Enhancement of Data Throughput in the AMC-Employed DS-CDMA Systems through Suppression of Channel Frequency Selectivity by a MTMR Antenna System

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SUMMARY In this paper, a new algorithm for MTMR adaptive array antenna (AAA) system combined with analog-type transmit power control (TPC) is proposed for DS-CDMA systems in order to employ high level modulation schemes like 64 QAM in wireless multimedia services. A conventional AAA system considering the strongest path as a target path cannot work effectively when angular dispersion between the strongest path and other delayed paths is large, that is, beam selectivity is so small due to severe frequency selective multipath fading. So, in order to solve such a beam selectivity problem, a beam directivity control scheme using a path manipulation technique is introduced for the BS and MS AAA combining in this paper, along with analog-type TPC. It utilizes virtual delay profiles which are modified from the measured complex delay profile and selects a desired path giving the maximum DUR with an optimized weight vector for BS and MS beamforming. We will show through computer simulation that the proposed scheme is very effective in enhancing the data throughput at the downlink of wideband DS-CDMA systems as compared with the conventional system.

key words: MTMR, DS-CDMA, adaptive array antenna, analog-type TPC, frequency selectivity test

1. Introduction

Demands on various multimedia services for high data rate transmission through wireless network are rapidly growing year after year, along with increase of demand for high speed Internet services. In order to meet such demands, enhanced specifications for the third generation (3G) systems are standardized, e.g. high speed downlink packet access (HSDPA) [1] and cdma2000 1X evolution data only (EV-DO) [2] in which peak user rate is enhanced by code multiplexing as well as adaptive modulation and coding (AMC) techniques.

In DS-CDMA systems, Rake receiver is used to discriminate and to coherently combine direct and delayed paths so as to obtain sufficient path diversity effect. It works well when spreading factor is so large that each component can be discriminated with high DUR. On the other hand, when smaller number of spreading factor (SF) is employed to increase transmit data rate, the system becomes less robust to multipath fading because of its insufficient suppression of multipath interference and degradation of interference immunity for multi-level quadrature amplitude modulation (QAM) [3], [4]. As a result, we have less chance to employ modulation schemes with higher modulation level, such as 16-ary or 64-ary QAM under such conditions. Therefore, how to suppress channel frequency selectivity thereby obtaining more chance for multi-level QAM to be employed, is very important to enhance peak user rate for DS-CDMA based wireless access systems under frequency selective fading conditions.

Multi-transmit and multi-receive (MTMR) adaptive array antenna (AAA) scheme [5], [6] is one of the most effective techniques to suppress multipath interference along with interference canceller [7], thereby keeping orthogonality between the code multiplexed signals, and making it more probable for 16QAM or 64QAM to be employed. When an AAA scheme is employed in DS-CDMA systems [8], [9], an ideal beam directivity control is to direct a main beam toward a path having the highest received signal power, and create nulls to the directions for the rest of the paths. In practice, however, it is impossible because the number of antenna elements in the BS and MS is limited to a small number, say up to 4-8 in the BS and 2-4 in the MS, which limits degrees of freedom for the number of nulls to be created. Therefore, how to effectively utilize degrees of freedom in the antenna directive control is a very critical issue for the AAA schemes.

One of the problems for antenna directive control for smaller number of antenna elements is, to which path the main beam is directed. We usually direct the main beam toward the strongest path to maximize signal to noise power ratio (SNR) [10]. However, it is not always a good strategy from the viewpoint of the suppression of frequency selectivity under frequency selective fading conditions, because angle of arrival (AOA) for the short-delayed path could be more spread, which means AOAs for some of the components in the short-delayed paths could be close to those for some of the other multipath components with different delay time [5], [11], which prevents availability of the multi-level QAM due to insufficient suppression of channel frequency selectivity. Therefore, it could be a better strategy to direct main beam toward a longer delayed path whose AOA is apart from those of the other multipath components even if its received signal level is lower than that of the direct path as shown in Fig. 1. Fortunately, transmit power control...
(TPC) can compensate for the path loss for the main-beam-directed path, thereby increasing probability for 16QAM and 64QAM to be selected.

Therefore, this paper proposes a beam directivity control scheme at the downlink of DS-CDMA systems using a path manipulation technique to create antenna directivity that minimizes frequency selectivity. Therefore, BS AAA corresponds to the Tx AAA and MS AAA corresponds to the Rx AAA in the following.

In the proposed scheme, after the measurement of the delay profiles between any combination of the antenna elements in both the BS and MS, we will create several virtual delay profiles based on the measured delay profiles, and calculate antenna beam directivity for the BS using the created virtual delay profiles. Then, we will calculate DURs after BS AAA combining for all the antenna beam patterns and select a beam pattern with a certain target path that minimizes frequency selectivity. The same process will then be conducted on the MS AAA to further suppress channel frequency selectivity. Furthermore, analog-type TPC is applied to compensate for the path loss due to selection of non-strongest path for main beam directivity [12], [13].

To verify performances of the proposed scheme, we have conducted computer simulation on the downlink DS-CDMA for single cell systems, and confirmed that the proposed scheme is very helpful to suppress channel frequency selectivity thereby increasing probability for multi-level QAM to be selected.

2. System Description

2.1 Propagation Channel Model

In this paper, a discrete-time frequency selective fading channel model for MTMR antenna system, which has compatibility with conventional time-domain channel model, is employed in the downlink [14], [15]. This model is an extension of geometrically based single bounce circular model (GBSBCM) and geometrically based single bounce elliptical model (GBSBEM), and it includes angle of departure (AOD) and angle of arrival (AOA) for each elementary path in addition to its amplitude and phase information.

For the proposed system, 3-cluster 24-path model and 7-cluster 56-path model are used as channel models, in which scattering objects around a terminal is modeled by one cluster (cluster \( \#0 \) in Fig. 2 and Fig. 3, and we will call these scatterers located around the MS as the “MS scatterers” in the following), and scattering objects that generate long-delayed paths are modeled by two or six clusters which are randomly distributed within the BS cell coverage (cluster \( \#1 \) and cluster \( \#2 \) in Fig. 2 and cluster \( \#1 \) to cluster \( \#6 \) in Fig. 3, and we will call these scatterers within the clusters of the BS cell coverage as the “BS scatterers”). Specifically, the center for MS scatterers and that of BS scatterers are randomly changed in both models to generate various multipath environments, and in each cluster, scatterers are randomly distributed in a preliminarily determined area for each cluster. The additive noise at each receive antenna is assumed to be subject to white and Gaussian with its spectral density of \( N_0 \) in the equivalent lowpass domain.
2.2 Proposed Algorithm for Suppression of Channel Frequency Selectivity

In our approach, the most important issue is to which path the antenna main beam is directed. Usually, antenna beam is directed to the direction of the strongest path to maximize channel gain. However, directions of some other paths could happen to be almost the same directions, thereby frequency selectivity of the channel cannot be sufficiently suppressed due to limitation of the spatial resolution of the adaptive array antenna. Therefore, in such a case, a better strategy for suppressing channel frequency selectivity is to direct main beam toward a path that achieves the smallest frequency selectivity after beamforming.

The proposed system places nulls to most of the dominant directions of the multipath interference except for the desired path in both the BS and MS using a criteria that maximizes desired to undesired signal power ratio (DUR). In other words, the proposed scheme minimizes frequency selectivity for the received signal after AAA combining in the MS.

Figure 4 shows operation of the weight processing block (WPB) located in terminal side in which antenna directivity for both the transmitter and receiver is jointly controlled using the measured delay profile according to the proposed algorithm.

In time-varying multipath environments, frequency selectivity will depend on which path the reference signal is synchronized to, because the optimum target path is dynamically changing. Moreover, the optimum number of paths for null steering also depends on the channel conditions. In the proposed system, a pilot channel which consists of unique PN sequence in each BS antenna element, is multiplexed and transmitted. Therefore, using the spread spectrum technique, we can measure a complex delay profile between any combination of BS and MS antenna elements.

First of all, we will measure delay profile for any combination of BS and MS antenna elements. Let us express the measured complex delay profile between the $i$-th BS antenna and $j$-th MS antenna elements as

$$h_{ij}(t) = \sum_{l=0}^{L-1} h_{ijl} \delta(t - \tau_l),$$  \hspace{1cm} (1)

where $h_{ijl}$ is the complex channel gain for $l$-th delayed path with its delay time of $\tau_l$, and $L$ is the number of delayed paths in the measured delay profile.

When the AAA weight vector is calculated using all the measured multipath components, we might not be able to sufficiently suppress frequency selectivity due to lack of degrees of freedom. A solution for this problem is to calculate the antenna weight vector from a virtual delay profile that consists of a limited number of paths of the measured delay profile (the number is smaller than the degrees of freedom of the AAA). However, at this stage the receiver cannot decide which paths should be selected in the virtual delay profile. Fortunately, although the number of nulls in the created beam directivity is limited by the the number of degrees of freedom of the AAA, some interference could be suppressed to some extent when AOA for such interference is close to the direction of one of the nulls. Therefore, we will create several virtual delay profiles based on the measured delay profile. In this paper, such a process will be called the “path manipulation technique,” which is outlined below:

**Step 1) BS virtual delay profile sets creation**

After the largest $k_{BS}^{max}$ paths are selected from $h_{ij}(t)$, several types of virtual delay profiles that consist of a target path and up to $k_{BS}^{max} - 1$ interference paths to be nulled out, are created. The value of $k_{BS}^{max}$ must be smaller than the degrees of freedom. The virtual delay profiles are then subgrouped according to the selected target path. As a result, the num-

![Fig. 4](image-url) Configuration of the weight processing block for the proposed algorithm.
ber of subgroups is \( k_{BS}^{max} \), and the number of virtual delay profiles in each group is \( 2^{k_{BS}^{max}} - 1 \).

**Step 2) BS frequency selectivity test and beamforming**

If the \( a \)-th path is selected as a target path, virtual delay profiles belonging to the same subgroup can be expressed by modifying Eq. (1) as

\[
c_{ij}(t) = h_{ij}(t - \tau_a) + \alpha \sum_{p=1}^{P} h_{ijp}(t - \tau_p),
\]

where \( \alpha \) is used to create a deeper null to the direction of the non-target path, \( P \) is the number of non-target paths ranging from 1 to \( k_{BS}^{max} - 1 \), and \( \tau_a \) and \( \tau_p \) are the delay time of taget path \( a \) and non-target path \( p \), respectively. Amplitude of the non-target paths in Eq. (2) is amplified by \( \alpha (\alpha \gg 1) \) to create deeper null to the direction of the non-target path [16] because antenna directivity with deeper null has more chance to suppress unwanted radiation to almost the same direction of the non-target paths.

Using this delay profile, a virtual received signal is generated by taking convolution of the delay profile and preliminary prepared QPSK baseband symbol sequence, and recursive least squares (RLS) algorithm is applied to obtain the optimum BS antenna weight vector, where reference symbol timing is synchronized to the target path timing for the used virtual delay profile [8]. When the BS antenna weights for the \( m \)-th virtual delay profile with its target path of \( a \)-th path are obtained as \( \mathbf{w}_{VBS}^{m} = [w_{VBS}^{m0}, w_{VBS}^{m1}, \ldots, w_{VBS}^{m(J-1)}]^{T} \), the delay profile for the \( j \)-th MS antenna element after BS antenna beamforming can be obtained by linear combination of the actual delay profile coming from each BS antenna element as

\[
\tilde{h}_{ij}(t) = \sum_{i=0}^{J-1} \sum_{l=0}^{L} w_{mi}^{VBS} h_{ijl}(t - \tau_l),
\]

where \( J \) is the number of BS antenna elements.

At this stage, the desired signal power and interference signal power in the received signal after averaging over all the received antenna elements are given by

\[
S_{BS}^{m} = \sum_{j=0}^{J-1} \sum_{i=0}^{I} |w_{mi}^{VBS} h_{ijl}|^2
\]

and

\[
I_{BS}^{m} = \sum_{j=0}^{J-1} \sum_{i=0}^{I} \sum_{l=0}^{L} |w_{mi}^{VBS} h_{ijl}|^2.
\]

As a result, DUR after BS AAA combining is given by

\[
DUR_{BS}^{m} = S_{BS}^{m} / I_{BS}^{m}.
\]

Using this relationship, we will calculate DUR averaged over all the MS antenna elements, and will select one of the virtual delay profile subgroups that includes a delay profile achieving the highest DUR. With this process (selection of the virtual delay profile subgroup), we can determine which path the main beam for the BS AAA should be directed to. In this paper, we will call such a searching process as ‘a frequency selectivity test for BS’ in the following because maximization of DUR corresponds to minimization of the channel frequency selectivity with almost the same manner.

**Step 3) MS AAA weight vector calculation**

After the selection of the virtual delay profile subgroup, the optimum MS AAA weight vector is calculated for each virtual delay profile in the selected delay profile subgroup, where the already-calculated BS AAA weight vector is used for each profile. As for the MS AAA weight vector calculation process, it is just the same RLS based process as that used in the BS AAA weight vector calculation. At this stage, a virtual delay profile consists of a target path and up to \( (J-1) \) interference paths. The delay time for the target path and the interference path is just the same as that for the target path and the interference path in the virtual delay profile selected in the BS antenna weight vector selection process.

**Step 4) MS frequency selectivity test and beamforming**

When the MS antenna weights for the \( m \)-th virtual delay profile are expressed as \( \mathbf{w}_{VMS}^{m} = [w_{VMS}^{m0}, w_{VMS}^{m1}, \ldots, w_{VMS}^{m(J-1)}]^{T} \), the delay profile after MS AAA combining is given by

\[
\tilde{h}_{ij}(t) = \sum_{j=0}^{J-1} w_{mj}^{VMS} \tilde{h}_{ij}(t) = \sum_{j=0}^{J-1} \sum_{l=0}^{L} w_{mj}^{VMS} w_{mi}^{VBS} h_{ijl}(t - \tau_l),
\]

where \( J \) is the number of elements in the MS AAA. And DUR for \( m \)-th virtual delay profile can be calculated as

\[
DUR_{MS}^{m} = S_{MS}^{m} / I_{MS}^{m},
\]

where

\[
S_{MS}^{m} = \sum_{j=0}^{J-1} \sum_{i=0}^{I} |w_{mj}^{VMS} w_{mi}^{VBS} h_{ijl}|^2
\]

and

\[
I_{MS}^{m} = \sum_{j=0}^{J-1} \sum_{i=0}^{I} \sum_{l=0}^{L} |w_{mj}^{VMS} w_{mi}^{VBS} h_{ijl}|^2.
\]

Then, DUR after both the BS and MS AAA beamforming is calculated for each virtual delay profile in the selected subgroup, and a virtual delay profile having the highest DUR is selected. The optimum BS and MS antenna weight vectors can be obtained as \( \mathbf{w}_{BS}^{m} = [w_{BS}^{m0}, w_{BS}^{m1}, \ldots, w_{BS}^{m(J-1)}]^{T} \) and \( \mathbf{w}_{MS}^{m} = [w_{MS}^{m0}, w_{MS}^{m1}, \ldots, w_{MS}^{m(J-1)}]^{T} \), where \( m_{c} \) is the index for the selected virtual delay profile.
After both the BS and MS antenna weight vector are optimized, DUR after MS AAA combining using the optimized BS and MS antenna weight vector can be obtained as

\[
DUR_{MS} = \frac{\sum_{j=0}^{J-1} \sum_{i=0}^{I-1} |w_{m,j}^{VBS} w_{m,j}^{VMS} h_{ij}|^2}{\sum_{j=0}^{J-1} \sum_{i=0}^{I-1} \sum_{l=0}^{L-1} |w_{m,i}^{VBS} w_{m,j}^{VMS} h_{ijl}|^2}. \tag{11}
\]

Step 5) Power calculation for analog-type TPC

Because the received SINR cannot exceed the obtained \(DUR_{MS}\), we will select a modulation scheme having the highest transmission rate while its required SINR is lower than \(DUR_{MS}\), and its transmit power level is controlled to achieve a required SINR determined by the selected modulation level information (MLI). Then, BS antenna weight vector and analog-type TPC command are fed back to the BS side, along with MLI. A conventional fixed step TPC in CDMA systems is not appropriate because the variable step TPC is necessary in this case. Thus, an analog-type TPC in which analog value is fed back [12] is introduced in the proposed system in order to fully obtain advantage of the proposed system. Here, the adjustable TPC gain is upper-limited by the maximum transmit power of the BS system.

2.3 Proposed System Description

Let us consider a CDMA based MTMR antenna system with \(I\) transmit and \(J\) receive antenna elements, having \(L\) resolvable paths due to the frequency selective multipath channel at the downlink.

Figure 5 shows configuration of the transmitter and receiver for the proposed system. Generally, both the BS and MS have the same configuration. In the BS, \(K\)-stream of the transmitted data sequence for traffic channel is fed to the baseband signal generator (BSG) for the adaptive modulation and coding (AMC) where the modulation and coding schemes are selected according to the modulation level information (MLI) returned via the uplink. Then the baseband signal of each channel is spread by an orthogonal short spreading sequence called orthogonal variable spreading factor (OVSF) code, in order to orthogonalize and multiplex traffic channels followed by randomization process by a long PN code having a period of \(2^{42} - 1\).

The randomized signal is copied to \(I\) streams, where \(I\) corresponds to the number of BS Tx antenna elements, multiplied by weight vector for BS Tx beamforming, and then multiplexed with a pilot channel for channel sounding allocated to each Tx antenna for the measurement of delay profiles between any combination of antenna elements in the BS and MS. After the baseband signal for each antenna element is lowpass filtered, it is fed to the quadrature modulator.

In the receiver of the MS, after the received signal in each receive antenna is quadrature demodulated and lowpass filtered, TCH and PCH as well as the side information (MLI, Tx antenna weight vector and TPC command) channels are demultiplexed. And then, using the PCH, delay profiles for the received signal in each antenna are detected, and they are used to calculate antenna weight vectors for both transmitter and receiver sides in the weight processing block.

Weight vector for the transmit antenna is fed back to the transmitter side (this corresponds to the BS in this paper because we consider downlink), and weight vector for the receiver side is used in the Rx beam former. At the same time, using delay profiles for each receive antenna and the MS antenna weight vector, channel state information to be used in the Rake receiver is generated, where the number of
3. Simulation

3.1 Simulation Model

Table 1 shows computer simulation parameters in the downlink. For the simulation test, \( k_{\text{MS}}^{\text{max}} \) and \( k_{\text{BS}}^{\text{max}} \) are 3 and 2, respectively and the number of transmit antenna \( J \) is 4 and 2, respectively. As for the multiplexed number of traffic channels, we will employ 10 OVSF code multiplexing in the following, where this is one of the typical numbers used in the 3GPP evaluation [1]. The cell radius of 100 m is employed in our simulation, because we consider application field of our scheme as the microcellular systems. 100 cases of channel propagation characteristics are generated, in each of which, the MS as well as scattering objects are randomly distributed within the cell coverage at every case in both 3-cluster 24-path model and 7-cluster 56-path model. Maximum resolvable path number, \( L \), generated in both 3-cluster 24-path model and 7-cluster 56-path model reaches to 3-5 and 7-11, respectively. To exclude performance degradation due to fast channel variation in our initial performance evaluation, each propagation channel characteristics is assumed to be quasi-stationary in both channel models in which coherence time is much longer than a frame length, that is, Doppler shift is almost zero.

When \( k_{\text{MS}}^{\text{max}} \) is set to three, largest three paths are selected from the measured delay profile. We will call, Path \#0, Path \#1 and Path \#2 as the strongest path, 2nd strongest path and 3rd strongest path in the following. In this case, we will consider nine types of virtual delay profiles as shown in Table 2. When “Target path” is shown in the column for path \#n, it means path \#n will be regarded as the target path. As for interference paths (disregarded paths), Inf \#0 and Inf \#1 represent two interference paths to be considered. For example, when Inf \#0 is shown under column of Path \#2, the third largest path will be regarded as one of the interference paths. When only one interference path is included in the virtual delay profile, one path is selected as the target path, and another path is selected as the interference path and the remaining path will not be used, which is indicated by \( \times \) in Table 2. The left most column represents the virtual delay profile subgroup, each of which includes three virtual delay profiles. Because the target path is the same in each virtual delay profile subgroup, this process corresponds to selecting a target path for the main beam to be directed. At this stage, the virtual delay profiles to be evaluated are reduced to a certain number by the frequency selectivity test for the BS. In the case of Table 2, the number of virtual delay profiles is reduced to three. When the number of MS antenna elements is limited to two, this delay profile consists of a target path and an interference path, as \( k_{\text{MS}}^{\text{max}} = 2 \). In this case, delay time for the target path is just the same as that for the target path in the virtual delay profile selected in the BS antenna weight vector selection process, and delay time for the interference path is just the same as that for the interference path \#0 (Inf \#0).

3.2 Simulation Results

Figure 6 shows cumulative distribution of SINR after Rake reception in the MS for the proposed algorithm and that for the strongest path selection algorithm, when 3-cluster 24-path model and 7-cluster 56-path model are applied. By the employment of the proposed algorithm, cumu-
relative distribution at low SINR is getting low compared with the case of the strongest path selection algorithm employed system. For instance, 13 dB point of the cumulative distribution function (C.D.F) for the proposed scheme is 12%, whereas that for the strongest path selection algorithm employed system is 27% in the 3-cluster 24-path model. When the number of clusters for BS scatterers increases, probability for lower SINR increases because it is more probable for AOA of the paths with different delay time to be close to each other. However, probability for lower SINR in the proposed system is still low compared to the strongest path selection algorithm employed system. These results suggest that the proposed system is effective in reducing occurrence of the low SINR, in other words, to suppress frequency selectivity.

To further evaluate effects of the proposed system in suppression of frequency selectivity, we will evaluate occurrence and cumulative distribution of DUR in the MS after AAA combining. Fig. 7 to Fig. 10 show the performances for the proposed and strongest path selection algorithm employed systems in 3-cluster 24-path model and 7-cluster 56-path model. As can be seen from comparison of these two systems, probability for low DUR for the proposed system is lower than that for the strongest path selection algorithm employed system in both models.

With these results, we can figure out that the percentage of improved received SINR is nearly the same as that for the DUR in the MS when the proposed scheme is applied, because the DUR after AAA combining in the MS has a dominant impact on the SINR after Rake reception. In other words, it means that the improvement of received SINR can be accomplished by the improvement of DUR in the MS after AAA combining.

Table 3 shows occurrence of each virtual delay profile for the proposed system in both 3-cluster 24-path model and
Table 3  Comparison about the occurrence of each candidate delay profile selected.

<table>
<thead>
<tr>
<th>Profile subgroup</th>
<th>Candidate profile No.</th>
<th>Occurrence</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-cluster 24-path model</td>
<td>0</td>
<td>33</td>
<td>83</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>29</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>21</td>
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<td>13</td>
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<td>6</td>
<td>2</td>
<td>4</td>
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<tr>
<td></td>
<td>7</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total case</td>
<td>100</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Profile subgroup</th>
<th>Candidate profile No.</th>
<th>Occurrence</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>7-cluster 56-path model</td>
<td>0</td>
<td>22</td>
<td>79</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>25</td>
<td>32</td>
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</tr>
<tr>
<td></td>
<td>8</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Total case</td>
<td>100</td>
<td></td>
<td></td>
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</tbody>
</table>

Table 4  Comparison of the selected number of the modulation schemes.

<table>
<thead>
<tr>
<th>Modulation scheme</th>
<th>Proposed algorithm</th>
<th>Strongest path</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-cluster 24-path model</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No transmission</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>QPSK</td>
<td>7</td>
<td>13</td>
</tr>
<tr>
<td>16 QAM</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>64 QAM</td>
<td>88</td>
<td>73</td>
</tr>
<tr>
<td>Total case</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

| 7-cluster 56-path model |
| No transmission       | 8                  | 14             |
| QPSK                 | 15                 | 18             |
| 16 QAM               | 14                 | 21             |
| 64 QAM               | 63                 | 47             |
| Total case            | 100                | 100            |

7-cluster 56-path model. In this table, the strongest path selection algorithm corresponds to selecting the candidate profile of No. 0. From this table, we can find that the candidate profile that corresponds to the strongest path selection algorithm is selected only 33% in the case of 3-cluster 24-path model and 22% in the case of 7-cluster 56-path model. Table 3 also shows that, among the cases that the strongest path is selected as the target path, only one interference path considered case (profile No. 1 and 2) is optimum with 50% probability in the 3-cluster 24-path model, and 57% probability in the 7-cluster 56-path model. Furthermore, with the probability of 17% for the 3-cluster 24-path model case, and with the probability of 21% for the 7-cluster 56-path model case, candidate profiles that do not target to the strongest path are selected.

In Table 4, the number of selection for each modulation scheme is shown for both 3-cluster 24-path model and 7-cluster 56-path model cases. We can figure out from the table that selection probability for higher modulation level scheme is increased compared with the strongest path selection algorithm employed system. For example, although occurrence probabilities of 64QAM in the strongest path selection algorithm employed system are 73% and 47%, for 3-cluster 24-path model and 7-cluster 56-path model cases, respectively, they become 88% and 63% in the proposed system. Moreover, because average user rates for QPSK, 16QAM and 64QAM in the proposed system are 1.018 Mbit/s, 2.042 Mbit/s, and 3.066 Mbit/s, respectively, average throughputs for both 3-cluster 24-path and 7-cluster 56-path models are about 2.83 Mbit/s ((2 × 0 Mbit/s + 7 × 1.018 Mbit/s + 3 × 2.042 Mbit/s + 88 × 3.066 Mbit/s)/100) and 2.37 Mbit/s ((8 × 0 Mbit/s + 15 × 1.018 Mbit/s + 14 × 2.042 Mbit/s + 63 × 3.066 Mbit/s)/100), respectively. When the average throughputs are calculated for the strongest path selection algorithm employed system using the same manner, they are 2.513 Mbit/s in the 3-cluster 24-path model and 2.053 Mbit/s in the 7-cluster 56-path model cases. These results confirm that the proposed system is very effective in enhancing average throughput by suppressing frequency selectivity of the channel.

Although purpose of this paper is to evaluate the proposed scheme for single-cell systems, it would also be important to estimate applicability of the proposed scheme to multi-cell (cellular) systems. Therefore, we have also evaluated C.D.F. for the transmit power for both the proposed and the strongest path selection algorithms. Figure 11 shows C.D.F. of the transmit power for the proposed and strongest path selection schemes in the 3-cluster 24-path model, and Fig. 12 shows that for the 7-cluster 56-path model, where transmit power is normalized by the 50% value for the strongest path selection scheme in both figures. First of all, we can find from these figures that 50% value of the transmit power for the proposed scheme is 3 dB higher than that for the strongest path selection scheme, which is mainly due to the fact that the proposed scheme sometimes selects non-strongest path as the target path to achieve lower frequency selectivity by sacrificing transmit power. However, when we observe peak transmit power (e.g., 20 dB or more higher than the 50% value) for the proposed system, its probability
is lower than that for the strongest path selection scheme. Such a reduction of peak transmit power would be more important to reduce inter-cell interference radiation. Anyway, it will be necessary to evaluate impact of the proposed scheme on the throughput and capacity for multi-cell systems in the future.

4. Conclusion

In this paper, a new algorithm for MTMR AAA system with analog-type TPC is suggested in the downlink DS-CDMA systems.

Computer simulation confirms that the proposed scheme is very effective in enhancing the throughput of the high rate DS-CDMA systems compared with the strongest path selection algorithm employed system. Particularly, it has been shown that the proposed system is more suitable for AMC employed CDMA systems under severe frequency selective fading channel.

Future research includes analysis under fast varying channel conditions including its countermeasures, and system throughput analysis under multicell conditions including various zone radius cases.

References


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