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

Title : Performance and Complexity Comparison of Enhanced CPM and Current 3GPP Cell Search Schemes

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1. Introduction

CPM (code position modulation) scheme was proposed in December 1998 [1,2] as an alternative method to the current cell search scheme which has 2 SCH structure. At that time, the commonly known receiver algorithm for the 3GPP scheme was based on 30 msec accumulation length in stage 1 and non-coherent stage 2. The original CPM scheme has better performance than the 3GPP cell search scheme using that algorithm. But current 3GPP cell search scheme proponents adopt coherent 2nd stage and longer accumulation time in stage 1 (larger then 100 msec) especially for the target cell search. So, the performance of 3GPP scheme becomes almost the same as original CPM scheme. Currently coherent 2nd stage, overlapping problem and longer accumulation time (that is, larger than 50 msec) of 3GPP scheme are pending issues in Ad-hoc 12. Also we do believe that the coherent 2nd stage and longer accumulation time of 3GPP scheme has many problems in real environment.

Anyway, we have optimized the CPM scheme, and found efficient structure which gives almost 3dB gain over original CPM scheme with much less receiver complexity. We call this new CPM scheme as ECPM (enhanced CPM) scheme hereafter.

This document presents the structure of ECPM scheme and its receiver algorithm. The performances are compared by the simulations and the complexity is compared by analyses between ECPM and the current 3GPP schemes. After comparisons of the performance and complexity of the two schemes, we have found the major merits of ECPM scheme over current 3GPP scheme as follows:

1) Initial Cell Search Case: ECPM scheme has almost **3 dB performance gain** compared to that of current 3GPP cell search scheme in terms of total SCH power loading.

2) Target Cell Search Case: ECPM scheme has almost **2.5 to 3 dB performance gain** compared to that of current 3GPP cell search scheme in terms of total SCH power loading.

3) The required memory read/write operations per frame of ECPM receiver is less than **1%** of that of current 3GPP cell search scheme for initial cell search, and is **1% to 8%** for target neighbor cell search. (Current 3GPP cell search scheme requires (5120+17x(2))x16 memory read/write operations per frame in stage 1 and, this may consume very much power besides matched filter operations itself.)

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4) The inherent pseudo random time hopping characteristics let CPM **free from overlapping problem**. Current 3GPP scheme, however, should adopt sophisticated interference cancellation technique in stage 1 to avoid overlapping problem. In addition, if current 3GPP scheme adopts coherent stage 2, then there are no way to detect target cell over-lapped with home cell. In addition, CPM scheme is **robust to the clock drift** and hence its performance is hardly affected by clock drift. But in order to enhance the performance, current 3GPP scheme also should adopt longer accumulation time in stage 1 (that is, at least 100 msec). This should be heavily dependent on clock drift due to high vehicle speed and/or clock difference between locked base station and target base station.

5) The SCH signal can be transmitted through the two antennas with a half power in each antenna because the noncoherent detection is used in the CPM receiver. However, current 3GPP scheme cannot use this transmission diversity if coherent detection is utilized in 2nd stage.

2. ECPM Scheme Structure and its Receiver Algorithm

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

- 4 codes per frame are transmitted. [16 for the original CPM]
- The length of hopping code is 4 and the alphabet size is 160. [16 and 20 for the original CPM]
- The length of minislot is 64 chips. [128 for the original CPM]
- The number of minislot per slot is 40. [20 for the original CPM]
- The maximum hitting between codewords is 1. [4 for the original CPM]

The down-link SCH structure of ECPM scheme is given in Figure 1.

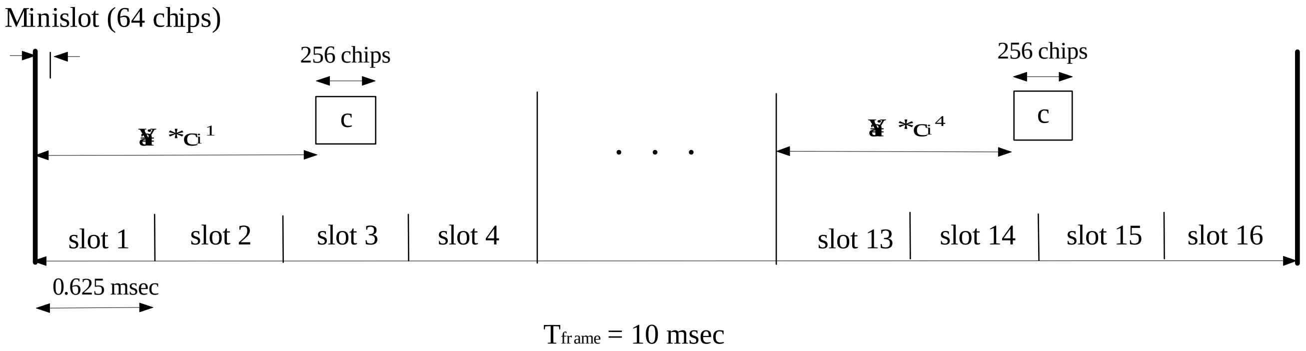

Figure 1. Down-link Synchronization Channel structure of ECPM scheme.

For ECPM scheme, the number of SCH code symbols transmitted on the down link SCH is only 4, which is one of the most distinguishing parameters from the original CPM[1,2] transmitting 16 SCH code symbols per frame.

The four-symbol SCH in ECPM enables the reduction of the number of decision variables for stage 2 up to 1/4, and the decrease of number of Add operation and Memory Read/Write operation in stage 2. When the same power per frame is allocated to SCH signal, the detection probability in stage 1 of ECPM scheme is greater by 3 dB than that of original 16-symbol CPM, because the instantaneous power is quadrupled in ECPM.

3. ECPM Receiver Algorithm and Receiver Complexity

3.1 Initial Cell Search

An example receiver algorithm of ECPM in case of initial cell search is shown in Figure 2.

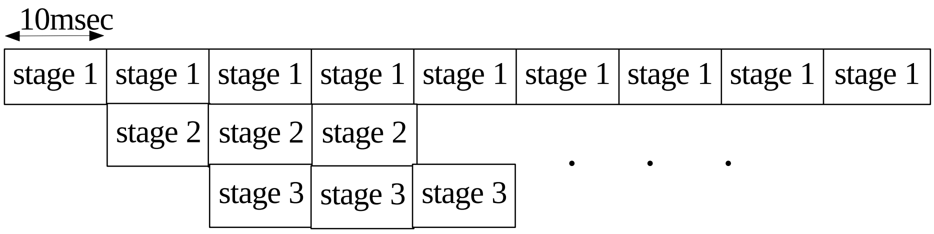

Figure 2. ECPM receiver algorithm for initial cell search (one example).

There can be two Options in the operation of this receiver algorithm.

3.1.1 Option 1: Run 2nd stage hypotheses without memorizing the matched filter output

- Stage 1 (1st 10 msec): Select L peaks and corresponding positions among 40960 candidates.
- Stage 2 (2nd 10 msec): At every 64 chip point corresponding to respective stage 1 candidates, add the matched filter output to a decision variable which has corresponding hypothesis to that position. So, 4xG_{INI}xL memories are required for memorizing the decision variables. And 4x4xG_{INI}xL memory reads/writes operations are required per frame, where G_{INI} is the number of Group for initial cell search.

The detailed ECPM receiver algorithm for Option 1 with L of 1 is depicted in Figure 3.

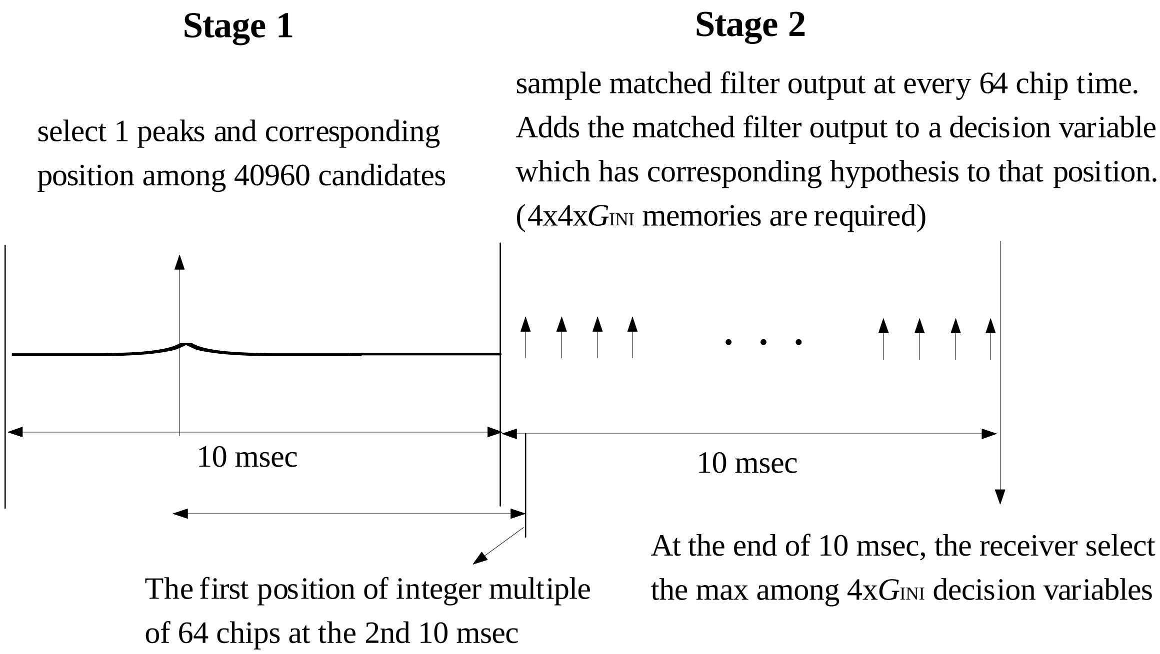

Figure 3. Detailed ECPM receiver algorithm for initial cell search (Option 1).

3.1.2 Option 2: Memorize the matched filter output and then run 2nd stage hypotheses

- Stage 1 (1st 10 msec): Select L peaks and corresponding positions among 40960 candidates.
- Stage 2 (2nd 10 msec): Memorize 640 matched filter output samples (64 chip resolution) corresponding to respective stage 1 candidates. So, 640xL memories are required. And 640xL memory reads/writes are required per frame. Finally, 2nd stage hypothesis tests are performed using G_{INI} time hopping codes and 640xL sample values, where G_{INI} is the number of Group for initial cell search.

The detailed ECPM receiver algorithm for Option 2 with L of 1 is depicted in Figure 4.

For Option 2, the receiver has a very simple algorithm and required memory is independent of the number of Group. However, the memory requirement could be larger than for Option 1 when the number of Group gets smaller. On the other hand, Option 1 has more or less complicated algorithm, but the required memory and Read/Write operation per frame gets reduced as the number of Group becomes smaller. Which Option is used in the real mobiles depends upon the manufacturers.
As the Figures show, Options 1 and 2 have the same stage 1 and the memory resets are not needed because only L peaks and their corresponding positions are sufficient for stage 1.

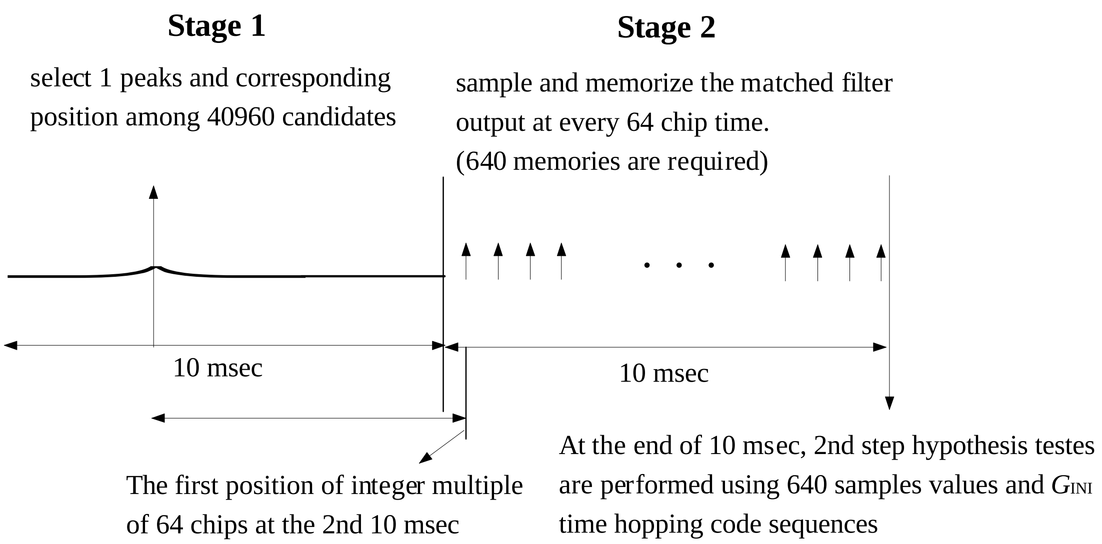

Figure 4. Detailed ECPM receiver algorithm for initial cell search (Option 2).

3.1.3 Complexity Comparison of ECPM and current 3GPP cell search scheme in initial cell search

The cell search algorithms used for the complexity comparison of initial cell search of CPM scheme are based on Figure 2 and Figure 3 (Option 1). For 3GPP scheme, the algorithm is based upon Figure 2, and the slot-wise accumulation technique is adopted[3,5]. And 2 samples per chip is used for complexity calculation.

3.1.3.1 Memory Requirement

- ECPM (Receiver Option1)

$4G_{INI}xL + 2L$ (1)

In the ECPM scheme (for receiver Option 1), we need to store the time index and the matched filter output values of L candidates in stage 1, as well as metrics of all $4xG_{INI}xL$ hypotheses in stage 2.

- current 3GPP scheme

5120 + 16x17 + 1 (2)

In the current 3GPP scheme, there are 5120 candidates for slot boundary. In addition, one extra memory is needed for storing the best candidate position.

Table 1. Comparison of Memory requirement (initial cell search).

ECPM*			Current 3GPP scheme		
L=1	L=2	L=4	4.096Mcps	8.192Mcps	16.384Mcps
130	260	520	**5393**	10513	20753

* The memory requirement for ECPM scheme is almost the same for higher chip rates.

We can notice that required memory for ECPM(L=1) is only 2.3 % of that of current 3GPP scheme.

3.1.3.2 Memory Read/Write Operations per Frame

According to some manufacturers, memory read/write operations for stage 1 accumulation of current 3GPP cell search scheme consumes very much power in receiver besides matched operation itself. Some manufacturers say that, the power consumption of read/write operations for stage1 is almost the same as that of matched filter operation itself. Anyway, it is very important to reduce the number of memory read/write operation per frame.

- ECPM (Receiver Option1)

  $4G_{INI}xLx4$ (3)

  In ECPM scheme, 2^{nd} stage memory element of $4xG_{INI}xL$ are updated 4 times per frame.

- current 3GPP scheme

  5120x16+17x16 (4)

  In current 3GPP cell search scheme, each 1^{st} stage memory element of 5120 is updated 16 times per frame. And each 2^{nd} stage memory element of 17x16 is updated once per frame.

Table 2. Comparison of Memory Read/Write Operation per frame (initial cell search).

ECPM*			Current 3GPP scheme		
L=1	L=2	L=4	4.096Mcps	8.192Mcps	16.384Mcps
512	1024	2048	**86272**	168192	20752

* The memory Read/Write operations per frame for ECPM scheme are almost the same for higher chip rates.

We can notice that required memory Read/Write operations per frame for ECPM(L=1) is only 0.6 % of that of current 3GPP scheme.

3.1.3.3 The number of Add/Comp Operations per frame

- ECPM (Receiver Option1)

$$4G_{INI}xLx4 + 4xG_{INI}xL\text{-}1 \quad (5)$$

In the ECPM scheme, let L be the number of candidates produced by the stage 1 process in every frame. For each candidate, there are 4xG_{INI} hypotheses for decoding the RS code, and for each hypothesis, there are 4 symbols. So there are 4xG_{INI}xLx4 adds per frame. In (5), 4xG_{INI}xL-1 is for searching for the largest metric among 4xG_{INI}xL candidates.

- current 3GPP scheme

$$(32x5+32x7)x2x16+17x16x3+512x16+512 \quad (6)$$

In (6), the term "(32x5+32x7)" is for correlating with 17 second search codes, utilizing Fast Walsh Transform. This term is multiplied by 2, for SSC correlations on I and Q channels, and then by 16, for there are 16 SSC symbols per frame. The term "17*16*3" is for coherent demodulation of SSC symbols, assuming three operations for calculating the real part of a complex product. The term "512x16" is for calculating the metric for decoding the Comma-Free RS code. Finally, the term "512" is for finding the maximum metric among all 512 hypotheses (32 code groups x 16 shifts).

Table 3. Comparison of Add/Comp Operation per frame (initial cell search).

ECPM*			Current 3GPP scheme
L=1	L=2	L=4	**22808**
639	1279	2559	

We can notice that required register Add/Comp operations per frame for ECPM(L=1) is only 2.8 % of that of current 3GPP scheme.

3.2 Target Neighbor Cell Search

The mobile station should search the neighbor cells continuously for the seamless handover in the Idle or Active states. In target cell search mode, the mobile should, in general, be able to search the target cell, even when the received signal power from target cell is smaller than for home cell by 3 to 6 dB. Therefore, the cell search performance in target search case is generally worse, compared to the initial case. For the target cell search case, however, we can take advantage of a priori information, and the mobile's local clock is synchronized to the home cell. With the help of information such as neighbor cells' long code group and long code, we can reduce the number of candidate cells to be examined. And because mobile's local clock is synchronized to the clock of base station, which is more accurate than that of mobile station, parameters of cell search algorithm can be adjusted to improve the performance.

3.2.1 ECPM receiver algorithm for target neighbor cell search

Figure 5 shows an example ECPM receiver algorithm for the target cell search.

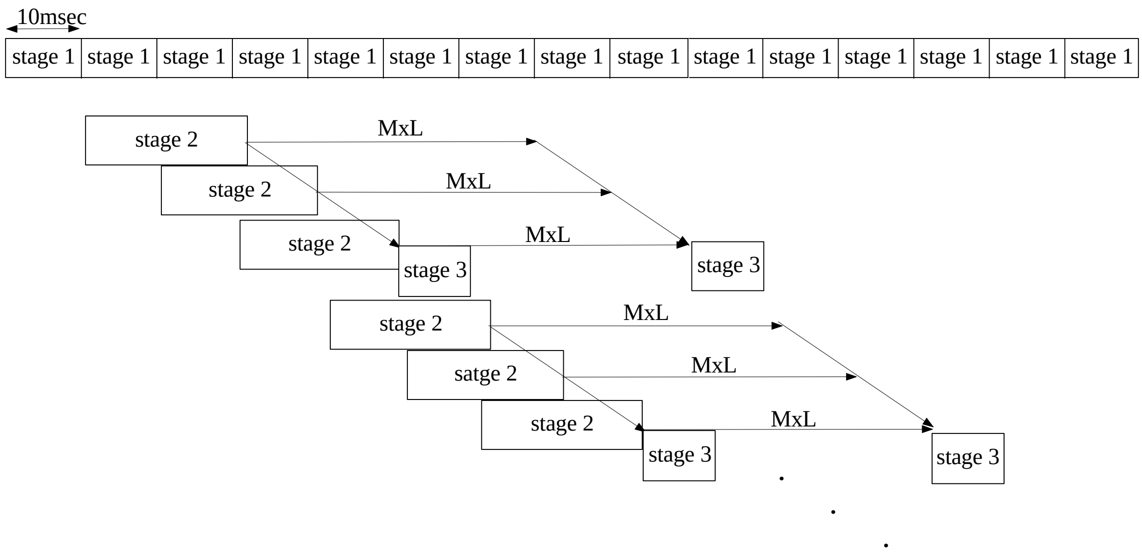

Figure 5. ECPM receiver algorithm for target cell search.

The operations of the receiver algorithm are described as follows:

- Stage 1 (1st 10 msec): Select L peaks and corresponding positions among 40960 candidates (excluding the home cell code position by position nulling technique).

- Stage 2 (2nd and 3rd 10 msecs): Test the 2nd stage hypotheses. (There are $4xG_{TG}xL$ hypothesis tests in this stage, and G_{TG} is the number of groups to be searched in target search mode.). At the end of this stage, MxL peaks among $4xG_{TG}xL$ decision variables are selected.
- Stage 2E (4th to 7th 10 msecs): Test MxL hypotheses again.

3.2.2 Complexity Comparison of ECPM and current 3GPP cell search scheme in target search mode

The cell search algorithm used for the complexity comparison of target cell search of ECPM scheme is based on Figure 5. For 3GPP scheme, the algorithm is based upon Figure 6, and the slot-wise accumulation technique is adopted as in initial cell search [4]. And the 2nd stage is 20 msec long and T_{acc} is 50 msec to 100 msec[5].

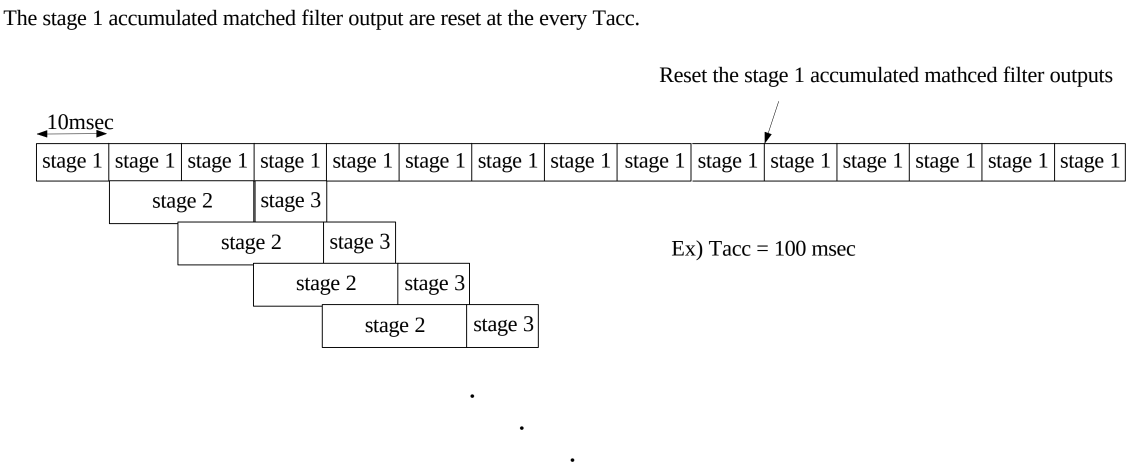

Figure 6. Current 3GPP receiver algorithm for target cell search.

3.2.2.1 Memory Requirement

- ECPM

$$2L + 2x4G_{TG}xL + 4xMxL \quad (7)$$

In the ECPM scheme, we need to store the time index and the matched filter output values of L candidates in stage 1, as well as metrics of $2x4xG_{TG}xL$ hypotheses in stage 2, where the factor of 2 is to account for 200% duty factor of stage2. In addition we need to store additional metrics of 4xMxL, where the factor of 4 is the number of parallel branches of stage 2E.

- current 3GPP scheme

$$5120 + 16x17x2 + 1 \quad (8)$$

In the current 3GPP scheme, there are 5120 candidates for slot boundary. In addition, one extra memory is needed for storing the best candidate position. And in stage 2, 2x16x17 additional memories are required, where the factor of 2 is to account for 200% duty factor of stage2.

Table 4. Comparison of Memory requirement (Target cell search).

G_{TG}	ECPM				Current 3GPP scheme		
	L=1	L=4	L=8	L=16	4.096Mcps	8.192Mcps	16.384Mcps
1	26	104	208	416	**5665***	10785	21025
5	58	232	464	928			
10	98	**392***	784	1568			

* The memory requirement for ECPM scheme is almost the same for higher chip rates

We can notice that required memory for ECPM (L=4, G_{TG}=10) is only 6.9% of that of current 3GPP scheme.

* Note: In Table 4, we did not consider the difference between one memory cell of ECPM and one memory cell of current 3GPP scheme according to different accumulation intervals and accumulation frequencies. For example, let's consider the case in which the stage 1 reset time of current 3GPP scheme (Tacc) is 100 msec, and total accumulation frequency for 1 sample during 100 msec is 160 times. In this case, additional 8 bit memory is required per each memory cell. But in ECPM scheme, 8 to 24 times of accumulation is required for stage 2 (and stage 2E) decision variable. So only 3 to 5 bits additional memory is required for each memory cell. If we consider this factor, then the difference between memories of two schemes is greater. For example, we assume number of bits for matched filter output as 13 bits. Then the required memory for current 3GPP scheme is almost 5120x(13+8)+16x17x2x13 and that for ECPM scheme is almost Lx13+Lx16+(2x4G_{TG}xL)x(13+3) +4xMxLx(13+5).

So if we consider real situation, the required memory for ECPM (L=4, G_{TG}=10) is only 6388 bits/frame and that of 3GPP scheme is 114592 bits/frame, therefore the required memory for ECPM is only 5.57 % of that of current 3GPP scheme.

3.2.2.2 Memory Read/Write Operations per Frame

- ECPM

$$2x4G_{TG}xLx4 + 4xMxLx4 + Lx4G_{TG}x\gamma_{GTG} \quad (9)$$

In (9), stage 2 memory element of 4xG_{TG}xL are updated 4 times per frame and 2 frames are used for stage 2. And stage 2E memory element of MxL are updated 4 times per frame and 4 frames are used for stage 2E. In (9), γ_{GTG} is a coefficient which comes from M peaks selection among 4G_{TG} candidates and sorting in every frame (that is selecting M peaks from $4G_{TG}$). According to our computer simulation, when we use bubble sorting, if G_{TG} is 5 and M is 4, then γ_{GTG} is 0.5. And G_{TG} is 10 and M is 4, then γ_{GTG} is 0.3. Of course, if G_{TG} is 1 and M is 4, then γ_{GTG} is 0.

- current 3GPP scheme

$$5120x16+2x17x16 \quad (10)$$

In current 3GPP cell search scheme, each 1st stage memory element of 5120 is updated 16 times per frame. And each 2nd stage memory element of 17x16 is updated once per frame and 2 frames are used for stage 2.

Table 5. Comparison of Memory Read/Write Operations per frame (Target cell search).

G_{TG}	ECPM				Current 3GPP scheme		
	L=1	L=4	L=8	L=16	4.096Mcps	8.192Mcps	16.384Mcps
1	96	384	768	1536	**82464**	10784	20752
5	234	936	1872	3744			
10	396	**1584**	3168	6336			

* The memory Read/Write operations per frame for ECPM scheme is almost the same for higher chip rates

We can notice that required memory Read/Write operations per frame for ECPM (L=4, G_{TG}=10) is only 1.9 % of that of current 3GPP scheme (Target neighbor cell search).

3.2.2.3 The number of Add/Comp Operations per frame

- ECPM

$$: 2x4G_{TG}xLx4 + Lx4G_{TG}x(1+\gamma_{GTG})+4xMxLx4+ 0.33x\{(3L-1) +(3MxL-1)\} \quad (11)$$

In target cell search mode as shown in Figure 5, for each candidate, there are $4G_{TG}$ hypotheses for decoding the RS code in stage 2, and for each hypothesis, there are 4 symbols. And 2 frames are used for stage 2. So there are $2x4G_{TG}xLx4$ adds per frame. In (11), the term "$Lx4G_{INI}x(1+\gamma_{GTG})$" is the number of comp. operations per frame which comes from at the end of each stage 2 (that is, selecting M from $4G_{TG}$). We already explained the term "γ_{GTG}" in 3.2.2.2. in detail. In (11), the term "4xMxLx4" is the number of add operations for stage 2E. Finally, the term "0.33x{(3L-1) + (3MxL-1)}" includes the calculation of finding the maximum metric among 3L hypotheses and the maximum metric among 3MxL hypotheses, where 0.33 is duty factor of final selection process.

- current 3GPP scheme

$$2x((32x5+32x7)x2x16+17x16x3)+17x16+16G_{TG}x16+16G_{TG}-1 \quad (12)$$

In (12), the term "(32*5+32*7)" is for correlating with 17 second search codes, utilizing Fast Walsh Transform. This term is multiplied by 2, for SSC correlations on I and Q channels, and then by 16, for there are 16 SSC symbols per frame. The term "17*16*3" is for coherent demodulation of SSC symbols, assuming three operations for calculating the real part of a complex product. The term "2" at the front is, for 2 frames are used for stage 2. "17x16" reflects the additions by accumulation of the 2nd frame and the previous correlation values. The term "16G_{TG}x16" is for calculating the metric for decoding the Comma-Free RS code. Finally, the term "16G_{TG} -1" is for finding the maximum metric among 16G_{TG} hypothesis (G_{TG} code groups x 16 shifts)

Table 6. Comparison of Add/Comp Operation per frame (Target cell search)

G_{TG}	ECPM				Current 3GPP scheme
	L=1	L=4	L=8	L=16	
1	105	420	840	1680	26751
5	259	1036	2072	4144	27839
10	441	**1764**	3528	7056	**29199**

We can notice that required register Add/Comp operations per frame for ECPM(L=4, G_{TG}=10) is only 6.1 % of that of current 3GPP scheme.

4. Link Level Simulation Results

4.1 Initial Cell Search

Figure 7 shows the simulation condition for initial cell search. We assume signals from other cell including thermal noise as white Gaussian noise. Only SCH code signal of home cell is generated. We assume multiple access interference of home cell as additive Gaussian. We assume the SCH power for current 3GPP scheme is evenly split between FSC and SSC.

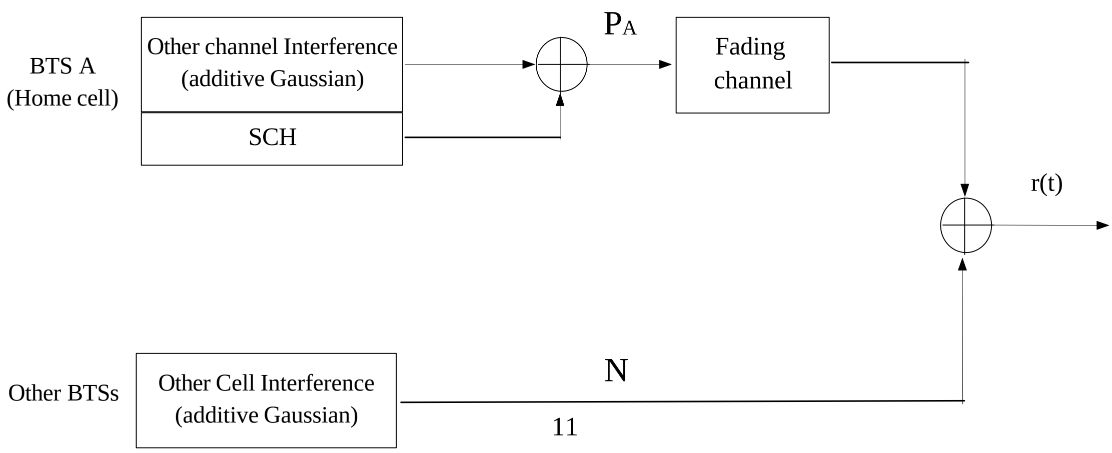

Figure 7. Simulation model for initial cell search.

The cell search algorithm used for the simulation of ECPM scheme is based on Figure 2. The algorithm in Figure 2 is also used for 3GPP scheme. However, the slot-wise accumulation technique is adopted in 3GPP scheme, and the accumulation length of stage 1 is 10 msec[4]. If 3GPP cell search scheme uses Tacc longer than 10 msec in initial cell search, the performance might be degraded with the clock drift of 3 ppm because the total length of stages 1, 2 and 3 exceeds 30 msec.

Figures 8 and 9 present the cell search performances of the two schemes with mobile speeds of 60 km/h and 5 km/h. The results for the original CPM (16-slot CPM) are also given in Figure 8 to show the performance gain of ECPM scheme relative to the original one.

Note that the ECPM scheme with L of 1 has about 3 dB gain over 3GPP scheme, as the Figure shows, with regard to per-frame SCH power, regardless of vehicle speed.

What is as important as the results in Figures is the complexity of mobile. As mentioned in chapter 3.1.3, when L is 1, the required memory for ECPM scheme is only 2.3% of that of current 3GPP cell search scheme. And the number of memory read/write operations and the number of add/com operations are 0.6% and 2.8% of that of current 3GPP scheme, respectively.

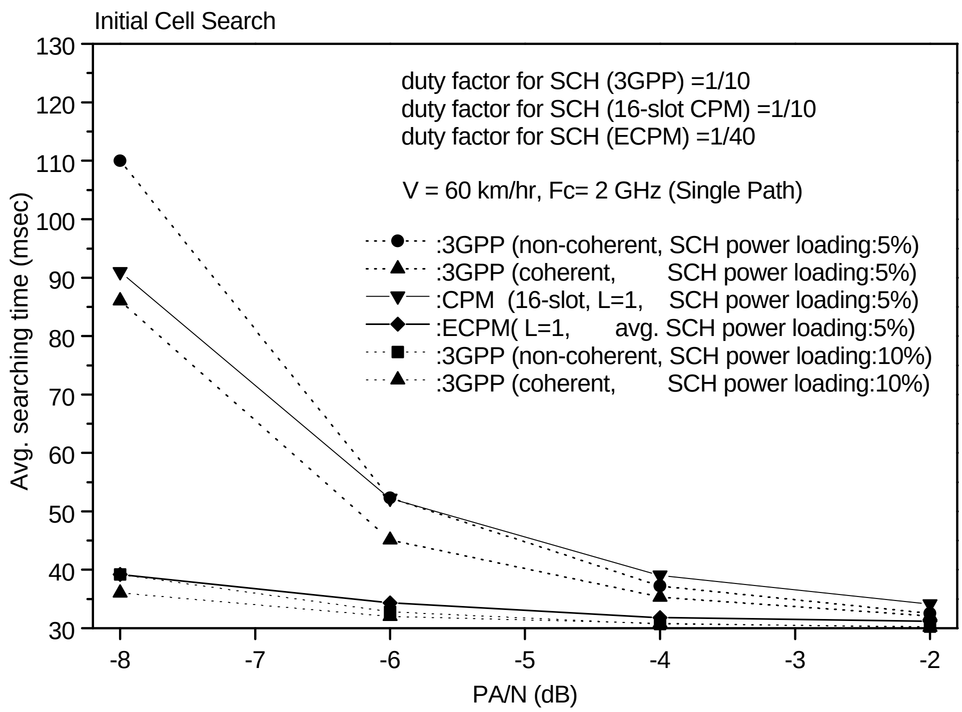

Figure 8. Simulation results for initial cell search (V= 60km/hr).

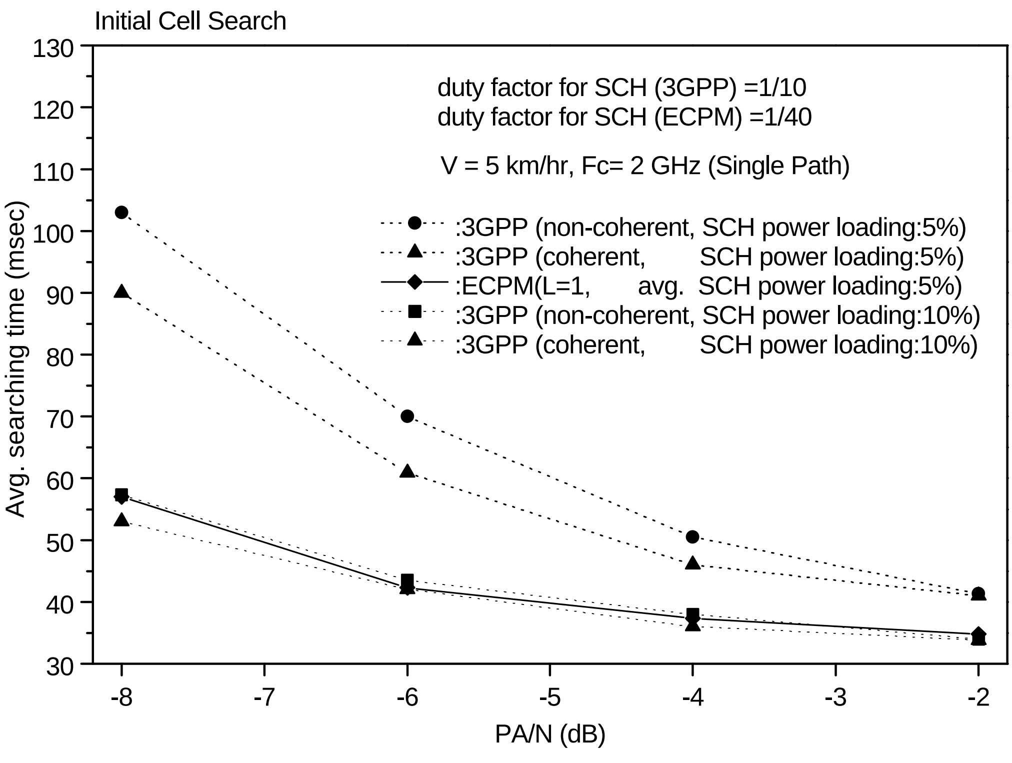

Figure 9. Simulation results for initial cell search (V= 5km/hr).

4.2 Target neighbor cell search

Figure 10 shows simplified 2-BTS channel model. The channel model cannot reflect all the effects of real environment, but it was devised to verify the performance of cell search scheme for the case of target cell search

with relatively simple simulations. Traffic channels of home cell and target cell were modeled as additive white Gaussian noise, and there are two SCH sequences from home cell and target cell. Signals from home cell and target cell go through Rayleigh fading channel, and white Gaussian noise modeled signals from the other cells are added to those signals to form received signal at the mobile station.
In the simulations P_A and P_B are total powers from home cell and target cell respectively, and N stands for power density of other cell interference. P_A/P_B ratio was set to be 6 dB, that means target cell has 6 dB lower SCH power than home cell. The condition looks very tough, but the condition is realistic and cell search performance under that condition is meaningful.

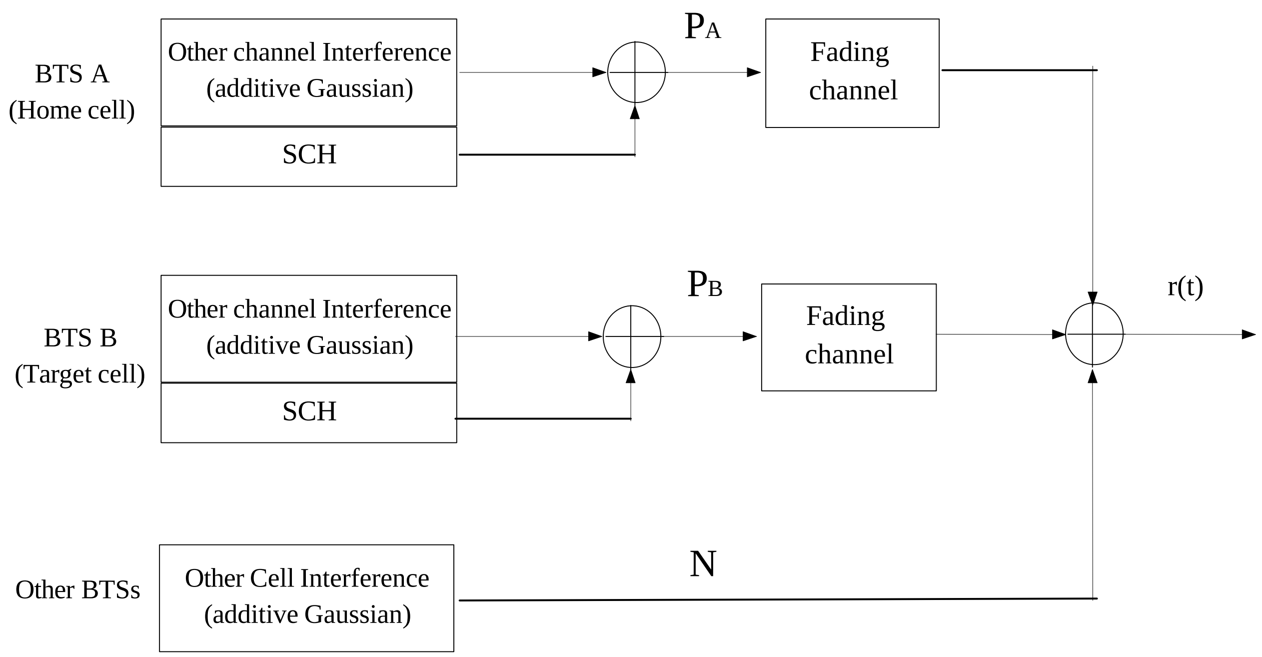

Figure 10. Simulation condition for target cell search.

To improve target cell search performance we utilizes Peaks Nulling Technique as described in [3]. That is, at the stage 1, the terminal nullifies the metrics at the position corresponding to the SCH code position of active base station.

The parameters used in the simulation are described in Table 7. And receiver algorithms of both schemes for target cell search are based on Figure 5 and Figure 6.

Table 7. Simulation parameters for target neighbor cell search.

Parameter	ECPM	Current 3GPP scheme
SCH power	Avg. 5% (intant:20%, duty factor is 1/40)	5% or 10% (duty factor is 1/10) evenly split to FSC and SSC
Number of Group	10 BS's in the candidate list	
PA/PB	6 dB	
PA/N	-2, -4, -6, -8 dB	
Time for Stage 1	10 msec	10 msec
Time for stage 2	(20 + 40) msec	20 msec
Time for stage 3	10 msec	10 msec
Stage 1 metric reset time(Tacc)	-	100 msec
Duty factor for stage 3	0.67	1
L	1, 4, 16	-
M	4	
Sampling rate	1 sample per chip	

Figure 11 and 12 show the performance of the current 3GPP and ECPM scheme for two mobile velocities, 60 km/h and 5km/hr, respectively. In the this figure we can find that ECPM scheme with L of 4 or L of 16 has almost 3dB power gain compared to the current 3GPP scheme. We also notice that even when L is 1, EPCM scheme has 2 dB gain compared to the current 3GPP scheme.

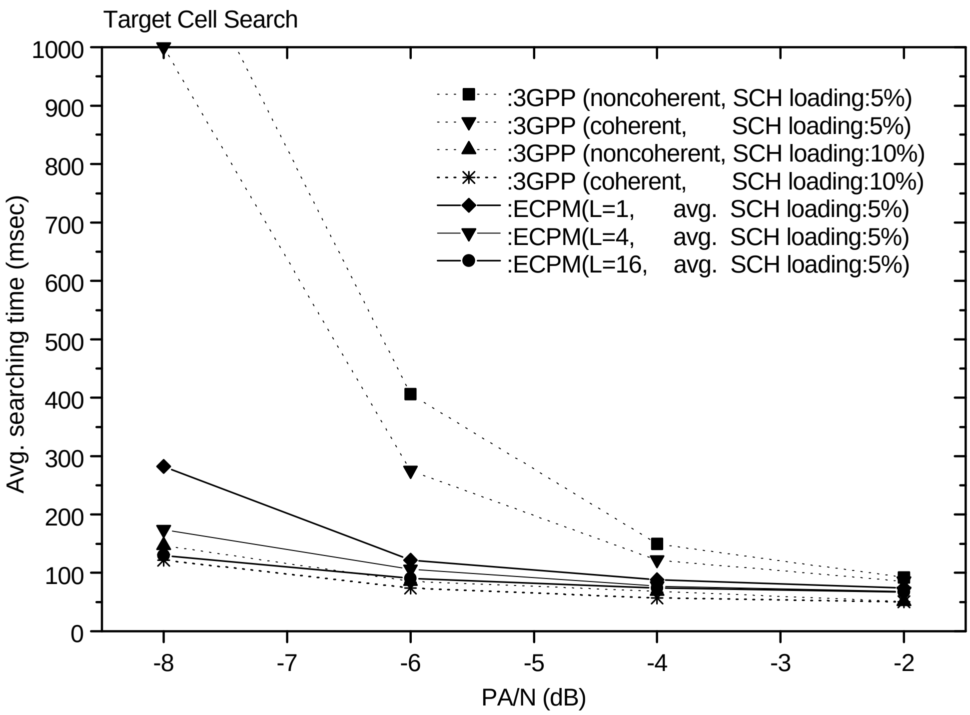

Figure 11. Simulation results for Target cell search (V= 60km/hr, PA/PB = 6dB).

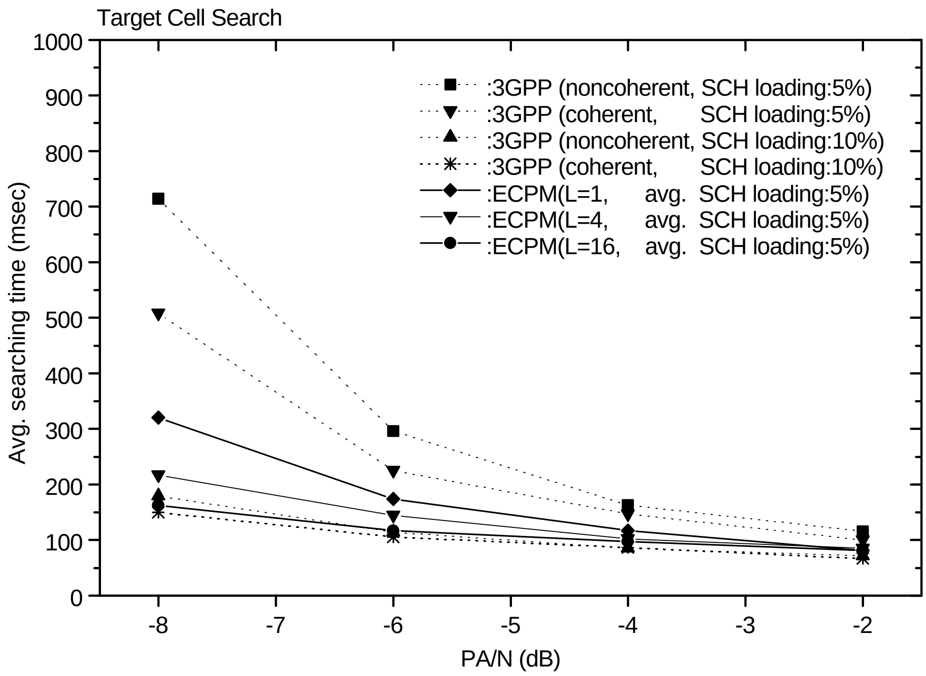

Figure 12. Simulation results for Target cell search (V= 5km/hr, PA/PB = 6dB).

5. Conclusions

This document presents the structure of ECPM scheme and its receiver algorithm. The performances are compared by the simulations and the complexity is compared by analyses between ECPM and the current 3GPP schemes. After comparisons of the performance and complexity of the two schemes, the major merits of ECPM scheme over current 3GPP scheme are as follows:

- Initial Cell Search Case : **3 dB performance gain** in terms of total SCH power loading.
- Target Cell Search Case: **2.5 to 3 dB performance gain** in terms of total SCH power loading.
- The memory Requirement in initial cell search : **2.3 %** of current 3GPP scheme
- The memory Requirement in target cell search : **6.9 % (5.57%)** of current 3GPP scheme
- The memory read/write operations in initial cell search: **0.6%** of current 3GPP scheme
- The memory read/write operations in target cell search: **1.9%** of current 3GPP scheme
- The Add/Comp operations in initial cell search: **2.8%** of current 3GPP scheme
- The Add/Comp operations in target cell search: **6.1%** of current 3GPP scheme

The effectiveness of the cell search algorithm is critical to the wide approval of W-CDMA system. When all the factors are put together, ECPM scheme is believed to perform better than the current scheme in every view point and in all operating environment, especially in extreme conditions. And it is future-proof algorithm with transparent extensibility to the higher chip rates.

Thus, we recommend ECPM based cell search algorithm to be accepted for the inclusion in 3GPP documents.

References

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Appendix A. One example of time hopping code for ECPM

3, 9, 27, 81,	124, 82, 49, 25,
12, 90, 121, 38,	14, 108, 29, 99,
21, 44, 88, 122,	73, 109, 79, 5,
30, 125, 55, 79,	99, 89, 26, 36,
39, 79, 22, 36,	121, 33, 30, 72,
48, 33, 116, 120,	31, 90, 76, 69,
57, 114, 83, 77,	6, 53, 120, 103,
66, 68, 50, 34,	104, 46, 57, 44,
75, 22, 17, 118,	110, 78, 5, 48,
84, 103, 111, 75,	100, 71, 24, 20,
20, 35, 7, 28,	79, 77, 9, 54,
101, 2, 91, 22,	89, 30, 78, 116,
109, 74, 104, 12,	120, 72, 26, 103,
36, 52, 33, 8,	92, 30, 111, 34,
54, 87, 94, 49,	39, 78, 113, 126,
43, 115, 92, 31,	79, 58, 87, 113,