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NOVEL RADIO CHANNEL MODELS FOR EVALUATION OF DVB-H BROADCAST SYSTEMS

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ABSTRACT

A new area of digital television broadcasting has emerged in the from of hand held reception. This has created a need for new standard channel models, which describe more accurately the conditions in portable reception. Hence, the Finnish partners of the multinational CELTIC Wing-TV project performed a comprehensive measurement campaign during autumn 2005. The analysis of the measurement results show that in most scenarios a strong specular or line-of-sight component is present and clearly dominating. This is noted from the very large values of Rician K-factor. The SFN characteristics of the DVB-H reception is clearly visible while considering the RMS delay spreads, total excess delays and variations of the number of taps. Based on the analysis of the measured data this contribution presents novel tapped delay line (TDL) channel models suitable for DVB-H testing.

I. INTRODUCTION

The signal environment seen by the DVB-H (Digital Video Broadcast Hand held) terminal receiver differs from the environment available for cellular telephony devices. This follows from the fact that DVB-H networks are so-called Single Frequency Networks (SFN) i.e. there may be two or more transmitters in the range transmitting at the same frequency. Because of this the channel parameters, such as total excess delay and RMS delay spread, diverge from the traditional case where only one transmitter is visible to the receiver.

The SFN characteristics of the DVB-H reception and the portability of the terminals introduce a need for new standard channel models. Traditionally the channel models used in the planning of the digital television broadcasting are intended to describe the rooftop antenna reception, portable indoor reception or cellular mobile reception. For rooftop antenna reception a multipath static Ricean channel has been widely used and for portable reception static multipath Rayleigh channel has been applied [1]. For cellular mobile reception channel models like the Typical Urban (TU) from the COST 207 project have been in use. However, these models are not suitable for handheld digital television broadcasting applications. The static Rayleigh channel seems to be too pessimistic when compared to the real channel conditions and the mobile TU-channel with small Doppler leads to too high C/N-requirements. Despite the shortcomings of the TU-6 model it is used as the de facto model in the development of DVB-H terminals. The multinational CELTIC Wing-TV project [2] recognized the problem that the use of inaccurate channel models causes and the Finnish partners of the project performed a comprehensive measurement campaign during the autumn of 2005. The aim of the campaign was to gather channel data in various indoor and outdoor environments with varying mobile speed. A set of new channel models was then developed based on the measured data.

This paper presents some of the measurement results, describes the analysis of the measurement data and introduces novel channel models for three different environments. The paper is organized as follows. Section II clarifies the need for a new set of channel models. Section III presents the essential technical details of the DVB-H standard. In Section IV the measurement setup and scenarios are introduced. Section V explains the analysis of the measurement data and presents the relevant results. Section VI concludes the paper and summarizes the results.

II. MOTIVATION FOR NEW CHANNEL MODELS

The need for new set of channel models arose while comparing DVB-H receiver performance between field test measurements and simulations with COST207 6-tap Typical Urban (TU6) channel model. The field test were performed in Turku test network with measurement software equipped Nokia 7700 handheld terminals. The speed of the mobile in urban environment was 30-50km/h.

The results of the measurements and simulations are presented as MPE-FEC (Multi-Protocol Encapsulation/Forward Error Correction) Frame Error Ratio (MFER) as a function of the signal-to-noise ratio (SNR) in Fig.1. Because of difficulties in calibration of measured signal strengths and simulated SNR the most interesting measure is not the SNR value but the shape of the measured MFER curves and their correspondence to the simulated curves. The results show quite poor correspondence and from this can be deduced that the mobile DVB-H channel is poorly modelled by TU6.

III. DVB-H

DVB-H is a digital broadcasting standard developed by international DVB Project with the purpose of developing a technique to receive broadcasted TV signal by handheld terminals. The DVB-H is a spin-off of the DVB-T (Digital Video Broad-Casting Terrestrial) standard, but some modifications have been made considering the required properties of the portable terminals i.e. small size, light weight and low power consumption [3]. The technology is based on specifications [1, 4–6].

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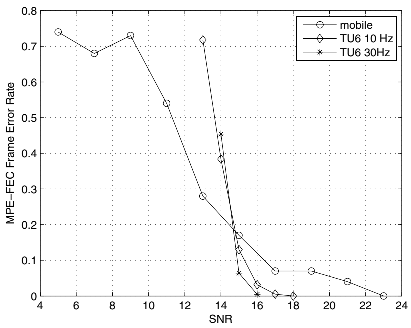

Figure 1: The mobile measurement results vs. TU6 simulations with Doppler frequencies 10 Hz and 30 Hz.

DVB-H is a IP (Internet Protocol) based broadcasting technology providing a total data rate of several Mbit/s. The broadband, high capacity downlink channel makes the technology feasible e.g. in audio and video streaming applications [3]. The base of the air interface is OFDM (Orthogonal Frequency Division Multiplexing) technique with variable FFT length (2048, 4096 or 8192), guard interval length (ranging from 1/4 FFT length to 1/32 FFT length) and 8MHz RF bandwidth. The number of data subcarriers is defined in the specifications to be 1512, 3024 or 6048. The specified modulations for transmission are QPSK, 16QAM and 64QAM, which are selected based on the amount of transmitted data and channel conditions. It should be noted that the 64QAM is used very seldom, because of the inherent sensitivity of this modulation technique to noise and other sorts of errors originating from the mobile channel.

IV. Measurement system

A. *Measurement setup*

The channel measurements were performed with Elektrobit OFDM test receiver, which was connected to a single RX antenna. The platform is designed to be fully programmable, software controlled radio device for development and verification of air interface algorithms and concepts. Fig.2. depicts the simplified block diagram of the measurement device.

The Elektrobit OFDM test receiver is capable of storing data during measurements for post-processing purposes. The stored parameters include frequency responses, Received Signal Strength Indication (RSSI), Signal-to-Noise Ratio (SNR) and location information in GPS form.

The measurements were performed in three Finnish cities Oulu, Turku and Helsinki. The RF bandwidth of the measurements was 8MHz and the center frequency varied depending on the venue (Oulu 522MHz, Turku 498MHz, Helsinki 610MHz).

The DVB-H terminals are expected to be used by mobile users and this causes new challenges to the receiver compared to the traditional stationary TV-signal receivers. To capture the real effects of moving environment the measurement equipment were mounted into a trolley for pedestrian measurements and into a car for vehicle measurements.

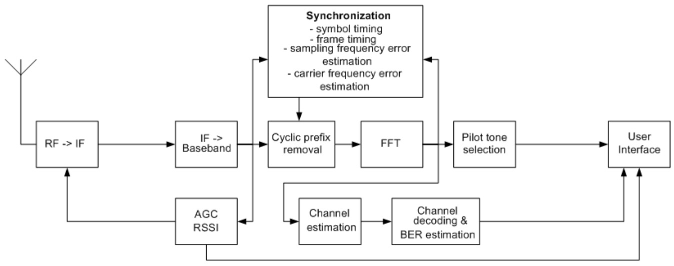

Figure 2: Block diagram of the measurement device.

B. *Measurement scenarios*

The measurement scenarios were chosen so that they would represent the typical user environments. The main categorization of the measurement scenarios was done according to the number of transmitters. In Oulu there is one transmitter plus one gap filler (repeater), in Turku there exists two transmitters and in Helsinki three transmitters and several gap fillers. The actual measurement environments varied from indoor to urban, suburban and rural surroundings. The speed of the receiver also varied depending on the means of transport, speed limits and traffic.

In Oulu there were two different measurement scenarios: motorway rural and vehicular suburban. The motorway environment is characterized by four-laned roads and a moderate amount of tree stand. There are only a few buildings in the vicinity of the motorway, the traffic intensity is moderate and the speed limit is 100km/h. The vehicular suburban measurements were performed in a relatively open area where the surrounding buildings form the major reflectors. It should be also noted that in the suburban scenario the traffic intensity was greater than in the motorway scenario, which caused the speed of the vehicle to vary from 30km/h to 40km/h.

The Turku measurements were subdivided into three categories: pedestrian indoor, motorway rural and vehicular urban. The indoor measurements were carried out in an office building characterized by long corridors covered with metallic structures and glass windows at the ends. It is notable that one of the transmitters was very close to the measurement location (few hundred meters) and visible from the window. The motorway environment was quite similar to the corresponding Oulu measurement. The urban measurements were performed in downtown Turku. There were three different routes selected and the speed of the vehicle varied between 30 - 40km/h. The street layout in Turku downtown is relatively regular grid surrounded by five-storeyed buildings.

The location for vehicle urban measurements in Helsinki was Kallio district, which is characterized by concrete apartment houses and hilly terrain.

V. Analysis and results

In the analysis we have chosen an appropriate power threshold to cut noise. After studying the measurement data a conclusion was drawn that 30dB is a proper value for the dynamic range of the impulse responses. This means that everything which

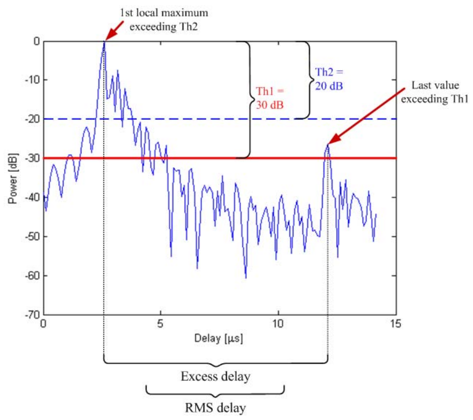

Figure 3: Total excess delay and RMS delay spread.

is 30dB or more below the strongest power level is considered to be noise. Path loss and shadowing effects were removed by normalizing the peak power of each impulse response to 0dB. It should be noted that the normalization was not performed in the calculation of the K-factors.

A. *Channel parameters*

There were three parameters analyzed from the acquired data: total excess delay, RMS delay spread (DS) and the number of taps.

The total excess delay by definition is the delay difference between the first and the last of the received taps as described in [7]. From the DVB-H measurements the total excess delay was calculated by finding the delay value of the first local maximum above -20dB threshold and the last delay value, which exceeded the -30dB threshold. The applied method is illustrated in Fig.3.

The RMS delay spread was calculated from [7]

$$\tau_{RMS} = \sqrt{\frac{1}{P_T}\sum_{i=1}^{n} P_i \tau_i^2 - \tau_0^2}. \qquad (1)$$

where $P_1, ..., P_n$ are the powers of individual taps, P_T is the total power in the channel i.e. the sum of the individual powers, $\tau_1, ..., \tau_n$ are the excess delays of the taps and τ_0 is the mean delay given by [7]

$$\tau_0 = \frac{1}{P_T}\sum_{i=1}^{n} P_i \tau_i \qquad (2)$$

The number of taps was determined by counting the number of delay bins in which the power level exceeded the -30dB threshold. See Fig.4 for reference.

In Table 1 the calculated channel parameters are listed for a subset of the measurement scenarios (the numbers are averages of several measurements in the same environment). The scenarios are chosen so that the results are comparable.

By comparing the numbers can be deduced that the number of transmitters and gap fillers have an effect to the total excess delay and RMS delay spread. In the two transmitter scenario

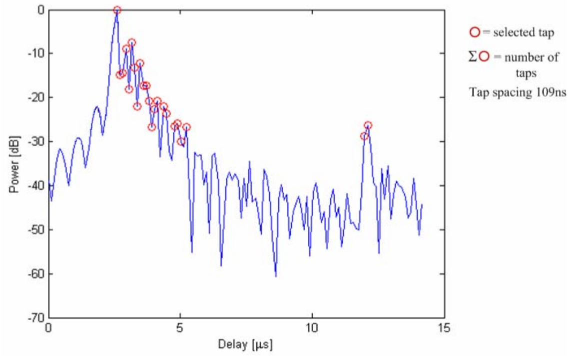

Figure 4: Determination of the number of taps.

Table 1: Channel parameters.

Scenario	Excess delay[μs]	RMS DS [μs]	No. taps
Oulu highway	2.21	0.25	20
Turku highway	5.77	0.57	32
Oulu suburban	3.94	0.36	24
Turku urban	11.34	1.07	41
Helsinki urban	27.2	4.94	48

(Turku highway) the total excess delay is approximately doubled compared to the total excess delay in the one transmitter case (Oulu highway). The same phenomenon can be noted by observing the total excess delay and RMS delay spread values from Oulu suburban, Turku urban and Helsinki urban measurements. These results support the assumption that the SFN characteristics affect the channel parameters. Therefore, traditional one transmitter channel models are inadequate while testing DVB-H receivers.

B. *Power delay profile*

The power delay profiles (PDP) were determined by using the same method as described in [8] i.e. the impulse response data was divided into smaller sets time-wise to satisfy the stationarity requirement. Then the average PDP of each set was calculated and finally the PDPs from several measurements (from the same environment) were averaged.

Figure 5. presents example PDPs from three different scenarios. As mentioned earlier there were different number of transmitters present in different measurement locations. This is clearly visible in the PDP figures.

C. *K-factors*

In some radio propagation environments, the complex path gain consists of line-of-sight (LOS) path (or dominant specular component) and a zero-mean fluctuating component. If the fluctuating part is complex Gaussian the time-varying envelope will have Rician distribution. The Rician distribution

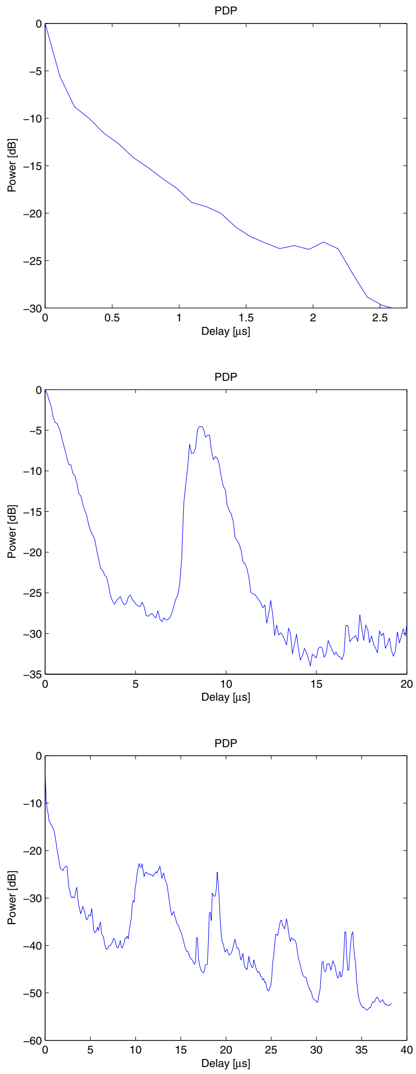

Figure 5: Power delay profiles. Top: Oulu motorway (one transmitter). Middle: Turku pedestrian indoor (two transmitters). Bottom: Helsinki urban (three transmitters, several gap fillers)

is often described in terms of parameter called K-factor, which can be interpreted as the power ratio of the fixed and fluctuating components. [9, 10]

The Rician K-factors for the line-of-sight tap in each measurement scenario have been determined by using the method of moments (MoM) [9]. A tap is defined as a delay bin with 109ns uniform intervals. In derivation of K-factors the IRs should have low correlation in time, otherwise the derived K-factors will not be accurate. Therefore, we have calculated the K-factors in pieces. From the original time-wise data containing 10000 samples we have formed data blocks each containing 25-2000 time samples (the number of samples in a block varies with speed and sampling frequency). Then we have determined a local K-factor from every data block. Finally, the average of these K-factors has been calculated. Table 2 presents K-factors of the strongest tap from Oulu highway, Turku indoor and Helsinki urban measurements.

Table 2: K-factors of the strongest tap

Scenario	K-factor [dB]
Oulu highway	14.3
Turku indoor	11.8
Helsinki urban	14.0

As can be seen from the K-factor values the strongest tap is pronouncedly Ricean. This is due to the fact that there were a line-of-sight connection to the transmitting antenna almost throughout the measurements.

D. *TDL-models*

Derivation of the tapped delay line models was based on average power delay profiles of the selected channel types. 24 tap channel models were formed by visual inspection from these averaged PDPs. One criterion in the tap selection process was the frequency correlation of the taps. The selected taps should have a low frequency correlation on the bandwidth of the receiver. Fig. 6 shows three TDL models from different environments. The models have been constructed from the corresponding PDPs shown in Fig. 5. The exact delay and power values of the taps for the models are given in Table 4. The reason to select 24 taps is evident if the calculated tap numbers from Table 1 are observed. This number is a compromise between accuracy and complexity of the channel model. It was also desired to unify the models, and hence the number of selected taps was chosen to be 24 in all the models.

E. *Doppler*

Analyzing the Doppler functions of the measurement results is a very important aspect while forming new TDL models. The analysis of the Doppler is still ongoing so we do not present exact results in this contribution. However, we have performed simulations with the DVB-H receiver and the measured channel models to get an idea of how the Doppler phenomenon affects the receiver performance. Table 3 lists required minimum Carrier-to-Noise ratios (C/N) of the DVB-H receiver with different maximum Doppler frequencies. From the numbers can be deduced that even the smallest amount of Doppler causes the C/N requirement to increase significantly with respect to zero Doppler case.

VI. Conclusion

Novel measurement based TDL channel models for evaluation of DVB-H devices have been proposed. The models were constructed by analyzing the measured radio channel data. It is believed that the new models are better suited for testing of portable digital video terminals than the traditional static or cellular type models. As further work the Doppler spectra of the

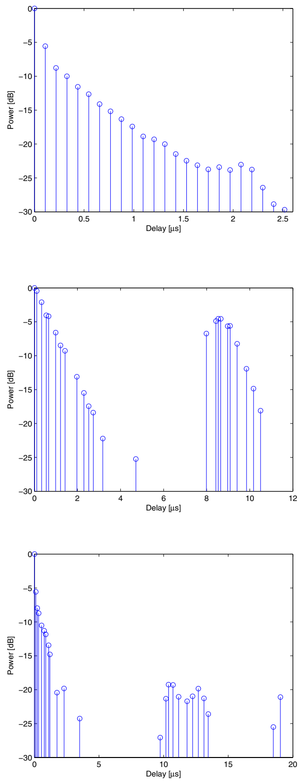

Figure 6: TDL models. Top: Oulu motorway. Middle: Turku indoor. Bottom: Helsinki urban.

Table 3: The effect of Doppler to C/N

Max.Doppler [Hz]	C/N [dB]
0	7.8
0.2	12
1	12
2	11.9

measured data should be analyzed, because it seems highly unlikely that a simple Classical Doppler characteristics would be found in realistic environments.

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Table 4: TDL models

	Oulu motorway		Turku indoor		Helsinki urban	
Tap no.	Delay [μs]	Power [dB]	Delay [μs]	Power [dB]	Delay [μs]	Power [dB]
1	0	0	0	0	0	0
2	0.1125	-5.56	0.1125	-0.47	0.1125	-5.56
3	0.225	-8.78	0.3375	-2.11	0.225	-7.94
4	0.325	-10.01	0.5500	-4.02	0.325	-8.71
5	0.4375	-11.57	0.6625	-4.20	0.55	-10.53
6	0.55	-12.66	0.9875	-6.58	0.7625	-11.30
7	0.6625	-14.12	1.2125	-8.48	0.875	-11.82
8	0.7625	-15.17	1.4250	-9.26	1.1	-13.43
9	0.875	-16.34	1.9750	-13.09	1.2	-14.79
10	0.9875	-17.41	2.3000	-15.49	1.75	-20.42
11	1.1	-18.86	2.5250	-17.45	2.3	-19.83
12	1.2	-19.32	2.7375	-18.41	3.5	-24.24
13	1.3125	-20.01	3.1750	-22.22	9.74	-27.06
14	1.425	-21.46	4.7125	-25.25	10.175	-21.31
15	1.5375	-22.46	7.9875	-6.75	10.3875	-19.27
16	1.6375	-23.12	8.4250	-4.88	10.725	-19.32
17	1.75	-23.73	8.5375	-4.55	11.1625	-21.04
18	1.8625	-23.41	8.6500	-4.53	11.8125	-21.71
19	1.975	-23.82	8.9750	-5.64	12.25	-20.97
20	2.075	-23.04	9.0875	-5.57	12.6875	-19.84
21	2.1875	-23.76	9.4125	-8.25	13.125	-21.27
22	2.3	-26.42	9.8500	-11.91	13.45	-23.58
23	2.4125	-28.86	10.1750	-14.84	18.4875	-25.51
24	2.5125	-29.71	10.5000	-18.13	19.0375	-21.08

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