# PERFORMANCE ANALYSIS OF ARRAY ANTENNA SYSTEM USING MULTIUSER DETECTION AND HARQ

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## ABSTRACT

Multi-user detection(MUD) technique eliminates both inter-symbol interference (ISI) and multiple-access interference (MAI) in the received signal over time-varying multipath channels. Hybrid ARQ(Automatic Repeat reQuest)(HARQ) technique combines the advantages of FEC and ARQ and offers much better performance, especially for time-varying multipath channels. In this paper, we analyze a smart antenna system and diversity antenna system using MUD and HARQ. In general, the smart antenna system can increase the capacity of a mobile radio network due to the capability of mitigating the interference. The diversity antenna system can improve the reliability of a received signal by utilizing two or more communication channels with different characteristic, in order to combat fading and interference. By using the HARQ technique, the smart antenna system and diversity antenna system improved a performance due to increase diversity order. The performance analysis of smart antenna system and diversity antenna system is shown in terms of BER(bit error rate) and complexity in the HSDPA(High-Speed Downlink Packet Access).

## 1. INTRODUCTION

The various methods to increase the capacity and data speed of the base-station in mobile communication have been studied. One of the methods to increase the base-station capacity in mobile communication is to enhance the frequency efficiency. Also, array antenna can increase the system capacity.

In this paper, we analyze the performance of the diversity technology and smart antenna technology which are used in array antenna system. The diversity antenna system shows the optimum performance when the received signals at the base-station antenna element are uncorrelated. But, to do so, the distance of the antenna elements in diversity antenna system should be large. But, the performance enhancement in smart antenna system can be obtained in case that the correlation value of the received signal at antenna element is large. The beamforming technology to minimize the interference of the unwanted signals by forming the null of the interference signal is one of the advantages of the smart antenna system.

In this paper, we propose the system model of smart antenna system and diversity antenna system and apply the joint detection algorithm in TD-SCDMA signal environments. In addition, we analyze the performance of smart antenna system and diversity antenna system and check if there exists diversity gain by utilizing the HARQ.

Section 2 of this paper shows the mathematical modeling of the received signal and describes the system frame structure of the paper. Section 3 shows the system structure of the smart antenna and diversity antenna and we analyzed the system performance in TD-SCDMA system environments in section 4. Section 5 gives a conclusion of the paper.

## 2. RECEIVING SIGNAL MODELING

Let us consider an uniform linear array consisting of $N$ antenna elements. The baseband signal of $k$ th mobile station, transmitted to the base station in the uplink channel, is denoted by $s_k(t)$. Without loss of generality, we assume that the pattern of each antenna element is omni-directional. Then, the down-converted output of the $m$ th element of receiving antenna is

$$x_m(t) = \sum_{k=1}^{K}\sum_{w=1}^{W} R_{k,w}\left(\frac{1}{\sqrt{L}}\sum_{l=1}^{L} s_k(t-\tau_{k,w}) e^{j2\pi\left[(f_c + f_d\cos\varphi_{k,w,l})t - f_c\tau_{k,w,l}\right]} e^{-j2\pi(d_m/\lambda_c)\sin\theta_{k,w,l}}\right) + n_m(t) \quad (1)$$

where $K$, $R_{k,w}$, $W$ and $L$ are the number of transmitting subscribers, the receiving signal magnitude factor of $w$ th multipath of the $k$ th user, the number of multipaths of each subscriber, and the number of scattered components at each path, respectively, and $\tau_{k,w}$ and $f_d$ are the propagation delay and the maximum Doppler frequency, respectively. $d_m$, $\lambda_c$, $\theta_{k,w,l}$ and $n_m(t)$ are the distance of reference antenna and $m$ th antenna, the wavelength of the carrier frequency, the perturbed angle of arrival, and the additive

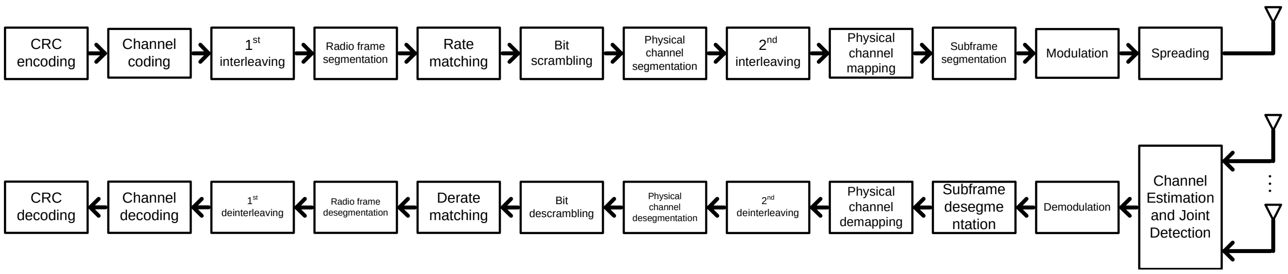


Fig. 2 TD-SCDMA System Block Diagram

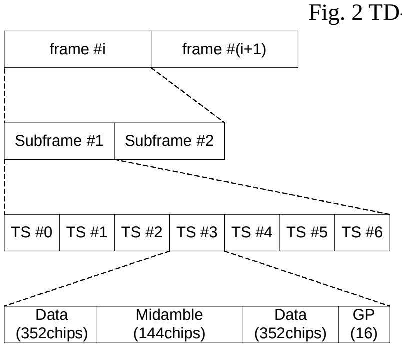


Fig. 1 Frame structure

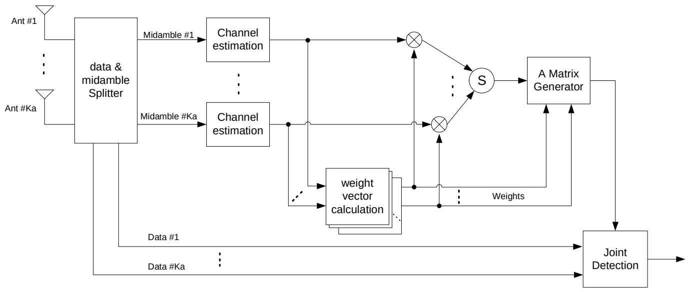


Fig. 3 Channel Estimation and Joint Detection Part in Smart Antenna System(JSA)

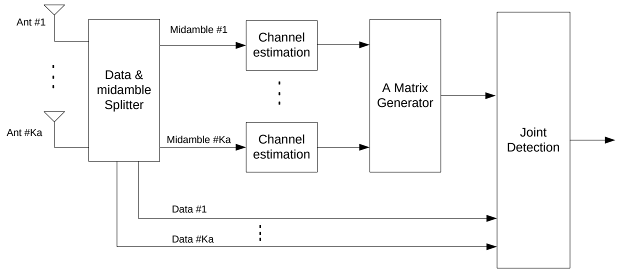


Fig. 4 Channel Estimation and Joint Detection Part in Diversity Antenna System(JDA)

white Gaussian noise. In (1), it is assumed that propagation delay of every scattered component within a given propagation path is identical for every subscriber.

Fig. 1 shows the frame structure of TD-SCDMA (WCDMA LCR TDD). As shown in Fig. 1, one frame, which has the duration of 10ms, consists of 2 subframes and there are 7 timeslots in one subframe. The duration of each subframe is 5ms. Each timeslot consist of data part, midamble part, and guard period(GP) part, respectively. In general, the midamble is used to estimate the channel. Also, the midamble is used for calculation of weight vector in smart antenna system.

## 3. SYSTEM STRUCTURE

Fig. 2 shows the overall block diagram of the TD-SCDMA system. The system structure of the smart antenna system is the same as that of the diversity antenna system except for the channel estimation and joint detection part.

### 3.1. Receiver Structure of the Smart Antenna System

Fig. 3 shows the channel estimation and joint detection structure in smart antenna system. The system performance in smart antenna system is enhanced according to the number of retransmission. In this paper, the Lagrange algorithm is used to calculate the weight vector in order to obtain the beamforming gain. In Fig. 3, the data & midamble splitter block separates the data part and the midamble part from each timeslot. The channel estimation block calculates the channel estimation value by using FFT(Fast Fourier Transform). Also, the weight vector calculation block calculates the weight vector from the channel estimation value. The channel estimation value and the weight vector are combined to obtain the system matrix in the matrix generator block. The joint detection block, which uses CF(Cholesky Factorization), obtains an array gain by combining the data of each array and the system matrix value. In this paper, we call the structure of Fig. 3 the JSA(Joint Detection and Smart Antenna).

### 3.2. Receiver Structure of the Diversity System

Fig. 4 shows the channel estimation and joint detection structure in diversity antenna system. The diversity gain in the diversity antenna system is obtained by using independent channel characteristics of the received signal at each antenna element. The system performance in diversity antenna system is enhanced according to the number of retransmission. But, the performance enhancement of the diversity antenna system is less than that of the smart antenna system. The difference of the receiver structure in the diversity antenna system is that there is no weight vector calculation block. In this paper, we call the structure of Fig. 4 the JDA(Joint Detection and Diversity Antenna).

### 3.3. Hybrid ARQ Structure

Hybrid ARQ is the combination of FEC(Forward Error Correction) and ARQ(Automatic Repeat reQuest). Hybrid ARQ corrects the errors by utilizing the FEC and retransmits the data if it fails to correct the errors. Hybrid ARQ consists of IR(Incremental Redundancy) and CC(Chase Combining). The IR transmits additional parity information to incrementally enhance the error correction capability when retransmission happens. The CC adds parity information to every transmission data. In this paper, we chose the CC. The retransmission is requested through feedback channel when there is a frame error by utilizing the CRC check. In this paper, we confined the number of the retransmission to two times.

## 4. NUMERICAL RESULTS

In this section, we analyze the performance in TD-SCDMA system environments. In general, the beamforming gain is obtained by using the phase difference of the received signal at each antenna element. The diversity antenna system improves the reliability of a received signal by utilizing independent channel characteristic of the received signal. The performance analysis of smart antenna system and diversity antenna system in this paper is shown in terms of coded BER(Bit Error Rate) and complexity. Table 1 shows the system parameters of TD-SCDMA System used in this paper.

Table 1. Simulation parameters.

| parameters | value |
|---|---|
| Number of users | 4 |
| Number of symbols per data field | 44 |
| Number of multipath | 1, 2, 4 |
| Maximum delay of channel | 8 |
| Spreading factor | 8 |
| Channel Coding | CC(R=1/3,K=9) |
| Channel Estimation | FFT |
| Joint Detection | CF(Cholesky Factorization) |
| Modulation | QPSK |
| Hybrid ARQ | Chase Combining |

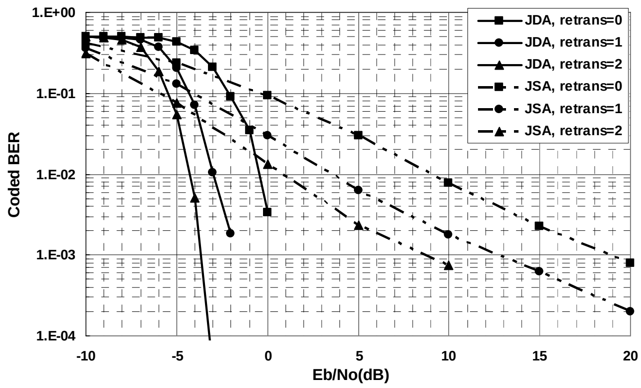


Fig. 5 BER performance comparison in 1-path Rayleigh fading environment of JSA and JDA according to the number of retransmission in HARQ

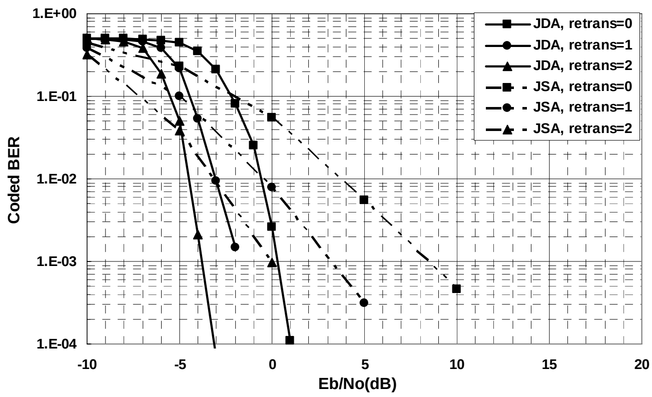


Fig. 6 BER performance comparison in 2-path Rayleigh fading environment of JSA and JDA according to the number of retransmission in HARQ

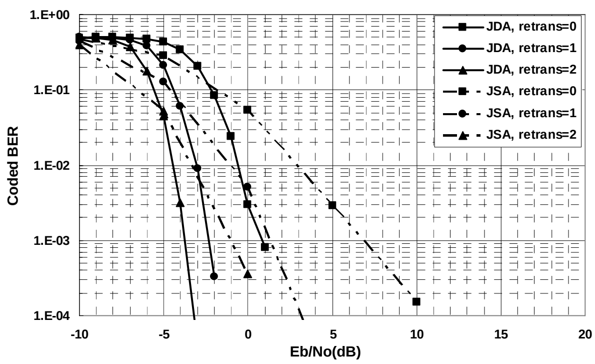


Fig. 7 BER performance comparison in 4-path Rayleigh fading environment of JSA and JDA according to the number of retransmission in HARQ

Fig. 5, 6, and 7 show the coded BER performance in Rayleigh fading environment in smart antenna system and diversity antenna system according to the number of retransmission in H-ARQ. The receiving performance of the diversity antenna system depends on the number of independent channel, which is called diversity order. For example, the diversity order becomes two if the receiving signal experiences single path in case that the number of antenna element is set to 2. The receiving performance of the diversity antenna system is proportional to the diversity order. As shown in Fig. 5, the performance of the diversity antenna system increases as the number of retransmission increases. In this paper, 1% BER is set to performance measure criterion. From Fig. 5, we can obtain 2.5dB and 1.5dB performance enhancement, respectively, when the number of retransmission is set to 1 and 2, respectively in diversity antenna system.

In smart antenna system, diversity order does not depend on the number of antenna element. As shown in Fig. 5, the performance enhancement of the smart antenna system is larger than that of the diversity antenna system as the number of retransmission increases. From Fig. 5, we can obtain 5.5dB and 3dB performance enhancement, respectively, when the number of retransmission is set to 1 and 2, respectively in smart antenna system.

Fig. 6 and 7 shows the performance in case of 2-multipath and 4-multipath, respectively. The diversity order increases as the number of multipah increases in diversity antenna system. But, the diversity gain saturates in diversity antenna system. In smart antenna system, the performance enhancement due to the diversity gain increases as the number of multipath increases. As shown in Fig. 6, we can see 1.5dB performance difference between the smart antenna system and diversity antenna system when the retransmission is set to 2.

Fig. 8 shows the amount of the various calculations. As shown in Fig. 8, we can see that there is no difference of the amount of calculation between the JSA and JDA as the receiver structure of the two system is similar.

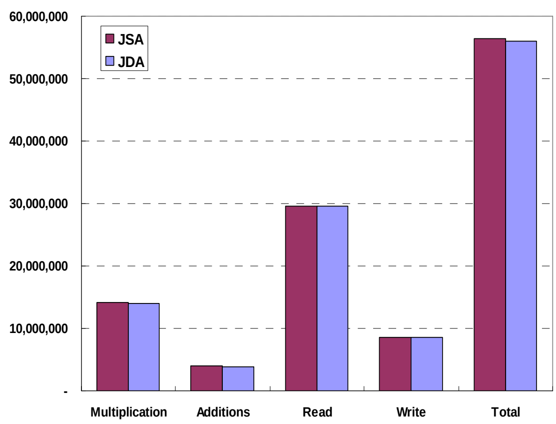


Fig. 8 Amount of calculation in JSA and JDA

## 5. CONCLUSIONS

In this paper, we analyzed the performance of the smart antenna system and diversity antenna system using HARQ. The smart antenna system improved the performance by increasing diversity order or the number of mltipath. Whereas, there was a saturation of diversity gain by utilizing two or more communication channels with different characteristic in diversity antenna system and the diversity antenna system could improve the performance due to increase the retransmission. In addition, we could find that by using HARQ technique, both the smart antenna system and the diversity antenna system improved a performance due to the retransmission.

## ACKNOWLEDGEMENT

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