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# TURBO–CODED DIGITAL VIDEO BROADCASTING FOR MOBILE ENVIRONMENTS

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## ABSTRACT

**The system performance of a range of turbo coded digital video broadcasting (DVB) schemes is studied using a variety of orthogonal frequency division multiplex (OFDM) modem modes in both stationary and mobile envorinments. The turbo codec is shown to provide substantial performance adavantage over conventional convolutional coding both in bit error rate and video quality terms.**

## 1 SYSTEM OVERVIEW

Following the standardisation of the Pan-European Digital Video Broadcast Terrestrial (DVB-T) system [1] a range of system performance studies were conducted and disseminated in the literature [2, 3, 4, 5]. In this contribution we propose invoking turbo coding as a powerful means of improving the standard system's performance and embark on a comparative performance study of the various operational modes over both stationary and fading mobile channels.

The schematic of the DVB-T transmitter is shown in Figure 1[1], which is constituted by an MPEG-2 video encoder, channel coding complex and an Orthogonal Frequency Division Multiplex (OFDM) modem [6]. Due to the poor error resilience of the MPEG-2 video codec, strong concatenated channel coding is employed, consisting of a shortened Reed-Solomon RS(204,188) outer code [7], which corrects up to eight erroneous bytes in a block of 204 bytes, and a half-rate inner convolutional encoder with a constraint length of 7 [7]. The overall code rate can be adapted by the variable puncturer, which supports code rates of 1/2 (no puncturing) as well as 2/3, 3/4, 5/6, and 7/8. The parameters of the convolutional encoder are summarised in Table 1.

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| | |
|---|---|
| Rate | 1/2 |
| Const. Length | 7 |
| $k$ | 1 |
| $n$ | 2 |
| Polynomials (octal) | 171,133 |

Table 1. Parameters of the CC(n,k,K) convolutional inner encoder in the DVB-T modem.

A second video stream can be multiplexed with the first one by the inner interleaver, when the DVB modem is in its so-called hierarchical mode [1]. However, the non–hierarchical mode is employed in our system.

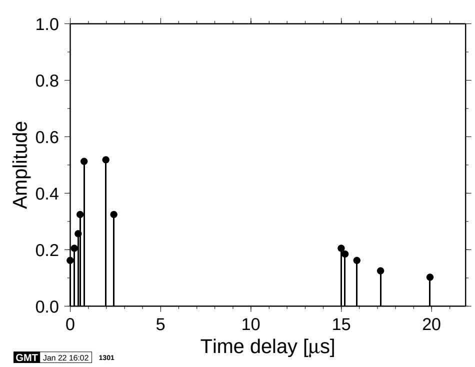


Figure 2. COST 207 hilly terrain (HT) type impulse response.

In the system characterised here we have used a carrier frequency of 500MHz and a sampling rate of $7/64\mu$s. The channel model employed in this study was the twelve–path COST 207 [8] hilly terrain (HT) type impulse response, with a maximal relative path delay of 19.9 $\mu$s. Each of the paths was faded independently with a Rayleigh fading distribution,

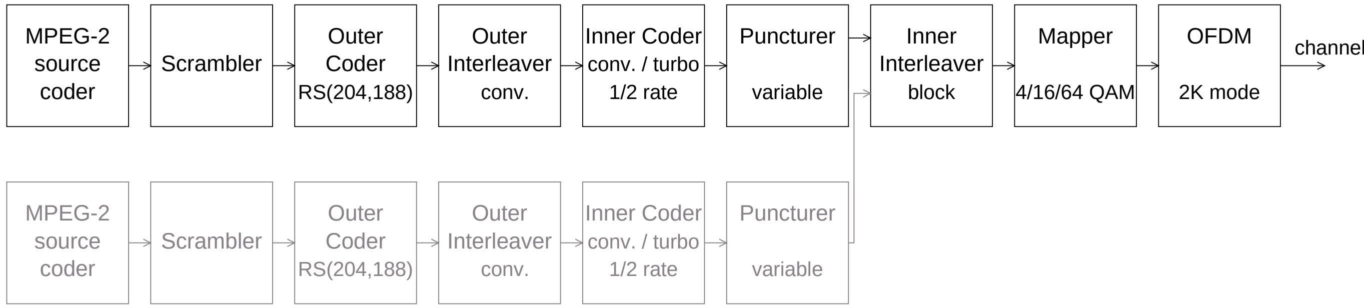


Figure 1. Schematic model of the DVB-T transmitter functions.

according to a normalised Doppler frequency of $10^{-5}$. This corresponds to a worst-case vehicular velocity of about 200 km/h. The unfaded impulse response is depicted in Figure 2.

| | |
|---|---|
| Rate | 1/2 |
| Input block length | 17952 bits |
| Interleaver | random |
| Number of iterations | 8 |
| Constr. Length | 3 |
| $k$ | 1 |
| $n$ | 2 |
| Polynomials | 7,5 |

Table 2. Parameters of the inner turbo coder replacing the DVB-T modem's convolutional coder.

The standard-based inner convolutional code was also replaced by a turbo codec [9], in order to enhance the error resilience of the system. The turbo codec's parameters are displayed in Table 2.

## 2 DISCUSSION OF RESULTS

In this section, we shall elaborate on our findings, when replacing the convolutional code used in the standard DVB scheme [1] with a turbo code. The "Football" HDTV video sequence was used in our experiments. In Figures 4 and 5 the bit error rate (BER) performance of the various modem modes in conjunction with the diverse channel coding schemes are portrayed over stationary Additive White Gaussian Noise (AWGN) channels, where the turbo codec exhibits a significantly steeper BER reduction in comparison to the convolutionally coded arrangements.

Specifically, comparing the performance of the various turbo and convolutional codes for QPSK and 64QAM at a BER of $10^{-4}$, the turbo code exhibited a coding gain of about 2.24 dB and 3.7 dB respectively, when using half-rate codes in Figures 4 and 5. However, for a coding rate of 7/8 the convolutional codec tolerated puncturing better and hence exhibited an advantage of 1.4 dB and 1.3 dB for QPSK and 64QAM, respectively. Hence the Peak Signal to Noise Ratio (PSNR) versus channel Signal to Noise Ratio graphs in Figure 10 demonstrate that approximately 2 dB and 3.5 dB lower channel SNRs are required in conjunction with the rate 1/2 turbo codec for QPSK and 64QAM, respectively, in order to

Figure 3. Frame 79 of "Football" sequence which illustrated minor decoding error at BER of $2.10^{-4}$ after convolutional decoding. The PSNR degradation observed is approximately 2 dB. The sequence was coded using rate 7/8 convolutional codes and transmitted using QPSK modulation.

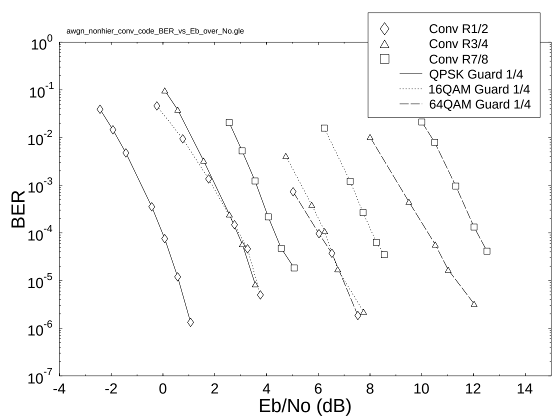


Figure 4. BER after convolutional decoding for the standard DVB scheme [1] over stationary AWGN channels

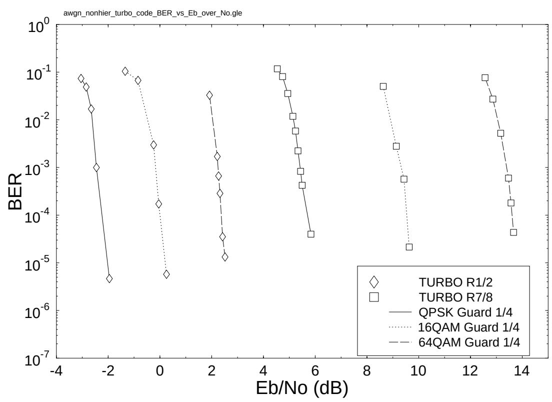


Figure 5. BER after turbo decoding for the otherwise standard-complient DVB scheme [1] over stationary AWGN channels

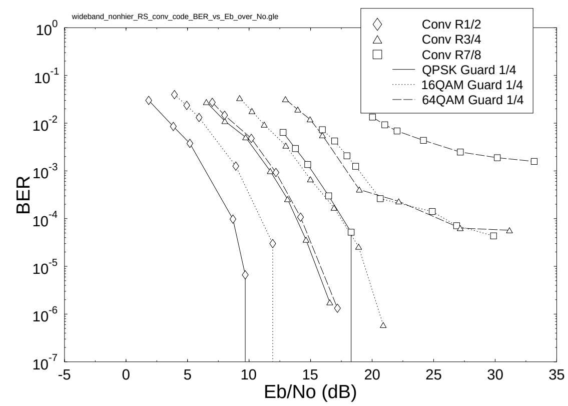


Figure 8. BER after Reed-Solomon and convolutional decoding for the DVB scheme [1] over the wideband channel of Figure 2

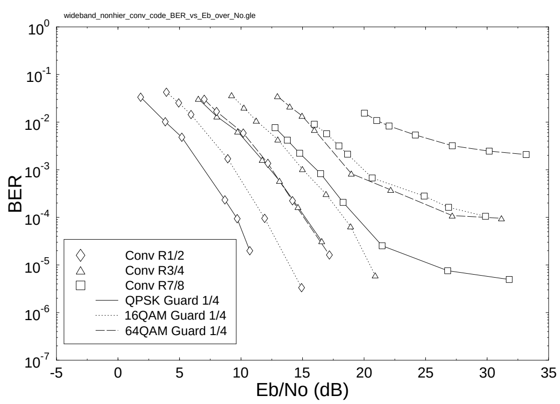


Figure 6. BER after convolutional decoding for the DVB scheme [1] over the wideband channel of Figure 2

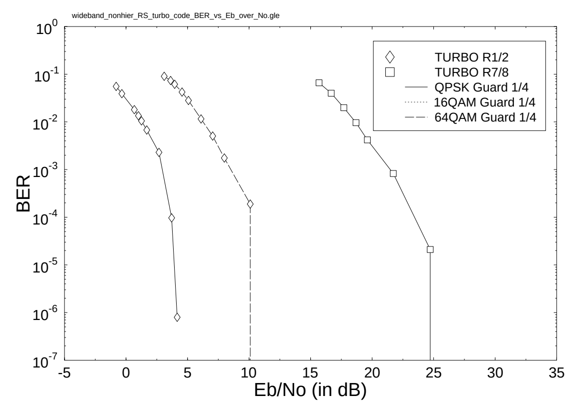


Figure 9. BER after Reed-Solomon and turbo decoding for the DVB scheme [1] over the wideband channel of Figure 2

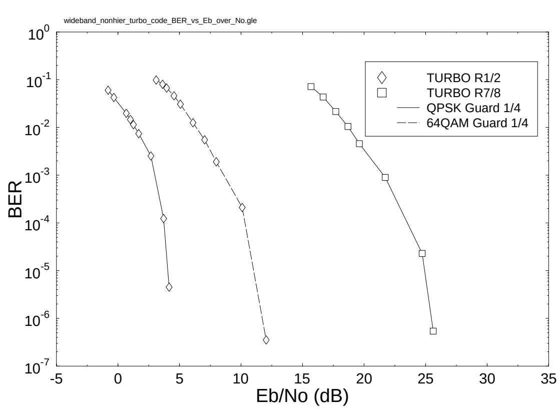


Figure 7. BER after turbo decoding for the DVB scheme [1] over the wideband channel of Figure 2

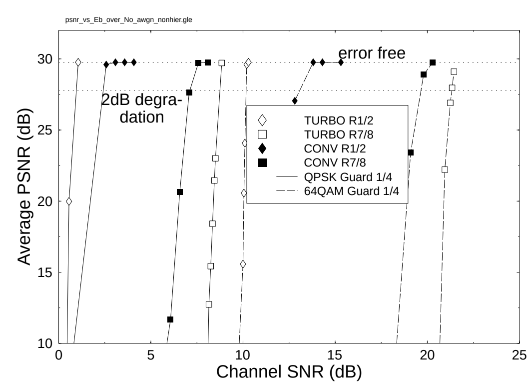


Figure 10. Average PSNR versus Channel SNR of the DVB scheme [1] over AWGN channels

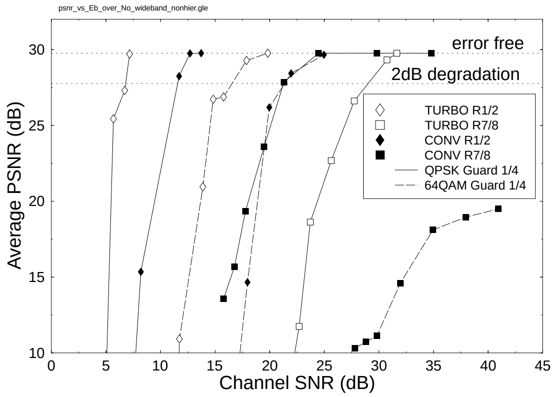


Figure 11. Average PSNR versus Channel SNR of the DVB scheme [1] over the wideband channel of Figure 2

maintain error free video performance. In contrast to this, approximately 0.8 dB and 0.7 dB higher SNRs were necessitated by the rate 7/8 turbo codec for QPSK and 64QAM respectively due to the detrimental effect of puncturing.

Comparing the performance of the 1/2-rate convolutional decoder in Figure 6 and the so-called Max-Log-Map turbo decoder using eight iterations in Figure 7 for QPSK modulation over the worst-case fading mobile channel of Figure 2 we observe that the turbo code provided an additional coding gain of 6dB in comparison to the convolutional code at a BER of about $10^{-4}$. By contrast, for 64QAM using similar codes a 5 dB coding gain was observed at this BER. However, for rate 7/8 codes and QPSK modulation a 4 dB coding gain was obtained by the convolutional code. This is not surprising, since turbo codes tend to lose their performance advantage upon strong puncturing at their output. Hence for favourable channel conditions, when using a high coding rate of 7/8 the convolutional codec was preferred.

Similar observations were also made with respect to the average Peak Signal to Noise Ratio (PSNR) versus channel Signal to Noise Ratio (SNR) plot of Figure 11. For example, for the QPSK modulation mode and a 1/2 coding rate, the turbo code required an approximately 5.5 dB lower channel SNR than the convolutional code for maintaining error free video transmission. However, as expected on the basis of the associated BER curves at a coding rate of 7/8 an approximately 7.25 dB higher channel SNR was required by the turbo coded scheme due to its heavy puncturing.

## 3 CONCLUSION

In conclusion, Tables 4 and 3 summarize the system performance in terms of the required channel SNR (CSNR) in order to maintain less than 2dB PSNR video degradation. It was observed that at this degradation, the decoding error was still perceptually unnoticable to the viewer due to the 30 frames/s refresh-rate, although the still-frame shown in Figure 3 exhibits some degradation.

| Mod. | Code | CSNR (dB) | $E_b/N_0$ | BER |
|---|---|---|---|---|
| QPSK | Turbo (1/2) | 1.02 | -1.99 | $6{\cdot}10^{-6}$ |
| 64QAM | Turbo (1/2) | 9.94 | 2.16 | $2{\cdot}10^{-3}$ |
| QPSK | Turbo (7/8) | 8.58 | 5.57 | $1.5{\cdot}10^{-4}$ |
| 64QAM | Turbo (7/8) | 21.14 | 13.36 | $4.3{\cdot}10^{-4}$ |
| QPSK | Conv (1/2) | 2.16 | -0.85 | $1.1{\cdot}10^{-3}$ |
| 64QAM | Conv (1/2) | 12.84 | 5.06 | $6{\cdot}10^{-4}$ |
| QPSK | Conv (7/8) | 6.99 | 3.98 | $2{\cdot}10^{-4}$ |
| 64QAM | Conv (7/8) | 19.43 | 11.65 | $3{\cdot}10^{-4}$ |

Table 3. Summary of performance results over AWGN channels assuming a PSNR degradation of 2dB.

| Mod. | Code (dB) | CSNR | $E_b/N_0$ | BER |
|---|---|---|---|---|
| QPSK | Turbo (1/2) | 6.63 | 3.62 | $2.5{\cdot}10^{-4}$ |
| 64QAM | Turbo (1/2) | 15.82 | 8.03 | $2{\cdot}10^{-3}$ |
| QPSK | Turbo (7/8) | 28.47 | 25.46 | $10^{-6}$ |
| QPSK | Conv (1/2) | 10.82 | 7.81 | $6{\cdot}10^{-4}$ |
| 64QAM | Conv (1/2) | 20.92 | 13.14 | $7{\cdot}10^{-4}$ |
| QPSK | Conv (7/8) | 20.92 | 17.91 | $3{\cdot}10^{-4}$ |

Table 4. Summary of performance results over wideband channels assuming a PSNR degradation of 2dB.

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