CHAPTER FIVE

NUMERICAL PERFORMANCE EVALUATION OF ADAPTIVE FPC ALGORITHMS

5.1 Introduction

Following the development of the power-sensitive model, including transmitted power level, channel impairment, processing gain and MAI described in Chapter 2, this chapter presents a numerical evaluation of the QoS-based APC structure [Chapter 4] using the Monte Carlo simulation package in a Turbo-coded, RAKE-combining and uplink W-CDMA system. More specifically, we compare balanced and unbalanced step-size FPC algorithms under the following conditions:

1. Multipath components (section 5.3.1) in
    - an AWGN channel,
    - a vehicular channel,
    - an outdoor channel.
2. Doppler spread (section 5.3.2) of
    - 10 km/h,
    - 120 km/h,
    - 200 km/h.
3. Coding schemes (section 5.3.3) in
    - an AWGN channel with uncoded, convolutional and Turbo codes;

- a vehicular channel with uncoded, convolutional and Turbo codes;
- an outdoor channel with uncoded, convolutional and Turbo codes.

4. Number of antennae (section 5.3.4)
5. Number of users (section 5.3.5) with
    - one active user in the cell;
    - two active users in the cell.

The BER performance and SINR outage probability for the eight FPC algorithms under the conditions specified above are compared in this chapter. Further, we demonstrate numerically that to evaluate QoS-based PC algorithms it is essential that all these parameters in the power-sensitive model must be taken into account in order to accurately measure improvements in system performance. We also show that, in order to deliver QoS to subscribers optimally, OPC algorithms with RRM are required because of the stochastic nature of the wireless channels and interference.

5.2 Description of System Parameters

The system under consideration in this dissertation is an uplink, *direct-sequence*, W-CDMA system. The modulation scheme used in the system is QPSK; the carrier frequency, f_c, is equal to 4.096M chip/s; and the transmission rate is 128K bps coded information data. Rate $1/3$ coding is used with a constraint length equal to eight. The data frame length is $10ms$ (= interleaving length). The base-station receiver uses a six-finger (three fingers/antenna) RAKE combiner and sends the FPC command back to the mobile every $0.625ms$ to raise or lower the mobile transmitted power by x dB, depending on the FPC algorithm used. The number of iterations in the Turbo decoder is set to eight iterations before recovery of the received information data. The radio-link parameters are listed in Table 5.1, and the UMTS uplink simulation described is based on the specification for the FDD system [18].

TABLE 5.1: FDD W-CDMA radio-link parameters.

Definition of the notations	
Parameter	**Description**
Chip rate	41472/frame
User data rate	48 kbps/256 kbps/1024 kbps
Spreading factor	32/16/4
Interleaving	10 ms
Modulation	QPSK
Sampling rate	4
No. of slots/frame	16
No. of fingers/antenna	3
Initial power	0.5 W
Diversity (receiver antenna)	2
FEC	Uncoded
	Convolutional with soft-input Viterbi decoder
	Turbo encoder with iterative MAP decoder
FPC algorithms (DM1)	balanced DM FPC with step-size = 1 dB
(DM2)	balanced DM FPC with step-size = 2 dB
(DM3)	balanced DM FPC with step-size = 3 dB
(PC5)	balanced PCM FPC with 2 increasing, 1 unchanged and 2 decreasing
(PC7)	balanced PCM FPC with 3 increasing, 1 unchanged and 3 decreasing
(unDM)	unbalanced DM FPC
(uPC4)	unbalanced PCM FPC with 2 increasing, 1 unchanged and 1 decreasing
(uPC6)	unbalanced PCM FPC with 3 increasing, 1 unchanged and 2 decreasing

- Operating environment

  Three distinct operating environments are analyzed. These are an AWGN channel, an outdoor channel and a vehicular channel. The differences in these environments are mainly due to the temporal distribution, Doppler spread and multipath power profile for each case.

- Multipath power profile

  Different operating environments have different power profiles as shown in Figure 2.10.

- Number of multipath signals

  Different operating environments generate different multipath components. The number of multipath components is consistent with measurements taken in UMTS standards for bad urban environments [83].

- Number of users

  i = 1

  For the purpose of evaluating BER performance and SINR outage probability for different channels, receiver structures and coding schemes, it is assumed that there is only one user active in the cellular system. The influence of number of users is presented at the end of this chapter.

- RAKE receiver

  L = 3

  It is assumed that the base station employs a three-branch RAKE receiver capable of receiving the first three multipath signals arriving at the base station.

- Adaptive antenna array

  M = 2

  It is assumed that a uniform linear array with two elements is used to receive signals at the base station. Such an adaptive array is typical of existing cellular systems.

- Temporal fading model

  It is assumed that all multipath components received by the RAKE receiver will exhibit identically independent distributed (iid) Rayleigh fading.

- Multi-access interference

  It is assumed that all MAI plus background noise received by the RAKE receiver will exhibit iid Gaussian noise to the desired signals.

Nine FPC algorithms are considered for possible implementation in the UMTS standard. These are:

- DM1 FPC (section 4.3.1.2),
- DM2 FPC (section 4.3.1.2),
- DM3 FPC (section 4.3.1.2),
- PCM5 (section 4.3.1.3),
- PCM7 (section 4.3.1.3),
- unDM1 (section 4.3.1.4),
- unPC4 (section 4.3.1.5),
- unPC6 (section 4.3.1.5),
- perfect FPC.

5.3 Simulation Results For Unbalanced Step-size FPC Algorithms

5.3.1 Influence of Multipath Components

Using the system model outlined above, the time-dispersion channel model is set for AWGN, outdoor and vehicular channel models.

To generate the BER curves for the eight FPC algorithms, the same power levels are transmitted initially and the same desired SINR values are set for each user. At the receiver end, the RAKE combining and coherent demodulator is used to dissolve the multipath components and to extract the desired signals from corrupted received signals through a matched-filter technique. The output of the matched-filter is then fed into the SINR estimator to determine the received SINR value. The estimated received SINR value is then compared to the pre-determined SINR value and a power command is calculated for each FPC algorithm used. The BER value of each user is calculated using hard-decisions of desired signals, and the average BER values are then calculated and used in the BER

Table 5.2: BER performance of different FPC algorithms in an uncoded W-CDMA system with the AWGN channel at 16 dB.

$E_b/I_0 = 16$ dB	BER
unPC6	0.000147
unPC4	0.000177
unDM	0.000185
DM1	0.000201
DM2	0.000258
DM3	0.000285
PCM5	0.000293

performance plot. Since coding schemes are not used in this simulation, we can evaluate the influence of number of multipath components on FPC algorithms only. The BER curves and SINR outage probability simulation results obtained after Monte Carlo simulation are presented in this section.

5.3.1.1 BER Performance in an AWGN Channel

In the case where there are no multipath components and only the AWGN is introduced in the channel, the uncertainty of estimating time-varying wireless channels is negligible in a consideration of performance. Figure 5.1 shows the BER performance of the system with the eight APC algorithms in the AWGN channel. The results show that except for the perfect FPC algorithm, most of the algorithms have similar BER performance. This is primarily due to the fact that in a non-fading channel environment transmitted power waveform and power level are preserved, and only a constant background noise power affects the transmitted signals. As a result, these APC algorithms control the received SINR more effectively and efficiently than in fading environments.

However, when the BER performance of the eight FPC algorithms is compared at 16 dB [see Table 5.2], there is little improvement with unbalanced FPC algorithms in AWGN channel conditions, although AWGN channels still yield slightly better results with unbalanced FPC algorithms. Generally, unbalanced PCM algorithms outperform unbalanced DM algorithms and unbalanced FPC algorithms outperform balanced FPC algorithms.

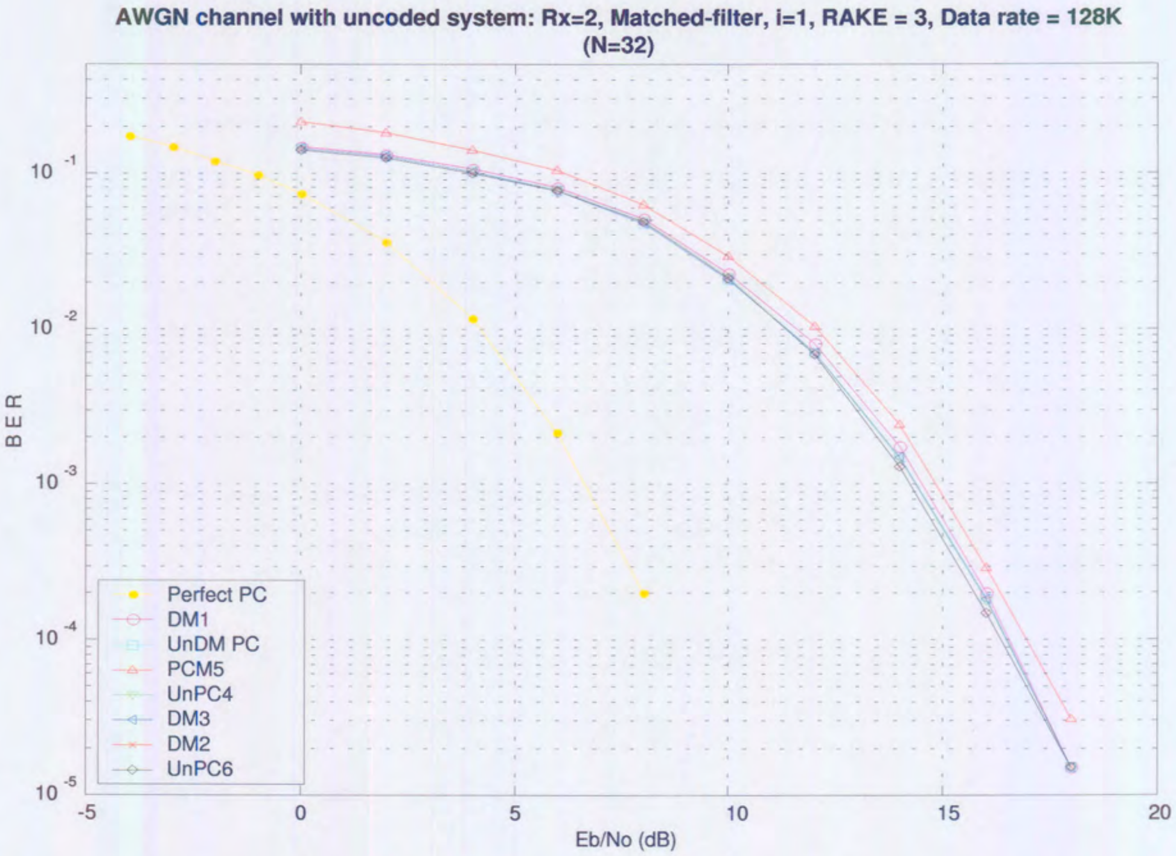


FIGURE 5.1: Influence of multipath components. BER performance curves of different FPC algorithms in an uncoded W-CDMA system with an AWGN channel, Rx=2, i=1, RAKE fingers=3, N=32 and matched-filter detector.

5.3.1.2 SINR Outage Probability in an AWGN Channel

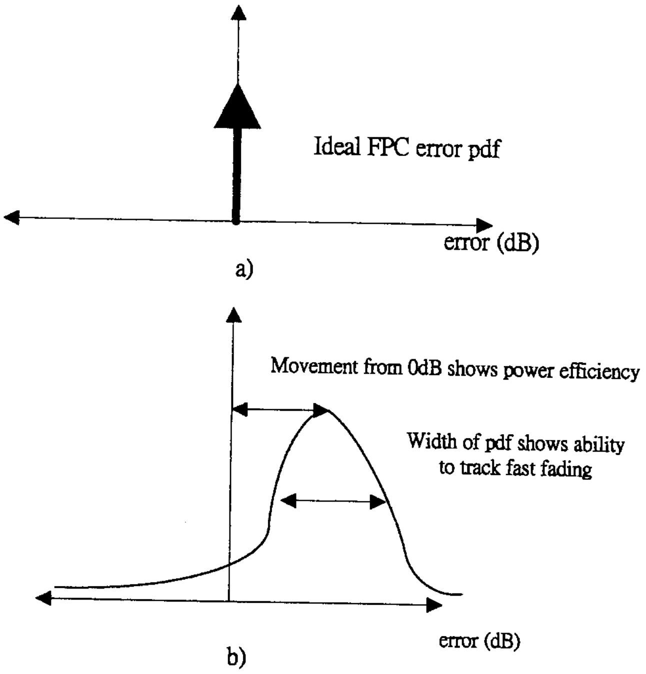


FIGURE 5.2: (a) Ideal and (b) practical FPC error-signal pdfs

Focusing on the actual SINR versus the target SINR, it is clear that the main characteristic of the ideal FPC algorithm is that actual and target SINR values are the same, irrespective of the channel variations. Thus, it follows that the pdf of the error signal is an impulse at 0 dB, as shown in Figure 5.2.

Two specific aspects of the pdf are of paramount importance: width and mean value. The width of the pdf is a measure of the ability of an FPC algorithm to cope with fast changes in the channel. If the algorithm has a limited dynamic range or responds slowly to changes in channel variations, the error signal at a specific instant in time will range from small values to large ones. Secondly, the mean value of the error signal provides a measure of the power efficiency of the FPC algorithms. Therefore, FPC algorithms can be compared by considering the mean and variance of the error signals generated by the algorithms. The lower the mean value, the better the power efficiency of the algorithm; and the lower the variance of the error signals, the better the algorithm can cope with short-term channel variations.

These simulation results of SINR outage probability [Figures 5.3 to 5.7] show how these eight FPC algorithms performed in the AWGN channel environment. Note that the higher the mean variation of the measured SINR compared to the desired SINR value, the more MAI will be created for other users, especially in multi-media services.

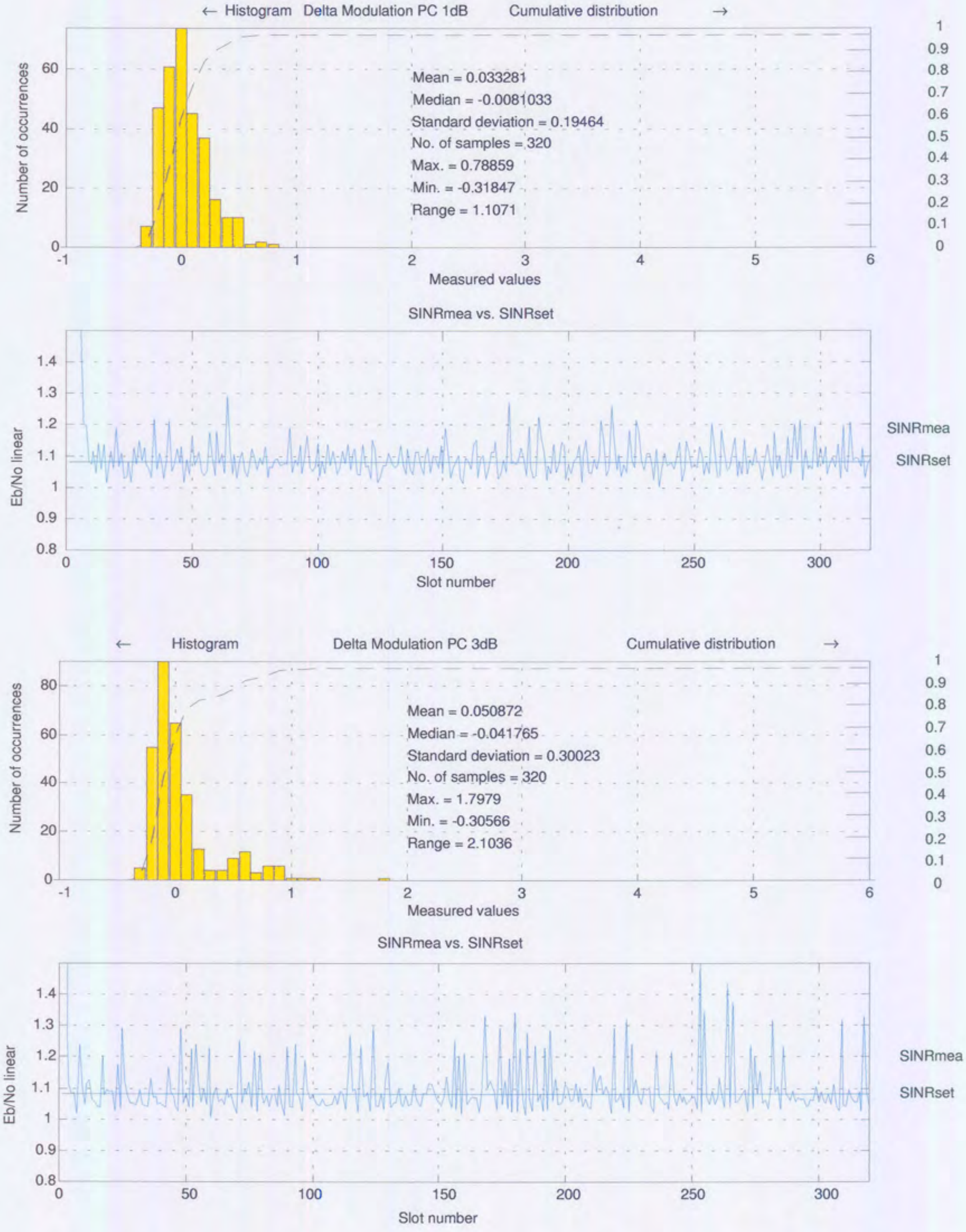


FIGURE 5.3: SINR outage probability simulation results and error-signal pdf for different FPC algorithms. The top figure shows the pdf of DM1 FPC with same settings as BER performance simulation. The bottom figure shows the pdf of DM3 FPC.

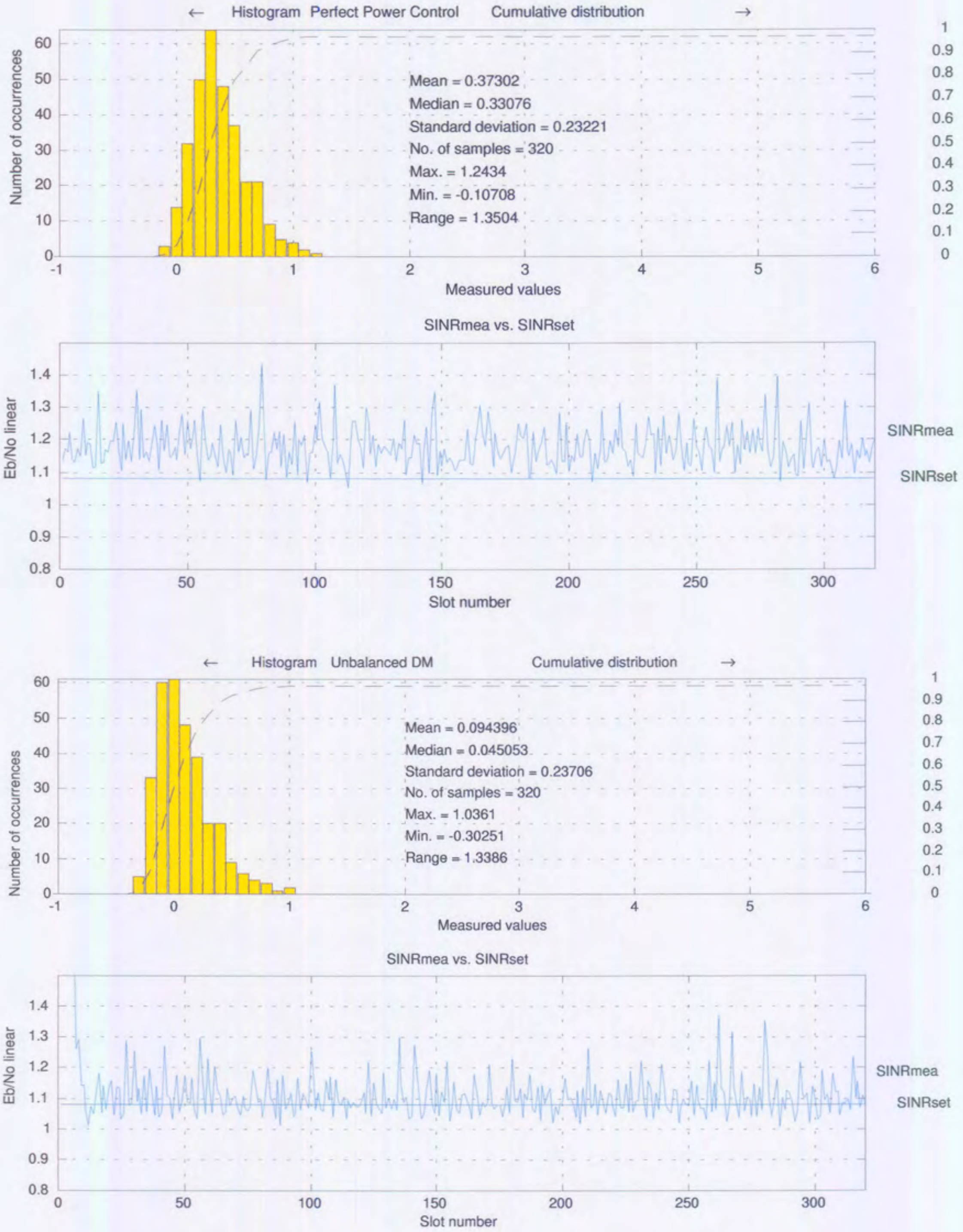


FIGURE 5.4: SINR outage probability simulation results and error-signal pdf for different FPC algorithms. The top figure shows the pdf of perfect FPC with same settings as BER performance simulation. The bottom figure shows the pdf of unDM FPC.

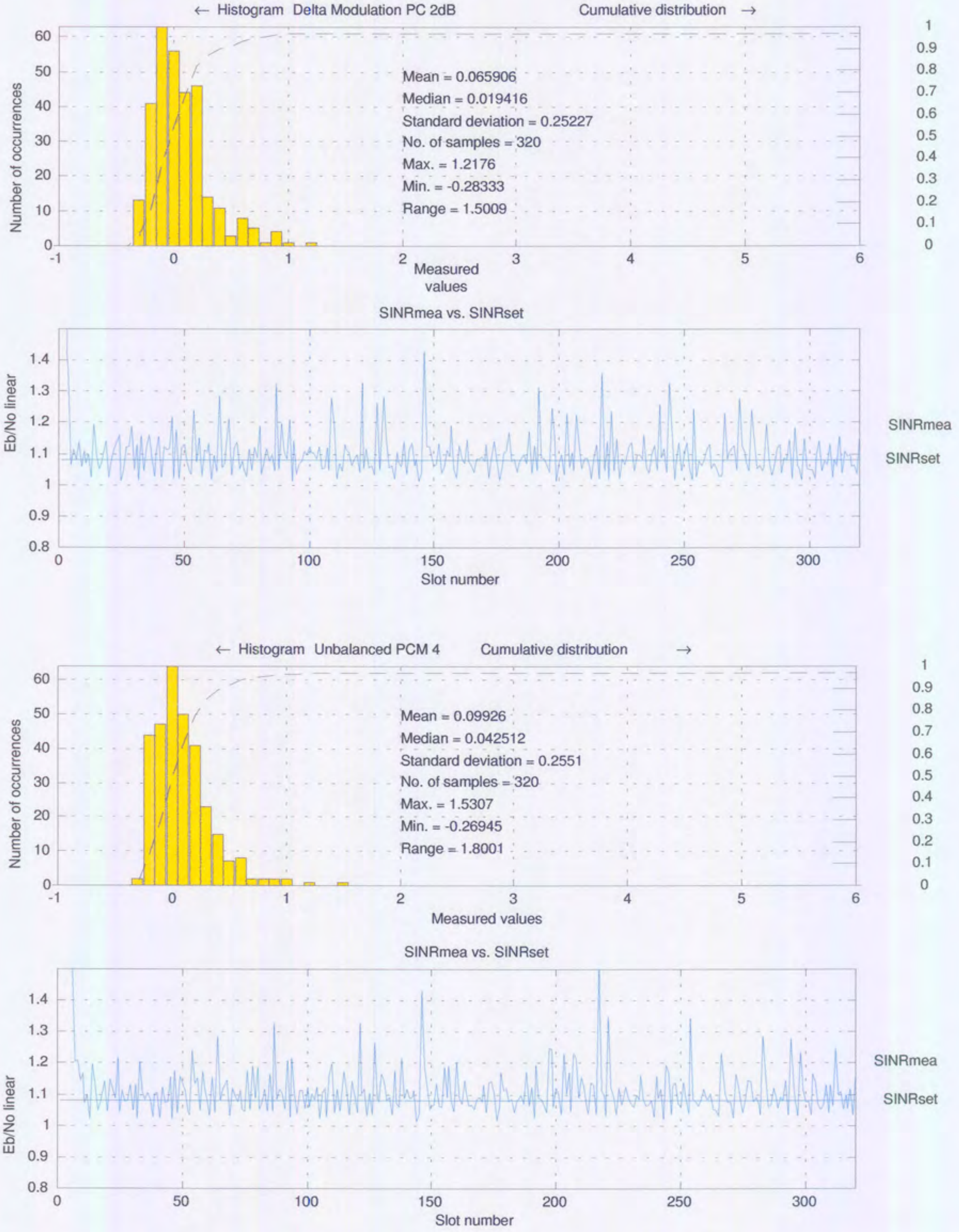


FIGURE 5.5: SINR outage probability simulation results and error-signal pdf for different FPC algorithms. The top figure shows the pdf of DM2 FPC with same settings as BER performance simulation. The bottom figure shows the pdf of unPC7 FPC.

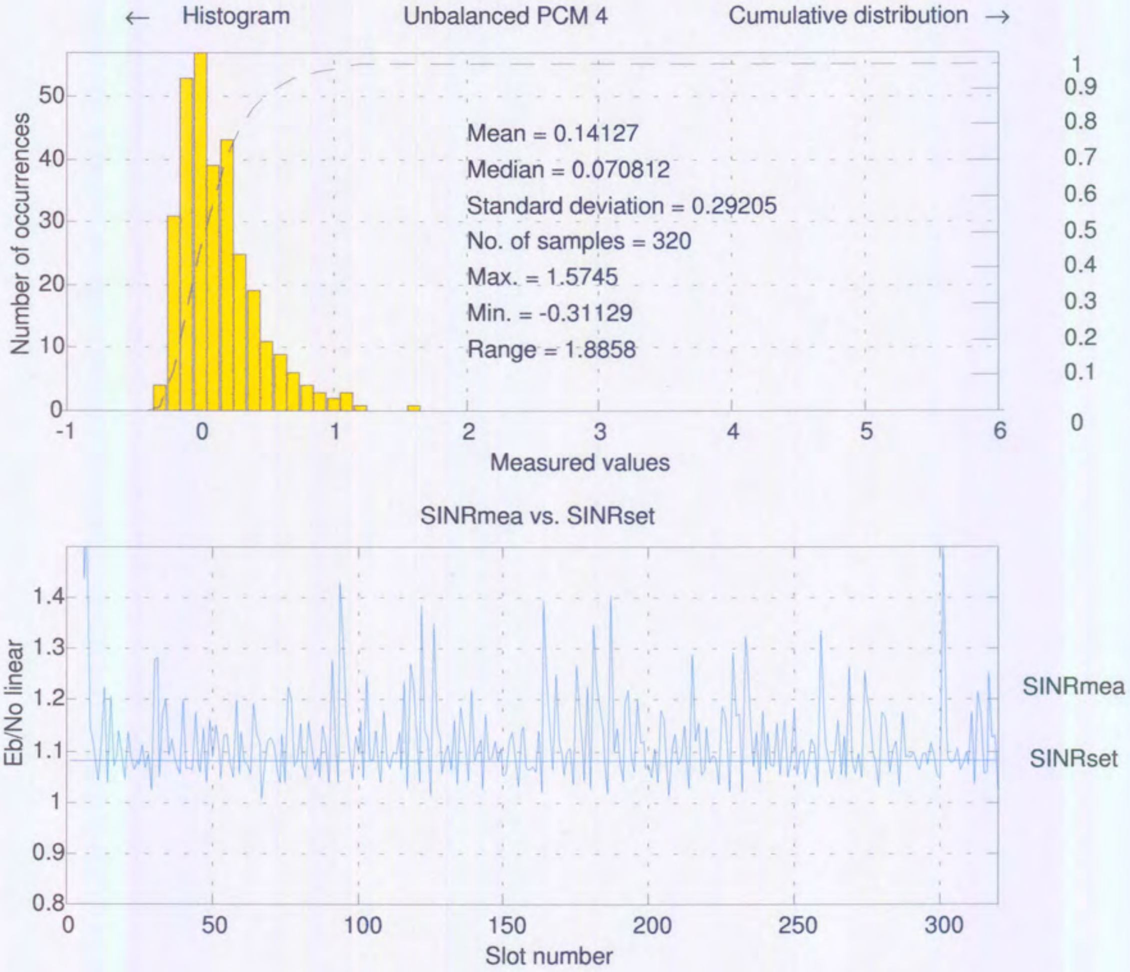


FIGURE 5.6: SINR outage probability simulation results and error-signal pdf for different FPC algorithms. The figure shows the pdf of unPC4 FPC with same settings as BER performance simulation.

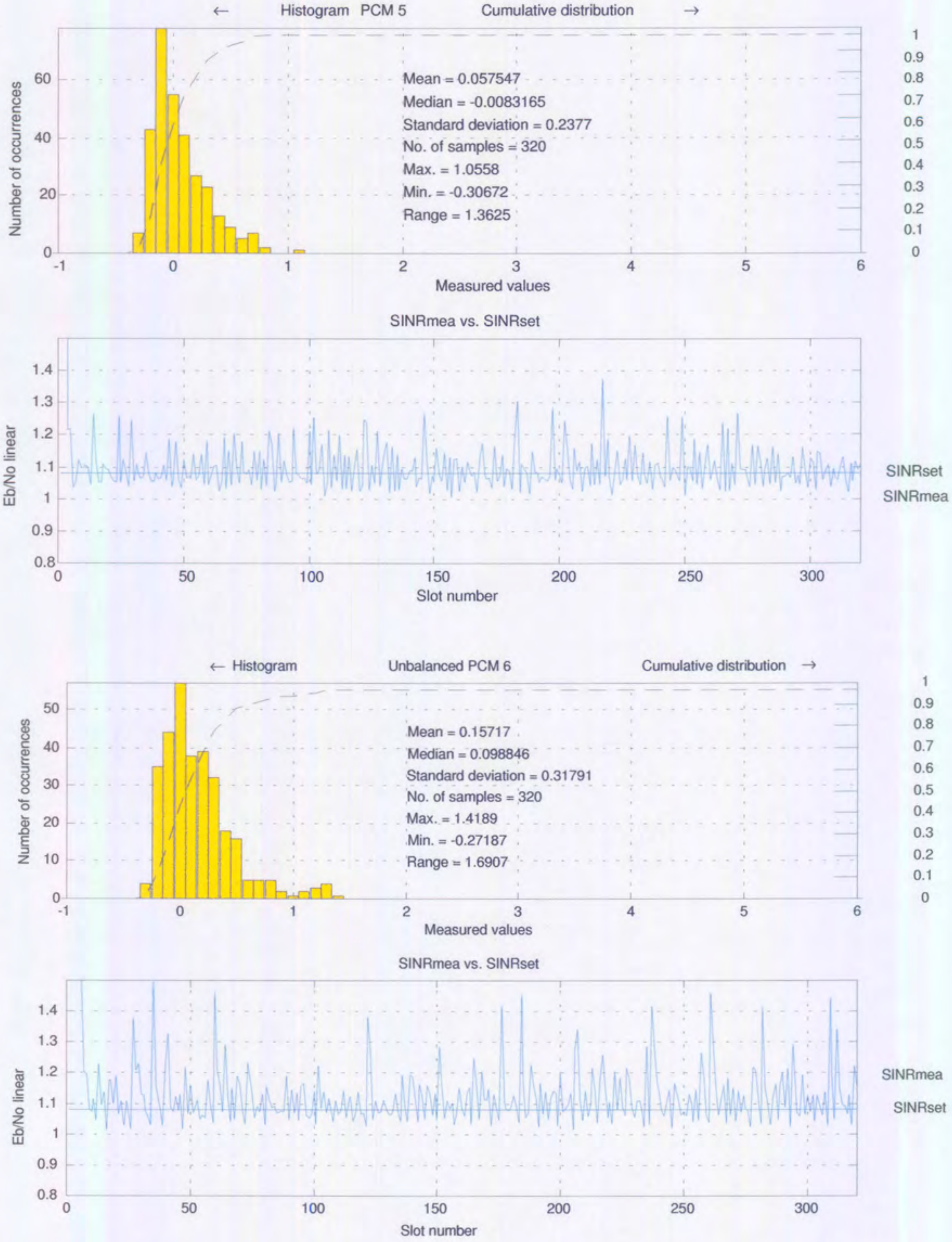


FIGURE 5.7: SINR outage probability simulation results and error-signal pdf for different FPC algorithms. The top figure shows the pdf of PCM5 FPC with same settings as BER performance simulation. The bottom figure shows the pdf of unPC5 FPC.

FIGURE 5.8: Mean variation, standard deviation and range comparisons for different FPC pdf algorithms are depicted in this figure with an AWGN channel, Rx=2, i=1, RAKE fingers=3, N=32 and matched-filtered W-CDMA system.

A summary of mean variation, variance and range comparisons for these FPC algorithms is shown in Figure 5.8. The balanced FPC algorithms have lower mean variance and therefore yield better power efficiency than the unbalanced FPC algorithms in AWGN channels. Comparing DM and PCM algorithms, we have found the variance of both balanced DM and unbalanced DM algorithms is less than that of balanced and unbalanced PCM techniques, respectively. Thus, it is important to note that the more quantization levels used in FPC algorithms, the better the BER performance, but the more the overshoot and steady state error for the SINR outage probability test. The smaller the step-size, the less overshoot and steady state error, but the lower the BER performance.

These observations can be attributed to the fact that, firstly, the unbalanced FPC algorithms increase the average transmitted power more than balanced FPC algorithms do. Thus, BER performance yields better power efficiency with unbalanced FPC algorithms. Secondly, since there is no time-dispersion and rapid time-variation of the received envelope, unbalanced FPC algorithms can control the transmitted power more effectively. Thirdly, since the rate of change in amplitude, phases and time-delay of the transmitted signals is slower than the transmitted signals in fast-fading channels with Doppler spread effects, unbalanced FPC algorithms are able to control the transmitted power more efficiently. It is expected that as the number of multipath components and the Doppler spread increase, so the effectiveness and efficiency of these FPC algorithms will decrease.

5.3.1.3 BER Performance in a Vehicular Channel

Thus far, no multipath components and AWGN channel were assumed in the previous simulation. Let us now assume there are multipath components in the vehicular channel setting and Rayleigh envelope fading is also introduced in the wireless channel.

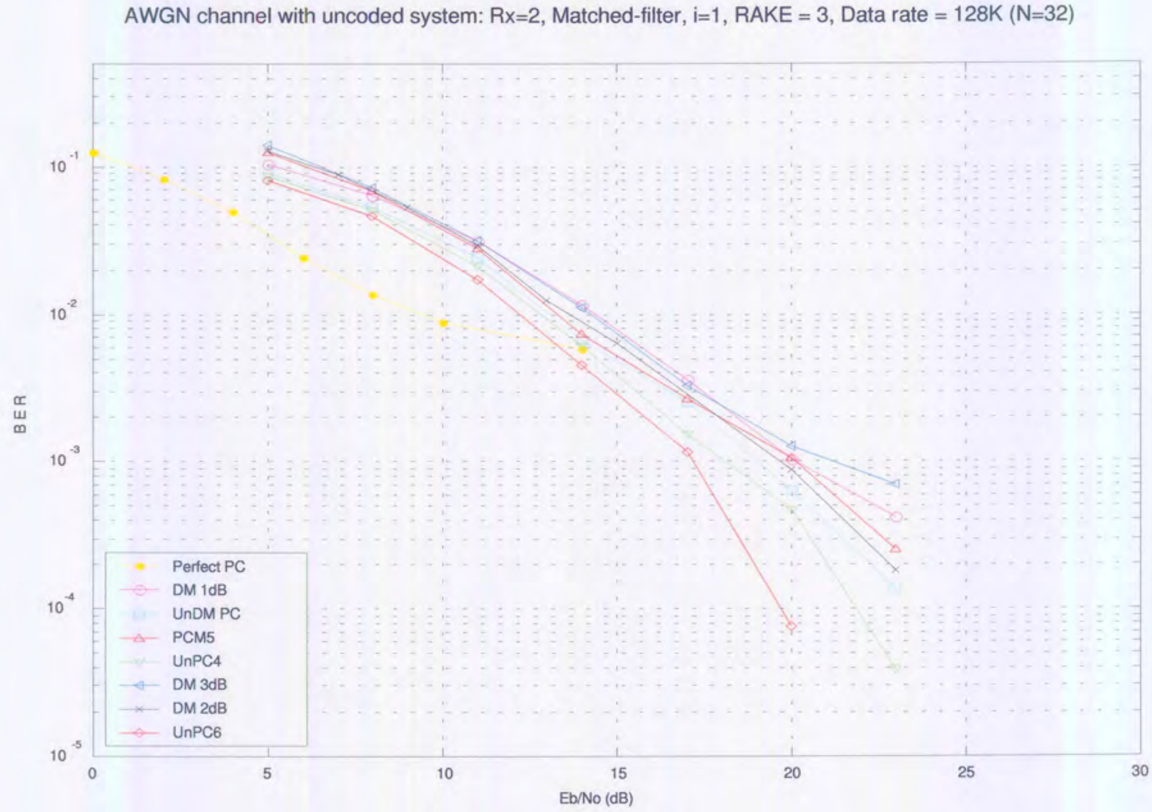


FIGURE 5.9: Influence of multipath components. BER performance curves of different FPC algorithms in an uncoded W-CDMA system with a vehicular channel, Rx=2, i=1, RAKE fingers=3, N=32 and matched-filter detector.

Figure 2.10 shows that the vehicular channel has fewer multipath components than outdoor channels, and it is assumed that an increase in the number of multipath components and Doppler spread results in a frequency-selective, fast-fading channel environment. This implies that the rate of change in amplitude, phases, and time delay of any of the multipath components varies faster than the transmitted signal [81], thereby decreasing the effectiveness and efficiency of the FPC algorithms. This can be observed by comparing the BER performance curves in AWGN of vehicular channels [Figures 5.1 and 5.9] it is observed that the effect of a frequency-selective, fast-fading channel on W-CDMA system capacity is substantial. There is a decrease in power efficiency of 9 dB comparing the performance of a balanced DM FPC in an AWGN and a vehicular channel.

Figure 5.9 shows the BER performance of the system with the eight FPC algorithms in the vehicular channel. The results show that there is a substantial improvement with unbalanced FPC algorithms compared to balanced FPC algorithms, especially at high SINR values. This is primarily due to the fact that the power signals fade more quickly than when they are increasing in a typical Rayleigh and Ricean frequency-selective fading. Thus, unbalanced FPCs outperform balanced ones in a Rayleigh fading channel.

It is claimed [85] that the smaller the FPC error-signal pdf, the shorter the error-free run length in the system. In other words, burst errors occur less frequently. Since unbalanced FPC algorithms improve SINR outage probability by increasing average transmitted power, burst errors can be better controlled and eliminated by our proposed FPC algorithms, especially at high SINR levels [Figure 5.10]. Later in this chapter, we show how FPC algorithms, by incorporating coding schemes, can improve the BER performance significantly.

When the BER performance of the eight FPC algorithms is compared in a vehicular channel at 20dB, generally, there is a 4 dB improvement with the unbalanced DM algorithms over the balanced DM algorithms. This is because DM algorithms cannot cope with fast variations in the vehicular channel condition. This deficiency can be lessened by introducing PCM algorithms where more control bits are required for control. There is a slight improvement with the unbalanced PCM algorithms compared with unbalanced DM algorithms: in general, a 5 dB improvement is experienced with unPCM6 compared with unDM, the improvement rate declining as the transmitted SINR values decrease.

5.3.1.4 SINR Outage Probability in a Vehicular Channel

The error distribution pdfs of SINR outage probability [Figures 5.12 to 5.15] show how these FPC algorithms perform in a vehicular channel environment.

A summary of mean variation, variance and range comparisons for these FPC algorithms is shown in Figure 5.11. When a frequency-selective, fast-fading channel is introduced in the system, the FPC error-distribution pdf also changes. The balanced FPC algorithms still

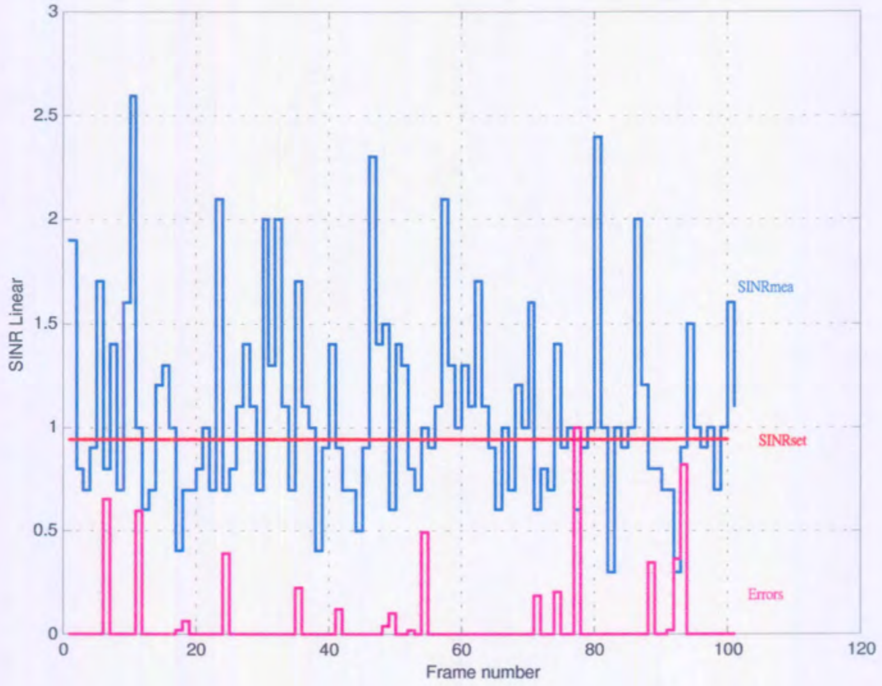


FIGURE 5.10: Influence of received SINR values on the BER performance of a W-CDMA cellular system. Blue line shows the average received SINR value for a frame; red line shows the number of errors occurring within a frame. Burst errors occur more frequently when received SINR is low.

Table 5.3: BER performance of different FPC algorithms in an uncoded W-CDMA system with vehicular channel at 20 dB.

$E_b/I_0 = 20$ dB	BER
unPC6	0.000077
unPC4	0.000471
unDM	0.000633
DM1	0.001042
PC5	0.001065
DM2	0.001120
DM3	0.001265

yield lower mean variation values than the unbalanced FPC algorithms, However the increase in mean value is generally about five times more than in an AWGN channel. Therefore, the balanced FPCs improve power efficiency considerably more than unbalanced FPCs do. Also, the balanced and unbalanced DM have lower aggregate values. Thus, DM FPC algorithms yield better tracking ability and robustness in the different channel conditions.

Validation of the Gaussian approximation of FPC error distribution in frequency-selective fading channel is also investigated in the simulation, which shows that the Gaussian approximation of FPC error distribution is not valid in a conventional RAKE receiver structure.

It is our view that the BER performance curves should plot the BER against the measured SINR and not the desired SINR values in order to integrate the effect of the FPC error distribution into the BER performance results. Figure 5.16 shows the BER results of FPC algorithms in the vehicular channel. These diagrams show that both unbalanced and balanced DM algorithms outperform others. Also, unbalanced PCM algorithms generally outperform balanced PCM ones.

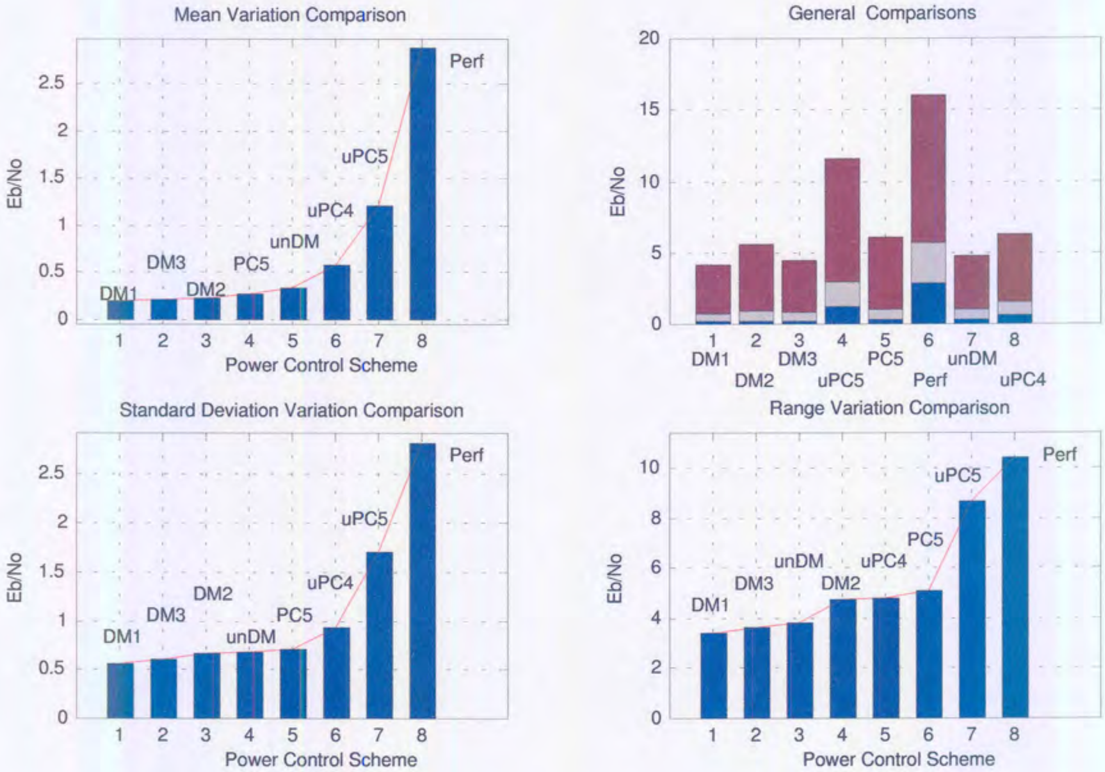


FIGURE 5.11: Mean variation, standard deviation and range comparisons for different FPC pdf algorithms with a vehicular channel, Rx=2, i=1, RAKE fingers=3, N=32 and matched-filtered W-CDMA system.

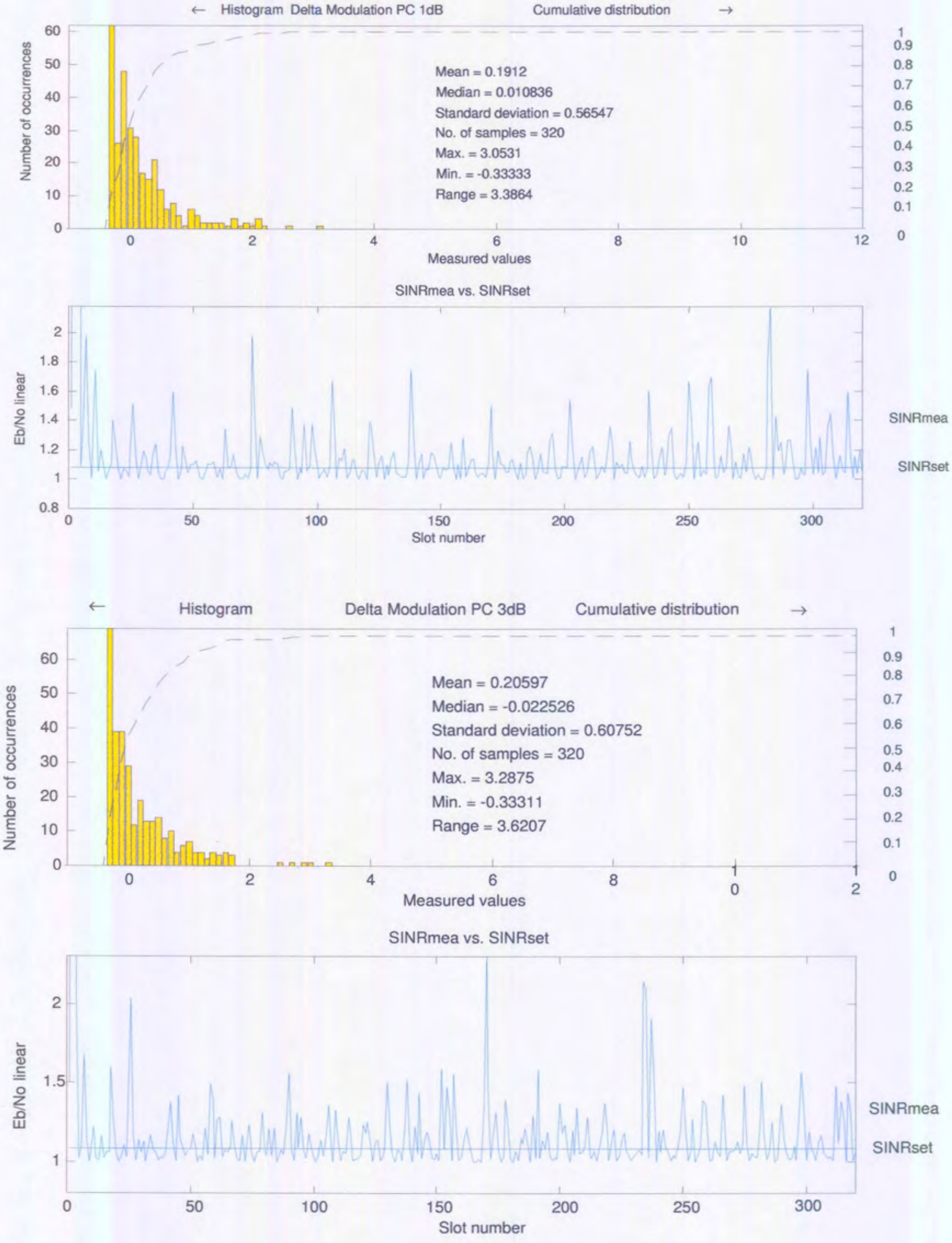


FIGURE 5.12: SINR outage probability simulation results and error-signal pdf for different FPC algorithms. The top figure shows the pdf of DM1 FPC with same settings as BER performance simulation. The bottom figure shows the pdf of DM3 FPC.

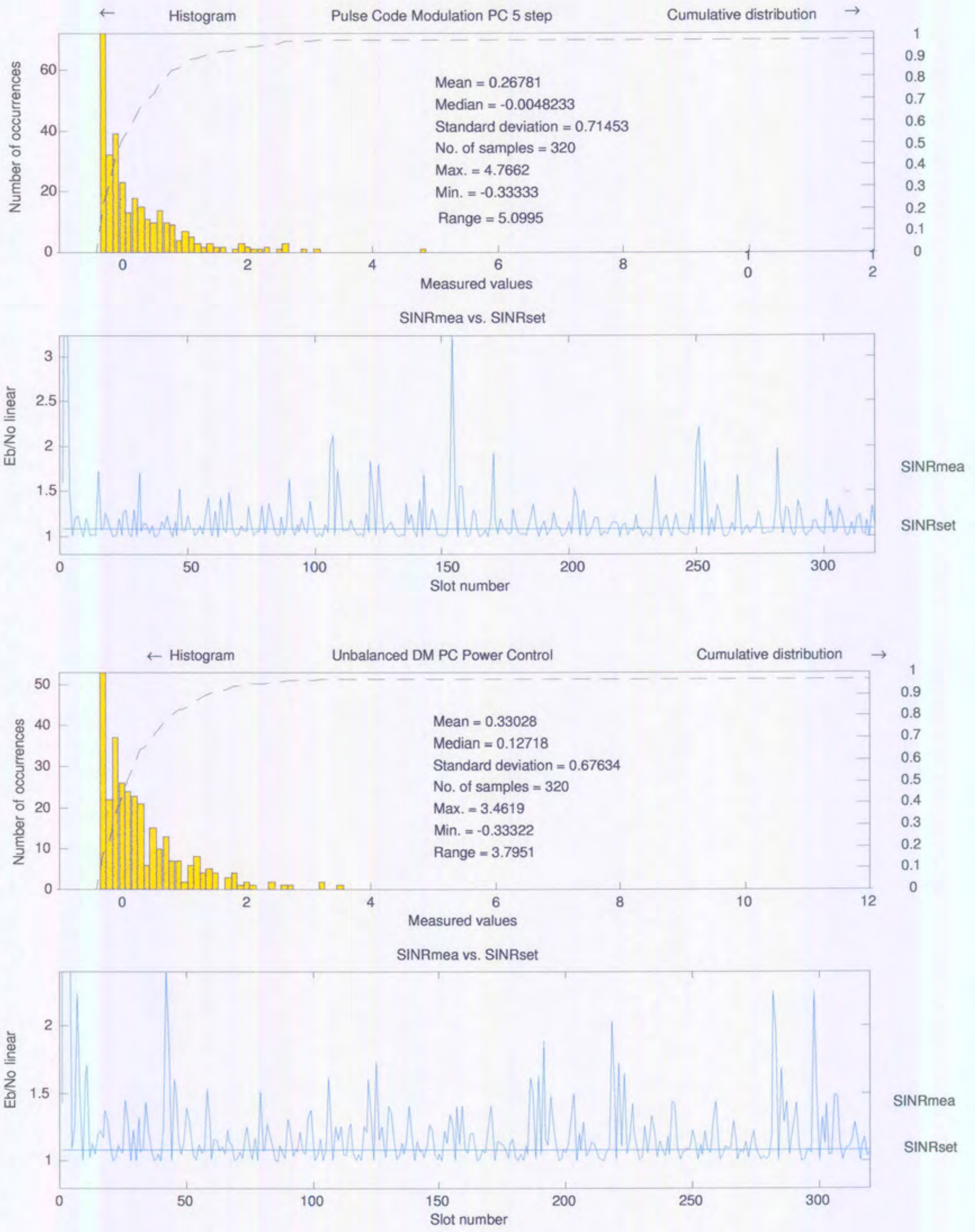
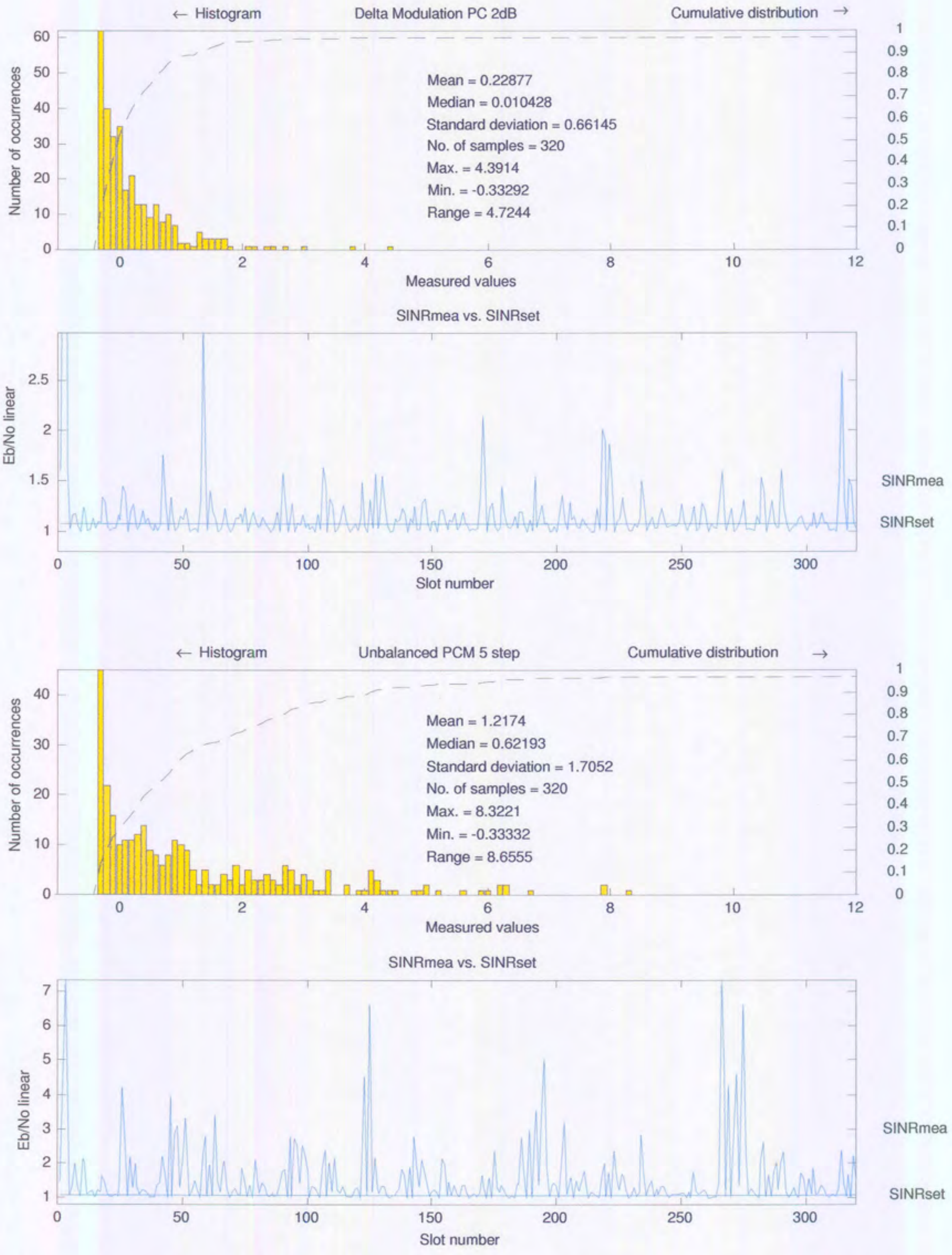


FIGURE 5.13: SINR outage probability simulation results and error-signal pdf for different FPC algorithms. The top figure shows the pdf of PCM5 FPC with same settings as BER performance simulation. The bottom figure shows the pdf of unDM FPC.



Delta Modulation PC 2dB

SINRmea vs. SINRset

Unbalanced PCM 5 step

SINRmea vs. SINRset

FIGURE 5.14: SINR outage probability simulation results and error-signal pdf for different FPC algorithms. The top figure shows the pdf of DM2 FPC with same settings as BER performance simulation. The bottom figure shows the pdf of unPC6 FPC.

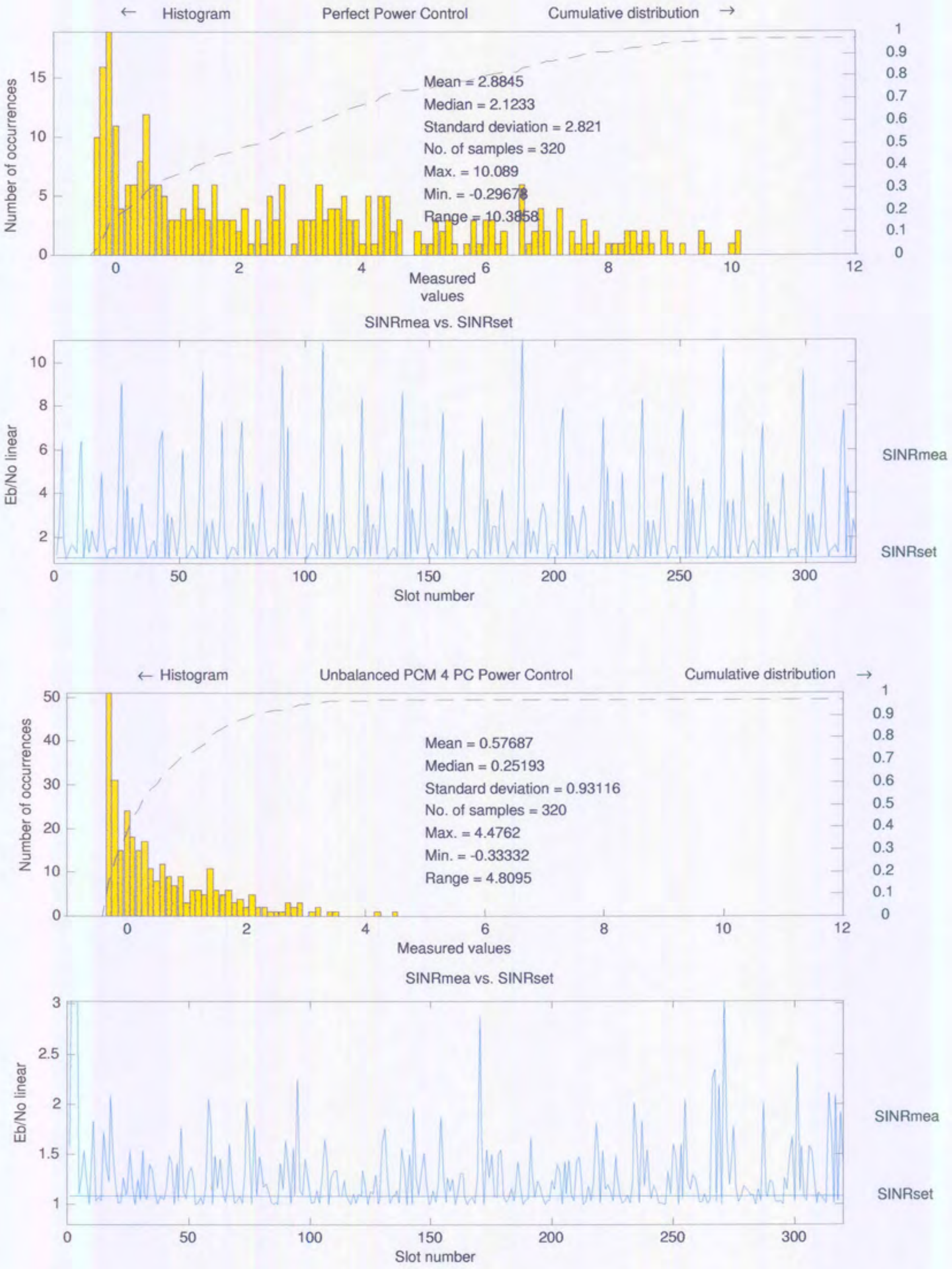
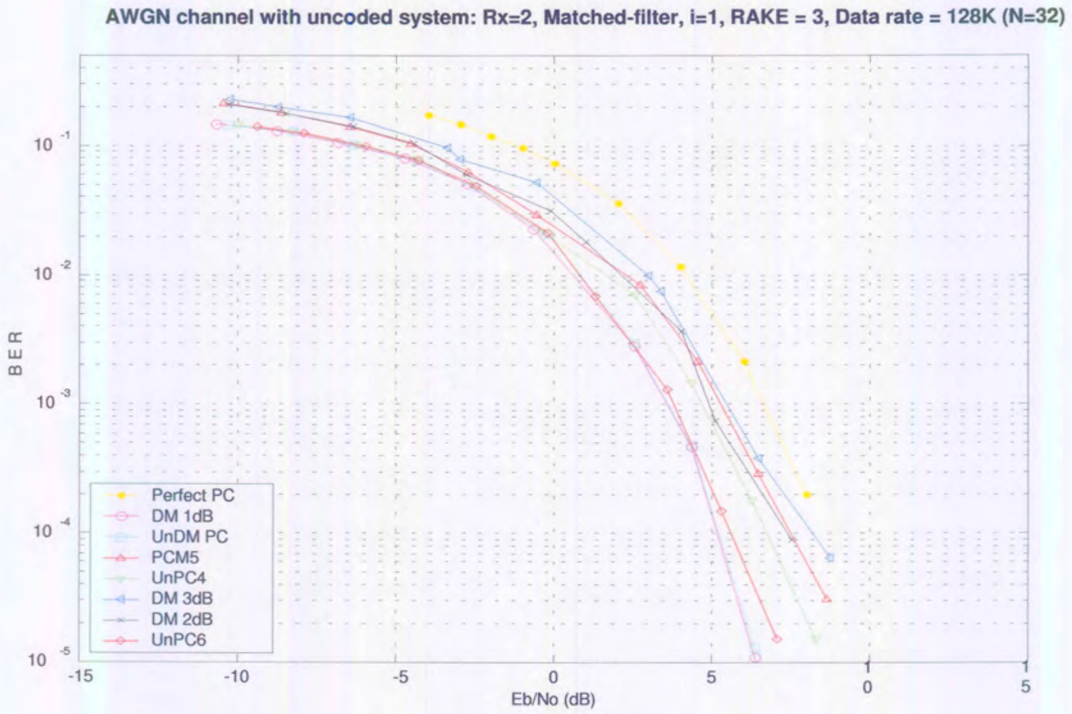
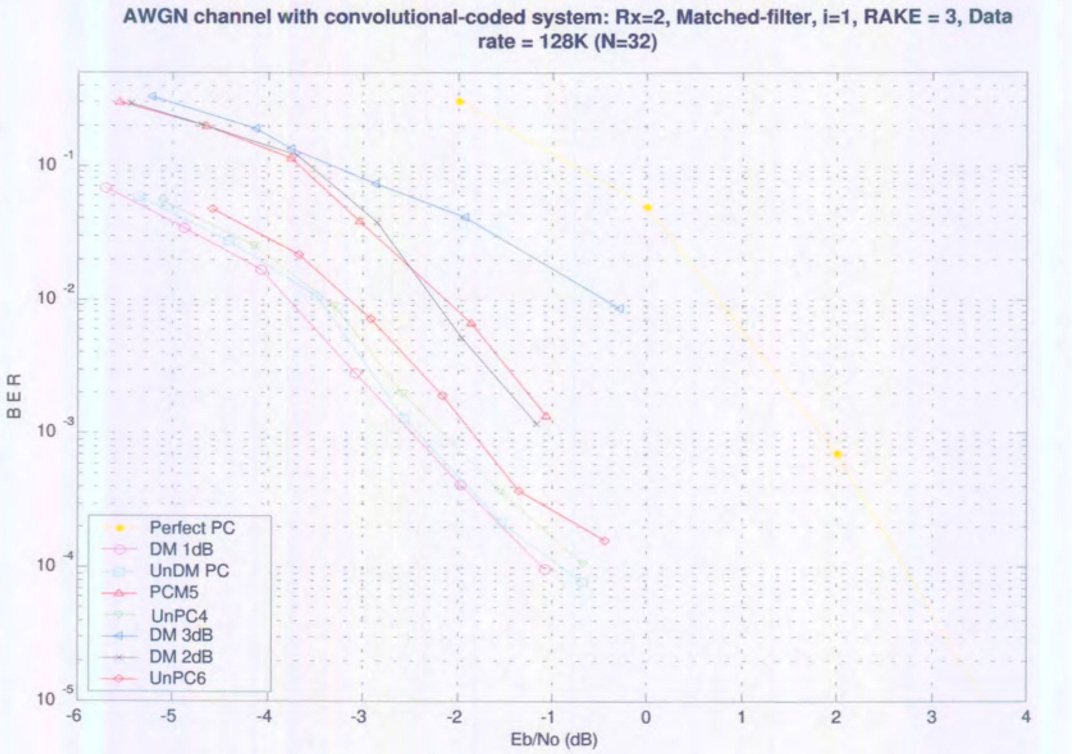


FIGURE 5.15: SINR outage probability simulation results and error-signal pdf for different FPC algorithms. The top figure shows the pdf of perfect FPC with same settings as BER performance simulation. The bottom figure shows the pdf of unPC4 FPC.



AWGN channel with uncoded system: Rx=2, Matched-filter, i=1, RAKE = 3, Data rate = 128K (N=32)



AWGN channel with convolutional-coded system: Rx=2, Matched-filter, i=1, RAKE = 3, Data rate = 128K (N=32)

FIGURE 5.16: Different FPC Algorithms vs. measured SINR in an AWGN channel. The top figure shows the results without a coding scheme; the bottom figure shows the results with a convolutional coding scheme.

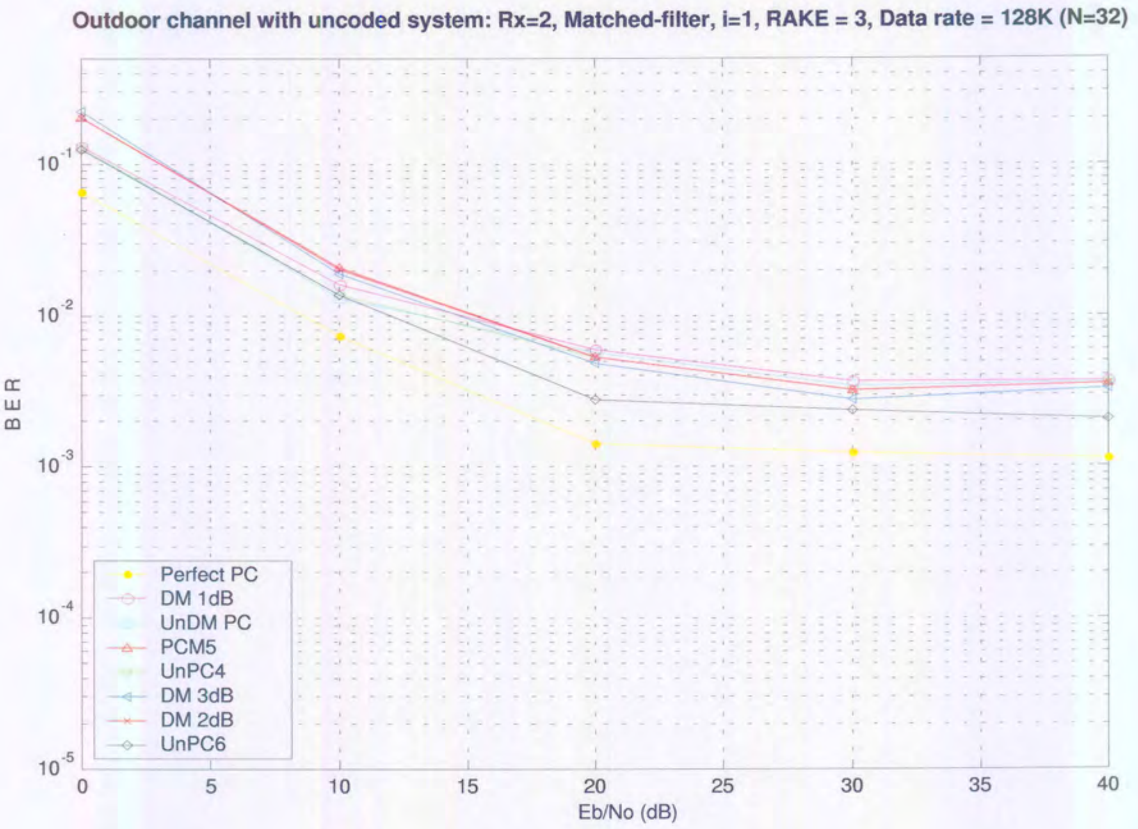


FIGURE 5.17: Influence of multipath components. BER performance curves of different FPC algorithms in an uncoded W-CDMA system with an outdoor channel, Rx=2, i=1, RAKE fingers=3, N=32 and matched-filter detector.

5.3.1.5 BER Performance in an Outdoor Channel

Thus far, it has been assumed that three multipath components are received by the base station. We now consider the introduction of additional multipath components in the time-dispersion channel model and evaluate the influence of power profile on system performance.

Figure 5.17 shows the BER performance of the system with the eight FPC algorithms in outdoor channels. The results show that the BER performance fails to deliver acceptable QoS to subscribers. This is primarily due to the fact that when the number of multipath components exceeds the number of received antennae and RAKE fingers, other multipath components become a source of interference to the desired signals, and noise power level increases. Consequently, received signals fluctuate more rapidly and stochastically. This can be improved by incorporating antenna space-diversity and coding schemes in the simulation to combat inter-symbol interference and MAI. Sections 5.3.3 and 5.3.4 investigate and compare the influence of coding schemes and diversity algorithms in an outdoor channel.

5.3.1.6 SINR Outage Probability Performance in an Outdoor Channel

A summary of mean variation, variance and ranges of different FPC algorithms is shown in Figure 5.18. The balanced FPC algorithms still yield better power efficiency and the balanced DM algorithms also yield better tracking ability. However, there is no significant improvement in the BER performance curve. The effect of different multipath components on BER performance curve is that FPC algorithms trigger only the working point of the systems, and the BER is mainly determined by the coding, interleaving and receiver structure, and FPC algorithms attempt to narrow the received SINR levels at the base station. Thus, the BER performance is completely characterized by the pdf of the error signal, and more specifically its mean and variance, and its absolute effect on the overall system performance is a function of the underlying receiver structure (i.e. coding, antenna space diversity and interference cancellation algorithms used).

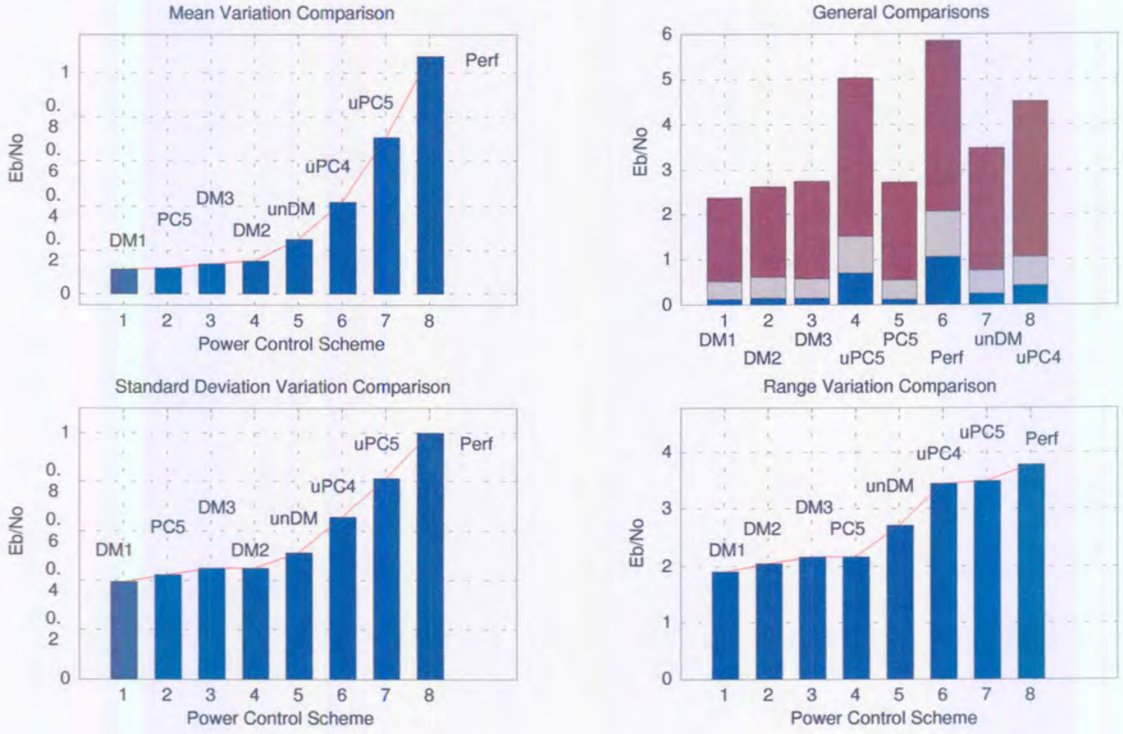


FIGURE 5.18: Mean variation, standard deviation and range comparisons for different FPC pdf algorithms with an outdoor channel, Rx=2, i=1, RAKE fingers=3, N=32 and matched-filtered W-CDMA system.

A perfect FPC algorithm would mean that the receiver structure always operates at the same working point. In reality, power cannot be perfectly controlled due to overshoot, rising time and loop delay. Also, the capacity of a W-CDMA system would be maximized if FPC algorithms were employed and supplementary to other receiver structures.

5.3.1.7 Conclusions of The Influence Of Multipath Components

Figure 5.19 compares the BER performance for different FPC algorithms in three channel conditions.

Unbalanced FPC algorithms do not improve BER performance in AWGN channels significantly because the channel model does not take multipath components and Doppler spread into account. When a frequency-selective, Rayleigh, fast-fading channel is introduced in the channel model, there is a significant improvement in BER performance compared to balanced FPCs. This is primarily due to the fact that the power signals fade more quickly than they rise in a typical Rayleigh distributed channel. Also, unbalanced FPC algorithms outperform balanced FPC algorithms by decreasing the burst-error length. It is also shown that the assumption of Gaussian approximation of FPC error distribution is not valid in frequency-selective fading channels, as seen from SINR outage probability test results.

It is important to note that the BER is mainly determined by the coding, interleaving and receiver structure, and FPC algorithms attempt to narrow the received SINR levels at base station as much as possible. Thus, the performance is completely characterized by the pdf of the error signal, and more specifically its mean and variance, and its absolute effect on the overall system performance is a function of the underlying receiver structure (i.e. coding, antenna-space diversity and interference cancellation algorithms used).

The SINR outage probability simulation results show that balanced FPCs yield the best power efficiency, and balanced and unbalanced DMs yield the best robustness in different channel conditions.

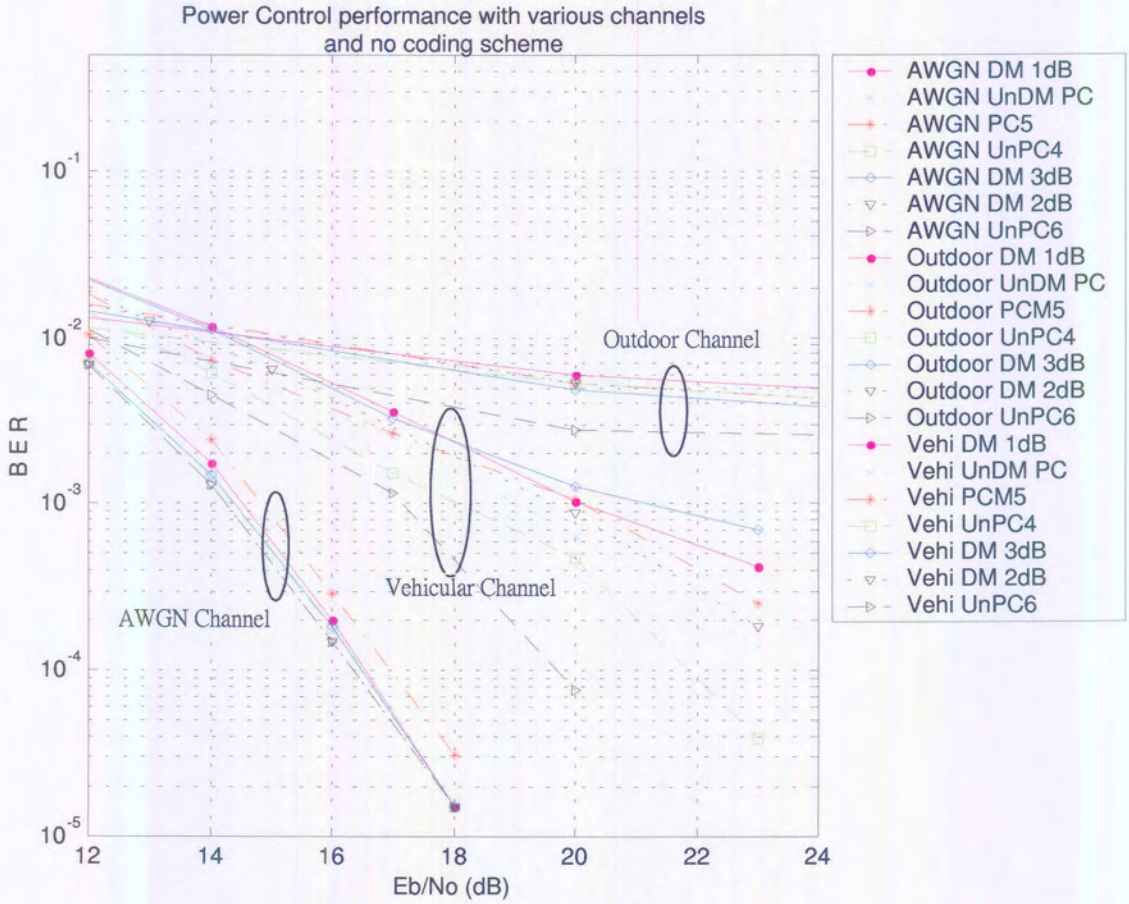


FIGURE 5.19: Comparison of performance for different FPC algorithms in three channel conditions.

5.3.2 Influence of Doppler Spread

Whereas previous sections have investigated the influence of time-dispersion effects on FPC algorithms, the influence of Doppler spread is the theme of this section. Doppler spread is the relative motion between the base station and the handset, which results in random frequency-demodulation of the received signals. This leads to signal distortion. To facilitate these effects in a simulation environment, a fast-fading channel environment in which the coherent time of the channel is less than the symbol period of the transmitter signals is programmed.

Three relative speeds are considered in this simulation, namely v = 10km/h, 120km/h and 200km/h, respectively, in an outdoor channel environment with two-receiver antennae and matched-filter W-CDMA receiver. The BER performance curves of different mobile speeds are shown in Figure 5.3.2. Comparing these BER performance curves for different speeds, it

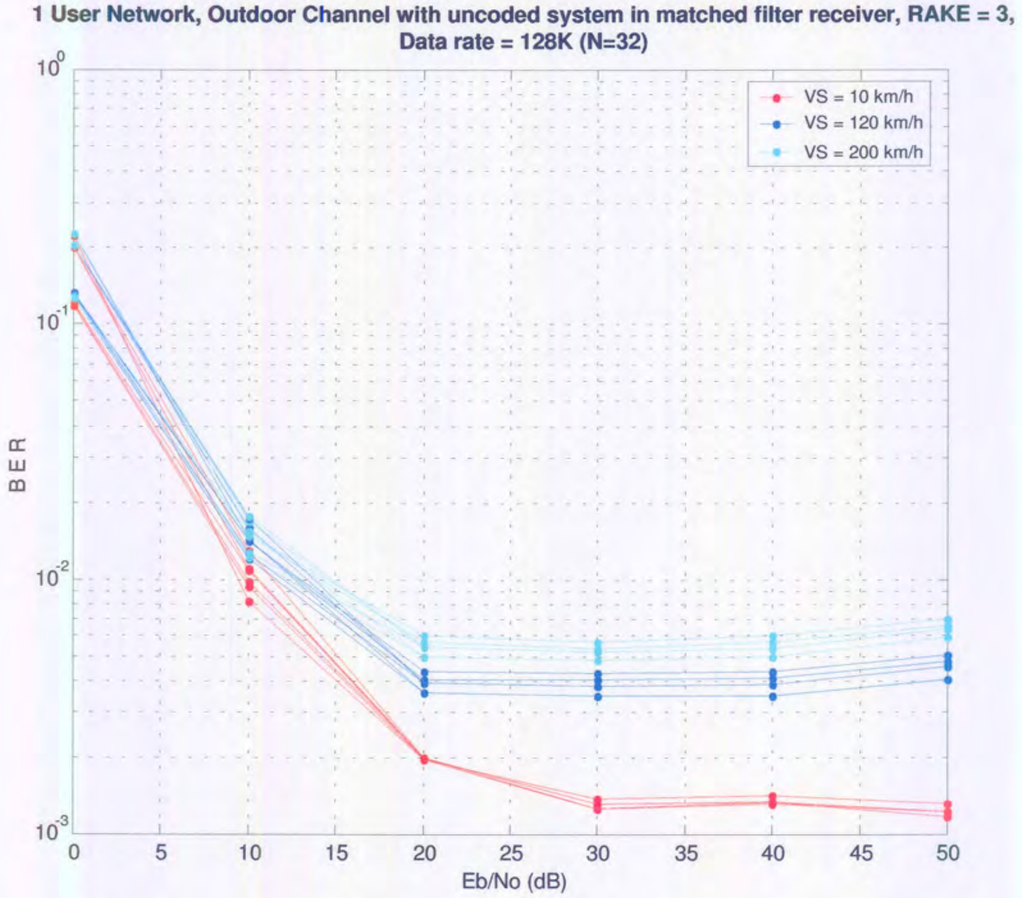


FIGURE 5.20: Influence of Doppler spread. BER performance curves of different FPC algorithms in a uncoded, three-vehicle speed, W-CDMA system with an outdoor channel, Rx=2, i=1, RAKE fingers=3, N=32 and matched-filter detector.

is clear that an increase in the speed of a mobile further degrades the BER performance due to the rapid variation of the transmitted signals, by about 10 dB if mobile speed is 120 km/h and by about 20 dB if mobile speed is 200 km/h.

5.3.3 Influence of Coding Schemes

Using the power-sensitive model outlined above, the spreading gain for each user is equal to 32 and coding gain is three. Simulation is carried out in AWGN, outdoor and vehicular channel conditions with no coding, convolutional and Turbo codes. This section investigates the influence of coding schemes with unbalanced FPC algorithms. Although it has been shown that coding schemes may increase power-efficiency and W-CDMA system capacity [Figures 5.21 to 5.22], this section will focus on how FPC algorithms further improve system capacity in a coded system.

Table 5.4: BER performance of different FPC algorithms in a convolutional-coded W-CDMA system with an AWGN channel at 5 dB.

$E_b/I_0 = 5$ dB	BER
unDM	0.000018
unPCM6	0.000060
unPCM4	0.000086
DM1	0.000098
DM2	0.001181
PCM5	0.001366
DM3	0.008681

Table 5.5: BER performance of different FPC algorithms in a Turbo-coded W-CDMA system with an AWGN channel at 5 dB.

$E_b/I_0 = 5$ dB	BER
unPCM6	0.000024
unPCM4	0.000042
unDM	0.000052
DM1	0.000090
DM2	0.000394
PCM5	0.000810
DM3	0.009653

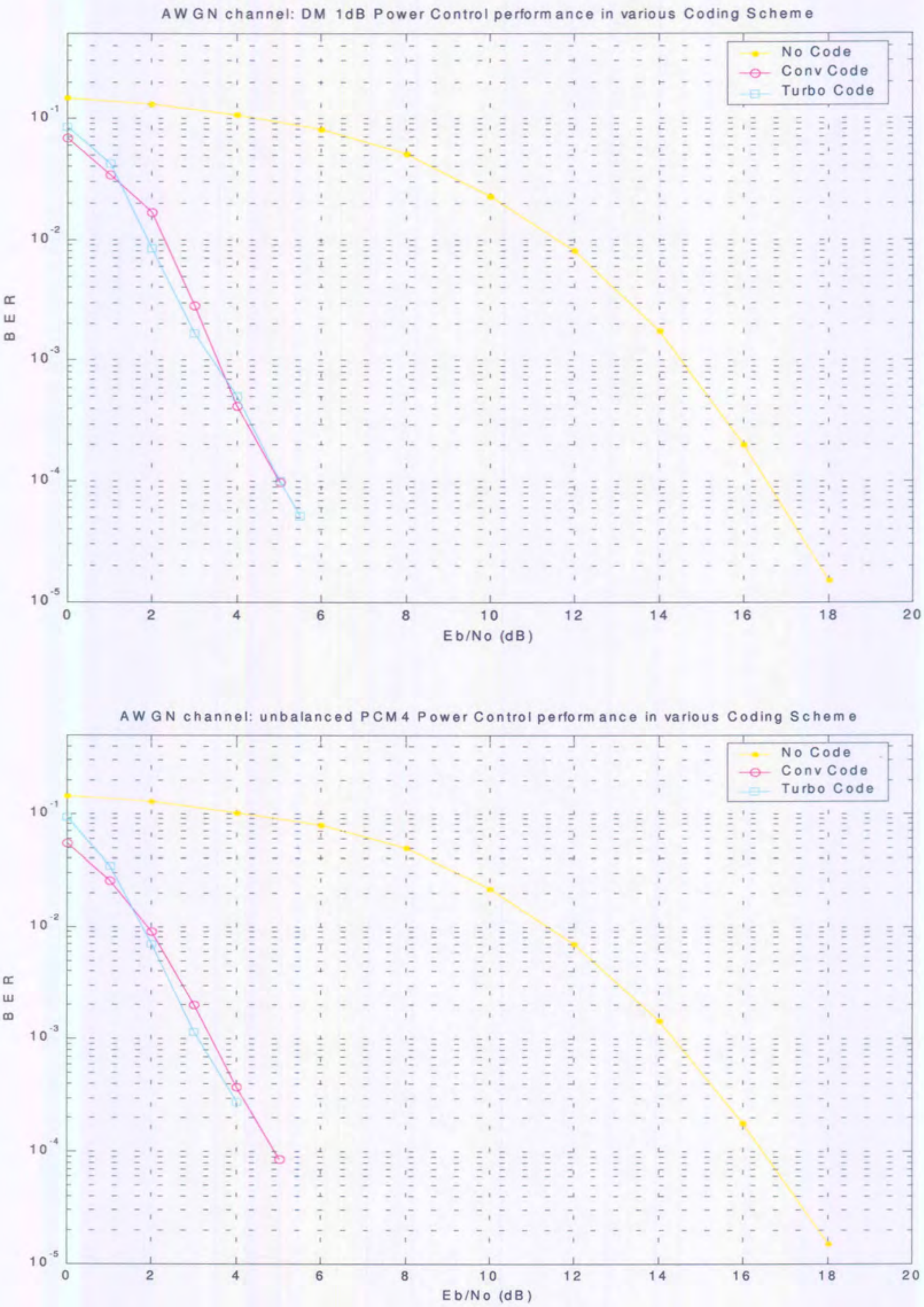


FIGURE 5.21: BER performance for FPC algorithms in an AWGN channel with uncoded, convolutional and Turbo coding. The top figure shows the improvement of BER performance on DM1 FPC with different coding schemes. The bottom figure shows the improvement of BER performance of unPC4 FPC with different coding schemes.

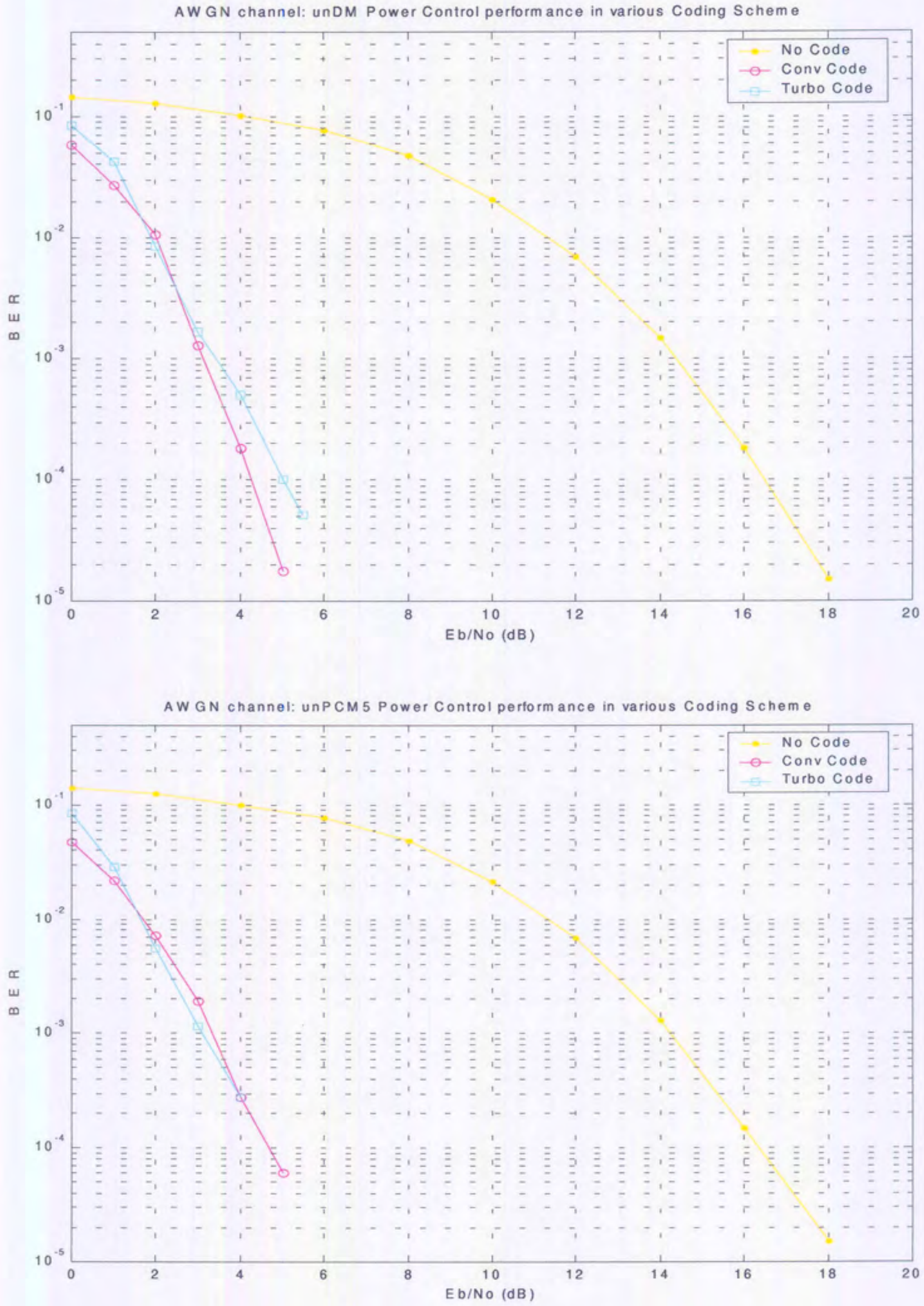


FIGURE 5.22: BER performance for FPC algorithms in an AWGN channel with uncoded, convolutional and Turbo coding. The topional and Turbo coding. The top BER performance on unDM FPC with different coding schemes. The bottom figure shows the improvement of BER performance of unPC6 FPC with different coding schemes.

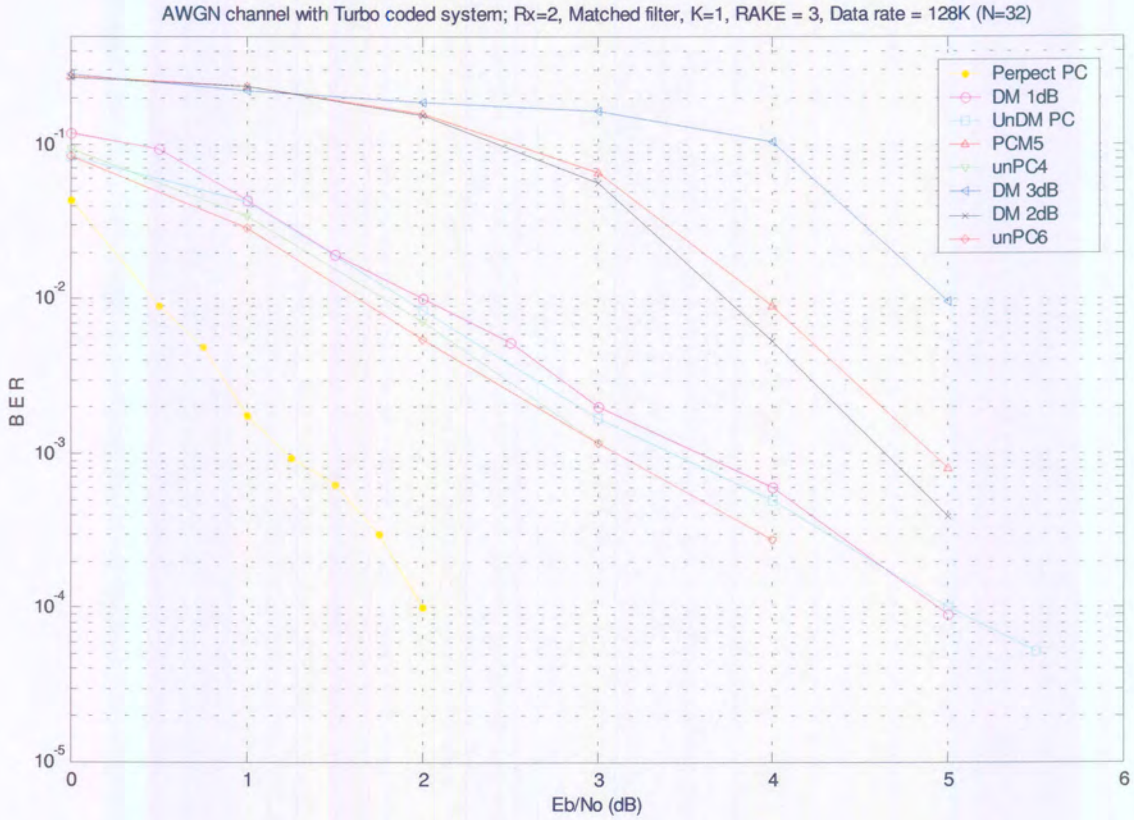


FIGURE 5.23: Influence of coding schemes. BER performance curves of different FPC algorithms in a Turbo-coded W-CDMA system with an AWGN channel, Rx=2, i=1, RAKE fingers=3, N=32 and matched-filter detector.

5.3.3.1 BER Performance for an AWGN Channel

The BER performance of the system in an AWGN channel is shown in Figures 5.21 and 5.22. Significant improvements are observed when coding schemes are incorporated in the simulation package. Generally, a 10 dB coding gain is observed from the simulation results. This is primarily due to the fact that the channel coding protects digital data from errors by selectively introducing redundancies in the transmitted data.

Figure 5.23 shows the BER performance of the eight FPC algorithms in an AWGN channel with Turbo codes. The results show that, generally, the unbalanced DM FPC technique yields a 11 dB coding gain at BER = 10^{-4} when we compare the BER performance curves of an uncoded AWGN channel to that of a Turbo-coded AWGN channel. Comparing the BER performance of unbalanced and balanced PCM FPC algorithms, unbalanced PCM algorithms outperform balanced ones significantly; since the unbalanced FPC algorithms improve and compensate for the burst errors more effectively, it is less probable that errors will occur in a burst sequence which coding schemes cannot detect and correct and the improvement rate increases as the transmitted SINR values increase.

Comparing the BER performance of the eight FPC algorithms at 5 dB, we see that there is a significant improvement with unbalanced FPC algorithms in a channel-coded system [Tables 5.4 and 5.5]. The BER performance of different FPC algorithms yields similar results in both channel-coded systems, but the performance of the Turbo-code system yields better results than the convolutional code system.

From these tables, it can be seen that the unbalanced DM FPC technique yields better power efficiency than the balanced DM FPC technique, but with an improvement of approximately 1 dB only. It is important to note that since the BER performance of the cellular system can also be influenced by spreading gain factors also, it is predicted that the system capacity will increase if spreading gain factors are increased.

5.3.3.2 BER Performance for Outdoor and Vehicular Channels

Thus far, we have shown that convolutional and Turbo codes introduced in the receiver system in an AWGN channel result in a significant improvement on the BER performance of different FPC algorithms. Let us now apply the same system in an outdoor channel condition where previously FPC algorithms failed to bring W-CDMA BER performance to within an acceptable BER.

The inevitable impairment of wireless channel conditions is the result of the numerous multipath components and Doppler spread effects on the transmitted signal. When the number of multipath components increases, the received SINR value of received signals decreases, and the BER performance of the different FPC algorithms also degrades. Whereas the pervious section has shown that coding schemes improve the BER performance in an AWGN channel condition by 11dB, this section will focus on how coding algorithms further improve BER performance in an outdoor channel condition by comparing Figure 5.17 to Figure 5.24.

Significant improvements are observed when coding schemes are incorporated in the outdoor channel condition. Generally, incorporating Turbo coding schemes result in greater QoS since W-CDMA systems provide a more robust service to the subscribers in unpredictable wireless environments.

Figure 5.24 shows the BER performance of the eight FPC algorithms in an outdoor channel with a Turbo-coded system. The results show that, generally, the unbalanced DM FPC technique yields acceptable BER performance at BER = 10^{-4} when we compare the BER performance curves of an uncoded outdoor channel to that of a Turbo-coded outdoor channel. Comparing the BER performance of unbalanced and balanced PCM FPC algorithms, unbalanced PCM algorithms outperform balanced ones significantly: since the unbalanced FPC algorithms improve and compensate for the burst errors more effectively, it is less probable that errors will occur in a burst sequence which coding schemes cannot detect and correct and the improvement rate increases as the transmitted SINR values increase.

Comparing the BER performance of the eight FPC algorithms at 3.5 dB [Tables 5.6], we see that there is a significant improvement with unbalanced FPC algorithms in a channel-coded system. And that the unbalanced DM FPC technique yields better power efficiency than the balanced DM FPC technique.

Figure 5.24 shows the performance of different FPC algorithms in an outdoor channel model with convolutional schemes. Although a convolutional-coded system yields better BER performance than a Turbo-coded system, both coded systems improve the BER

Table 5.6: BER performance of different FPC algorithms in a W-CDMA system with an outdoor channel and Turbo code at 3.5 dB.

$E_b/I_0 = 3.5$ dB	BER
unPCM6	0.000016
unPCM4	0.000046
UnDM	0.000231
DM1	0.000787
PCM5	0.013935
DM2	0.016019
DM3	0.031481

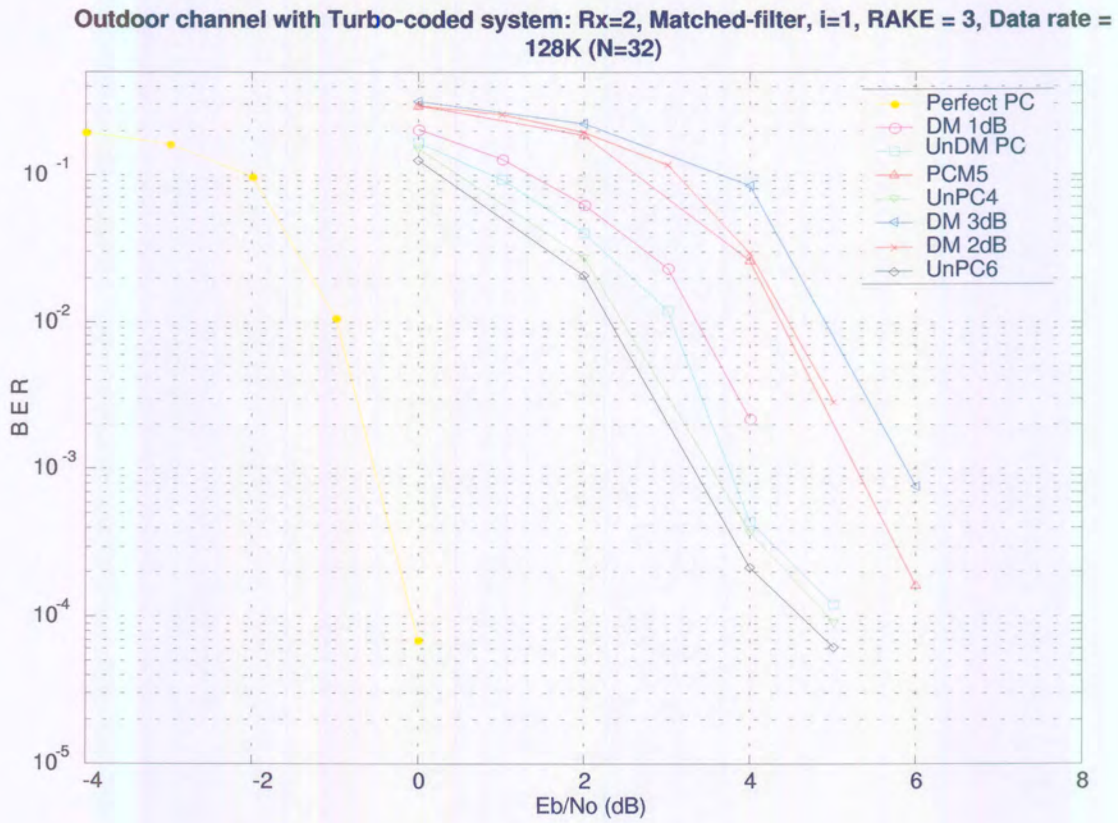


FIGURE 5.24: Influence of coding schemes. BER performance curves of different FPC algorithms in a Turbo-coded, W-CDMA system with an outdoor channel, Rx=2, i=1, RAKE fingers=3, N=32 and matched-filter detector.

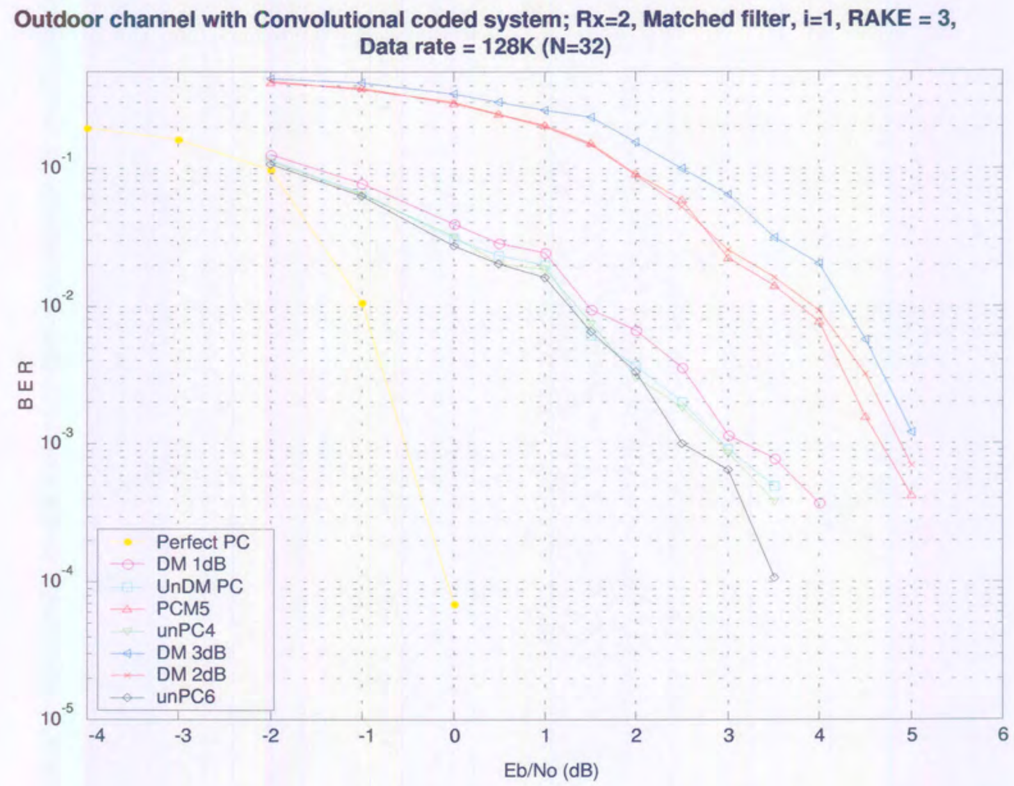


FIGURE 5.25: Influence of coding schemes. BER performance curves of different FPC algorithms in a convolutional-coded W-CDMA system with the outdoor channel, Rx=2, i=1, RAKE fingers=3, N=32 and matched-filter detector.

performance significantly compared to uncoded, outdoor channel systems.

Thus, a significant performance improvement can be achieved if FPC and coding schemes are both incorporated in the W-CDMA systems. It is also expected that FPC algorithms that correspond with other physical receiver structures, such as space-time diversity, multi-user detection and RRM, can further improve the system performance. This section investigates and compares the effects of coding schemes and shows that performance can be improved by combining coding schemes with FPC algorithms in a frequency-selective, Rayleigh, fast-fading environment. This phenomenon is also observed in a vehicular channel [Figure 5.26].

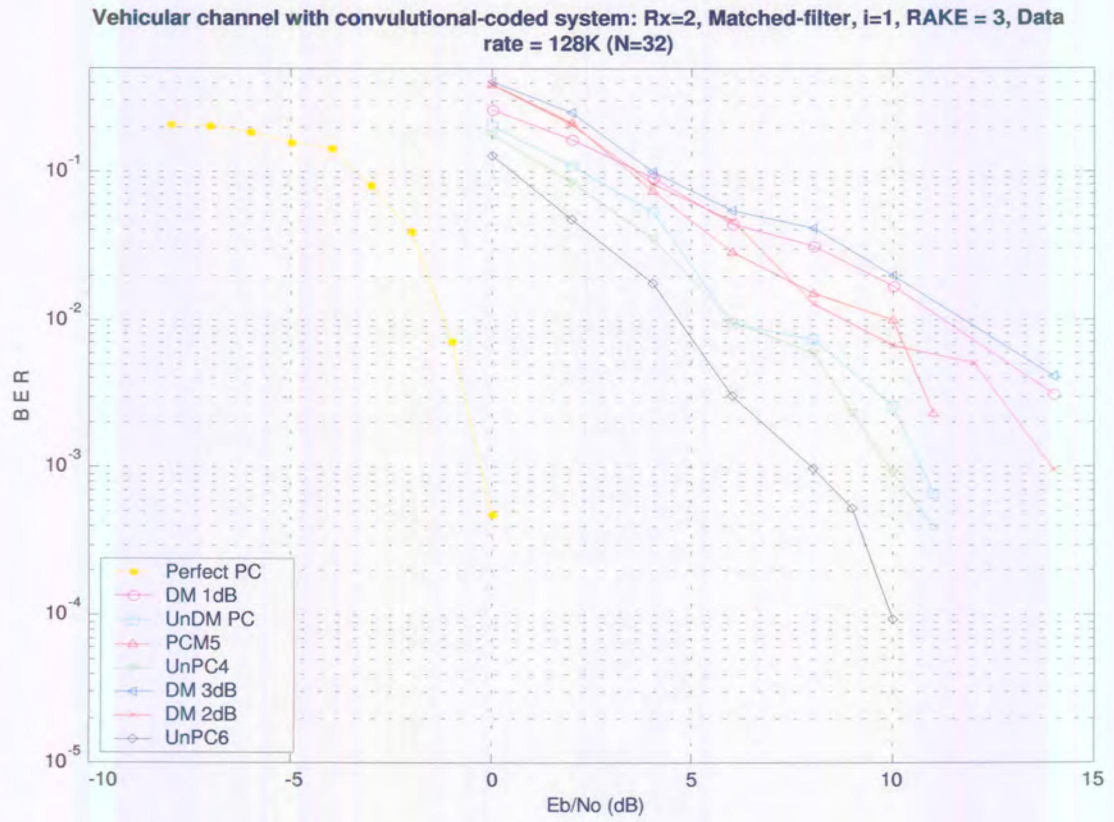


FIGURE 5.26: Influence of coding schemes. BER performance curves of different FPC algorithms in a convolutional-coded W-CDMA system with a vehicular channel, Rx=2, i=1, RAKE fingers=3, N=32 and matched-filter detector.

5.3.3.3 Conclusions Of The Influence Of Coding Schemes

The introduction of convolutional and Turbo-code schemes in AWGN, W-CDMA cellular systems improves power efficiency, generally, by about 10 dB with the different FPC algorithms. When a frequency-selective, Rayleigh fast-fading channel is introduced in the channel model, there is a significant improvement in BER performance with unbalanced DM and PCM algorithms, especially at high SINR levels. This is primarily due to the fact that the unbalanced FPC algorithms improve and compensate for the burst error of the Rayleigh fading channels more effectively since it is less probable that errors will occur in a burst sequence which coding schemes cannot detect and correct.

Unlike wireline systems where QoS can be predicted and controlled, cellular systems tend to be stochastic and unpredictable. Thus, the emphasis of most wireline systems research is on the layer 2 or higher protocols, such as routing, admission-control, congestion-control and collision-control etc. The challenge of W-CDMA technology is to control wireless communication systems such that QoS to subscribers can be predicted and controlled. Thus, transmitted power and power distribution must be carefully planned. It is important to note that the BER is determined mainly by the coding, interleaving and receiver structure, and FPC algorithms not only attempt to narrow the received SINR levels at the base station, but should also act as a supplementary mechanism for other receiver structures to deliver acceptable QoS levels.

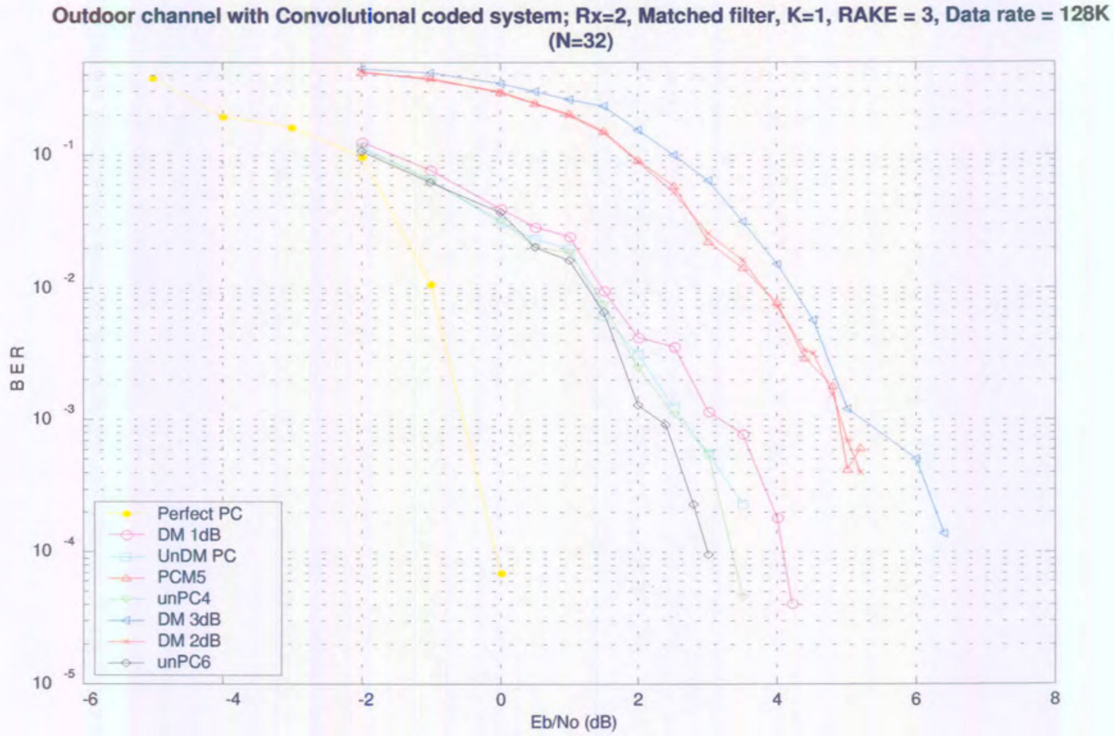
A mediation device is required to provide a physical-layer QoS monitoring facility and network-layer RRM decision-making facility while FPC algorithms do not improve the system performance significantly, they do provide online link QoS monitoring, online resource and interference management, and QoS assurance for adaptation to changes induced by mobility, channel impairment and traffic demand.

5.3.4 Influence Of Number Of Receiver Antennae

In the previous section it was shown that a decrease in the number of multipath components and the mobile speed significantly increase the BER performance of the cellular systems. Because of the large bandwidth of CDMA systems compared to TDMA/FDMA systems, CDMA systems are capable of receiving and exploiting a larger number of multipath components using a RAKE receiver and antenna space-diversity. Therefore, one approach to minimizing the effects of a large number of multipath components and Doppler spread is to increase the number of receiver antennae.

5.3.4.1 BER Performance for Different Number of Receiver Antennae

Thus far, the number of receiver antennae was set at two, and each antenna was assigned three RAKE fingers. Decreasing the number of antennae to one leads to a significant decrease in



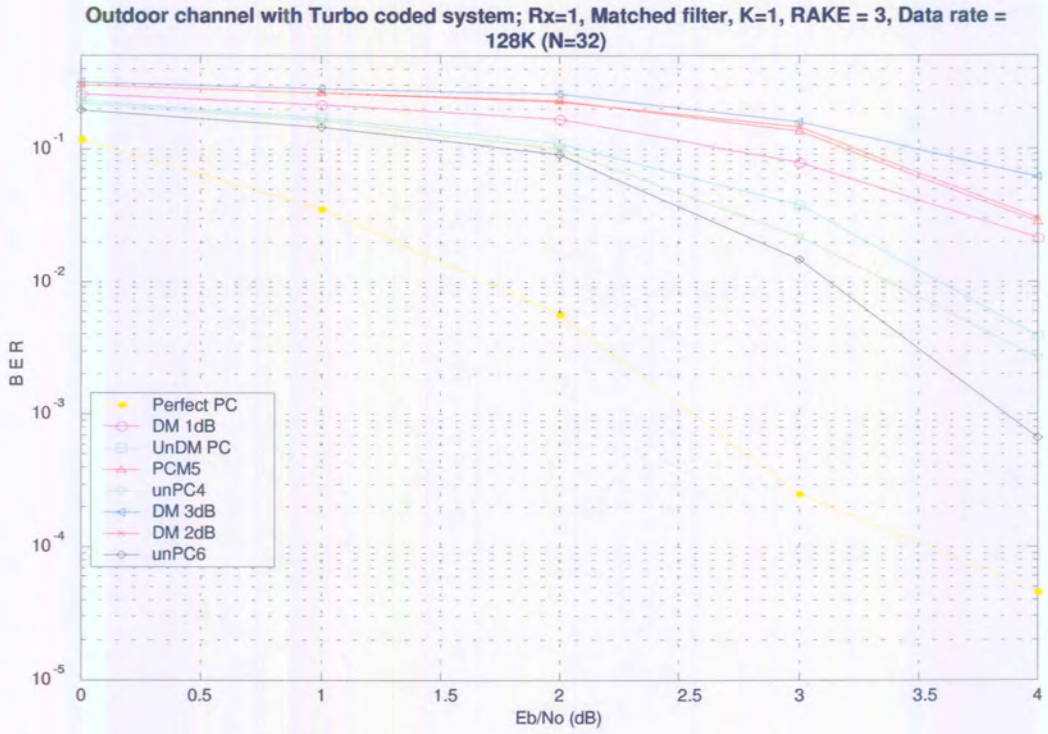


FIGURE 5.27: Different FPC algorithms vs. BER performance. The top figure shows the results with two receiver antennae. The bottom figure shows the results with one receiver-antenna in a convolutional-coded system with a matched-filter detector in an outdoor channel.

system BER performance as shown in Figure 5.27. This decrease in system performance is equally true for all FPC algorithms. Comparing the increase in system performance that can be achieved by increasing the number of branches in the RAKE as well as receiver antennae, it is clear that the increase of number of antennae will lead to a greater increase in system capacity. The same applies to antennae space-time processing techniques.

5.3.5 Influence Of Number Of Users

The power-sensitive model shown in Chapter 2 describes the significant effect of MAI on system capacity, especially in multi-media, multi-user W-CDMA systems. The following derivations show that the system capacity is largely dependent on intra-cell, inter-cell and MAI interference.

For a single-user, W-CDMA system, the outage probability can be denoted by:

$$P_r\left[\left(\frac{E_b}{I_o}\right)_i \geq \gamma_i\right] = P_r\left[\frac{h_{ik}P_i}{\delta^2 W}\frac{W}{R_i} \geq \gamma_i\right] \tag{5.1}$$

where i=1, j=1, and k=1. The outage probability is solely dependent on the channel impairments, processing gain, data rate and transmitted power level, However as the number of users increases, say to N, at cell k, the outage probability can be denoted by:

$$P_r\left[\left(\frac{E_b}{I_o}\right)_i \geq \gamma_i\right] = P_r\left[\frac{h_{ik}P_i}{\sum_{j\neq i}^{N} h_{jk}P_j + \delta^2 W}\frac{W}{R_i} \geq \gamma_i\right] \tag{5.2}$$

where $i = 1, ..., N$, $j = 1, ..., N$, N is the number of active users in cell k, $k = 1, ..., K$,K is the number of cells of the W-CDMA systems, $\gamma_i = \gamma_1, ..., \gamma_N$ and $R_i = R_1, ..., R_N$. Now, the outage probability is largely dependent on intra-cell, inter-cell and MAI interference. This section will focus on the influence of number of users in different channel conditions on the system capacity.

5.3.5.1 BER Performance In An AWGN Channel

The BER performance of a one-user, Turbo-coded W-CDMA system is shown in the top figure of Figure 5.28. The bottom figure of Figure 5.28 shows the BER performance of a two-user, Turbo-coded W-CMA system. Figure 5.29 depicts the BER performance of a four-user system with the same settings. The eight FPC algorithms are simulated in an AWGN channel, Rx=2, RAKE finger=3 and a matched-filter detector. The results show that an increase in number of users increases the BER and as a consequence decreases the system capacity. This is equally true for all eight FPC algorithms. This is primarily due

Table 5.7: BER performance of different FPC algorithms in a one-user, Turbo-coded, W-CDMA system with an AWGN channel at 4 dB.

$E_b/I_0 = 4$ dB	BER
unPCM6	0.000248
unPCM4	0.000278
unDM	0.000500
DM1	0.000600
DM2	0.005301
PCM5	0.008958
DM3	0.103519

Table 5.8: BER performance of different FPC algorithms in a two-users, Turbo-coded, W-CDMA system with an AWGN channel at 4 dB.

$E_b/I_0 = 4$ dB	BER
unPCM6	0.000672
unPCM4	0.000834
unDM	0.001113
DM1	0.001300
DM2	0.014676
PCM5	0.017870
DM3	0.119907

to the fact that since the MAI interference increases [Equ. 5.2], more transmitted power is required to compensate for both h_{ik} and MAI effects. Therefore the noise floor increases, and because cellular handsets need to utilize their battery power in the most efficient way, the handset must regulate its transmitted power at a pre-determined level. Thus, some calls will be dropped since the base station is not competent to sustain good SINR levels to subscribers as the MAI increases.

Table 5.9: BER performance of different FPC algorithms in a four-users, Turbo-coded, W-CDMA system with an AWGN channel at 4 dB.

$E_b/I_0 = 4$ dB	BER
unPCM6	0.035914
unPCM4	0.037830
DM1	0.048426
unDM	0.050289
DM2	0.069867
PCM5	0.084815
DM3	0.177257

Unbalanced FPC algorithms improve the BER performance in a multimedia, multi-user W-CDMA environment as seen in Figure 5.28, but as the number of users increases to four [Figure 5.29] so the rate of degradation of BER performance increases more than with the balanced FPC algorithms. This is primarily due to the fact that the unbalanced FPC algorithms are designed to compensate for the Raleigh fading channel by increasing the average transmitted power level of the handset. As the number of users increases, so the excess average transmitted power level generates more MAI interference to other users. Thus, the rate of BER performance degrades faster in unbalanced FPC algorithms than balanced FPC algorithms. These effects are summarised in Tables 5.7, 5.8 and 5.9.

Figures 5.30 to 5.34 compare the BER performance of a one-user, two-user and four-user system with different FPC algorithms.

5.3.5.2 Conclusions of The Influence Of Number of Users in AWGN Channel

The overall BER performance of different FPC algorithms in AWGN channel, Turbo-coded W-CDMA system is shown in Figure 5.35. As the number of users increases, so the excess

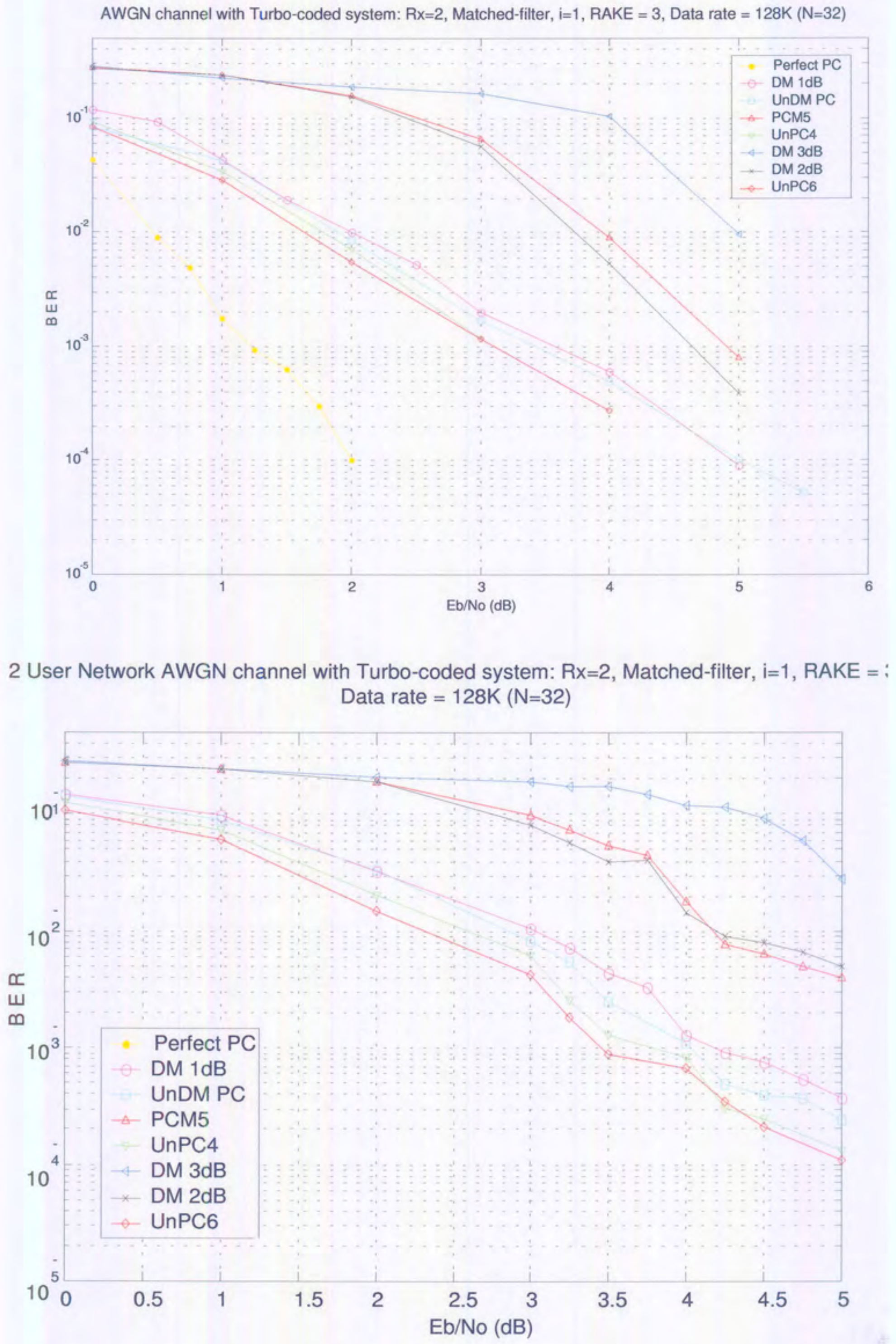


FIGURE 5.28: Influence of number of users. The top figure shows the BER performance results with a one-user, Turbo-coded W-CDMA system with an AWGN channel, Rx=2, RAKE fingers=3, N=32 and matched-filter detector. The bottom figure shows the BER performance results with a two-user, Turbo-coded W-CDMA system and same settings.

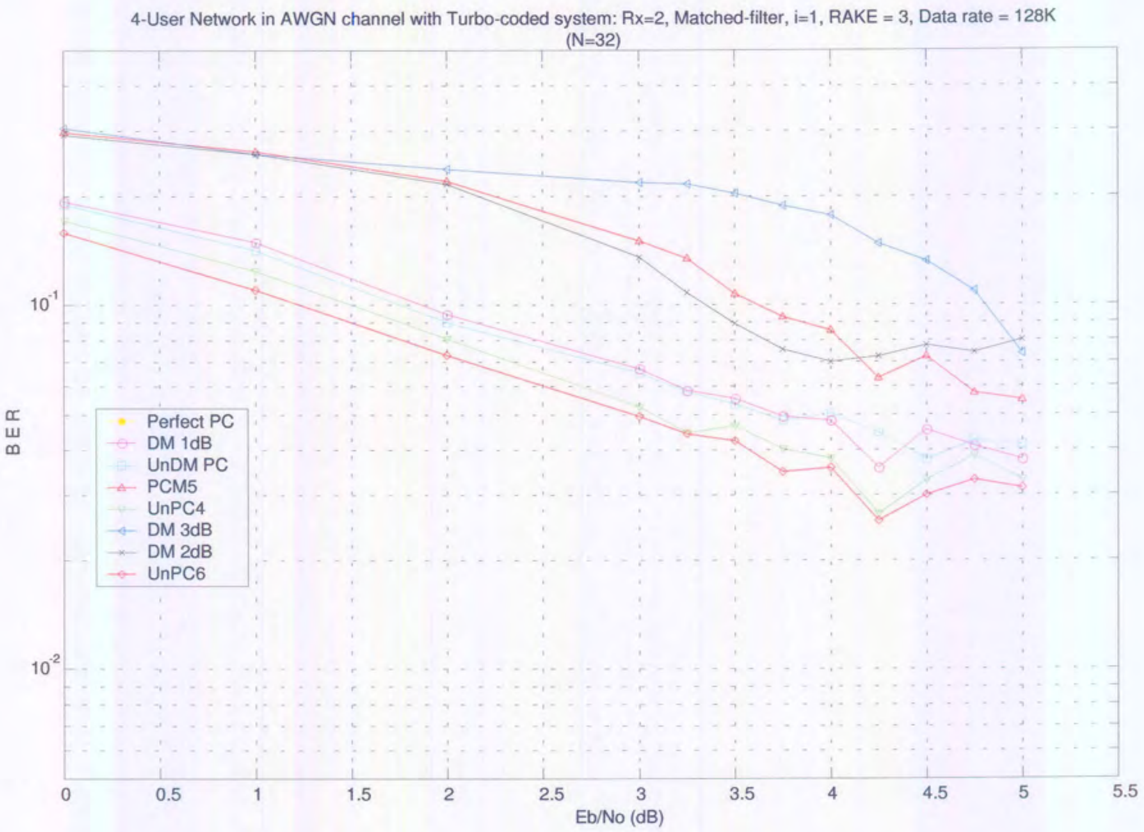


FIGURE 5.29: Influence of number of users. The top figure shows the BER performance results with a four-user, Turbo-coded W-CDMA system with an AWGN channel, Rx=2, RAKE fingers=3, N=32 and matched-filter detector.

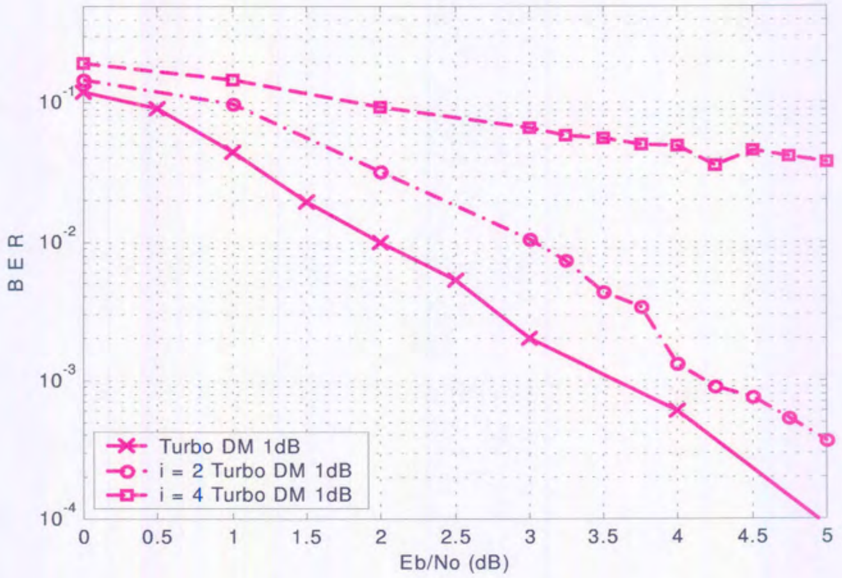


FIGURE 5.30: Influence of number of users. BER performance curve of DM1 FPC algorithm in a Turbo-coded, W-CDMA system with an AWGN channel.

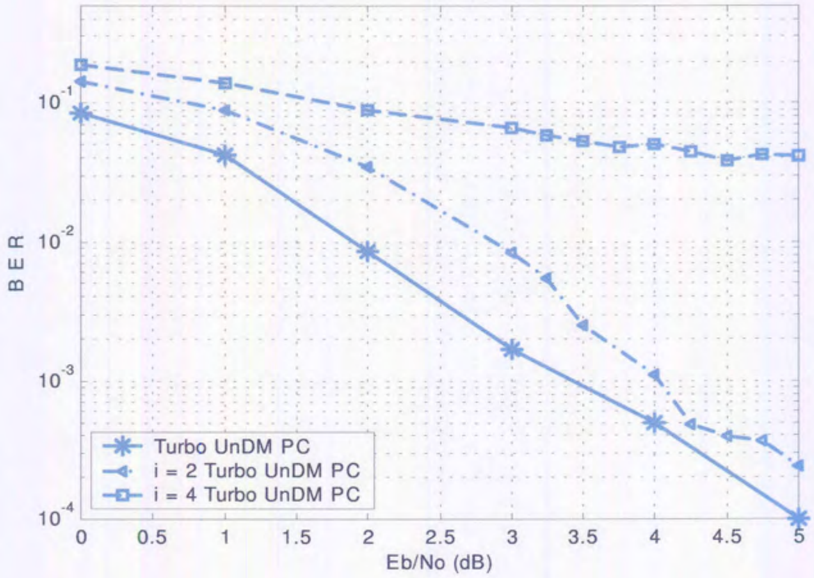


FIGURE 5.31: Influence of number of users. BER performance curve of unDM FPC algorithm in a Turbo-coded, W-CDMA system with an AWGN channel.

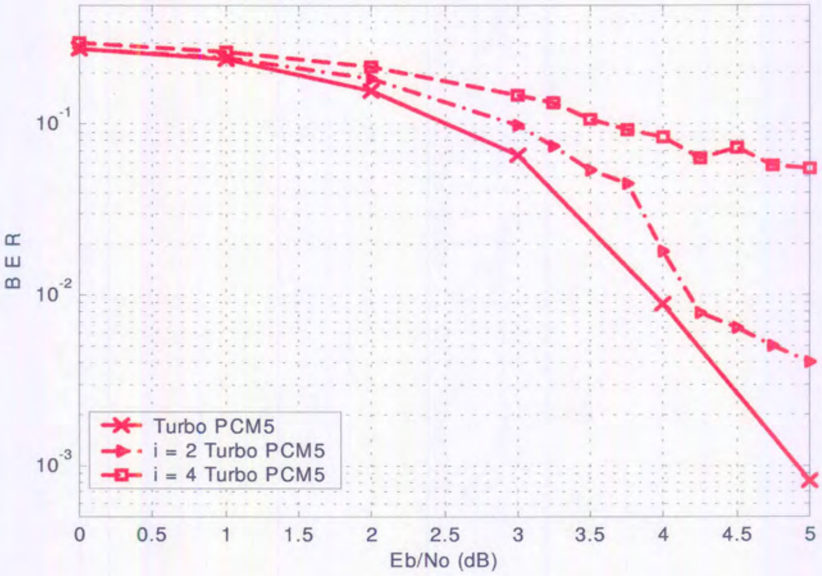


FIGURE 5.32: Influence of number of users. BER performance curve of PCM5 FPC algorithm in a Turbo-coded, W-CDMA system with an AWGN channel.

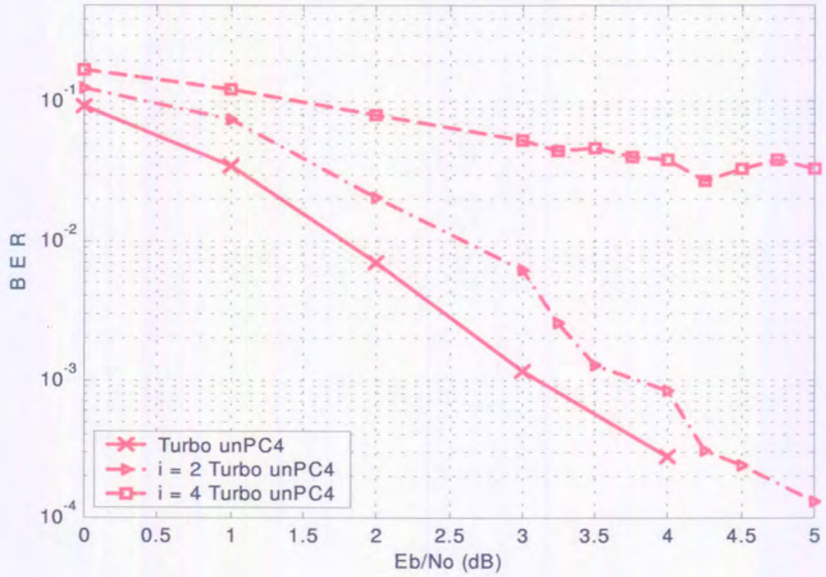


FIGURE 5.33: Influence of number of users. BER performance curve of unPC4 FPC algorithm in a Turbo-coded, W-CDMA system with an AWGN channel.

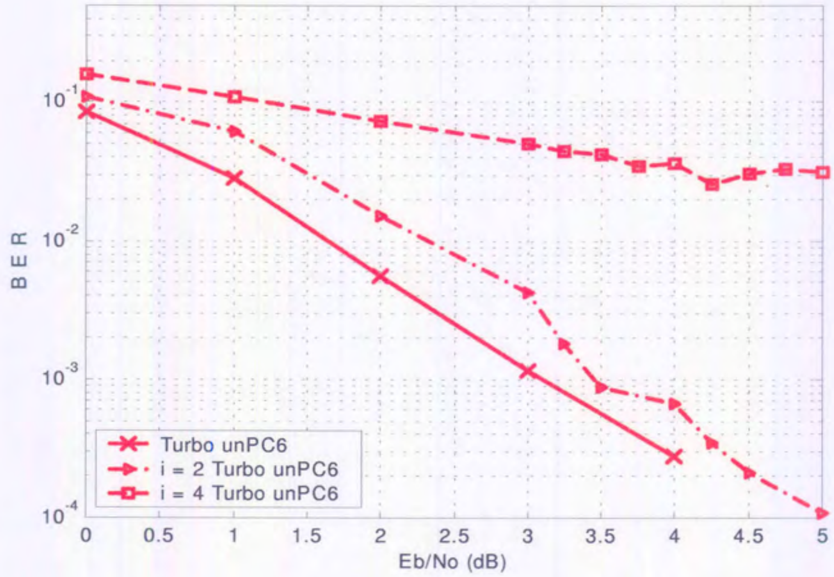


FIGURE 5.34: Influence of number of users. BER performance curve of unPC6 FPC algorithm in a Turbo-coded, W-CDMA system with an AWGN channel.

average transmitted power level will generate more MAI interference to other users. Thus, the rate of BER performance is worsen faster in unbalanced FPC algorithms than balanced FPC algorithms.

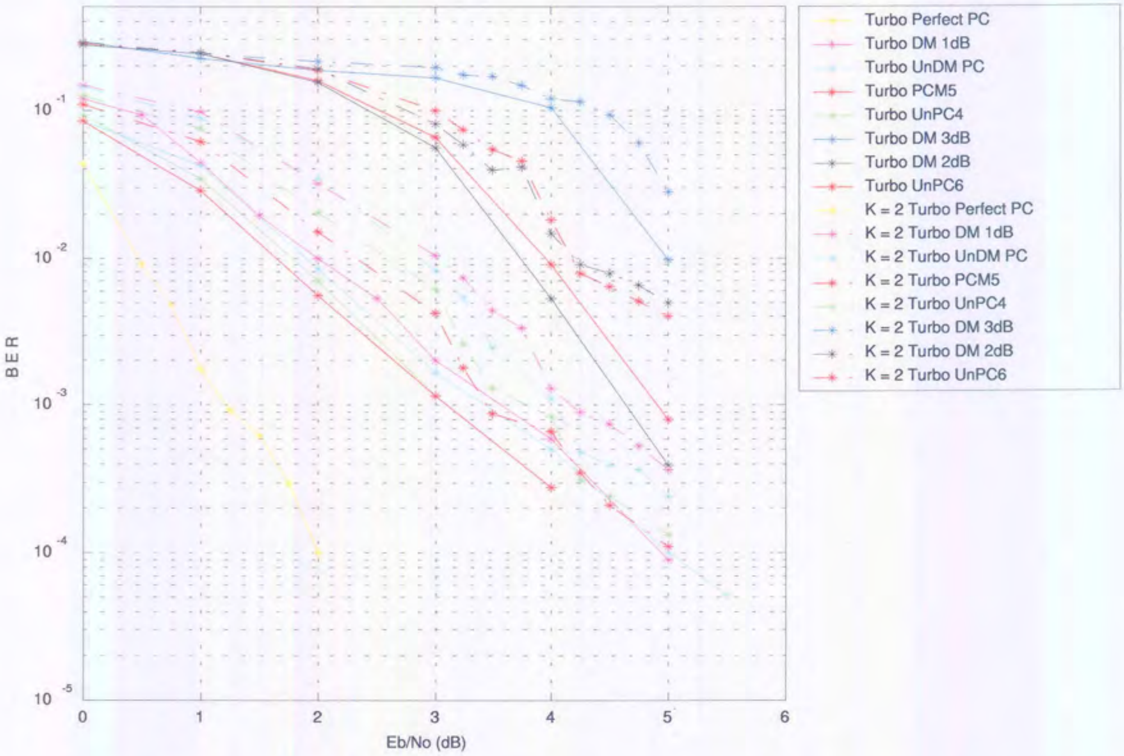


FIGURE 5.35: Influence of number of users. BER performance curve of different FPC algorithms in a Turbo-coded, W-CDMA system with an AWGN channel, Rx=2, i=2, RAKE fingers=3, N=32 and matched-filter detector.

5.3.5.3 BER Performance In An Outdoor Channel

Figure 5.36 depicts the BER performance curve of different FPC algorithms in a one-user, uncoded, W-CDMA system with an outdoor channel. This diagram shows clearly the significant effects of MAI interference on the W-CDMA system capacity, and also shows that either the unbalanced nor the balanced FPC algorithms improve the BER performance in an outdoor channel condition. Later in this section, we describe the effect of incorporating a Turbo code into the W-CDMA system.

Figure 5.37 depicts the BER performance curve of different FPC algorithms in a two-user, Turbo-coded, W-CDMA system with an outdoor channel. By comparing Figure 5.24 with Figure 5.37, we can observe that the BER performance of a two-user, Turbo-coded W-CDMA system degrades compared to a one-user, Turbo-coded W-CDMA system. It is

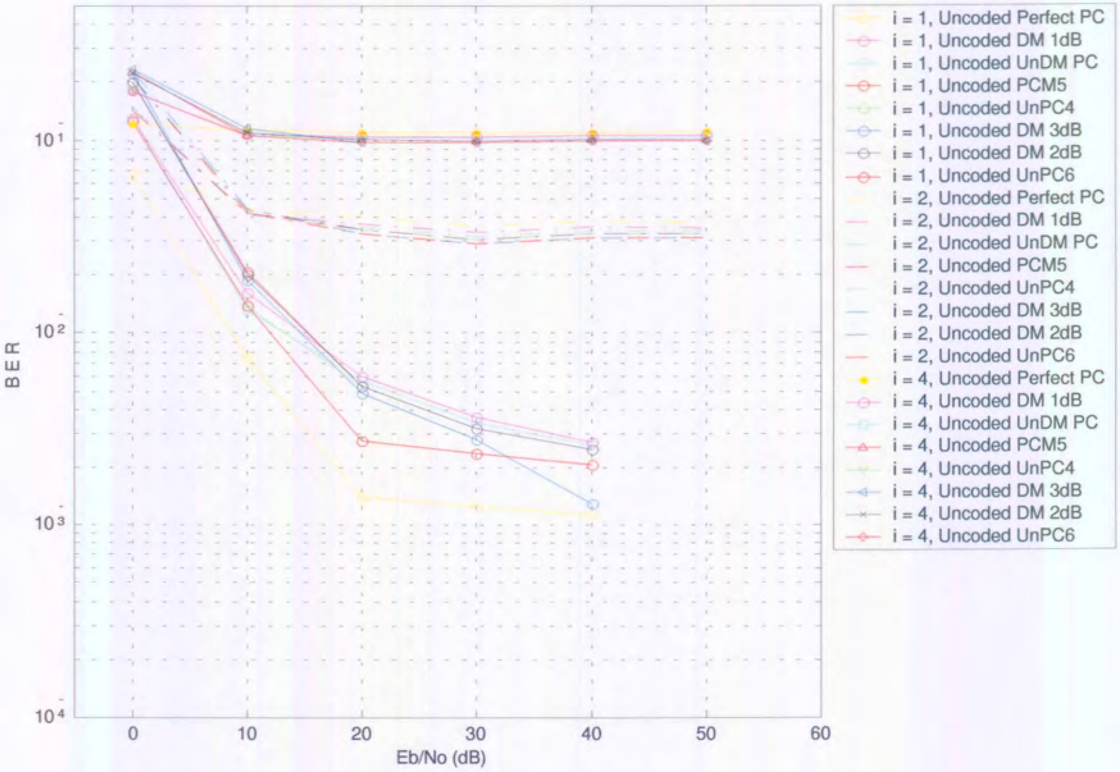


FIGURE 5.36: Influence of number of users. BER performance curve of different FPC algorithms in a uncoded, W-CDMA system with an outdoor channel, Rx=2, i=1, RAKE fingers=3, N=32 and matched-filter detector.

Table 5.10: BER performance of different FPC algorithms in a one-user, Turbo-coded, W-CDMA system with an outdoor channel at 4 dB.

$E_b/I_0 = 4$ dB	BER
unPCM6	0.000248
unPCM4	0.000278
unDM	0.000500
DM1	0.000600
DM2	0.005301
PCM5	0.008958
DM3	0.103519

Table 5.11: BER performance of different FPC algorithms in a two-users, Turbo-coded, W-CDMA system with an outdoor channel at 4 dB.

$E_b/I_0 = 4$ dB	BER
unPCM6	0.000672
unPCM4	0.000834
unDM	0.001113
DM1	0.001300
DM2	0.014676
PCM5	0.017870
DM3	0.119907

also true that the rate of degradation with unbalanced FPC algorithms increases faster than with balanced FPC algorithms. Thus, the rate of BER performance increases are faster with unbalanced FPC algorithms than with balanced FPC algorithms. We can conclude this from the data shown in Table 5.10 and 5.11.

Figures 5.38 to 5.44 depict the BER performance of one-user and two-users systems with different FPC algorithms.

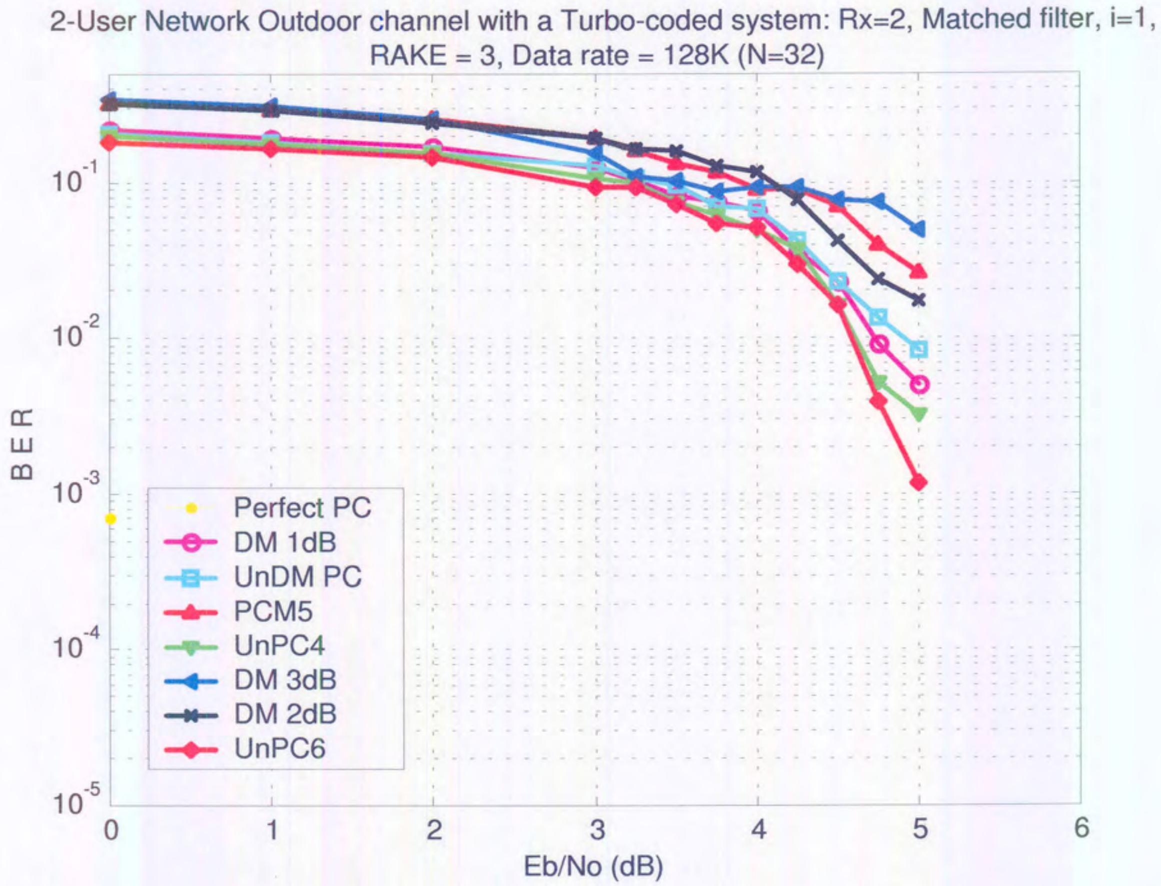


FIGURE 5.37: Influence of number of users. BER performance curve of different FPC algorithms in a Turbo-coded W-CDMA system with an outdoor channel, Rx=2, i=2, RAKE fingers=3, N=32 and matched-filter detector.

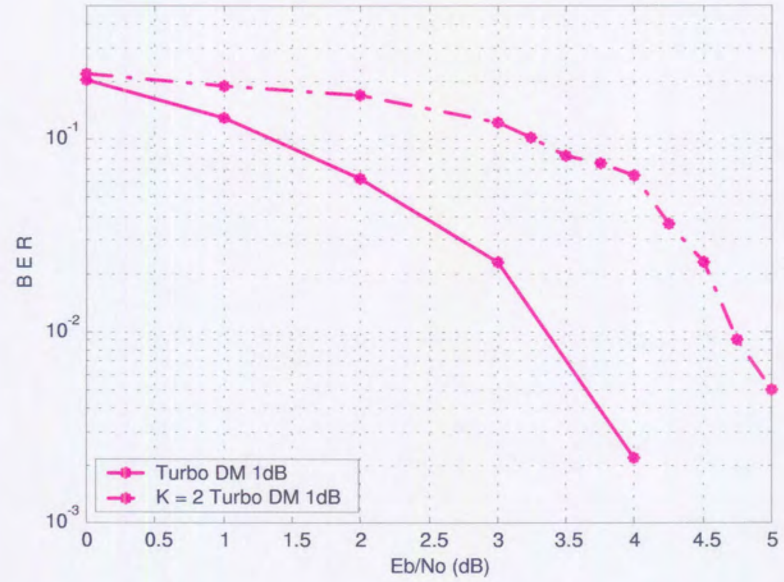


FIGURE 5.38: Influence of number of users. BER performance curve of DM FPC algorithm in a Turbo-coded, W-CDMA system with an outdoor channel.

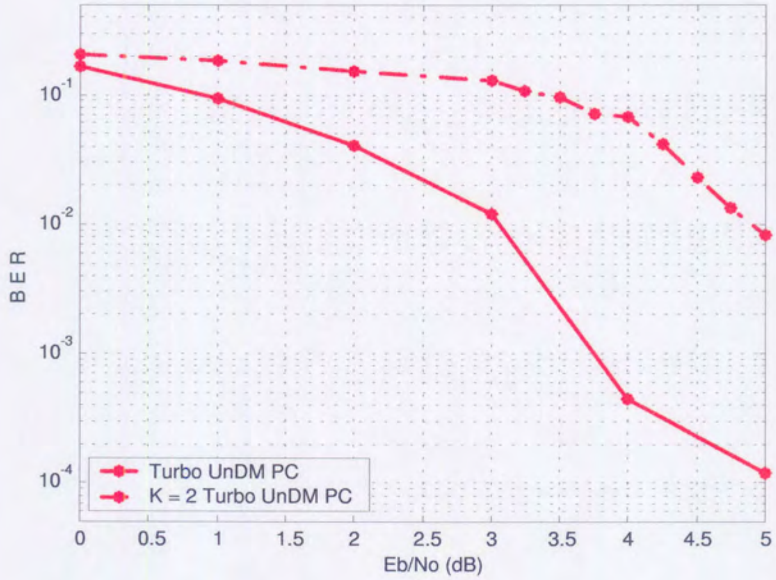


FIGURE 5.39: Influence of number of users. BER performance curve of unDM FPC algorithm in a Turbo-coded W-CDMA system with an outdoor channel.

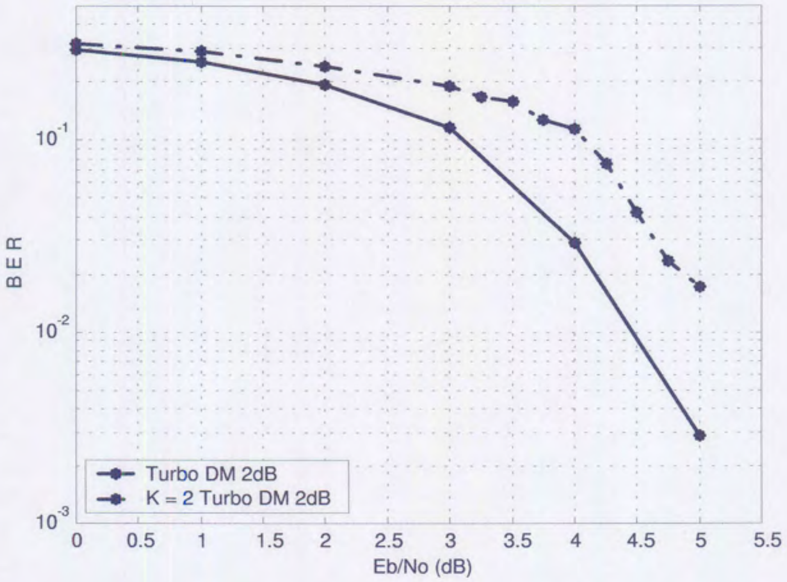


FIGURE 5.40: Influence of number of users. BER performance curve of DM2 FPC algorithm in a Turbo-coded W-CDMA system with an outdoor channel.

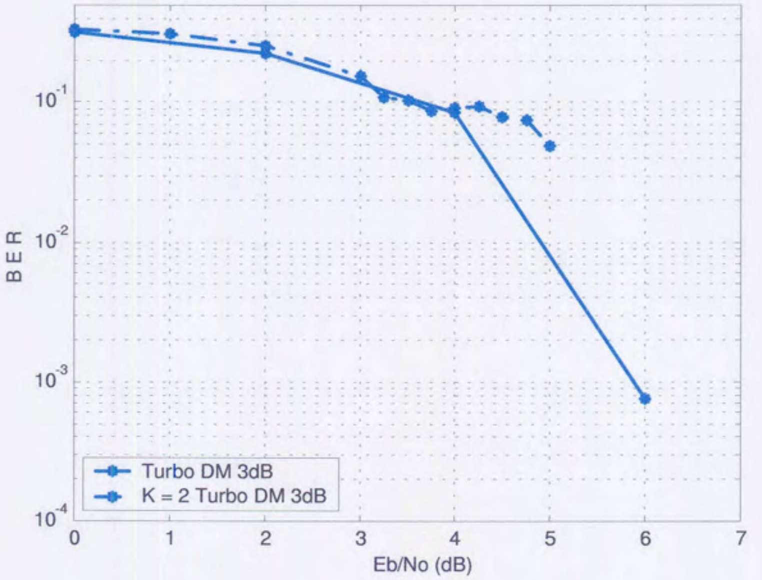


FIGURE 5.41: Influence of number of users. BER performance curve of DM3 FPC algorithm in a Turbo-coded, W-CDMA system with an outdoor channel.

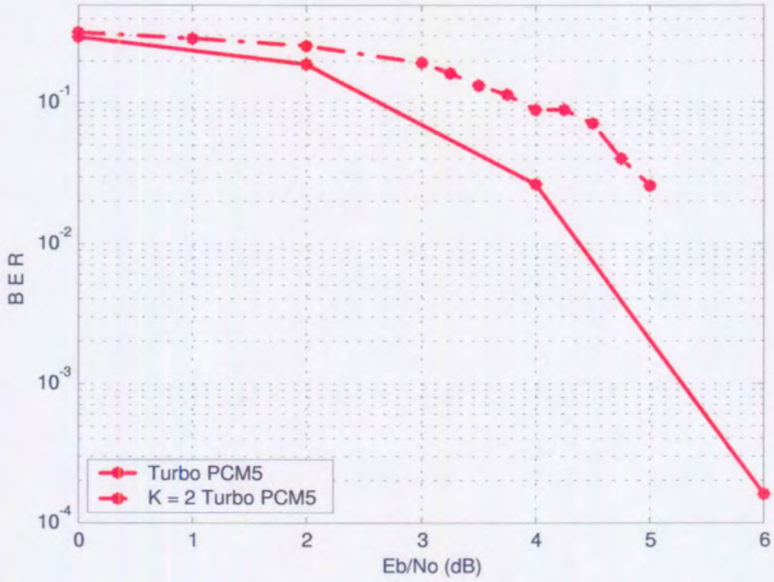


FIGURE 5.42: Influence of number of users. BER performance curve of PCM5 FPC algorithm in a Turbo-coded, W-CDMA system with an outdoor channel.

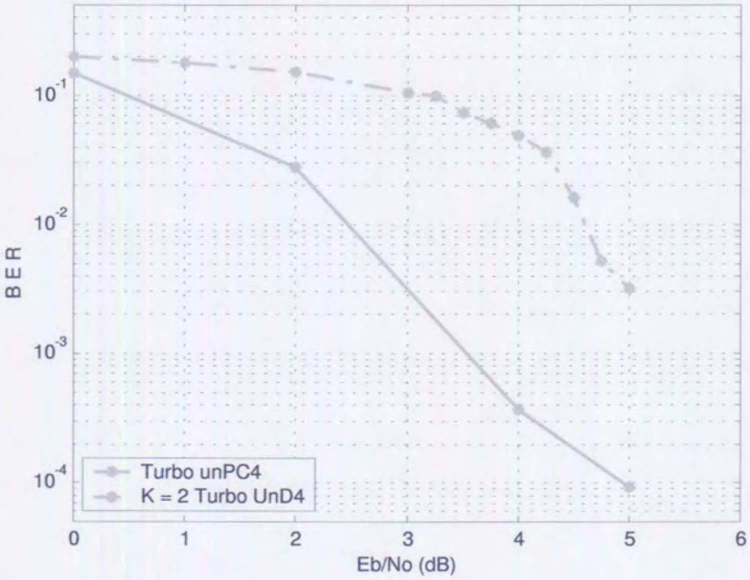


FIGURE 5.43: Influence of number of users. BER performance curve of unPC4 FPC algorithm in a Turbo-coded, W-CDMA system with an outdoor channel.

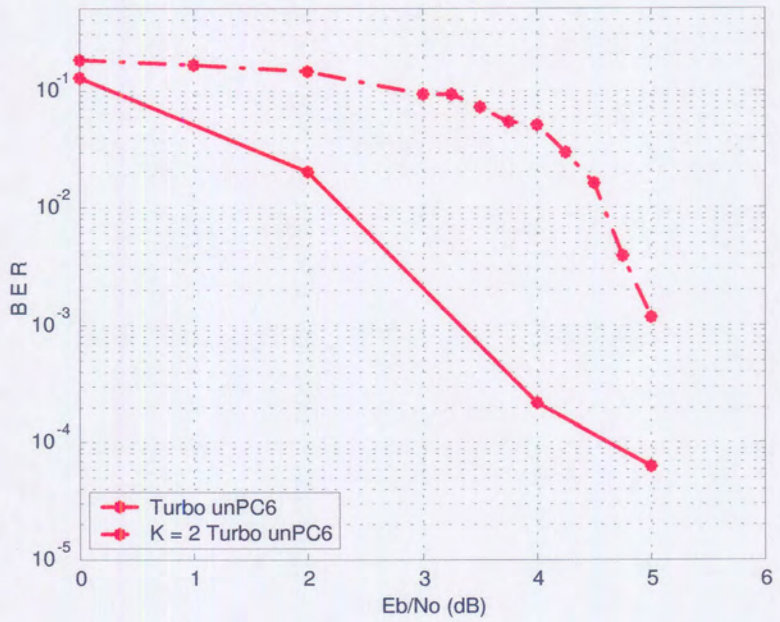


FIGURE 5.44: Influence of number of users. BER performance curve of unPC6 FPC algorithm in a Turbo-coded, W-CDMA system with an outdoor channel.

CHAPTER SIX

CONCLUSION

In this final chapter, the most important results and conclusions of this dissertation are summarized and the goals of the dissertation, as outlined in Chapter 1, are revisited and assessed in terms of whether they have been achieved. Recommendations for future research are also given.

6.1 Goals of The Dissertation

Below is a description of the main goals of the dissertation and the extent to which they have been met.

- To establish a general and mathematically tractable power-sensitive model for multi-media, W-CDMA cellular systems.

  A new power-sensitive model based on capacity analysis for multi-media cellular systems, as described in Chapter 2, has been developed. This model incorporates various physical realities of a cellular network including the influence of:

  - interference on the signal received at the base station (section 2.2.2.1)
  - resource-management on system capacity (section 2.2.2.2)
  - channel effects on the signal received at the base station (section 2.2.2.3)

  Total interference, PC error, traffic demand requirement and transmission rate are amongst the most important factors in defining the capacity limit.

- To establish a general framework structure for PC algorithms in multi-media W-CDMA cellular systems.

The power-sensitive model proposed in Chapter 2 is then used to establish a framework for various APC layers of multi-media CDMA cellular systems as described in Chapter 3. The factors that influence system capacity can be minimized if a complete PC structure is intelligently defined. The APC layers are divided into:

  - NPC (section 3.4)
  - OPC (section 3.5)
  - FPC (section 3.6)

- To propose new QoS-based PC algorithms based on the framework structure established above.

  The power-sensitive model is used to establish a framework for various PC algorithms. The PC layers are divided into:

  - interference management system: QoS-based FPC algorithm (section 4.3.1)
  - service management system: QoS-based OPC algorithm (section 4.3.2) and
  - network management system: QoS-based NPC algorithm (section 4.3.3)

- To program a Turbo-coded, RAKE combining and multi-media uplink W-CDMA simulation platform in a Monte Carlo simulation package with Matlab software.

- To compare balanced, step-size, FPC algorithms with the proposed unbalanced scheme based on BER performance and outage probability with various numbers of multipath components, Doppler spread, number of received antennae and various coding schemes. Using the proposed APC structure presented above, the influence of the following parameters on system performance and capacity is presented in Chapter 5:

  - power profiles (section 5.3.1)
  - diversity schemes (section 5.3.2)
  - coding schemes (section 5.3.3)
  - Doppler spreads (section 5.3.4)
  - number of users (section 5.3.5)

6.2 Overview and Background

After a review of the literature on W-CDMA communication systems in section 1.1, the potential advantages of W-CDMA over TDMA/FDMA for the growing mobile/personal communications market were outlined, the characteristic of *SS waveforms* and *sharing resources* gives CDMA the advantage of providing higher capacity and greater flexibility than TDMA/FDMA. However, the literature revealed at Chapter 1 that SS techniques are broadband in the sense that the entire transmission bandwidth is shared amongst all users at all times. This implies that the system capacity is very much dependent on MAI. Thus, the design of W-CDMA systems is considered as one of power management wireless network architecture, with PC being the central controller for resource allocation and interference management. In this dissertation, a power-sensitive model for the accurate evaluation of W-CDMA system gains has been developed and the influence of various parameters on overall system performance has been determined.

The specific APC structure that was mainly considered in this dissertation is QoS-based PC algorithms. In section 1.2.3, an overview of this APC structure is given with an explanation of how these techniques endeavor to:

- reduce inter-cell and intra-cell interference;
- extend radio resource usage and;
- extend system traffic capacity;

In section 1.3 the limitations of current PC algorithms for future multi-media cellular systems are presented. one of the limitations which is the lack of system treatment of existing APC algorithms is dealt with in more detail in chapters 2 and 3. Chapter 2 presents a newly proposed power-sensitive model for the evaluation of multi-media communication systems using APC structures. Chapter 3 presents a new APC framework for a systematic treatment of APC algorithms.

6.3 A General Power-Sensitive Model for W-CDMA Systems

Chapter 2 describes a mathematical, power-sensitive network model used to evaluate the performance of APC structure in a Turbo-coded, RAKE combining uplink W-CDMA system. Based on this model, we are able to show that W-CDMA system is a design of interference management network because W-CDMA is interference and resource limited. All the important parameters and basic assumptions, which are important for the simulated-wireless environment, are defined in Chapter 2.

As outlined in section 2.2, the parameters affecting the temporal fading of each multipath signal are orthogonal factor, transmitted power, receiver gains, Doppler spread, channel impairment and traffic demand. Specifically, the channel model assumes that each multipath signal is subject to frequency-selective, Rayleigh fading in indoor-office, outdoor and pedestrian and vehicular environments. All these parameters are combined into a single power-sensitive W-CDMA model.

6.4 Framework for Uplink Power Control Techniques

Chapter 3 formulates on APC framework systematically. Mathematical derivations and comparisons of existing PC algorithms in standard framework are the highlights of this chapter. From our review of the literature, the APC structure (NPC, OPC and FPC) have not previously been considered in such detail and that the concept of linear-receiver unbalanced and non-linear-receiver, unbalanced structures for APC algorithms is unique in the sense that this is the first time this concept has been investigated. All of the existing PC algorithms in publiched literature up to now can be categorize into this proposed framework system.

The main system parameters that are evaluated are:

- NPC (section 3.4)
    - PC and admission-control (section 3.4.2)
    - PC and base station assignment (section 3.4.3)
- OPC (section 3.5)
    - Linear-receiver SINR-balancing (section 3.5.1.1)
    - Linear-receiver SINR-unbalanced (section 3.5.1.2)
- FPC (section 3.6)
    - Iterative convergence to optimal power vector (section 3.6.2)

Previously, PC algorithms were treated as separated mechanisms, However in this dissertation these PC algorithms have been integrated into a state-of-the-art power-sensitive architecture. The inclusion of iterative decoding techniques was based on a discussion with P.G.W van Rooyen.

6.5 A Multiple-Target Utility-Based PC Strategy

An implementable state-of-the-art QoS-based PC strategy using iterative decoding techniques is presented in Chapter 4. Also included in this chapter are a definition of resources and QoS, and a detailed description of eight FPC algorithms. An analysis of the bounds on the stability of FPC algorithms are also presented.

Two OPC algorithms are also presented with emphasis on the accuracy of the BER-prediction algorithm based on iterative decoding techniques. The Turbo-code algorithm used in the simulation package was programmed by D. van Wyk [126]. The centralized linear-programming optimization problem for OPC algorithms is described, with mathematical equations and block diagrams.

6.6 Numerical Performance Evaluation of Adaptive FPC Algorithms

Having derived the proposed APC structure for the multi-media services of a W-CDMA wireless network, the influence of a number of parameters on each performance measure is described (Chapter 5). Specifically, the influence of power profile, Doppler spread, diversity, coding scheme and number of users in Turbo-coded, RAKE combining and uplink Rayleigh fading channel W-CDMA cellular package of eight FPC algorithms are compared in detailed.

- The influence of the multipath components, Doppler spread, coding scheme, diversity, and number of users was considered in this chapter. The mathematical power-sensitive models used in the evaluation of any adaptive PC system must take all of the mentioned aspects into account in order to obtain an accurate measure of system performance.
- Unbalanced FPC algorithms did not make a significant improvement in AWGN channels because multipath components and Doppler spread were not introduced in the channel model. Unbalanced FPC algorithms outperformed balanced FPC algorithms by decreasing the burst error length.
- Applying convolutional or Turbo-code schemes to AWGN and vehicular, W-CDMA cellular systems improved power efficiency, generally, by about 10 dB with the

different FPC algorithms. When a frequency-selective, Rayleigh, fast-fading channel was introduced in the channel model, there was a significant improvement in BER performance with unbalanced DM and PCM algorithms, especially at high SINR levels.

- It is important to note that the BER is determined mainly by the coding, interleaving and receiver structure, and FPC algorithms not only attempt to narrow the received SINR levels at the base station, but should also correspond to and act as a supplementary mechanism to other receiver structures, to deliver acceptable QoS levels.
- A mediation device is required to provide physical-layer QoS monitoring facility and network-layer RRM decision making facilities. FPC algorithms do not improve the system performance substantially. However, they provide online link QoS monitoring, online resource and interference management, and QoS assurance for adaptation to changes induced by mobility, channel impairment and traffic demand.
- These results show that in a multi-media cellular environment the BER performance at base station is highly unpredictable, stochastic, and the need for a centralized/distributed radio resource management mechanism is a paramount issue.

6.7 Conclusion

This dissertation proposed a new power-sensitive model based on capacity analysis and incorporate APC algorithms to evaluate W-CDMA systems. This model incorporates various physical parameters that influence the performance of power-based W-CDMA cellular systems and makes possible an analytical evaluation of the overall system performance, while at the same time considering a number of physical realities.

Having derived a new PC structure for a multi-media W-CDMA network, the influence of a variety of parameters on each PC structure was determined. Specifically, the number of resolvable multipath components, coding schemes, Doppler spread and number of users were evaluated under a Monte Carlo simulation package in a single-cell, Turbo-coded, RAKE-combining and uplink W-CDMA cellular environment. This dissertation also addressed the trade-off decisions a network operator faces when having to decide whether to implement a physical layer technique or an upper network and management layer scheme to police the link QoS and to increase system capacity. This dissertation shows that optimum performance can be obtained using complete QoS-based PC techniques.