

# Performance of a Base Station Feedback-Type Adaptive Array Antenna with Mobile Station Diversity Reception in FDD/DS-CDMA System

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## ABSTRACT

In this paper, Bit Error Rate (BER) performance of Feedback-type Adaptive Array Antenna (AAA) in Frequency Division Duplex/Direct Sequence Code Division Multiple Access system (FDD/DS-CDMA) with Mobile Station (MS) reception diversity will be investigated. The results include the effects of maximum Doppler frequencies ( $f_d$ ) and antenna element spacing at Base Station (BS) under flat fading and frequency selective fading. These effects are not clarified until now on this system. Moreover, the effect of rake receiver will be studied on this system. Computer simulation results show that the reception diversity shows better BER performance than single antenna reception at MS due to diversity effect.

Keywords: adaptive array antenna, reception diversity and CDMA.

## 1 INTRODUCTION

The demand for many radio services is increasing. New techniques are required to improve spectrum utilization to satisfy that demand without increasing the Radio Frequency (RF) spectrum that is used. One technique in a digital cellular system is the use of CDMA technique [1]. Another technique is diversity system. Actually the diversity system is used to mitigate the effect of multi-path fading for improvement of transmission quality and channel capacity [2-4]. Diversity system was described in details in [5]. Other technique is Adaptive Array Antenna (AAA) [6]. In fact, AAA is used to reduce the effect of interference. If the distance between antennas is high, AAA can also use to reduce the effect of fading where AAA is recommended at BS not at MS due to the size and the cost of MS [7-9]. The combinations between these techniques give better performance evaluation.

AAA are classified into two approaches, the open loop AAA and the closed loop AAA. For a Time Division Duplexed (TDD), up link and down link are highly correlated because up and down links use the same frequency. Therefore, it is easy to implement such a system by using weighting factors, which are determined for signal reception in the uplink, for down link transmission. This system is called open loop system. Feedback information is needed in closed loop AAA system. In this system, reference signals are transmitted periodically on the downlink. This reference signals are used on mobile station to estimate channel characteristics which are sent back

as a feed back message to BS.

In this paper, the performance of Feedback-Type AAA in FDD/DS-CDMA system with space diversity reception at MS will be investigated under changing  $f_d$  and spacing distance between antennas at BS and MS. Moreover, rake receiver will be used in case of frequency selective fading.

The paper is organized as follows: In Sect. 2, system model is introduced. Channel characteristic estimation will be explained in Sect.3. Propagation model are introduced in Sect.4. Computer simulation results are done in Sect. 5. Conclusions are made in Sect. 6.

## 2 SYSTEM MODEL

Fig. 1 shows the block diagram of feedback-type AAA at BS and reception diversity at MS that is used in this paper. Two antennas are assumed at BS and MS. Reference signals are inserted into information signals periodically (as shown in Fig.2) from a BS to determine channel characteristic between transmitter and receiver. Reference signals are transmitted from each antenna on the BS at the same time using two different spreading (Walsh) codes  $s_1(t)$  and  $s_2(t)$ , and a fixed weighting coefficients  $w_0$ . On the other hand, the information signals are sent with the same code  $s_0(t)$  with different weighting coefficients  $w_1$  and  $w_2$ .

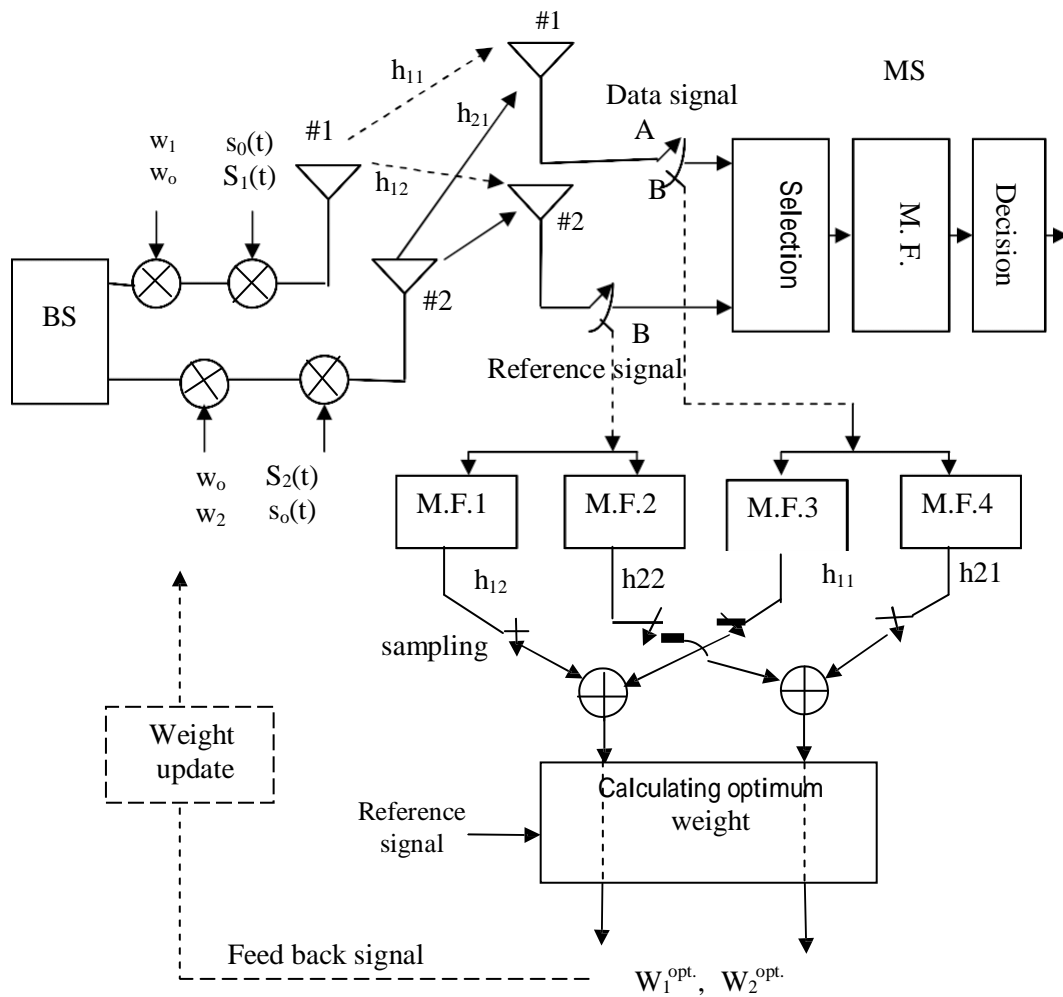


Fig. 1, Block diagram of transmission and reception of the signals.

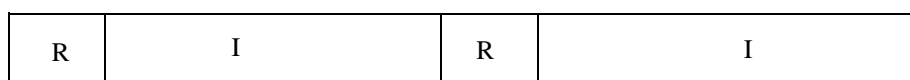


Fig. 2, Reference signal.

### 3 CHANNEL CHARACTERISTIC ESTIMATION

On receiving reference signals at MS: The switch select the matched filters which correspond to  $s_1(t)$  and  $s_2(t)$ . Outputs of the matched filters are given by:

$$y_i(t) = \sum_{i=1, j=1}^{i=2, j=2} w_o s_i(t) * h_{ij}(t) * s_i(t_m - t) \quad (1)$$

Where  $t_m$  is a time constant, if  $s_1(t)$  and  $s_2(t)$  are orthogonal, Eq.(1) can be written as,

$$\cong w_o \sum_{i=1, j=1}^{i=2, j=2} h_{ij}(t - t_m) \quad (2)$$

Where  $h_{ij}$  is the channel characteristic between antenna element  $i$  at BS and antenna element  $j$  at MS. If  $s_i(t)$  shows a sharp autocorrelation function, ideally delta function,  $y_i(t)$  becomes as:

$$y_i(t) \cong \sum_{i=1, j=1}^{i=2, j=2} w_o h_{ij}(t) * \sigma(t - t_m) \quad (3)$$

The channel characteristics are measured and sent back to the BS. We assume that there is no any errors in feedback signal message.

On receiving information signals: The same codes will be used. In this case, the switch select the receiver consists of the matched filter (spreading codes) followed with rake receiver. The output of the matched filter becomes:

$$y_0(t) = \sum_{i=1, j=1}^{i=2, j=2} w_i s_0(t) * h_{i,j}(t) * s_0(t_m - t) \quad (4)$$

Let us denotes  $h_o(t)=w_1(h_{11}+h_{12})+w_2(h_{21}+h_{22})$ , then  $h_o(t)$  is the channel characteristic from BS antennas to the MS antennas. The impulse response  $h_m(t)$  of the rake receiver is given by  $h_m(t)=h_o(T_o-t)$ , then the output  $y_m(t)$  of the rake receiver becomes,

$$y_m(t) = s_o(t) * s_o(T_m - t) * h_o(t) * h_o(T_o - t) \quad (5)$$

Sampling is made at  $T_s$  where  $T_s = T_o + T_m$ . Decision is made to obtain the received data.

#### 4 PROPAGATION MODEL

To model the Rayleigh fading, a set of eight plane wave is considered which arrives in random direction from 0 to  $2\pi$  at MS. Angle spread of incident waves arrives within the range of 12 degrees at the BS because the BS is located on long tower. Each of the plane waves has constant amplitude and takes the random initial phase distributed from 0 to  $2\pi$ . The distribution of arrival angle is the uniform distribution. Therefore, the Doppler frequencies have also uniform distribution from  $-f_d$  to  $+f_d$ . Where  $f_d$  is the maximum Doppler frequency. Propagation model will be shown in Fig. 3. The information signals are made up of 32 symbols, the reference signals are made up of 4 symbols. MS monitors reference signals and measure channel characteristics between

each antenna at BS and the 2 antennas at MS. After determining channel characteristics, we can compute weighting coefficients of each antenna at BS. We must take into consideration the errors due to AWGN when measuring channel characteristics. To reduce these errors, BS transmits reference signals several times by each antenna element. The channel characteristics are averaged during a given time duration and sent back them to the BS. QPSK is assumed. The distance between antenna elements at BS is  $0.5\lambda$  or  $5.25\lambda$ . Down link is considered. Table 1 shows the simulation parameters.

Table 1: Simulation parameters.

Modulation	QPSK
Demodulation	coherent detection
Symbol rate	30Ksps
Angle spread of incident waves	12 degree
The number of incident waves	8 waves
Maximum Doppler frequency	5.56Hz, 90Hz
Arrival angle of the signal	30 degree
Spreading factor	128
Spreading code	Walsh

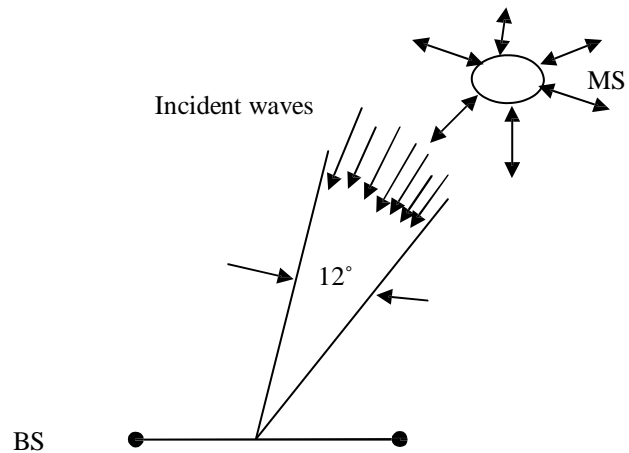


Fig. 3, Propagation model.

## 5 COMPUTER SIMULATION RESULTS

### A. Under Flat fading:

Figure 4 Shows BER performance vs.  $E_b/N_0$  (dB) for different number of antenna elements at BS and different  $f_d$ . The spacing is equal to  $0.5\lambda$  in case of number of antennas equal to 2. It is clear that the two antenna elements at BS has BER better than single antenna case due to diversity gain. Fig.5 shows the improvements in BER due to using two, three antenna elements at BS with spacing= $5.25\lambda$ . From this figure, we conclude that increasing the spacing distance leads to low correlation between antennas. Therefore the BER performance becomes better than the case of small spacing distance. Fig. 6 Shows BER performance for two antennas at BS with  $0.5\lambda$  antenna spacing for single antenna reception and duple reception diversity at MS (spacing  $0.5\lambda$  between antenna elements at MS) in the case of  $f_d=5.56\text{Hz}$  and  $90\text{Hz}$ . From this figure, we note that the reception diversity shows better BER performance than single antenna reception at MS due to diversity effect. We conclude also that the frequency  $5.56\text{Hz}$  gives better results than frequency  $90\text{Hz}$  because in case of high  $f_d$ , MS can't able to follow the rapid changing in channel characteristics. Fig 7 shows the same result but with antenna element spacing  $5.25\lambda$  at BS. Figure 8 shows BER performance in case of spacing distance equal to  $\lambda$  at MS and BS antenna element spacing equal to  $0.5\lambda$  and  $5.25\lambda$ . The figure shows that the element spacing  $5.25\lambda$  better than  $0.5\lambda$ .

### B. Under Frequency selective fading:

Fig. 9 shows the diversity reception with rake receiver and without rake receiver in the case of antenna element spacing equal to  $0.5\lambda$  at BS. This Figure shows that, the BER performance under frequency selective fading is better than flat fading due to using rake receiver. Fig. 10 shows BER vs.  $E_b/N_0$  (dB) in the case of antenna element spacing equal to  $5.25\lambda$  at BS. From this figure, we conclude that spacing  $5.25\lambda$  is better than  $0.5\lambda$  due to space diversity effect.

## 6 CONCLUSIONS

We evaluate the performance of the feedback-type AAA placed at BS in DS-CDMA and diversity reception at the MS under flat fading and frequency selective fading. Its performance was clarified by considering the effects of different conditions such as antenna elements spacing at BS and maximum Doppler frequencies in the Rayleigh fading. The BER performance of AAA depends on antenna element spacing and maximum Doppler frequency.

Computer simulation results show that the BER performance of reception diversity at MS is better than single antenna reception due to diversity gain. Computer simulation also shows better performance in BER performance for AAA with antenna element spacing  $5.25\lambda$  than with  $0.5\lambda$  due to space diversity effect. But with increasing the value of maximum Doppler frequency, the BER becomes worst. This is because weighting factors can not follow the change of the channel characteristics due to rapidly changing the fading with time. When using rake receiver in the case of frequency selective fading, the BER is better than frequency flat fading.

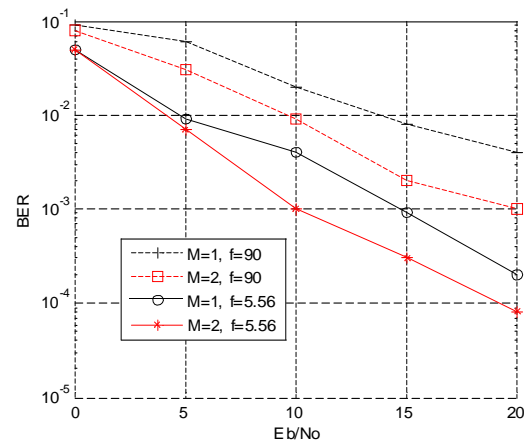


Fig. 4, BER vs.  $E_b/N_0$ (dB) at  $M=1, 2$  at BS.

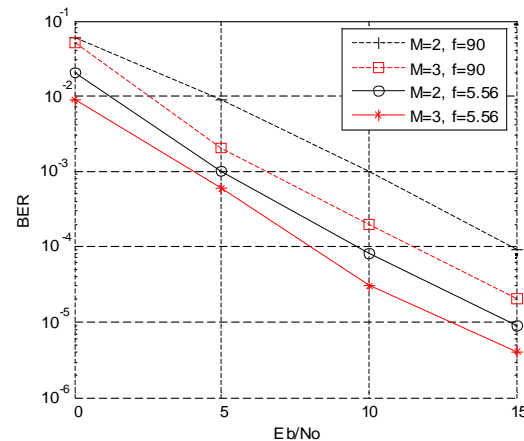


Fig. 5, BER vs.  $E_b/N_0$  (dB) at  $M=2, 3$  at spacing distance  $=5.25\lambda$  at BS.

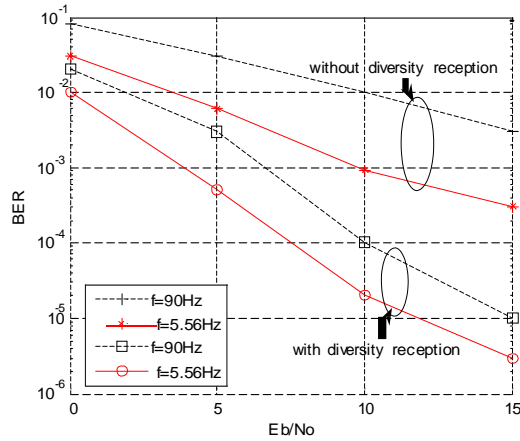


Fig. 6, BER vs.  $E_b/N_o$  (dB) at  $M=2$  and distance  $=0.5\lambda$  at BS with and without diversity reception at MS (spacing  $0.5\lambda$  between antenna elements) in case of maximum Doppler frequency= 5.56, 90 Hz.

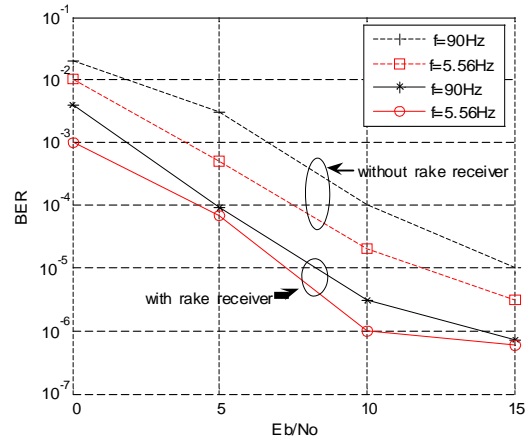


Fig. 9, diversity reception using rake receiver and without rake receiver (BS antenna element spacing= $0.5\lambda$ ).

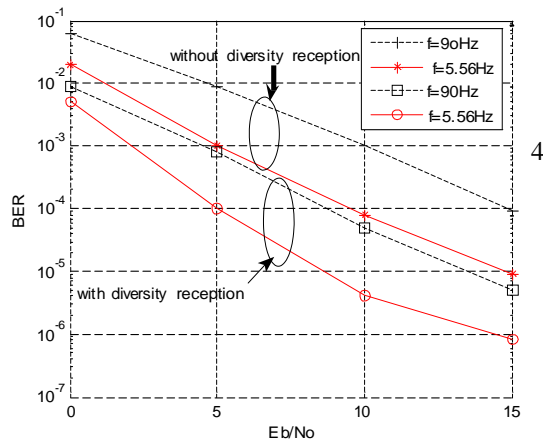


Fig. 7, BER vs.  $E_b/N_o$  (dB) at  $M=2$  and distance  $=5.25\lambda$  at BS with and without diversity reception at MS (spacing  $0.5\lambda$  between antenna elements) in case of maximum Doppler frequency= 5.56, 90 Hz.

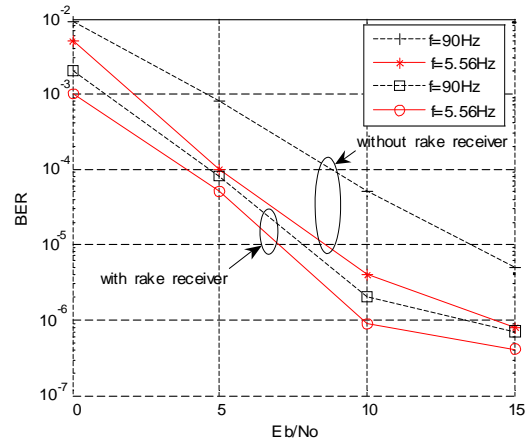


Fig. 10, diversity reception using rake receiver and without rake receiver (BS antenna element spacing= $5.25\lambda$ )

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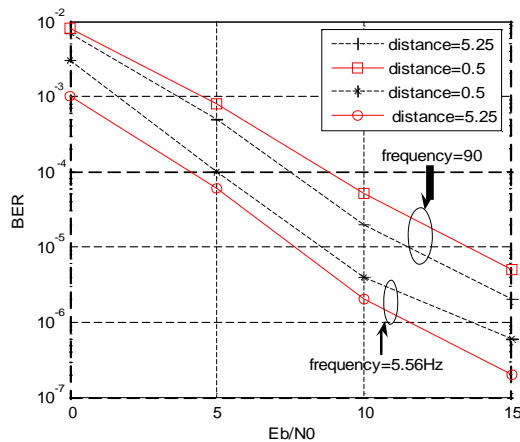


Fig. 8, BER vs.  $E_b/N_o$  (dB) at  $M=2$  and distance  $=5.25\lambda, 0.5\lambda$  at BS with diversity reception at MS (antenna element spacing= $\lambda$ ) in case of maximum Doppler frequency= 5.56Hz, 90 Hz.

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