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A COMPARATIVE STUDY OF COVERAGE ESTIMATION AND QUALITY OF SERVICE FOR DVB-H URBAN NETWORKS USING A SPECIALIZED RF PLANNING SOFTWARE

The Digital Video Broadcasting – Handheld (DVB-H) standard is the ETSI standard for delivering broadcasting services of high data rates to handheld devices, under high mobility conditions. This paper will compare the different modulation techniques used by the DVB-H standard from the coverage point of view. The coverage estimation simulations have been made with a specialized RF planning tool using real Geographic Data for the metropolitan region of Athens. Thus, we will present a comparative study, of various planning factors like coverage percentage and location probability and compare them for the different modulation schemes used.

Keywords DVB-H, Coverage Estimation, RF network planning.

1. Introduction

Digital video broadcasting for handheld terminals (DVB-H) [1], ratified by the European Telecommunications Standards Institute (ETSI), is an amendment of the terrestrial DVB standard (DVB-T). It is based on the Internet protocol (IP) and implements additional transmitting techniques like Multi-Protocol Encapsulation Forward Error Correction (MPE-FEC) and time-slicing, giving the ability for power-limited handheld devices to support multimedia broadcasting services, under high mobility conditions. Thus, it is designed to encompass various contemporary telecommunication challenges such as low power consumption for the handheld receivers, better performance in difficult channel conditions and flexibility in network planning.

For our investigations we used Cellular-Expert of HNIT-BALTIC UAB, a specialized RF (Radio Frequency) planning software which in general implements propagation model algorithms applying them to various geographic data like Digital Terrain Models (DTM), buildings databases and others. The algorithms are based on the standard propagation models proposed and used so far for RF planning purposes (i.e. recommendation ITU-R P.526, Okumura-Hata model, Cost231 models etc.).

For the herein simulations we followed the planning guidelines from the ETSI DVB-H standard transcripts [2], [3]. Moreover, real geographic data for the metropolitan region of Athens have been used. Thus, we will present a comparative study for various planning factors, like coverage percentage and location probability, for a realistic scenario. Consequently, various network planning options will be pointed out.

This paper is organized as follows: In Section 2 a theoretical analysis for the DVB-H urban network coverage is presented. In Section 3 the proposed realistic urban scenario and the functionality of the RF planning software are described. Section 4 shows our simulation results, and analysis. Finally, concluding remarks are given in Section 5.

2. Theoretical analysis

It is necessary to introduce a theoretical approach for the coverage estimation of a DVB-H urban network before we elaborate on our study. Section 2.1 presents an arbitrary network configuration and the respective planning parameters deriving from the numerical values of the ETSI transcripts. In Section 2.2 the formulation of the propagation model used is described. Based on that, in Section 2.3 we estimate the network's coverage percentage in function with the transmitted power. Since we are interested only in the coverage estimation, as a preliminary study the simulations will be made over a single network cell.

2.1 Network Configuration

Modern digital telecommunication standards like DVB-H use orthogonal frequency division multiplexing (OFDM) and the respective modulation and coding parameters for signal transmission. The theoretical network is assumed consisting of one transmitter deploying the following planning parameters shown in Table 1 based on [2], [3].

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Network Planning Parameters Tab. 1

Frequency	500 MHz
Bandwidth	8 MHz
OFDM transmitting mode	2K
Guard Interval	1/4
MPE-FEC code rate	3/4
Transmitter antenna height	21 m
Transmitter antenna type	Omni directional
Reception Mode	Portable Indoor, Class B
Integrated Receiver Antenna Gain	-12 dBd
Receiver Noise Floor	-102.5 dBm
Receiver Noise figure	6 dB
Additional Losses (GSM reject filter, man made noise, etc.	1.2 dB
Cell Radius	2 Km

Next we estimate the minimum receiver power levels (P_{min}) for each different OFDM modulation scheme of the DVB-H standard. According to [4], [6], using Equation (1) we can calculate P_{min} from the C/N_{min} (Carrier to Noise Ratio) values denoted on [3]. Those values represent the minimum required C/N ratios in order to meet a degradation criterion for the network performance, given the modulation level.

$$P_{min} = P_n + C/N_{min} + N - Ga + L_{others} + F \tag{1}$$

where

P_n: Receiver Noise Floor

N: Receiver Noise Figure

Ga: Integrated Receiver Antenna Gain

L_{others}: Additional Losses

F: Location correction factor

C/N_{min}: Minimum required C/N ratio

The degradation criterion suitable for DVB-H is the MPE-FEC frame error rate (MFER), referring to the error rate of the time sliced burst protected with the MPE-FEC. Since DVB-H signal caries IP packets, an erroneous frame will destroy the service reception for the whole interval between the bursts. In other words there will be no service although some frames have received correctly. Thus, it is appropriate to fix the degradation point to the frequency of lost frames. MFER is the ratio of the number of erroneous frames (i.e. not recoverable) and total number of received frames. To provide sufficient accuracy, at least 100 frames shall be analyzed.

$$MFER[\%] = \frac{Number\ of\ Erroneous\ Frames \times 100}{Total\ Number\ of\ Frames}$$

It has been agreed that 5% MFER is used to mark the degradation point of DVB-H service. The minimum CNR values, in order the network performance meet this degradation point, are derived from [3] based on simulations and measurements of the ETSI DVB-H verification task force. For the case of portable indoor channels, which will be our mode of study, the minimum CNR performance is shown in Table 2. Consequently, for our investigations we consider that the DVB-H network provides sufficient coverage when the predicted received signal meets the estimated minimum received power level.

For planning purposes we must also take into consideration the macro-scale signal variations by introducing an additional Location correction factor F which corresponds to the respective location probability. With the term "location probability" we mean the localized signal level variations that account for changes in the propagation environment which are not explicitly considered in the propagation model. Put another way, location probability refers to the spatial statistics of local ground cover variations including multipath variations [5]. Since these variations are considered to follow a normal distribution [3], [5], [8] we introduce a fade margin (or as referred previously a Location correction factor) F in order to evaluate higher location probability percentages thus higher Quality of Service (QoS). This is clearer in Figures 8 and 9. The fade margin is strictly connected with the standard deviation of the normal distribution. In our studies we will consider this fade margin as a relaxed factor in order to examine all the possible location percentages. The location correction factor at indoor locations is the combined result of the outdoor variation and the variation factor due to building attenuation. These distributions are expected to be uncorrelated. The standard deviation of the indoor field strength distribution can therefore be calculated by taking the root of the sum of the squares of the individual standard deviations [4]. As a consequence, the location variation of the field strength is increased for indoor reception. For the UHF (Ultra High Frequency) Band, where the macro-scale standard deviations are 5.5 dB [5] and 6 dB [3] for outdoor and indoor respectively, the combined value is 8.1 dB. This leads to a fade margin of 4, 10.5, and 14 dB for 70%, 90%, and 95% location probability

DVB-H C/Nmin (dB) and Pmin (dBm) in mobile channel Tab. 2

Modulation	Code rate	C/N_{min} (dB)	P_{min} (dBm)
QPSK	1/2	7.00	−81
QPSK	2/3	10.00	−78
16-QAM	1/2	13.00	−75
16-QAM	2/3	16.00	−72
64-QAM	1/2	17.00	−71
64-QAM	2/3	20.8	−67.2

Minimum threshold (dbm) for given location probability Tab. 3

Modulation	Threshold (dBm)		
	70%	90%	95%
QPSK 1/2	−77.00	−70.50	−67.00
QPSK 2/3	−74.00	−67.50	−64.00
16-QAM 1/2	−71.00	−64.50	−61.00
16-QAM 2/3	−68.00	−61.50	−58.00
64-QAM 1/2	−67.00	−60.50	−57.00
64-QAM 2/3	−63.20	−56.70	−53.20

respectively [3]. Adding those margins to the previous calculated thresholds will result to the variables of Table 3 which will be used for our simulations.

2.2 Propagation Model

In order to estimate the receiving power, the transmitting power and the signal attenuation are needed. The extended Okumura-Hata propagation model of the International Telecommunications Union (ITU) [5] will be used. Using an empirical propagation model provides a simple method for fast calculation of the receiving power. The results will be compared to simulation results using a more sophisticated (semi-empirical) propagation model described in Section 4 in order to show the practicability of the simplified method.

In Equation 2 the general propagation calculation is given. The parameter f [MHz] specifies the transmitting frequency, hb [m] specifies the transmitter antenna height, hm [m] is the receiver antenna height and r [km] specifies the distance between transmitter and receiver. For the calculations we assume that the receiving antenna height it at 1.5 m.

$$\begin{aligned} Loss(r) &:= 69.55 + 26.16\log(f) - \\ &- 13.82\log(hb) - a(hm) + n\cdot\log(r) \end{aligned} \tag{2}$$

where

$$a(hm) := \left(1.1\cdot\log(f) - 0.7\right)\cdot hm - \left(1.56\log(f) - 0.8\right)$$

$$n := 44.9 - 6.55\cdot\log(hb)$$

2.3 Coverage Percentage Estimation

Now we can estimate the coverage percentage within the cell radius for each OFDM transmitting modulation modes and for various location probability targets. According to [8] the percentage of useful service area $U(\gamma)$ (i.e. the percentage of area with a received signal that is equal or greater than a threshold value γ) can by found by equation (3):

$$U(\gamma) = \frac{1}{\pi R^2}\int_0^{2\pi}\int_0^R P\left[P_r(r) > \gamma\right] r\,dr\,d\theta \qquad (3),$$

where R is the cell Radius

Expression $P[P_r(r) > \gamma]$ of Equation (3) denotes the probability that the received signal at a given distance r will exceed a certain value γ. This term is also referred to as "location probability". Since we assumed a normal distribution for the macro-scale variations with a standard deviation of 8.1 dB, using the values of Table 3 for γ we can calculate this location probability in function with the EIRP (Effective Isotropic Radiated Power) of the DVB-H transmitter as it is shown in Figures 1, 2 and 3. As it is obvious from the figures an increase of the EIRP is mandatory in order to achieve the same coverage for a better location probability and higher modulation level. The grade of that increscent follows a normal cumulative probability distribution.

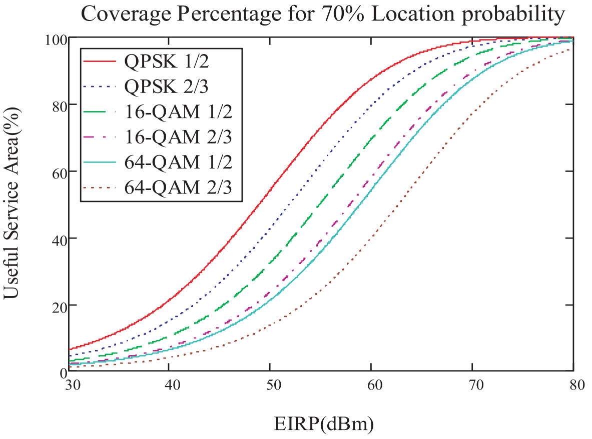

Fig. 1 Coverage Percentage for 70% Location Probability

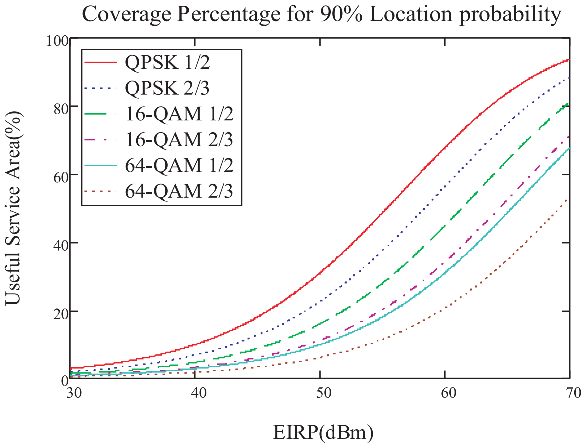

Fig. 2 Coverage Percentage for 90% Location Probability

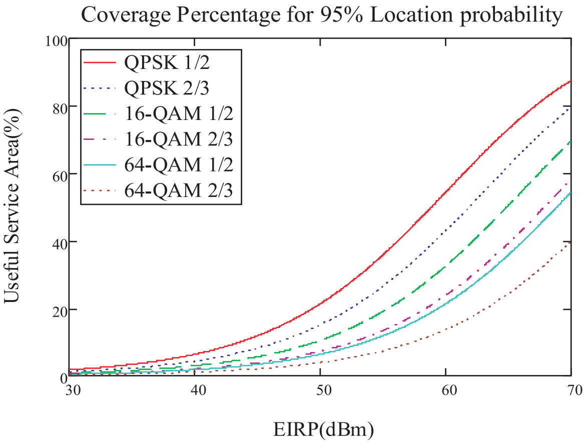

Fig. 3 Coverage Percentage for 95% Location Probability

3. Realistic Urban Network Scenario

In order to validate the theoretic results, a realistic urban DVB-H network scenario has been developed. According to this scenario a DVB-H base station transmitter will be placed on a building roof-top in the metropolitan region of Athens.

The DVB-H transmitter will be placed on a building of 21 meters height above ground level. The selection of the specific building is done in order to have a transmitter height above the average roof-top level. We also consider using an omni-directional antenna. The cell radius will be 2 km. This is because we want to have a uniform distribution of buildings around the transmitter so that the simulation results will be more reliable. We also consider a DVB-H 2K OFDM mode with a guard interval of 1/4. Thus, we follow the same parameters as in the previous theoretical approach.

3.1 Geographic Data

RF planning tools use geographic data in order to implement the propagation model algorithms over a certain area. Those geographic data are of great importance since the accuracy of the propagation predictions strictly depend on the accuracy of those geographic data. Generally there are 2 kinds of geographic data, raster and vector data. Raster data (or rasters) can be specified as a spatial data model that defines space as an array of equally sized "pixels" arranged in rows and columns, and composed of single or multiple bands. Each "pixel" contains an attribute value and location coordinates. Raster data usually represent terrain elevation or land use. Vector data store coordinates explicitly and generally represent building or streets structure. For our simulations we have at our disposal Digital Terrain Model (DTM) rasters for the terrain elevations of Athens area along with building vector data representing roof-top heights.

3.2 RF planning software functionality

In order to determine the coverage area of the DVB-H network cell, we use specialized RF planning software. As it has been discussed previously this software uses the available geographic data in order to apply certain propagation models. The result of this procedure is a raster, as it has been already described, in which each pixel represents this time the median predicted value in dBm, derived from the propagation model calculations. Thus, we can determine the regions over the cell having sufficient coverage by comparing these values with the minimum required threshold. Moreover, by entering the minimum thresholds for each modulation level shown in Table 3, the program gives us the ability to resolve the areas within the cell in which the respective modulation level is reached. Thus, we can estimate the cell coverage by post analyzing the simulation results in terms of counting the "pixels" that satisfy a certain threshold condition.

3.3 Propagation Model

The COST 231 Walfish-Ikegami propagation model [7] was selected for the receiving power estimation. It is verified for 800 to 2000 MHz and a cell radius up to 5 km. Similar to [6] it is also assumed to be valid for 500 MHz. This model is chosen due to its higher accuracy compared to empirical propagation models like Okumura-Hata or ITU-R Recommendation [5]. This is because it takes into account the propagation calculations the building databases which are available to us. For the calculations we assume that the receiving antenna height is at 1.5m above ground level.

4. Simulation results and analysis

Simulations for the DVB-H urban network scenario were performed with the above mentioned RF planning software using a range of transmitting powers for the EIRP of the DVB-H transmitter. Typical EIRP, used in broadcasting networks, extends from 30 W (≈45 dBm) to 30 kW (≈75 dBm). Since the EIRP is strictly connected with the cell radius, which for our study was being kept constant (2 km), the EIRP range for the performed simulations was narrowed up to 1kW (60 dBm). Figure 4 shows the prediction results over the DVB-H cell area. The map in Figure 4 displays 2 different levels, the prediction raster (colouring from red to green shades) and the building vector data (black and white shades). The colouring distribution of the prediction raster indicates the different receiving power levels starting from red (higher value) to green (lower value). This level displaying method gives us the ability to see the signal strength over any geographic data we choose. We can also see that the simulations were performed only on the buildings area adding to the prediction value a building penetration loss of 11 dB as indicated in [3]. The software gives us the ability to count the prediction raster pixels which meet a certain threshold condition. Thus, we can estimate the coverage percentage within the cell radius for various location probability targets. The RF planning software exports a 2 dimensional matrix $A_{m,n}$. The first column of the matrix contains the predicted values and

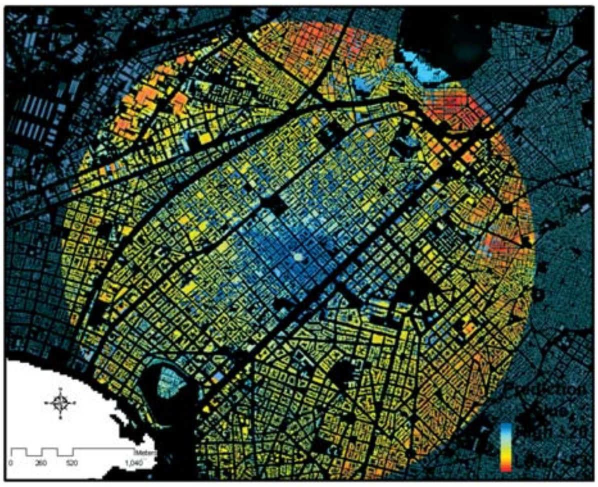

Fig. 4 Prediction Results over the DVB-H cell

the second one shows the number of prediction raster pixels having those values. Therefore, for our analysis Equation 3 that we used in the theoretical approach can be translated to the following Equation 4:

$$U(\gamma) = \frac{1}{S}\sum_{i=1}^{m}(A_{i,2})P(A_{i,1} > \gamma), \qquad (4)$$

where
m: matrix A rows
S: The total pixel number of the prediction raster
γ: certain minimum threshold

Factor $P(A_{i,1} > \gamma)$ of Equation 4 denotes the location probability for the predicted "pixel". In order to present our results for the post processed simulation predictions, we export the raster matrices described before for the simulations performed. Three nominal cases with transmitting EIRP of 40, 50 and 60 dBm respectively were taken into consideration. Using equation (4) and the threshold values of Table 3, we draw Figures 5, 6 and 7. In those figures we show the percentage of receiving locations within the cell which have a certain location probability for different modulation levels.

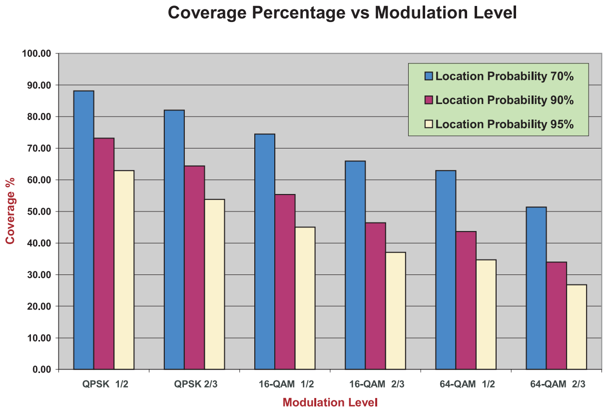

Fig. 5 Coverage Percentage for 60 dBm EIRP

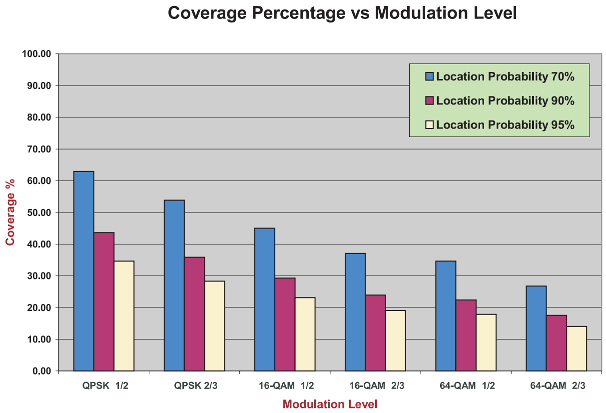

Fig. 6 Coverage Percentage for 50 dBm EIRP

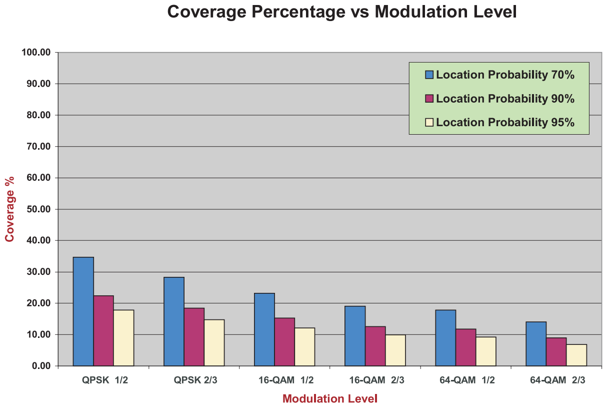

Fig. 7 Coverage Percentage for 40 dBm EIRP

The first obvious remark is that those results are in accordance with the theoretic results although we use a more accurate propagation model. The reason for that is the additional building penetration loss that we used making our semi-empirical propagation model as pessimistic as the empirical one. Secondly, we can observe that for both the theoretical and simulation results the coverage percentage follows a similar distribution in function with the EIRP, which resemblances a Gaussian cumulative distribution function (CDF). We can also notice that the coverage percentage converge to 100% for different EIRP depending on the location probability targets. This remark can be a useful rule for the early stages of a DVB-H network planning in which only empirical propagation models are used. For a broadcasting network, coverage, is a grade for Quality of Services (QoS) provided. Thus we can use the above results rating the grade of coverage in both the dimensioning and optimization phase of the network planning. Furthermore, the method we described earlier for the estimation of coverage percentage from the simulation results, can be used as a general guide way for network planning tools, calculating coverage probability when a closed form function cannot be deduced from the propagation model formulation. Finally, the above theoretical and simulation results can be easily compared with actual signal measurements which present the realistic situation for the network coverage. These measurements can optimize the propagation models and coverage estimations through model tuning.

5. Conclusions

In this paper a comparative study for the coverage estimation of a DVB-H urban network is presented. The theoretical results using an empirical propagation model show a certain relation of the coverage percentage with the transmitting power. In order to validate the theoretical approach a realistic urban DVB-H network scenario in the metropolitan area of Athens was developed. As a preliminary study a single DVB-H cell was examined using an RF planning software, applying a highly accurate propagation model over existing high resolution geographic data. Thus, the same grade of relationship between coverage and EIRP was derived.

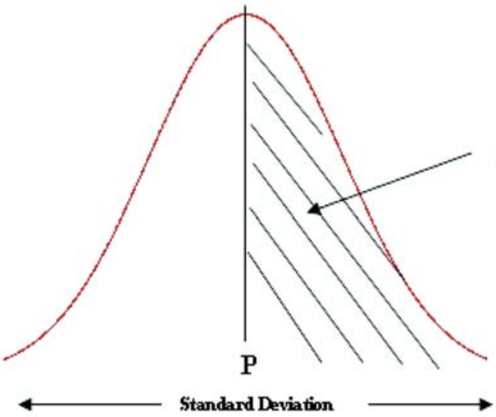

Fig. 8 Normal Distribution of a predicted median signal power level P

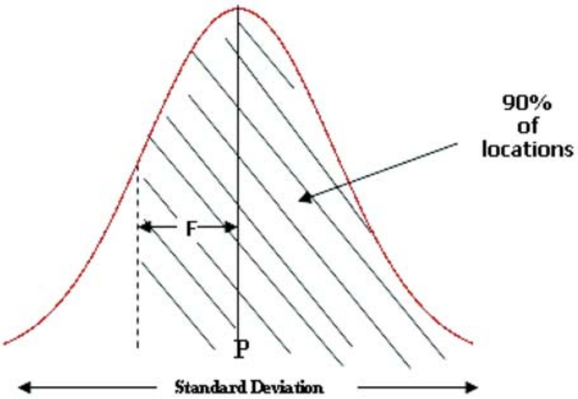

Fig. 9 Introduction of a Fade Margin F for higher location probability

6. Acknowledgments

This work was supported by HELETEL S.A. [9], HNIT-BALTIC UAB [10] and MARATHON DATA SYSTEMS [11].

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