THE VALIDATION OF THE NOVEL DVB-H RADIO CHANNEL MODELS

Roope Parviainen
Elektrobit
Tutkijantie 7
FIN–90570 Oulu, Finland
Email: roope.parviainen@elektrobit.com

Heidi Himmanen
University of Turku
Lemminkäisent. 14-18A
20520 Turku, Finland
Email: heidi.himmanen@utu.fi

Jukka Rinne
Tampere Univ. of Tech.
P.O.Box 553
33101 Tampere, Finland
Email: jukka.rinne@tut.fi

Pekka H.K. Talmola
Nokia
P.O. Box 4
Turku, Finland
Email: pekka.h.k.talmola@nokia.com

Jukka Henriksson
Nokia
P.O. Box 407
FIN-00045 Helsinki, Finland
Email:jukka.henriksson@nokia.com

***Abstract*—This paper provides results of the radio channel measurements performed in DVB-H network during autumn 2006. The purpose of these measurements was to acquire additional channel information in order to validate the channel models constructed from the earlier measurements [1], [2]. This paper presents the most relevant results of the measurements including Ricean K-factors, RMS delay spreads, total excess delays and the variations of the number of taps. By comparing these results to those presented in [1] can be stated that the values are similar. Therefore, the original models can be considered consistent.**

I. INTRODUCTION

The Work Package 4 in pan-European Celtic project Wing-TV was focused on validating the DVB-H (Digital Video Broadcasting Hand held) standards by laboratory tests and field trials [3]. One of the issues taken under consideration was the composition of radio channel models, which would describe accurately the radio environment in Single Frequency Networks (SFN) with low frequency band (400 - 800 MHz). This work has been reported in detail in [1] and [2]. The produced models, known within the Wing-TV project as the Pedestrian Indoor (PI) and the Pedestrian Outdoor (PO) models, have been used in several laboratory test sessions [3]. The tests with these models have confirmed the results discovered earlier in field trials that the TU6 (referring to COST207 Typical Urban 6), which has been used as the de facto channel model in DVB-H mobile testing, is too demanding a model in low speed pedestrian scenarios. In addition, TU6 and static Rayleigh model are lacking SFN characteristics.

The purpose of this contribution is to validate the PI and PO channel models. This is achieved by presenting results from new field measurements performed 1) in the same indoor location as in [1] and 2) in several similar indoor locations. The idea of the step one is to verify the previous results, presented in [1], by repeating the measurement. The purpose of the step two is to show that the models can be generalized also to other indoor locations.

The paper is organized as follows. Section II introduces briefly the PI and PO models. Section III describes the measurement environment and Section IV clarifies the differences of the models to TU6, explains the analysis of the measurement data and presents the relevant results. Finally, section V concludes the paper and summarizes the results.

II. THE PEDESTRIAN INDOOR AND PEDESTRIAN OUTDOOR CHANNEL MODELS

The Pedestrian Indoor and Pedestrian Outdoor models are Tapped Delay Line (TDL) models, with Doppler spectrum, amplitude distribution, power and delay value specified for each tap. The channel measurement analysis and the formulation of the original TDL models are presented in [1] and the final form of the PI and PO models can be found in [2].

The analysis of the Ricean K-factors of the 2005 measurements gave evidence that in SFN networks often contain one or several strong signal components with Rician distributed complex envelope. The TU6 does not take this into account unlike the PI and PO models, which have been derived directly from channel measurements. Therefore they represent all the characteristics of a real channel. The K-factors from the 2006 measurements are introduced in this paper and they confirm the earlier results.

III. THE VALIDATION FIELD MEASUREMENTS

The new DVB-H channel measurements were performed in Turku during 10.10.-11.10.2006. The measurement equipment was the same Elektrobit OFDM test receiver, which was used in 2005 measurements [1]. The focus of the measurements was on indoor environment and therefore two interesting locations were selected: Turku Polytechnic premises and Scandic Hotel Julia premises in downtown Turku. The Turku Polytechnic premises is the same indoor location as in [1] and the hotel environment was selected to obtain generality to the results.

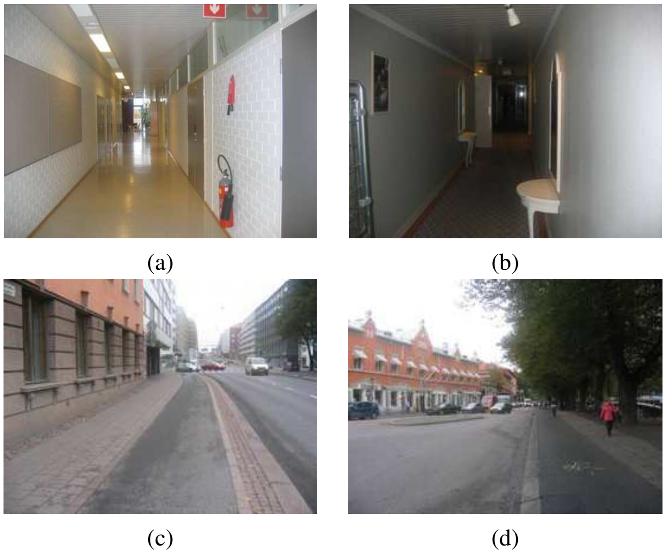

Fig. 1. Environments. (a) Turku Polytechnic premises (b) The hotel premises (c)&(d) Outdoor environment in downtown Turku.

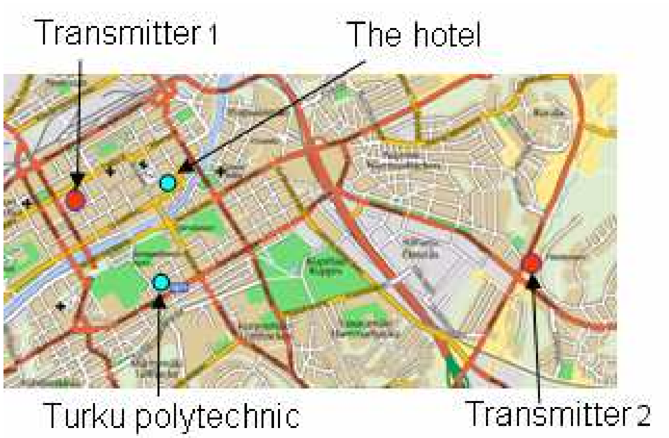

Fig. 2. The locations of the measurement venues and transmitters.

Pedestrian outdoor measurements were also performed at sidewalks surrounding the hotel.

The authors would like to point out that the hotel scenario was selected, because it was desired to imitate real user scenario i.e. it is believed that DVB-H terminals shall be used in places like hotels. Figure 1 depicts the different measurement environment, Figure 2 portrays the map of downtown Turku and Figures 3 and 4 present the floor plans of Turku Polytechnic 3rd floor and Hotel Julia 5th floor respectively. It should be noted that the 2nd and 3rd floor corridors in the Polytechnic are identical. This applies also to the 3rd, 4th and 5th floor corridors of Hotel Julia. The 6th floor corridor in the hotel is slightly shorter, but otherwise similar to the other floors.

The speed of the receiver was in all scenarios approximately 3km/h and the distances from the measurement sites to the transmitters 1 and 2 are as follows: from Polytechnic 1.0km and 3.6km and from Hotel Julia 0.9km and 3.49km respectively.

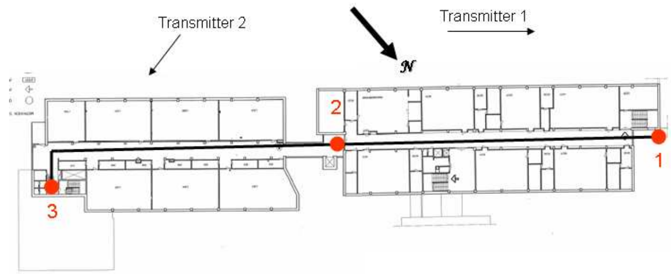

Fig. 3. The floor plan of Turku Polytechnic 3rd floor and measurement route. The letter N indicates North.

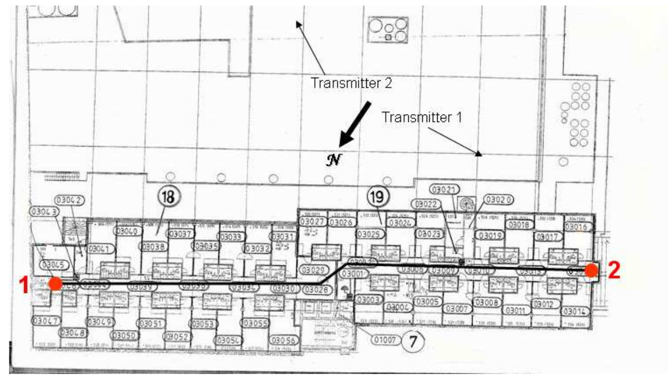

Fig. 4. The floor plan of Hotel Julia 5th floor and measurement route. The letter N indicates North.

IV. Analysis and results

A. PER and MFER simulations

Several simulations have been performed to compare the error performance of the DVB-H system in different fading scenarios. Figures 5 and 6 depict the MFER (MPE-FEC FER, Multi Protocol Encapsulation-Forward Error Correction Frame Error Rate) and IP PER (Internet Protocol Packet Error Rate) performance of the system with PI and PO models and compare these results to those achieved with the TU6 model.

The parameters used in the simulations and measurements shown in Figures 5-7 are 16-QAM (Quadrature Amplitude Modulation) modulation, convolutional code rate 1/2 and MPE-FEC code rate 3/4. The OFDM FFT size is 8192 and the guard interval is 1/4 of the FFT length. The errors are measured over the whole transport stream (TS), so the burst length and the duration of one MPE-FEC frame is 110 ms and the burst bit rate is 9.95 Mb/s at TS level.

It is evident that the results between PI&PO and TU6 differ significantly, which suggest that the distribution of the errors is clearly distinct. In PI and PO channels the errors occur in bigger bursts than in TU6 channel, but these large bursts appear less frequently. This phenomenon is presented in Figure 7, which shows the cumulative behavior of the IP packet errors with constant average Carrier-to-Noise ratio (C/N). Figure 7 presents also a curve labelled as ”PO field”. This curve is a measurement result from a real pedestrian outdoor scenario

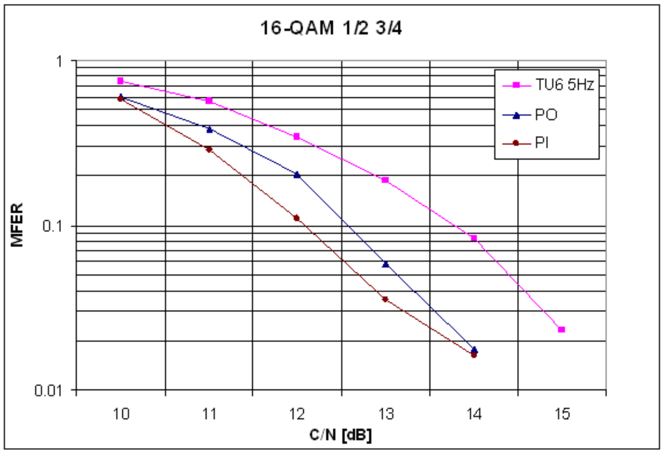

Fig. 5. The MFER performance of DVB-H system with different channel models.

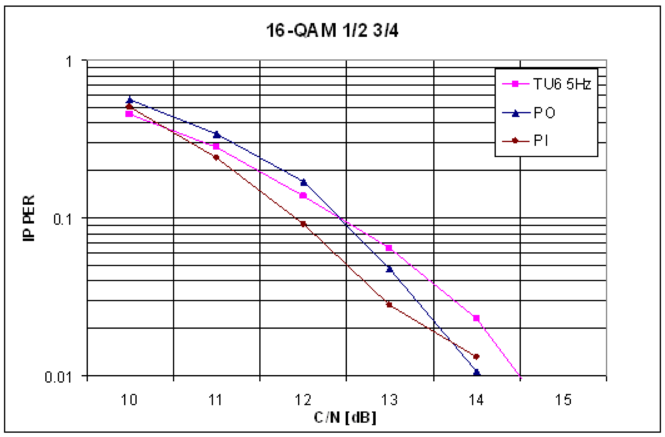

Fig. 6. The IP FER performance of DVB-H system with different channel models.

in downtown Turku. Note that in this field measurement a additional attenuator was used to adjust the C/N to 13dB. This curve can be used as a reference to which the simulation results can be compared. As can be seen the PO channel model mimics the real world behavior significantly better than the TU6.

The figures show very clearly that the behavior of the DVB-H system is different in PI and PO channels compared to the TU6 channel. In addition, Figure 7 gives support to the assumption posed in [1] that the TU6 is not realistic enough to be used in low speed mobile DVB-H testing.

B. Channel parameters

The theory to which the extraction of channel parameters is based on is presented extensively in [1]. Therefore, we present only the results here.

As can be seen from Tables I and II the differences between the 2005 and 2006 Turku Polytechnic measurements are small. From this can be deduced that the results in [1] can be regarded as reliable i.e. major flaws in the measurements can not be observed.

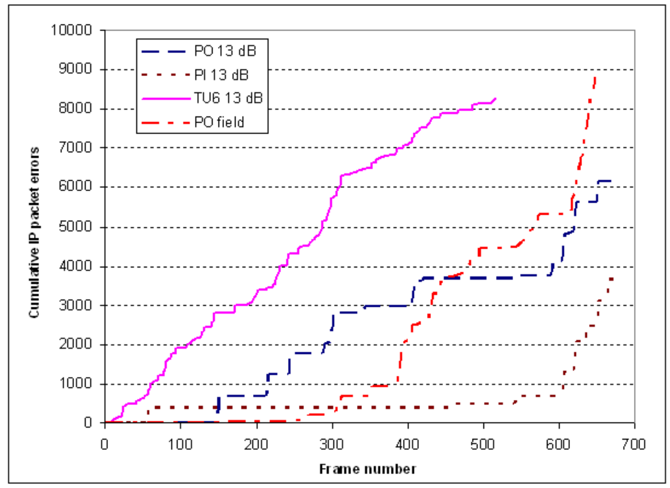

Fig. 7. The cumulative packet errors of DVB-H system with different channel models.

TABLE I
COMPARISON 2ND FLOOR CORRIDOR

	Excess delay[μs]	RMS DS [μs]	No. taps
2005	10.04	2.04	34
2006	9.30	1.85	33
Difference	7.4%	9.3%	2.9%

TABLE II
COMPARISON 3RD FLOOR CORRIDOR

	Excess delay[μs]	RMS DS [μs]	No. taps
2005	8.09	3.74	40
2006	9.63	4.10	38
Difference	16.0%	8.8%	5.0%

TABLE III
MEASUREMENTS IN THE HOTEL CORRIDORS

	Excess delay[μs]	RMS DS [μs]	No. taps
6th floor	9.01	2.9	31
5th floor	9.34	5.87	44
4th floor	9.26	5.33	42
3rd floor	9.13	5.24	39

The results from Turku Polytechnic should be compared also to the results acquired from the Hotel Julia premises. The channel parameters from the hotel measurements are listed in Table III. These numbers are similar to those measured from the Polytechnic. Therefore it can be stated that these results are a very good approximation of channel parameters in urban indoor environment.

C. K-factors

As stated in [1] the received radio signal in single frequency networks usually consists of one or two components with Rician distributed complex envelope and several weaker multipath components with Rayleigh distribution. The Rician distribution can be described in terms of K-factor, which is the power ratio of the fixed and fluctuating components. [5], [6]

The K-factors for the strongest path in each measurement have been determined by using the method of moments (MoM) [5]. A path is defined as a delay bin with 109ns uniform intervals. As described in [1] the calculation of the K-factors has been performed in pieces i.e. from the original time-wise data containing 50 000 - 120 000 impulse response samples we have formed data blocks each containing 1000 impulse responses (this equals the distance of 1.4 wave lengths). Then we have determined a local K-factor from every data block. Finally, the average of these K-factors has been calculated.

Figure 8 presents K-factors from Turku Polytechnic 2nd and 3rd floor measurements. As mentioned earlier, both of the corridors are identical with the floor plan shown in Figure 3. The measurement route was also similar in both floors. This explains the likeness of the K-factor behavior. The strongest path has originated from Transmitter 1 and has entered the Polytechnic building from the window at the end of the corridor. Because this phenomenon is similar in both floors, major differences can not be observed in the general behavior of the K-factor. However, the K-factor values clearly diminish as the measurement progresses. This is natural since the receiver moved away from the transmitter along the corridor as depicted in Figure 3.

The figures 9 and 10 show the behavior of the K-factor in the 4th and 5th floor of Hotel Julia. Again the floor plan of the both floors is similar to Figure 4. The two curves in each figure represent the K-factors of the strongest path from each transmitter. Interestingly Transmitter 2, which is farther away, is dominating at the beginning of the measurement route. This happens because the signal from the Transmitter 1 has to travel through the hotel building and in addition there are large buildings near the hotel, which further attenuate the signal. At the end of the measurement route the propagation conditions for the signals from different transmitters are reversed and the dominating signal is coming from Transmitter 1.

Table IV lists the average K-factor values for the strongest path in the different measurement locations. These values show uniformity with those listed in [1] and those decided for the PI and PO models [2].

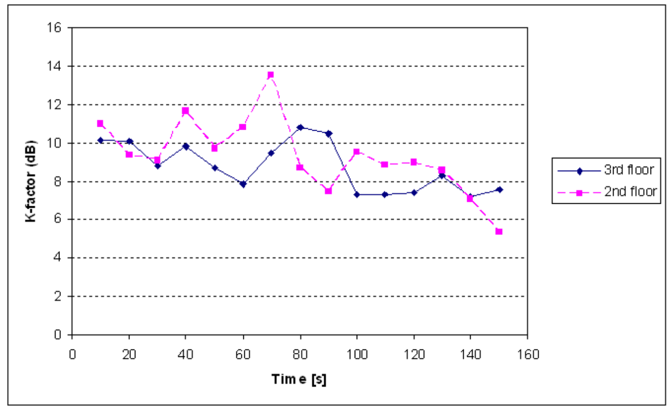

Fig. 8. The K-factors along measurement route in Turku Polytechnic 3rd floor.

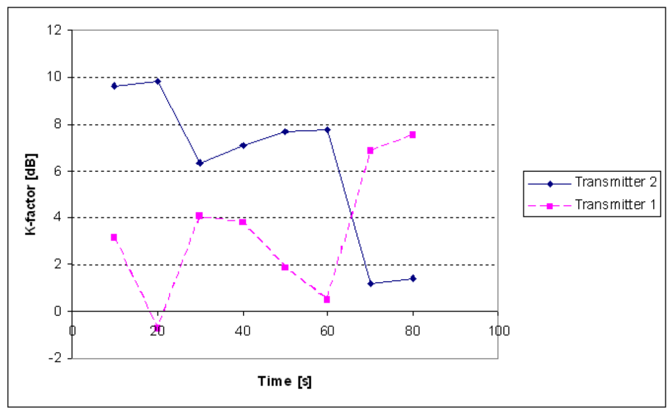

Fig. 9. The K-factors along measurement route in Hotel Julia 4th floor.

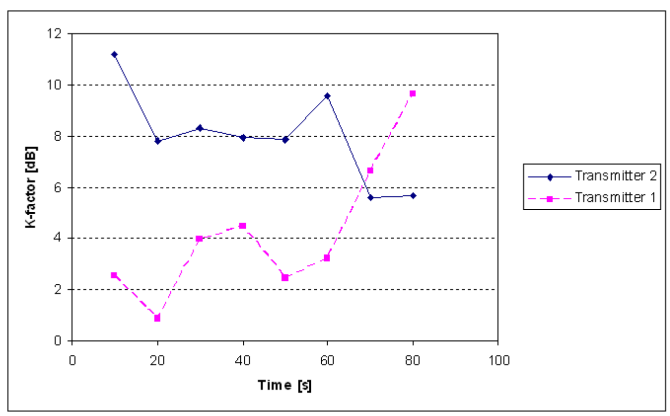

Fig. 10. The K-factors along measurement route in Hotel Julia 5th floor.

TABLE IV
K-FACTORS OF THE STRONGEST TAP

Scenario	K-factor [dB]
Polytechnic	9.3
Hotel Julia	7.8
Pedestrian Outdoor	11.2

TABLE V
RSSI VALUES FROM THE HOTEL

Floor #	RSSI mean [dBm]	RSSI variance [dB]
6th floor	-53.7	22.8
5th floor	-60.9	6.4
3rd floor	-66.2	17.6

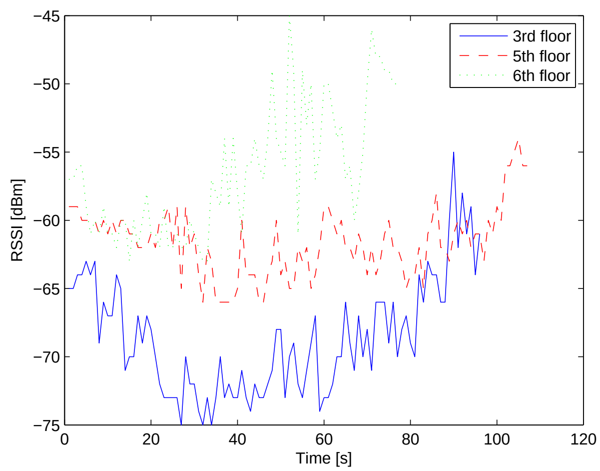

Fig. 11. The behavior of the received signal power.

D. RSSI results

Received Signal Strength Indication (RSSI) information was also collected during the measurements. With the help of the knowledge of the absolute received power we can draw conclusions of the attenuation between building floors. Table V shows the RSSI mean and variance values from the different floors of the hotel Julia. By observing the differences in the received signal strength we can conclude that the approximate value for the floor attenuation is 5-7dB. The behavior of the received signal power in function of time during the measurements is presented in Figure 11.

V. CONCLUSIONS

In this paper we addressed the validation process of the Pedestrian Indoor and Pedestrian Outdoor radio channel models for broadcasting systems. The results show that the models are realistic and hence serve the purpose of modelling pedestrian indoor and pedestrian outdoor scenarios. The models highlight the SFN nature of DVB-H networks and show that in many situations there exists a line of sight or a strong reflected component with high K-factor value. We showed also that the models represent accurately various urban pedestrian environments thus highlighting the generality needed in testing of advanced IP datacasting systems.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the Celtic Project Wing-TV for providing the support to carry out this work and the Turku Polytechnic for providing the RSSI data and a measurement location. We would also like to thank Jukka-Pekka Nuutinen, Mikko Lampela and Tero Alalauri from Elektrobit for performing the measurements and for the valuable technical support during the post processing of the data, and Pekka Kyösti for the helpful advises in the area of radio channel research. A special thanks is given to Scandic Hotel Julia, Turku for providing access to their premises for measurements.

REFERENCES

[1] H. Parviainen et al., ”Novel Radio Channel Models for Evaluation of DVB-H Broadcast Systems”, in *The 17th Annual IEEE International symposium on Personal, Indoor and Mobile Radio Communications*, Helsinki, Finland, September 2006
[2] Wing-TV Project Report, ”D11 – Wing TV Network Issues”, May 2006. http://projects.celtic-initiative.org/WING-TV/
[3] Celtic Project Wing-TV, http://www.celtic-initiative.org
[4] Wing-TV Project Report, ”D4 – Laboratory Tests Results”, June 2006. http://projects.celtic-initiative.org/WING-TV/
[5] L.J. Greenstein et al., ”Moment-method estimation of the Ricean K-factor,” *IEEE Commun. Letters*, vol. 3, no. 6, pp. 175-176, June, 1999.
[6] J. D. Parsons, *The Mobile Radio Propagation Channel*. London: Pentech Press, 1994, pp. 134-135.