

PERFORMANCE OF SWITCHED DIVERSITY WITH POST-EXAMINING SELECTION IN CDMA SYSTEM

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ABSTRACT

The aim of this paper is to investigate the performance of multi-branch Switch and Examine Combining with Post-examining Selection (SECPS) combining schemes. In this system, when no acceptable path is found after examining all paths, the best path among all these unacceptable paths is selected. With such a system, only one receiver is needed for all branches. We evaluate the performance of this system by considering the effects of spacing distance between antenna elements at Base Station (BS) and the maximum Doppler Frequency (f_d) on Bit Error Rate (BER) performance under optimum conditions. These effects are not clarified until now on this system. Moreover, simulation results are calculated under Rayleigh fading.

Keywords: Switch and Examine Combining with Post-examining Selection.

1 INTRODUCTION

System designers have always faced the problem of fading channels, where signals amplitude and phase can vary over time. Therefore, the designer copes against this problem by using diversity techniques. Diversity techniques are classified into many types, which described in [1] and [2]. Such as time diversity, frequency diversity, space diversity,....etc. In space diversity, the system can be implemented using several antennas. The distance between these antennas must be large enough to get uncorrelated signals on the receiver end.

Diversity combining is an excellent tool in wireless communication systems to mitigate fading, and it indicates the methods by which the signals from diversity branches are combined. Diversity combining requires a number of transmission replicas of the transmitted signal available to the receiver, all have the same data but giving independent fading statistics. There are several classification of diversity combining techniques such as Selection Combining (SC) and switched combining [3].

In this paper, we will investigate the performance of Switch and Examine Combining with Post-examining Selection (SECPS) by considering the effects of spacing distance between antenna elements at BS and the maximum Doppler Frequency (f_d) on Bit Error Rate (BER) performance under optimum conditions. These effects are not clarified until now on this system at optimum condition.

The paper is organized as follows, In Section 2, the system model of SECPS is introduced. The computer simulation conditions and results are explained in

Section 3. Conclusions are made in Sect. 4.

2 SYSTEM MODEL

There is several classical diversity combining schemes, as an example Selection Combining (SC) and switched combining [2], [3] and [4].

In SC, the receiver selects the best signal from the antennas for processing. The selection is based on the power of the desired signal or the SIR available at each antenna. Therefore, SC requires the estimation of the Signal to Noise Ratio (SNR) of all diversity paths [5]. While in switching diversity combining, the receiver try to use an acceptable diversity path by switching away from all paths. This is done by comparing the SNR of the paths with a fixed threshold. When the signal quality of the used branch is good (received SNR is above the required threshold), there is no need to look for other paths. When the signal quality of the used branch deteriorates (the SNR of the used path drops below the required threshold), other paths are needed. Switching from one diversity branch to another only when needed will reduce the complexity of the receiver [6]. The outage probability is the probability of having a received power lower than the given threshold, this threshold is adjusted in the receiver to a minimum received SNR for which the receiver can be able to detect and decode the transmitted signal. When the received SNR is lower than this threshold, the recovery of the transmitted signal is complicated. There are two different strategies can be used in switching diversity combining scheme. The first is Switch and Stay Combining (SSC), which is explained in details in [4]. The other strategy is

switch and examine which described now in detail. Switch and Examine Combining (SEC) used to take the advantages of the multiple diversity paths and has less signal discontinuities as compared to the switch and stay strategies. Fig. 1 shows the threshold level and discontinuous nature of a SEC. In this system the receiver tries to use acceptable path by examining as many paths as necessary, whoever, when no acceptable path is accepted, the receiver switch to the strongest of M-1 other signals only if it is level exceeds the threshold. Since all available diversity paths have been anyway examined. If there are no paths has a SNR greater than the threshold, a more preferred alternative would to use the strongest one among all these unacceptable paths is called Switch and Examine Combining with Post-examining selection (SECPS). Path switching with SECPS occur only when the SNR of the current path is less than the threshold and the SNR of the new path is better than the used path. Another type of SEC may be use randomly chooses an unacceptable path and use it for data reception. Note that, if we use SC with an output threshold it become equivalent to SECPS.

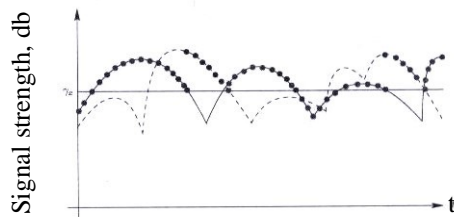


Figure 1: Threshold level and discontinuous nature of a SEC.

Consider SC scheme with an Output Threshold (SC-OT), therefore the CDF of the combined SNR, Γ is given by [4]:

$$P_{\Gamma}(x) = P_{\Gamma}[\Gamma \geq x] = \sum_{i=1}^M P_{\Gamma}[\Gamma = \max\{\gamma_1, \gamma_2, \dots, \gamma_i\} \& \Gamma \geq x]$$

Where, $\Gamma = \max\{\gamma_1, \gamma_2, \dots, \gamma_i\}$ denotes the event that an i-branch is used.

We must note that a single branch receiver is used when the SNR of the first path is above the threshold ($\gamma_1 \geq \gamma_{th}$), and an i-branch SC ($2 \leq i \leq M-1$) is used when the combined SNR of an i-1 branch is below the threshold whereas the combined SNR of an i branch SC is above the threshold (i.e. $\max\{\gamma_1, \gamma_2, \dots, \gamma_{i-1}\} < \gamma_{th}$ and $(\max\{\gamma_1, \gamma_2, \dots, \gamma_{i-1}, \gamma_i\} = \gamma_i \geq \gamma_{th})$ and an M branch SC is used when the combined SNR of an M-1 SC is below the threshold (i.e. $\max\{\gamma_1, \gamma_2, \dots, \gamma_{M-1}\} < \gamma_{th}$).

Therefore, the formula for the PDF of the combined SNR, Γ , is given by:

$$P_{\Gamma}(x) = \begin{cases} \sum_{i=0}^{M-1} [P_{\gamma}(\gamma_{th})]^i p_{\gamma}(x) & , x \geq \gamma_{th} ; \\ M [P_{\gamma}(x)]^{M-1} p_{\gamma}(x) & x < \gamma_{th} \end{cases}$$

where $P_{\gamma}(\cdot)$ is the single branch SNR PDF.

In this paper, we will make a combination between Code Division Multiple Access (CDMA) system and switched diversity combining. Therefore, we will simplify the operation of SECPS by considering M paths (as an example M=4). Fig. 2 shows the mode of operation of 4 paths SECPS used in this paper. We will consider the BS has 4 antennas and only one antenna at MS. Fig. 3 shows our system model. The signal transmitted from the BS antenna elements using the different spreading (Walsh) code.

The output at sampling of four Matched Filter (M.F.) are used at the receiver.

In this system the receiver tries to use acceptable path after each matched filter by examining as many paths (output of each matched filter after sampling) as necessary, whoever, when no acceptable path is accepted, the receiver switch to the strongest of M-1 other signals. i.e. the one with the highest SNR, used for data reception. more specifically, the receiver now continue to use the current path for data reception ($\Gamma = \gamma_i$) until its SNR is fall below a threshold ($\gamma_i < \gamma_{th}$), at that time, the receiver tries to find another acceptable path by sequentially examining the remaining M-1 paths. In the beginning, the second diversity path is examined and its SNR (γ_2) is compared with the threshold (γ_{th}), if ($\gamma_2 \geq \gamma_{th}$) then the second path is used for data reception ($\Gamma = \gamma_2$). Otherwise, [the receiver now will use the largest one between γ_1, γ_2] and the receiver begin to examine the third path, if ($\gamma_3 \geq \gamma_{th}$) then it is suitable for data reception ($\Gamma = \gamma_3$). Otherwise, [the receiver now will use the largest one between $\gamma_1, \gamma_2, \gamma_3$] until the fourth path is examined in the same manner.

If the fourth path is not accepted ($\gamma_4 < \gamma_{th}$), the receiver will use one from the four paths with the highest SNR for data reception. Since the receiver is previously estimate the SNR of all paths.

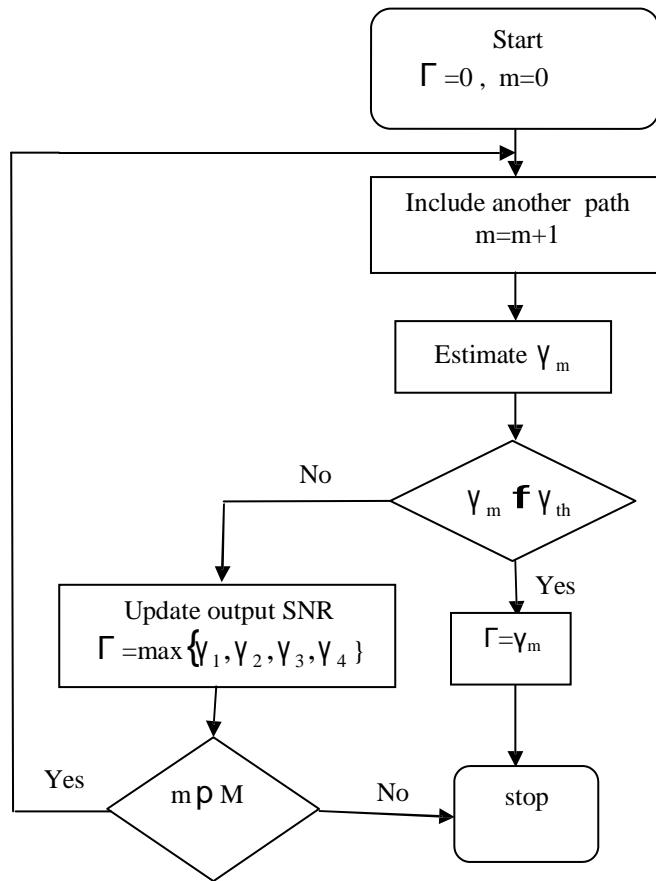


Figure 2: Operation of 4 paths SECPS.

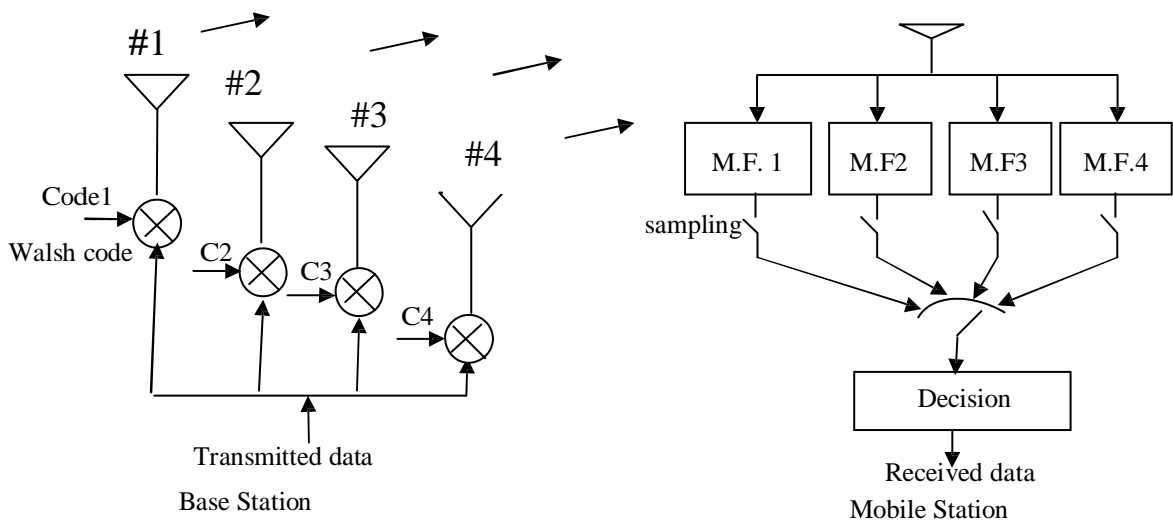


Figure 3: System model.

3 COMPUTER SIMULATION CONDITIONS AND RESULTS

3.1 Simulation Condition:

To model the Rayleigh fading, we consider a set of eight plane wave arrives in random direction from 0 to 2π at MS. Angle spread of incident waves arrives within the range of 12 degrees at the BS [7] 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 2π . 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. The multipath propagation model at BS in the case of flat fading is shown in Fig. 4. Table 1 show the simulation parameters.

3.2 Simulation Results:

The success of diversity techniques depends on the degree to which the signals on the different paths are uncorrelated. This correlation is determined by antenna element spacing, angle spread of incident waves (ϕ) and direction of arrival (θ) [8]. The distance between antenna elements at BS is a first criterion that can affect the performance.

Therefore, we have to look for the optimum antenna separation that yields good BER performance. Fig. 5, shows this effect. The ratio of distance between antenna elements to the wave length (d/λ) are varied between 0.1 to 10, where λ is the wavelength of the carrier. From the figure, we can see that as the separation increased, the performance of the BER is better and the optimal BER occur at $d/\lambda = 6$. we can see also, when the value of (d/λ) more than 6 does not give us any noticeable benefits. Fig. 6 gives us the optimum value for arrival angle of the signal (θ) which is 30° . To give the optimum value of angle spread of incident waves (ϕ) in the simulation, we vary ϕ between 0 and 90° , from Fig. 7, we can see that the optimum value for ϕ is 12° .

Fig. 8 shows the effect of maximum Doppler frequency f_d on BER performance. From this figure

we notice that, the BER decrease with increasing f_d due to increase in the speed of the MS. The lowest value of f_d that gives better BER is 90 Hz .

By using different values of thresholds to determine which one is the best, we find that increasing the value of receiver threshold will improve the performance at the expense of complexity. Therefore, it is suitable to compromise between complexity and required BER. We use the value of threshold equal to 21.20db. Increasing the distance between antenna elements at BS from 0.5λ to 6λ improve the BER performance, this is shown in Fig. 9 and Fig. 10 at maximum Doppler frequencies 5.56 and 90 Hz respectively.

4 CONCLUSIONS

Signal combining is a very important part of a diversity system. Switched diversity is a simple diversity combining and can be a good compromise between performance and complexity. We evaluate the performance of multi-branch Switch and Examine Combining with Post-examining (SECPS) selection schemes. SECPS takes full advantages of the available path estimation. 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. Computer simulation results show that the BER performance is better with wide antenna element spacing than with short antenna element spacing at BS due to multi path diversity. Inversely speaking, the BER performance is deteriorates with increasing the maximum Doppler frequency. Moreover, increasing the value of the receiver threshold which is the most important criterion in our proposed system give us good BER performance but this increase complexity and the system will approach the selection combining schemes. Decreasing this threshold to a lower value will deteriorates the BER performance. Therefore, we must compromise between the BER performance required and the complexity.

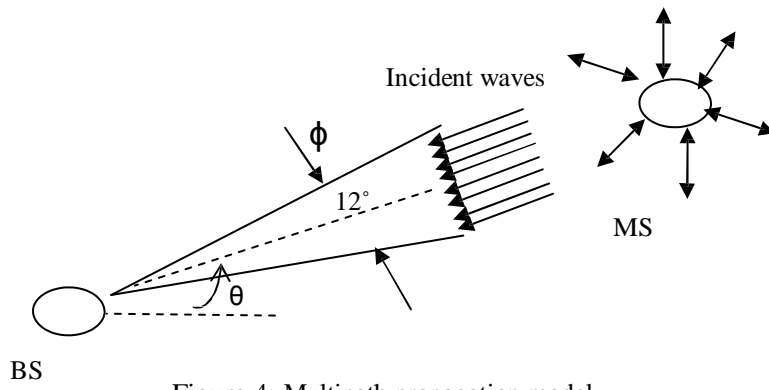


Figure 4: Multipath propagation model.

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

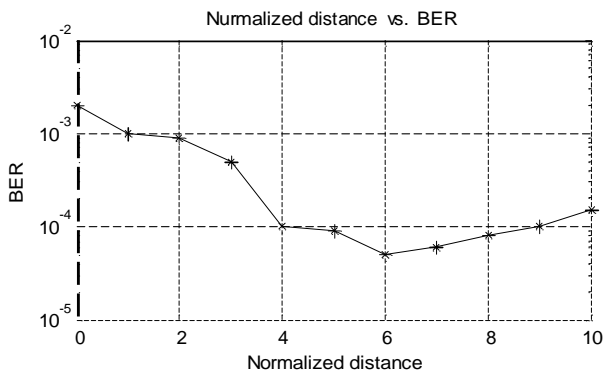


Figure 5: Normalized distance (d/λ) vs. BER

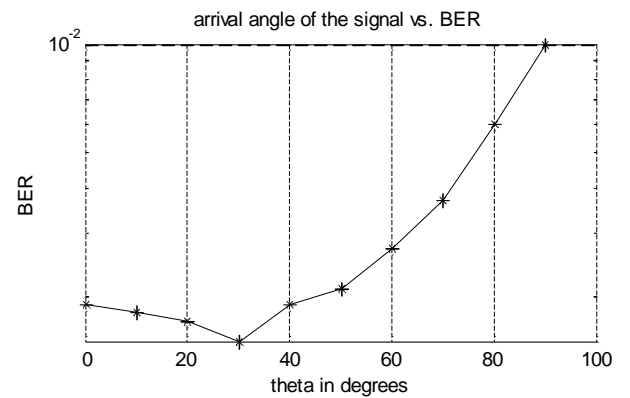


Figure 6: Arrival angle θ of the signal vs. BER

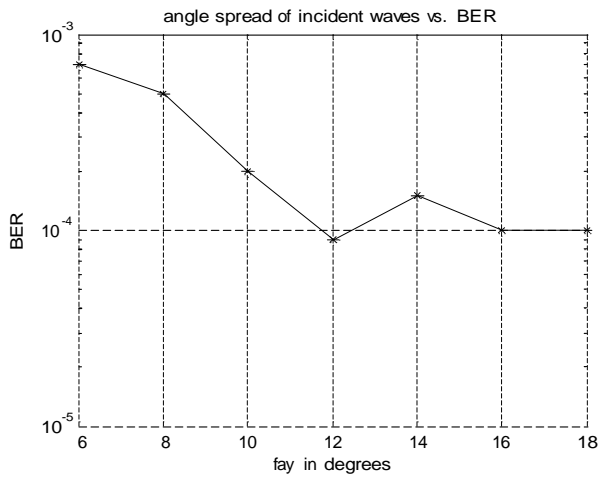


Figure 7: Angle spread of incident waves (ϕ) vs. BER

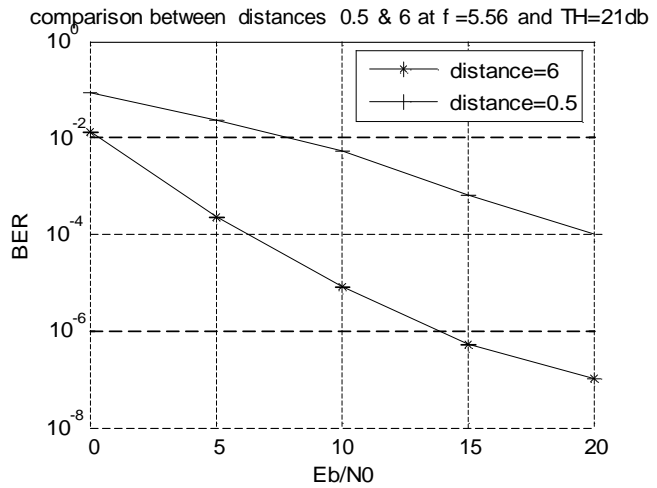


Figure 9: Comparison between distances 0.5 and 6 at $f=5.56\text{Hz}$, Threshold= 21.20db

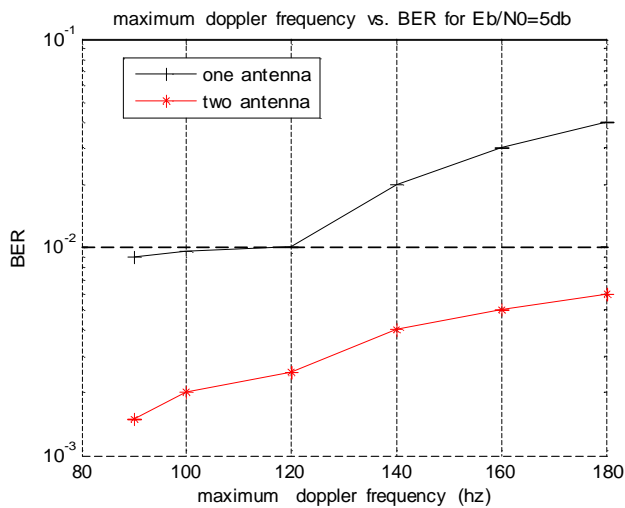


Figure 8: Maximum Doppler frequency (f_d) vs. BER for $E_b/N_0=5\text{db}$

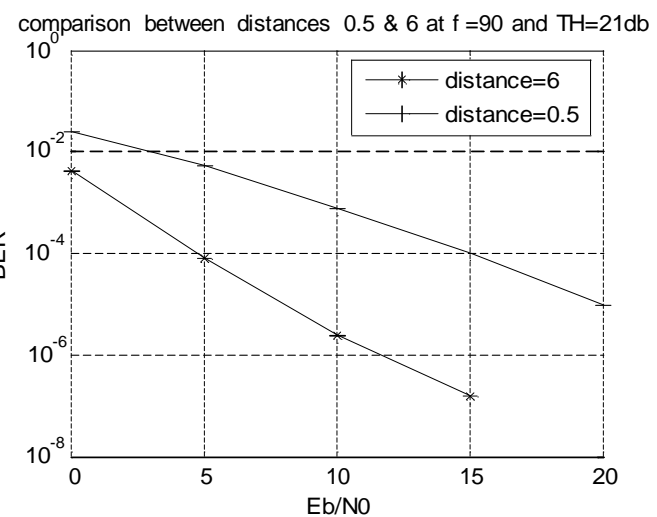


Figure 10: Comparison between distances 0.5 and 6 at $f=90\text{Hz}$, Threshold = 21.20db

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