COURSE ON SIMULATION IN INFORMATION TECHNOLOGY: THE GLOBAL SYSTEM FOR MOBILE COMMUNICATIONS

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ABSTRACT

Simulation in Information Technology is a course on system simulation that is offered by our department to graduate students which are majoring in communications engineering.

The course imparts a fundamental knowledge of simulation tools and of mobile communication systems. The simulation tool which is used in the course is COSSAP *(Communication Systems Simulation and Analysis Package)* and the considered communication system is GSM *(Global System for Mobile communications)*.

In this paper we give an introduction into COSSAP, into GSM and especially into the course structure. In addition, some simulation results will be given, i.e. the improvement of soft decision decoding versus hard decision decoding.

1. THE SIMULATION TOOL COSSAP

COSSAP is a stream driven, block oriented simulation environment from Cadis GmbH Aachen, Germany[5]. The simulation package includes all tools which are necessary for building up a configuration, running the simulation and presenting the results in a graphical or numerical manner. Furthermore, it provides some tools for postprocessing of the obtained results, e.g. correlation, fourier transformation, interpolation etc. An important feature is the optional generation of VHDL-*Very High Description Language*-Code and/or code for digital signal processors.

To build up a simulation, out of an extensive library the appropriate models are selected. This library is already provided by COSSAP. After placing the models on the simulation screen, they have to be connected with signal lines. In the next step all models have to be configured by setting the specific parameters for each model of the system. If one wants to use a function which is not available within the existing libraries, there are two possibilities in order to extend the collection of models. New models may be generated either by creating so called *hierarchical* models, i.e. already existing models may be combined to one block, or by implementing a new function as a source code in C or Fortran. Models which are created in the second way are called *primitive* models. Because the usage of existing models is transparent for the user, he does not need to know anything about the model implementation but only the relation between input and output and the model specific parameters. Therefore it is quite easy to reuse existing models for other simulations or projects.

2. ON THE GSM SYSTEM

The mobile communication system which is investigated in the course is GSM. We have chosen this system because it is an "up-to-date" digital mobile communication system which covers all relevant aspects of mobile communication.

In the year 1979, the frequency range around 900 MHz was reserved for an uniform european communication system. There were several proposals for such a system which were taken into consideration when specifying the final recommendations for GSM. Meanwhile, a lot of european countries have built up communication systems according to the GSM specification and also some noneuropean countries have taken over the GSM standard.

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2.1. The mobile radio channel

In radio transmission, there are several effects which have to be taken into account when simulating a transmission system[2]. These effects are for example:

- noise,
- fading,
- intersymbol interference,
- doppler shift and doppler spreading.

For the simulation of GSM, some reference models were specified which are based on measurements of the group COST207 *(European Cooperation in the Field of Scientific and Technical Research)*. Namely, these models are *rural area*, *typical urban* and *hilly terrain*. Additionally, an *equalizer test profile* was specified. The models are implemented as described e.g. in [11], i.e. as tapped delay line filters with a static delay but with multiplicative Rayleigh respectively Rice processes. The highest velocity of a mobile station which is considered in these models is 250 km/h.

2.2. The modulation scheme

The modulation scheme used in GSM is GMSK *(Gaussian Minimum Shift Keying)*[10]. GMSK has been selected because of its advantageous spectral properties. The symbol duration is 3.692 μs and each symbol corresponds to one transmitted binary digit.

The used frequency range is 890–915 MHz in the uplink and 935–960 MHz in the downlink. Each band of 25 MHz contains 125 carriers. For each carrier there exists an additional TDMA structure, i.e. the time axis is slotted into frames and each frame consists of eight time slots. Therefore, GSM is a combined FDMA/ TDMA system and a user channel is defined by a sequence of timeslots and corresponding carrier frequencies *(slow frequency hopping)*.

Each user sends his data embodied in a burst structure. There exist access bursts, frequency correction bursts, synchronization bursts and normal bursts. In the normal mode of transmission, i.e. after a communication link has been established, the normal burst is used. A time slot contains some guard bits, the information bits and also a midamble training sequence which is used for the estimation of the channel impulse response and provides the necessary information for channel matched filtering and equalization of the received signal.

2.3. Channel coding and interleaving

To reduce the bit error rate, which is untolerable high in the uncoded case, *forward error correction* is used in GSM, consisting of convolutional codes or a concatenation of block and convolutional codes[3]. In the course, only the traffic channels *full rate speech transmission (FS)* at a rate of 13 kbit/s and *full rate data transmission (F4.8)* at a rate of 4.8 kbit/s are considered[4].

In the case of speech transmission the analog speech signal is digitized. For this source encoding a *RPE-LPC-LTP-(Regular Pulse Excitation-Linear Predictive Coding-Long Term Prediction)-algorithm* is used. For *unequal error protection*, the encoded bits are divided into three different classes according to their importance for the speech quality. The most important bits are protected via a parity check code and then together with the second class by a convolutional code of rate $R = \frac{1}{2}$. The least important bits are transmitted uncoded.

In the case of data transmission *(equal error protection)*, all bits are protected by a convolutional code of rate $R = \frac{1}{3}$.

To break the bursty error structure of the channel, different interleaving schemes are used.

3. THE COURSE STRUCTURE

In the course only the transmission layer of GSM is investigated, i.e. no protocol aspects are considered. Furthermore, perfect synchronization is assumed. We want to stress, that all system aspects are built up exactly according to the GSM recommendations [4, 10, 12].

The course is divided into nine segments and for each segment, the students spend approximately four hours in the laboratory. In each segment, another part of the system is investigated until at the end of the course the complete system is built up. Figure 1 shows the structure for a communication link. The circled numbers indicate the course segments that deal with the specific components. The first two segments are not indicated, because they are devoted to the basic principles of COSSAP and digital signal processing.

In the following, the chapter numbers indicate the corresponding course segment.

3.1. Introduction to COSSAP

In this segment, only very simple simulations are performed, i.e. the Gaussian assumption for a noise source is checked by taking some histograms of the distribution of the samples. Then the locus of lowpass filtered complex Gaussian noise is displayed graphically and the last point is to take some scatter diagrams of MPSK

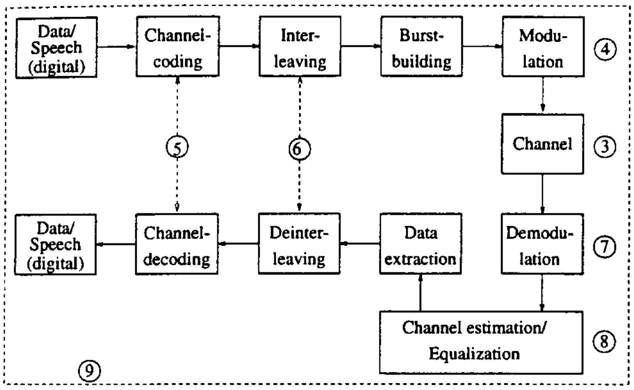

Figure 1: *Course structure. The circled numbers indicate the course day at which the special part of the system is investigated.*

alphabets. The purpose of this segment is to ensure, that the students learn to handle the most important features and functions of COSSAP.

3.2. BPSK-Modulation

A simple *BPSK-(Binary Phase Shift Keying)*-transmission is investigated. For the modulation, two types of filters are used, at first a rectangular one and second, a raised cosine filter. The eye patterns of both signals are compared and the bit error rates (BER) for the transmission over an additive white gaussian noise (AWGN) channel are simulated. In addition, the influence of an inaccurate sampling time is investigated for both filter types.

3.3. GSM channel models

The delay profile of the three channel models *Hilly Terrain, Rural Area* and *Typical Urban* is determined. Then the channel models are investigated with respect to their fading behavior, i.e. the received signal energy when transmitting narrowband and wideband signals is plotted versus the time axis.

3.4. Modulation schemes

The three modulation schemes BPSK, MSK *(Minimum Shift Keying)* and GMSK are compared with respect to their spectral properties. Then the BER for a transmission with GMSK over an AWGN channel is simulated. The last part is the simulation of GMSK transmission over a GSM channel model – without any equalization – to demonstrate, that a simple receiver structure is not sufficient to achieve acceptable performance of the transmission.

3.5. Channel coding

The performance of the specified channel coding schemes for FS and F4.8 is investigated when transmitting over a binary symmetric channel (BSC). The BER is calculated and also the quality of speech may be judged for various channel error probabilities by acoustic impressions.

3.6. Interleaving

The specified interleaving schemes are built up and are investigated in combination with channel coding when transmitting over a Gilbert-Elliott channel model, i.e. a two state channel model with a low error probability in the good state and a high error probability in the bad state. This model is appropriate to simulate the bursty error structure corresponding to deep fades in mobile radio channels. The maximum error burst length is determined which is still tolerated by the interleaving schemes.

3.7. Demodulation

The demodulation of differentially encoded GMSK by the method of *reverse rotation* as described in [1] is introduced. Also the channel estimation by the correlation method is investigated for BPSK and GMSK and for various types of multipath channels.

3.8. Channel matched filtering and equalization

The GMSK transmission is extended by an adaptive channel matched filter and a Viterbi equalizer of the Ungerböck type [13]. The BER for transmission over the GSM channel models is investigated for the uncoded case. Then the configuration is completed by channel coding and interleaving for F4.8 and also by the TDMA structure of GSM. The BER for this complete transmission is determined over $\frac{E_b}{N_0}$ in the case of hard decision decoding. Then the improvement by using soft information for the decoding procedure which is provided by the Viterbi equalizer[6] is investigated. The impressive results are shown in figure 2 for the hilly terrain channel with a vehicle velocity of 100 km/h.

3.9. The entire system

The existing configuration from segment 8 is extended to speech transmission by replacing the specific models for F4.8 by the models for FS. Then some speech examples are simulated for various velocities and channel models. The improvement of soft versus hard decision decoding is demonstrated by comparing the quality of the simulated speech examples.

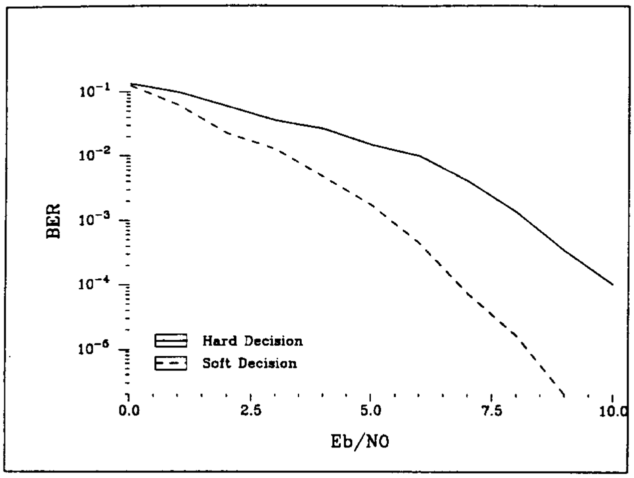

Figure 2: *Comparison of hard versus soft decision decoding for a hilly terrain channel and a vehicle velocity of 100 km/h.*

4. SUMMARY

We have described the main contents of our course *Simulation in Information Technology.* The course will be offered twice a year. So far three generations of students have already passed the course. The comments from the students were very positive. Specifically they stressed that they got "practical" experience with the basic principles and theories provided from other theoretical courses on communications engineering and signal processing. They remarked also – as a very positive aspect of this course – the possibility to transmit speech over the built up system, because these acoustic impressions were very helpful to understand some effects more clearly than any bit error curve can demonstrate it.

In the department we observed that those students who took part in the course had a profound base for their following student project and/or diploma thesis in the field of digital communications.

Acknowledgement:

The authors would like to thank M. Reiner from AEG Mobile Communication GmbH, Ulm for numerous helpful discussions.

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