The Effect of Time Delay on Adaptive QAM Schemes in Mobile Multimedia Communications

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이동 멀티미디어 통신에서 적응 QAM 변조의 시간지연에 대한 영향

정 연 호

Abstract

This paper provides a comprehensive study of the effect of time delay on adaptive transmission methods. By adaptive we mean that the transmission of data is made adaptive according to channel conditions. That is, the modulation level at the transmitter is carefully controlled for maximizing bandwidth efficiency, on the basis of the observation of instantaneous channel characteristics. By making use of the simulator developed for the present work, a large number of channel propagation environments including the models proposed in 3GPP were submitted to the simulator and the performance with respect to both time delay and SNR is observed. The results show that the performance is very sensitive to channel delay and in some cases the performance shows irreducible BER (IBER). A large amount of delay together with a high fading rate greatly affects the performance of adaptive transmission systems.

요 약

본 논문은 적응 전송시스템의 시간지연에 대한 영향을 고려한다. 적응 시스템은 채널의 조건들에 의해 데이터 전송을 적응적으로 수행하는 시스템을 말한다. 다시말해 심볼당 전송할 비트 수를 순간 채널특성을 조사하여 대역폭 효율을 증대시킬 수 있도록 제어한다. 개발된 시뮬레이터를 이용하여 3GPP에서 제안된 채널모델을 포함한 많은 채널 전파환경을 시뮬레이터에 적용하여 SNR 및 시간지연 요소에 대해 성능을 평가하였다. 성능 평가결과는 채널의 시간 지연성분에 대해 성능은 아주 민감하며 어떤 경우는 SNR 값과 상관없이 성능이 더 이상 줄어들지 않는 현상도 나타났다. 따라서 페이딩율과 시간지연의 정도에 따라 적응 시스템의 성능은 크게 영향을 받게 된다.

키워드

Adaptive, time delay, bandwidth efficiency, QAM

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접수일자

Ⅰ. Introduction

In third-generation mobile radio systems, it is vital to provide multimedia services with high throughput and quality. In order to achieve this goal, the development of reliable high-speed digital data transmission schemes is a prerequisite. One solution to this underlying issue is to deploy adaptive transmission schemes [1-3]. In other words, the data transmission is controlled by a mechanism where the modulation level is selected according to instantaneous channel characteristics. When the channel is sensed good, a large amount of data within limited bandwidth are transmitted, thus achieving high bandwidth efficiency, whereas a relatively small amount of data are transmitted when the channel is bad. In order to implement this adaptation technique, a number of important issues need to be addressed. First, an efficient modulation scheme is needed to be employed. In this paper, a differential Quadrature Amplitude Modulation (QAM) is employed. QAM scheme is widely used in adaptive systems and known to be effective in achieving high bit rate transmission using a limited bandwidth [2]. In addition to modulation method to be chosen, an adaptation mechanism is next to be determined. In other words, the adaptation can be made using the RSSI, based on which in the receiver the transmitted symbols are first detected and the receiver decides to increase or decrease the number of bits per symbol in the forthcoming block in the transmitter. There is another way of achieving adaptation where the adaptation is made to achieve an acceptable level of BER in the receiver [2]. It is known that although, in fading channels, the severe amplitude and phase changes occur and these often lead to a high bit error rate (BER) in QAM symbol transmissions, the QAM scheme can be applied to Rayleigh fading channels with acceptable performance by controlling the modulation level adaptively[3]. As the mobile radio channel often exhibits time delays, the applicability of adaptive QAM schemes to frequency selective fading channel environments should be addressed. Previous contributions in frequency selective fading channel environments attempted to mitigate the effect of channel delays by employing multicarrier transmission or an equalizer[4]. In this paper, a simple oversampling technique in the receiver was employed for mitigating intersymbol interference (ISI) present in frequency selective fading channels. In the following, the adaptive QAM schemes and adaptation mechanism are presented. In Section 3, the computer simulation of the adaptive QAM and its results are provided. In Section 4, conclusions are drawn.

II. Adaptive QAM transmission

In QAM modulation schemes, two possible arrangements of QAM constellation points are generally considered: square and circular shaped QAM constellation. Previous studies show that over Rayleigh fading channels, a circular shaped QAM is preferred. In order to mitigate fading effects more efficiently, differential encoding is utilized although this may reduce the performance slightly due to its encoding nature. In this paper, a circular QAM combined with differential encoding is considered and the adaptation is performed by way of the QAM modulation level. The range of modulation level to be varied is 2-QAM (BPSK) to 64-QAM. Although the performance of adaptive transmission schemes in fading channels shows the viability, the schemes need to be further analyzed, particularly under frequency selective fading conditions. This paper focuses on the effect of time delay on the performance of adaptive QAM transmission systems. In order to perform this, a simulator has been developed and various channel environments having different time delay were submitted to the simulator. The block diagram of the simulator is shown in Figure 1.

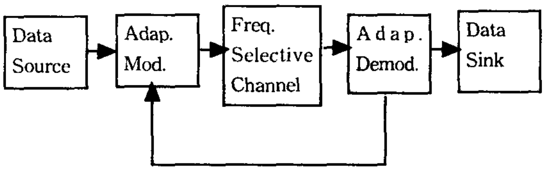


Figure 1. Block diagram of adaptive QAM system

One of the most important issues in adaptive modulation schemes is the accuracy and reliability of an adaptation parameter, based on which the increase or decrease of the modulation level is initiated. By assuming that the channel does not vary significantly over two symbol blocks, the QAM modulator in the transmitter directly utilizes the number of bits per symbol fed from the receiver. That is, the adaptation mechanism operates in the receiver with the assumption that an error-free transmission of the number of bits per symbol is made. After a normal demodulation at the receiver, it performs an adaptation process in which the number of bits per symbol to be used for the next symbol block is determined. The process is detailed as follows. It begins by measuring the received signal strength based on the signal for the present symbol block. This signal strength indicates what number of bits per symbol is appropriate to be used in the transmitter by way of making a comparison with an initial threshold. Depending upon how much the signal level is increased or decreased, the scheme carefully decides to increase or decrease the number of bits per symbol. The proposed scheme allows a 2- or 3-bit increase or decrease at a time, if the measured signal level is significantly high or low. This operation is carried out systematically by arranging a number of thresholds with an appropriate step size. That is, the received signal level is compared with the thresholds and then a proper threshold can be found. Based on the signal level of the previous symbol block, the number of thresholds moved up or down with respect to the previous threshold, is obtained. This information facilitates the number of bits per symbol to be used for the forthcoming symbol block.

III. Simulation results

Frequency selective fading channels are implemented as described in [5]. That is, a tapped-delay line model is utilized, thus realizing relative delay of each path as well as relative power of each path in the model. In total, 10 propagation models representing for different environments including UMTS models were considered. Figure 2 shows the model for UMTS outdoor to indoor and pedestrian environment [6]. The simulation parameters are as follows. For each simulation run, a total of 500 frames were transmitted over the channel and a carrier frequency of 1GHz was utilized. The block size of each frame consists of 100 symbols and the symbol rate is 32 Kbaud. In the present study, 2 samples were taken over each symbol period for improvements in BER performance. Figure 3 shows the BER performance for the

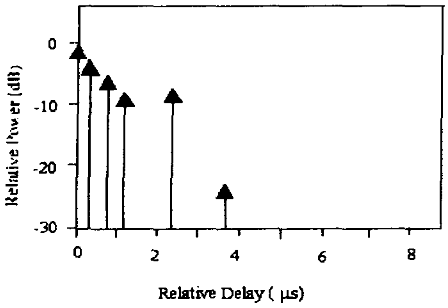


Figure 2. Channel model for outdoor to indoor and pedestrian environment

environments under consideration at the mobile speed of 3 km/h and the SNR value of 20dB. It can be seen that the performance is greatly affected by the amount of channel delay. The channel models whose delay spread is higher than approximately 4 μsec are unable to produce a BER of 10 ^{3}. The average number of bits per symbol for all propagation environments is approximately 4.2, which implies a very high bandwidth efficiency. It should be noted that unlike the approach adopted in this study, the adaptation process can be made to achieve a certain level of BER. When the mobile speed increases to 50 km/h, the performance becomes much worse. The results are shown in Figure 4 at the SNR value of 30dB. Figure 4 shows that the BER performance suffers from not only channel delay but also high fading rate. In other words, although the signal power is increased dramatically, no significant improvement in the BER performance is made. In order to observe the effect of channel delay on the performance more efficiently, the BER performance with respect to channel delay (expressed in terms of delay spread) is analyzed. Figure 5 and 6 show performance variations according to channel delay in the two simulation scenarios mentioned above. It is clear that the channel models having a

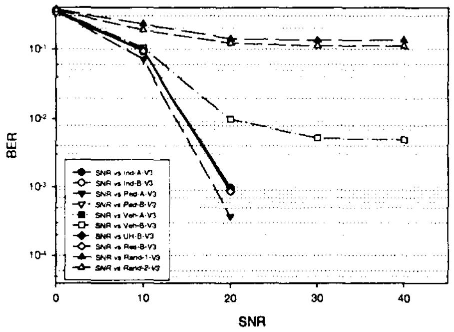
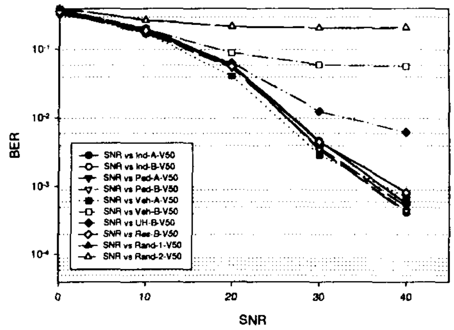


Figure 3. BER performance for various channel delays at the mobile speed of 3Km/h



n Figure 4. BER performance for various channel delays at the mobile speed of 50Km/h

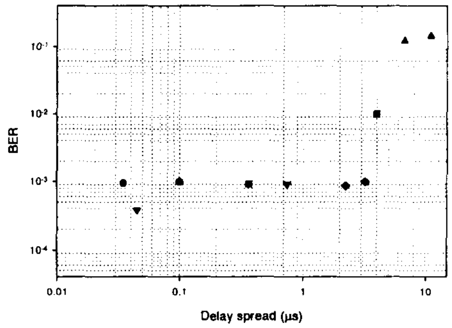


Figure 5. BER performance for various environments with respect to delay spread (3km/h)

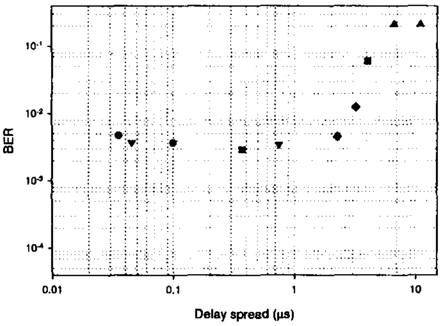


Figure 6. BER performance for various environments with respect to delay spread (50km/h)

delay spread higher than approximately 4μsec produce performance degradation. This phenomenon is also observed when the mobile speed is increased. Figure 6 shows the BER performance in relation to channel delay when the mobile speed is increased to 50km/h. It notes from Figure 6 that with a higher mobile speed the performance sharply degrades when delay spread is approximately 2μsec. That is, a higher fading rate combined with channel delay degrades the performance severely. In fact, the performance is unacceptable for efficient and reliable mobile multimedia communications. Therefore, it can be concluded that a comprehensive measure to compensate for channel delay as well as fast fading is essential for adaptive transmission schemes to be viable for future mobile communication systems.

Ⅳ. Conclusions

In this paper, the effect of time delay on adaptive transmission schemes is studied. Simulation results show that channel delay greatly affects the performance and it often makes the performance unacceptable as it goes below 10^{3}. It is found that techniques such as Turbo coding, equalization or complex spreading, etc. need to be implemented in order to compensate the effect of channel delay. It is believed to be first time that the severity of channel delay on the performance of adaptive transmission schemes, which is critical for their viability, is comprehensively studied.

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