The BER Evaluation of UMTS under Static Propagation Conditions

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Abstract: - The paper is concerned with the BER evaluation of UMTS under static propagation conditions. The main goal is to analyse the BER dependency on Eb/No ratio for various spreading factors. There are described basic operations, such as uplink spreading, uplink scrambling and modulation. The UMTS model of signal processing in an uplink direction proposed for this work is also presented. The simulation results for various spreading factors are graphically expressed.

Key-Words: - UMTS, Propagation, Static Channel, BER, Modelling, Signal processing

1 Introduction

Wideband Code Division Multiple Access (WCDMA) is the most widely adopted air interface for Third Generation systems. It provides peak bit rates of 2 Mbps, variable data rate on demand, a 5 MHz bandwidth, and a significant reduction of the network round trip time. In UMTS the chip rate is set to 3.84 Mchip/s.

UMTS uses direct sequence CDMA (DS-CDMA), where every symbol of the data signal sequence is multiplied with multiple code chips from a CDMA code sequence. Direct sequence spreading causes the resulting spread signal to occupy a wider bandwidth than the original signal, and multiple spread data sequences can be transmitted simultaneously in the same frequency band. The DS-CDMA receiver despreads the received chip sequence with the right code.

2 Signal processing in uplink

The basic operations, which are performed with signal, are spreading and scrambling. The signal is first spreaded by OVSF code (Walsh codes are used). This leads to extension of signal band. After that, the wideband signal is scrambled by scrambling code (S(2) or Gold codes are used). This operation does not cause additional extension of the bandwidth. The details of above mentioned operations are described below.

2.1 Uplink Spreading

For the uplink DPCCH spreading code, there is a restriction. The same code cannot be used by any other code channel even on a different I or Q branch. The reason for this restriction is that physical channels transmitted with the same channelisation codes on I and Q branches with the dual channel QPSK principle cannot be separated before the DPCCH has been detected and channel phase estimates are available.

This causes the restriction, that with multicode transmission for DPDCH, the number of parallel spreading codes possible to allocate to DPDCH is six and not eight, when considering the spreading factor of 4 (which would be used in the case of DPDCH multicode transmission).

In the uplink direction the spreading factor on the DPDCH may vary on frame-by-frame basis. The spreading codes are always taken from the code tree. When the channelisation code used for spreading is always taken from the same branch of the code tree, the despreading operation can take advantage of the code tree structure and avoid chip-level buffering. The terminal provides data rate information, or more precisely the Transport Format Combination Identifier (TFCI), on the DPCCH, to allow data detection with a variable spreading factor on the DPDCH.

2.2 Channelisation Codes

Transmissions from a single source are separated by channelisation codes, i.e. downlink connections within one sector and the dedicated physical channel in the uplink from one terminal. The spreading/channelisation codes of UTRA are based on the Orthogonal Variable Spreading Factor (OVSF) technique [1]. The use of OVSF codes allows the spreading factor to be changed and orthogonality between different spreading codes of different lengths to be maintained. The codes are picked from the code tree, which is illustrated in figure 1.

In case the connection uses a variable spreading factor, the proper use of the code tree also allows despreading according to the smallest spreading factor. This requires only that channelisation codes are used from the branch indicated by the code used for the smallest spreading factor.

There are certain restrictions as to which of the channelisation codes can be used for a transmission from a single source. Another physical channel may use a certain code in the tree if no other physical channel to be transmitted using the same code tree is using a code that is on an underlying branch, i.e. using a higher spreading factor code generated from the intended spreading code to be used. Neither can a smaller SF code on the path to the root of the tree be used. The downlink orthogonal codes within each base station are managed by the radio network controller (RNC) in the network.

The definition for the same code tree means that for transmission from a single source, from either a terminal or base station, one code tree is used with one scrambling code on top of the tree. This means that different terminals and different base stations may operate their code trees totally independently of each other; there is no need to coordinate the code tree resource usage between different base stations or terminals.

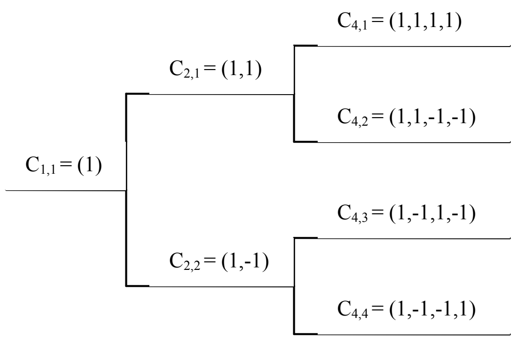

Fig. 1: Beginning of the channelisation code tree.

2.3 Scrambling

In addition to spreading, part of the process in the transmitter is the scrambling operation. This is needed to separate terminals or base stations from each other. Scrambling is used on top of spreading, so it does not change the signal bandwidth but only makes the signals from different sources separable from each other. With scrambling, it would not matter if the actual spreading were performed with identical codes for several transmitters. As the chip rate is already achieved in spreading by the channelisation codes, the symbol rate is not affected by the scrambling.

2.4 Uplink Scrambling Codes

The transmissions from different sources are separated by the scrambling codes. In the uplink direction there are two alternatives: short and long scrambling codes. Both of the two scrambling code families contain millions of scrambling codes, thus, in the uplink direction, code planning is not needed.

The short scrambling codes have been chosen from the extended S(2) code family. The long codes are Gold codes. The complex-valued scrambling sequence is formed in the case of short codes by combining two codes, and in the case of long codes from a single sequence where the other sequence is the delayed version of the first one [1].

2.5 Uplink modulation

In the uplink direction there are basically two additional terminal-oriented criteria that need to be taken into account in the definition of the modulation and spreading methods. The uplink modulation should be designed so that the terminal amplifier efficiency is maximized and/or the audible interference from the terminal transmission is minimised. Therefore, in a WCDMA uplink the two dedicated physical channels are not time multiplexed but I-Q/code multiplexing is used.

The continuous transmission achieved with an I-Q/code multiplexed control channel is shown in figure 2.

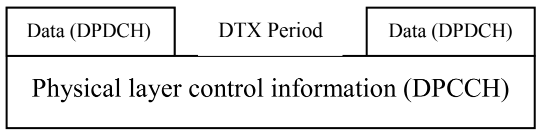

Fig. 2: Parallel transmission of DPDCH and DPCCH when data is present/absent (DTX).

Now, as the pilot and the power control signalling are maintained on a separate continuous channel, no pulsed transmission occurs. The only pulse occurs when the data channel DPDCH is switched on and off, but such switching happens quite seldom. The average interference to other users and the cellular capacity remain the same as in the time-multiplexed solution. In addition, the link level performance is the same in both schemes if the energy allocated to the pilot and the power control signalling is the same [3].

With the I-Q/code multiplexing, also called dual-channel QPSK modulation, the power levels of the DPDCH and DPCCH are typically different, especially as data rates increase, and would lead in extreme cases to BPSK-type transmission when transmitting the branches independently. This has been avoided by using a complex-valued scrambling operation after the spreading with channelisation codes [3].

2.6 Uplink Dedicated Channel

As described earlier, the uplink direction uses I-Q/code multiplexing for user data and physical layer control information. The physical layer control information is carried by the DPCCH with a fixed spreading factor of 256. The higher layer information, including user data, is carried on one or more DPDCHs, with a possible spreading factor ranging from 256 down to 4.

The uplink transmission may consist of one or more DPDCHs with a variable SF, and a single DPCCH with a fixed SF. The DPDCH data rate may vary on a frame-by-frame basis. Typically with a variable rate service the DPDCH data rate is informed on the DPCCH. The DPCCH is transmitted continuously and rate information is sent with the Transport Format Combination Indicator (TFCI), the DPCCH information on the data rate on the current DPDCH frame.

3 UMTS Model

Mathematical model is designed in MATLAB. It is based on 3GPP specifications. The model simulates signal processing in the uplink direction of Dedicated Physical Data Channel (DPDCH) and Dedicated Physical Control Channel (DPCCH) in I-Q/code multiplex. The block scheme of designed model shows Fig. 3.

Binary data (from random generator) are firstly mapped for processing purposes - binary 1 is mapped as -1 and binary 0 is mapped as 1. Then, the data are multiplied with channelisation code. In each branch (DPDCH and DPCCH) is used different channelisation code - for data spreading $C_{ch,SF}$ and for control information spreading C_C. The Walsh codes are used.

The value of spreading factor is between 4 and 256 for DPDCH and 256 for DPCCH. This means one data bit is multiplied by sequence of length from 4 to 256. Longer spreading code means lower bit rate but higher spreading gain and higher number of applicable codes. Corresponding bit rates for various spreading factors are shown in table 1.

Then, both branches are multiplied by the same scrambling code. Second branch is additionally multiplied by complex unit and both branches are then combined into complex chip flow. The chip rate is 3,84 Mchip/s. After this operation several channels may be combined. Finally, the pulse shaping by root raised cosine filter is performed.

Radio environment presents AWGN channel -

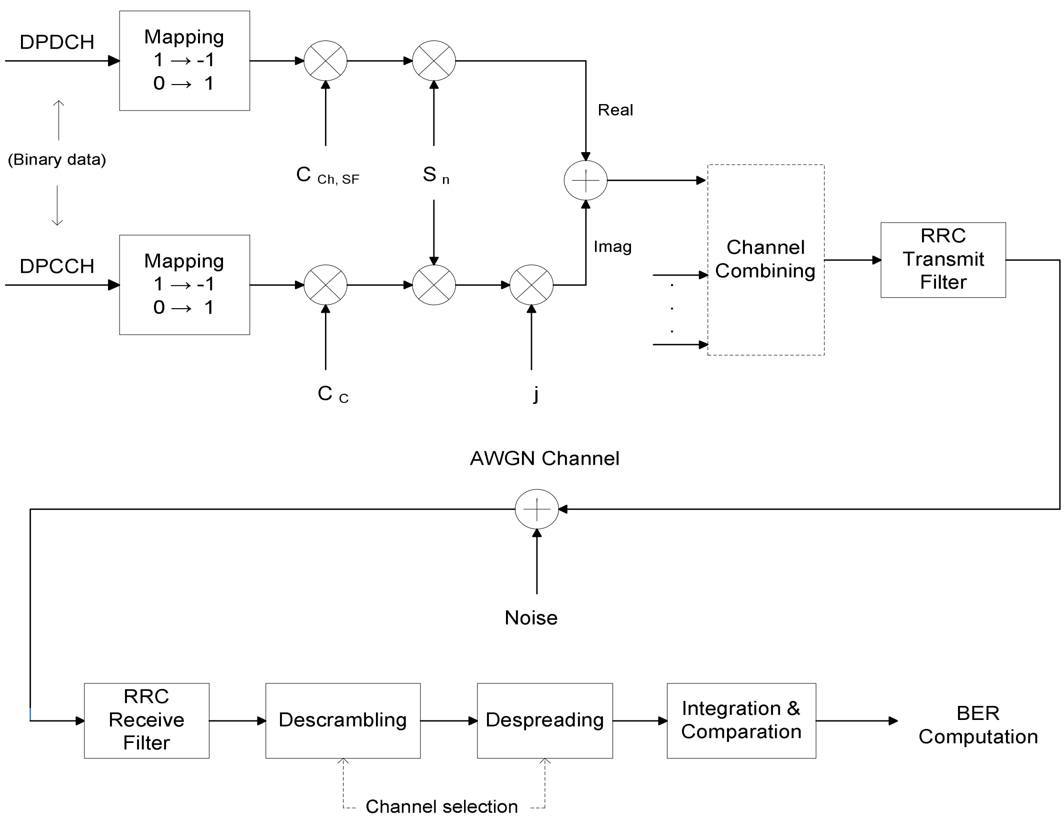

Fig. 3: Block scheme of signal processing in the uplink direction.

white Gaussian noise is added to transmitted signal. Receiving side performs inverse operations - descrambling and despreading (selecting required channel) by using the proper scrambling and channelisation code. After this, data flow is restored (by integration and comparation) and bit error ratio of received data is evaluated.

Table 1: Uplink DPDCH data Rates.

DPDCH spreading factor	DPDCH channel bit rate (kbps)
256	15
128	30
64	60
32	120
16	240
8	480
4	960

Simulation has been performed for spreading factor values from 4 to 256 and for Eb/No ratio from -5 dB to 10 dB, 1000 data bits have been always transmitted for each SF and each Eb/No ratio. For channelisation has been always used independent codes, because the code constitution has inconsiderable influence to results. The results obtained from simulation are graphically expressed in Fig.4.

4 Conclusion

The physical layer, especially signal processing in the uplink direction of UMTS, was analysed in this work. Mathematical model of the radio interface (UTRA FDD mode) and its design in Matlab 7.0 Simulink was described.

The goal was to evaluate the dependency of BER on different Eb/No ratio and for various values of spreading factor (no Forward Error Correction FEC was used). The results of the simulations from this model can be used in UMTS network planning and optimization process.

The future task of this project is design of the complete model of UMTS physical layer and radio channel. The complex graphical tool will be also created.

Acknowledgement

This research is supported by the Grant Agency of the Czech Republic, Grant project No. 102/04/2080 and also Czech Ministry of Education, FRVŠ project No. IS 1840140. This research also represents a part of the Research Program of the Czech Ministry of Education MSM 262200011, Research of Electronic Communication Systems and Technologies and MSM 262200022, Research of Microelectronic Systems and Technologies MIKROSYT.

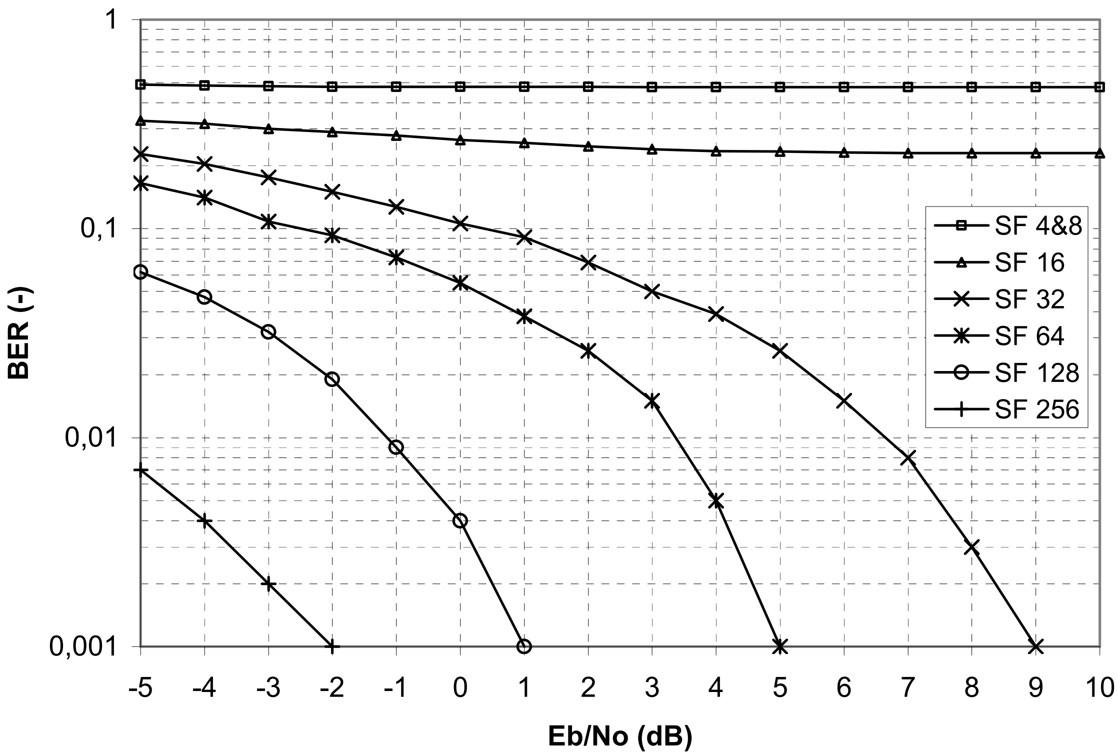

Fig. 4: BER dependency on Eb/No ratio.

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