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Source: InterDigital Communications Corporation

Title: A BPSK Modulated Secondary Synchronization Codes based Cell Search in UTRA TDD

Abstract

In this contribution a new algorithm is proposed to be used for the 2nd step of the cell search procedure for UTRA TDD. The first and the third step of the cell search procedure are retained as current working proposal of 3GPP [1-4]. For Step 2, six orthogonal, length-256 Secondary Synchronization Codes (SSC's) are used, as compared to the 17 codes used for the 3GPP proposal. These codes are modulated by the code group and frame timing information and sent alongside the unmodulated Primary Synchronization Code (PSC). Using these codes for the second step, decreases complexity of this step, and improves the performance of code group/frame timing detection.

1. Introduction

For the UTRA TDD, the base stations in a cluster are syncronized to each other. For the cell search procedure, the base stations transmit the PSC and SSC's in the time slot dedicated for synchronization, e.i. Physical Synchronization Channel (PSCH). In order to avoid PSC signal for different base stations arriving to the User Equipment (UE) at the same time, each base stations transmits PSC signal with a time offset, t_{offset}.

For the base station acquisition, a three step cell search procedure is used. In the first step the UE is syncronized to the slot baundary with a time offset of t_{offset}. For this step a PSC common to all the base stations is used. In [2], a hierarchical sequence was proposed as PSC for this step to reduce the complexity.

In the second step of the cell search procedure the code group that the base station is using and the slot timing in the frame is identified. The SSC's are used for this step. In [5-7] 17 SSC's are proposed to be used as indexes to 32 RS(16,3) codes, so called "Comma Free Method." In [8], 32 cyclic hierarchical codes are proposed to be used as SSC's.

In this paper, we propose to use 6 SSC's for the second step. These codes are chosen among the same family of codes, as suggested by 3GPP working proposal. They are BPSK modulated by code group number and PSCH slot location in the frame. Then they are transmitted alongside unmodulated PSC.

This scheme improves the detection performance of the cell search procedure, as well as reduces the complexity of the second step compared to other two proposals mentioned above [7,8].

In the following section the PSCH structure for the suggested proposal is first explained. In Section 3, the implementation details of the cell search procedure as well as the required complexity for the implementation is given. The complexity requirement of the suggested proposal is also compared to the other cell search proposals in this section. The simulation results performed for the Step 1 and Step 2 of the cell search procedure are given in Section 4. Finally in Section 5, the conclusion is drawn from the simulation results and the complexity calculations.

2. The Physical Synchronization Channel:

The cell search procedure is performed using Physical Synchronization Channel (PSCH). The PSCH is a common downlink channel transmitted in the slot(s) dedicated for cell search. We assume that two time slots per frame are allocated for PSCH, namely slots k and k+8 where k = 0,...,8. In Fig. 1, k is assumed to be 0 without loss of generality and the PSCH is transmitted in time slot 0 and 8 with a time offset, $t_{offset,n}$, from the slot boundary. The $t_{offset,n}$ depends on the code group n for the base station and was proposed in [9] as,

$$t_{offset,n} = n \cdot T_c \left\lfloor \frac{2560 - 96 - 512 - t_{gap} / T_c}{31} \right\rfloor \tag{1}$$

where n is the code group number, T_c is the chip duration and $\lfloor x \rfloor$ denotes the largest integer number less than or equal to x.

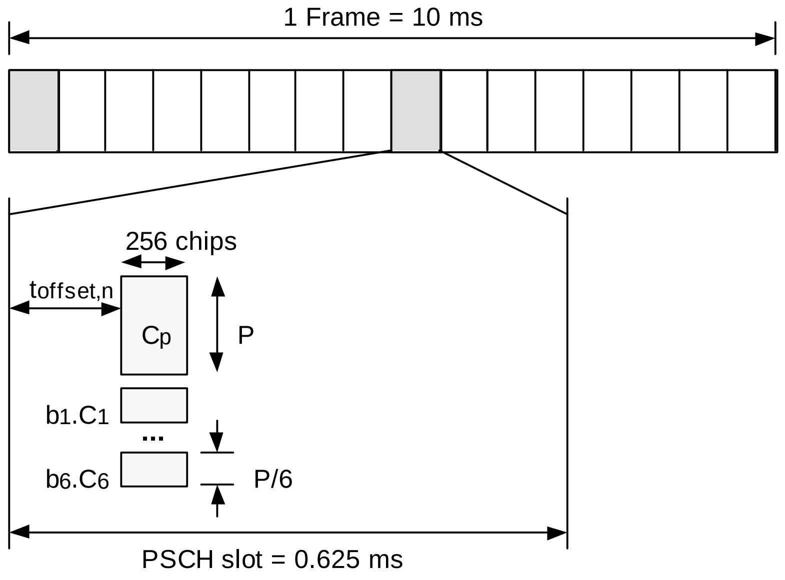

Fig 1: The Physical Synchronization Channel (PSCH) Structure for the Proposed Scheme.

In Fig. 1 the PSCH proposed for this scheme is depicted. From this figure t_{gap}/T_c is equal to –256.

$$t_{offset,n} = n \cdot T_c \left\lfloor \frac{2560 - 96 - 256}{31} \right\rfloor \qquad (2)$$
$$= n \cdot 71T_c \; ; \quad n = 0,\ldots,31$$

The PSCH consists of two sets of codes; Primary Synchronization Code (PSC), C_p , and the Secondary Synchronization Codes (SSC's), $\{C_1, ..., C_6\}$. The C_p and the $\{C_1, ..., C_6\}$ are common to all the base stations. However note that the C_p is not modulated, wheras $\{C_1, ..., C_6\}$ are BPSK modulated with the code group of the base station. Also note that a half of the total power dedicated for PSCH is used for C_p and the other half is used for $\{C_1, ..., C_6\}$.

In the following subsections the Primary Synchronization Code and the Secondary Synchronization Codes are explained in detail.

2.1. The Primary Synchronization Code:

The PSC is an unmodulated length 256 hierarcical code common to all base stations. For a base station with code group n the PSC is transmitted in the PSCH time slot(s) with a time offset of $t_{offset,n}$ from the slot boundary. The t_{offset} is calculated according to the code group n that the base station belongs to -- see Eqn. (1).

The PSC, C_p, was proposed in [2] to be constructed from a length 16 hierarchical sequences x_1 and x_2 in order to reduce the complexity in the cell search procedure. The details are as follows:

Let**,**
x_1 = [1, 1, -1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, 1, -1],

x_2 = [1, 1, -1, -1, -1, -1, 1, -1, 1, 1, -1, 1, 1, 1, -1, 1], (3)

then a sequence y is constructed as

y(i) = x_1(i mod 16) * x_2(i div 16), i = 0,…,255. (4)

The PSC, C_p , is obtained by position wise multiplication of y and the first row of length 256 Hadamarad matrix, h_0. Since h_0 is all one sequence then

C_p(i) = y(i) * h_0(i),
= y(i) , i = 0, ..., 255. (5)

2.2. The Secondary Syncronization Codes:

The Secondary Synchronization Codes (SSC's) are proposed to be common to all the base stations. However, before the transmission, they are BPSK modulated with the code group that the base station belongs to.

The SSC's $\{C_1, C_2, \ldots, C_6\}$ are constructed from position wise multiplication of sequence y(i) given in Eq. (4) and rows h_{24}, h_{40}, h_{56}, h_{104}, h_{120}, h_{136} of Hadamarad matrix, H_8 respectively. The H_8 is obtained recursively by,

$$H_0 = (1),$$

$$H_k = \begin{pmatrix} H_{k-1} & H_{k-1} \\ H_{k-1} & -H_{k-1} \end{pmatrix}, \quad k \geq 1 \tag{6}$$

The rows are numbered from the top starting with row 0, h_0, (the all one sequence). Then from Eqs. (4) and (6), the SSC's are constructed as

$$C_k(i) = h_{r(k)}(i) * y(i), \ \ i = 0, \ldots, 255 \ ;k=1,\ldots 6 \text{ and } r(k)=[24,40,56,104,120,136]. \tag{7}$$

The BPSK modulated SSC's for code group n are obtined by multiplication of $C_k(i)$ with $b_{k,n}$, i.e $b_{k,n}* C_k(i)$ where $b_{k,n}$ are given as

Code Group, n	$b_{6,n}$	$b_{5,n}$	$b_{4,n}$	$b_{3,n}$	$b_{2,n}$
0	1	1	1	1	1
1	1	1	1	1	-1
2	1	1	1	-1	1
…	…	…	…	…	…
31	-1	-1	-1	-1	-1

The bit $b_{1,n}$ represent the frame timing and it is '1' for 'slot k' and '-1' for 'slot k+8' for all the code groups.

Note that, the C_p and $\{C_1, \ldots, C_6\}$ are pairwise mutually orthogonal and the C_p is chosen to have good aperiodic cross correlation properties with $\{C_1, \ldots, C_6\}$ (see Figs. 3 and 4).

3. The Cell Search Implementation Details and Complexity:

In this section the implementation details and the complexity of the algorithm is given. The complexity of the algorithm is also compared to the cell search algorithms proposed in [7] and [8].

1st Step: The C_p is matched to the sampled received signal by using matched filter or any similar device. Due to hierarchical structure of the C_p, at each chip sample 16+16=32 complex correlations are performed in two stages, rather than 256 complex correlations (see [1], [2]). Each complex correlation is equivalent to one complex addition or two real additions, therefore for each PSCH slot 2560*32*2 = 163,840 real additions are needed. The 1st step is common to all three algorithms. Therefore in this step each algorithm needs the same amount of complexity.

2nd Step: In this step of the cell search algorithm, first the chip sampled received signal is correlated with Primary Synchronization Code C_p and the Secondary Synchronization

Codes $\{C_1,\ldots,C_6\}$ at the C_p position detected in Step 1. Let us denote these correlation values by $R(C_p)$, $R(C_1),\ldots,R(C_6)$ respectively.

From Eqs. (5) and (7) the C_p and $\{C_1,\ldots,C_6\}$ are constructed from Hadamarad sequences such that length 32 Fast Hadamarad Transform can be applied.

The details of the procedure are as follows:
Let us denote the sampled received signal sequence starting at the position of $C_p(0)$ as

$$r = [r(0),r(1),\ldots,r(255)]. \tag{8}$$

Then, 32 correlation values are obtained by performing consecutive length 8 correlations between the Cp and r,

$$\text{corr}(i) = \sum_{k=0}^{7} r(8i+k)C_p(8i+k)\,; \quad i = 0,\ldots,31 \tag{9}$$

For these correlations <u>16*16=256 complex additions</u> are needed.

The Fast Hadamarad Transform is applied to corr(0),…,corr(31) to obtain the correlation values $R(C_p)$, $R(C_1),\ldots,R(C_6)$. For this process <u>$2*16*\log_2 16 + 7 = 135$ complex additions</u> are needed.

Since the C_p is not modulated, the phase of $R(C_p)$ is used as a reference for $R(C_1)$,…, $R(C_6)$. That is, the complex conjugate of normalized $R(C_p)$ is multiplied with $R(C_1)$, …, $R(C_6)$. Finding normalized $R(C_p)$ requires 4 real multiplications and 1 real addition. Each multiplication of corr(C_p) conjugate with $R(C_i)$, i=1, …, 6, requires 4 real multiplications and 2 real additions. Therefore for this procedure we need <u>4+6*4 = 28 real multiplications</u> and <u>1+6*2=13 real additions</u>.

Hence this algorithm needs a total of 256*2+135*2+13 = 795 real additions and 28 real multiplications in this step.

The following table provides the complexity requirement of this algorithm in comparison to the proposals submitted

Algorithm	The complexity at each SCH slot	During the decision
The suggested algorithm	795 real additions+28 real mult.	none
Comma Free Method	1,361 real additions+34 real mult.	512 real additions
Hierarchical Scheme	17,344 real additions+128 real mult.	64 real additions

4. The Simulation Results

In this section the detection performance of the suggested cell search procedure is evaluated.

4.1. The Primary Synchronization Code Acquisition

For the first step of the cell search procedure the Cp is matched to the received signal. In order to avoid a false acquisition in this step, the sidelobes of aperiodic auto-correlation of Cp and the aperiodic cross-correlation between Cp and the SSC’s are desired to be small.

Fig. 2 depicts the aperiodic auto-correlation of Cp. From this figure it is observed that the maximum sidelobe is equal to 34 and the average sidelobe is equal to 5 relative to the main peak, which is 256.

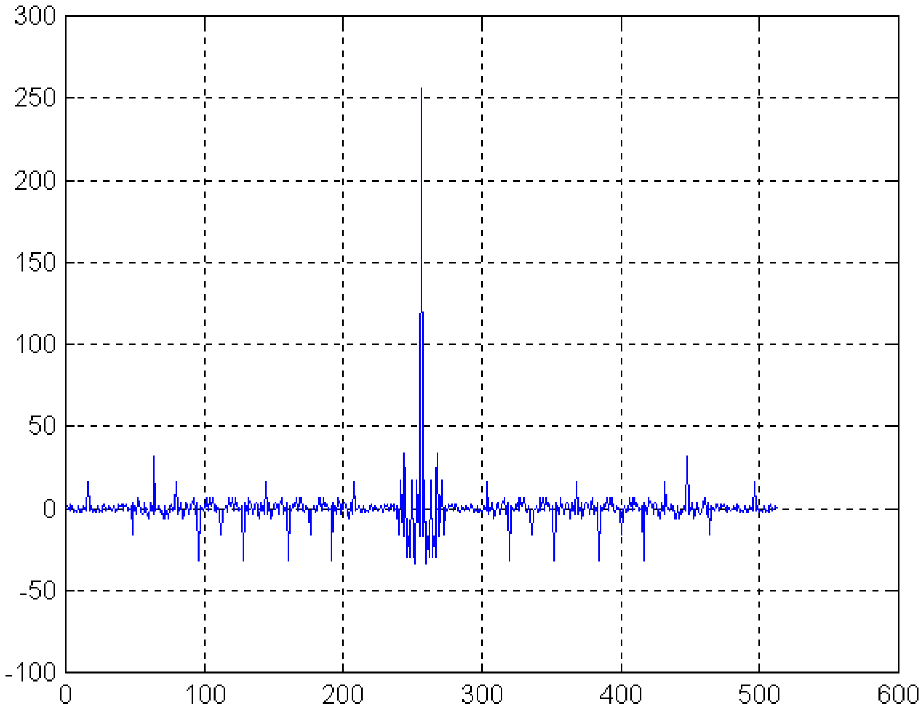

Fig. 2: Aperiodic auto-correlation of Cp

Fig. 3 shows the maximum aperiodic cross-correlation between Cp and 31 possible SSC’s among which 6 SSC’s, i.e. C_1, ..., C_6 are selected. For this scheme, we have chosen the SSC’s numbered as 3, 5, 7, 13, 15 and 17. It can be observed that these codes have the minimum amount of maximum aperiodic cross-correlation with Cp. For the selected 6 codes the maximum aperiodic cross-correlation can reach up to 75.

The 17 SSC codes for the comma free method are also chosen among these 31 possible codes. From this figure one can observe that, for the comma free method the maximum aperiodic cross-correlation can reach up to 97.

The average aperiodic cross-correlation between Cp and SSC’s is depicted in Fig. 4. From this figure it is observed that, the average aperiodic cross-correlation for all possible 31 SSC’s is similar and about 5.5 relative to the main peak of 256. Therefore for the average aperiodic cross-correlation there is no difference between the suggested method and the comma free method.

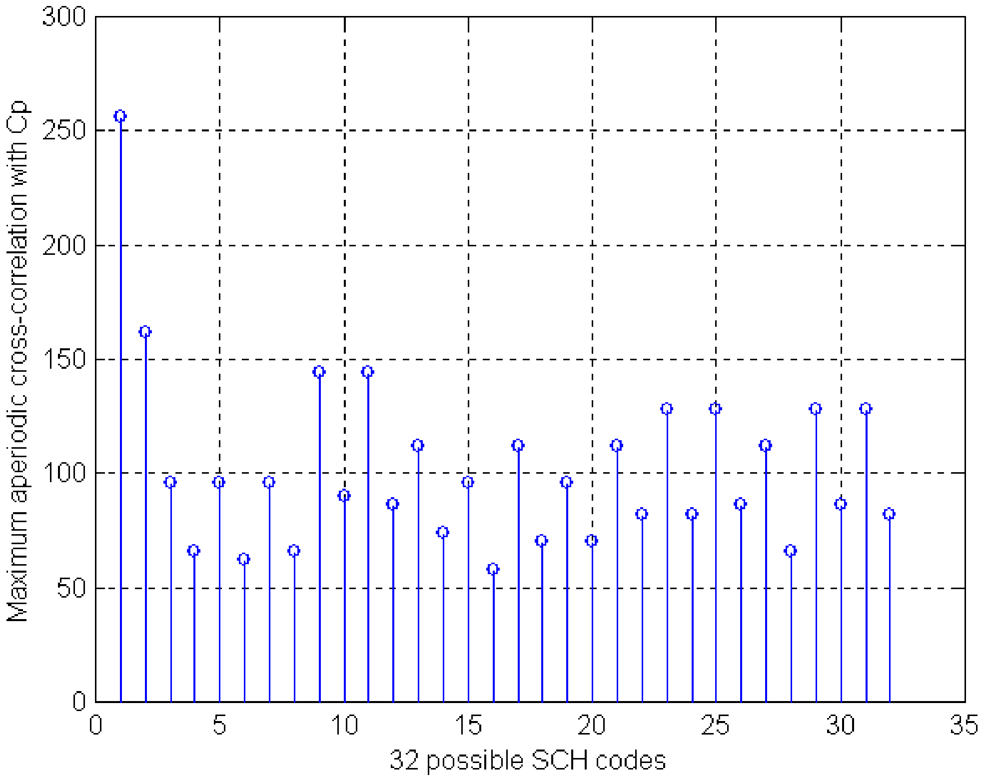

Fig. 3: Maximum aperiodic cross-correlation between Cp and all possible SSC's.

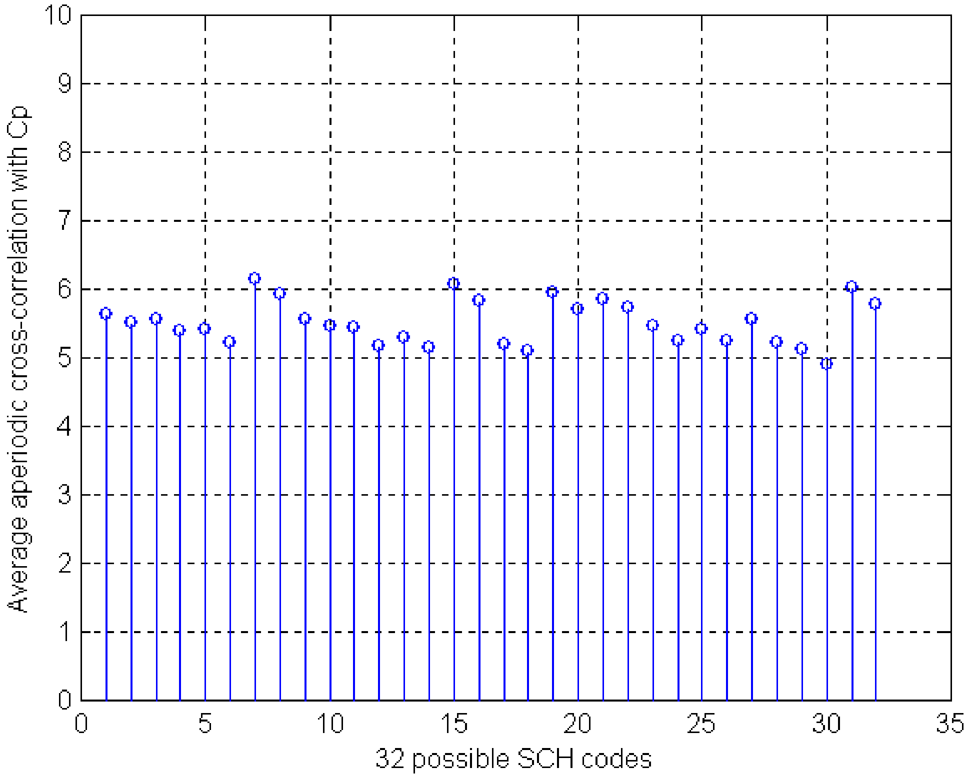

Fig. 3: Average aperiodic cross-correlation between Cp and all possible SSC's.

Fig. 4 shows a typical aperiodic cross-correlation of transmitted PSCH with Cp.

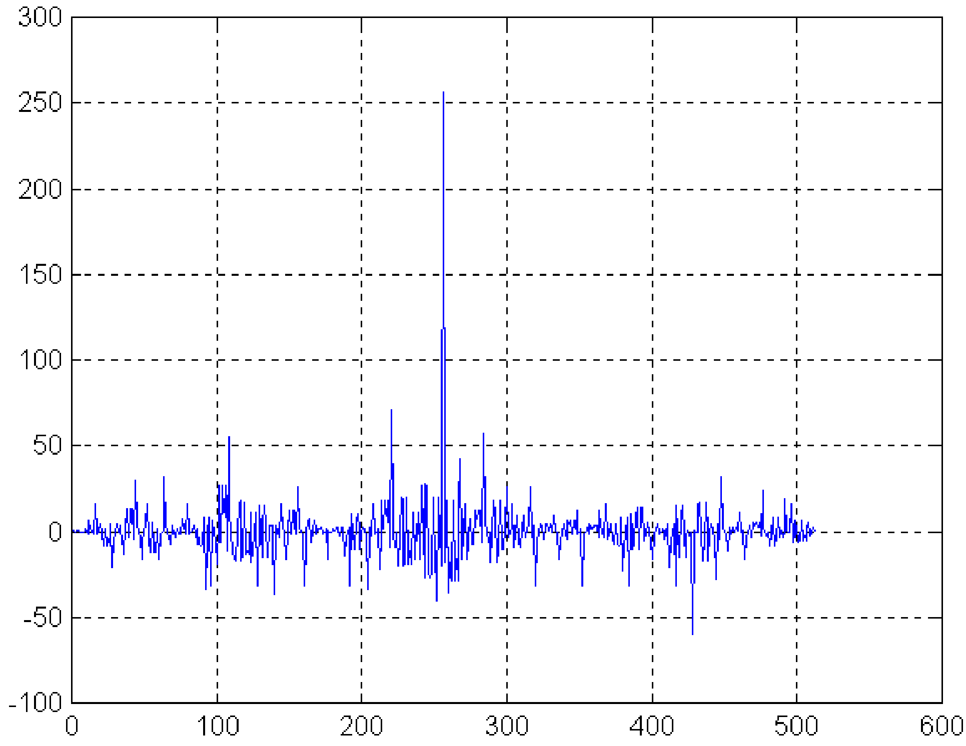

Fig. 5: A typical aperiodic cross-correlation between Cp and PSCH .

4.2. The Incorrect Acquisition Rate in Step 2

In Step 2, we assume that the Step 1 is successfully achieved, that is the Cp location in the PSCH is identified correctly. Then in this step, we simulate the code group/slot location identification for all three methods, namely the Modulated SSC, Comma Free Method and Hierarchical Scheme.

The results of the simulations are depicted in Fig. 6 through Fig. 12 for different channel models. From these figures we obseverved that, the proposed scheme always performs better than the Comma Free method. We also observed that the proposed scheme performes comparable to the Hierarchical scheme in most cases. From Figs. 13 and 14 we note that, in case of very large frequency offset the proposed scheme performes better than the Hierarchical scheme.

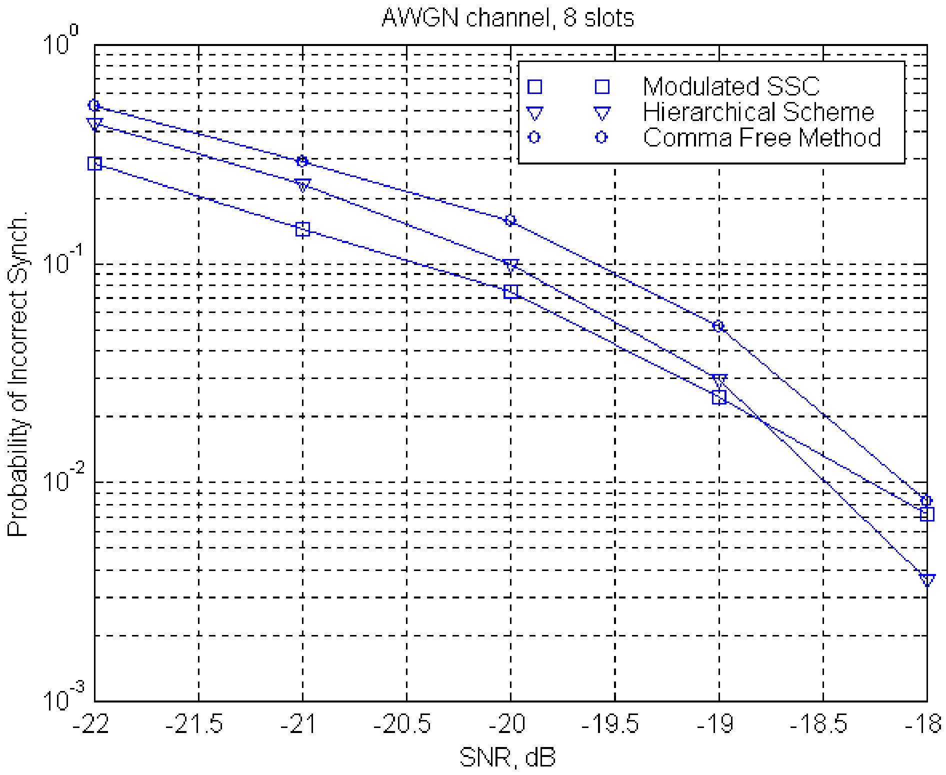

Fig. 6: Probablity of incorrect code group/frame timing synchronization in AWGN, 8 slots integration is used.

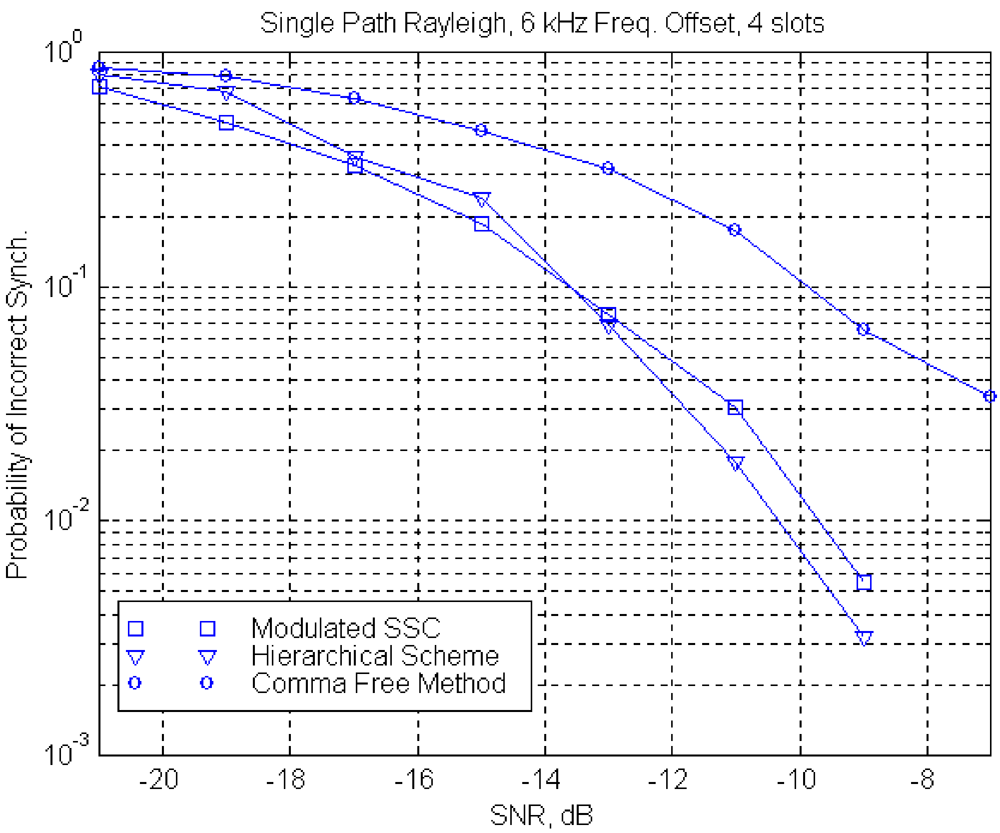

Fig. 7: Probablity of incorrect code group/frame timing synchronization in single Rayleigh fading, 6 kHz Freq. Error, 4 slots integration is used.

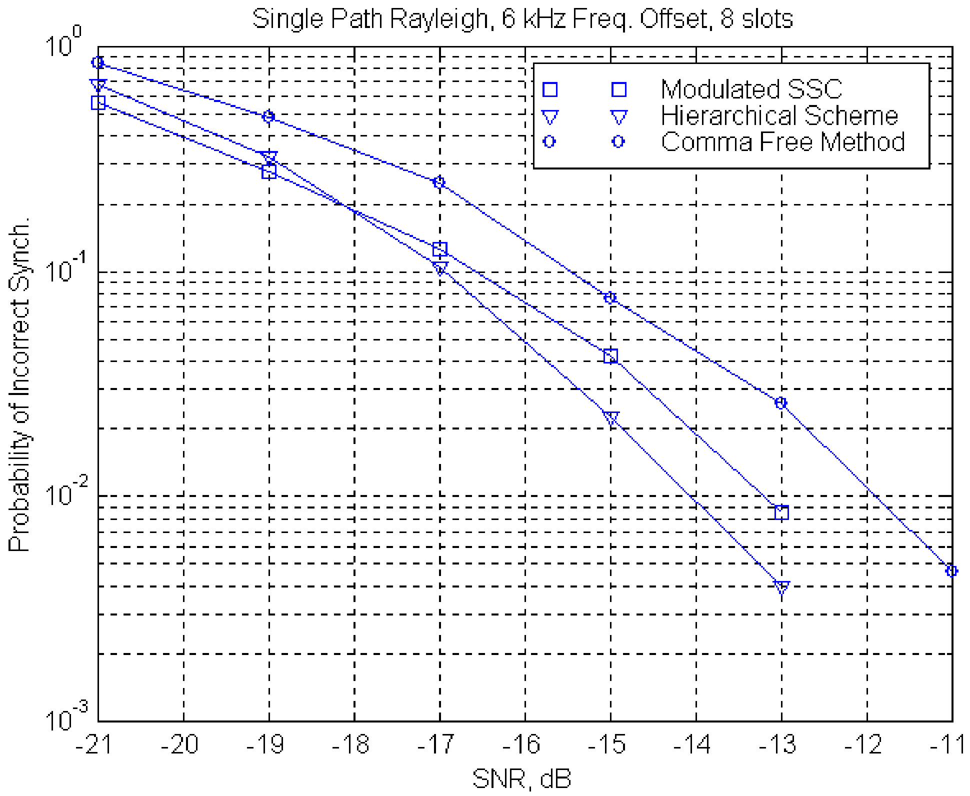

Fig. 8: Probablity of incorrect code group/frame timing synchronization in single Rayleigh fading, 8 slots integration is used.

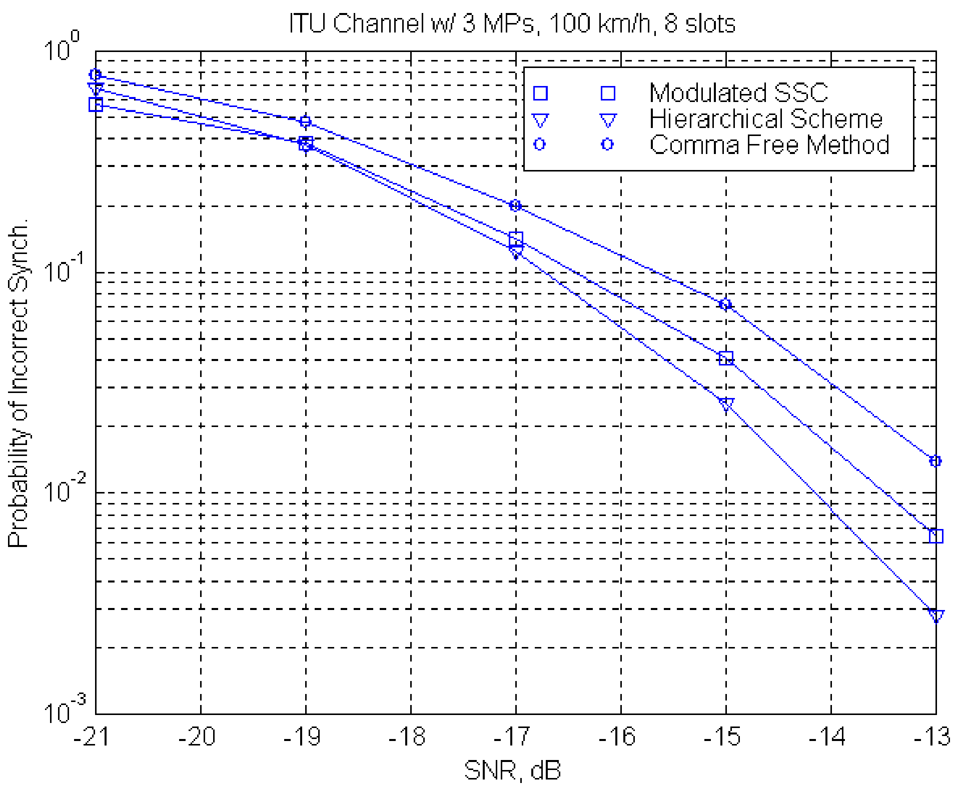

Fig. 9: Probablity of incorrect code group/frame timing synchronization in ITU channel with 3 multipaths (0, -6.9, -2.4 dB), 100 km/h doppler, 8 slot integration.

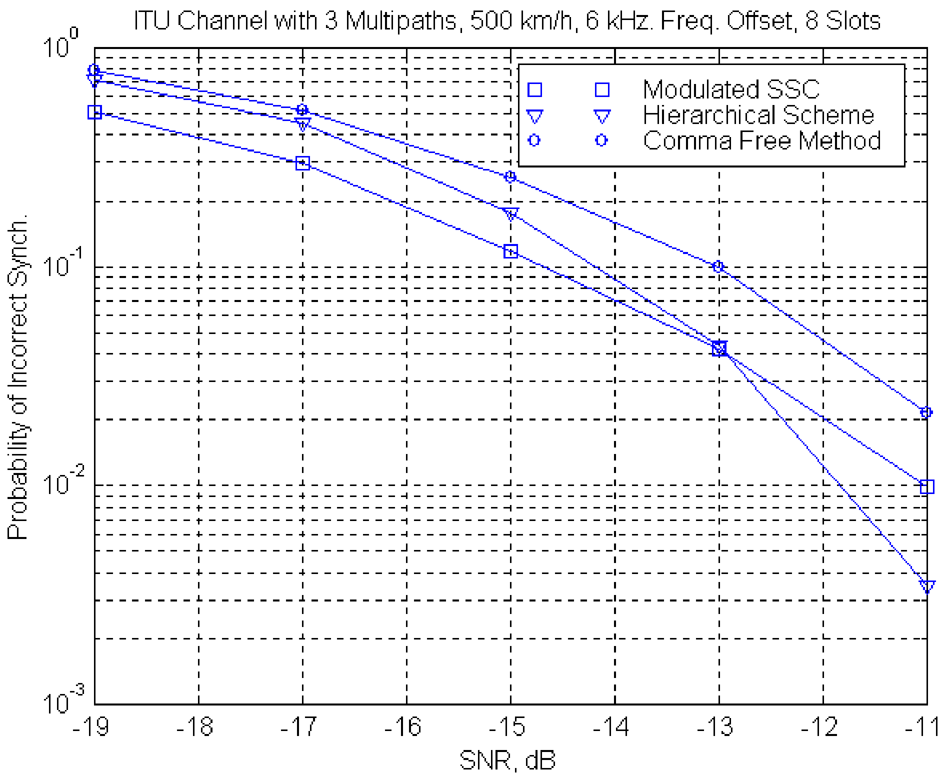

Fig. 10: Probablity of incorrect code group/frame timing synchronization in ITU channel with 3 multipaths, 500 km/h doppler, 6kHz Freq. error, 8 slot integration.

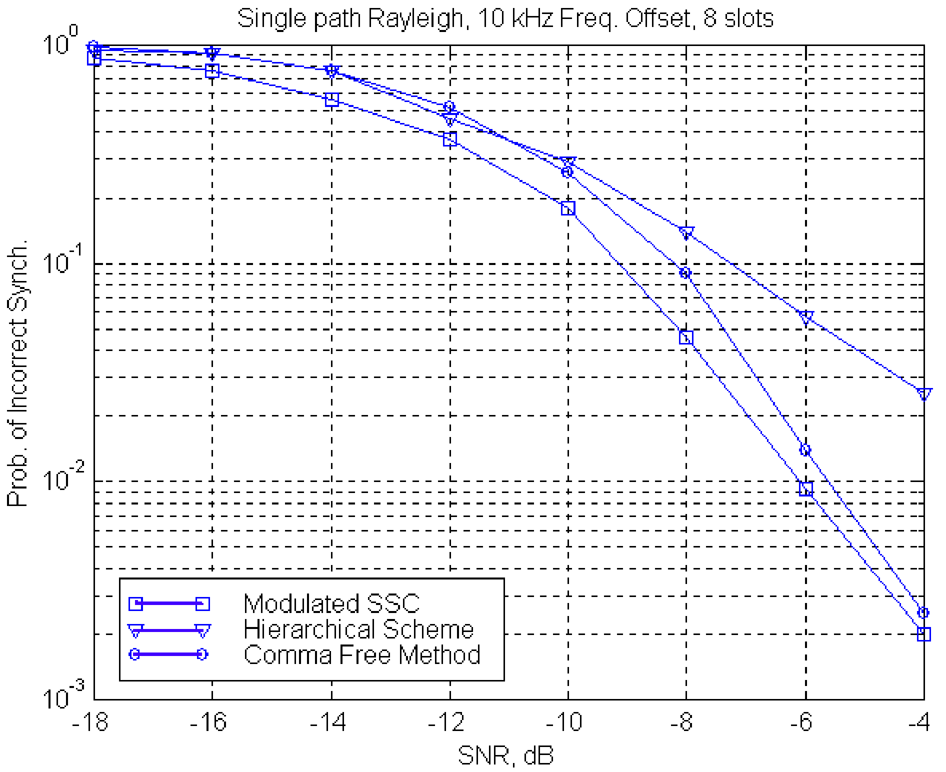

Fig. 11: Probablity of incorrect code group/frame timing synchronization in single Rayleigh fading, 10 kHz. freq. offset, 8 slots integration is used.

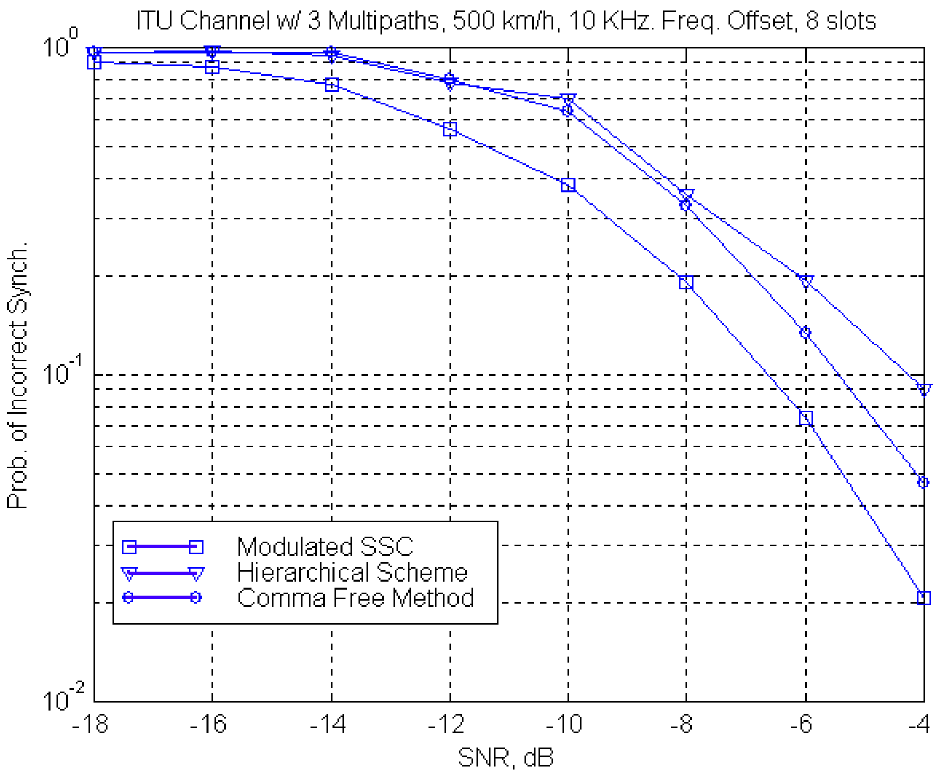

Fig. 12: Probablity of incorrect code group/frame timing synchronization in ITU Ch. with 3 multipaths, 500 km/h doppler, 10 kHz Freq. Offset, 8 slot integration.

5. Conclusion

A new cell search procedure, based on modulated SSC's is proposed. The six SSC's used for this procedure have low aperiodic cross-correlation with Cp.

These SSC's are also chosen such that at Step 2 of cell search procedure the Fast Hadamarad Transform can be applied to correlate them. This reduce the complexity of the algorithm. In Section 3, it is shown that, the proposed scheme has lower complexity compared to the Comma Free method and Hierarchical scheme.

In section 4 it is shown that the proposed scheme performs better than the current 3GPP proposal and performs comparable to the Hierarchical scheme. Due to high complexity of the Hierarchical scheme in the second step, we propose this scheme be approved to be used in UTRA TDD.

References

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