On the Impact of Channel and Channel Quality Estimation on Adaptive Modulation

by

Payal Jain

Thesis submitted to the Faculty of the

Virginia Polytechnic Institute and State University

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

in

Electrical Engineering

Keywords: Adaptive Modulation, Channel Quality Estimation, Long term SNR estimation, Short term SNR estimation, Pilot Symbol Assisted Modulation, Channel Estimation, Rayleigh Fading, Quadrature Amplitude Modulation

Approved:

_____

Dr. R. M. Buehrer

_____ _____

Dr. B. D.Woerner **Dr. I. Jacobs**

December 2002
Blacksburg, VA

On the Impact of Channel and Channel Quality Estimation on Adaptive Modulation

by

Payal Jain

(**Abstract**)

The rapid growth in wireless communications has given rise to an increasing demand for channel capacity using limited bandwidth. Wireless channels vary over time due to fading and changing interference conditions. Typical wireless systems are designed by choosing a modulation scheme to meet worst case conditions and thus rely on power control to adapt to changing channel conditions. Adaptive modulation, however, exploits these channel variations to improve the spectral efficiency of wireless communications by intelligently changing the modulation scheme based on channel conditions. Necessarily, among the modulation schemes used are spectrally efficient modulation schemes such as quadrature amplitude modulation (QAM) techniques.

QAM yields the high spectral efficiency due to its use of amplitude as well as phase modulation and therefore is an effective technique for achieving high channel capacity. The main drawbacks of QAM modulation are its reduced energy efficiency (as compared to standard QPSK) and its sensitivity to channel amplitude variations. Adaptive modulation attempts to address the first drawback by using more energy efficient schemes in low SNR conditions are reserving the use of QAM for high SNR conditions. The second drawback leads to a requirement of high quality channel estimation. Many researchers have studied pilot symbol assisted modulation for compensating the effects of fading at the receiver. A main contribution of this thesis is the investigation of different channel estimation techniques (along with the effect of pilot symbol spacing and Doppler spread) on the performance of adaptive modulation.

Another important parameter affecting adaptive modulation is the signal–to-noise ratio. In order to adapt modulation efficiently, it is essential to have accurate knowledge of the channel signal–to-noise ratio. The performance of adaptive modulation depends directly on how well the channel SNR is estimated. The more accurate the estimation of the

channel SNR is, the better the choice of modulation scheme becomes, and the better the ability to exploit the variations in the wireless channel is. The second main contribution of this thesis is the investigation of the impact of SNR estimation techniques on the performance and spectral efficiency of adaptive modulation. Further, we investigate the impact of various channel conditions on SNR estimation and the resulting impact on the performance of adaptive modulation. Finally, we investigate long term SNR estimation, its use in adaptive modulation and present a comparison between the two approaches.

ACKNOWLEDGEMENTS

I am very thankful to my advisor Dr. R.M.Buehrer without whose support this thesis would not have been possible. His invaluable advice has helped me to reach this important milestone of my life. He has been a mentor in guiding me through my graduate career. It has been a great honor for me to work under his guidance. I also would like to use this opportunity to thank Dr. Jacobs and Dr. Woerner to serve as my committee members. Their help and guidance are deeply appreciated.

I thank my parents Dr. Ashok K. Jain and Mrs. Sarita Jain, and my brother Gaurav, for loving me and encouraging me throughout my life. Many thanks to my colleagues at the MPRG who have contributed greatly to my learning over the course of these two years and for their generosity in sharing their knowledge. I wish to thank Vikash Srivastava for his love and support. Finally, I want to express my gratitude to God whose blessings made this effort fruitful.

TABLE OF CONTENTS

3 INTRODUCTION TO ADAPTIVE MODULATION

4 ANALYSIS OF CHANNEL QUALITY (SNR) ESTIMATION ON ADAPTIVE MODULATION

5 CONCLUSIONS AND FUTURE WORK

LIST OF FIGURES

LIST OF TABLES