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**TV receiver subjective picture  
failure thresholds and the associated  
minimum quasi error free levels  
for good quality reception**

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## REPORT ITU-R BT.2341-0

**TV receiver subjective failure thresholds and the associated minimum quasi error free levels for good quality reception**

(2014)

**Keywords**

Subjective failure point, SFP, quasi-error free, QEF, bit error rate, BER, ATSC, DVB-T, DVB-T

**1 Introduction**

TV transmission standards have a common theme of being capable of delivering a viewing experience to the end user consumer of apparently error free programs. This has been the background through all the formats across satellite DVB-S, cable DVB-C, and digital terrestrial television ATSC and DVB-T as well as the more recent versions including portable handheld variants.

This Report is to help provide the practical background to the various measurement methods for protection ratios in today's standards and the necessary link to establishing a quasi-error-free (QEF) working system environment when planning transmission networks.

The QEF capability requires suitable wanted signal to total noise plus interference signal levels and has its origins in the earlier days of these standards well over 20 years ago. The relevant background information has almost disappeared from current literature leaving in many cases only a short description of measurement techniques. The background to the pragmatic measurement approaches has been lost especially where consumer goods do not always provide access to the raw decoder telemetry outputs.

This Report provides information on the different measurement methods used in the TV industry to determine DTT receiver performance in the presence of noise, multipath effects and interference. The aim is to show the differences between  $C/N$  relating to the picture quality tests used in ITU-R study group measurement contributions, and the  $C/N$  relating to acceptable picture quality (typically better than QEF – one visible error/hour) for normal broadcast reception.

This contribution only considers the case where the channel impairment is static in time so that the observed picture errors are relatively independent of the video source coding characteristics such as I-frame separation (which becomes more important when dealing with infrequent bursts of interference).

Measurements were made of DVB-T post-Viterbi BER and post-Reed-Solomon (RS) decoder BER on a DVB-T demodulator using PRBS data in three different static channel conditions to compare with the DVB defined QEF BER conditions (post-Viterbi BER of  $2 \times 10^{-4}$  or post-RS BER  $< 1 \times 10^{-11}$ ). These measurements were compared with picture failure measurements made with real video streams in the same three channel conditions using the criteria of no visible errors in 60 seconds, noting the difference in  $C/N$  between the two sets of measurements for each channel condition.

Measurements were also made with a DVB-T2 demodulator for a fixed Ricean channel, noting the difference in  $C/N$  between QEF and no visible errors in 60 s.

In addition, measurements were made with the ATSC digital television system. These measurements involve an in-depth comparison of reception thresholds determined by the visual subjective failure point (SFP) method and the objective measurement of bit error rate (BER).

## 2 Results and conclusions

For DVB-T, the  $C/N$  required to meet the post Viterbi BER  $2 \times 10^{-4}$  QEF equivalent was up to 1.6 dB higher than the  $C/N$  required for no visible errors in a 60 s observation period. The measured  $C/N$  difference varied with channel conditions and broadly agreed with other receiver specifications that estimate this difference as shown in the table below where QMP2 is the measured failure level.

**DVB-T  $C/N$  delta values to get from QMP2 to the QEF level**

Channel model	This report $\Delta$ dB	DTG D-book (Ref. 4) $\Delta$ dB	IEC 62216 E-Book (Ref. 3) $\Delta$ dB	Nordig unified test specification, ver. 2.2.2 (Ref. 2) $\Delta$ dB
1) AWGN	1.2	1.3	1.3	1.3
2) Ricean channel RC6	1.3		1.3	
3) N + 1 adjacent DVB-T DACI	1.6	2.0	2.0	

For DVB-T2, the  $C/N$  difference was much smaller (0.2 dB) as expected due to the very sharp waterfall BER characteristic of the LDPC decoder as shown in the table below where X is the  $C/N$  in dB at the measured point of failure.

**Test results for DVB-T2 tests using RC6 channel**

$C/N$ (dB)	Post LDPC BER min	Post LDPC BER max	Picture quality	Audio quality
X	$1 \times 10^{-6}$	$4 \times 10^{-5}$	No motion, picture constantly freezing	Stutters in sync with picture freezing
X + 0.1	$3.7 \times 10^{-8}$	$6.3 \times 10^{-6}$	Motion but unwatchable, multiple macro blocking per second	Unrecognizable, stutters in sync with picture blocking
X + 0.2	0	0	No errors in 60 s	No errors in 60 s

For both DVB-T and DVB-T2, the differences in  $C/N$  to obtain 60 s error free video, and the  $C/N$  to obtain two out of three 10 s periods of error free video were negligible.

For ATSC, a BER of  $3 \times 10^{-6}$  was taken as the SFP threshold. Based upon the results of the testing, the visual SFP threshold occurs within  $\pm 0.25$  dB of the BER SFP for both static and dynamic test scenarios.

## 3 Conclusions

Planning studies using ITU-R measurement contributions based on picture failure criteria are expected to ensure that the protection ratios being used have a suitable  $C/N$  allowance in order to maintain QEF reception quality particularly for DVB-T where this delta  $C/N$  is more significant. Tabulated standard values for additional allowances for Ricean and Rayleigh environments are

provided in Recommendations ITU-R BT.1368 and ITU-R BT.2033. These Recommendations also include supplementary information on the potential effects of bursty interference. These time varying channel effects are out of scope in Annex 1 but are included for ATSC in Annex 2.

#### 4 Glossary of terms

AWGN	Additive white Gaussian noise
BCH	An error correcting code invented by Bose, Chaudhuri & Hocquenghem
DACI	Digital adjacent channel interference
LDPC	Low-density parity-check (error correcting code)
PRBS	Pseudo random binary sequence
QEF	Quasi-error-free
QMP2	A method of picture failure measurement used in the Nordig specification based on observation of error free video for 60 s
RC6	A six path Ricean channel derived from the 20 path model in the DVB-T PHY specification EN 300 744
RS	Reed Solomon (error correction code)

## Annex 1

### Description and measurement of picture failure thresholds used for DVB-T and DVB-T2 TV receiver performance measurements in static channel conditions

#### 1 Introduction

This Report provides information on the different measurement methods used in the TV industry to determine DTT receiver performance in the presence of noise, multipath effects and interference. The aim is to show the difference between  $C/N$  (and indirectly PR) from the picture quality tests used in ITU-R study group measurement contributions, and the  $C/N$  (and indirectly PR) relating to acceptable picture quality (typically better than QEF – one visible error/hour) for normal broadcast reception. This contribution only considers the case where the channel impairment is static in time so that the observed picture errors are relatively independent of the video source coding characteristics, such as I-frame separation (which becomes more important when dealing with infrequent bursts of interference).

It has to be noted that for the DVB transmission standards the audio and video are part of the same data stream packets error correction framing and subject to identical chance of having errors.

Some of the popular measurement methods for signal level failure of DVB-T and DVB-T2 are:

- a) **Ref BER** – (used in many specifications including DVB-T EN 300 744, Nordig, IEC 62216 E-Book, DTG D-book, – see ref. 1-4)

For DVB-T this is the post-Viterbi decoder BER usually measured inside the demodulator and made available to the host TV software via a register interface. Post-Viterbi BER is only suitable for

channels where there are no time varying effects on multipath, noise or interference. DVB (see Reference 1) defines the post-Viterbi BER of  $2 \times 10^{-4}$  as corresponding to the so called Quasi Error Free (QEF) condition at the demodulator output. QEF is defined in the DVB-T specification as:

“Quasi Error Free (QEF) means less than one uncorrected error event per hour, corresponding to a BER =  $10^{-11}$  at the input of the MPEG-2 demultiplexer.”

For DVB-T2 (see Reference 5), the same DVB definition of QEF applies but instead of using  $2 \times 10^{-4}$  post-Viterbi BER, the post-LDPC BER of  $1 \times 10^{-7}$  is used as an equivalent to QEF. This is also measured inside the demodulator and made available to the host TV software via a register interface although this may not always be provided externally to the viewer.

**b) QMP2** (Used in the Nordig test specification (see Reference 2) for DVB-T/T2)

This is a subjective quality measurement suitable for when Ref BER receiver telemetry is not available, or when the channel conditions vary with time. The QMP2 condition is when the decoded audio/video is free of noticeable errors for 60 s. This is a practical measurement that keeps receiver testing time within acceptable levels and it is assumed that network planners add a “delta” to the measured  $C/N$  to achieve QEF reception conditions.

**c) SFP or PF** subjective failure point or picture failure point (used in the UK DTG D-book and ITU-R BT.2033 (see Reference 6) for DVB-T/T2)

This is another subjective quality measurement suitable for when Ref BER receiver telemetry is not available, or when the channel conditions vary with time. The SFP condition is when the decoded audio/video is free of visible errors for two out of three 10 s periods. The periods do not have to be consecutive. Again it is assumed that network planners add a “delta” to the measured  $C/N$  to achieve QEF reception conditions.

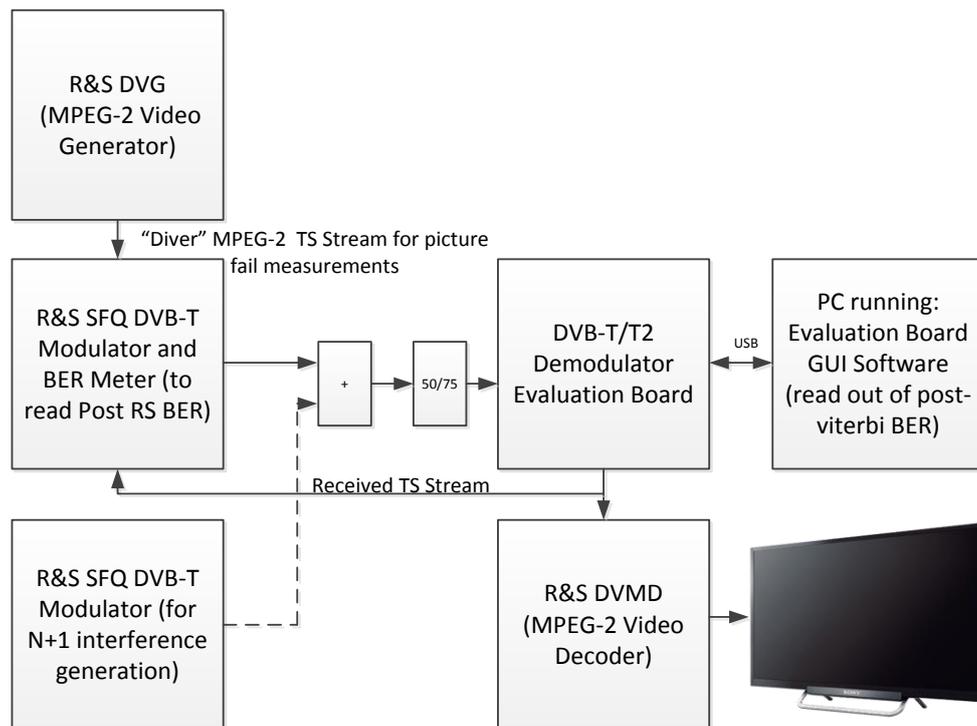
**d) ESR5** errored second ratio 5% (used in IEC 62002 MBRAI specification for mobile receivers (see Reference 7))

This is another subjective quality measurement suitable for when Ref BER receiver telemetry is not available, or when the channel conditions vary with time. It is often used in mobile TV measurements and is not covered further in this contribution. The ESR5 condition is when the decoded audio/video has 1 second containing some noticeable errors in a 20 s period – i.e. 5% of the time.

## 2 Test setup for DVB-T

The test setup is shown in Fig. 1. The wanted DVB-T mode was 8K 64QAM 2/3 1/32. The wanted channel frequency was 666 MHz and the wanted signal level at the tuner input –50 dBm.

FIGURE 1  
Test equipment setup for DVB-T tests



### 3 Test procedure for DVB-T

There were three different channel models tested:

- 1) AWGN. This was generated internally in the SFQ modulator.
- 2) AWGN plus 6-path Ricean channel (RC6). The noise and multipath was generated internally in the SFQ modulator. The RC6 model is based on taking the 6 strongest paths from the static Ricean channel in Annex B of the DVB-T specification EN 300 744. This model is shown in Table 1.
- 3) AWGN plus  $N + 1$  DVB-T digital adjacent channel interference set 35 dB higher than the wanted signal. The added noise was generated internally in the SFQ modulator, and a second SFQ used to supply the  $N + 1$  interferer.

TABLE 1  
RC6 Ricean channel model

Path	Delay ( $\mu$ s)	Attenuation (dB)	Phase (deg.)
1	0	0.4	0
2	0.5	16.2	336
3	2.75	18.8	127
4	1.95	16.3	8.8
5	0.45	19	339.7
6	3.25	17.5	174.9

It was not possible to measure post-RS BER directly using a real video sequence because the BER meter requires the use of PRBS data sequences, so the measurements were made in two phases.

### Phase 1 (PRBS data)

Post-Viterbi and post-Reed Solomon (RS) BER was measured for each of the three channels models over a range of  $C/N$ . For each  $C/N$  setting the post-Viterbi BER was measured in the demodulator and read out using the GUI. Measurement of post-RS BER required an external BER meter (part of the SFQ) and a transport stream (TS) comprising a PRBS sequence which is generated internally to the SFQ and compared with the received PRBS TS from the demodulator output to calculate the BER. The SFQ automatically selects the appropriate measurement time according to the BER level measured.

### Phase 2 (Video data)

A real 4.5 Mbit/s MPEG-2 video stream from the R&S DVG was input to the SFQ modulator used to generate the DVB-T RF signal. The received TS stream was decoded by the R&S DVMD and the video output displayed on a TV/Monitor. For each of the three channel models, the  $C/N$  was increased to determine the  $C/N$  and post-Viterbi BER where the audio and picture were error free for 60 s or more (QMP2). The  $C/N$  and post-Viterbi BER measured here was then matched against the  $C/N$  and post-Viterbi BER measured in Phase 1, to determine the post-RS BER corresponding to the QMP2 condition for this real video stream.

## 4 Receiver tested

The DVB-T/T2 demodulator was mounted on a manufacturer's evaluation board complete with silicon tuner. It is programmed and monitored via a software GUI running on a PC via USB.

DVB-S and DVB-T receivers employ a concatenated coding FEC consisting of a Viterbi decoder followed by a byte de-interleaver and a RS decoder (Fig. 2). The purpose of the byte de-interleaver is to break up bursts of errors from the Viterbi decoder, making it easier for the RS decoder to correct them. The RS decoder has an error correction capability of 8 bytes per 204 byte TS packet. The post-RS BER waterfall characteristic is much sharper than the post-Viterbi BER waterfall characteristic, but not as sharp as the DVB-T2 post-LDPC BER waterfall characteristic.

In the case of a DVB-T2 receiver, the time de-interleaving occurs before the LDPC decoder. The BCH decoder following the LDPC decoder serves to remove any small error floor of the LDPC decoder to ensure a sharp straight waterfall BER characteristic (Fig. 3).

FIGURE 2  
DVB-T forward error correction (FEC)

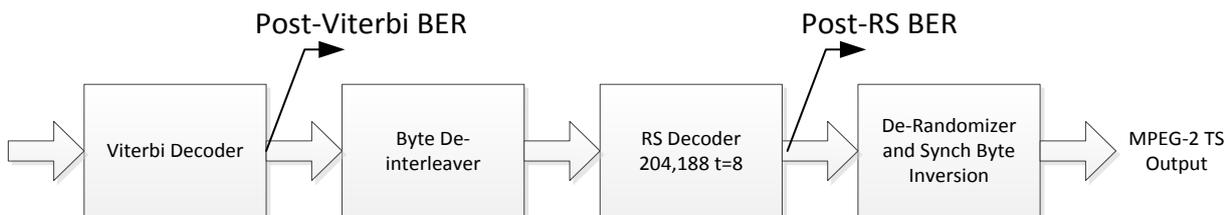
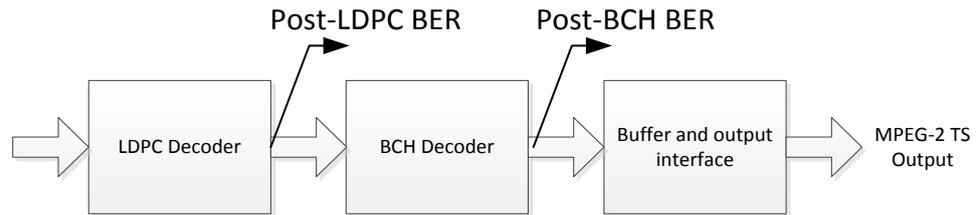


FIGURE 3  
DVB-T2 forward error correction (FEC)



## 5 Test results for DVB-T

The measured BERs of Phase 1 and Phase 2 are shown in Fig. 4 plotted against relative  $C/N$  on the X axis (the absolute  $C/N$  values are Not required in this investigation).

The post-Viterbi BER curves for the three channels end at the standard post-Viterbi BER of  $2 \times 10^{-4}$ . Directly below these end points are the corresponding  $1 \times 10^{-11}$  post-RS BER points corresponding to the DVB QEF condition. Note the latter 3 points are just for reference, they were not measured.

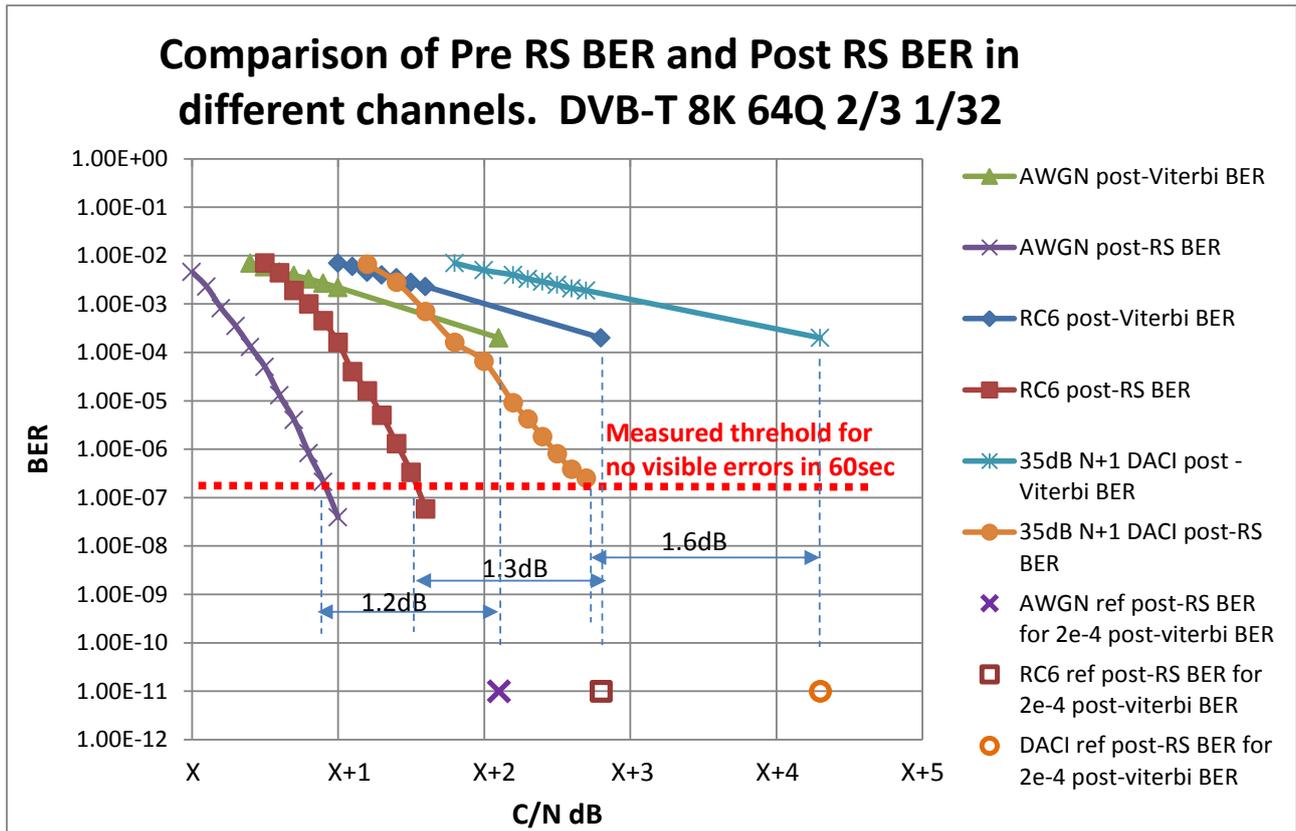
The post-RS BER curves for each channel condition slope down rapidly and the trend of the slopes suggests that this particular demodulator can achieve the  $1 \times 10^{-11}$  post-RS BER QEF condition at a slightly lower  $C/N$  than required for the  $2 \times 10^{-4}$  post-Viterbi BER condition.

The horizontal dotted red line shows the results of the Phase 2 testing with a real video signal. This line is the QMP2 threshold on the post-RS BER above which on average there was at least 1 visible error in a 60 s period. The threshold corresponded to approximately the same post-Viterbi/ post-RS BER for each channel model – the spread of values was:  $(1.9 \times 10^{-3}$  to  $2.8 \times 10^{-3})$  post-Viterbi BER /  $(2.1 \times 10^{-7}$  to  $3.3 \times 10^{-7})$  post-RS BER. The Phase 2 testing also tried to find the  $C/N$  point where the SFP criteria was satisfied (two out of three 10 s periods error free video), but in each case it was within 0.1dB of the QMP2 threshold due to the steepness of the BER curves and therefore the two methods are approximately equivalent.

The horizontal blue arrows at the bottom of the figure show the difference in  $C/N$  between the measured failure point using the QMP2 picture failure criteria of 60 s error free video, and the  $1 \times 10^{-11}$  QEF point of less than 1 visible error every hour.

These differences match fairly well with estimated delta values in some receiver specifications such as DTG D-book, IEC 62216 E-book, and the Nordig test specification – see Table 2.

FIGURE 4  
Test results of phase 1 and phase 2



These results show that in static channels there are differences of up to 1.6 dB between measurements made using QMP2 or SFP (typical of measurement contributions to the ITU-R study groups), and the target picture failure rates expected for reception in a real broadcast service which are typically better than QEF.

TABLE 2  
DVB-T C/N delta values between measured QMP2 and QEF

Channel model	This report $\Delta$ dB	DTG D-book (Ref. 4) $\Delta$ dB	IEC 62216 E-Book (Ref. 3) $\Delta$ dB	Nordig unified test specification, ver. 2.2.2 (Ref. 2) $\Delta$ dB
1) AWGN	1.2	1.3	1.3	1.3
2) Ricean channel RC6	1.3		1.3	
3) N + 1 adjacent DVB-T DACI	1.6	2.0	2.0	

## 6 Test setup for DVB-T2

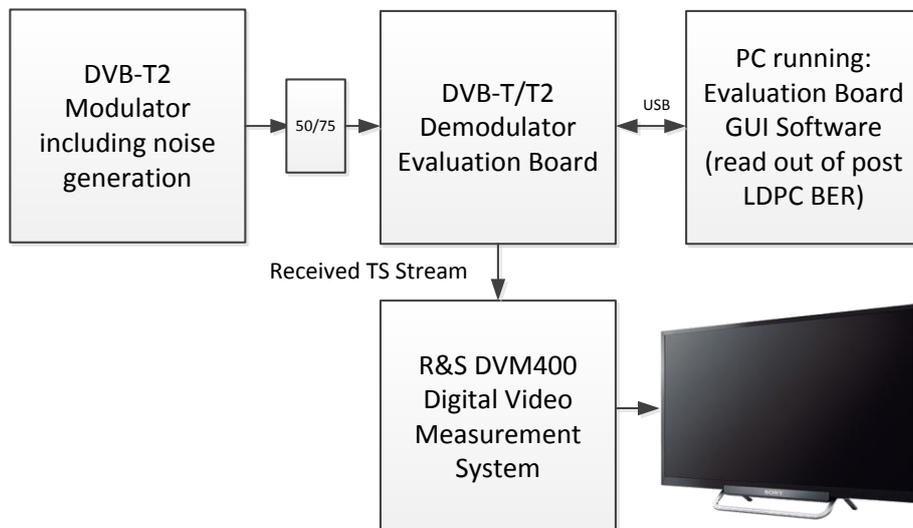
The DVB-T2 mode used was the UK broadcast mode, single PLP, 32 Kext, 256 QAM rot, CR2/3, 1/128 guard,  $L_f = 60$  symbols/frame, no PAPR giving a 40.2 Mbit/s data rate. The wanted signal level was  $-50$  dBm at the tuner input.

Four different MPEG streams were used to drive the modulator but the results for each stream were identical within the limits of measurement tolerance due to the sharp waterfall characteristic of the DVB-T2 LDPC decoder.

TABLE 3  
Details of test streams used in the DVB-T2 signal

Stream	Video	Audio
1	MPEG-2, 4.4 Mbit/s	MPEG-2, 199 kbit/s
2	H.264 AVC, 12.3 Mbit/s	MPEG-1, 205 kbit/s
3	H.264 AVC, 1.8 Mbit/s	HE-AAC, 134 kbit/s
4	H.264 AVC, 12.2 Mbit/s	HE-AAC, 200 kbit/s

FIGURE 5  
Test equipment setup for DVB-T2 tests



## 7 Test procedure for DVB-T2

Only one channel model was tested – the RC6 Ricean model used in the DVB-T tests.

The test swept  $C/N$  whilst reading the post-LDPC BER and observing the audio/picture failure over a 60 s period for each  $C/N$  point. The low BER values fluctuated so minimum and maximum values were recorded.

## 8 Test results for DVB-T2

TABLE 4

Test results for DVB-T2 tests using RC6 channel

C/N (dB)	Post LDPC BER min	Post LDPC BER max	Picture quality	Audio quality
X	$1 \times 10^{-6}$	$4 \times 10^{-5}$	No motion, picture constantly freezing	Stutters in sync with picture freezing
X + 0.1	$3.7 \times 10^{-8}$	$6.3 \times 10^{-6}$	Motion but unwatchable, multiple macro blocking per second	Un recognizable, stutters in sync with picture blocking
X + 0.2	0	0	No errors in 60 s	No errors in 60 s

These results show that due to the very sharp waterfall BER characteristics of the DVB-T2 LDPC decoder, the difference between a very poor picture and a very good picture is only 0.1 to 0.2 dB. Thus QMP2 and QEF for DVB-T2 are virtually identical, and allowing a small delta of a few points of a dB from QMP2 based measurements should give QEF reception in a static channel.

## 9 References

- 1) Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television, ETSI EN 300 744 V1.6.1 (2009-01)*.
- 2) Nordig Unified Test Specifications for Integrated Receiver Decoders v2.2.2.
- 3) IEC 62216 Ed 1, 2009, *Digital terrestrial television receivers for the DVB-T system*.
- 4) Digital Terrestrial Television Requirements for interoperability. D-Book 7 part A v3, Digital TV Group (UK).
- 5) Digital Video Broadcasting (DVB); *Implementation guidelines for a second generation digital terrestrial television broadcasting system (DVB-T2), ETSI TS 102 831 V1.2.1 (2012-08)*.
- 6) Recommendation ITU-R BT.2033 (01/2013), *Planning criteria, including protection ratios, for second generation of digital terrestrial television broadcasting systems in the VHF/UHF bands*.
- 7) Mobile and portable DVB-T/H radio access – *Part 1: Interface specification, IEC 62002-1, ed. 2.0, 2008*.

## Annex 2

## Description and measurement of picture failure thresholds used for ATSC TV receiver performance measurements in static and dynamic channel conditions

## 1 Introduction

In the digital environment, especially with systems such as ATSC that have a sharp “cliff” effect, the SFP threshold is a very repeatable and defined criterion. A small change in the desired to undesired signal ratio,  $D/U$ , less than 0.5 dB, is expected to change a perfect picture into an unusable one. In

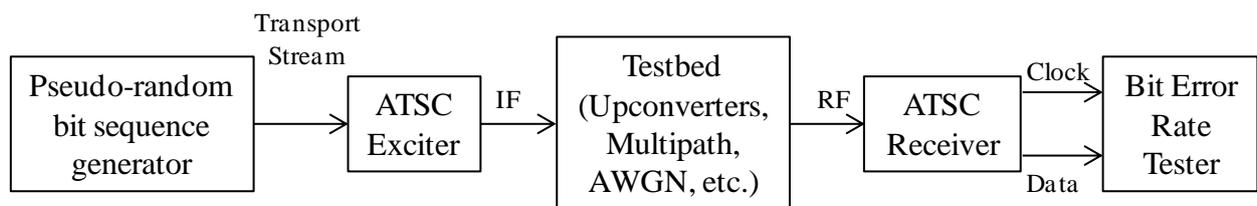
the ATSC system, the SFP threshold was determined by a BER measurement on pseudorandom data transmitted through the test system. For ATSC, a BER of  $3 \times 10^{-6}$  was taken as the SFP threshold. Based upon the results of the testing, the visual SFP threshold occurs within  $\pm 0.25$  dB of the BER SFP. The following sections described the ATSC test setup, procedure, and test results.

## 2 Test setup for ATSC

Figure 1 illustrates a block diagram of the test setup. The output of the pseudo-random bit sequence is a PN sequence of length  $2^{23}-1$  bits. The BER tester (BERT) is a Hewlett-Packard Model 3784A with Option H18.

FIGURE 6

Test setup for the measurement of BER in the ATSC System



## 3 Test procedure for ATSC

### 3.1 Relationship between visual SFP and BER for ATSC

The relationship between the visual SFP threshold and BER threshold was confirmed using the following steps:

**Step I:** For each of the two impairment conditions, random noise and impulse noise, the visual SFP threshold was determined using a panel of three expert observers and two increasing/decreasing cycles of the impairment level. The undesired signal level was varied in two 0.25 dB steps (the power resolution of the test bed) above, at, and below the visual SFP. The observations of the experts were recorded at each of the five steps. Then, using the pseudo-random data applied to the ATSC exciter, the BER was measured at each step of the impairment level.

**Step II:** For each of the two impairment conditions, random noise and impulse noise, the BER threshold was determined using the procedure in § 3.3 below. The undesired signal level was varied in two 0.25 dB steps above, at, and below the visual SFP. The BER was measured at each of the five steps.

**Step III:** The following subset of 13 static and dynamic tests was used to confirm that the BER threshold is comparable to the visual SFP threshold using expert observers. Impairment levels at 0.25 dB steps above and below the threshold were used. The simplified visual SFP procedure of Step I was used.

1. Random noise interference into ATSC at a strong desired signal level ( $-28$  dBm).
2. Impulse noise interference into ATSC at a moderate desired signal level ( $-53$  dBm).
3. Co-channel NTSC interference into ATSC at a weak desired signal level ( $-68$  dBm).
4. Lower adjacent channel NTSC interference into ATSC at: a) strong; b) moderate; and c) weak desired signal levels.
5. Upper adjacent channel NTSC interference into ATSC at: a) strong; b) moderate; and c) weak desired signal levels.

6. Multipath interference into ATSC at a strong desired signal level ( $-28$  dBm) using ATSC R.21 ensemble #1 (see Reference 1) with path 6 delay at  $+18$   $\mu$ s (lagging echo), path 5 ( $+5.7$   $\mu$ s lagging echo) attention at 14 dB, and phase rotation with four flutter frequencies (0, 0.05, 0.5, and 5 Hz) on path 4 ( $+1.8$   $\mu$ s lagging echo).

### 3.2 Definition of visual SFP for ATSC

The visual SFP for the impairment of the ATSC signal is defined to be a BER of  $3 \times 10^{-6}$ . This corresponds to 2.5 block errors per second. The measurement requires 50 errors. Therefore, the observation of the error rate takes place in a 20 s interval. The BER must be no greater than  $3 \times 10^{-6}$  for three consecutive 20 s interval.

### 3.3 Determination of visual SFP for ATSC

The procedure for determining the visual SFP for ATSC using the BER tester is as follows:

1. Acquire the ATSC signal. "Acquisition" means to simultaneously meeting three conditions within five seconds; 1) indication of signal lock; 2) the BER tester indicates synchronization; and 3) an observed decrease in the BER.
2. The impairment level is increased until the SFP threshold is reached.  
The BER tester is reset when the undesired power level has been established and a set of three consecutive 20 s measurements are made. A successful measurement is the result of all three BER measurements being less than or equal to  $3.0 \times 10^{-6}$ . If the first set fails, one additional set of three consecutive 20 s runs is permitted at this power level. Then, all three runs must result in BER measurements being less than or equal to  $3.0 \times 10^{-6}$ . Otherwise, the undesired power level is decreased.
3. The RF signal to the receiver is disconnected for seconds and then reconnected.
4. In the system reacquires the desired signal, then the SFP threshold level is as determined in step 2 above; otherwise, the impairment signal level is reduced until the receiver can acquire in order to find the SFP threshold.

If the receiver acquires on the first attempt, no further tries are required. If the receiver fails to acquire on the first attempt, a second attempt is permitted. If acquisition fails on the second try, the undesired power level is decremented. If the receiver does acquire on the second attempt, then it must acquire on a third attempt (i.e. two consecutive successful acquisitions out of three tries are required).

When the SFP threshold is reached, the BER is measured for three consecutive 20 s measurement intervals at impairment levels 0.25 dB and 0.50 dB above and below the SFP threshold.

## 4 Test results for ATSC

The following test results confirm the relationship between the determination of the SFP threshold by either the visual SFP method or the BER method (see References 2 and 3). Table 1 tabulates a comparison of the visual SFP threshold and the BER threshold for 13 different test scenarios. For both adjacent channel tests at the strong desired signal level (Tests 4a and 5a) the thresholds could not be achieved at the maximum available undesired signal level. All tests except for test 6a, the thresholds for visual SFP and BER are within 0.5 dB of each other. Test 6a exhibited a further anomaly using the visual SFP method in that the receiver failed to acquire at the threshold level.

TABLE 1

**Comparison between the visual SFP and BER methods for various static and dynamic interference into ATSC**

Test number	Description	Visual SFP method				BER method		
		Desired power		Desired to undesired ratio (dB)		Desired power	Desired to undesired ratio (dB)	
		Level	dBm	ACQ	Threshold	dBm	ACQ	Threshold
1	Random noise	S	-27.89		15.28	-28.12	YES	15.19
2	Impulse noise	M	-52.93		0.38*	-53.10	YES	0.40*
3	Co-channel	W	-67.86		2.05	-68.10	YES	1.81
4a	Lower adjacent NTSC into ATSC	S	-27.85	NT	<-22.94	-28.04	NT	<-23.18
4b	Lower adjacent NTSC into ATSC	M	-52.86	YES	-44.37	-53.05	YES	-44.46
4c	Lower adjacent NTSC into ATSC	W	-67.86	YES	-47.61	-68.04	YES	-47.73
5a	Upper adjacent NTSC into ATSC	S	-27.85	NT	<-22.98	-28.05	NT	<-23.18
5b	Upper adjacent NTSC into ATSC	M	-52.87	YES	-44.44	-53.04	YES	-44.44
5c	Upper adjacent	W	-67.86	YES	-48.54	-68.04	YES	-48.71
6a	Dynamic echo (0 Hz)	S	-27.86	5.40	5.00	-27.89	YES	4.20
6b	Dynamic echo (0.05 Hz)	S	-27.86	YES	7.85	-27.89	YES	7.60

TABLE 1 (*end*)

Test number	Description	Visual SFP method				BER method		
		Desired power		Desired to undesired ratio (dB)		Desired power	Desired to undesired ratio (dB)	
		Level	dBm	ACQ	Threshold	dBm	ACQ	Threshold
6c	Dynamic echo (0.5 Hz)	S	-27.86	YES	9.00	-27.89	YES	9.10
6d	Dynamic echo (5 Hz)	S	-27.86	YES	12.70	-27.89	YES	12.50

ACQ – indicates whether acquisition was achieved.

NT – indicates that the maximum power was reached before the threshold could be determined. The “less than” (“<”) symbol appears in the data preceding the D/U ratio corresponding to the maximum undesired signal level.

\* Desired signal level minus the noise level relative to zero attenuation of the noise.

Table 2 through 12 tabulate the BER for three consecutive measurements for various ATSC signal levels with different interference scenarios. Except for Table 7 (Test 5b) additional BER measurements were obtained at impairment levels above and below threshold in order to determine the threshold characteristic.

TABLE 2

**BER about threshold with random noise  
interference into a strong desired ATSC signal level (Test 1)**

	-0.50 dB	-0.25 dB	Threshold	+0.25 dB	+0.50 dB
<b>Desired to undesired ratio (dB)</b>	14.69	14.94	15.19	15.44	15.69
<b>Bit error rate</b>	5.74E-04	3.55E-05	7.32E-07	0.00E+00	0.00E+00
	5.89E-04	3.67E-05	8.22E-07	0.00E+00	0.00E+00
	5.95E-04	3.55E-05	1.03E-06	0.00E+00	0.00E+00

TABLE 3

**BER about threshold with impulse noise  
interference into a moderate desired ATSC signal level (Test 2)**

	-0.50 dB	-0.25 dB	Threshold	+0.25 dB	+0.50 dB
<b>Relative noise level (dB)*</b>	-53.00	-53.25	-53.50	-53.75	-54.00
<b>Bit error rate</b>	6.34E-06	6.20E-06	1.36E-06	2.17E-06	7.11E-07
	9.56E-06	7.06E-06	1.87E-06	1.19E-06	4.06E-07
	1.41E-05	5.42E-06	1.26E-06	1.10E-06	1.40E-07

\* Noise level relative to zero attenuation of noise

TABLE 4

**BER about threshold with NTSC co-channel interference  
into a weak desired ATSC signal level (Test 3)**

	<b>-0.50 dB</b>	<b>-0.25 dB</b>	<b>Threshold</b>	<b>+0.25 dB</b>	<b>+0.50 dB</b>
<b>Desired to undesired ratio (dB)</b>	1.31	1.56	1.81	2.06	2.31
<b>Bit error rate</b>	4.76E-05	9.85E-06	1.40E-06	2.10E-07	0.00E+00
	4.89E-05	1.07E-05	1.23E-06	4.61E-07	6.80E-08
	4.77E-05	1.18E-05	1.26E-06	4.00E-08	0.00E+00

TABLE 5

**BER about threshold with lower adjacent channel NTSC interference  
into a moderate desired ATSC signal level (Test 4b)**

	<b>-0.50 dB</b>	<b>-0.25 dB</b>	<b>Threshold</b>	<b>+0.25 dB</b>	<b>+0.50 dB</b>
<b>Desired to undesired ratio (dB)</b>	-44.96	-44.71	-44.46	-44.21	-43.96
<b>Bit error rate</b>	8.13E-04	2.95E-05	2.20E-07	0.00E+00	0.00E+00
	7.95E-04	2.68E-05	6.10E-08	0.00E+00	0.00E+00
	8.43E-04	2.71E-05	9.50E-08	0.00E+00	0.00E+00

TABLE 6

**BER about threshold with lower adjacent channel NTSC interference  
into a weak desired ATSC signal level (Test 4c)**

	<b>-0.50 dB</b>	<b>-0.25 dB</b>	<b>Threshold</b>	<b>+0.25 dB</b>	<b>+0.50 dB</b>
<b>Desired to undesired ratio (dB)</b>	-48.23	-47.98	-47.73	-47.48	-47.23
<b>Bit error rate</b>	2.72E-04	2.05E-05	5.40E-07	0.00E+00	0.00E+00
	2.41E-04	1.73E-05	7.59E-07	0.00E+00	0.00E+00
	2.60E-04	1.83E-05	4.79E-07	0.00E+00	0.00E+00

TABLE 7

**BER at threshold with upper adjacent channel NTSC interference  
into a moderate desired ATSC signal level (Test 5b)**

	<b>Threshold</b>
<b>Desired to undesired ratio (dB)</b>	-44.44
<b>Bit error rate</b>	0.00E+00
	0.00E+00
	7.40E-08

TABLE 8

**BER about threshold with upper adjacent channel NTSC interference  
into a weak desired ATSC signal level (Test 5c)**

	<b>-0.50 dB</b>	<b>-0.25 dB</b>	<b>Threshold</b>	<b>+0.25 dB</b>	<b>+0.50 dB</b>
<b>Desired to undesired ratio (dB)</b>	-49.21	-48.96	-48.71	-48.46	-48.21
<b>Bit error rate</b>	3.89E-04	3.56E-05	1.19E-06	0.00E+00	0.00E+00
	3.81E-04	3.48E-05	1.14E-06	1.00E-07	0.00E+00
	3.80E-04	4.02E-05	1.26E-06	0.00E+00	0.00E+00

TABLE 9

**BER about threshold with dynamic echo ensemble interference  
at 0 Hz into a strong desired ATSC signal level (Test 6a)**

	<b>-0.50 dB</b>	<b>-0.20 dB</b>	<b>Threshold</b>	<b>+0.20 dB</b>	<b>+0.50 dB</b>
<b>Desired to undesired ratio (dB)</b>	3.70	4.00	4.20	4.40	4.70
<b>Bit error rate</b>	6.20E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	6.51E-05	1.70E-07	0.00E+00	0.00E+00	0.00E+00
	4.95E-05	4.21E-05	0.00E+00	0.00E+00	0.00E+00

TABLE 10

**BER about threshold with dynamic echo ensemble interference  
at 0.05 Hz into a strong desired ATSC signal level (Test 6b)**

	<b>-0.50 dB</b>	<b>-0.20 dB</b>	<b>Threshold</b>	<b>+0.20 dB</b>	<b>+0.50 dB</b>
<b>Desired to undesired ratio (dB)</b>	7.10	7.40	7.60	7.80	8.10
<b>Bit error rate</b>	3.49E-05	4.56E-07	0.00E+00	1.42E-06	0.00E+00
	3.69E-05	1.58E-06	7.90E-08	9.20E-06	0.00E+00
	5.66E-05	1.31E-04	4.74E-07	8.40E-08	0.00E+00

TABLE 11

**BER about threshold with dynamic echo ensemble interference  
at 0.5 Hz into a strong desired ATSC signal level (Test 6c)**

	<b>-0.50 dB</b>	<b>-0.20 dB</b>	<b>Threshold</b>	<b>+0.20 dB</b>	<b>+0.50 dB</b>
<b>Desired to undesired ratio (dB)</b>	8.60	8.90	9.10	9.30	9.60
<b>Bit error rate</b>	NO SYNC	NO SYNC	NO SYNC	0.00E+00	NO SYNC
	NO SYNC	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	NO SYNC	NO SYNC	0.00E+00	0.00E+00	0.00E+00
NO SYNC indicates that the HP3784A BER tester has lost the reference pattern synchronization					

TABLE 12

**BER about threshold with dynamic echo ensemble interference  
at 5 Hz into a strong desired ATSC signal level (Test 6d)**

	<b>-0.50 dB</b>	<b>-0.20 dB</b>	<b>Threshold</b>	<b>+0.20 dB</b>	<b>+0.50 dB</b>
<b>Desired to undesired ratio (dB)</b>	7.10	7.40	7.60	7.80	8.10
<b>Bit error rate</b>	NO SYNC	6.10E-08	0.00E+00	0.00E+00	0.00E+00
	NO SYNC	NO SYNC	0.00E+00	0.00E+00	0.00E+00
	NO SYNC	1.10E-07	0.00E+00	0.00E+00	0.00E+00
NO SYNC indicates that the HP3784A BER tester has lost the reference pattern synchronization					

## 5 Conclusion

Planning studies using laboratory and field measurements based on picture failure criteria for the ATSC system should ensure that the protection ratios being used have a suitable margin to ensure quality reception for extended periods of time. These margins are particularly significant for dynamic environments.

## 6 References

- 1) ATSC Document A/74:2010, *ATSC Recommended Practice: Receiver Performance Guidelines*, 7 April 2010. [http://atsc.org/cms/standards/a\\_74-2010.pdf](http://atsc.org/cms/standards/a_74-2010.pdf)
- 2) *Record of Test Results – digital HDTV Grand Alliance System*, Advisory Committee on Advanced Television Service (ACATS) of the Federal Communications Commission (FCC), pp. I-3-1 to I-3-5, October 1995. <http://apps.fcc.gov/ecfs/document/view?id=1546110001>
- 3) *Record of Test Results – digital HDTV Grand Alliance System*, Advisory Committee on Advanced Television Service (ACATS) of the Federal Communications Commission (FCC), p. I-3-6, October 1995. <http://apps.fcc.gov/ecfs/document/view?id=1546110002>