Performance of switched selection transmission diversity in FDD/DS-CDMA system

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In this paper, the performance of switched selection transmission diversity in Frequency Division Duplex/Direct Sequence-Code Division Multiple Acccess (FDD/DS-CDMA) system will be investigated. Down link is assumed. 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. This performance is not clarified until now. Moreover, the effect of error on Feedback Antenna Selection bit on uplink will be stuidied. Rayleigh fading will be assumed.

سيتم، فى هذا البحث، دراسة أداء تنوع الارسال ذو الاختيار التبديلي فى نظام الدخول المتعدد ذو الأكواد المقسمة، وذلك فى وصلة النزول. وسيقيم هذا الأداء من ناحية تأثير كل من البعد الفراغى بين الهوائيات وتردد دوبلر الأعلى على معدل خطأ البيانات و ذلك فى أفضل الأوضاع. والى الآن لم يتم دراسة هذا الأداء من قبل. علاوة على ذلك، سيتم دراسة تأثير الخطأ في الإرسال الخلفى لمعلومة إختيار الهوائى أثناء وصلة الصعود. مفترضين تأثيرخفوت يخضع لتوزيع رايلى الاحتمالى.

Keywords: DS-CDMA, Antenna selection and transmission diversity

1. Introduction

New techniques are required to improve spectrum utilization to satisfy the increasing demand for many radio services without increasing the used radio frequency spectrum. One technique in a digital cellular system is the use of Code Division Multiple Acccess (CDMA) technology [1-3]. Another technique is diversity system [4-6]. Cooperation between a CDMA system and diversity system has also been studied in [7]. Actually the diversity system is used to mitigate the multipath fading problem. This problem increases the distortion of the signals in Mobile Radio Communications. There are two types of diversity systems, which are transmission and reception diversity. Many these combining techniques are used in diversity systems [2]. One of which is the selection combining. Selection transmission diversity already was studied in [4].

This paper proposes a more effective diversity technique in Frequency Division Duplex/Direct Sequence-Code Division Multiple Acccess (FDD/DS-CDMA) system called Switched Selection Transmission Diversity. The performance of the proposed scheme will be stuided by considering the effect of space distance between antennas at Base Station (BS) and f_d. This study is not clarified until now under optimum conditions. Moreover, the effect of errors on the feedback message of Antenna Selection (AS) bit will be investigated. Two antennas are assumed at BS. The performance of this technique will be compared with a single antenna case at the BS.

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

2. System model and its analysis over Rayleigh fading

2.1. System model

A flow chart of the proposed scheme is shown in fig. 1. In this method, initially BS transmits the signal from its first antenna then Mobile Station (MS) measures the power

pr_1 of this signal. After that BS transmits the same signal from its second antenna with the same transmitted power as the first antenna and MS measures this power pr_2. If $pr_1 > pr_2$, the MS will send a one-bit Antenna Selection (AS) message of "1" to the BS to select antenna #1 to transmit all data from it. Otherwise, if $pr_1 < pr_2$, the MS will send AS of "0" to the BS to select antenna #2. The MS continuously monitors the transmitted power (pr_1 and pr_2) from each antenna of the BS to estimate which one has little propagation loss. BS switches transmit antenna from the one currently used to another one depending on AS bit from MS corresponding to each antenna.

Fig. 2 shows system model for the Switched Selection Transmission Diversity (SSTD) that is used here. In this system, 2 antennas are assumed at BS and one antenna is used at MS. Walsh code $s(t)$ is used. At the receiver, a Matched Filter (MF) is used. Sampling is done and a decision is made to obtain the received data.

The received information signals $y_1(t)$ and $y_2(t)$, in the absence of noise are given as,

$$y_1(t) = d(t)\, s(t) * h_1(t). \quad (1)$$

$$y_2(t) = d(t)\, s(t) * h_2(t). \quad (2)$$

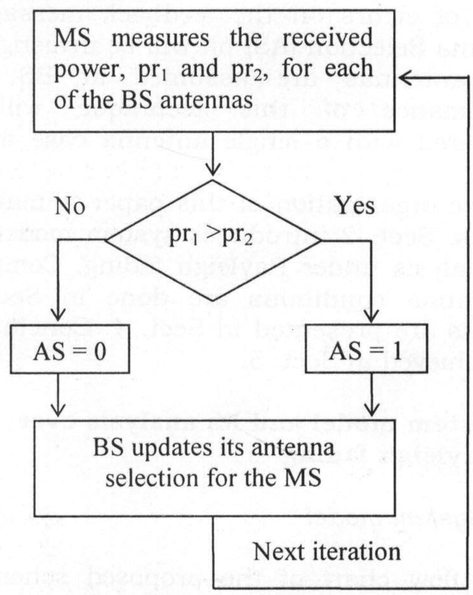

Fig. 1. Flow chart of the switched selection transmission diversity.

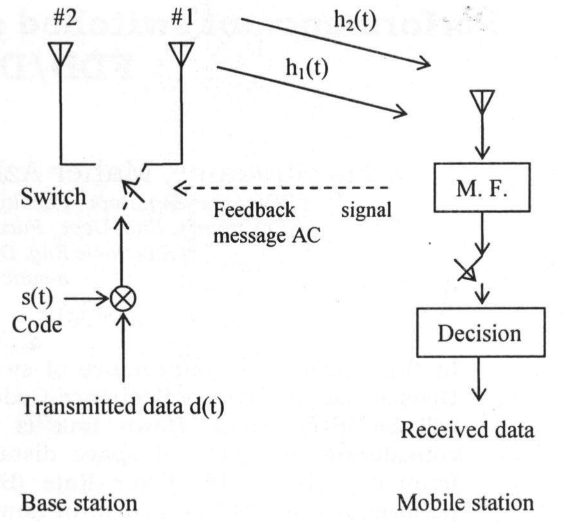

Fig. 2. Transmission and reception of the signals.

where * means the convolution integral, $d(t)$ is the transmitted data, $s(t)$ is the spreading Walsh code, $h_1(t)$ and $h_2(t)$ are the channel characterstics between antenna elements 1 and 2 at BS and MS antenna, respectively.

2.2. Analysis of the system over Rayleigh fading

To get expressions for both Signal-to-Noise Ratio (SNR) and Bit Error Rate (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 [6]:

$$r_k(t) = R_k e^{j\alpha_k} e^{j\Psi_m(t)} + n_k(t) \quad k=1, 2. \quad (3)$$

Where

$\Psi_m(t)$ is the transmitted information signal;

R_k is a Rayleigh – distributed amplitude With E[R12]=2seqma1 and [R22]= 2seqma2.

α_k is a uniformly distributed phase factor;

$N_k(t)$ is zero – mean Additive White Gaussian Noise (AWGN).

For simplicity, it can be assumed that the average power received from a dual branch diversity combining is identical, that is $\sigma^2 = \sigma^2 = \sigma^2$.

The received signal can be described by:

$$r_k(t) = [X_k + jY_k]e^{j\Psi_m(t)} + n_k(t) \quad k=1, 2. \tag{4}$$

Where X_1, X_2, Y_1, and Y_2 are all Gaussian random variables with zero mean and variance σ^2.
The expectation can be expressed as,

$$E[X_i Y_k] = 0 \qquad i = 1, 2; \quad k=1, 2. \tag{5}$$

$$E[X_1 X_2] = E[Y_1 Y_2] = \rho\sigma^2 . \tag{6}$$

Where σ is the correlation coefficient between the fading channels.

Also, the noise components are independent of the signal components and are uncorrelated with each other, therefore

$$E[n_1 n_2] = E[n_i X_k] = E[n_i Y_k] = 0$$
$$i=1, 2 ; \quad k = 1, 2 . \tag{7}$$

The average SNR after envelope detection for the kth branch is given by

Gamak=segmak2/Nk...k =1, 2, (8)

where Nk=E[nk2(t)] is the average noise power received from the kth diversity branch.

Now, on applying the transformation materix T to transform the correrelated received signals r_1 (t) and r_2 (t) into two new uncorrelated signals r^2 (t) and r_2 (t) therefore,

$$\begin{bmatrix} r_3(t) \\ r_4(t) \end{bmatrix} = T \begin{bmatrix} r_1(t) \\ r_2(t) \end{bmatrix} . \tag{9}$$

Where

$$T = \begin{bmatrix} \frac{\sqrt{2}}{2} & \frac{\sqrt{2}}{2} \\ -\frac{\sqrt{2}}{2} & \frac{\sqrt{2}}{2} \end{bmatrix} . \tag{10}$$

The two new received signals can be expressed as,

$$r_k(t) = [X_k + jY_k]e^{j\Psi_m(t)} + n_k(t) k = 3,4. \tag{11}$$

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,

$$E[X_3^2] = E[Y_3^2] = \sigma_3^2 = (1+\rho)\sigma^2 . \tag{12}$$

$$E[X_4^2] = E[Y_4^2] = \sigma_4^2 = (1-\rho)\sigma^2 . \tag{13}$$

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. (12 and 13), a new SNR is defined for each uncorrelated signal $r_2(t)$ and $r_4(t)$:

$$\Gamma_3 = (1+\rho)\Gamma . \tag{14}$$

$$\Gamma_4 = (1-\rho)\Gamma . \tag{15}$$

Where Γ 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 [8],

$$BER = \frac{1}{2}\left[1 - \sqrt{\frac{\Gamma_3}{\Gamma_3+1}} - \sqrt{\frac{\Gamma_4}{\Gamma_4+1}} + \sqrt{\frac{\Gamma_3\Gamma_4}{\Gamma_4\Gamma_3+\Gamma_3+\Gamma_4}}\right] . \tag{16}$$

3. Computer simulation conditions

Two antennas at the BS and one antenna at the MS is assumed. Fig. 3 shows propagation model at the BS. Table 1 shows simulation parameters.

Table 1
Simulation parameters

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

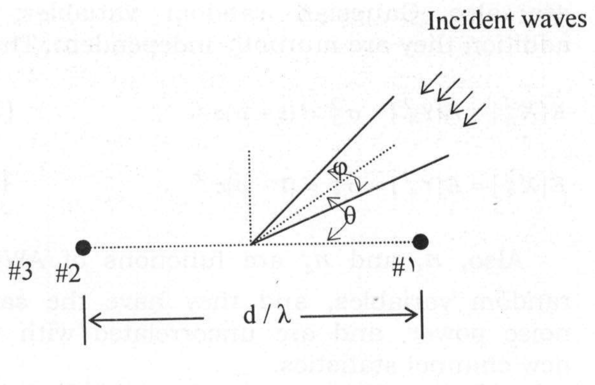

Fig. 3. Linear array and propagation model at BS.

To model the Rayleigh fading, we consider a set of eight plane waves that are transmitted in random direction within the range of φ degrees at the BS [9]. The value of φ 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 2π. The eight incident plane waves arrive in random direction θ from 0 to 2π at the MS.

The Doppler frequency is uniformly distributed from + f_d to − f_d (f_d: is the maximum Doppler frequency). QPSK is assumed with coherent detection. A square root raised cosine filtering with a roll-off factor α of 0.5 is employed. A symbol rate of 30 ksps is assumed. The spreading code is Walsh code with spreading factor of 128. The Rayleigh fading channels were disturbed by AWGN.

4. Computer simulation results

The Performance of the diversity system depends on correlation between antenna elements. Therefore, the basic requirement for space diversity is that, the spacing of the antennas in the receiving or transmitting array is chosen so that the individual signals are uncorrelated [4]. This correlation is determined by antenna elements spacing, angle spread of incident waves φ and direction of arrival θ [10]. Thus, we have to optimize these values to get better BER performance.

Fig. 4 and 5 show the effect of arrival angle, θ, of the signal and angle spread of incident waves φ on BER performance, respectively at E_b/N_o=5dB, f_d=90 Hz and d/λ=0.5. From fig. 4, it can be concluded that when θ=30°, BER has its lowest value. Therefore, we use in our simulation the value 30° of θ. From fig. 5, it can be concluded that changing the value of φ gives slightly small effect. Therefore, we select the value of 12° which gives better BER performance.

To get maximum transmit diversity at BS, a large antenna separation is required. For this reason, we have to look for the optimum antenna separation that yields better BER performance. Simulations were performed where the ratio d/λ was varied between 0.1 and 10. The results are indicated in fig. 6. It is clear that as the ratio is increased, the BER performance is better. When d/λ is 6, we already have optimal BER results. Also, increasing d/λ beyond 6 does not have any noticeable benefits.

We use these values on the following simulations.

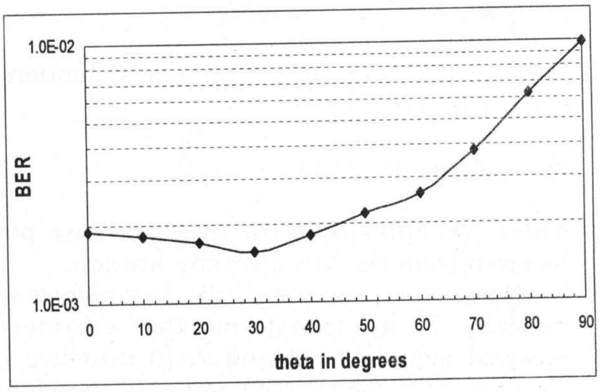

Fig. 4. Arrival angle of the signal θ vs. BER.

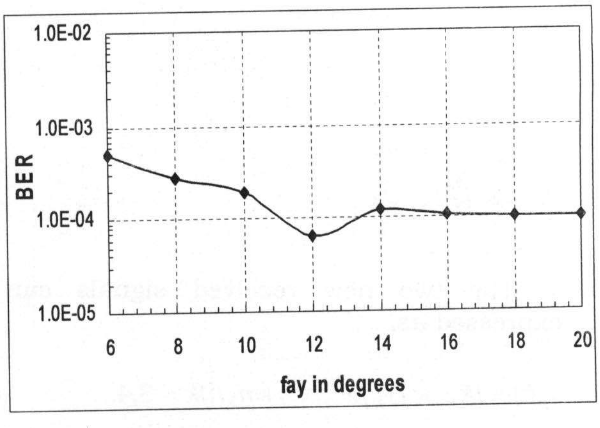

Fig. 5. Angle spread of incident waves φ vs. BER.

Fig. 7 displays comparisons between the BER performances due to single antenna case and the proposed scheme. The simulations are executed with two different antenna separations d/λ of 0.5 and 6. It is clear that the proposed method has better BER than the single antenna case. The improvement in E_b/N_0 for BER=10^{-3} is about 2 dB for '=5dB, φ=12°, θ=30° and d/λ=6. As f_d increases, due to the increase in the speed of the Mobile, BER performance will degrade. This degradation is due to rapid changes in channel characteristics. If f_d increases more than 200 Hz, the maximum value illustrated in this Figure, the BER also degrades. Moreover, If f_d decreases lower than 90 Hz, the BER also degrades. Therefore, the lowest value of f_d that gives better BER is 90 Hz.

Next, we will study how SSTD performs when there are errors in the Antenna Selection (AS) messages from the MS to the BS. These errors are due to noise on the uplink and affect the feedback signal bit. Table 2 lists the required transmitted E_b/N_0 for BER=10^{-3} fig. 9 shows that the proposed scheme has robustness against feedback errors.

Table 2
Required transmitted *Eb/No* for BER=10^{-3} when erroneous feedback loop is used

Error ratios	Transmitted E_b/N_o (dB)
0%	6
2.5%	7.5
5%	9
10%	10.6
20%	14

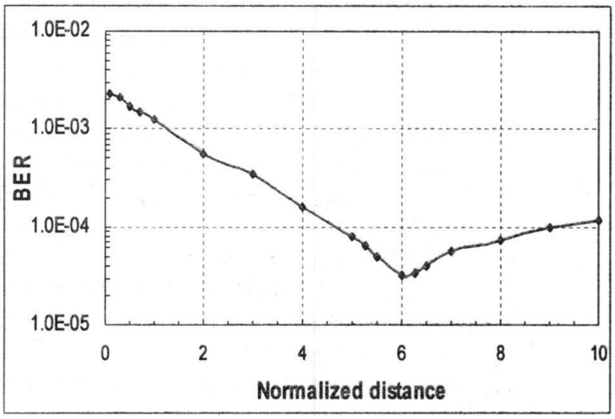

Fig. 6. Normalized distance (d/λ) vs. BER.

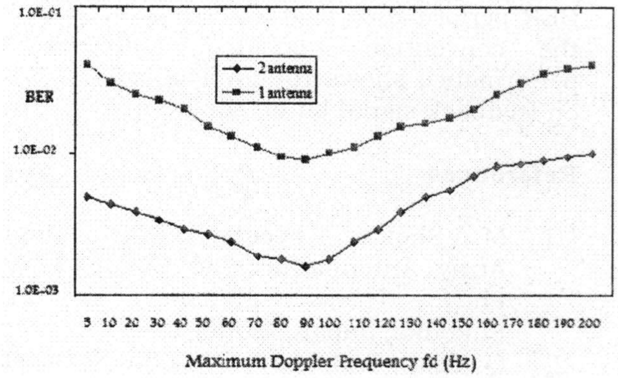

Fig. 8. Maximum Doppler frequencies (f_d) vs. BER for E_b/N_o=5 dB.

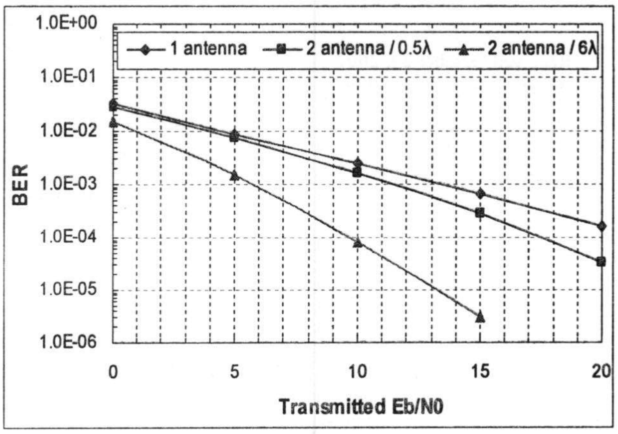

Fig. 7. BER due to 1 antenna and the array of 2 antennas at d/λ=0.5 and 6.

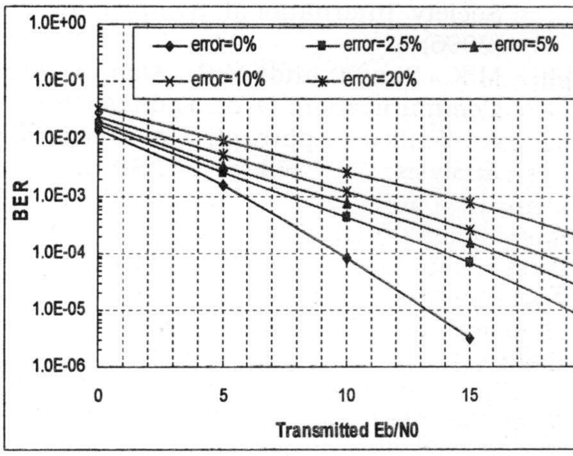

Fig. 9. Effect of errors in AS message on SSTD performance.

5. Conclusions

In this paper, the performance of Switched Selection antenna Transmit 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. The proposed scheme significantly decreases the average transmit power at the Base Station or the Mobile Station and shows robustness against the BER performance degradation compared with the conventional scheme. Moreover the performance shows robustness against errors on feedback signal bit on the uplink.

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