEEE Journal on Select Areas in Comm.* Vol. 16, No. 8, Oct. 1998, pp. 1451 – 1458.

[5] A. J. Goldsmith and S. G. Chua, "Variable-Rate Variable-power MQAM for Fading Channels", *IEEE Trans. Comm.*, vol. 45, No. 10, pp. 1218 - 1230, Oct. 1997.

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