Simulation and Measurement of the Transmission Distortions of the Digital Television DVB-T/H

Part 3: Transmission in Fading Channels

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Abstract. *The paper deals with the third (and last) part of results of the Czech Science Foundation research project that was aimed into the simulation and measurement of the transmission distortions of the digital terrestrial television according to DVB-T/H standards. In this part the transmission of the digital television according to DVB-T/H standard over the fading channels and their models and profiles for fixed, portable and mobile reception is analyzed. Impact of the fading channels and their models on Modulation Error Rate from I/Q constellations and Bit Error Rates before and after Viterbi decoding in DVB-T/H signal decoding is presented.*

Keywords

Digital television, fading channel, fixed reception, portable reception, mobile reception, DVB-T/H.

1. Introduction

On behalf of the works within the project "*Analysis and Simulation of the Transmission Distortions of the Digital Television DVB-T/H*" (for the reference number please see Acknowledgment section) an introduction to the DVB-T/H modulator performance was made in [1] and performance of the Hierarchical modulation and its implementation in DVB-T/H was analyzed in [2]. In these two papers, the *MER* (Modulation Error Rate) from I/Q constellation and the *BER* (Bit Error Rate) before and after Viterbi decoding in DVB-T/H signal decoding were evaluated and discussed deeply with simulation and measurements results. The last part of the work deals with the DVB-T/H transmission in fading channel profiles and all the results of the *MER* and *BER* within the simulation and measurement are presented in this paper.

The DVB-T (Digital Television Broadcasting – Terrestrial) [3], [4] and DVB-H (Handheld) [5], [6] are technical standards that specify framing structures, channel coding and modulation for digital terrestrial television broadcasting. They both are flexible systems that allow networks in SFN (Single Frequency Network) to be designed for the delivery of a wide range of services, from LDTV (Low Definition), over SDTV (Standard Definition) to HDTV (High Definition). They both allow fixed, portable, mobile and even handheld reception. It is in conjunction with standard DVB-H for mobile TV terminals that was built on the proven mobile performance of the DVB-T.

Profile	Characteristics	Paths	Reception
AWGN	Noise channel	all	All
RC20	Ricean fading without Doppler shift	20 All const. phase and without Doppler	Fixed
RL20	Rayleigh fading without Doppler shift	20 All const. phase and without Doppler	Portable
PI	Direct path and echoes with Doppler shift - speed 3 km/h	12 All pure Doppler	Portable
PO	Direct path and echoes with Doppler shift - speed 3 km/h	12 All pure Doppler	Portable
TU6	Rayleigh fading Urban area - speed 50 km/h	6 Rayleigh	Mobile
RA6	Ricean fading Rural area - speed 100 km/h	1 Ricean 5 Rayleigh	Mobile

Tab. 1. DVB-T/H transmission channel profiles.

2. Fading Channels Profiles

Distribution of DVB-T/H and digital television programs by way of terrestrial transmitters is the classical technology of broadcasting. Received signal in good quality should be interpreted as the overall effect, the sum of various influences including the many possible disturbances created by noise and interference [7].

Types and scenarios of reception of the DVB-T/H discussed in next paragraphs are fixed, portable and mobile receptions with available fading channel models and profiles (Tab. 1).

2.1 Fixed Reception and its Scenario

With focus on digital TV implementation aspects it is most important to determine the reception environment. The option "fixed" is associated with reception by a rooftop outdoor antenna to fixed receiver. Reception with a rooftop antenna can be viewed as stationary reception and the directivity of the antenna can be used either for the selection of the direct signal or at least for choosing a dominant echo signal as the main reception signal and can partially reduce echo impairments caused by reflection from hills, buildings etc. [8].

The performance of the DVB-T/H has been simulated during the development of the standard [3], [4] with two channel models - for fixed reception (RC20) and portable reception (RL20), respectively. These are theoretical channel profiles for simulation without Doppler shift. For DVB-T/H transmission analysis the RC20 and RL20 channels with twenty paths is convenient and it was used for *C*/*N* performance evaluation [3], [4].

2.2 Portable Reception and its Scenario

The "portable" means that the device can be easily carried or taken from one point to another. It contains omni directional antenna and it operates in a nomadic mode (not operated while moving fast). In the context of DVB-T/H, portable antenna reception is defined as the reception at no speed or very low speed (walking speed, approx. 3 km/h).

The Portable Indoor (PI) and Portable Outdoor (PO) channel models have been developed by the Wing-TV project for describing the slowly moving hand held reception indoors and outdoors. The channel models are based on measurements in DVB-H Single Frequency Networks and have paths from two different transmitter locations. PI and PO profiles are defined in [5], [6].

2.3 Mobile Reception and its Scenario

The "mobile" means reception while moving at high speeds in cars, buses, trains etc. Mobile antenna reception is defined as the reception at medium to high speed (no walking speed, approx. 50 km/h and higher). Mobile reception suffers from all impairments relevant for portable reception (noise AWGN, multipath reception, narrowband interferers, impulse interferers etc.) [8]. In addition Doppler shift is experienced and the properties of the transmission channel change over time. Doppler shift results in a frequency shift of the received OFDM carriers as a function of the speed and the direction of the movement. The receiver has to track channel variations in time and frequency (channel estimation) and it must handle noise-like distortions. It must be correctly synchronized in a mobile channel (guard interval for coarse timing, scattered pilots for fine timing and continual pilots for frequency synchronization) and the received field strength and carrier-to-noise ratio is sufficient [7].

Primary profiles for realtime simulation with Doppler shift (mobile channel simulations) are presented in [4]. They reproduce characteristics of the terrestrial channel propagation with a single transmitter – for Typical Urban reception (TU6) and Rural Area reception (RA6). These profiles are included in Annex K.3 of ETSI technical report as DVB-T channel characteristics [4]. These channel profiles were selected to reproduce the service delivery situation in a mobile environment.

3. Analysis of the DVB-T/H Transmission in Fading Channels

The analysis of the DVB-T/H transmission in fading channels including some typical measurement results has been already made in [9] and [10].

4. Simulation of the DVB-T/H Transmission in Fading Channels

The method for input data generation and its processing for the transmission is performed and described in the DVB-T/H specification [3] – [6]. The procedure of the modulation, IFFT (Inverse Fast Fourier Transformation) method, GI (Guard Interval) insertion and filtering with RRC (Root Raised Cosine) filter is described in [7], [8].

When the modulation on the carrier is performed, the transmission through the channel can be simulated. Resources for the simulation of the transmission and signal processing are included in Matlab and functions of the Communication Toolbox. This toolbox also includes models of different types of transmission channels with various parameters. In Matlab, the transmission channel with fading can be applied to the signal with filtering using functions `ricianchan` and `rayleighchan`. But, for utilization of these Matlab functions it is necessary to use a filter, which is also in this case, with low sampling, very slow. Moreover, these functions do not enter the phase shift of paths, which is defined in the standards. Therefore, for the modeling of channel environments with fading, there was used a custom algorithm based on equations, which are described in [3]. The final code for the modeling and simulation of Rician channel (RC20) is given below:

```
% Channel parameters - Ricean (ETSI EN 300 744

% vector of gain [-]
pz = [0.057662 0.176809 0.407163 0.303585 0.258782...
      0.061831 0.150340 0.051534 0.185074 0.400967...
      0.295723 0.350825 0.262909 0.225894 0.170996...
      0.149723 0.240140 0.116587 0.221155 0.259730];

% vector of delay [sec]
tau = [1.003019 5.422091 0.518650 2.751772 0.602895...
       1.016585 0.143556 0.153832 3.324866 1.935570...
       0.429948 3.228872 0.848831 0.073883 0.203952...
       0.194207 0.924450 1.381320 0.640512 1.368671];

% vector of phase shift [rad]
theta = [4.855121 3.419109 5.864470 2.215894 3.758058...
         5.430202 3.952093 1.093586 5.775198 0.154459...
         5.928383 3.053023 0.628578 2.128544 1.099463...
         3.462951 3.664773 2.833799 3.334290 0.393889];
```

```
% Definition of the direct path
K = 10;
p0 = sqrt(K*sum(pz.^2));
pz = [p0 pz];
tau = [0 tau]*1E-6;
theta = [0 theta];

number_of_paths = length(tau);
length_of_Data_to_channel = length(Data_to_channel);

shifting = fix(tau./Ts_OFDM);
Max_shifting = max(shifting);

Signal_from_channel =
zeros(1,length_of_Data_to_channel+Max_shifting);

% Modeling of the Ricean channel

for path = 1:number_of_paths

    Signal_Path =
    zeros(1,length_of_Data_to_channel+Max_shifting);
    Signal_Path(shifting(path)+1:shifting(path)+length_of_
    Data_to_channel) = Data_to_channel;
    gain = pz_gain(path)*exp(-1i*theta(path));
    Signal_Path = Signal_Path*gain;
    Signal_from_channel = Signal_from_channel + Signal_Path;

end

% Normalization

Signal_from_channel =
Signal_from_channel(1:length_of_Data_to_channel);
norm = sqrt(sum(pz.^2));
Data_from_channel_fading = Signal_from_channel/norm;
```

Ricean channel represents the transmission model with reflected signals and one direct path. For the modeling of the Ricean channel, the standard [3] defines 20 paths. Because the model includes one direct path, 21 paths parameters were defined for the simulation. The "0" in vectors `tau` and `theta` represent the direct path. Parameter `p0` presents a calculation of the gain of the direct path.

Modeling and simulation of the Rayleigh channel is very similar to the Ricean channel. The difference is only in the direct path, because Rayleigh channel contains only reflected signals, not the direct path.

The next paragraphs of the paper briefly describe the channel profiles with Doppler shift. In the first part of this section, there are presented TU6 and RA6 channel profiles. The second part is focused on the PI and PO channel models.

Both channel profiles, TU6 and RA6 [4], are fundamentally different. Channel RA6 consists of one direct path and five reflected paths. In the RA6 the expected speed of the receiver is v = 100 km/h, so the Doppler shift is two times higher than in TU6, where v = 50 km/h. For the simulation 2k OFDM mode was chosen (better used for mobile reception). Therefore, the impact of this frequency shift was minimized.

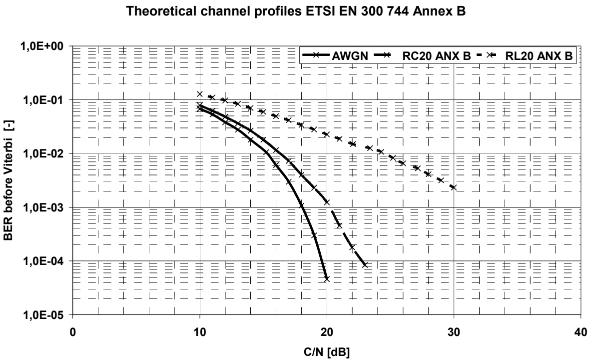
In the code presented below the example is focused on the modeling and simulation of the RA6 channel:

```
% Channel parameters - RA6

pz = [0.0 4.0 8.0 12.0 16.0 20.0];  % vector of gain [dB]

tau = [0.0 0.1 0.2 0.3 0.4 0.5];    % vector of delay [-]

% Definition of parameters for simulation
K = 10;
v = 100;             % speed of the receiver
Ts = 1/fs_OFDM;      % Tx signal sample period
fc = 626;            % Frequency of carrier 626 (MHz)
vc = 3e8;            % speed of light
fd = v*fc/(3.6*300);    % Doppler shift
fd_ratio = 0;           % fd ratio for the direct path
pz_gain = 10.^(-pz/20);
number_of_paths = length(tau);
length_of_Data_to_channel = length(Data_to_channel);
Data_from_fading = zeros(1,length(Data_to_channel));
Signal_Path=
zeros(number_of_paths,length_of_Data_to_channel);

% Modeling of the RA6 channel

for path = 1:number_of_paths

   if pz_gain(1,path)== 1   % direct path

       ch = ricianchan(1e-10,fd,K);
       ch.DirectPathDopplerShift = fd_ratio(1,path)*fd;
       ch.NormalizePathGains = false;
       ch.ResetBeforeFiltering = true;

       Signal_Path(path,:) = filter(ch,Data_to_channel);
       Signal_Path(path,:) =
       pz_gain(1,path)*Signal_Path(path,:);
       del = round(tau(1,path)*1E-6/Ts);
       Signal_Path(path,:) = [zeros(1,del)
       Signal_Path(path,1:length_of_Data_to_channel-del)];
       Data_from_fading = Data_from_fading +
       Signal_Path(path,:);

   else

       ch = rayleighchan(1e-10,fd);   % reflected paths
       ch.NormalizePathGains = false;
       ch.ResetBeforeFiltering = true;
       Signal_Path(path,:) = filter(ch,Data_to_channel);
       Signal_Path(path,:) =
       pz_gain(1,path)*Signal_Path(path,:);
       del = round(tau(1,path)*1E-6/Ts);
       Signal_Path(path,:) = [zeros(1,del)
       Signal_Path(path,1:length_of_Data_to_channel-del)];
       Data_from_fading = Data_from_fading +
       Signal_Path(path,:);

   end

end
```

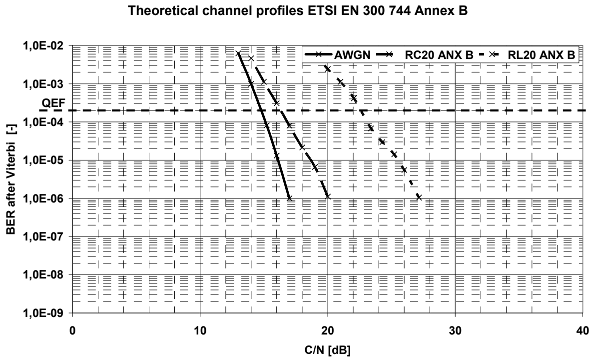
For the simulation, in this case, both of Matlab functions `ricianchan` and `rayleighchan` were used. The first path in RA6 channel model is a direct path, so for this part `ricianchan` was used, and for the other paths `rayleighchan` was used. In case of TA6 model we use only the function for the simulating of indirect paths.

The last part of this section is focused on the modeling and simulation of channel profiles PI (Pedestrian Indoor) and PO (Outdoor) with a relatively small Doppler shift. Both channel models have one direct path, which is shifted in frequency by half of the maximum value of the Doppler shift. This value is the same for both channels, as well as a speed of the receiver (v = 3 km/h). The main difference between these channel models is in the length of the impulse response and the delay of output paths. PI model has longer maximum delay, but all delayed paths are more attenuated than in PO model. In both models the influence of attenuation is dominant therefore the PO has worse results in simulation. The steps for implementing of the channel model parameters in Matlab are very similar as in the previous example:

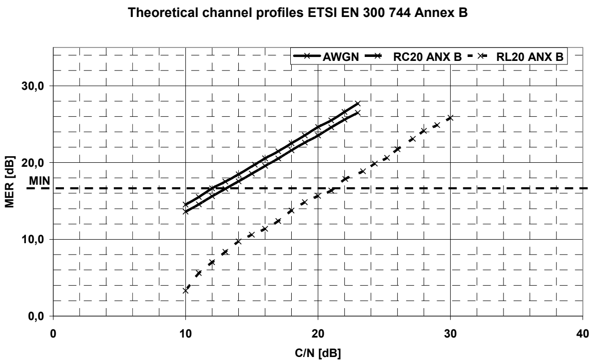
```
% Channel parameters - PI

% vector of gain [dB]
pz = [0.0 6.4 10.4 13.0 13.3 13.7 16.2 15.2 14.9 16.2 11.1
11.2];

% vector of delay [-]
tau = [0.0 0.1 0.2 0.4 0.6  0.8 1.0 1.6 8.1 8.8 9.0 9.2];

% Definition of parameters for simulation

K = 10;
v = 3;                  % speed of receiver
Ts = 1/fs_OFDM;         % Tx signal sample period
fc = 626;               % Frequency of carrier 626 (MHz)
vc = 3e8;               % speed of light
fd = v*fc/(3.6*300);    % Dopplers shift
fd_ratio = fd*0.5;      % fd ratio for the direct path
```



a) $BER_1 = f(C/N)$

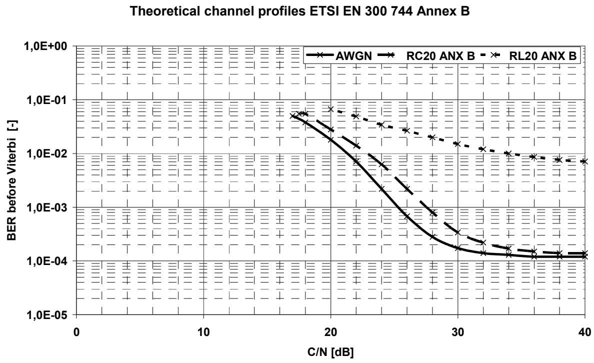


b) $BER_2 = f(C/N)$

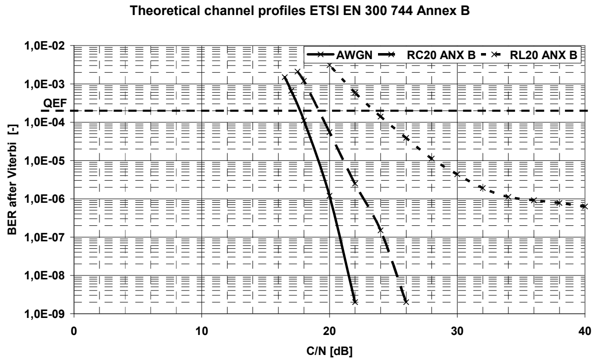


c) $MER = f(C/N)$

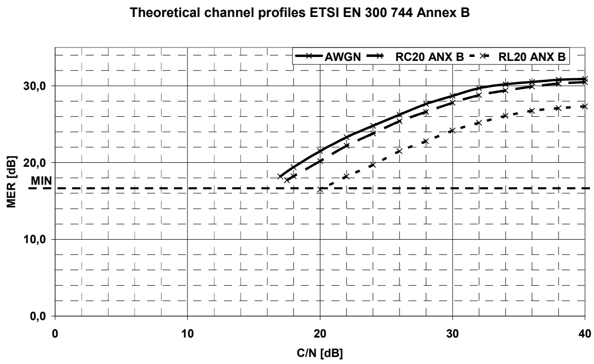
Fig. 1. Simulation: Fixed reception scenario (64-QAM, 8k mode, code rate 2/3 and GI 1/8) and DVB-T/H performance in typical transmission channel profiles.



a) $BER_1 = f(C/N)$



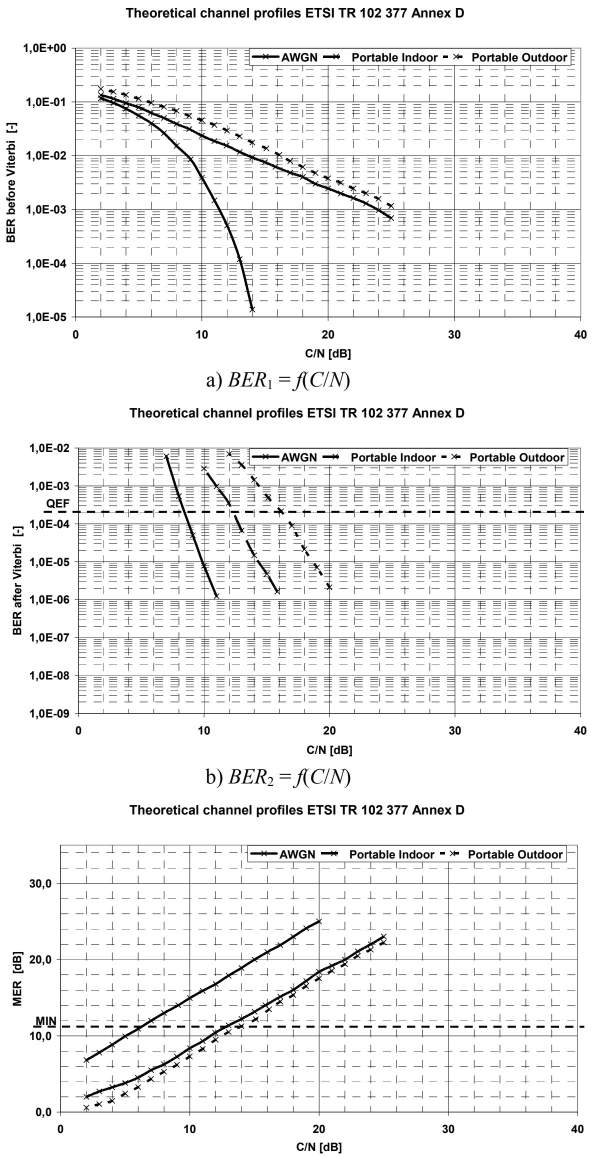
b) $BER_2 = f(C/N)$



c) $MER = f(C/N)$

Fig. 2. Measurement: Fixed reception scenario (64-QAM, 8k mode, code rate 2/3 and GI 1/8) and DVB-T/H performance in typical transmission channel profiles.

```
STD_norm = 0.08        % STD norm

pz_gain = 10.^(-pz/20);
number_of_paths = length(tau);
length_of_Data_to_channel = length(Data_to_channel);
Data_from_fading = zeros(1,length(Data_to_channel));
Signal_Path=
zeros(number_of_paths,length_of_Data_to_channel);

for path = 1:number_of_paths

   if pz_gain(1,path)==1     % Rice-Gauss

      ch = ricianchan(Ts,fd,K);
      ch.DirectPathDopplerShift = fd_ratio(1,path)*fd;
      ch.NormalizePathGains = false;
      ch.ResetBeforeFiltering = true;
      ch.DopplerSpectrum =
      doppler.gaussian(STD_norm(1,path));

      Signal_Path(path,:) = filter(ch,Data_to_channel);
      Signal_Path(path,:) =
      pz_gain(1,path)*Signal_Path(path,:);
      del = round(tau(1,path)*1E-6/Ts);
      Signal_Path(path,:) = [zeros(1,del);
      Signal_Path(path,1:length_of_Data_to_channel-del)];
      Data_from_fading = Data_from_fading +
      Signal_Path(path,:);

   else                        % Rayleigh-Gauss

      ch = rayleighchan(Ts,fd);
      ch.NormalizePathGains = false;
      ch.ResetBeforeFiltering = true;
      ch.DopplerSpectrum = doppler.gaussian(STD_norm);


      Signal_Path(path,:) = filter(ch,Data_to_channel);
      Signal_Path(path,:) =
      pz_gain(1,path)*Signal_Path(path,:);
      del = round(tau(1,path)*1E-6/Ts);
      Signal_Path(path,:) = [zeros(1,del)
      Signal_Path(path,1:length_of_Data_to_channel-del)];
      Data_from_fading = Data_from_fading +
      Signal_Path(path,:);

   end

end
```

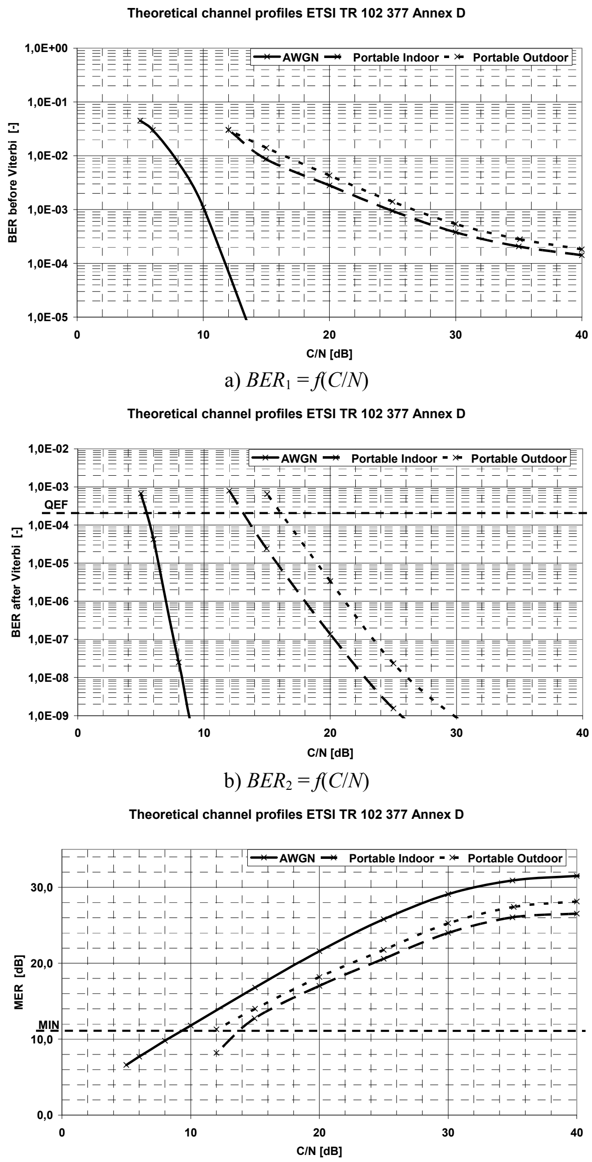


a) $BER_1 = f(C/N)$

b) $BER_2 = f(C/N)$

c) $MER = f(C/N)$

Fig. 3. Simulation: Portable reception scenario (16-QAM, 4k mode, code rate 2/3 and GI 1/8) and DVB-T/H performance in typical transmission channel profiles.



a) $BER_1 = f(C/N)$

b) $BER_2 = f(C/N)$

c) $MER = f(C/N)$

Fig. 4. Measurement: Portable reception scenario (16-QAM, 4k mode, code rate 2/3 and GI 1/8) and DVB-T/H performance in typical transmission channel profiles.

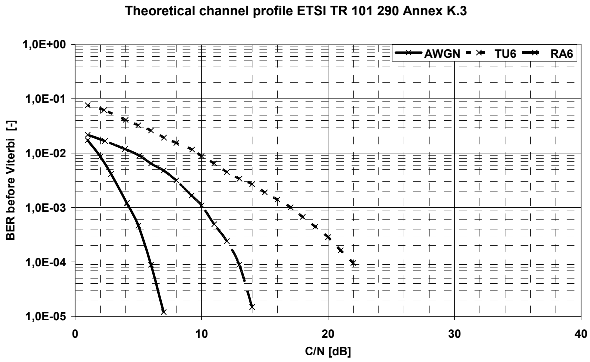
5. Measurement DVB-T/H Transmission in Fading Channels

Experimental testing of the DVB-T/H broadcasting and transmission in fading channels was realized in the laboratory of digital television at the Department of Radio Electronics, Brno University of Technology (configuration of the devices was the same as in [2], Par. 5, Fig. 3).

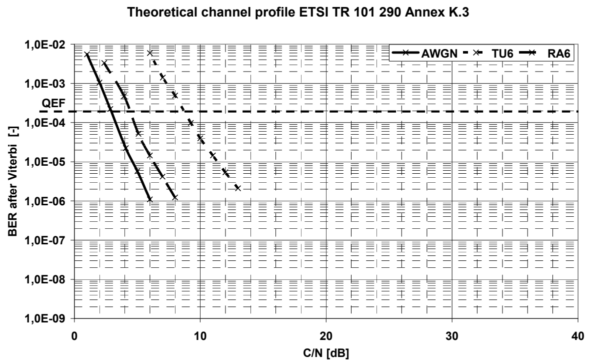
The DVB-T/H system transmission parameters were set to the European most common type of DTV broadcasting. These parameters are the most characteristic for the mid to large size of the DVB-T/H SFN networks:

- RF level 60 dBuV (medium sensitivity),
- 8 MHz channel (bandwidth 7.608 MHz),
- QPSK (mobile), 16QAM (portable), 64QAM (fixed),
- 2k (mobile), 4k (portable) and 8k (fixed) mode,
- 2/3 convolutional code (robust protection),
- 1/8 or 1/16 Guard Interval (mid to small size of SFN).

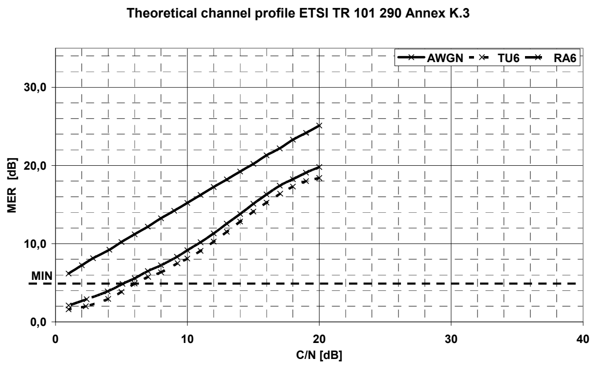
For the measurement results the Gaussian (AWGN) channel was used as reference. The results in Ricean (RC20) and Rayleigh (RL20) channels profiles for fixed reception, PI (Portable Indoor) and PO (Portable Outdoor) channels profiles for portable reception and TU6 (Typical Urban) and RA6 (Rural Area) channels profiles for mobile reception of the DVB-T/H broadcasting were evaluated.



a) $BER_1 = f(C/N)$

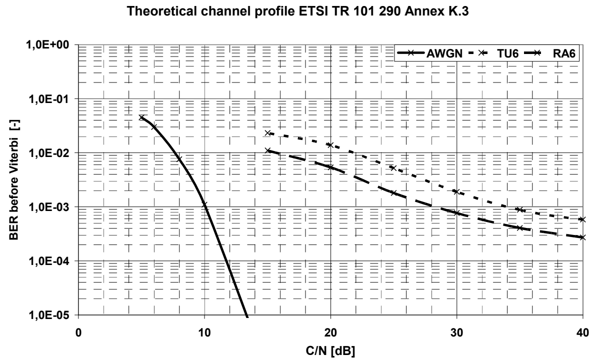


b) $BER_2 = f(C/N)$

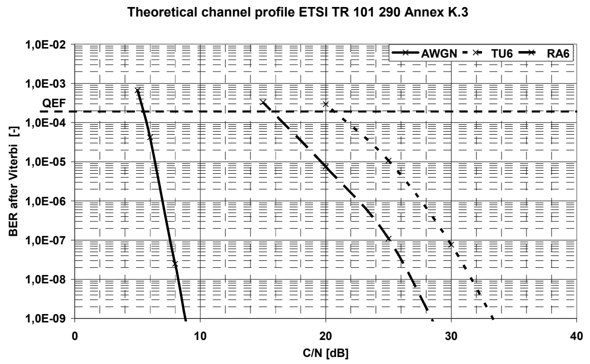


c) $MER = f(C/N)$

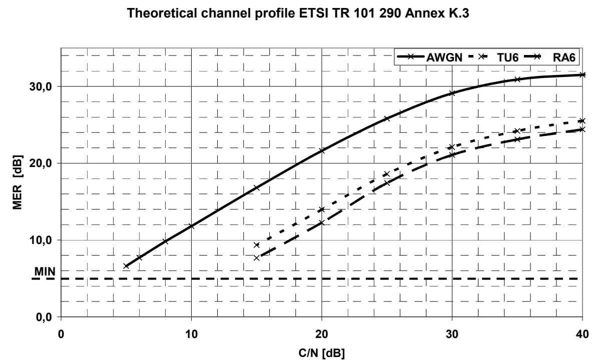
Fig. 5. Simulation: Mobile reception scenario (QPSK, 2k mode, code rate 2/3 and GI 1/16) and DVB-T/H performance in typical transmission channel profiles.



a) $BER_1 = f(C/N)$



b) $BER_2 = f(C/N)$



c) $MER = f(C/N)$

Fig. 6. Measurement: Mobile reception scenario (QPSK, 2k mode, code rate 2/3 and GI 1/16) and DVB-T/H performance in typical transmission channel profiles.

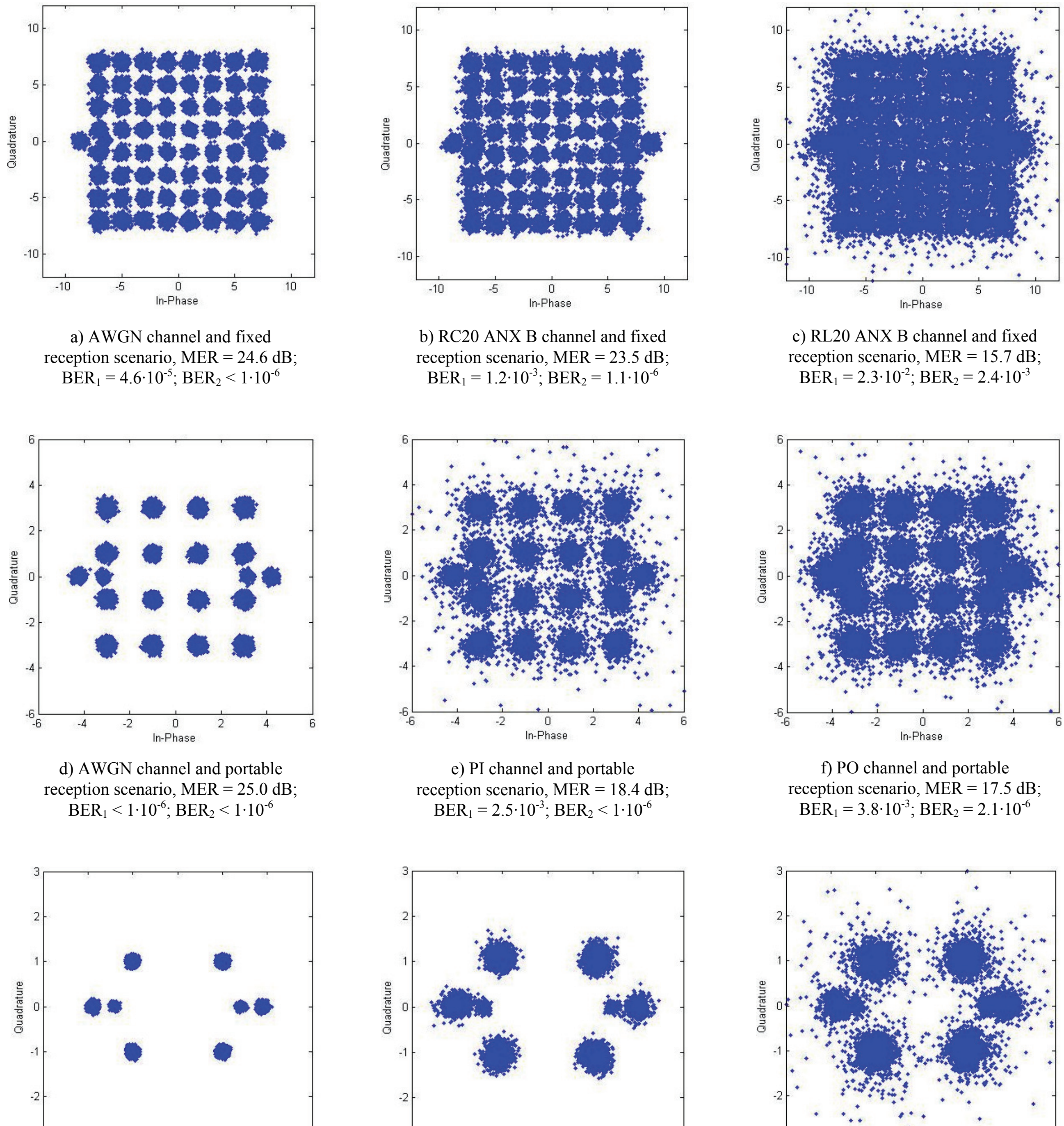
The influence of the fading channels and their models on *MER*, BER_1 (before Viterbi) and BER_2 (after Viterbi) was evaluated for specific constellation diagrams to compare the simulation and measurements results.

6. Experimental Results

Detailed results of the simulation and laboratory measurement of the *BER* before and after Viterbi decoding characteristics and *MER* (Modulation Error Ratio) from constellation analysis in dB for DVB-T/H services (used for fixed, portable and mobile scenarios) are available in Fig. 1 a) to c) to Fig. 6 a) to c). In these figures there are typical waterfall curves for the various scenarios.

The "QEF" symbol in all the figures indicates the situation where the *BER* after Viterbi decoding is equal to 2.10^{-4}. This was the defined condition of practically error-free signals at the input of the MPEG-2 TS demultiplexer [3], [4]. The "MIN" symbol indicates the situation where the DVB-T/H with modulation 64QAM, 16QAM and QPSK and convolutional code rate 2/3 has the minimal required *C*/*N* equal to the reference value of DVB-T/H in a no-interference reception. Table of *C*/*N* is available in [4].

The difference in *BER* and *MER* results for the various transmission scenarios and channel types is also easy to compare in Tab. 2. Typical results and the constellation diagrams for the various transmission scenarios and channel types are also easy to see in Fig. 7 and Fig. 8.



a) AWGN channel and fixed reception scenario, MER = 24.6 dB; $BER_1 = 4.6 \cdot 10^{-5}$; $BER_2 < 1 \cdot 10^{-6}$

b) RC20 ANX B channel and fixed reception scenario, MER = 23.5 dB; $BER_1 = 1.2 \cdot 10^{-3}$; $BER_2 = 1.1 \cdot 10^{-6}$

c) RL20 ANX B channel and fixed reception scenario, MER = 15.7 dB; $BER_1 = 2.3 \cdot 10^{-2}$; $BER_2 = 2.4 \cdot 10^{-3}$

d) AWGN channel and portable reception scenario, MER = 25.0 dB; $BER_1 < 1 \cdot 10^{-6}$; $BER_2 < 1 \cdot 10^{-6}$

e) PI channel and portable reception scenario, MER = 18.4 dB; $BER_1 = 2.5 \cdot 10^{-3}$; $BER_2 < 1 \cdot 10^{-6}$

f) PO channel and portable reception scenario, MER = 17.5 dB; $BER_1 = 3.8 \cdot 10^{-3}$; $BER_2 = 2.1 \cdot 10^{-6}$

g) AWGN channel and mobile reception scenario, MER = 25.1 dB; $BER_1 < 1 \cdot 10^{-6}$; $BER_2 < 1 \cdot 10^{-6}$

h) RA6 channel and mobile reception scenario, MER = 19.8 dB; $BER_1 < 1 \cdot 10^{-6}$; $BER_2 < 1 \cdot 10^{-6}$

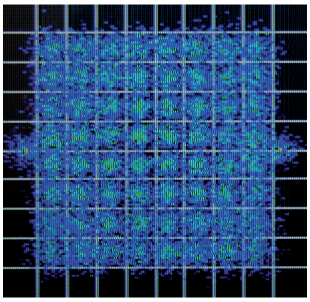
i) TU6 channel and mobile reception scenario, MER = 18.4 dB; $BER_1 = 2.9 \cdot 10^{-4}$; $BER_2 < 1 \cdot 10^{-6}$

Fig. 7. Simulation: I/Q constellation of: a) to c) fixed scenario with 64QAM, d) to f) portable scenario with 16QAM, g) to i) mobile scenario with QPSK and also within typical DVB-T/H fading channels (all the constellations incl. channel correction and pilots, $C/N = 20$ dB).

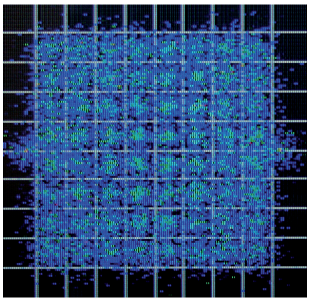
All these results are comparison of the simulation and measurement and they are valid for the various channel type with the $C/N = 20$ dB. This C/N ratio in dB is a reasonable and realistic value for fixed reception scenario and could be used as a demonstration for the individual inner modulations performance and for the comparison.

7. Conclusions

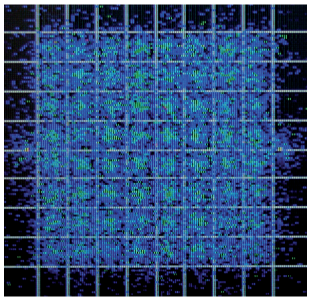
This paper concludes works on the grant project aimed into the analysis, simulation and measurements of the transmission and distortions in the area of the digital television according to standards DVB-T and DVB-H.



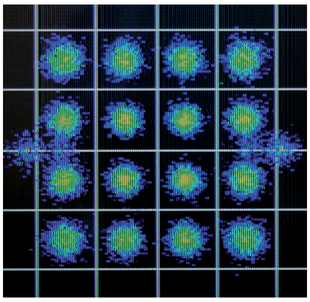
a) AWGN channel and fixed reception scenario, MER = 21.5 dB; $BER_1 = 1.8\cdot10^{-2}$; $BER_2 = 1.2\cdot10^{-6}$



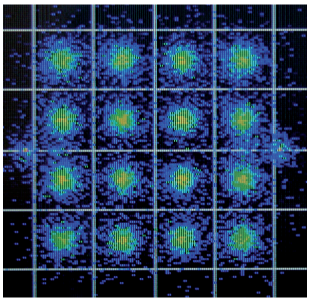
b) RC20 ANX B channel and fixed reception scenario, MER = 20.2 dB; $BER_1 = 2.8\cdot10^{-2}$; $BER_2 = 5.5\cdot10^{-5}$



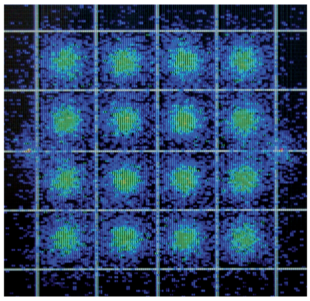
c) RL20 ANX B channel and fixed reception scenario, MER = 16.5 dB; $BER_1 = 6.7\cdot10^{-2}$; $BER_2 = 3.1\cdot10^{-3}$



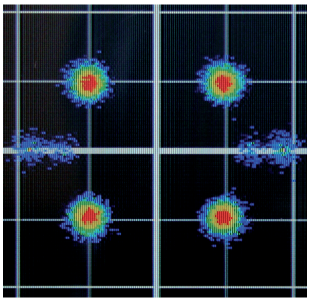
d) AWGN channel and portable reception scenario, MER = 21.6 dB; $BER_1 < 1\cdot10^{-6}$; $BER_2 < 1\cdot10^{-9}$



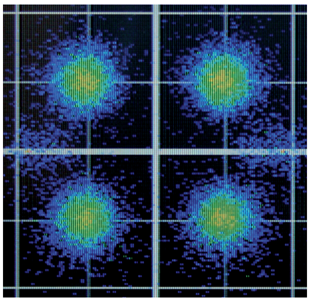
e) PI channel and portable reception scenario, MER = 18.2 dB; $BER_1 = 2.8\cdot10^{-3}$; $BER_2 = 1.4\cdot10^{-7}$



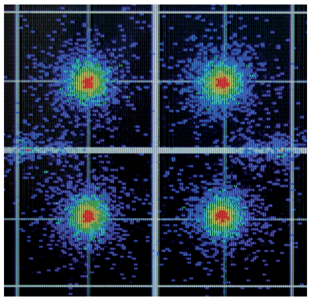
f) PO channel and portable reception scenario, MER = 17.0 dB; $BER_1 = 4.3\cdot10^{-3}$; $BER_2 = 3.4\cdot10^{-6}$



g) AWGN channel and mobile reception scenario, MER = 21.6 dB; $BER_1 < 1\cdot10^{-6}$; $BER_2 < 1\cdot10^{-9}$



h) RA6 channel and mobile reception scenario, MER = 14.0 dB; $BER_1 = 5.4\cdot10^{-3}$; $BER_2 = 7.5\cdot10^{-6}$



I) TU6 channel and mobile reception scenario, MER = 12.3 dB; $BER_1 = 1.4\cdot10^{-2}$; $BER_2 = 3\cdot10^{-4}$

Fig. 8. Measurement: I/Q constellation of: a) to c) fixed scenario with 64QAM, d) to f) portable scenario with 16QAM, g) to i) mobile scenario with QPSK and also within typical DVB-T/H fading channels (all the constellations incl. channel correction and pilots, C/N = 20 dB).

Within this project various aspects of the digital television and DVB-T/H broadcasting were analyzed, simulated and measured. Novelty of all the works rest on the complex view on DVB-T/H parameters and their discussion and application in various transmission conditions and scenarios. Within the project solution several simulation applications in Matlab were developed including two original software applications for the fading channels design up to 20 direct/indirect paths and echoes. The results of the *MER* and *BER* as the main parameters of the DVB-T/H services availability were presented. All the results were verified within the laboratory experiments.

Scenario	Modulation	Channel	Simulation			Measurements		
			BER_1 [-]	BER_2 [-]	MER [dB]	BER_1 [-]	BER_2 [-]	MER [dB]
Fixed (8k mode)	64QAM	AWGN	$4.6\cdot10^{-5}$	$<1\cdot10^{-6}$	24.6	$1.8\cdot10^{-2}$	$1.2\cdot10^{-6}$	21.5
		RC20	$1.2\cdot10^{-3}$	$1.1\cdot10^{-6}$	23.5	$2.8\cdot10^{-2}$	$5.5\cdot10^{-5}$	20.2
		RL20	$2.3\cdot10^{-2}$	$2.4\cdot10^{-3}$	15.7	$6.7\cdot10^{-2}$	$3.1\cdot10^{-3}$	16.5
Portable (4k mode)	16QAM	AWGN	$<1\cdot10^{-6}$	$<1\cdot10^{-6}$	25.0	$<1\cdot10^{-6}$	$<1\cdot10^{-9}$	21.6
		PI3	$2.5\cdot10^{-3}$	$<1\cdot10^{-6}$	18.4	$2.8\cdot10^{-3}$	$1.4\cdot10^{-7}$	18.2
		PO3	$3.8\cdot10^{-3}$	$2.1\cdot10^{-6}$	17.5	$4.3\cdot10^{-3}$	$3.4\cdot10^{-6}$	17.0
Mobile (2k mode)	QPSK	AWGN	$<1\cdot10^{-6}$	$<1\cdot10^{-6}$	25.1	$<1\cdot10^{-6}$	$<1\cdot10^{-9}$	21.6
		RA6	$<1\cdot10^{-6}$	$<1\cdot10^{-6}$	19.8	$5.4\cdot10^{-3}$	$7.5\cdot10^{-6}$	14.0
		TU6	$2.9\cdot10^{-4}$	$<1\cdot10^{-6}$	18.4	$1.4\cdot10^{-2}$	$3.0\cdot10^{-4}$	12.3

Tab. 2. Comparison of the simulation and measurement results for the DVB-T/H with *C/N* = 20 dB.

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