

## PERFORMANCE OF TRANSMISSION SPACED SELECTION DIVERSITY IN DS-CDMA SYSTEMS

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### ABSTRACT

The performance of transmission spaced selection diversity (SD) placed at base station (BS) in DS-CDMA system remains insufficiently clear. This performance will be evaluated by considering the effect of space distance between antennas and the maximum Doppler frequency ( $f_d$ ) on bit error rate (BER) performance under optimum conditions which are not clarified until now. Moreover, analysis of this system is presented under the effect of Rayleigh fading.

**Keywords:** DS-CDMA, transmission spaced selection diversity, Rayleigh fading.

### 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 spectrum that is used. One technique in a digital cellular system is the use of spread spectrum Code Division Multiple Access (CDMA) technology [1]. Another technique is diversity system. Cooperation between a CDMA system and diversity system has also been studied in [6]. Actually the main purpose of diversity system is mitigating the multipath fading which has negative effect on the quality of transmission of mobile radio communication.

There are classifications of diversity system. One view of classifications is transmission and reception diversity. Other classifications are frequency diversity, polarization diversity, spaced diversity, time diversity and angle diversity. All these classifications are presented in detail in [2]. To combine diversity branches, many combining techniques are explained in detail in [1] and [2], including space Selection Diversity SD. In SD one of the M antenna branches that provides the highest Signal-to-Noise Ratio (SNR) is selected for data recovery.

The success of diversity techniques depends on the degree to which the signals on the different branches are uncorrelated. This requires that the spacing between the antenna elements in the

receiving or transmitting array is greater than a certain minimum distance.

In this paper, the performance of transmission spaced diversity under the effects of spacing distance between antennas and the maximum Doppler frequency will be studied under using optimum conditions. These effects are not clarified until now.

The organization of this paper is made as follows: Sect. 2 introduces the analysis of the system under Rayleigh fading. Computer simulation conditions are done in Sect. 3. Results are presented in Sect. 4. Conclusions are achieved in Sect. 5.

### 2 ANALYSIS OF THE SYSTEM OVER RAYLEIGH FADING

To get expressions for both SNR and BER values, we consider a two – branch diversity system at BS with correlated fading channels.

The received signal from each branch of the system can be modeled as [3]

$$r_k(t) = R_k e^{j\alpha_k} e^{j\psi_m(t)} + n_k(t) \quad k=1,2 \quad (1)$$

Where  $\psi_m(t)$  is the transmitted signal,  $R_k$  is a Rayleigh – distributed amplitude factor,  $\alpha_k$  is a uniformly distributed phase factor, and  $n_k(t)$  is zero – mean Additive White Gaussian Noise (AWGN). The received signal can be described by:

$$r_k(t) = [X_k + jY_k] e^{j\psi_m(t)} + n_k(t) \quad k=1,2 \quad (2)$$

Where  $X_1, X_2, Y_1,$  and  $Y_2$  are all Gaussian random variables with zero mean and variance  $\sigma^2$ .

The expectation can be expressed as,

$$E[X_i Y_k] = 0 \quad i=1,2; \quad k=1,2 \quad (3)$$

$$E[X_1 X_2] = E[Y_1 Y_2] = \rho \sigma^2 \quad (4)$$

Where  $\rho$  is the correlation coefficient between the fading channels.

Another assumption is that the channel statistics are independent of the AWGN variables, which are also uncorrelated with each other, therefore

$$E[n_1 n_2] = E[n_i X_k] = E[n_i Y_k] = 0 \quad i=1,2; \quad k=1,2 \quad (5)$$

Ref. [3] introduces a transformation matrix  $T$  to transform the correlated received signals  $r_1(t)$  and  $r_2(t)$  into two new uncorrelated signals  $r_3(t)$  and  $r_4(t)$  therefore,

$$\begin{bmatrix} r_3(t) \\ r_4(t) \end{bmatrix} = T \begin{bmatrix} r_1(t) \\ r_2(t) \end{bmatrix} \quad (6)$$

$$\text{Where } T = \begin{bmatrix} \frac{\sqrt{2}}{2} & \frac{\sqrt{2}}{2} \\ \frac{\sqrt{2}}{2} & -\frac{\sqrt{2}}{2} \end{bmatrix} \quad (7)$$

The two new received signals can be expressed as,

$$r_k(t) = [X_k + jY_k] e^{j\psi_m(t)} + n_k(t) \quad k=3,4 \quad (8)$$

By writing out the expressions of  $X_3, X_4, Y_3,$  and  $Y_4$ , it can be seen that they are functions of Gaussian random variables, therefore they are also Gaussian random variables; in addition they are mutually independent. Thus,

$$E[X_3^2] = E[Y_3^2] = (1+\rho) \sigma^2 \quad (9)$$

$$E[X_4^2] = E[Y_4^2] = (1-\rho) \sigma^2 \quad (10)$$

Also,  $n_3$  and  $n_4$  are functions of AWGN random variables, and they have the same noise power, and are uncorrelated with the new channel statistics.

If the noise power at each receiver for the original correlated signals is the same, then, from

Eq. (9) and Eq. (10), a new SNR is defined for each uncorrelated signal:

$$\Gamma_3 = (1 + \rho) \Gamma \quad (11)$$

$$\Gamma_4 = (1 - \rho) \Gamma \quad (12)$$

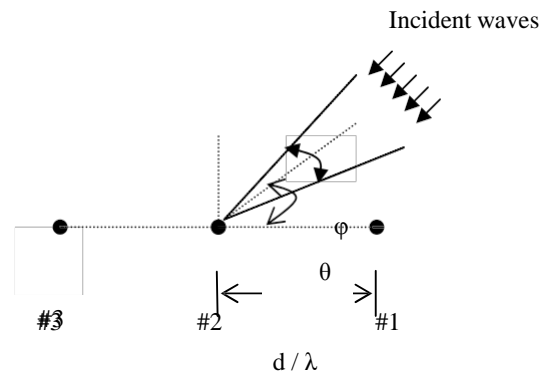
Where  $\Gamma$  is the SNR of the original correlated signals.

Now the BER values for a two-branch selective diversity system can be calculated from the following expression [3],

$$\text{BER} = \frac{1}{2} \left[ 1 - \frac{\sqrt{\Gamma_3}}{\sqrt{\Gamma_3+1}} - \frac{\sqrt{\Gamma_4}}{\sqrt{\Gamma_4+1}} + \frac{\sqrt{\Gamma_3 \Gamma_4}}{\sqrt{\Gamma_4 \Gamma_3 + \Gamma_3 + \Gamma_4}} \right] \quad (13)$$

### 3 COMPUTER SIMULATION CONDITIONS

DS-CDMA system with three antennas at the BS and one antenna at the MS is assumed. Fig. 1 shows propagation model at the BS. Table 1 shows simulation parameters.



**Figure1:** Linear array and propagation model at BS.

**Table 1:** Simulation parameters

Modulation	QPSK
Demodulation	Coherent detection
Symbol rate	30 Ksps
Spreading code	Walsh code
Spreading factor	128

To model the Rayleigh fading, we consider a set of 8 plane waves that are transmitted in random direction within the range of  $\varphi$  degrees at the BS [4]. The value of  $\varphi$  will be determined in the next section. Each of the plane waves has constant amplitude and takes the random initial phase distributed from 0 to  $2\pi$ . The Doppler frequency is uniformly distributed from  $+f_d$  to  $-f_d$  ( $f_d$  : is the maximum Doppler frequency). The 8 incident plane waves arrive in random direction from 0 to  $2\pi$  at the MS. QPSK is assumed with coherent detection. A square root raised cosine filtering with a roll-off

factor  $\alpha$  of 0.5 is employed. A symbol rate of 30 kbps is assumed. The spreading code is Walsh code with spreading factor of 128. The Rayleigh fading channels were disturbed by AWGN.

The Performance of the diversity system depends on correlation between antenna elements. The correlation is determined by antenna elements spacing, angle spread of incident waves  $\phi$  and direction of arrival  $\theta$  [5]. Thus, we have to optimize these values to get better BER performance.

#### 4 COMPUTER SIMULATION RESULTS

Fig. 2 shows the effect of arrival angle,  $\theta$ , of the signal on BER performance at  $E_b/N_0=10\text{dB}$ . From this figure, it can be concluded that changing the value of  $\theta$  gives slightly small effect. Therefore, we use in our simulation the value  $30^\circ$  of  $\theta$ .

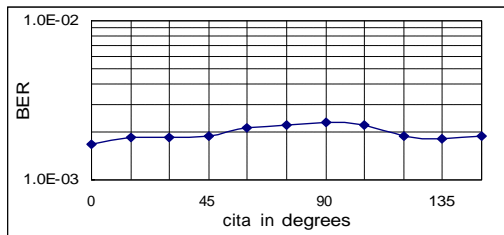


Figure 2: Arrival angle of the signal  $\theta$  vs. BER.

The effect of angle spread of incident waves  $\phi$  is presented in Fig. 3. From this figure, we select the value of  $12^\circ$  which gives better BER performance.

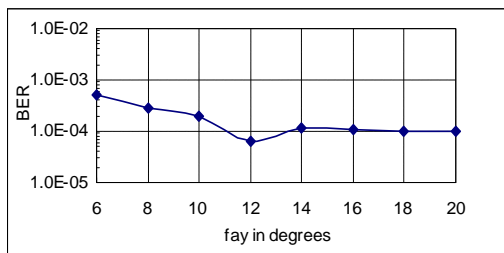


Figure 3: Angle spread of incident waves  $\phi$  vs. BER

The effect of  $f_d$  on BER performance is shown on Fig. 4. As  $f_d$  increases, due to the increase in the speed of the Mobile, BER performance will degrade. This degrading is due to rapid changes in channel characteristics. The lowest value of  $f_d$  that gives better BER is 90 Hz.

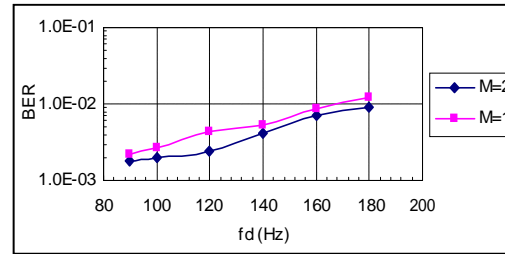


Figure 4: Maximum Doppler frequencies ( $f_d$ ) vs. BER for  $E_b/N_0=10\text{ dB}$

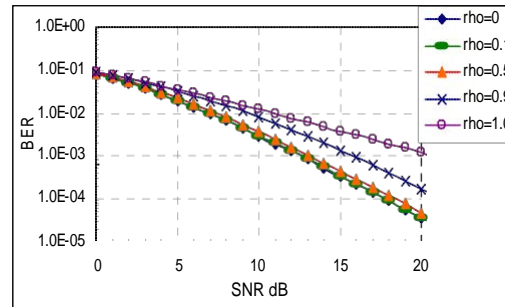


Figure 5: Effect of branch correlation on BER performance of SD with two-branch diversity (theoretical)

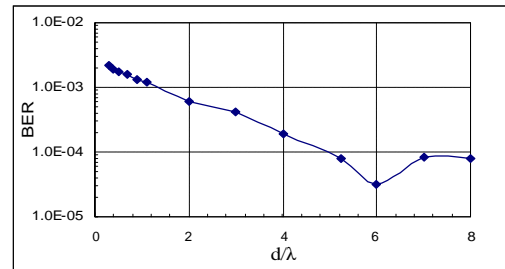
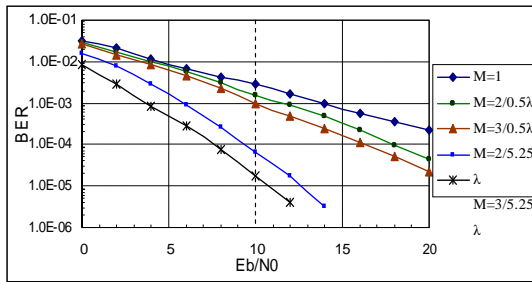


Figure 6: Normalized distance ( $d/\lambda$ ) vs. BER

We use these values on the following paragraphs.

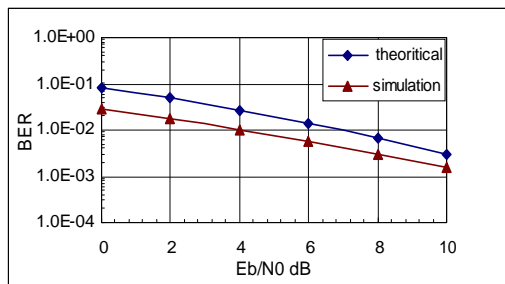
Fig. 5 shows the results of the theoretical BER in Eq.13 for two-branch diversity system with different values of the correlation coefficient  $\rho$ . From this Figure it can be concluded that as the correlation coefficient increases the BER performance decrease. Also, as the coefficient approaches 1, one of the diversity branches is effectively removed; this leads to lose the advantage gained from antenna diversity. On the other hand, reducing values  $\rho$  correspond to an increase in the spatial separation between antennas. For this reason we have to look for the optimum antenna separation that yields better BER performance. Simulations were performed where the ratio  $d / \lambda$  was varied between 0.1 and 8. The results are indicated in Fig. 6. It is clear that as the ratio is increased, the BER performance is better. When  $d / \lambda$  is 6, we already have optimal BER

results. Also, increasing  $d / \lambda$  beyond 6 does not have any noticeable benefits.



**Figure 7:** BER vs.  $E_b/N_0$  for  $f_d=90$  Hz  
 $d/\lambda=0.5, 5.25$   $M=1, 2,$  and  $3$

Fig. 7 displays the BER of transmit diversity for different numbers of antennas,  $M=1, 2,$  and  $3,$  and different values of antenna separation  $d / \lambda$  at the base station. It is clear that increasing  $M$  and  $d / \lambda$  have a positive effect on the BER performance. Numerically, the amount of improvement in  $E_b/N_0$  for  $M = 2,$  and  $3$  is 4dB and 6dB with respect to  $M=1$  at  $d / \lambda=0.5$  and  $BER=10E-4,$  respectively. Also, more improvement has been got at  $d / \lambda=5.25.$  It is increased to be 12dB and 14dB for  $M=2$  and  $3$  with respect to  $M=1$  and  $BER$  of  $10E-4.$



**Figure 8:** Comparison of simulated and theoretical results

Figure 8 compares the simulated and theoretical results of BER for  $M=2.$  It shows that the simulation results are a close match to the BER in Eq. (13). The small difference is due to optimizing the simulation parameters.

## 5 CONCLUSIONS

In this paper, the performance of transmission selection spaced diversity in DS-CDMA system was studied. This performance is not clarified until now under the effect of changing the space distance between antennas at BS and the maximum Doppler frequency by using the optimum conditions. The results show that increasing the space distance between antennas gives better BER performance

due to diversity gain. This gain comes from uncorrelated diversity branches. Moreover increasing the maximum Doppler frequency degrades the BER performance due to the rapid changes of channel characteristics. Moreover the analysis of this system is explained under Rayleigh fading.

## 6 REFERENCES

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