DVB-T/H Portable and Mobile TV Performance in the New Channel Profiles Modes

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Abstract. This paper deals with an experimental laboratory assessment of new channel profile modes in the transmission of DVB-T/H portable and mobile TV over fading channels. These new profiles called PI (Pedestrian Indoor), PO (Pedestrian Outdoor), VU (Vehicular Urban) and MR (Motorway Rural) are originally from the Celtic Wing TV project. The DVB-T/H performance was tested in a laboratory environment using R&S test and measurements equipments. The results of the BER before and BER after Viterbi decoding and MER (Modulation Error Rate) were evaluated as the objective criteria for the DVB-T/H portable and mobile TV reception.

Keywords: digital terrestrial television, portable TV, mobile TV, profile mode, fading channel, DTT, DVB-T/H.

1 Introduction

The DVB-T (Digital Television Broadcasting – Terrestrial) [1] [2] and DVB-H (Digital Television Broadcasting – Handheld) [3] [4] are technical standard that specifies the framing structure, channel coding and modulation for digital terrestrial television (DTT) broadcasting. They 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 DVB-T.

With focus on portable and mobile TV implementation aspects it is most important to determine the reception environment. The option "stationary" is associated with reception by a rooftop outdoor antenna to fixed receiver. The "portable" means that the device can easily be 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). The "mobile" means reception while moving at high speeds in cars, buses, trains etc. In the context of DVB-H, portable antenna reception is defined as the reception at no speed or very low speed (walking speed, approx. 3 km/h) and mobile antenna reception is defined as the reception at medium to high speed (no walking speed, approx. 30 km/h and higher up to 100 km/h in vehicular traffic).

R. Mehmood et al. (Eds.): EuropeComm 2009, LNICST 16, pp. 163–174, 2009.

Mobile reception suffers from all impairments relevant for portable reception (noise AWGN, multipath reception, narrowband interferers etc.) [5]. 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 (Orthogonal Frequency Division Multiplex) 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 *C/N* (Carrier-to-Noise) have to be sufficient [6].

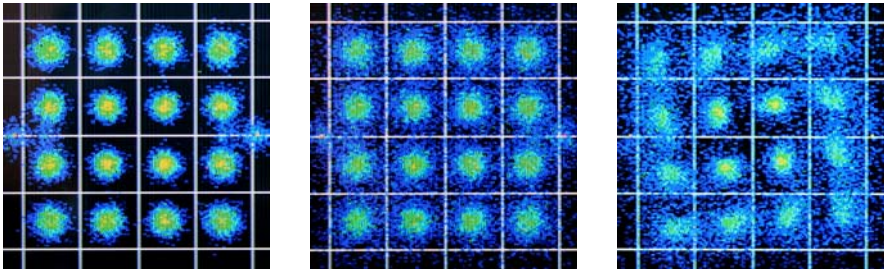
The paper is organized as follows: After a short introduction the standard and new channel profiles for portable and mobile environment are presented. Then the laboratory environment is presented including its setup for portable and mobile TV transmission. After that the experimental results are commented including the figures of bit error rates during the mobile TV transmission. These results were achieved by using a professional and reference test and measurement system made by Kathrein and classical mobile TV receiver (handheld device by Nokia). The conclusion makes a short evaluation of results and it deals with practical implementation in mobile TV environment. The reference list contains not only relevant DVB and ETSI documents, textbooks and reports, but it is also supplemented with previous works of the author.

2 Standard and New Channel Profiles Modes

The terrestrial propagation channel is considered to be frequency selective because of their respective coherence bandwidths. A frequency selective fading is classically characterized through a Power Delay Profile (PDP) which gives the relative time of arrival, the relative power and the type (Ricean or Rayleigh distribution, spectrum) of each group of unresolved echoes (also called taps).

The performance of the DVB-T system has been simulated during the development of the standard [2] with two channel models - for fixed reception (F1) and portable reception (P1), respectively. These profiles are included in Annex B of quoted ETSI standard as DVB-T channel characteristics as RC20 ANX B and RL20 ANX B. These are theoretical channel profiles for simulation without Doppler shift. For DVB-H transmission analysis the P1 channel with twenty paths is convenient and it was used in [8] for *C/N* performance evaluation. For practical implementations profiles with reduced complexity have been used successfully. In many cases it is sufficient to use only six paths with the highest amplitude. Primary profiles for realtime simulation with Doppler shift (mobile channel simulations) are presented in [7]. These profiles are included in Annex K of quoted ETSI technical report as DVB-T channel characteristics. Three channel profiles were selected to reproduce the service delivery situation in a mobile environment. Two of them reproduce the characteristics of the terrestrial channel propagation with a single transmitter – for typical urban reception (TU6), typical rural area reception (RA6). The third one reproduces the situation coming from an SFN operation of the DVB-T network (0dB echo profile).

Previous profiles are for real time simulation with Doppler shift (mobile channel simulation). For DVB-H transmission analysis the TU6 channel is convenient and it



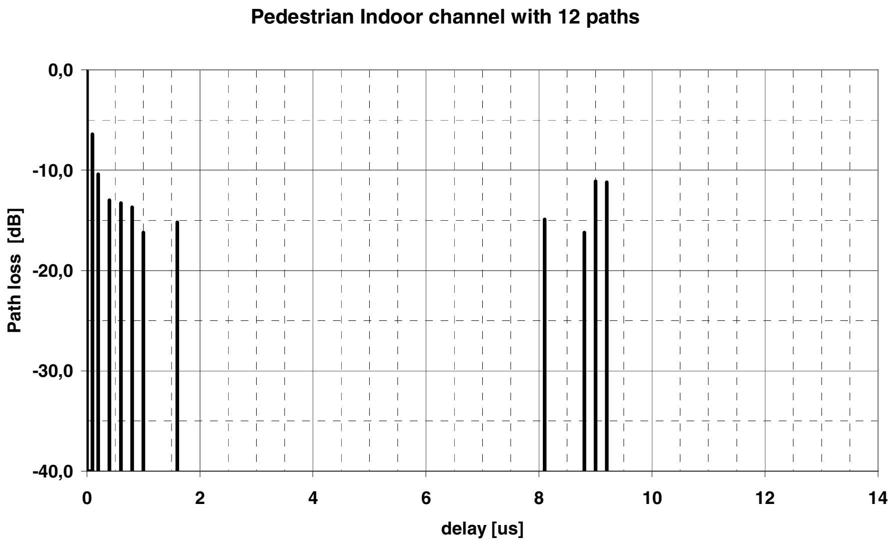
a) b) c)

Fig. 1. DVB-T/H constellation analysis a) Gaussian channel (noise AWGN), b) Rayleigh channel with 20 paths P1 without Doppler shift (RL20 ANX B), c) Vehicular Urban VU30 channel with Doppler shift. The figures are real measurement examples of portable and mobile TV environment influence on 16-QAM constellation (C/N in the channel was approx. 20 dB).

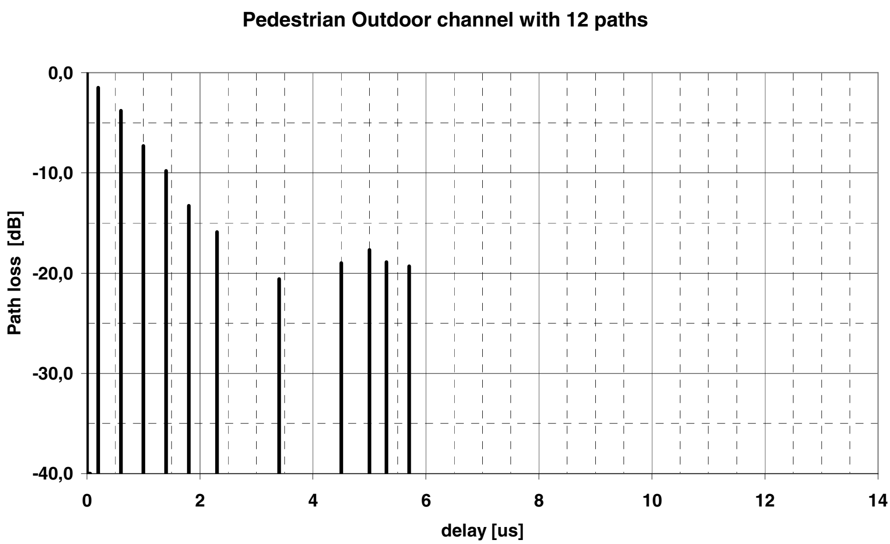
was used in [8] for *C/N* performance evaluation. This profile reproduces the terrestrial propagation in urban area. It is made of delayed six paths and having wide dispersion in delay and relatively strong power. Influence of the channel type and presence of the Doppler shift on DVB-T/H constellation of 16-QAM is in Fig. 1 as an example.

To conclude, standard portable and mobile channel models for DVB-T/H are defined in [2] [7] [8]. These models were used for the effective simulation in digital terrestrial television transmission and partly in GSM (Global System for Mobile Communications) tests. The mobile channel TU-6 could be used. This profile reproduces the terrestrial propagation in an urban area. It has been defined by COST 207 as a TU6 (Typical Urban) profile and is made of 6 paths having wide dispersion in delay and relatively strong power. But using the TU6 channel profile leads to some difficulties. At low speeds (e.g. pedestrian movement), the TU6 is not well adapted and creates more demanding than real pedestrian movement conditions. New channels models were developed to manage these difficulties. The portable indoor (PI) and portable outdoor (PO) channel models with 12 paths have been developed for describing the slowly moving handheld reception (at speed 3km/h) indoors and outdoors. The channel models are based on measurements in DVB-T/H SFN and have paths from two different transmitter locations. The indicated Doppler frequency of 1.69 Hz is corresponding 3 km/h velocity at 666 MHz [8].

There were used new fading channel profiles models presented in Celtic Wing TV project report [9] for the experimental transmission. The basis of the new channel models were real measurement data, which was acquired from extensive DVB-H field measurements. The measured data was studied extensively and parameters such as total excess delay, delay spread, number of taps, power delay profiles, K-factors and Doppler spread were obtained. The derivation of the tapped delay line models was based on average PDP determined from the impulse response of four different channel types. Finally, these channels are PI3 (Pedestrian Indoor at speed 3km/h, see Fig. 2a), PO3 (Pedestrian Outdoor at speed 3 km/h, see Fig. 2b), VU30 (Vehicular Urban at speed 30 km/h, see Fig. 3a) and MR100 (Motorway Rural at speed 100 km/h, see Fig. 3b) with 12 paths and Doppler spectrum characteristics [9].

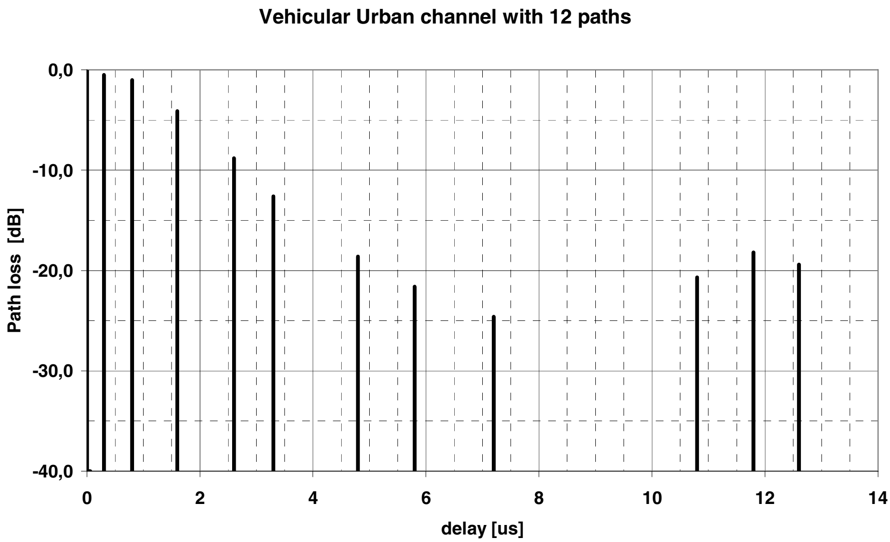


a) PI3 channel model impulse response *Path loss* $_{PI3} = f(delay)$

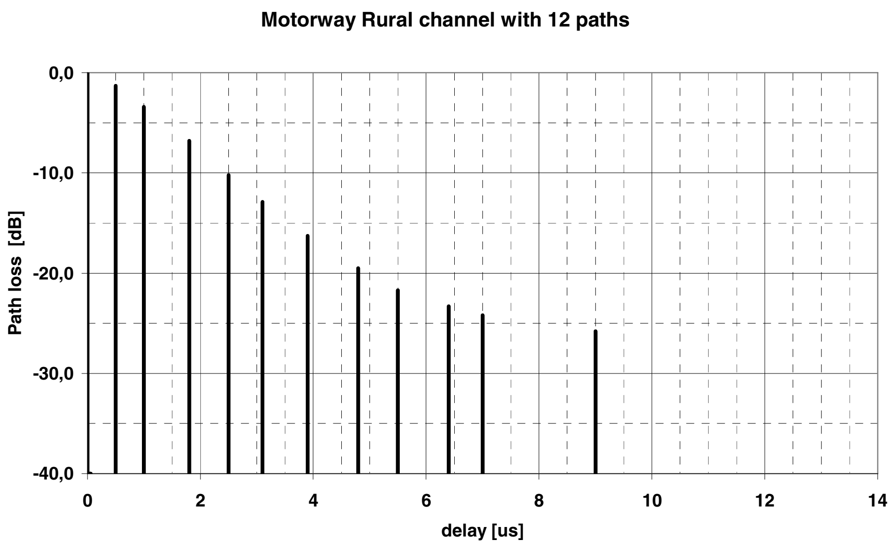


a) PO3 channel model impulse response *Path loss* $_{PO3} = f(delay)$

Fig. 2. DVB-T/H portable channel profiles and their impulse responses performance a) PI3 (Pedestrian Indoor, 3 km/h), b) PO3 (Pedestrian Outdoor, 3 km/h). Direct path and all the indoor or outdoor echoes are formed by using Gaussian Doppler Spectrum. Actual Doppler shift in both pedestrian channels and TV channel C39 (618 MHz) is approx 1.71 Hz (related to the velocity of light and transmitted frequency).



a) VU30 channel model impulse response *Path loss* $_{VU30}$ = f(*delay*)



a) MR100 channel model impulse response *Path loss* $_{MR100}$ = *f*(*delay*)

Fig. 3. DVB-T/H mobile channel profiles and their impulse responses performance a) VU30 (Vehicular Urban, 30 km/h), b) MR100 (Motorway Rural, 100 km/h). Direct paths are formed by using Gaussian Doppler spectrum and all the mobile echoes are formed by Classical (Rayleigh) spectrum. Actual Doppler shift in urban and rural channels and TV channel C39 (618 MHz) are approx 17.17 Hz and 57.26 Hz, respectively (related to the velocity of light and transmitted frequency).

3 Laboratory Transmission Setup

Experimental testing of the DVB-T/H portable and mobile TV transmission in the new channel profiles was realized in the laboratory environment. The transmitter and receiver test beds (see Fig. 4) were consisted of DVB-T/H test transmitter R&S SFU with noise generator and fading simulator up to 20 paths, MPEG-2 TS generators included in SFU and external R&S DVRG, reference test receiver Kathrein MSK-33, DVB-T receiver (STB, set-top box) and DVB-H receiver (mobile phone).

There was tested transmission of the variable content possible for portable and mobile reception of digital television: e.g. SDTV service MPEG-2 MP@ML stream (portable reception) and LDTV service MPEG-4 Part 10 stream (mobile reception). There were also used the new fading channel profiles models – Pedestrian Indoor, Pedestrian Outdoor, Vehicular Urban and Motorway Rural.

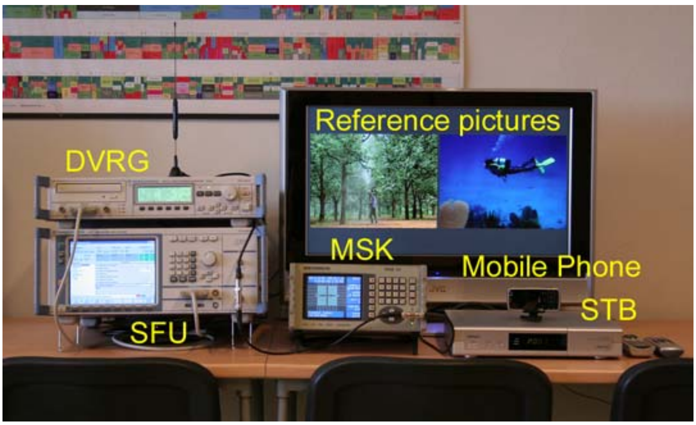


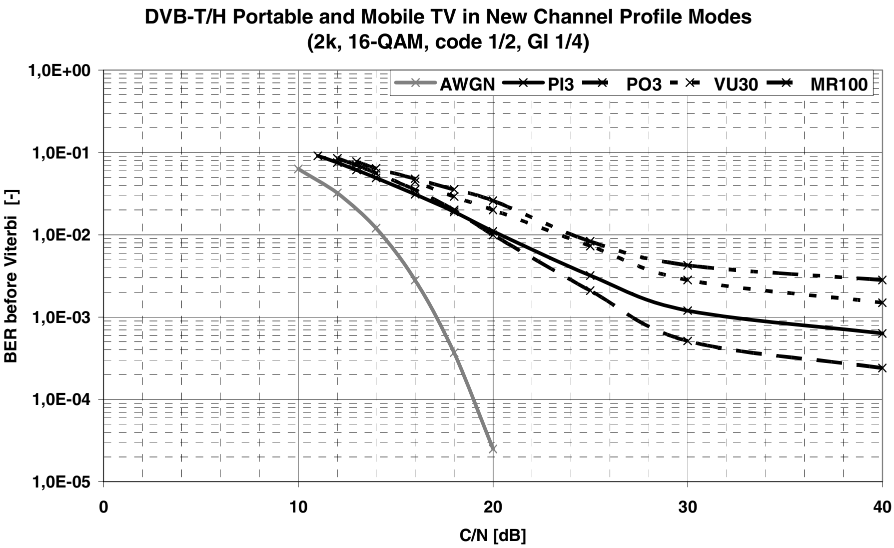
Fig. 4. Laboratory environment for DVB-T/H transmission: DVB-T/H transmitter R&S SFU, MPEG-2 TS (Transport Stream) player R&S DVRG, DVB-T reference test receiver Kathrein MSK-33, DVB-T set-top box Topfield with LCD TV screen and DVB-H mobile phone Nokia.

4 Experimental Results

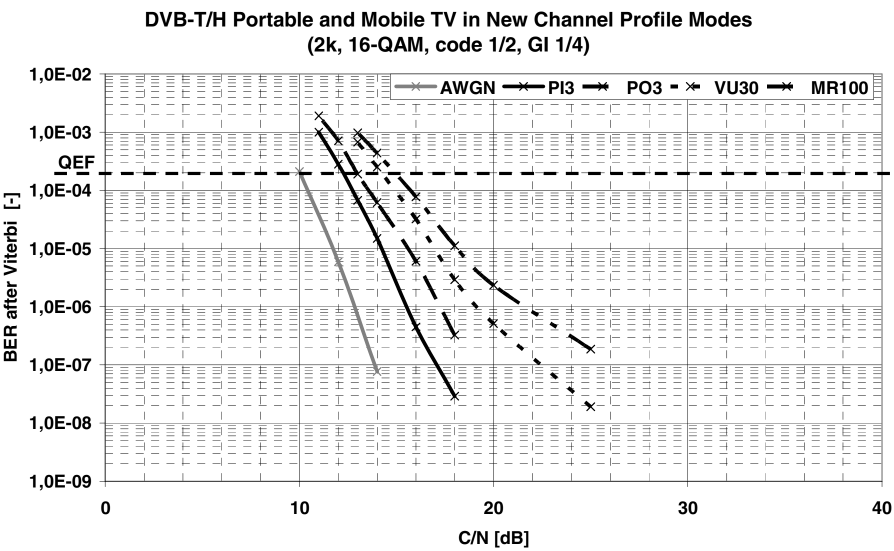
System parameters of the analyzed DVB-T/H transmission were set to a configuration of 16-QAM, OFDM mode 2k or 8k with one of the code rates 1/2 (higher robustness) or 2/3 (lower robustness). The transmitted data were MPEG-2 TS (Transport Stream) statistically multiplexed with several programs compressed with MPEG-2 and MPEG-4 AVC and data rate of the stream from 5.1 up to 14.5 Mbit/s.

Table 1. DVB-T/H in a new channel profiles and its minimal *C/N* in dB performance details

Mode	Code rate	Channel profiles				
		AWGN	PI3	PO3	VU30	MR100
2k	1/2	10.0	12.2	13.1	14.2	15.0
2k	2/3	10.2	14.3	15.1	16.3	17.0
8k	1/2	10.2	12.8	13.6	N/A	N/A
8k	2/3	10.6	14.8	15.4	N/A	N/A

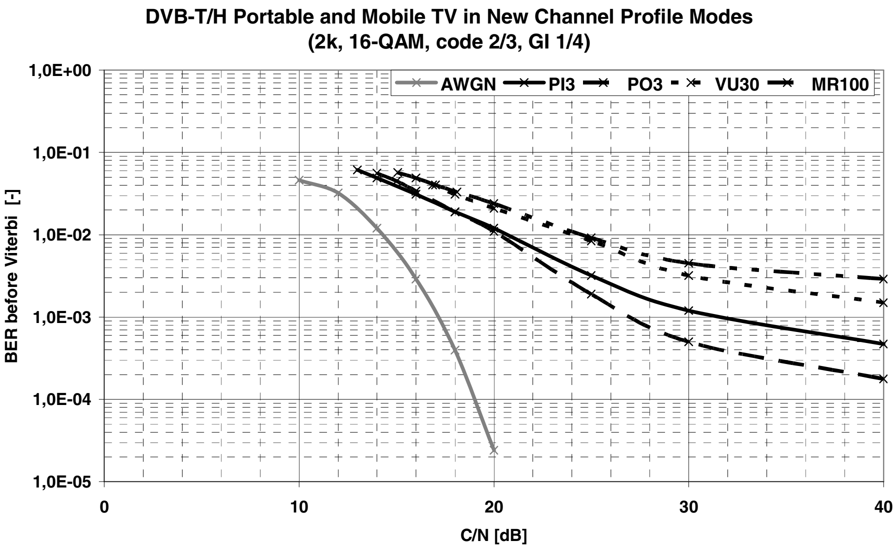


a) $BER_{\text{before Viterbi}} = f(C/N)$

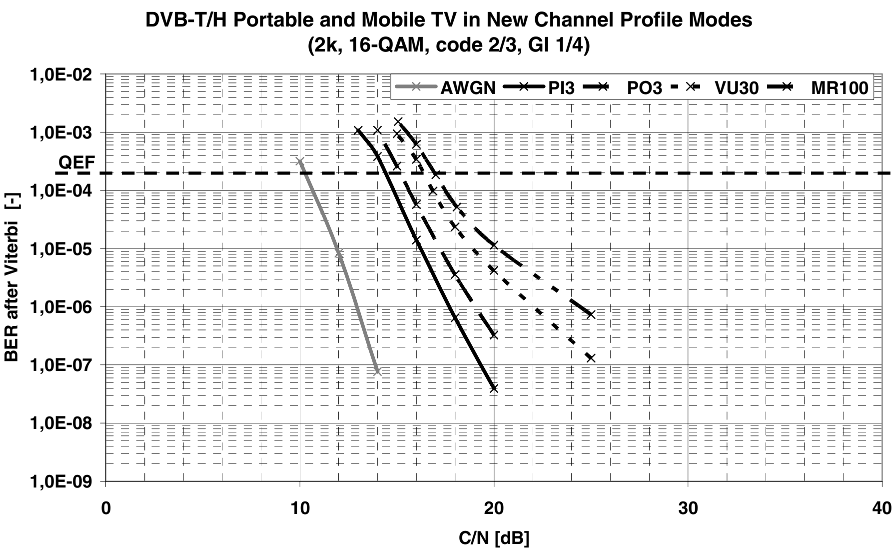


a) $BER_{\text{after Viterbi}} = f(C/N)$

Fig. 5. DVB-T/H portable and mobile TV performance in the new fading channel models – PI3 (Pedestrian Indoor, 3 km/h), PO3 (Pedestrian Outdoor, 3 km/h), VU30 (Vehicular Urban, 30 km/h) and MR100 (Motorway Rural, 100 km/h). Setup details: RX level 60 dBuV, channel C39 (618 MHz), 8 MHz channel bandwidth, OFDM mode 2k, non-hierarchical modulation 16-QAM, code rate 1/2, guard interval 1/4.

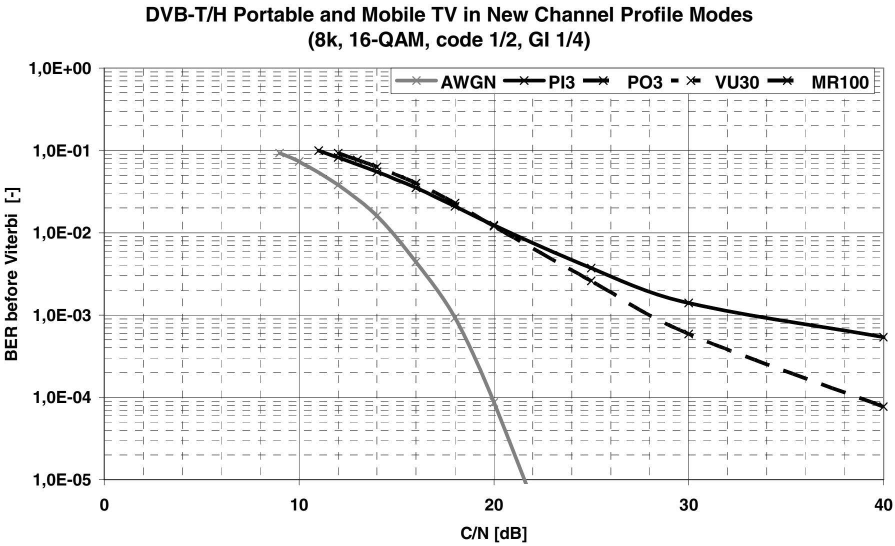


a) $BER_{\text{before Viterbi}} = f(C/N)$

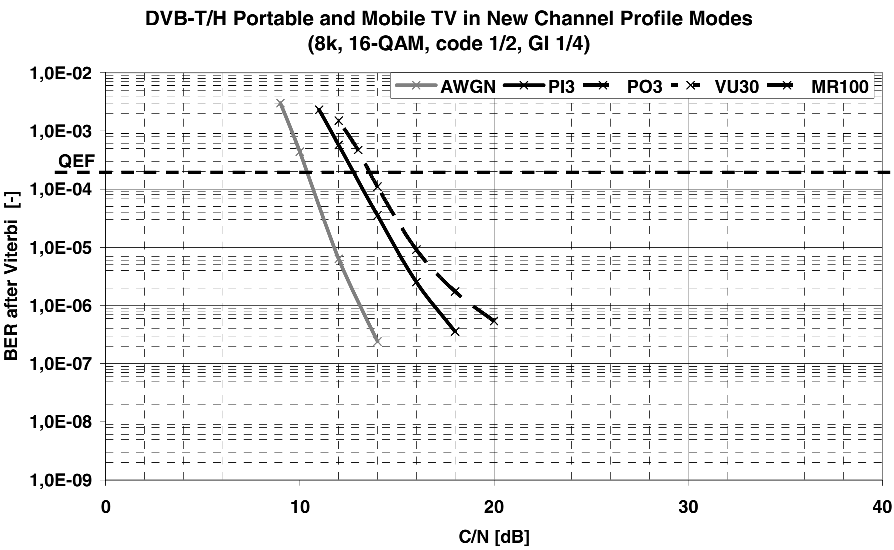


a) $BER_{\text{after Viterbi}} = f(C/N)$

Fig. 6. DVB-T/H portable and mobile TV performance in the new fading channel models - PI3 (Pedestrian Indoor, 3 km/h), PO3 (Pedestrian Outdoor, 3 km/h), VU30 (Vehicular Urban, 30 km/h) and MR100 (Motorway Rural, 100 km/h). Setup details: RX level 60 dBuV, channel C39 (618 MHz), 8 MHz channel bandwidth, OFDM mode 2k, non-hierarchical modulation 16-QAM, code rate 2/3, guard interval 1/4.

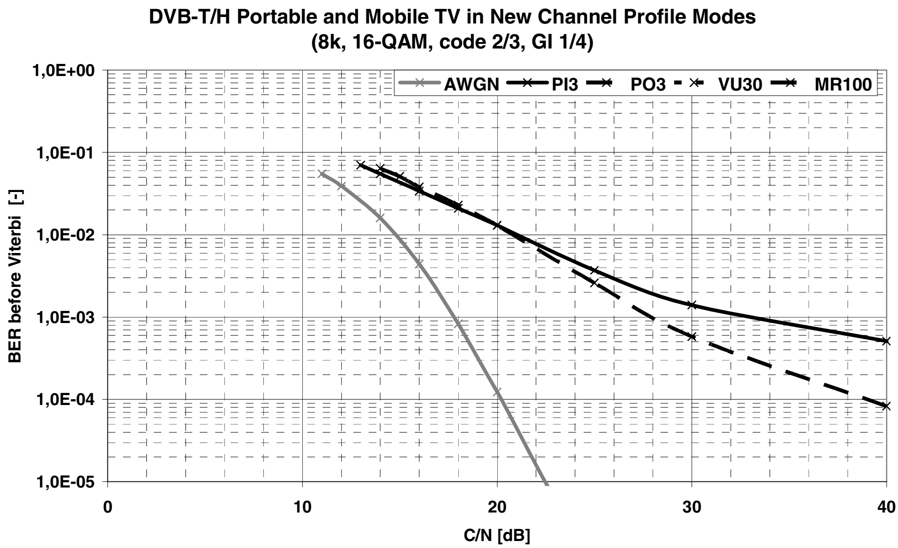


a) $BER_{\text{before Viterbi}} = f(C/N)$

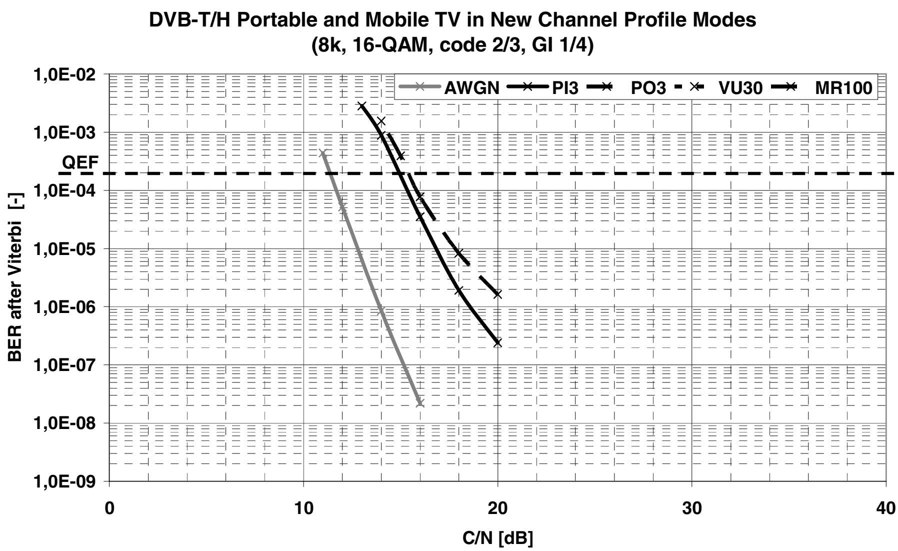


a) $BER_{\text{after Viterbi}} = f(C/N)$

Fig. 7. DVB-T/H portable and mobile TV performance in the new fading channel models – PI3 (Pedestrian Indoor, 3 km/h), PO3 (Pedestrian Outdoor, 3 km/h), VU30 (Vehicular Urban, 30 km/h) and MR100 (Motorway Rural, 100 km/h). Setup details: RX level 60 dBuV, channel C39 (618 MHz), 8 MHz channel bandwidth, OFDM mode 8k, non-hierarchical modulation 16-QAM, code rate 1/2, guard interval 1/4. (Note: VU30 and MR100 N/A).



a) $BER_{\text{before Viterbi}} = f(C/N)$



a) $BER_{\text{after Viterbi}} = f(C/N)$

Fig. 8. DVB-T/H portable and mobile TV performance in the new fading channel models - PI3 (Pedestrian Indoor, 3 km/h), PO3 (Pedestrian Outdoor, 3 km/h), VU30 (Vehicular Urban, 30 km/h) and MR100 (Motorway Rural, 100 km/h). Setup details: RX level 60 dBuV, channel C39 (618 MHz), 8 MHz channel bandwidth, OFDM mode 8k, non-hierarchical modulation 16-QAM, code rate 2/3, guard interval 1/4. (Note: VU30 and MR100 N/A).

The minimal *C/N* (Carrier-to-Noise Ratio) in dB in all laboratory transmission experiments was determined at which the channel *BER* (Bit-Error Rate) before Viterbi for the code rate of 1/2 or 2/3 is equal or less than 3.10^{-2}. Then the further *BER* after Viterbi decoding of inner error protection is equal or less 2.10^{-4}. This condition finally leads to error-free signals QEF (Quasi Error Free) at the input of the MPEG-2 TS demultiplexer and final *BER* after RS decoding is equal or less than 1.10^{-11} [7].

These evaluation criteria were used in last decade and they are valid if the channel is not time varying and burst errors do not occur. The recent works modified the criteria to additional ESR (Erroneous Second Ratio) and FER (Frame Error Rate). The first criterion is the ratio between the number of correct blocks and the total number of blocks transmitted. It was established due to the burst errors sensitivity in indoor portable reception. The second criterion was used in DVB-H analysis and the FER is the ratio of uncorrected frames during an observation period. FER is usually evaluated as FER5 where threshold ratio is 5%. These criteria should better correspond with time varying channels in case of portable and mobile reception.

The results for DVB-T/H transmission with portable and mobile reception environments and required minimal *C/N* ratio in dB based on QEF determination are shown in the Tab 1. The results were measured using reference test receiver Kathrein MSK-33. Detailed results of referenced *BER* before Viterbi decoding and *BER* after Viterbi decoding (*BER* before RS decoding) for portable and mobile TV reception are available in Fig. 5 to Fig. 8. The approximation condition for the QEF reception was previously defined as *BER* after Viterbi decoding equal to 2.10^{-4} or less. This is the limit at which the subsequent FEC Reed-Solomon decoder still delivers an output *BER* of 1.10^{-11} or less. This presents one error per hour. There were analyzed results of the OFDM in 2k and 8k mode with GI (Guard Interval) used in large SFN and equal to 1/4.

5 Conclusion

The results are not available in 8k mode and VU30 and MR100 channels, where 2k mode is better to use in case of mobile TV reception. Experimental results were compared with reference results presented in [9] [10]. Theoretical minimal *C/N* value in 8k mode, code rate 1/2 and non-hierarchical modulated 16-QAM is equal to (13.5, 13.8, 14.5, 14.6) dB in the (PI3, PO3, VU30, MR100) channel profile respectively. Theoretical minimal *C/N* value in 8k mode, code rate 2/3 and non-hierarchical modulated 16-QAM is equal to (17.4, 17.4, 17.9, 18.0) dB in the (PI3, PO3, VU30, MR100) channel profile respectively. These results were achieved using Nokia reference receiver and these theoretical results are not available for the 2k mode.

Presented results supplement existing results of measurements in portable and mobile TV environment [10] – [13]. It can be used for DVB-T/H transmission distortions analysis and evaluation of the non-hierarchical and hierarchical modulation on portable and mobile reception of digital TV services.

Acknowledgments

This paper was supported by the Research program of Brno University of Technology no. MSM0021630513, "Electronic Communication Systems and New Generation Technology (ELKOM)" and the research project of the Czech Science Foundation no. 102/08/P295, "Analysis and Simulation of the Transmission Distortions of the Digital Television DVB-T/H".

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