UMTS Network Model for Interference Analysis - Optimization of Spreading Codes Order

Zdeněk RŮŽIČKA, Stanislav HANUS

Dept. of Radio Electronics, Brno University of Technology, Purkyňova 118, 612 00 Brno, Czech Republic

xruzic20@stud.feec.vutbr.cz, hanus@feec.vutbr.cz

Abstract. *This article deals with mathematical modeling of UMTS network. The presented model is designed for interference analysis in this network. The paper presents the set of simulations based on an idea of a specific order of Walsh codes.*

In the first part the mathematical model is presented. This model is designed for Matlab and is based on 3GPP specifications. The second part describes the method of specific ordering of Walsh spreading codes. The specific order can decrease the interference level in the radio network of UMTS which is caused by multipath propagation. The simulation results are presented, too.

Keywords

UMTS, orthogonal codes, optimization.

1. Introduction

The UMTS network, as a member of the third generation of mobile communications, requires a different approach than previous systems. The main difference is that 3G systems use CDMA technique and only one frequency for all subscribers connected in the network [1]. This fact requires a different approach in comparison with 2G systems. All signals with another spreading code are rated as interferences; therefore there are rather different C/I ratios. Spreading codes used for channelisation are orthogonal, but in the case of a time shift between two codes the orthogonality is distorted. This leads to the C/I ratio decreasing and to the signal quality degradation.

The delay between two codes can be evoked by multipath propagation. The signal can go from a transmitter to a receiver through different ways. Delayed (indirect) paths can partly disturb and decrease the quality of the useful signal at the receiving place.

The mathematical model described in this article is designed for UMTS network interference analysis. The presented simulation is focused to multipath propagation and shows the way to BER decrease by specific ordering of Walsh spreading codes.

2. Model Description

The described model is programmed in Matlab. Its structure is based on 3GPP specifications [2], [3]. This model simulates DPDCH channel processing in downlink. The basic scheme of a transmitting part of the presented model is depicted in Fig. 1.

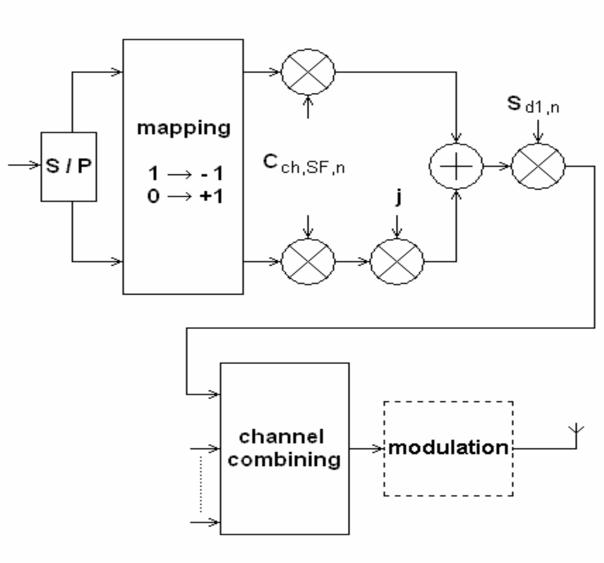

Fig. 1. Transmitting part of the UMTS model.

Data flow is divided into two branches and mapped for modulation purposes. In this case QPSK modulation with pulse shaping by root raised cosine filter is used. Data mapping is following

$$b^o\{0,1\} \rightarrow b_b^o\{1,-1\} \quad b^e\{0,1\} \rightarrow b_b^e\{1,-1\} \qquad (1), (2)$$

where $b^{o,e}$ represents binary data in both branches and $b_b^{o,e}$ represents mapped data.

In each branch it is used channelisation code for data spreading and for orthogonal separation of different channels. In UMTS system the Walsh codes are used. The value of the spreading factor is between 4 and 512. That means one bit is multiplied by the orthogonal sequence of length from 4 to 512. A longer spreading code means a lower bit rate but a higher spreading gain and a higher number of applicable codes.

Both branches use the same code. The second branch is multiplied by the unit complex number and both branches are then combined into a complex chip flow. The chip rate is 3,84 Mchip per second. The spreading process is described by these equations:

$$s_i^o(t) = c_{ch,SF,m}.b_b^o(t), \quad s_i^e(t) = c_{ch,SF,m}.b_b^e(t), \quad (3), (4)$$

$$T_b = SF.T_c \quad (5)$$

where $s_i^{o,e}$ represents the spread signal in both branches, $c_{ch,SF,m}$ is the spreading code, SF is the spreading factor, T_b is the time period of input data and T_c is the chip period of spread data. This complex chip flow is multiplied by the scrambling code:

$$ch_i(t) = \left(s_i^o(t) + j.s_i^e(t)\right).c_{s,d1,n}(t) \quad (6)$$

Scrambling codes are derived from Gold sequences and serve for Node B recognition. These codes do not spread input chip flow. The length of these codes is 38400 chips which corresponds with the UMTS frame length. One frame time duration is 10 ms. After this operation channels are merged:

$$m(t) = \sum_{i=1}^{x} p_i ch_i(t) \quad (7)$$

where p_i is the power weight for the i-th channel.

In simulations presented thereinafter the modulation process is omitted for time saving reasons. The signal is only shaped by the root raised cosine filter with the pulse characteristic:

$$h = \frac{4\alpha}{\pi\sqrt{T}} \frac{\cos\left(\frac{(1+\alpha)\pi t}{T}\right) + \frac{T}{4\alpha t}\sin\left(\frac{(1-\alpha)\pi t}{T}\right)}{1-\left(\frac{4\alpha t}{T}\right)^2} \quad (8)$$

where α is the filter roll off factor.

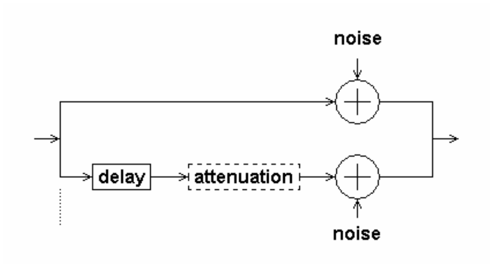

Fig. 2. Radio environment simulation.

The first action is indirect path delay and attenuation. After this, noise is added to both paths. Both paths are combined and used as an input signal for the receiving side of the model. The receiving side of the model is shown in Fig. 3. It performs descrambling and selecting the required channel using channelisation code. After this, the data flow is restored and the required value, in this case the bit error ratio of the received data flow, is evaluated.

Fig. 3. Receiving part of UMTS model.

The generators of Walsh codes and complex scrambling codes are important parts of this model. The model structure and all used parameters can be modified for the specific situation to obtain required results.

3. Method Description

Walsh orthogonal codes are used for channelisation due to good correlation properties. The cross correlation between two Walsh codes is equal to zero. This property is valid in the case of time synchronized codes only. If these codes are not synchronized, cross correlation property can be non-zero.

Two groups of Walsh codes can be created. The codes in the first group have the cross correlation property equal to zero during the whole period, without dependence to a time shift between the codes. The course of cross correlation of the first-group codes is shown in Fig. 4.

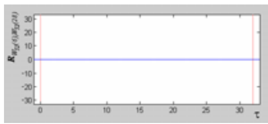

Fig. 4. First-group codes cross correlation property.

The second group is formed by codes with zero cross correlation for zero time shift and non-zero cross correlation for non-zero time shift. The examples of cross correlation course are depicted at Fig 5.

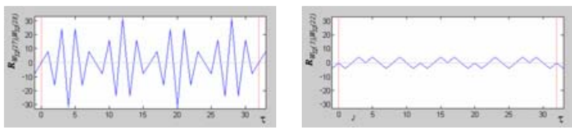

Fig. 2. Second-group codes cross correlation property.

Presented courses show that the codes from the first group don't increase the interference level because there is no influence between channels that use these codes, without dependence on a time shift.

If the codes from the second group are used, there is no influence in the case of ideal time synchronization only. In other case the interference level in the radio environment is increased.

In terms of cross correlation courses the following simulations can be performed. There is two channels simulation. The simulation output is the BER dependence on the time shift between the paths of the signal. In the first case the spreading codes from the first group are used. The second simulation uses spreading codes from the second group. The simulation results are shown in Fig. 6.

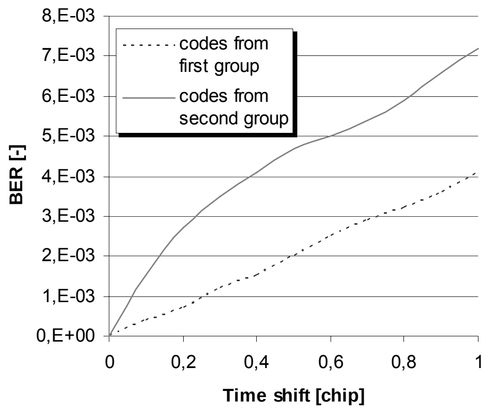

Fig. 6. Two channels simulation with Walsh codes from different groups.

It can be seen from the courses in Fig. 6. that the BER increase is greater in the case of the second-group codes. The BER increase in the simulation with the spreading codes from the first group is caused by the influence of the same code with a different time shift.

It can be seen from Fig. 5. that the different codes from the second group have different cross correlation course and therefore the influence rate is different, too. The following simulation is similar to the previous one. The two different pairs of the spreading codes from the second group are used. Fig. 7. shows the simulation results.

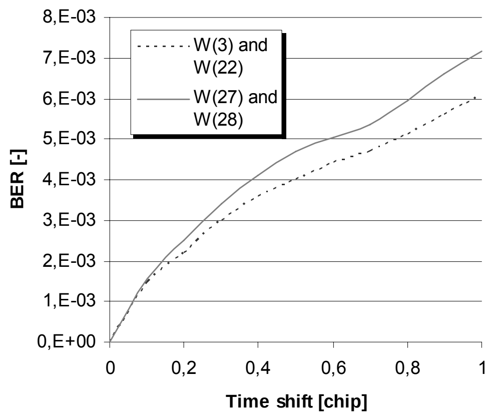

Fig. 7. Two channel simulation with different pairs of Walsh codes from the second group.

It can be seen from these courses that the code sensitivity to the time shift can be different for the different code pair. The BER increase is directly proportional to this sensitivity based on cross correlation properties. The information presented above leads to the concept of the Walsh spreading codes specific order. There are two basic possibilities.

The first way is to use the first group code only. This possibility is probably the simplest, but leads to an important capacity decrease. The second way is to create a new specific order of the spreading codes. The system capacity is saved, but the principle is more complicated.

The following text is focused to the second possibility. On the basis of simulation results presented above the code order can be formed in the following steps:

- codes from the first group,
- codes from the second group ordered according to the time shift sensitivity.

The issue is that the cross correlation of codes signed x and y can be equal to zero and cross correlation of codes x and z is non-zero. The line between two presented groups of spreading codes changes in dependence on the used spreading codes.

Therefore, the usage of some optimizing algorithm can be effective way to solve this problem. UMTS uses a variable spreading factor between 4 and 512 in the downlink. Therefore it is necessary to optimize the whole spreading code tree. In this case the genetic algorithm was chosen. The cost function is defined by this equation:

$$Q = \sum_{i=1}^{SF} \frac{1}{i} \sum_{k=1}^{i} BER_{i,k} \qquad (9)$$

where i is the number of the processed channels, k is the just processed channel and $BER_{i,k}$ is the bit error ratio of the k-th channel. The Q value is minimized by the genetic algorithm with these parameters:

- 7 members in a generation,
- 20 – 50 generations,
- 4 new members in each generation (2 members by crossing, 2 members by random generation),
- 100% mutation (except elite member).

A member is defined by the specific order of the spreading codes. The calculation of cost function is a very time consuming process.

4. Simulation Results

Here the results of single simulations are presented. Each simulation corresponds to one value of the spreading factor.

On the basis of previous results the following simulation was performed. There is a downlink signal formed by DPDCH channels with a different spreading factor. This signal is divided to two radio paths and the second path is delayed from 0 to 1 of the chip period. The output of the simulation is the total BER in all channels. In the first case the spreading codes are assigned by the normal order and in the second case by the optimized order.

This simulation is performed for three traffic types: Mostly voice, mostly data and a combined traffic. The channel assignment for each simulation variant is shown in Tab. 1. The overall number of channels represents 50% of the orthogonal codes capacity.

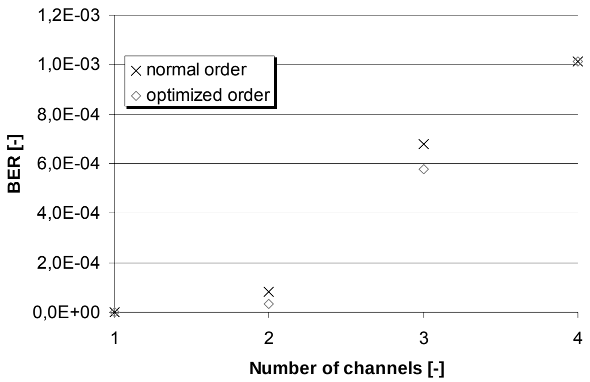

Fig. 8. Simulation for SF = 4.

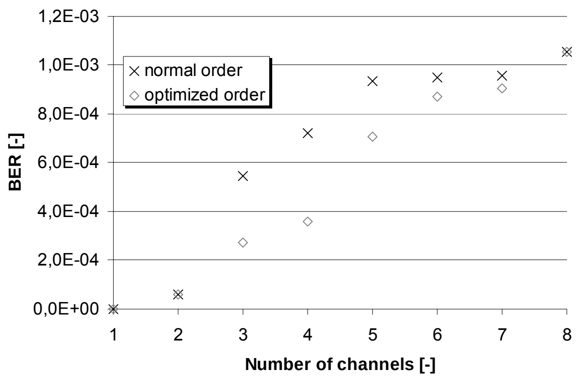

Fig. 9. Simulation for SF = 8.

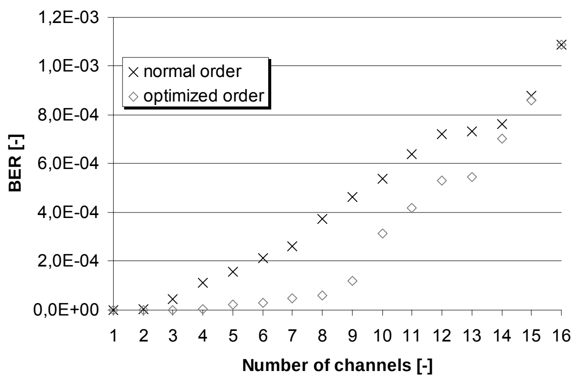

Fig. 10. Simulation for SF = 16.

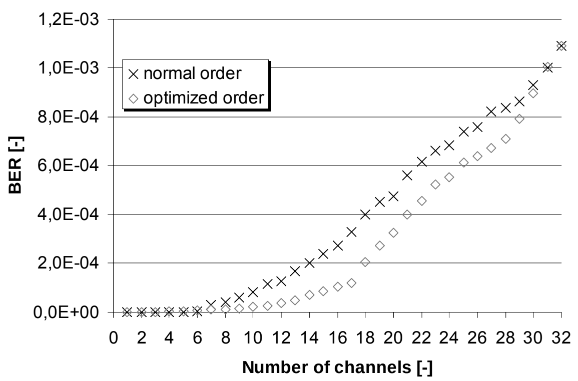

Fig. 11. Simulation for SF = 32.

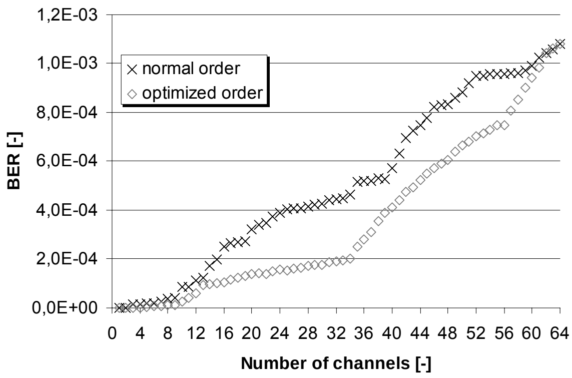

Fig. 12. Simulation for SF = 64.

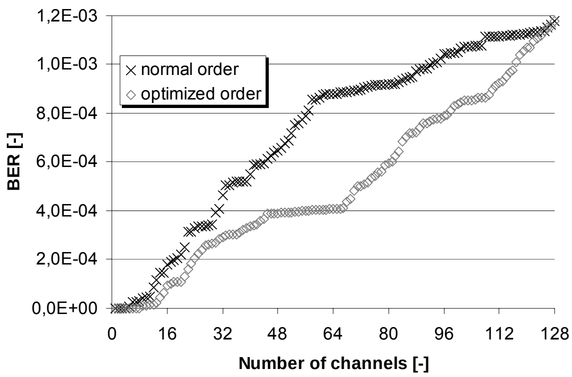

Fig. 13. Simulation for SF = 128.

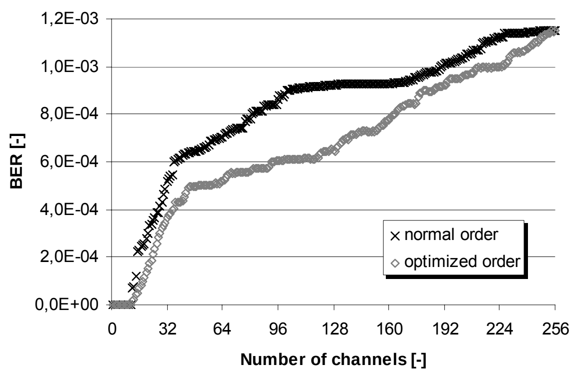

Fig. 14. Simulation for SF = 256.

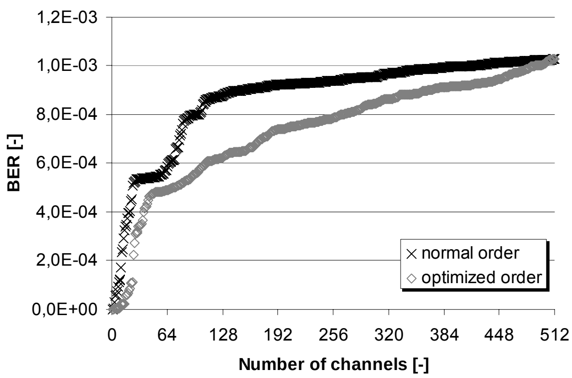

Fig. 15. Simulation for SF = 512.

SF	Number of channels		
	mostly voice	mostly data	uniform
4	0	0	1
8	0	2	1
16	2	2	1
32	4	4	1
64	0	0	1
128	32	0	1
256	0	0	1
512	0	0	1

Tab. 1. Channel assignment.

The results are presented at the Fig. 16. - 18.

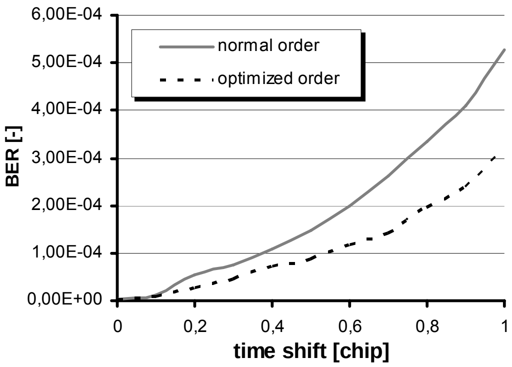

Fig. 16. Mostly voice traffic.

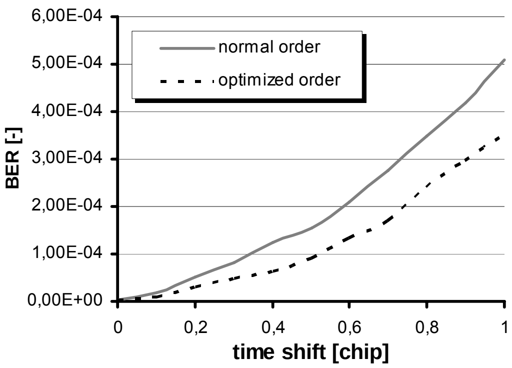

Fig. 17. Mostly data traffic.

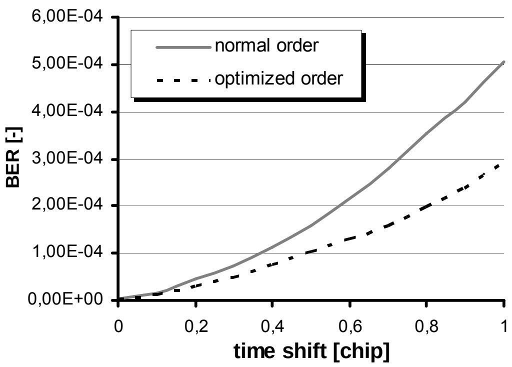

Fig. 18. Uniform traffic.

5. Conclusion

The presented method of spreading codes assignment can lead to an interference level decrease in the radio environment. These simulations are very time consuming processes. Better results can be obtained by using more sufficient computer resources and longer simulations.

Acknowledgements

This work has been supported by the research project of the GA CR (Czech Science Foundation) No. 102/07/1295 “Models of Mobile Networks and their Parts”, by the doctoral project of the GA CR No. 102/03/H109 "Methods, Structures and Components of Electronic Wireless Communication", and by the research program No. MSM 0021630513 “Advanced Electronic Communication Systems and Technologies” (ELCOM).

References

[1] KORHONEN, J. *Introduction to 3G Mobile Communications.* Norwood: Artech House, 2001.

[2] 3GPP Technical Specification Group Radio Access Network - *Spreading and Modulation (FDD)*; TS 25.213 V6.3.0 [online], available at http://www.3gpp.org, 2005.

[3] 3GPP Technical Specification Group Radio Access Network - *Physical Layer, General Description*; TS 25.201 V6.2.0 [online], available at http://www.3gpp.org, 2005.

[4] BOSTELMANN, G., ZARITS, R. *UMTS Design Details & System Engineering.* Karlsruhe: INACON GmbH, 2002.

[5] WIESER, V., PŠENÁK, V. Hybrid adaptation simulator for next generation of mobile communication networks. In *6th International Conference on Research in Telecommunication Technology - RTT 2005.* Hradec n/Moravicí (Czech Republic), 2005.

[6] WIESER, V., PŠENÁK, V. Data rate increasing for high speed multimedia services in enhanced WCDMA mobile radio network. In *IWSSIP 2006, 13th International Conference on Systems, Signals and Image Processing.* Budapest (Hungary), 2006, p. 75-78.

About Authors...

Zdeněk RŮŽIČKA was born in Přílepy, Czech Republic, in 1980. He received the Ing. (M.Sc.) degree from the Brno University of Technology. He is Ph.D. student at the Department of Radio Electronics, Faculty of Electrical Engineering and Communication in Brno. His research is concentrated on Mobile Communications, especially on 3G networks.

Stanislav HANUS was born in Brno, Czech Republic, in 1950. He received the Ing. (M.Sc.) and CSc. (Ph.D.) degrees from the Brno University of Technology. He is Professor at the Department of Radio Electronics, Faculty of Electrical Engineering and Communication in Brno. His research is concentrated on Mobile Communications and Television Technology.