The Impact of Channel Estimation on the Performance and System Complexity of MIMO-OFDM Technique in Wireless Communications Systems

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Implementation of MIMO-OFDM technique in Wireless Communications Systems is conducted in coherent channel condition. In fact, it is difficult to acquire an ideal coherent channel. In order to obtain channel condition, a channel estimation technique is applied. In multicarrier system, channel response experienced by each subcarrier can be different. In order to guarantee the same S/N ratio on each subcarrier, so a channel estimation scheme is needed in each subcarrier. Yet, this scheme adds system complexity. In this paper the research is focused on the influence of channel estimation scheme application to the system complexity and performance in MIMO-OFDM over wireless communication systems. Particularly, trade-off between performance and system complexity is considered. The research is adapted in selective fading channel condition. In the future wireless communication systems, communication system is not only expected to serve a very high data rate, but also to serve a high mobility user. Consequently, this channel estimation effect will be observed in high as well as low velocity of user.

Key words: MIMO-OFDM, coherent channel, estimation scheme

1. Introduction

In the next generation of wireless communication system, one of high data rate systems is the application of MIMO OFDM system. It is assumed that the communication system is implemented with coherent channel transmission scheme. In order to support transmission scheme, several channel estimation methods have been developed that are employed in MIMO system and MIMO OFDM system as well. Previous researches are focused on the investigation of multipath channel influence on system performance.

While for selective channel condition, multicarrier scheme such as OFDM system could be used. In these systems, channel estimations method is applied in each subcarrier, i.e. in each MIMO OFDM system antenna. This is performed in order to guarantee similar signal quality in each subcarrier, in each MIMO's antenna, i.e. in [(1),(3),(8)]. From previous researches result, this method is good enough to overcome the effects of multipath channel. The limitation of this method is apparent when operated in rapidly changing environment due to high data rate transmission.

It is well known that in the future, wireless communication system is implemented in high speed mobility. The objective of our research is to observe whether the channel estimation method could accommodate the highly fluctuate channel. Furthermore, it is also aimed to investigate the increase in system complexity, the guaranties of this method to system performance and subcarrier performance. The outcome of this research is expected to provide recommendation on the future system developments.

Our research model is based on [(8)], which that paper is focused in performance evaluation due to mutipath. However, in our research we emphasize in performance evaluation due to motion and increase of its complexity.

The paper is organized as follows. In Section 2, we review multicarrier wireless system model for high data rate transmission scheme. Next, in Section 3 we talk about the channel estimation schemes on MIMO OFDM system. Then, in Section 4 we explore the evaluated performance of channel estimation schemes in MIMO OFDM wireless communication system. Finally our main conclusions are summarized in Sections 5.

2. Multicarrier Wireless System Model

The direction of the future wireless communication system is shifted from private access to public access. Hence, the support of high data rate transmission scheme is necessary. Consequently, the system could obtain wide bandwidth yet be prone to selective fading. On the other hand, wide bandwidth necessity is also limited by transmission bandwidth, i.e. unlimited and non renewable natural resource. The combination between multicarrier scheme and MIMO system is one of solutions to overcome those problems.

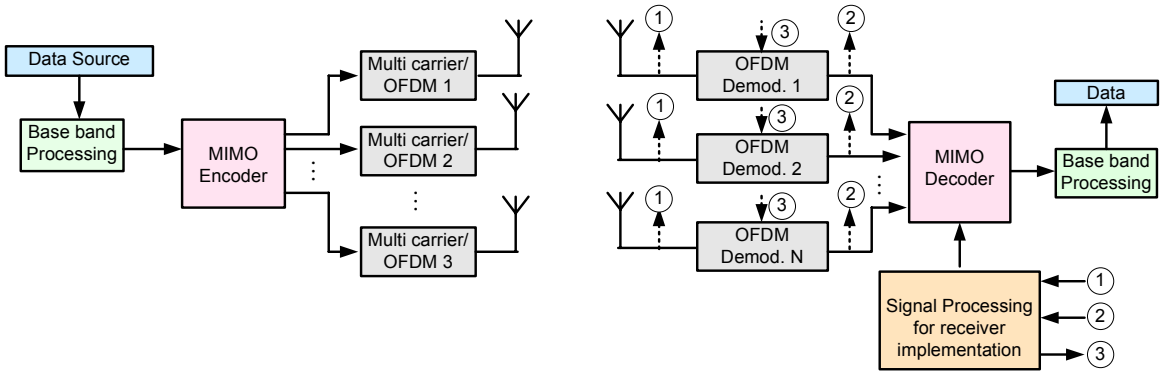

Fig. 1. Multi carrier scheme in MIMO wireless communication system

Multicarrier techniques can combat frequency selective fading, because of the robustness against this fading is very attractive for high speed data rate. There are many kind of multicarrier techniques, which are developed for fourth generation (4G). Those are OFDM scheme; coded OFDM scheme to gain frequency diversity effect; and combination of OFDM and CDMA which has synergistic effects of robustness against frequency selective fading and high scalability in possible data rate [6]. In this paper, we emphasize OFDM-based techniques in MIMO wireless communication system.

3. Channel Estimation Schemes on MIMO OFDM System

In fixed or low speeds wireless communication systems, transmission system with coherent channel scheme is applied; in which channel acknowledgment is performed by a channel estimation method. In MIMO OFDM system, to guarantee similar performance in each subcarrier, channel estimation scheme is implemented in each subcarrier of MIMO's antenna.

In contrary, high speed wireless system, it might be difficult or costly to estimate the channel accurately in high-mobility situations. Channel estimation over fast fading environment requires more training symbols and complex computing power. While, the perfect estimates of channel conditions assumption is acceptable if the channel changes slowly compared with the symbol rate, because the transmitters can send training symbols which allow the receiver to estimate the channel accurately[2],[5].

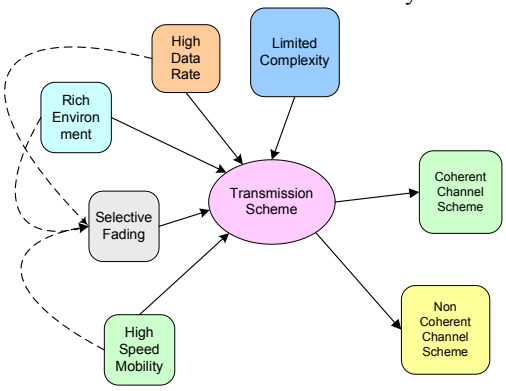

Fig. 2. Transmission schemes diagram in wireless communication systems

In this paper, we present channel estimation model, which is based on preamble symbol channel estimation method. This method extends by employing the scattered pilot preamble symbol conjunction with interpolation method, i.e. discrete cosine transform channel estimation [8]. We consider applying this channel estimation in two schemes, i.e. in interpolation based and non interpolation based.

4. Simulation Results and Discussion

The objective of channel estimation scheme in MIMO OFDM wireless system is to keep system performance and guarantee signal performance in each subcarrier, particularly in selective channel condition. Nonetheless, the application of these schemes will raise overall system complexity. Besides, another limitation of this scheme is its difficulty to acquire good result is rapidly changing channel.

In this paper, research result pertinent to those problems will be presented as follows. In the first part, the research is conducted to observe how the channel estimation application, especially with interpolation estimation scheme, could influence in the various speeds multi carrier system. The implication of these schemes that is taken into account includes performances and simulation time. Simulation time is assumed to represent system complexity in estimating channel condition. In this case, it is affected by number of transmitted bits to obtain channel condition, so that better performance is acquired.

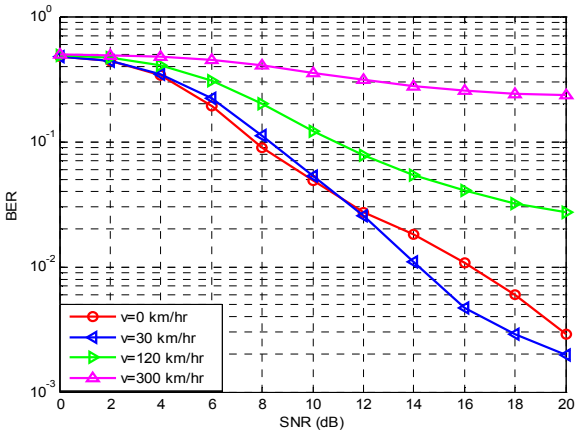

Fig. 3 The BER performance of channel estimation scheme in MIMO OFDM wireless system with interpolation scheme

In Fig.3, it is apparent that with a few number of pilot bits, signal performance of low speed user is good enough. In contrast, at high speed condition (120 km/hour and 300 km/hour) and for similar Eb/No, if the number of pilot bits is fixed, then the performance will be poorer. In the other words, the number of pilot bits is not sufficient to anticipate the rapidly changing of channel condition.

In the second part, the observation is performed on the variation of this channel estimation scheme to system performance and simulation time, in high speed condition (300 km/hour). As comparison, system performance with this scheme is confronted to other system, such MIMO OFDM system with Valenti estimation method in which channel estimation is applied at each MIMO antenna arm. Besides this system is also compared with MIMO system with another multi carrier scheme, such as a non coherent channel scheme i.e. multilevel DUSTF coding scheme [5]. Hence, the improvement of performance could be observed in accordance with its complexity.

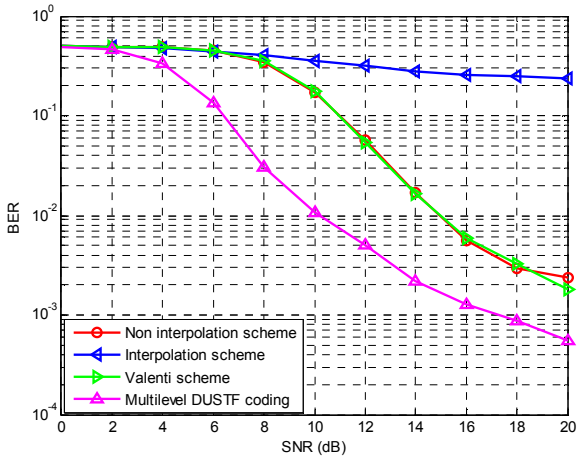

Fig. 4. The BER performance comparison of four transmission schemes

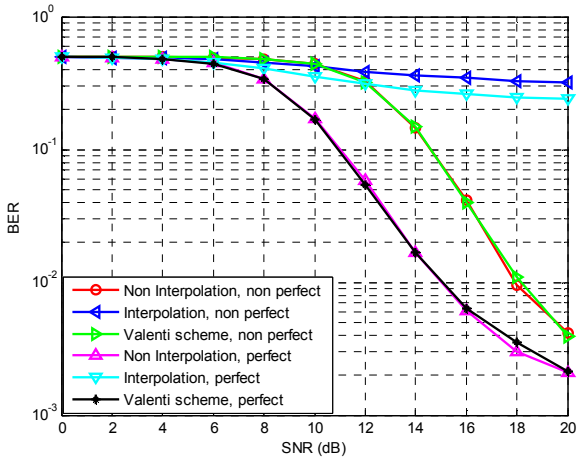

Fig. 5. The impact of variation number of pilot bits in high speed conditions

Fig. 4 shows the comparison among the MIMO systems performance, i.e. MIMO OFDM system with channel estimation: with interpolation scheme and without interpolation scheme (perfect estimation); MIMO OFDM system with Valenti estimation method [7]; and MIMO system with multilevel DUSTF coding scheme [5]. The figure shows that in similar channel condition, i.e. selective channel, and in high speed condition (300 km/hour), then MIMO OFDM system without interpolation estimation method has better performance than the system that is applied with interpolation estimation scheme.

Furthermore, although the estimation method is simpler, i.e. a single carrier estimation method of MIMO system, Valenti method, the performance is excellent, but this system does not accommodate equal performance guaranty in each sub carrier, as shown in Fig. 4 and Fig. 5.

To overcome the rapidly changing of channel condition, the number of pilot bits should be in accordance with channel condition; at least it changes with respect to channel variation or user velocity, as shown in Fig. 5.

Then, MIMO system with multilevel DUSTF coding scheme in high speed condition, which is applied as non coherent channel transmission scheme, shows superior performance than the others, as shown in Fig. 4.

Table 1. The comparison among the mean simulations processing time in MIMO OFDM systems

Transmission scheme	**Velocity (km/hr)**	**Pilot bits**	**Processing time (sec/block data)**
Interpolation estimation based	300	perfect non perfect	3.797 3.22748
Non interpolation estimation based	300	perfect non perfect	2.30174 1.38836
Valenti method	300	perfect non perfect	2.62534 1.6965
Multilevel DUSTF coding (non coherent channel scheme)	300		1.609

Next, we will observe the comparison of simulation processing time that is need to evaluate the system performance. In this analysis, transmission delay is assumed uniform and small, so that the noticeable parameter to estimate model complexity is simulation processing time. It is assumed that transmission parameters are equal and also equal computer system. Research results data can be seen in Table 1.

It is apparent that processing time of channel estimation scheme in MIMO OFDM wireless system is in accordance with the number of pilot bits required to estimate channel condition, where the optimum number of pilot bits depends on channel condition. Moreover, it depends on estimation method application scheme as well. In addition, non coherent channel scheme, i.e. multilevel DUSTF coding scheme, needs nearly similar simulation time than non interpolation estimation scheme. Due to this system applies differential schemes, i.e. frequencies function. However, in high velocity condition, as shown in Fig. 4, achievable performance is more excellent compared with the other estimation methods.

5. Conclusion

From the research result that has been conducted, it seems that generally the number of certain pilot bits could merely

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give excellent channel response at particular condition, with also particular user velocity. To conserve stable system performance, the number of pilot bits should be applied adaptively, according to channel condition as a consequence of user velocity variation.

Estimation method application scheme could also affect system performance, mainly at high speed. Furthermore, from research result, it is concluded that in high speed user, the application of estimation bits at OFDM subcarriers without interpolation estimation scheme, in each MIMO antenna arm, provides nearly similar performance than the application of estimation method for single carrier, i.e. Valenti method.

Next, we presume simulation time is proportional to system complexity in estimating channel condition. From research, it is obtained that fast channel change due to high speed user mobility requires, at least, the same number of bits as information bits. Even though signal performance achieved is only the same as that of low speed user mobility. This is because the channel changes rapidly compared with the system rate. In other words, it is costly to estimate the channel accurately in high-mobility situations. On the other hand, the MIMO OFDM system with a coherent channel scheme, i.e. multilevel DUSTF coding scheme, achieves more excellent performance compared with the other estimation methods and also needs fewer simulations processing time.

Based on this research result, we propose to develop a non coherent channel transmission scheme in high data rate wireless communication system that can accommodate high speed user mobility and various bandwidth usage, QoS or channel response for every user. The system can be the novelty of this proposal has been submitted in [4].

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