Influence of Modulation Scheme on the Range for Good Reception in DVB-H Networks

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Abstract—DVB-H networks allow high data rate broadcast access for hand-held terminals. A new method to determine the range corresponding with good reception in such a DVB-H network will be investigated in this paper. To this end, a subjective criterion is proposed, based on the viewing experience of the users. This criterion is related to the percentage valid reception. Also, a comparison with existing criteria is made. The ranges are determined for mobile reception inside a car. The influence of the modulation scheme on the range will be investigated.

I. INTRODUCTION

The digital broadcasting standard DVB-H (Digital Video Broadcasting - Handheld), based on the specifications and guidelines of ETSI [1], [2], [3], [4], enables a high data rate broadcast access for hand-held terminals (e.g., portable, pocket-size battery-operated phones). The broadband downstream channel features a useful data rate of up to several Mbps and may be used for audio and video streaming applications, file downloads, and many other kinds of services.

The standard is based on DVB-T (Digital Video Broadcasting - Terrestrial) [2], but some adaptations have been introduced: time-slicing to reduce power consumption, and MPE-FEC (Multi-Protocol Encapsulation-Forward Error Correction) at the link layer to improve performance for mobile reception.

Only very limited data about the calculation of the range of DVB-H systems is available. In [3], [4], [5], [6], [7], performance of DVB-H systems is evaluated. A subjective criterion for good viewing reception has also been developed in [8] for DMB (Digital Multimedia Broadcasting).

The MFER5 (5%) objective criteria [3], [4] correspond to a "good/fair" recovery of audiovisual programmes subjectively reported by two observers. It has been also revealed that an MFER10 (10%) corresponds to annoying recovery [3].

The objective of this paper is to investigate the "range" of a DVB-H system. The range will be defined as the largest distance from a transmitter where "good" reception is possible. The influence of the modulation scheme on the range will be analyzed and a comparison with the existing criteria will be made. This paper investigates the range for good reception in a DVB-H system in a suburban environment in Ghent, Belgium. A new subjective criterion to determine the range of a DVB-H system is proposed, based on the viewing experience of the users. It makes use of a new quality criterion, percentage valid reception. This paper will enable future DVB-H trials to select optimal settings and to define a region where good reception will be possible.

The outline of the paper is as follows: the transmitting network, the measurement method, and the procedure to calculate the range and the investigated schemes are described in Section II. Section III presents the results for the different modulation schemes. Finally, the conclusions are presented in Section IV.

II. METHOD

A. Transmitting network

The transmitting network is located in a suburban environment in Ghent, Belgium. The single-frequency network (SFN) contains three base station antennas (BS). All transmitting antennas are omnidirectional. The heights of these Tx are h_{TX} = 57 m, h_{TX} = 64 m, and h_{TX} = 63 m, with an EIRP (Equivalent Isotropically Radiated Power) of 36.62 dBW, 39.93 dBW, and 40.90 dBW, respectively. Fig. 1 shows a map of Ghent with the location of the three base stations marked with blue dots.

B. Measurement method

A DVB-H tool implemented on a PCMCIA (Personal Computer Memory Card International Association) card with a small receiver antenna Rx is used to perform the measurements. The gain of the antenna is - 5 dBi. The PCMCIA card is plugged into a laptop, which is used to collect and process the measurement data.
Every 0.5 s, a sample is recorded, while the receiver is either locked or unlocked, depending on the signal strength. A locked receiver can receive DVB-H frames, which are either correct or incorrect. Incorrect tables can (sometimes) be corrected by the MPE-FEC code. The tool logs parameters as \( \frac{C}{N+I} \)-MFER (Multi-Protocol Encapsulation FER), and electric-field strength. MFER is the ratio of the number of residual erroneous frames (i.e., not recoverable) and the number of received frames [3]. Location and speed are recorded with a GPS device.

Using the right packet identifier, the receiver can stream a channel of the transmitted DVB-H signal. By opening a session description protocol (sdp) file, we can monitor the channel on the laptop with a media player. The observation of the visual and auditive reception quality is related to \( \% \) Valid reception, defined in Section II-C. The analysis in this paper will be performed for mobile reception at a height of 1.5 m inside a small van, driving around at a speed of 20 km/h.

C. Parameters used to analyze performance

This paragraph defines the parameters used to analyze the range of the DVB-H system. First, parameters corresponding with MPE tables and signal quality are explained, followed by parameters related to the range.

- Parameters corresponding with MPE tables

  - \( \% \) Lock: the percentage of the time that the receiver is “locked” (the TS (transport stream) synchronization is achieved and the TS packet is valid). When the receiver is “locked”, it is possible to receive tables.
  - \( \% \) Incorrect tables = MFER
  - \( \% \) Valid reception: the percentage of the time that the receiver is locked and receives either correct, or corrected tables = 
    \[
    100 - \left( \frac{\% \text{Not locked} \times \% \text{Incorrect tables}}{100} \right)
    \] (1)

- Signal quality requirements

  - \( \frac{C}{N+I} [\text{MFER5\%}] \): the minimal value of \( \frac{C}{N+I} \) [dB] for which the MFER is at most 5%.
  - \( E [\text{MFER5\%}] \): the minimal value of \( E \) [dB\( \mu \)V/m] for which the MFER is at most 5%.

- Range

  - \( R \): estimated range in a particular direction based on \( \% \) Valid reception.
  - \( E[R] \): average \( \frac{C}{N+I} \) value at a distance equal to \( R \).
  - \( E[R] \): average E value at a distance equal to \( R \).

More detailed definitions of the parameters related to the range of the system can be found in Section II-D.

D. Range

The range of the DVB-H network in Ghent will be determined for four routes (North, South, East, and West). Fig. 1 shows the four investigated routes in black. The ranges are calculated as the distance from a location noted as the “imaginary transmitter” ITx. The location \((x,y,z)\)-coordinates of this imaginary transmitter is chosen as a weighted average of the positions of the three transmitters (see Fig. 1). \((x,y,z)\)\_ITx are the Lambert coordinates of the imaginary transmitter:

\[
(x,y,z)\_\text{ITx} = \frac{W1 \cdot (x,y,z)\_\text{Tx1} + W2 \cdot (x,y,z)\_\text{Tx2} + W3 \cdot (x,y,z)\_\text{Tx3}}{W1 + W2 + W3}
\] (2)

with \((x,y,z)\)\_Tx, the Lambert coordinates of the base stations in Ghent \((i = 1, 2, 3)\). The weights \(W1, W2,\) and \(W3\) correspond with their respective EIRP of 4594 W, 9844 W, and 12304 W. The criterion that will be used to determine the range of the DVB-H system is the correctness of the received video stream (\( \% \) Valid reception, see Section II-C).

The definition of \( R \) is based on the definition of \( \% \) Valid reception (formula (1), see Section II-C). To calculate \( R \), a window of 80 samples is chosen. This corresponds with at most 20 tables, since tables are received every 2 s or slower (sampling occurs every 0.5 s). A window of 80 samples corresponds with a window length of 222 metres, when driving at 20 km/h. This length is small enough to obtain sufficient resolution, and large enough to obtain a sufficient number of samples to calculate a certain percentage of valid reception. The range \( R \) is calculated for a valid reception of 95% within the window, corresponding with a subjective criterion based on the viewing experience of the users: maximally 1 bad image within the window is allowed for good experience. A tag is assigned to every sample: 0 or 1, with 0 for invalid reception and 1 for valid reception. The procedure of labeling the samples causes the \( \% \) Valid reception of 95% to correspond with no more than one incorrect table received within the window, as proposed in our subjective criterion.

Fig. 2 shows this procedure for the labeling of the samples. The tag of a sample is zero if the receiver is not locked or if the receiver is locked, but an incorrect table is received. When for a certain sample the receiver is locked, but no table is received,
E. Investigated schemes

The parameters that have been tuned are modulation scheme and inner code rate. A list of the different investigated parameter sets, together with the corresponding bit rate [Mbps] is provided in Table I. The influence of the modulation scheme on the range is investigated. For the variation of the modulation scheme, an MPE-FEC 7/8 has been chosen [6], [7], [9]. The 4K mode and a guard interval of 1/8 have been selected for all tests [6], [9].

III. Results

In this section, the influence of the modulation scheme on the range of the DVB-H network is analyzed. The range R based on 95% valid reception and our subjective criterion of good reception, i.e. maximally one bad image is received within one window. Since the window size is 80 samples, the 95% valid reception range ends when 2 incorrect tables within one window are encountered (see Fig. 2), or when the receiver is not locked for five samples within the window. This corresponds with the subjective limit for good reception experienced by the viewers when watching the DVB-H stream during the tests. Two consecutive incorrect images or no images at all (when at least 5 successive samples are not locked) observed by the viewer correspond with a valid reception percentage dropping below 95% and is the limiting requirement for a good viewing experience.

Finally, the range R characterizing the distances for valid reception of the system is defined as the distance between ITx and \((x_{95}, y_{95})\), with \(x_{95}\) and \(y_{95}\) the coordinates of the point that is located the furthest from ITx in the last window before valid reception reduces to values lower than 95%. The difference in height between \((x_{95}, y_{95})\) and ITx (z-coordinates) will be neglected in the range calculation, because the influence of the height difference on the range is negligible compared to the influence of the \(x, y\)-coordinates. \(C_{N+I}^{R}\) and \(E_{R}\) are the average values of \(C_{N+I}^{R}\) and \(E\) respectively, over the samples in this last window before valid reception drops below 95%.

In [8], a subjective criterion for good viewing reception has been developed as well (for DMB): 7% freeze frames in 20 seconds was considered the maximum rate, while in our paper, the maximum was 5% in 40 seconds (or 80 samples). Our criterion can be considered somewhat more restrictive. It will be shown in Section III that our criterion corresponds well with the MFER 5% criterion [3], [4].
The $C_{N+I}/R$ and $E_R$ requirement is lower for route North than for the other directions due to the less dense environment (more rural): the receiver suffers less from multipath reception in the North direction, lowering the $C_{N+I}/R$ requirement. The range is also higher for North, due to the more open environment. Another reason is the selection of the location of ITx: the relatively higher weights of the two most southern BS pull the location of ITx southwards, resulting in higher distances in the North (and West) direction. It must also be noted that the differences between the ranges for the different parameter sets are more important than the absolute values to draw conclusions. These results will enable future DVB-H trials to select optimal settings and to define a region where good reception will be possible.

IV. CONCLUSIONS

In this paper, a new method to determine the range for good reception in DVB-H networks is proposed. Measurements were performed with a DVB-H tool implemented on a PCMCIA card in a laptop in a suburban environment in Ghent, Belgium, for a DVB-H network operating at 602 MHz and with a bandwidth of 8 MHz. The measurements have been performed at a height of 1.5 m inside a vehicle for different modulation schemes. Lower modulation schemes have higher ranges (up to 3000 m): from 3473 m (64-QAM 2/3) to 6427 m (QPSK 1/2). The range can increase by up to about 1400 m when changing the inner code rate from 2/3 to 1/2. One has to make a compromise between higher ranges (more inner coding, lower constellations) and the resulting lower data rates. The MFER 5% values ($C_{N+I}/R|\text{MFER5\%}$ and $E_R|\text{MFER5\%}$) correspond well with the $C_{N+I}/R$ and $E_R$ values.

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REFERENCES


### TABLE II

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<tr>
<th>Modulation scheme</th>
<th>North $\mu V/m$</th>
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<th>South $\mu V/m$</th>
<th>East $\mu V/m$</th>
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<tr>
<td>QPSK 1/2</td>
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