DVB-T Systems in Hungary

József Biró

Rózsa u. 10/C
H-2314 Halásztelek, Hungary
josy@mailbox.hu

Endre Borbély

Budapest Tech
Tavaszmező út 15-17
H-1084 Budapest, Hungary
borbely.endre@kvk.bmf.hu

Abstract: In Europe, the end of the 20th century was the period of the changing to digital systems, including television broadcasting. In Hungary the first digital terrestrial pilot transmissions were started in 1999 and the supplier company started the full services in autumn 2004, so the time is right to give a brief technical description what is it about and why is it good for us and how does it work in Hungary.

Keywords: Digital Video Bradcasting – Terrestrial (DVB-T), OFDM modulation, multi-carrier, constellation diagram, bit error, frequency spectrum, trial transmissions, final launch, coverage

1 Introduction

The first Terrestrial Digital Video Broadcasting pilot transmissions were started in the late 90's, and the first commercial system was established in Great Britain. In the next few years the digital broadcasting system has been set up in many countries, and the boom of the digital terrestrial transmission is estimated in the next few years, while the analogue transmission will be cancelled within about 15 years.

1.1 Why DVB-T?

The greatest advantage of the digital system is the effective use of the frequency spectrum and its lower radiated power in comparison with the analogue transmission, while the covered area remains the same. Another key feature is the possibility of designing a so-called Single Frequency Network (SFN), which means that the neighbouring broadcast stations use the same frequency and the adjacent signals do not interfere. The digital system transmits a data stream, which means that not only television signals but data communication (e.g. Internet service) may be used according to the demands. The data stream consists of an MPEG-2 bit stream, which means a compression is used, enabling the transfer of even 4 or 5 television via the standard 8 MHz wide TV channel. For the viewer, the main advantages are the perfect, noise-free picture, CD quality sound, and easier handling, as well as services like Super Teletext, Electronic Programme Guide, interactivity and mobility.

2 Technical Issues

2.1 Modulation

The DVB-T Orthogonal Frequency Division Multiplexing (OFDM) modulation system uses multi-carrier transmission. There are 2 modes, the so-called 2k and 8k modes, using 1705 and 6817 carriers respectively, with each carrier modulated separately and transmitted in the 8 MHz TV channel. The common modulation for the carriers is typically QPSK, 16-QAM or 64-QAM. Each signal can be divided into two, so-called „In Phase" (I) and „Quadrature Phase" components, being a 90° phase shift between them. This modulation can be demonstrated in the constellation diagram, where the 2 axes represent the 2 components (I and Q). In case of using 16-QAM modulation, the number of states is 16, so 1 symbol represents 4 bits. The constellation diagram and the bit allocation is shown in figure 1.

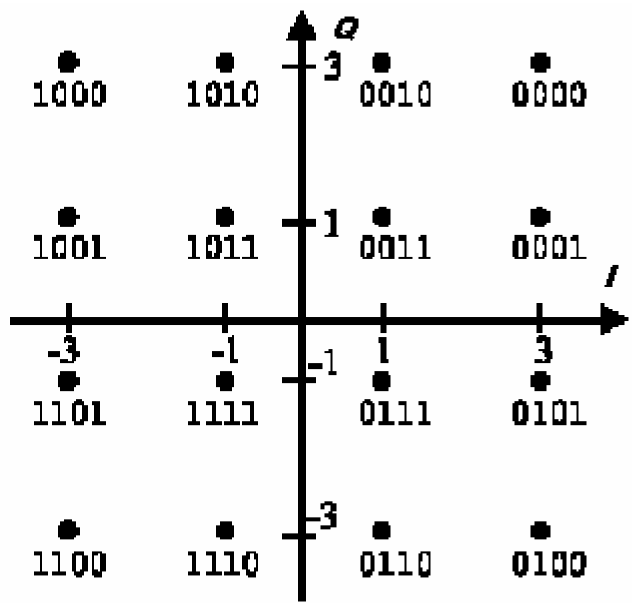

Figure 1
16-QAM constellation diagram and bit allocation

2.2 Bit Errors

If we simulate all the carriers in the constellation diagram we get not just 1 discrete point, but many points, forming a „cloud" and representing each state. In case of additive noise the „cloud" gets bigger and the receiver may decide incorrectly, resulting in bit errors. Figure 2 shows the measured constellation diagram without and with additive noise.

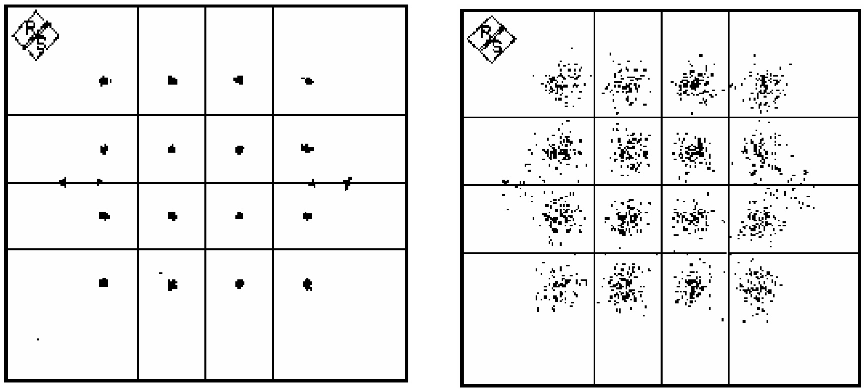

Figure 2
Measured 16-QAM constellation diagram
a) without additive noise b) with additive noise

To ensure perfect picture quality, the DVB-T system uses a 2 level error correction (Reed-Solomon and Viterbi). This corrects the bad bits at an even 10^{-4} Bit Error Rate (BER) and enables error-free data transmission.

2.3 The Multi-carrier Structure

The structure of carriers can be illustrated also in the function of time (Figure 3). The horizontal axis is the frequency and the vertical axis is the time. The 8 MHz channel consists of many carriers, placed 4462 Hz or 1116 Hz far from each other according to the modulation mode (2k or 8k). There are some reserved, so-called Transmission Parameter Signalling (TPS) carriers that do not transfer payload, just provide transmission mode information for the receiver, so the total number of "useful" carriers is 1512 and 6048 respectively in the two transmission modes, and the resultant bit rate is between 4,97 and 31,66 Mbit/s, depending on the modulation (QPSK, 16-QAM or 64-QAM), the transmission mode (2k or 8k), the Code Rate (CR) used for error correction and the selected Guard Interval (GI). This guard interval means that there is a small time gap between each symbol, so the transmission is not continuous. This guarding time enables perfect reception by eliminating the errors caused by multipath propagation.

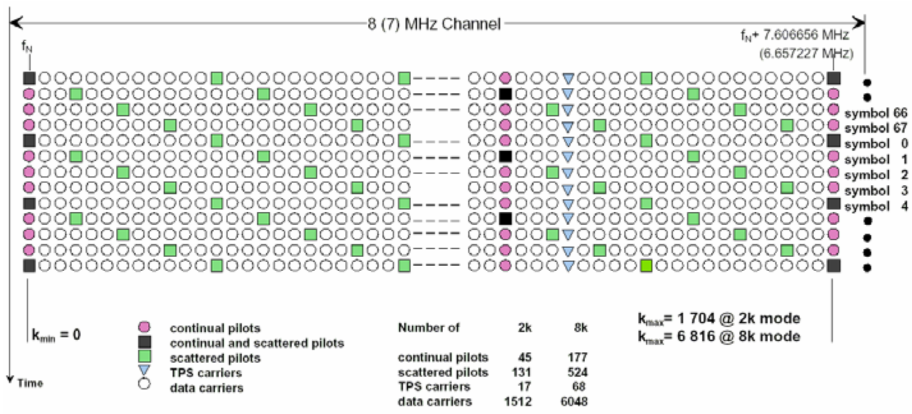

Figure 3
Structure of OFDM carriers

2.4 Frequency Spectrum

In 2k mode, 1705 carriers are modulated in the 8 MHz TV channel, so each carrier is 4462 Hz far from its neighbour, while in 8k mode this distance is 1116 Hz. In digital broadcasting, there are no vision and sound carriers, so the power for each carrier is the same. This means the amplitude of the frequency spectrum of the DVB-T signal is constant in the TV channel, and the radiated power is smaller than in the case of analogue broadcasting. A measured spectrum is shown in figure 4, where there are three TV channels, two of them digital (DVB-T), and one of them analogue (PAL signal).

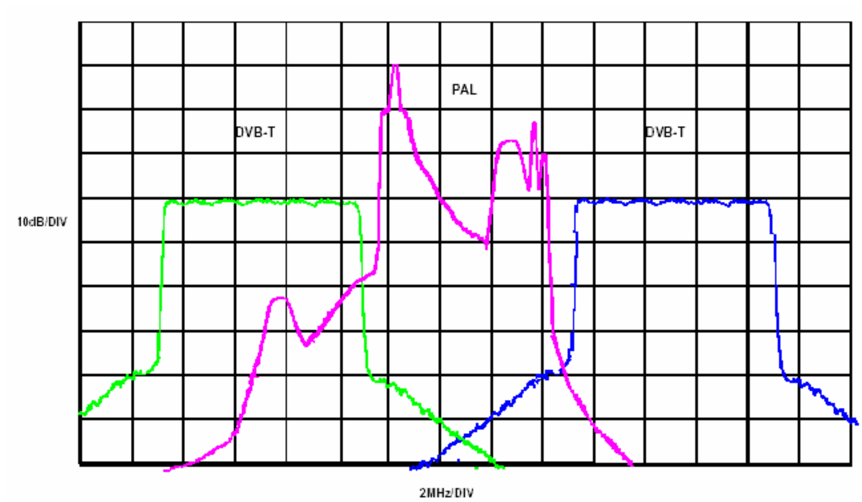

Figure 4
Frequency spectrum of DVB-T and analogue signals

3 The Digital Video Broadcasting System in Hungary

In the late 90's the first digital terrestrial transmissions were started in Europe. Great Britain was the pioneer, later Sweden, Spain and Germany also started their commercial broadcasts. In Hungary the service provider started its trial transmissions in 1999. Since then they continuously analyse the reception parameters and also the possibilities for the later updates. The plans for the future were: start of interactive services, installation of the nationwide coverage and to obtain 3 frequencies from the authorization organizations. This may result even up to 15 good quality television programmes nationwide, giving a more effective use of frequency spectrum.

The third section of this paper is to introduce some results of measurement taken in the largest district of Budapest, which give us the quality insurance for the later spread of the high-quality digital transmission.

3.1 The Trial Transmission

All the introduced technical parameters can be measured with an appropriate equipment. For the quality analysis the 2 most important are the constellation diagram and the frequency spectrum.

```
RF 650.000000 MHz              LEVEL  -64.3 dBm
FFT 2K   GI 1/32  64 QAM       ALPHA 1 NH   CR 2/3
BER BEFORE VIT 4.7E-4          BER BEFORE RS 1.9E-8
BER AFTER RS 0.0E-7
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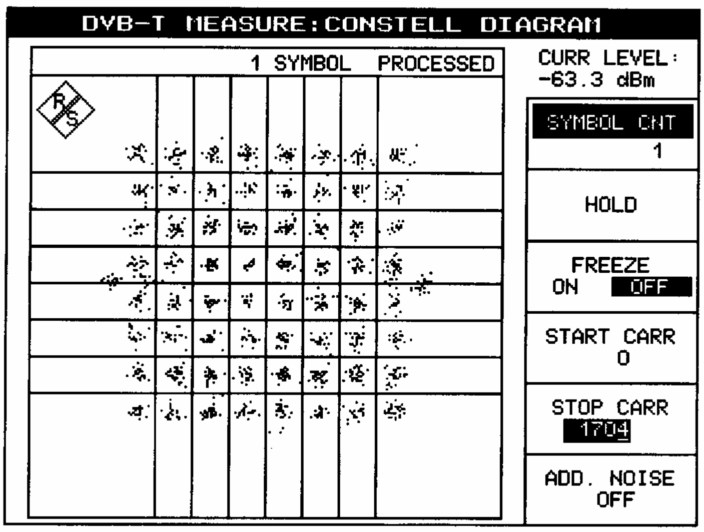

Figure 5
Constellation diagram of the trial transmission

Figure 5 shows the constellation for the broadcasted signal including some other important transmission parameters and measured results. The centre frequency is 650 MHz, which is the 43rd channel of the UHF band. The used modulation is 64-QAM, the chosen mode is 2k, the values of the guard interval is 1/32 and of the code rate is 2/3. These parameters are set during the transmission, so the main reception indicator qualitative values are the bit error rates. These values are:

$$\text{BER before VIT} = 4{,}6 * 10^{-4}$$

$$\text{BER before RS} = 6{,}0 * 10^{-9}$$

$$\text{BER after RS} = 0{,}0 * 10^{-8}$$

These values give an optimistic approach for the future, they mean there are no errored bits in the resulting data stream. At the input of the decoder every 2000th bit was false, so the error correction is a smart and necessary module of the system. But the perfect reception is not only due to this.

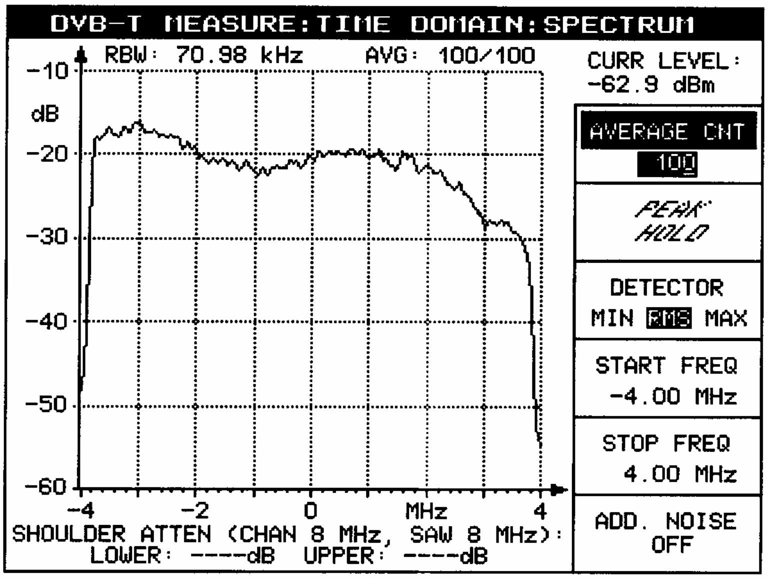

Figure 6

Frequency spectrum of the trial transmission

In the ideal case the spectrum is constant in the whole frequency interval, but in reality this is different (Figure 6). The differences are caused by linear distortions in the whole broadcasting channel. But these do not disturb the final picture and sound quality. The OFDM signal is so well constructed, that the different distortions and noise do not affect greatly the main signal, so the reception remains perfect. And this is proven with the bit error rate values.

3.2 2004 – The Year of the Final Launch

These trial transmissions were successful, so the broadcasting company started the final launch in October 2004. The main transmission parameters were modified many times during the test procedure to obtain the best results for the final program. In comparison with the trial one, only the mode has been differed, but this does not affect the constellation and frequency spectrum diagrams. Earlier the company planned to reach 3 nationwide frequencies to gather the full coverage, by the end of 2004, in the district of Budapest, there are only 2 of them available for digital terrestrial broadcasting. These are channels 43 and 51 in the UHF band, so it is possible to compare 2 existing television broadcast channels set up for the final transmission.

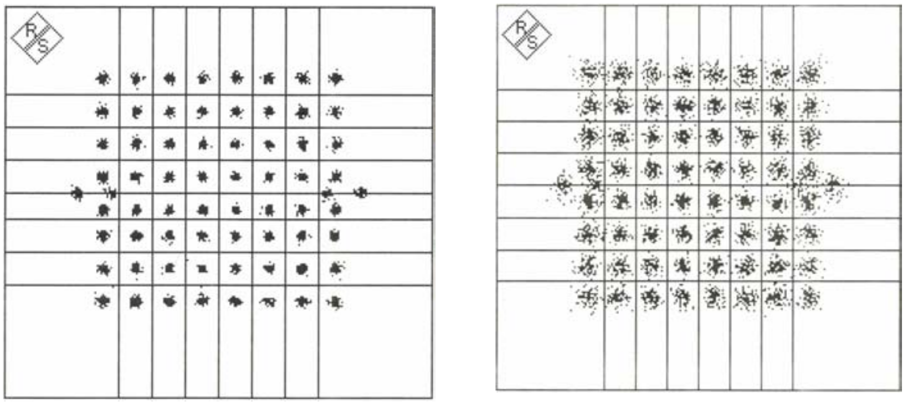

Figure 7
Constellation diagrams for the DVB-T transmissions in UHF channels 43 and 51

The constellation diagrams are shown in figure 7. These indicate a small difference, the "clouds" for each decision point are definitely bigger for channel 51, and this affect also the bit error values (Table 1).

	650 MHz Channel 43	*714 MHz Channel 51*
BER before VIT	**$3{,}1*10^{-5}$**	**$1{,}4*10^{-3}$**
BER before RS	**$3{,}7*10^{-9}$**	**$1{,}0*10^{-8}$**
BER after RS	**0**	**0**

Table 1
Comparison of measured bit error rate values

This table proves us the difference in the easy numerical way. The error correction modules eliminate all the false bits from the data stream, so the final result, the picture and sound quality remains perfect.

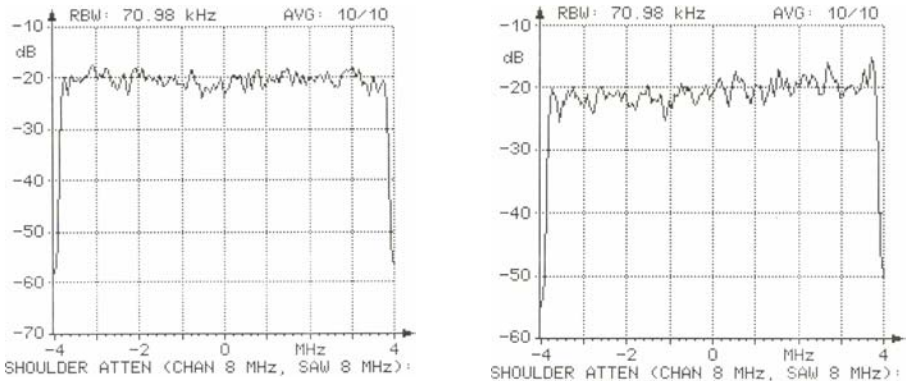

Figure 8
Frequency spectra for the DVB-T transmissions in UHF channels 43 and 51

The 2 frequency spectra (Figure 8) also show a slight difference, meaning that there is a physical reason for the difference in the resulting bit errors. The only sure point, that this disturbing phenomenon is frequency-dependent, it may be a unique overlay of a building or even the Danube. Whatever it might be, it is very difficult to find out in a large city, and the most important thing: it is not necessary. The OFDM signal itself is so robust even against frequency-dependent distortions, that the receiver at its output gives the noise-free results.

Summing up the measurement results it seems that the chosen parameters for the final transmission are properly set for the noise-free reception, which is one of the most important questions in connection with the installation of the whole DVB-T system in Hungary. The technical background is now given for the big launch of digital terrestrial television, and after settling the legal and administrative questions the nationwide coverage may be set up in the next few years.

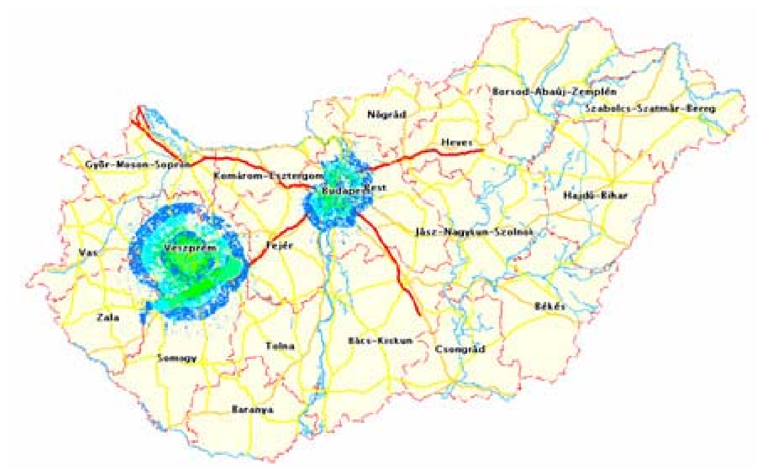

Figure 9
DVB-T coverage in Hungary, 2004

Conclusions

In conclusion, the Orthogonal Frequency Division Multiplexing used in Terrestrial Digital Video Broadcasting is a new and a very complex modulation form. This is a multi-carrier system, where each carrier is modulated digitally. Due to the error correction, the Guard Interval, and to the fact that the carriers are dispersed in the frequency spectrum, OFDM is a very robust and noise-resistant modulation system. The transmitted data stream can be used not only for video broadcasting, but if solely TV channels are transmitted, due to the MPEG compression 4-5 TV programs can be transferred in 1 TV channel, so the frequency spectrum can be allocated more effectively. And even the mobile reception is possible, which means that the viewer sits in his up-to-date car and watches digital broadcast channels, while receiving better picture quality and has access to more services, so the time is right to change progressively the present analogue broadcasting systems and make a step forward.

In Hungary the service provider already had the necessary steps and started the trial service in 1999. The early start enabled the avoiding of technical problems in the final launch. This was in October 2004. At this time we have two regions supplied by DVB-T transmission, and the measurements prove that even in average reception conditions, the resulting quality is much better than it was in the analogue broadcasts.

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