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Title: **Complexity analysis for parallel GSM synchronisation**

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1. Abstract

To examine GSM synchronisation properties from UTRAN we already did computer simulations in connected mode using the GSM propagation profile for typical urban environment and verified, that parallel GSM detection leads to a better synchronisation performance than the conventional search scheme [2]. Beside the improvement in higher detection probability the scheme is advantageous in halving the number of compressed frames and reducing the power consumption of the terminals. Capacity loss caused by transmission gaps is reduced and the talk time of terminals is increased.

In this contribution we show, that the base band complexity for the parallel detection of FCCH and SCH bursts with real time evaluation is 28.5 MIPS. From state of the art digital signal processor chips for GSM terminals and the fact that during downlink UTRAN compressed mode the UMTS signal processing load of the mobile receiver part is low, we conclude that the additional computation complexity can be handled, particularly because digital processing resources can be used which are anyhow idle during compressed mode.

2. Introduction

In the following a complexity analysis for UTAN to GSM synchronisation is presented. We compare a terminal using the parallel synchronisation as described in [1] and a terminal using a conventional GSM synchronisation approach. To achieve minimum detection time an optimised pattern for compressed mode is used for the parallel FCCH/SCH search. It is obvious that the average computational baseband complexity added into the user equipment for parallel search leads to a reduction of compressed frames. The expenditure of calculation under the view of digital signal processing is estimated and possible implementations are discussed.

3. UTRAN to GSM synchronisation

In any given GSM cell the set of FCCH and SCH channel is broadcast to help the mobile acquiring synchronisation. Additionally the signal from neighbour cells is evaluated to get information for handover. Therefore reports are transmitted from the mobile to the serving base station on a dedicated control channel during connected mode.

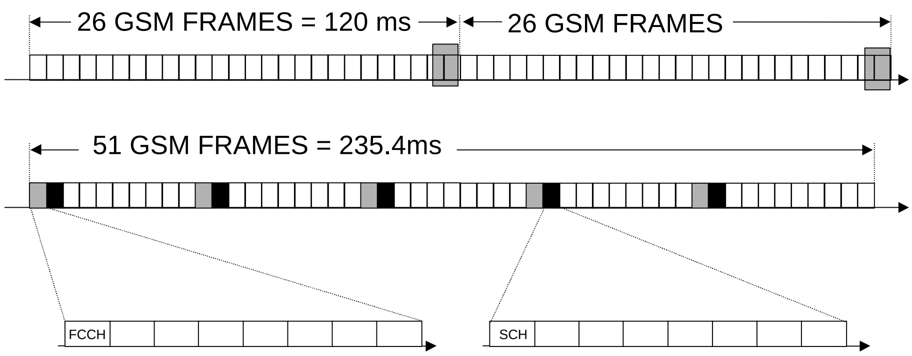

Figure 1: *GSM FCCH/SCH time organisation*

In a GSM network for example the received signal strength of neighbour cells is reported. Regarding the time structure of the GSM broadcast channels the synchronisation burst is located one frame after the frequency correction burst which is transmitted in frame 0,10,20,30 and 40. That means the time between two consecutive frequency or synchronisation bursts is 10*120/26 ms or 11*120/26 ms. Figure 1 shows the conventional GSM search for FCCH. The consecutive idle periods are scheduled every 120 ms.

A UTRAN connected mobile station during downlink compressed mode is able to receive from time to time - depending on the transmission gap and gap period of the compressed mode - FCCH or SCH bursts. By doing so the mobile acquires synchronisation and handover information on surrounding GSM cells. The conventional approach as described in [1] is to search first for frequency correction bursts. After such a burst is encountered the position of the corresponding SCH bursts within a few symbols is known. Because of the poor autocorrelation properties of the FCCH burst, the position in general is reconfirmed using the extended training sequence of the SCH burst. On the other hand the parallel approach is to search for FCCH and SCH bursts together. For both discussed schemes the demodulation of the SCH burst data part starts after detection of its position. We therefore exclude this part of the digital processing from our complexity analysis, because it is identical for both approaches.

4. Search scheduling

For the conventional UTRAN to GSM synchronisation scheme search frames are scheduled every 120 ms. This is derived as shown in figure 1 from the GSM structure for traffic channels. The number of necessary search frames to detect an FCCH burst can be calculated. It depends on the frame number of the FCCH/SCH multiframe structure in which the search is started.

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	8	6	4	2	11	9	7	5	3	1	8	6	4	2	11	9

17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
7	5	3	1	10	8	6	4	2	9	7	5	3	1	10	8	6

34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
4	2	9	7	5	3	1	10	8	6	4	2	11	9	7	5	3

Frame number of the FCCH/SCH multiframe structure in which the search is started
Number of search frames which are needed to detect a FCCH burst

Figure 2: *Number of search frames for the conventional scheme depending on the frame in which the search is started*

The average number of search frames is 5.6 frames. That means for detecting a FCCH burst an average of 5.6 search frames has to be evaluated. From there an average search time of 0.6 s is calculated.

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1	4	4	2	2	5	5	3	3	1	1	4	4	2	2	5

17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
5	3	3	1	1	6	4	4	2	2	5	3	3	1	1	6	4

34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
4	2	2	5	3	3	1	1	6	4	4	2	2	5	5	3	3

Frame number of the FCCH/SCH multiframe structure in which the search is started
Number of search frames which are needed to detect a FCCH or SCH burst

Figure 3: *Number of search frames for the parallel scheme depending on the frame in which the search is started*

For the parallel scheme it is advantageous to adopt the scheduling. We chose the distance between consecutive search frames to be unequal and alternating between 26 and 78 GSM frames every search frame. Both 26 and 78 GSM frames are a multiple of 10 ms which makes sure all compressed frames are well aligned with the UTRA frame structure. From there a periodic search time of 480 ms including two search frames results. Figure 3 shows the number of search frames which are needed to detect a FCCH burst or a SCH burst assuming the parallel scheme. It depends on the frame number of the FCCH/SCH multiframe structure in which the search is started. The average number of search frames that have to be evaluated is 3.0 and therefore reduced by 46.4 %. Also the average search time is reduced to 0.5 s. The improvement is based on the combination of the parallel search scheme and the adopted scheduling algorithm.

5. Complexity evaluation

5.1. Conventional FCCH burst detection

Compared to the initial search there is for the conventional detection of a GSM FCCH burst during UTRAN connected mode in general only a low frequency error between user equipment and base station, mainly caused by a doppler shift. From there a sliding average algorithm for detection of the FCCH burst is appropriate. We used in our simulations [2] to proof the better performance of the parallel search a sliding average detector over 142 GSM symbols. A new detector output value is calculated by deleting the last symbol and adding the new one to update the sum on a symbol by symbol basis. Not negligible is that some digital pre-processing like scaling, offset compensation, derotation or baseband filtering (pulse shape matched filtering) and post-processing like envelope calculation and threshold testing has to be done. For searching the FCCH burst structure within a GSM frame a total number of 9 GSM time slots containing 1407 symbols is evaluated. Because of additional time needed e.g. for switching the synthesisers an analogue search frame of more than 5.2 ms results.

Pre-processing	12 instructions per symbol * 1407 symbols

Calculation of sliding average	141 complex adds
Updating sum	2 complex adds per symbol * 1406 symbols

Post-processing	6 instructions per symbol * 1407 symbols

Figure 4: *Conventional search baseband computation complexity*

We obtain for the sliding average calculation an effort of 5906 instructions, assuming two real instructions per complex addition and four per complex multiplication. For pre- and post-processing we have additional 25326 real instructions. Thereby one real multiplication and one real addition is counted to be one instruction, assuming a MAC instruction is possible within one DSP clock cycle . This gives a complexity for calculation of 31232 instructions. For a real-time solution without buffering of the input frame a total amount of about 5.5 MIPS results. The processing time is one search frame plus the following synthesiser switching time.

5.2. Parallel FCCH burst and SCH burst detection

Searching the SCH burst means to detect the extended training sequence of the burst structure. This can be done by calculating the convolution between the input signal and the training sequence matched filter impulse response of length n+1. A very efficient algorithm is to divide the input sequence into smaller segments of length l and calculate the convolution segment by segment using a fast Fourier transformation. Therefore the segments are filled to a length l+n sequence by zero-padding. The construction of the output sequence is evaluated according the principle of superposition. Note that the same correlation technique (without segmentation) is already proposed for the efficient joint channel estimation for TDD, which means no extra algorithms have to be implemented and dedicated hardware (if used as an implementation option for TDD) can be reused.

As can be seen in figure 5, we obtain 122738 instructions for the fast overlay and add convolution. For pre- and post-processing we have again additional 25326 instructions. This gives a complexity for calculation of 148064 instructions and a total amount of 25.9 MIPS results for SCH burst only detection.

From the data given above the effort for parallel detection of FCCH and SCH bursts can be calculated easily. For pre- and post-processing we have 33768 instructions, because pre-processing has to be done only once, but post-processing twice for both FCCH and SCH search independently. Adding 122738 instructions for the SCH detection and 5906 instructions for the FCCH search gives 162412 instructions and a total amount of 28.5 MIPS results.

Pre-processing	12 Instructions per symbol * 1407 symbols
7 times FFT of length 256 segments	7*256*ld(256) = 14336 complex multiplications and additions
7 times multiplication of length 256	7*256 = 1792 complex multiplications
7 times inverse FFT of length 256 segments	7*256*ld(256) = 14336 complex multiplications and additions
7 times addition of overlapping parts	7*63 = 441 complex additions
Post-processing	6 instructions per symbol * 1407

Figure 5: *Baseband complexity for SCH only detection (l=193, n=63)*

Assuming a separate GSM and UMTS baseband hardware, the GSM signal processing part can execute the parallel synchronisation scheme independently and deliver appropriate results every 120 ms. But also UMTS baseband receiver hardware parts can be reused during compressed mode. For example existing rake fingers seem to be suitable to be used during GSM synchronisation. Because of the high clock frequency of 3.84 MHz which is about 14 times GSM symbol rate, the parallel scheme represents only low computation load. Adapting the UMTS hardware structure slightly we think 5 rake fingers will be well enough for the parallel GSM search.

6. Conclusion

Our analysis shows, that the parallel scheme requires about 5 times higher baseband computational complexity. For a real-time evaluation of search frames a total amount of 28.5 MIPS results. But during UTRAN compressed mode the signal processing load of the mobile station in general is low and therefore free resources can be allocated for GSM synchronisation e.g. downlink despreading units or matched filter units. An other approach is to buffer parts of the received samples and then perform the required processing "off line", in this way the processing requirements can be relaxed down to about 2 MIPS. Any trade off between storage requirements and peak processing requirements is possible as an implementation option. On the other hand by the parallel approach the average number of search frames to evaluate is reduced by 46.4 %. In addition the synchronisation performance is improved. With respect to the reduction in evaluated search frames the average signal processing expenditure for the parallel scheme can be estimated to be a factor of 2.7 compared to the conventional scheme.

The goal of the scheme is mainly the reduction in search frames . It enables us to reduce the power consumption especially in the analogue domain and the talk time can be increased. Because the power consumption of analogue parts is in general higher than the power consumption of the digital parts in the mobile and the fact, that power consumption of digital parts degreases faster than power consumption of analogue parts in future development relocation of the complexity from the analogue part to the digital part seems to be promising and this is in line with future trends.

From the system point of view we achieve by reducing the number of search frames less interference through less compressed mode idle times and therefore a better quality of services and a higher capacity when using the parallel search scheme.

We therefore propose to use the parallel GSM synchronisation for GSM handover measurements from UTRA using compressed mode. Additionally to maintain best performance it would be advantageous to optimise the scheduling for the parallel search. We propose to use a scheduling between consecutive search frames to be alternating between 120 ms and 360 ms.

7. References

[1] Tdoc SMG2 UMTS L1 636/98; Parallel FCCH/SCH search for GSM synchronisation; Siemens
[2] Tdoc SMG2 UMTS L1 398/99; Simulation Results for Parallel GSM Synchronisation; Siemens
[3] Digital cellular telecommunications system (Phase 2); Multiplexing and multiple access on the radio path (GSM 05.02 version 4.9.0)