TSG-RAN Working Group 1 (Radio) meeting #7 ***TSGR1#7(99)c33***
Hannover, Germany, Aug. 30-Sep. 3, 1999

**Agenda Item : **(Physical ad-hoc 1 meeting)

**Source : **Shinsegi Telecomm, Inc.[1], Hyundai Electronics Industries, Co., Ltd.

Title : CPM Based Cell Search Scheme for UTRA TDD

**Document for : **Decision

---

1. Introduction

In this contribution, we propose Code Position Modulation (CPM) based cell search scheme for 3GPP TDD This new proposal maintains the existing UTRA TDD slot structure but there exists only primary SCH code signal at each PSCH slot. When the same power is allocated for the SCH, the SNRs of the first step and the second step of this proposal are almost twice that of previously proposed methods because first step and second step of this proposal utilize the same (and only one) SCH.

This document presents the structure of CPM scheme and its receiver algorithm. The performances are compared base on the simulations between CPM and the other schemes (Length 4 CFC scheme and QPSK modulated SSC scheme) which have been discussed in Ad Hoc 1. The 2nd stage complexities of three schemes are also compared. After comparisons, we have found the major merits of CPM scheme over the other schemes as follows:

1) **Cell planning** : Length 4 CFC scheme and QPSK modulated SSC scheme requires different t_{offset} values for different code groups to avoid capture effect between SCH code signals of different code groups. This may cause sophisticated cell planning for W-CDMA TDD operator. In CPM cell search scheme, however, due to the inherent pseudo random time hopping characteristic, cell planning is very simple and flexible.

2) **Stage 1 performance** : CPM scheme has **3 dB performance gain** compared to those of other schemes.

3) **Stage 2 performance** : CPM scheme has 1~2 **dB performance gain** compared to those of other schemes.

4) **Sage 2 complexity** : Because CPM scheme does not need additional parallel correlator or Fast Hardamard Transform, the operation of 2nd stage is very simple compared to Length 4 CFC as well as modulated SSC schemes.

5) **PAR problem** : Because proposed CPM scheme does not need multi-code transmission for secondary code, there is no PAR problem.

2. Slot structure for CPM

Figure 1 shows the TDD frame structure which contains SCH code whose position is modulated by a time hopping code elements. As we can see, there is only one SCH code signal.

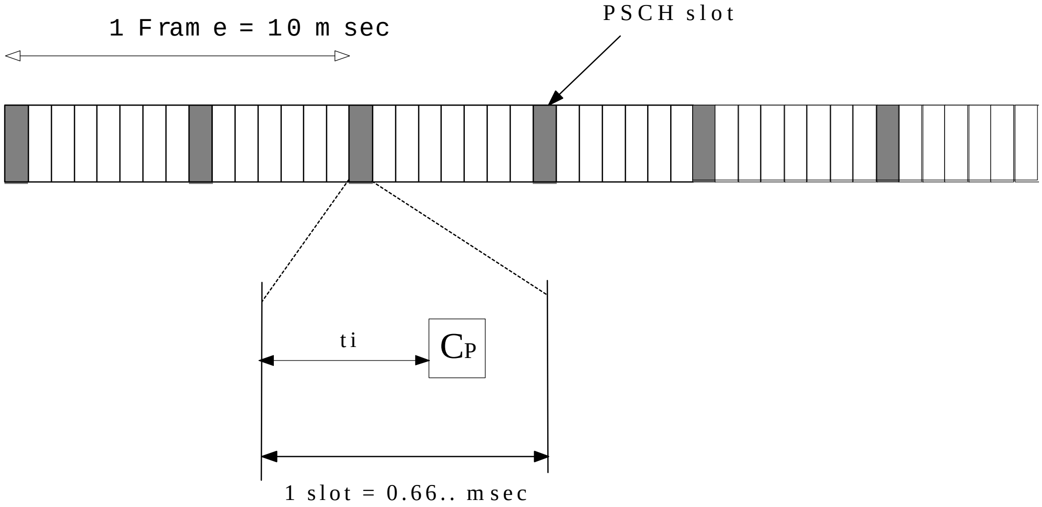

Figure 1. Frame structure

Where $t_i = C_{i,n} \cdot d$,

d : minimum resolution for time hopping (minislot)

$C_{i1}\ C_{i2}\ C_{i3}\ C_{i4}\ C_{i5}\ C_{i6}\ C_{i7}\ C_{i8}$: time hopping code sequence for long code group i (code length is 8)

$$\delta = T_c \left\lfloor \frac{2560-96-256}{31} \right\rfloor = 71T_c$$

The structure of synchronization channel (SCH) for CPM scheme is characterized by the following parameters.

- For case 2 and case 3, 2 SCH codes per frame are transmitted and for case 1 1 SCH code per frame is transmitted.
- The length of hopping code is 8 (4 frames for case 2 and case 3, 8 frames for case 1).
- The alphabet size of hopping code is 32
- The number of minislot per slot is 32

In the proposed method, the long code groups, which used in the system, are distinguished by different time hopping codes. In Tdoc R1-99c34 [3], we present the detailed time hopping codes for 32 groups as well as 256 groups. The time hopping code set for 32 groups are a subset of that of 256 groups.

3. CPM Receiver Algorithm

Typical 3 step receiver algorithm of CPM for TDD which utilizes 10 msec (2 slots) averaging for stage 1 and 20 msec (4 slots) averaging is shown in Figure 2.

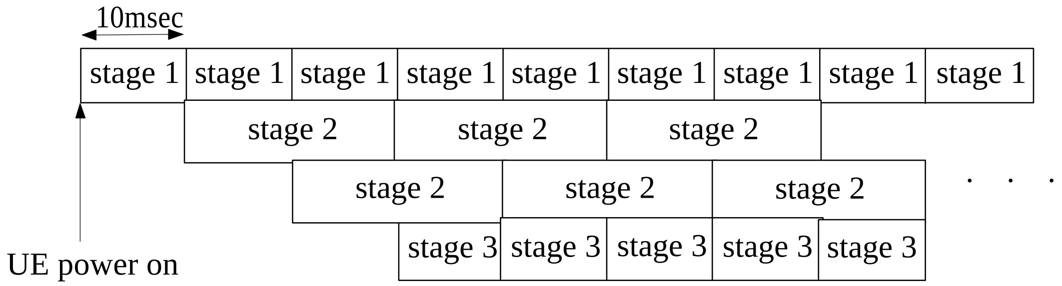

Figure 2. Typical 3 step CPM receiver algorithm.

Every 10 msec, the stage 1 process gives one candidate for further verification in stage 2. Stage 2 takes the candidate from stage 1 and memories 63x6 matched filter outputs via 20 msec corresponding to stage 1 hypothesis and using this values, UE performs simple RS code decoding. The detailed CPM receiver algorithm for stage 1 and stage 2 is shown in figure 3. The length for stage 2 is receiver option and figure 2 is one example which has 4 slots for stage 2. We guess that appropriate length for stage 2 of CPM scheme is 4~7 slots for case 2. For more detail how can CPM scheme get frame boundary as well as long code group ID in stage 2, refer to [1].

Stage 1 (10msec)

UE selects 1 peak and corresponding position among 38400 candidates

Stage 2 (20 msec)

UE memorizes 63x6 matched filter outputs via 20 msec correspoding to stage 1 hypothesis and using this values, calculates 32x8 decision variables. And selecting the max among them, UE can identify the Long Code Group and exact frame boundary as well as frame number.

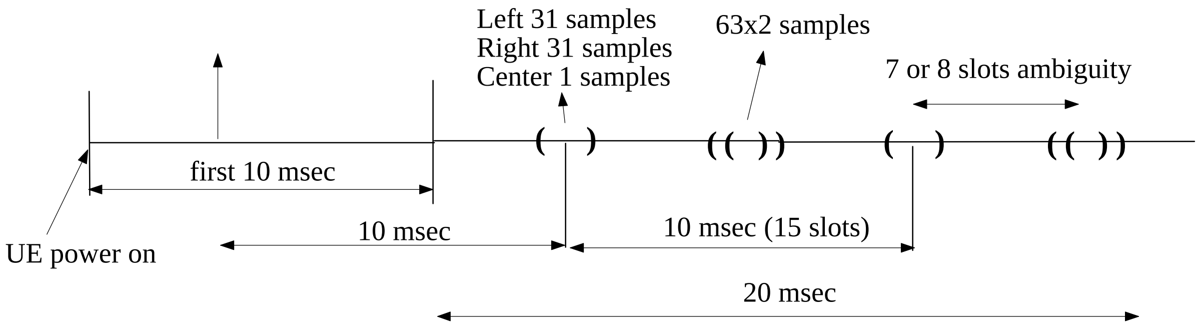

Figure 3. Detailed CPM receiver algorithm (4 slots for stage 2)

Figure 4 is another example of CPM receiver algorithm in which the averaging length for stage 1 is 20 msec.

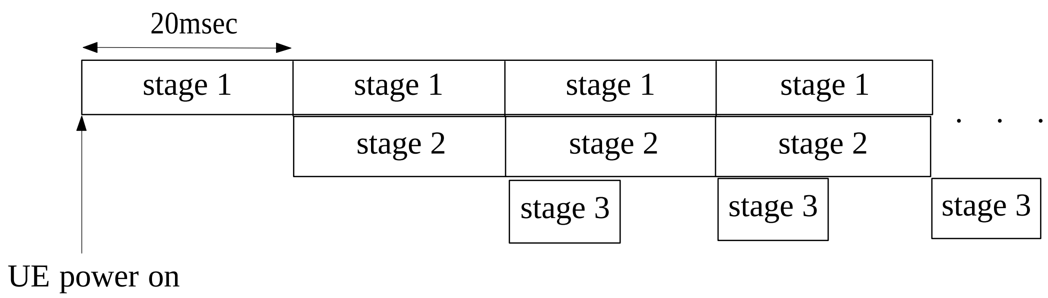

Figure 4. Another example of CPM receiver algorithm.

4. Complexity Comparison

The complexity of stage 1 and 3 of acquisition is the same for all the 3 schemes. We therefore compare only the second stage complexity. For fair comparison, we utilized most recently updated version for CFC scheme as well as modulated SSC scheme. That is, we used L4-CFC scheme [6] instead of L2-CFC shcme [5] and used QPSK modulated SSC scheme [8] instead of BPSK modulated SSC shcmee [7].

In the complexity calculation, we assume 4 slots averaging case

1. CPM

CPM scheme requires 32×8×3 = 768 real additions and 32×8-1 = 255 comparisons for the case 2 of TDD cell search with 4-slot accumulation. CPM scheme can figure out frame boundary and the position of the frame within an interleaving period of 20 msec as well as long code group. To perform stage 2 operation of CPM scheme 256×8×3 = 6144 real additions and 256×8-1 = 2047 comparisons for the case 3 with 4-slot accumulation.

2. Modulated SSC

The complexity of modulated SSC scheme can be obtained as follows for the case 2. In this case we assumed 2 sets of 4 SSC's.

1) Coherent detection of SSC's

   $4\times\{2\times32\times7 + 2\times32\log_2 32 + 1 + 8\times2\} = 3148$ real additions

   $4\times\{4 + 8\times4\} = 144$ real multiplications

2) Accumulation of correlation values of SSC's for 4 slots

$2 \times 8 \times 3 = 48$ real additions

3) Decision variables

$2 \times 7 = 14$ real additions

2 comparisons

Therefore modulated SSC method should perform 3210 real additions, 144 real multiplications, and 2 comparisons for the case 2.

3. Length 4 CFC

For the case 2, the complexity of length 4 CFC is calculated as follows. We assumed that 7 SSC's are used to distinguish 32 long code groups and the position of frame.

1) Coherent detection of SSC's

$4 \times \{2 \times 32 \times 7 + 2 \times 32 \log_2 32 + 1 + 7 \times 2\} = 3132$ real additions

$4 \times \{4 + 7 \times 4\} = 128$ real multiplications

2) Calculation of decision variables

$4 \times (128/2) = 256$ real additions

3) Accumulation of decision variables for 4 slots

$128 \times 3 = 384$ real additions

4) Selection of maximum value

$128 - 1 = 127$ comparions

Length 4 CFC requires 3772 real additions, 128 real multiplications, and 127 comparisons for the case 2.

Following table (Table 1) gives the summary of the complexity of stage 2 for the case 2 and 3.
For the case 3, we assumed that for modulated SSC 2 sets of 7 SSC's are used and that 17 SSC's will be selected among 32 candidates for length 4 CFC.

In the above calculations it was assumed that the position of slot was known except for CPM.

Table 1. Comparison of the complexities of 2nd stage of three schemes(4 slot averaging case)

	CPM	**L4-CFC**	**QPSK modulated SSC**
Case 2	768 real additions 255 comparisons	3772 real additons 128 real multiplications 127 comparisons	3210 real additions 144 real multiplications 2 comparisons
Case 3	6144 real additions 2047 comparisons	8332 real additions 288 real multiplications 1023 comparisons	3298 real additions 240 real multiplications 2 comparisons

5. Simulation Condition

The simulation condition is based on the Tdoc A52 which proposed by TI and Inter Digital in the last meeting. For fair comparison as in the complexity comparison case in the chapter 4, we utilized most recently updated version for CFC scheme as well as modulated SSC scheme. That is, we used L4-CFC scheme [6] instead of L2-CFC shcme [5] and used QPSK modulated SSC scheme [8] instead of BPSK modulated SSC shcmee [7].

In our simulations, the following conditions and assumptions are used.

1. Synchronization time is 20 msec (4 slot averaging) for stage 1 and 10~20 msec (4 or 7 slots for CPM and 4 or 8 slots for L4-CFC) for stage 2 of both schemes.
2. No over-sampling and optimal sampling time.
3. Coherent detection is used for stage 2 of L4-CFC scheme
4. T_{gab} for L4-CFC is –256 chips, that is PSC code and SSC code are collocated.
5. No quantization is applied to the received signal.
6. The power for SCH signal is evenly divided for Primary SCH and Secondary SCH in the L4-CFC.
7. GHG code is used for PSC codes of both schemes and Hardmard code multiplied by GHG code is used for secondary code of L4-CFC.

The above condition is the same as that of Tdoc A52.
For fair comparison, the CNR is defined as the ratio between total synchronization channels and total interference. So that for the L4-CFC scheme and QPSK modulated SSC scheme,

$$CNR = (P_{PSC}+P_{SSC})/I$$

And for the CPM scheme,

$$CNR = P_{PSC}/I$$

Where P_{PSC} is the power for primary SCH code signal and P_{SSC} is that for secondary SCH code signal.

5-1 stage 1 performance

We assumed that the synchronization time for the stage 1 is 20 msec, that is, 4slot averaging was used for stage 1 simulation. This means that one peak position among 38400*2 candidates was selected in the stage 1.
There are 4 correct SCH code positions among 38400*2 candidates. So if we select one of 4 correct SCH code positions, then it is declared success otherwise fail. The synchronization error rate in stage 1 is defined as the probability of the failing to detect the correct SCH code positions. In the multi-path environment (that is, vehicular A environment), we assumed that if the mobile finds the strongest path or the other one which is within 3dB from the strongest path (in the average sense), then it is declared success otherwise fail. In vehicular A model, the second path has –1 dB less power than that of the first path, so we also assumed the 2nd path as correct path in addition to the 1st path. In the vehicular A environment, we also assumed that multipath interference obtained according to ITU model. And in the L4-CFC scheme and QPSK modulated SSC scheme, SSC interference to PSC is included.

Figure 5 indicates the stage 1 performances of three schemes in the AWGN channel environments and figure 6 and figure 7 indicate the stage 1 performance of three schemes in the vehicular environments. We can notice that CPM scheme has 3 dB gain over Length 4 CFC scheme and QPSK modulated SSC scheme for all the channel condition.

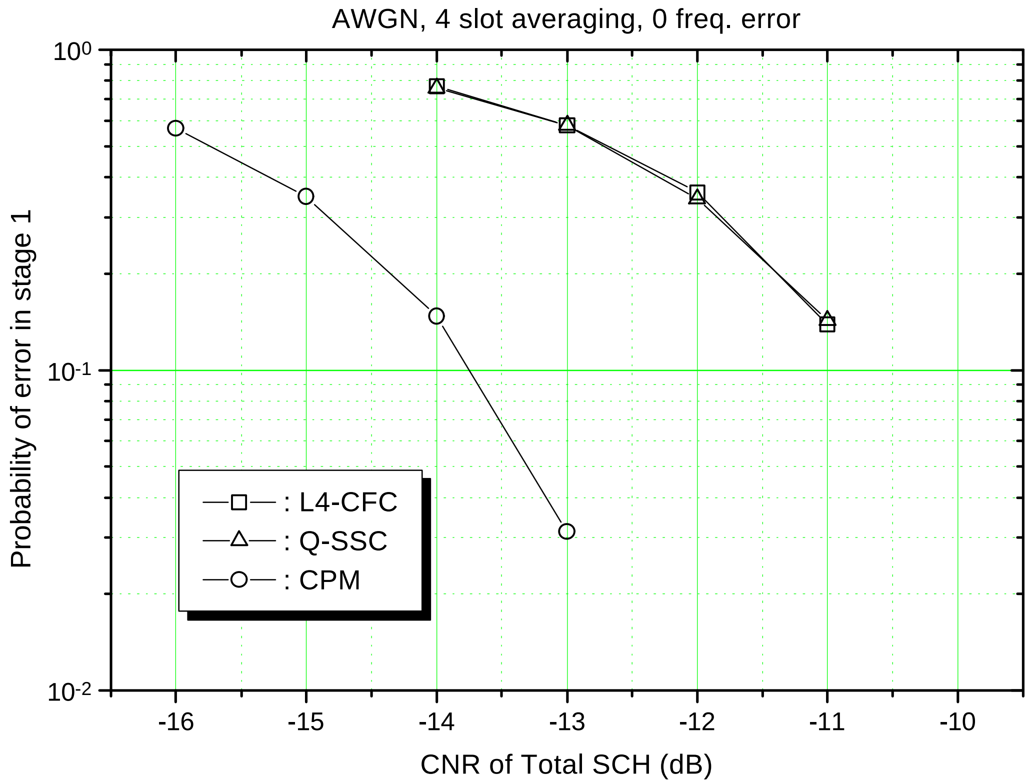

Figure 5. Performance of stage 1 in AWGN without frequency offset.

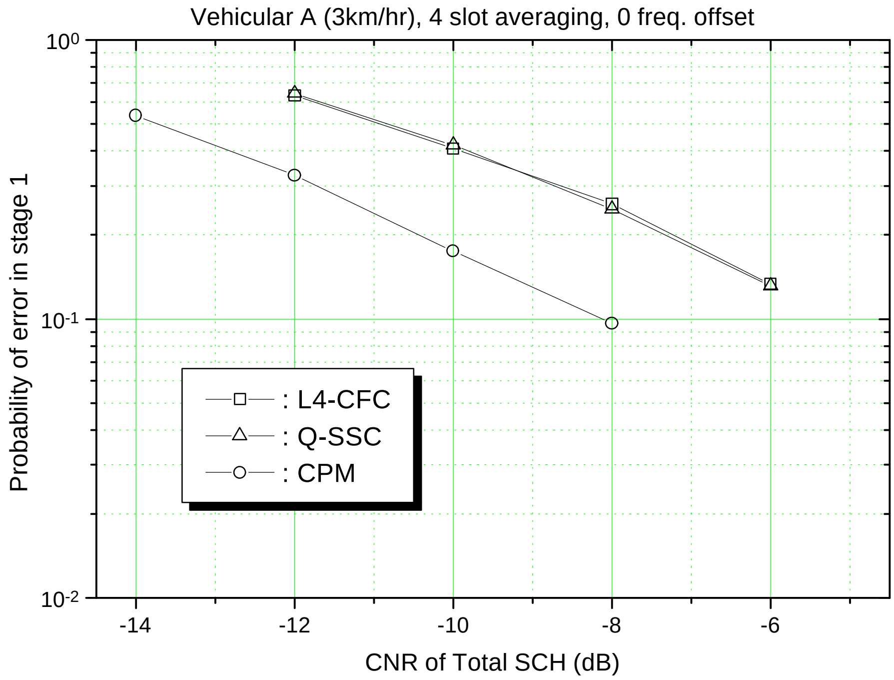

Figure 6. Performance of stage 1 in multi path environment without frequency offset.
(3 km/hr vehicle speed)

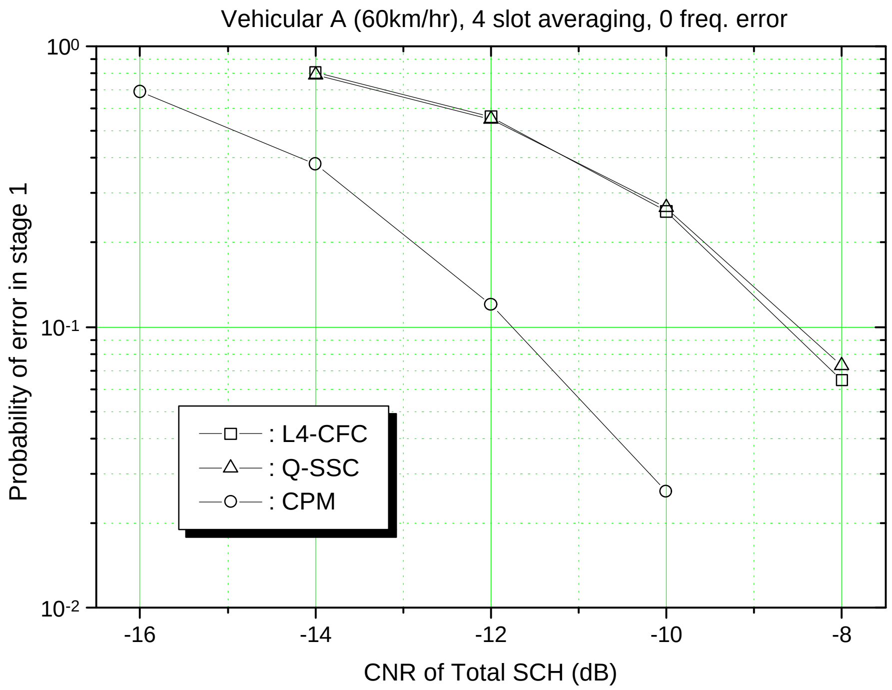

Figure 7. Performance of stage 1 in multi path environment without frequency offset.
(60 km/hr vehicle speed)

5.2 Stage 2 performance

We assumed T_{gab} = -256 and coherent detection for Length 4 CFC in this simulation. Also, it was assumed that stage 2 of all schemes take the correct SCH code position from the stage 1. In the vehicular A environment, we assumed that the stage 1 identifies the strongest path perfectly and multipath interference obtained according to ITU model. In the L4-CFC scheme and Q-SSC scheme, PSC interference to SSC is included.

15 slot frame structure (OHG slot structure) was used for this simulation. In the 16 slot frame structure, the distance between adjacent PSCH slots was uniform as 8 slot interval but in 15 slot structure (OHG structure), the distance is 7 or 8 slots. So there is the ambiguity of the 7^{th} or the 8^{th} slot for calculating the decision variables in the every odd slot position. The decision variable which has odd number of cyclic shift is based on the assumption of 7^{th} slots position but the decision variable which has even number of cyclic shift is based on the assumption of 8^{th} slot position.

The performance of 15slot case is slightly better than 16slot case. Anyway, in this simulation, we used 15 slot structure for L4-CFC scheme as well as CPM scheme for stage 2 (in previous simulation [1] we used 16 slots for stage 2 of both schemes).

The number of decision variable for L4-CFC is 128 (=32x4) and that for CPM is 256 (=32x8) since the number of groups used in this simulation is 32 for both schemes and the comma free code lengths for each scheme is 4 and 8 respectively.

For the Q-SSC scheme, we assumed 2 cases. The one is the known case of two slot in a frame and the other is unknown case. Known case means that the UE a priory knows the 2 SCH code positions in a frame and unknown case means that there is the ambiguity of the 7th or the 8th slot.

Section 5.2.1 is the simulation results for the test case which defined in Tdoc A52 [6]. Section 5.2.2 and 5.2.3 are the simulation results for the case 2 (32 groups) and the case 3 (256 groups). For QPSK modulated SSC scheme, we only included the test case.

Figure 8, 9 and 10, in the sub section 5.2.1, shows the stage 2 probability of error versus CNR of total SCH signal. We can notice that the performance of L4-CFC is almost the same as that of known case of Q-SSC scheme. But there is a little bit performance degradation of the unknown case of Q-SSC scheme compared to L4-CFC scheme in the fading channel. We also see that the CPM scheme has almost 2 dB gain compared to the other schemes in AWGN channel and 1~1.5 dB gain in the single path independent Rayleigh fading channel with 6 KHz frequency offset.

The performance of stage 2 for simulation condition (2), that is, 32 group case, is plotted in figure 11 through 16. Figure 11 and 12 indicates the AWGN performance with and without frequency error and the other figures indicate the performance in Rayleigh channels. It can be seen from these figures that the CPM scheme performs about 1~2 dB that the L4-CFC scheme.

The performance of stage 2 for simulation condition (3), that is, 256 group case, is plotted in figure 17 through 22.
It can be seen from these figures that the CPM scheme also outperforms than the L4-CFC scheme in the 256 group case.

5.2.1 Test Case

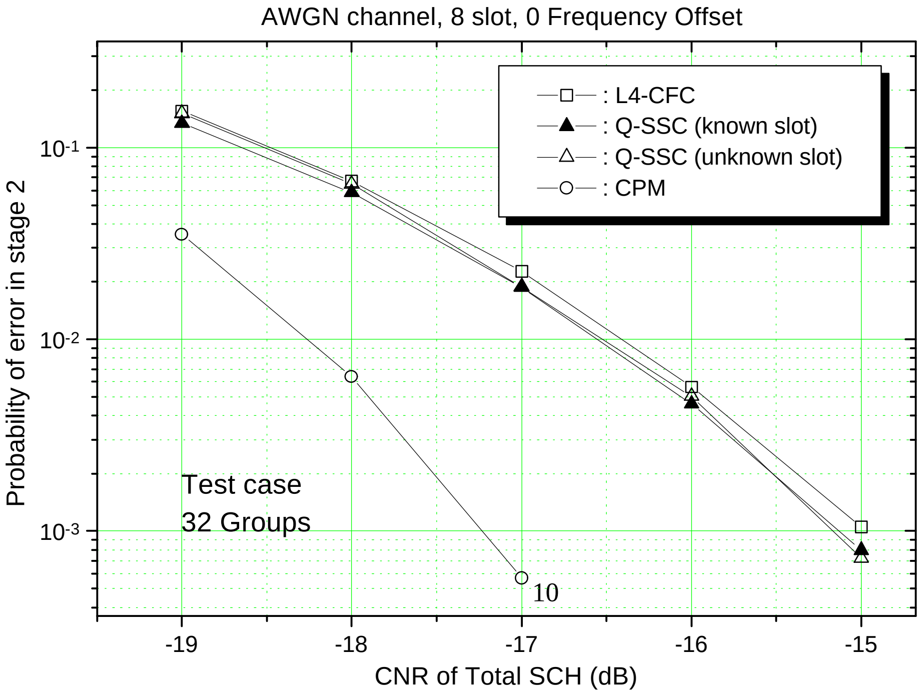

Figure 8. Performance of stage 2 in AWGN channel without frequency offset.
(Test Case, 8 slot averaging (7 slots for CPM), 32 groups)

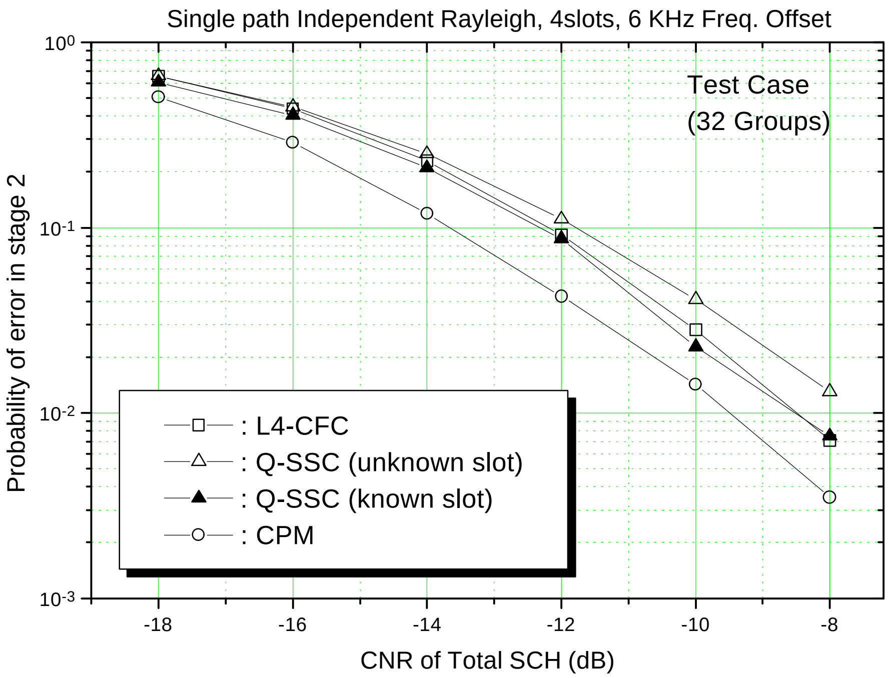

Figure 9. Performance of stage 2 in single path independent fading channel

(with 6 KHz frequency offset. Test case, 4 slot averaging, 32 groups)

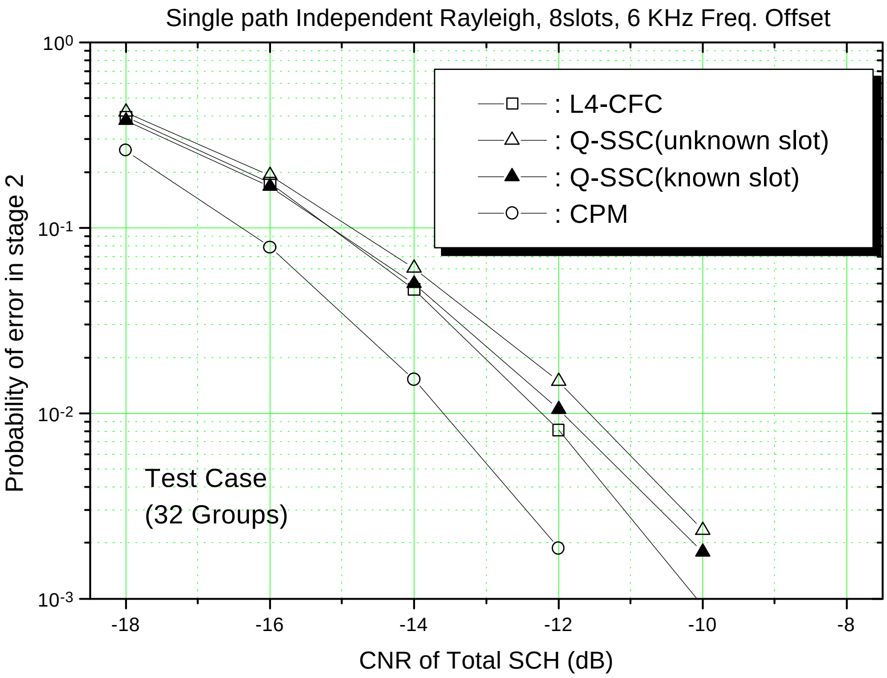

Figure 10. Performance of stage 2 in single path independent fading channel
(with 6 KHz frequency offset. Test case, 8 slot averaging (7 slot for CPM) , 32 groups)

5.2.2 (2) Simulation : 32 Groups

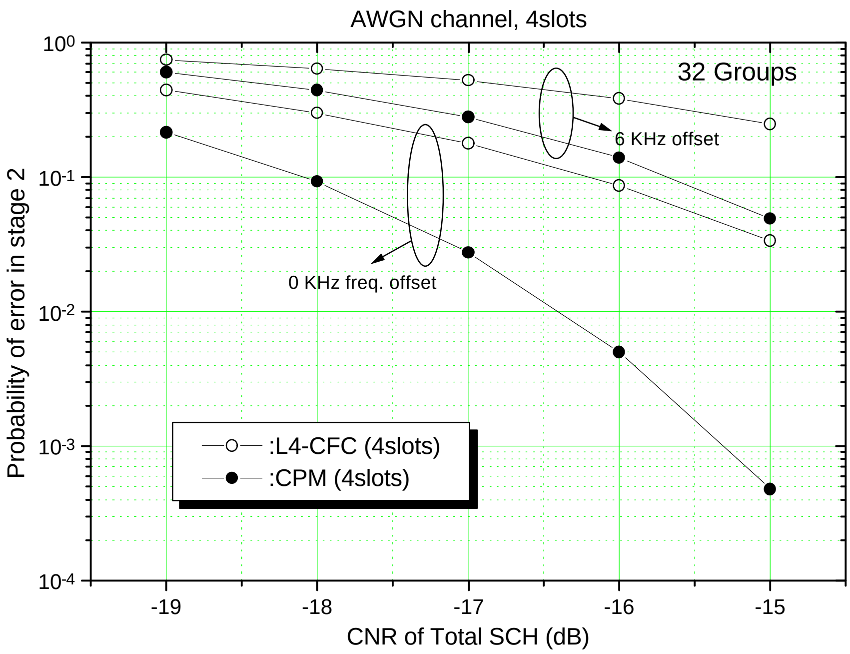

Figure 11. Performance of stage 2 in AWGN channel with and without frequency offset.

(32 groups, 4 slots averaging for stage 2)

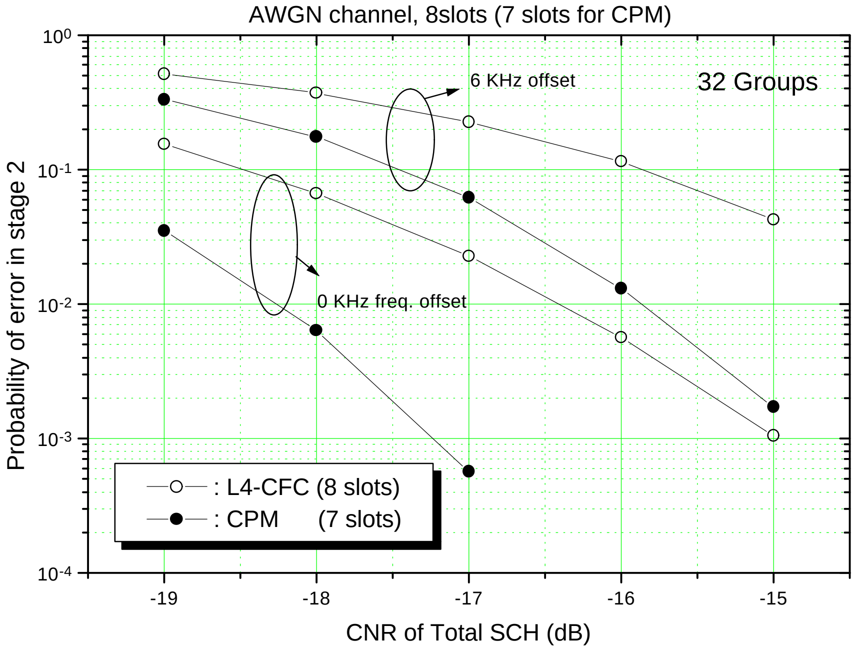

Figure 12. Performance of stage 2 in AWGN channel with and without frequency offset.
(32 groups, 8 slots (7 slots for CPM) averaging for stage 2)

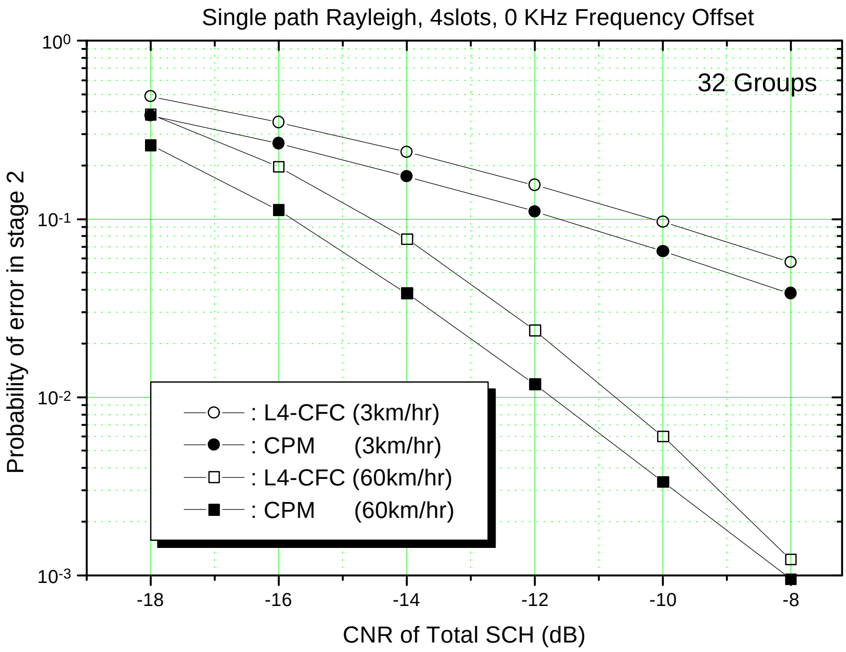

Figure 13. Performance of stage 2 in single path fading channel.
(32 groups. Single path Rayleigh fading channel model, 0 KHz frequency offset)

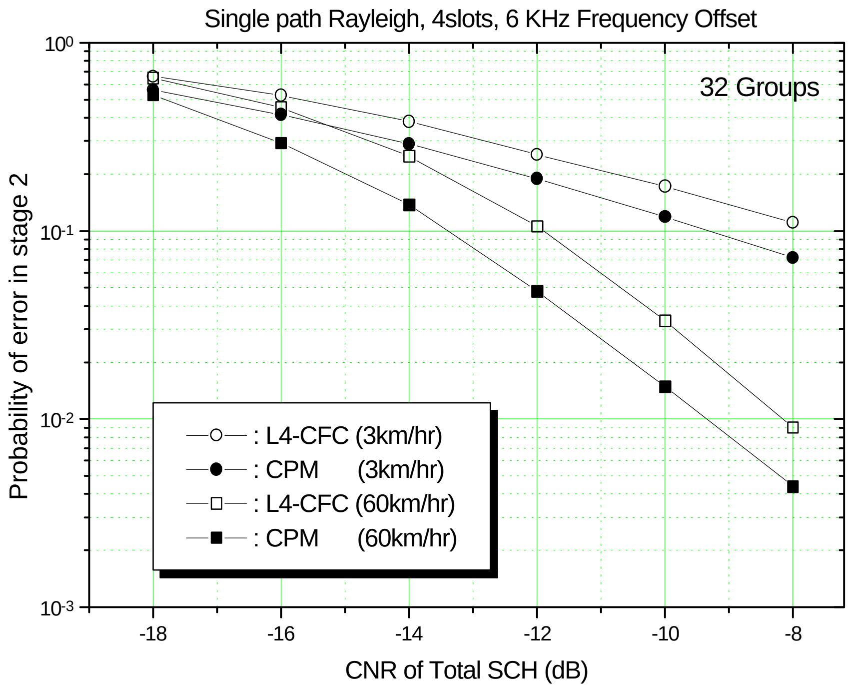

Figure 14. Performance of stage 2 in single path fading channel.
(32 groups. Single path Rayleigh fading channel model, 6 KHz frequency offset)

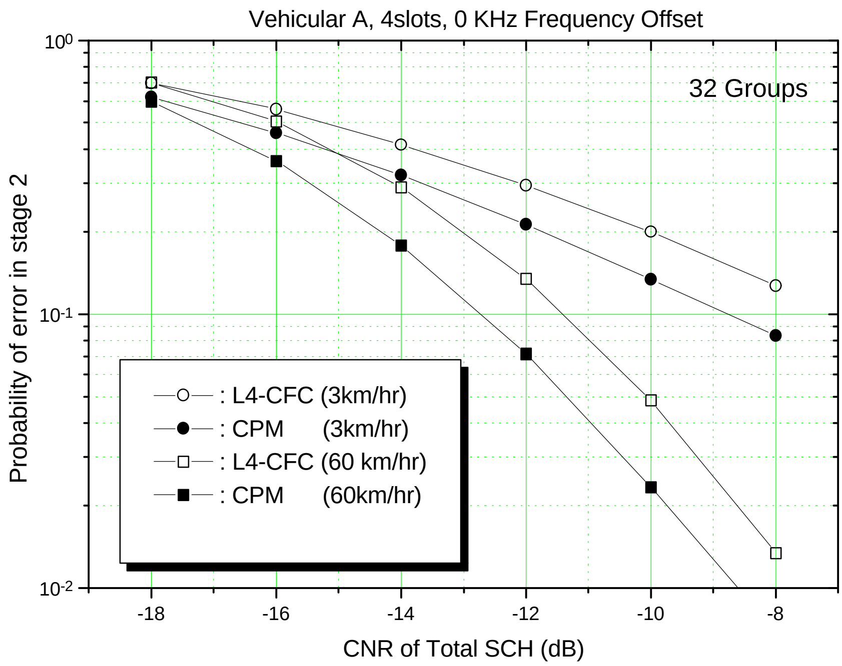

Figure 15. Performance of stage 2 in multipath environment.
(32 groups, vehicular A model, 0 KHz frequency offset)

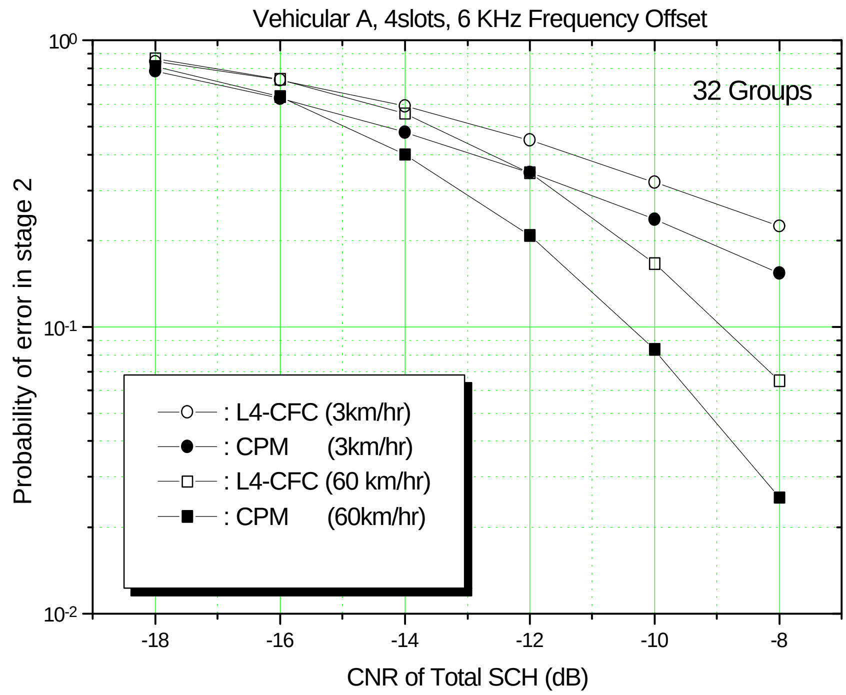

Figure 16. Performance of stage 2 in multipath environment.
(32 groups, vehicular A model, 6 KHz frequency offset)

5.2.3 (3) simulation : 256 Groups

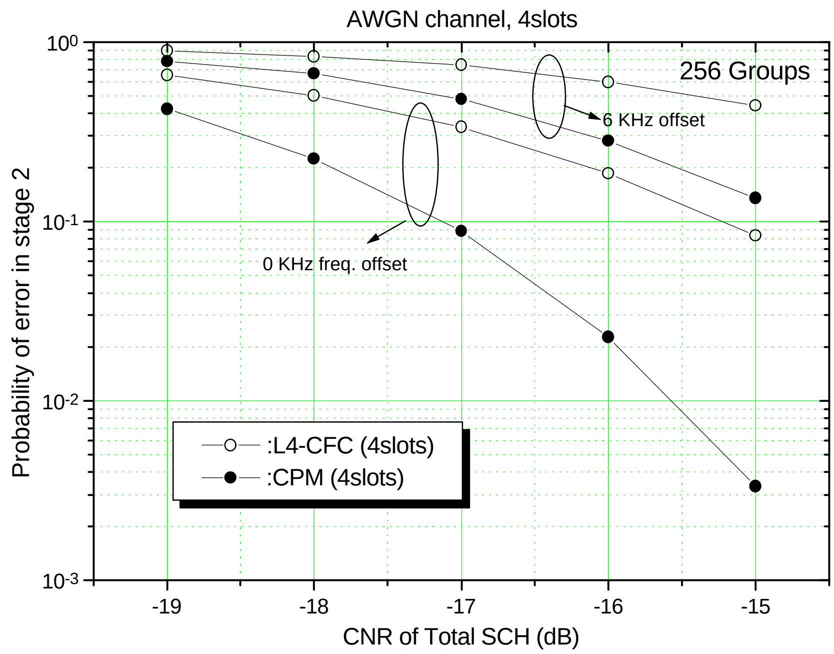

Figure 17. Performance of stage 2 in AWGN channel.
(256 groups, "0" frequency error)

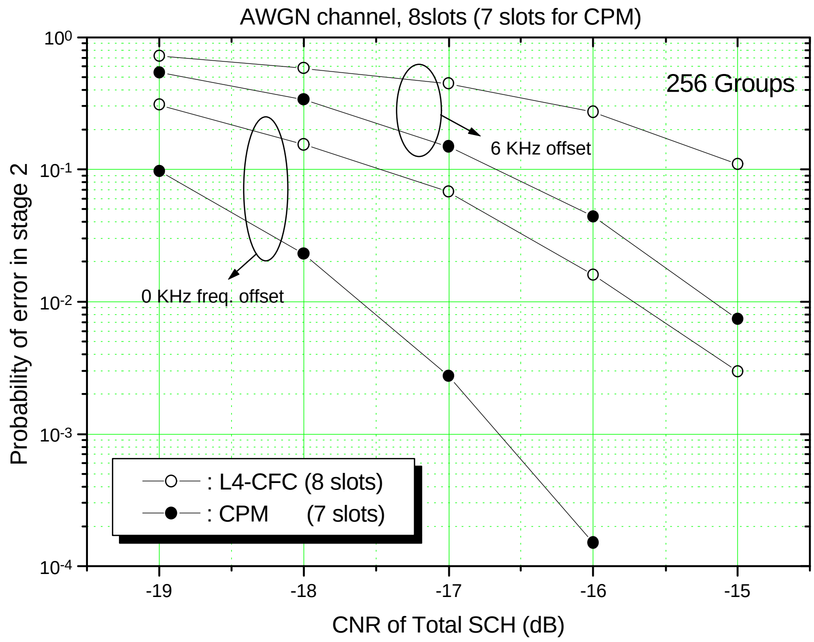

Figure 18. Performance of stage 2 in AWGN channel.
(256 groups, "0" frequency error)

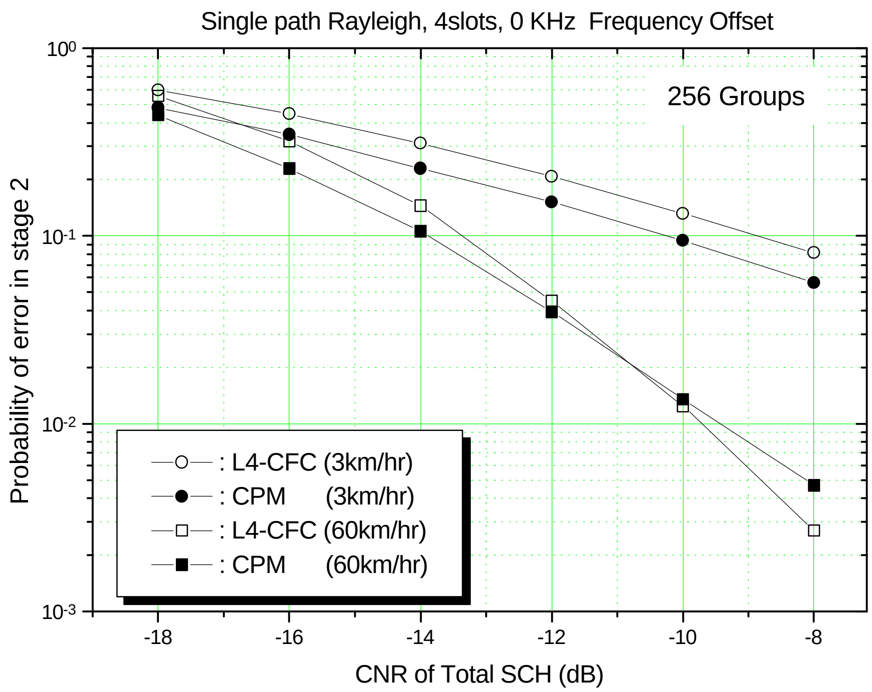

Figure 19. Performance of stage 2 in single path fading channel.
(256 groups, single path Rayleigh fading channel model, 0 KHz frequency offset)

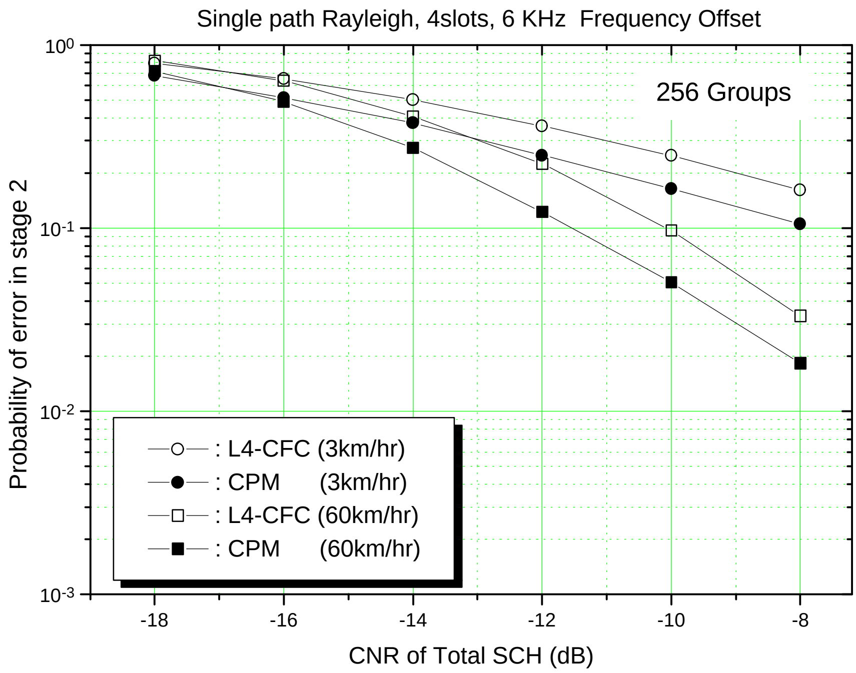

Figure 20. Performance of stage 2 in single path fading channel.
(256 groups, single path Rayleigh fading channel model, 6 KHz frequency offset)

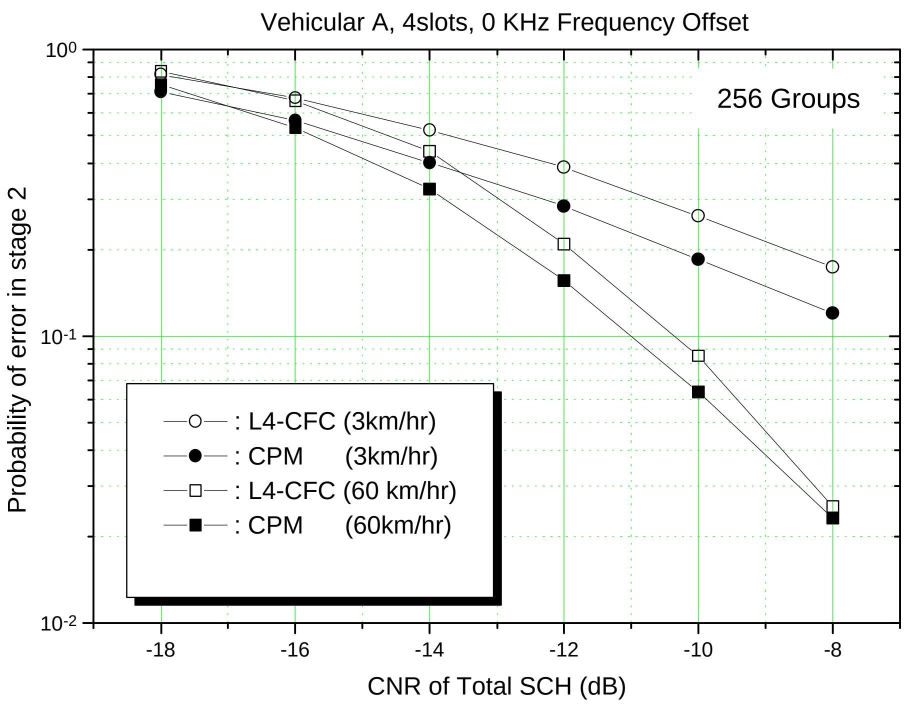

Figure 21. Performance of stage 2 in multi path fading channel.
(256 groups, vehicular A model, 0 KHz frequency offset)

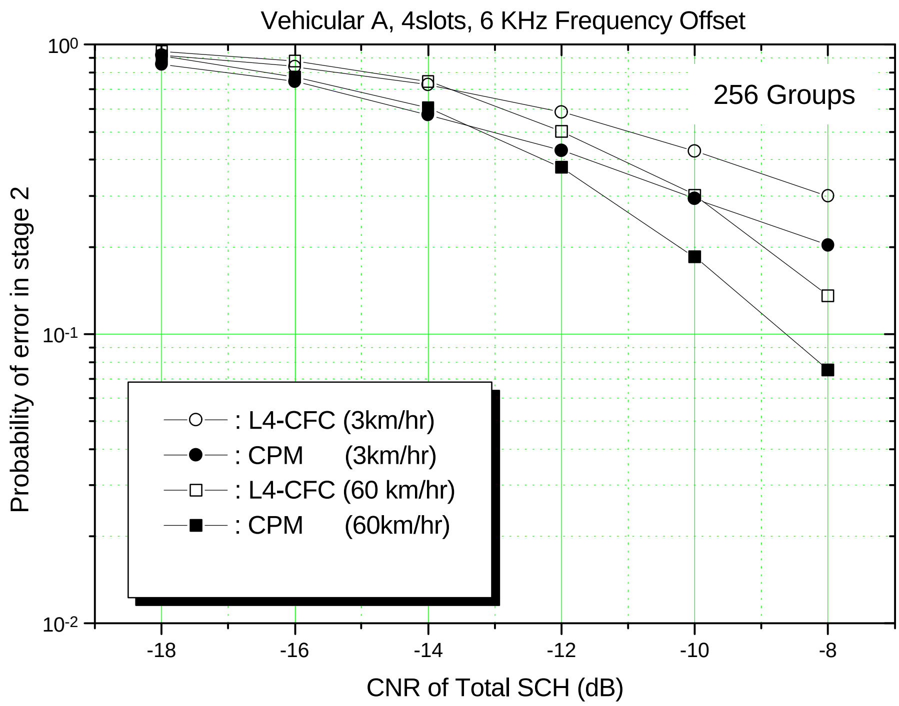

Figure 22. Performance of stage 2 in multi path fading channel.
(256 groups, vehicular A model, 6 KHz frequency offset)

6. Conclusion

In this document, we proposed CPM based cell search scheme for UTRA TDD and compare the performance of that with length 4 CFC scheme as well as QPSK modulated SSC scheme. From the simulation, it was shown that the CPM scheme has 3 dB or more gain in stage 1 and 1~2 dB gain in stage 2 compared to L4-CFC scheme and QPSK modulated SSC scheme . This means that CPM scheme has the same performance as that of the other schemes with only 2~2.5 dB less power in terms of total SCH power.

Also note that, with CPM scheme, cell planning is very simple and flexible. For example, with CPM scheme, it is possible to locate two cell cites, which have the same long code group ID, in the close area. But with the L4-CFC scheme or with modulated SSC scheme, the two cell cites should be far apart in order to avoid capture effect between SCH code signals from the two cells. And in L4-CFC scheme or in modulated SSC scheme, cluster concept should be adopted but this may require complex cell planning. In CPM scheme, however, cluster concept does not need.
And with CPM scheme, the SCH code positions vary in each PSCH slot, so it is possible to minimize the periodical interference to other fields. In addition, because proposed CPM scheme does not need multi-code transmission for secondary code, there is no PAR problem.

References

[1] "CPM based Fast Cell Search Algorithm", Tdoc SMG2 UMTS-L1 634/98, Dec..14-18, Inc., Espoo, Finland, Shinsegi Telecomm.

[2] "Performance and Complexity Comparison of Enhanced CPM and Current 3GPP Cell Search Schemes", TSGR#5(99)659, 2-4 June.1999, Cheju, Korea, Shinsegi Telecomm. and Hyundai Electronics

[3] "TDD Cell Search Text Proposals for 25.221, 25.223 and 25.224 (CPM Based Cell Search Scheme)", TSGR#7(99)c34, Aug. 30-Sep. 3, 1999, Hannover, Germany, Shinsegi Telecomm. and Hyundai Electronics

[4] "Simulations parameters for cpmaring modulated SSC and CFC 2 techniques for UTRA TDD synchronization", TSGR1#6(99)A52, July 13th ~16th 1999, Espoo, Finland.

[5] "A New Comma Free Code scheme for TDD Synchronization", TSGR1#6(99)815, Texas Instruments.

[6] " Adhoc 1:SCH codes for TDD, simulation parameters", E-mail discussion document, Mon ,26 July 1999, Texas Instruments.

[7] "A BPSK Modulated Secondary Synchronization Codes based Cell Search in UTRA TDD", TSGR1#5(99)578, InterDigital Comm. Corp.

[8] "QPSK Modulated Secondary Synchronization Codes (SSC) Algorithm", E-mail contribution, August 9, 1999. InterDigital Comm. Corp.