CELL SEARCH PROCEDURE IN S-UMTS NETWORKS

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Abstract - W-CDMA and SW-CDMA air interfaces are based on code division multiple access and as in all spread spectrum systems the initial acquisition procedure is a challenging issue. This procedure is identified as *cell search* in W-CDMA and *beam search* in SW-CDMA. Although the terrestrial air interface W-CDMA and the satellite one SW-CDMA are very similar, the suggested cell/beam search procedures are different. In this paper, the two procedures are introduced and the numerical results are shown both in single path and in multipath propagation environments. Cell search and beam search procedures are compared in terms of time to acquisition and receiver complexity.

Keywords - IMT-2000, CDMA, Fading channel, Code Acquisition, Satellite Networks, Multicast/Broadcast Multimedia Services

I. INTRODUCTION

The introduction of new attractive services in future 3G mobile systems will have a strong impact in the market penetration. In this framework, multicast and broadcast services (MBMS) are definitely promising candidates. The 3GPP (3^{rd} Generation Partnership Project) standardization group is working towards the MBMS introduction and several technical reports and specifications are now available [1], [2], [3]. A terrestrial network is highly inefficient to supply multicast-broadcast services: the delivery of MBMS through a terrestrial link requires information stream replication in all cells where at least a user equipment (UE) registered to MBMS is located. Hence, many different resources, such as frequencies, codes, network connections, etc. are basically reused to transmit the same information. On the contrary, a way to efficiently deliver broadcast/multicast information is based on the exploitation of the satellite link. A GEO satellite is in fact able to cover wide areas with a reduced number of resources. The main issue that arises in satellite networks is the need to have an unobstructed line of sight (LOS) to close the link budget. Therefore, both indoor and urban propagation environment may not be covered by satellite signal and many MBMS subscribers may not be able to receive services via the satellite link. A possible solution to cope with this problem is the use of terrestrial repeaters, also known as boosters, gap fillers, or intermediate module repeaters (IMRs) located in the line of sight with the satellite. It is worth nothing that this satellite utilization is different from that envisaged by previous satellite consortia, such as Iridium and Globalstar, which were concerning with a geographical complement to the terrestrial network.

Both in W-CDMA and in SW-CDMA two levels of spreading are used, channelization, achieved with Orthogonal Variable Spreading Factor (OVSF) codes [4], and scrambling, obtained using Long Gold codes [5]. The cell search procedure [6] aims at identify-

ing the downlink cell/beam specific primary scrambling code. Once the primary scrambling code is available, the UE is able to acquire the broadcast and cell/beam specific information carried by the Broadcast Channel (BCH), since it is channelized with a fixed OVSF. Although the terrestrial and the satellite air interfaces are very similar, the 3GPP and ETSI (European Telecommunications Standards Institute) technical specifications suggest two different cell search procedures [6], [7]. In this paper both procedures are addressed comparing their performance in terms of total acquisition time and terminal complexity. SATIN propagation environments are considered regarding the presence of IMRs.

The paper is organized as follows. In Section II the addressed synchronization procedures are briefly introduced, whereas the synchronization subsystem is described in III. The evaluation scenarios are detailed in Section IV, while numerical results are reported in Section V. Finally, conclusions are drawn in Section VI.

II. Cell/Beam Search Procedure

In the downlink of W-CDMA and SW-CDMA air interfaces physical channels are arranged into 10 ms radio frames (T_{frame}), which consist of 15 slots of 0.67 ms each (T_{slot}), corresponding to 2560 chips, i.e. 3.84 Mchip/s. Without any knowledge about slot and frame boundaries, the cell/beam search procedure would require too much time. The total number of employed scrambling code is 8192, each one 38400 chips long. They belong to the Gold family and are divided into 512 sets. Each set contains one primary and 15 secondary scrambling codes (512x16 = 8192). Moreover, the 512 sets are organized in 64 *scrambling code groups*, each of which contains 8 primary scrambling codes and the associated 8 x 15 secondary codes. In order to avoid a large number of comparisons to find the downlink primary scrambling code, in [6] a three step procedure that employs three different physical channels is suggested. The channels envisaged by W-CDMA are the Primary Synchronization Channel (P-SCH), the Secondary Synchronization Channel (S-SCH) and the Primary Common Pilot Channel (P-CPICH). Instead, SW-CDMA standard suggests a two step procedure [7] plus a frame synchronization word (FSW) detection. Two physical channels, the P-SCH and the Primary Common Control Physical Channel (P-CCPCH) are provided to this aim. The channel structure is depicted in Fig. 1 and in 2. In the first step, the UE aims at synchronizing with the P-SCH (256-chip primary synchronization code, PSC). Every slot contains the same 256-chip sequence, thus, when this sequence is acknowledged, the terminal is slot synchronized. The S-SCH is used to obtain the frame synchronization in W-CDMA air interface. There are 16 possible secondary synchronization codes (SSC) and their combinations define 64 macro-sequences, each constituted by 15 SSC. The terminal tests all 15 positions and all 64 macro-sequences and decides which is the macro-sequence carried by the S-SCH. Since the macro-sequences belong to a cyclic 16 level Reed-Solomon code, once the cell specific macro-sequence is identified, the frame boundary is known. Moreover, the 64 macro-sequences are associated with the 64 scrambling code groups. Hence, the UE knows the scrambling code group used in the cell so that only the 8 scrambling codes belonging to the identified group are concerned in the last step exploiting the P-CPICH. The latter can be used to test the 8 scrambling codes because it carries a predefined symbols sequence spread with a fixed channelization code. In the SW-CDMA, the slot synchronization provided by the first step is used to identify the frame synchronization and the primary scrambling code in only one additional step. This is obtained exploiting the FSW carried by the P-CCPCH. As the primary CCPCH is scrambled with the primary synchronization code and is spread with a fixed OVSF code, once the FSW is detected, the frame synchronization and the scrambling code are both identified.

III. Synchronization subsystem description

The first step is identical for W-CDMA and SW-CDMA. Passive correlation based on a hierarchical matched filter (H-MF) [8], coherent accumulation over entire PSC (i.e. 256 chips), non-coherent post detection of order M [9], and MAX decision criterion [10] are performed. Moreover, in order to obtain a coarse synchronization within less then a half chip time, more than one hypothesis per chip is addressed. Using two hypotheses per chip, the time uncertainty region consists of 5120 cells and in the proposed scheme this is obtained by downsampling with factor 2 the output of the chip matched filter (a square root raised cosine, SRRC, filter with roll-off factor 0.22). The architecture adopted for the W-CDMA, is reported in Fig. 3. In order to reduce the terminal complexity, the second and the third step (W-CDMA only) are fed with one sample per chip, i.e. the SRRC output is again downsampled in order to have a single sample per chip. The sampling device is driven by the output of the first step. The received sequence is non-coherently correlated against each one of the 16 SSCs; notably, at this stage the non-coherent approach is mandatory since no phase reference exists before the third step is completed. The located macro-sequence of 16 SSCs spots out the code group used by the serving cell. Actually, a shorter correlation can be used, since it is possible to verify that a sequence of 3 SSCs is sufficient to identify both the code group and the frame bounds. As a matter of fact, each sequence of three SSCs in a macro-sequence associated to a code group is never repeated in any other macro sequence, thus allowing code group determination, nor in the same one, thus allowing frame bound localization. In the third step the downsampled sequence is descrambled with each one of the 8 primary scrambling code belonging to the scrambling code group determined in the second step and despread with the fixed OVSF code. The pilot data symbols are then non-coherently detected to determine which one of the scrambling code is used.

The architecture adopted for the second step of SW-CDMA, is reported in Fig. 4. In the second step the SRRC output is again downsampled in order to have a single sample per chip, descrambled with each one of the primary scrambling codes, and despread. Then hard detection on the FSW takes place.

IV. Evaluation scenario

The two air interfaces are evaluated in the SATIN propagation scenarios [11]. As well as the Additive White Gaussian Noise (AWGN) channel, Ricean channel, with mild Rice factor (K=5 and 15 [dB]), and Rayleigh one path fading channel are taken into account. Moreover, since IMRs coverage introduces a terrestrial multipath channel, the 6 taps vehicular and indoor channels suggested in [12] are considered. The power delay profiles of the two channels are reported in Table 1 and 2, respectively. Finally, different UE speeds are considered to evaluate the fading correlation effects on system performance. UE is supposed to move at a low speed of 3 km/h, at a medium speed of 50 km/h, at a high speed of 130 km/h, and at very high speed of 200 km/h.

V. Numerical Results

Fig. 5 shows the false acquisition probability of the first step with different post detection integration length (M) in AWGN channel. The larger is M, the better are the performance. The first step performance respect to different propagation channel are depicted in Figs. 6 and 7. The performance in a multipath environment are better than the AWGN one with low signal to noise ratio since any one of the six possible alignments is considered correct. Figs. 8, 9, and 10 show the false acquisition probability of the second and third steps of the W-CDMA cell search procedure. The false acquisition probability is reported as a function of the ratio of the energy per chip, E_c, over the noise power

spectral density, N_0, for the considered propagation channels and speed values. In particular, in Figs. 9 and 10 the false acquisition probability is reported for the third step in two different synchronization hypotheses: the ideal correct chip, slot and frame synchronization, indicated as *ideal*, and the *real* synchronization hypothesis provided by the first and second steps, indicated as *real*. Pilot symbols detection concerns only one slot of P-CPICH. Fig. 11 shows the detection probability, the missed detection probability, and the error probability for the second step of the SW-CDMA beam search procedure. In this case, ideal performance of the first step are assumed. Again, in the case of the multipath radio channel, correct acquisition is assumed when the receiver is correctly aligned with any one of the six path.

Finally, it is worthwhile comparing the two different air interfaces in terms of acquisition time and receiver complexity. The acquisition time for the W-CDMA procedure is:

$$T_{acq-WCDMA} = (15 + 15 + N)T_{slot}$$

where N is the number of slots considered in the third step. Two different options are possible for SW-CDMA. In the first one, the same descrambler is serially used for all the 15 possible frame alignments whereas in the second one a receiver parallel structure is envisaged with 15 descrambler for each scrambling code. Therefore, the acquisition time is:

$$T_{acq-SW-CDMA-1} = 15T_{slot} + 15T_{frame}$$

or

$$T_{acq-SW-CDMA-2} = 15T_{slot} + 2T_{frame}$$

Table 3 shows the receiver complexity in terms of the number of the correlators. K is the number of scrambling code considered. Without any knowledge on the scrambling code employed in the beam, the UE has to take into account all the available 512 codes ($K = 512$).

VI. Conclusions

In this paper, the cell/beam search procedures employed by a UE to acquire initial synchronization in W-CDMA and SW-CDMA air interface based system were considered. In particular, the performance of the two proposed architectures were evaluated in a significant scenario, in which the satellite coverage is enhanced in urban and suburban environment through the use of terrestrial intermediate repeaters. Furthermore, a comparison between the two architectures has been outlined based on acquisition time and implementation complexity. The satellite second step requires a higher number of correlators than that used in the terrestrial second and third steps. In the case of UE *cold* start, the UE can use its internal satellite constellation model, time reference and coarse location knowledge to locally generate a list of candidate scrambling sequences. If the UE has some more accurate knowledge of its position (*warm* start), the number of scrambling codes to be searched can be further reduced, together with the search time and the receiver complexity.

Acknowledgements

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Tap	Relat. Power (dB)	Relat. Delay (ns)
0	0	0
1	-1	310
2	-9	710
3	-10	1090
4	-15	1730
5	-20	2510

Table 1
Vehicular multipath power delay profile used in simulation

Tap	Relat. Power (dB)	Relat. Delay (ns)
0	0	0
1	-3	50
2	-10	110
3	-18	170
4	-26	290
5	-32	310

Table 2
Indoor multipath power delay profile used in simulation

Correlators required	W-CDMA	SW-CDMA
1^{st} step	1 (hierarchical)	1 (hierarchical)
2^{nd} step	16	K - (1) K*15 - (2)
3^{rd} step	8	-

Table 3
Number of correlators used in the two air interfaces

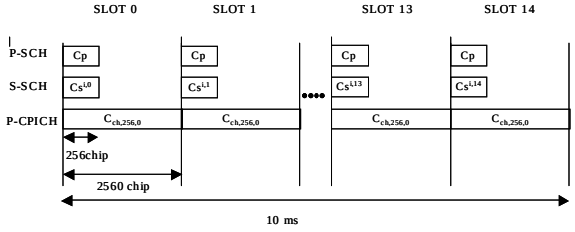

Fig. 1. Structure of the physical channels used for cell search; W-CDMA air interface

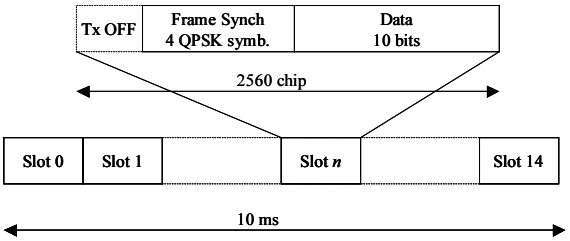

Fig. 2. Structure of the P-CCPCH used for beam search; SW-CDMA air interface

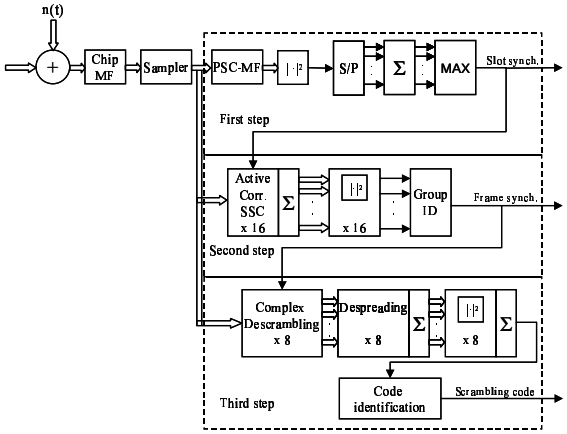

Fig. 3. Synchronization subsystem used for W-CDMA cell search

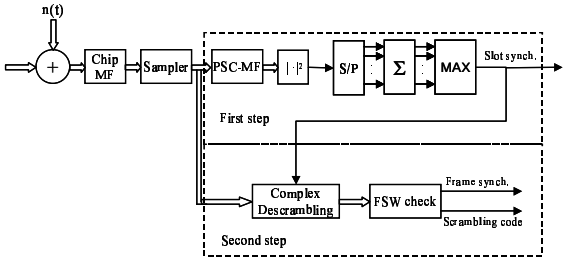

Fig. 4. Synchronization subsystem used for SW-CDMA beam search

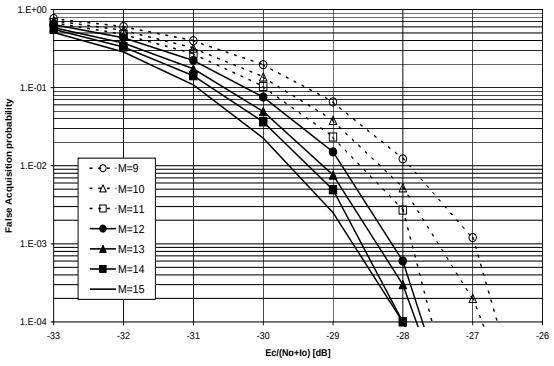

Fig. 5. False Alarm probability vs. Ec/No, step 1, in AWGN channel. M=9, 10, 11...15

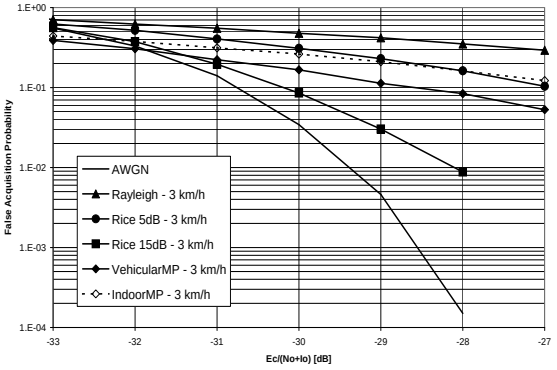

Fig. 6. False Alarm probability vs. Ec/No, step 1. Speed 3 km/h; Rayleigh, Rice and multipath channels

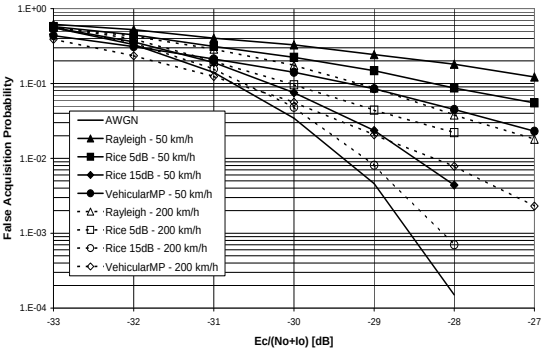

Fig. 7. False Alarm probability vs. Ec/No, step 1. Speed 50 and 200 km/h; Rayleigh, Rice and multipath channels

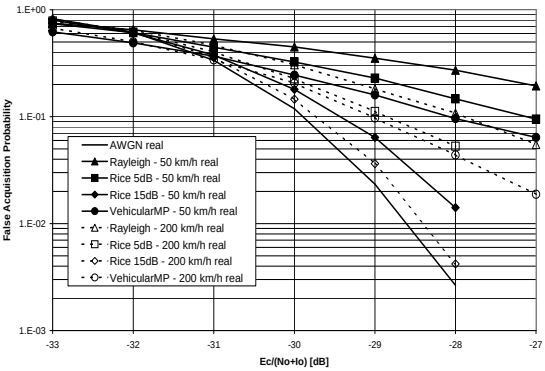

Fig. 8. False Alarm probability vs. Ec/No, W-CDMA air interface, step 2. Speed 50 and 200 km/h; Rayleigh, Rice and multipath channels

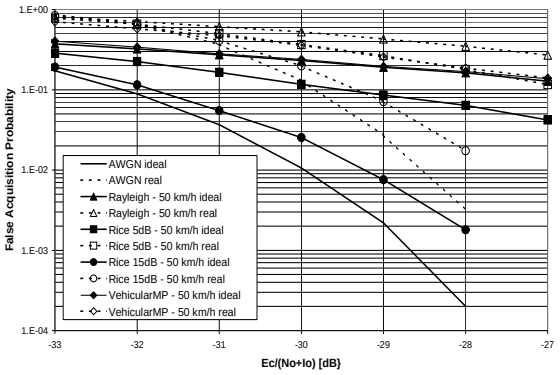

Fig. 9. False Alarm probability vs. Ec/No, W-CDMA air interface, step 3. Speed 50 km/h; Rayleigh, Rice and multipath channels

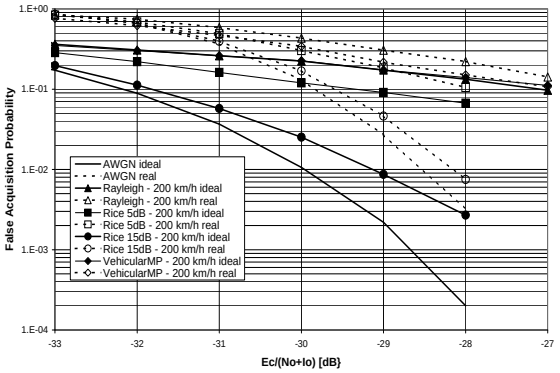

Fig. 10. False Alarm probability vs. Ec/No, W-CDMA air interface, step 3. Speed 200 km/h; Rayleigh, Rice and multipath channels

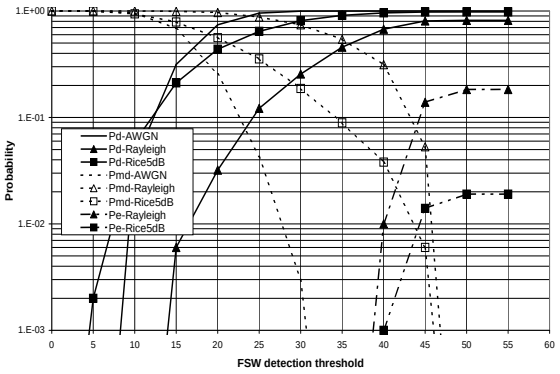

Fig. 11. Detection, Missed detection, and Error Probability vs. FSW detection threshold, SW-CDMA air interface, step 2. Speed 130 km/h; Rayleigh and Rice channels