Society of Cable Telecommunications Engineers

ENGINEERING COMMITTEE
Interface Practices Subcommittee

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Test Method for Downstream Bit Error Rate

NOTICE

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1.0 SCOPE

The purpose of this test is to measure Bit Error Rate (BER) of downstream (forward path) broadband telecommunications QAM signals. This procedure will address mainly pre-Forward Error Correction BER results for 64 and 256 QAM.

It is important to rely upon both the pre-FEC and post-FEC BER results. In North America, most 64 and 256QAM signals incorporate Annex B, FEC encoding. It is therefore important to reference the post-FEC result, but extremely dangerous to rely solely upon it. BER suffers from what is commonly known as a "cliff effect" in which the post-FEC BER remains error free up to a point and then begins to rapidly decline. Referring to the pre-FEC BER result can yield insight as to how much margin is available prior to reaching the cliff.

Although ITU J.83 Annex B is the standard of choice for forward error correction in North America, it can lead to an overoptimistic pre-FEC BER result. When utilizing ITU J.83 Annex B, the pre-FEC measurement is after the Trellis decoder, but before the Reed Solomon decoder. Therefore, the Annex B pre-FEC test results will include the improvements of the Trellis coding.

ITU J.83 Annex C is similar to Annex B in that it relies on Reed Solomon Error Correction and occupies a 6MHz channel; however, Annex C does not incorporate Trellis coding. Since Annex C does not contain Trellis coding, it allows the test to yield a result closer to the true pre-FEC performance. Annex C is however, not likely to be the FEC encoding used in the field in North America.

This test is a static measurement at a single, specified DUT (Device Under Test) input level. It does not provide performance over an input operating range. Also, the user will have the option of either testing with Annex B or Annex C. The final test results must clearly indicate which standard was utilized.

In addition to a Bit Error Rate measurement, Appendix B refers to the parameters, Errored and Error-Free Seconds, which can be a useful tool in determining the impairments resulting in the bit errors.

Appendix A: TEST INTEGRATION TIME

Appendix B: ERRORED AND ERROR-FREE SECONDS

2.0 DEFINITIONS AND ACRONYMS

2.1 **Adaptive Equalizer** – Real-time signal compensation for the linear distortion created by the components of a cable system, such as frequency response and group delay.

2.2 **Bit Error Ratio (BER)** - The number of erroneous bits divided by the total number of bits transmitted, received, or processed over some stipulated period.

2.3 **Errored Second** – A one second period with one or more Errored blocks.

2.4 **Forward Error Correction (FEC)** - A system of error control for data transmission wherein the receiving device has the capability to detect and correct any character or code block that contains less than a predetermined number of symbols in error. ITU J.83 Annex B (North America standard) FEC is composed of four processing layers

2.5 **Interleaving** – Evenly disperses the symbols, protecting against a burst of symbol errors being sent to the RS decoder.

2.6 **International Telecommunications Union –** An international organization within the United Nations System where governments and the private sector coordinate global telecom networks and services.

2.7 **ITU-T J.83** – T refers to the Telecommunications Standardization sector of the ITU. Series J applies to the transmission of television, sound programme and other multimedia signals. Recommendation J.83 is specific to digital multi-programme systems for television, sound and data services for cable distribution.

2.8 **Quadrature Amplitude Modulation (QAM)** - Method of combining two amplitude-modulated signals into a single channel, thereby doubling the effective bandwidth. In a QAM signal, there are two carriers, each having the same frequency but differing in phase by 90 degrees (one quarter of a cycle, from which the term quadrature arises). One signal is called the I (in phase) signal, and the other is called the Q (quadrature) signal. Mathematically, one of the signals can be represented by a sine wave, and the other by a cosine wave. The two modulated carriers are combined at the source for transmission. At the destination, the carriers are separated, the data is extracted from each, and then the data is combined to recreate the original modulating information.

2.9 **Randomization** – Randomizes the data on the channel to allow effective QAM demodulator synchronization.

2.10 **Reed-Solomon Coding** – Provides block encoding and decoding to correct one symbol for each pair of R-S symbols within an R-S block (correction of up to 3 symbols in J-83 Annex B and up to 8 symbols in Annex C).

2.11 **Symbol Rate** – The number of symbols transmitted over a give time.

2.12 **Trellis Coding** – Increases the symbol constellation (redundancy) without increasing the symbol rate or power spectrum. The redundancy allows for an improved Signal-to-Noise threshold.

3.0 NORMATIVE REFERENCES

The following documents contain provisions, which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreement based on this standard are encouraged to investigate the possibility of applying the most recent editions of the documents listed below.

3.1 ITU-T Recommendation J.83 (1997), Series J: Transmission of Television, Sound Programme and other Multimedia Signals. Digital Transmission of Television Signals.

4.0 INFORMATIVE REFERENCES

The following documents may provide valuable information to the reader but are not required when complying with this standard.

4.1 NCTA Engineering Committee's Subcommittee for Standards of Good Engineering Practices, 2002. NCTA Recommended Practices for Measurements on Cable Television Systems, Third Edition Washington, DC: NCTA, 2002.

4.2 Edgington, Francis and Thomas, Jeffrey. Digital Basics For Cable Television Systems. Upper Saddle River: Prentice Hall PTR, 1999.

5.0 TEST SETUP

5.1 Test Equipment List

5.1.1 Digital modulator(s). Quantity to be determined by the amount of channel loading being tested.

- 64 and/or 256 QAM
- ITU J.83(B) and/or ITU J.83(C)
- Variable Interleaver controls

5.1.2 RF up-converter(s). Quantity to be determined by the amount of channel loading being tested.

- Variable from 54 to 860MHz, minimum
- Above 860MHz desirable

5.1.3 Simulated Digital Loading (optional)
Aside from the QAM channels under test, the remaining digital loading may be simulated digital loading vs. actual QAM channels

- AWGN Generator
  - Variable output power or incorporate an external variable attenuator
- Appropriate bandpass (high/low pass) filter to shape the noise loading in accordance with the specified channel plan
  - 16dB minimum return loss, 75ohm
  - +/- 10MHz from edge frequency, >40dB rejection
  - +/- 0.25dB flatness
  - < 1.5dB insertion loss
- Notch filters (channel deletion filters)
  - Center frequency = Center frequency of test channel
  - 16dB minimum return loss, 75ohm
  - 6MHz wide, >50dB rejection
  - +/- 2MHz from bandedge, <3.0dB insertion loss
  - +/- 0.25dB flatness in the passband
  - < 1.5dB insertion loss

5.1.4 One lab amplifier (optional)

- Gain as needed in order to meet the DUT specified input, minimal distortion or noise contribution
- 75ohm

5.1.5 One variable, RF attenuator

- 16dB minimum return loss, 75ohm

5.1.6 One multi-channel signal generator

- Capability to produce signals on all the nominal visual carrier frequencies for all the channels in the frequency band to be tested
- Ability to adjust the power of each individual channel
- Ability to turn individual channels on/off.
- CSO, CTB, or spurious signals generated within the signal source(s) should be at least 20dB below those of the DUT
- For testing with non-coherent carrier frequencies, the capability to maintain individual non-coherent frequencies to within +/- 5kHz of the nominal carrier frequencies.

5.1.7 Two RF combiners, may be RF splitter/combiner or a directional coupler.

- Minimum isolation of 20dB, 75ohm

5.1.8 One 6MHz wide, bandpass filter with the center frequency set to that of the channel under test

- +/- 10MHz from center frequency, > 25dB rejection
- 75ohm, 18dB minimum return loss
- May not be required depending on the model of demodulator/analyzer used.

5.1.9 One QAM analyzer.

- 64 and 256 QAM capabilities
- ITU J.83(B) and/or ITU J.83(C)
- QAM analyzer should be able to display pre-FEC and post-FEC BER results
  Note: The QAM analyzer pre-FEC results are to be strictly based on an errored bit count relative to the total # of transmitted bits. It is not to be derived based on a theoretical value relative to a signal to noise measurement.

5.1.10 Spectrum Analyzer (optional)

5.2 Follow all calibration requirements recommended by the manufacturers of the test equipment, including adequate warm-up and stabilization time.

5.3 Setup Verification

5.3.1 Connect the equipment as depicted in Figure 1. Bypass the DUT with a straight coaxial connection from the combined analog and digital to the input of the bandpass filter.

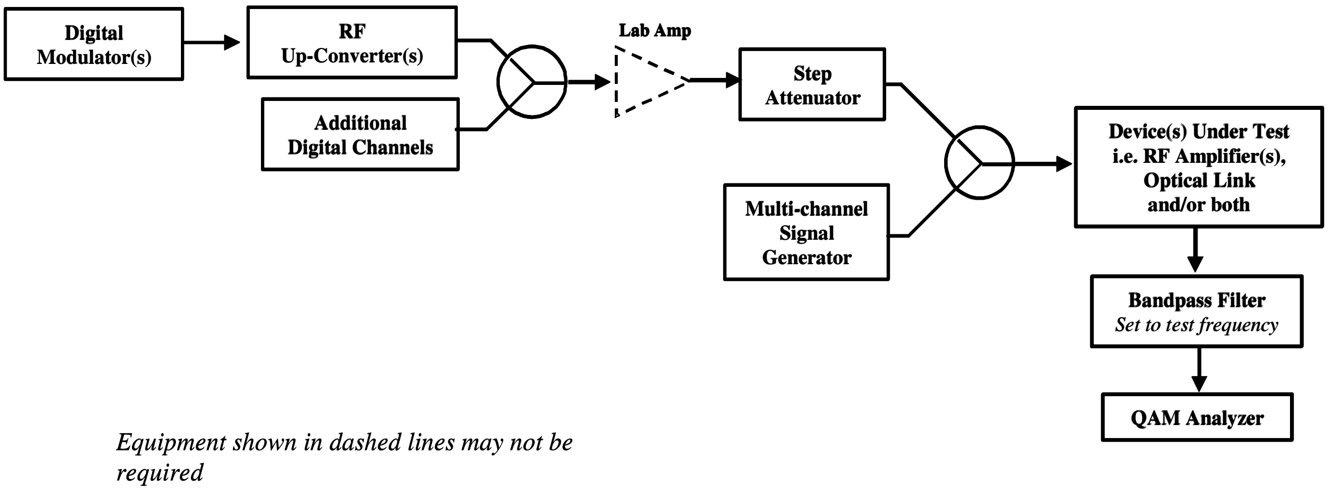

Figure 1 – Downstream BER Test Diagram

5.3.2 Digital Modulator

- Set the modulation to the proper format (i.e. 64 or 256 QAM)
- Set the Symbol Rate according
  - Annex B
    - 64 QAM – 5.056941Msps
    - 256 QAM – 5.360537Msps
  - Annex C
    - 64 QAM – 5.309734Msps
    - 256 QAM – 5.309734Msps
- Information bit rate / Transmitted bit rate
  - Annex B
    - 64 QAM – 26.97035Mbps / 30.342Mbps
    - 256 QAM – 38.81070Mbps / 42.8843Mbps
  - Annex C
    - 64 QAM – 29.359708Mbps / 31.644Mbps
    - 256 QAM – 39.146278Mbps / 42.192Mbps
- Set the Interleaver accordingly
  - Annex B
    - 64 QAM – I=128, J=4
    - 256 QAM – I=128, J=4
  - Annex C
    - 64 QAM – I=12, J=17
    - 256 QAM – I=12, J=17
- Set the Roll-off Factor accordingly
  - Annex B
    - 64 QAM – 18%

- 256 QAM – 12%
- Annex C
  - 64 QAM – 13%
  - 256 QAM – 13%

5.3.3 RF Upconverter

- Set the RF center frequency as required per the channel plan
  - As a minimum, the first and last digital channel performance should be verified for BER performance.
- The RF output level should be adjusted such that all digital channels are at an equal level as indicated in Figure 2.

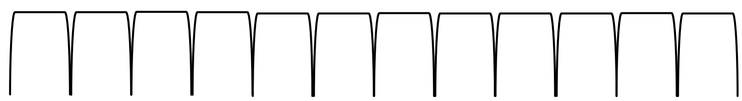

Figure 2 – QAM only Display

5.3.4 Simulated Digital Loading (optional)

- When using a combination of Simulated Digital Loading (AWGN) and QAM channels, the actual QAM channel will appear to be higher in level than the SDL when viewed on a spectrum analyzer. This is due to the fact that the total channel power is within a 5.06MHz (64 QAM, Annex B) or 5.36MHz (256 QAM, Annex B) spectrum versus the 6MHz of the SDL. The total power within a 6MHz channel is to be equal. This may be accomplished by setting the spectrum analyzer to measure power per 6MHz channel or measuring in power/Hz.

Figure 3 – QAM & AWGN Display

5.3.5 Step Attenuator

- Adjust the step attenuator in order to achieve the DUT specified input for the digital channel loading relative to the analog input.

5.3.6 Multi-channel generator

- Each channel to be operated as a CW tone (Continual Wave) at its specified operating level.

- Set the output to provide all of the signals need for the applicable frequency plan.
- The analog carrier frequencies for noncoherent frequency plans should be randomly dispersed with a +/-5 kHz about the nominal visual carrier frequency, in order to obtain the most stable, repeatable result.

5.3.7 Input the combined analog and digital channel loading to the 6MHz bandpass filter. Tune or select the center frequency of the filter to the center frequency of the channel under test.

5.3.8 Input the filtered test channel to the QAM analyzer.
- Ensure that the input of the QAM analyzer is at the proper RF level. Refer to the manufacturer's specification sheet.

5.3.9 QAM Analyzer
- Mode
  - J.83, Annex B or J.83, Annex C
- Modulation format
  - 64 or 256 QAM
- Set the Symbol Rate according
  - Annex B
    - 64 QAM – 5.056941Msps
    - 256 QAM – 5.360537Msps
  - Annex C
    - 64 QAM – 5.309734Msps
    - 256 QAM – 5.309734Msps
- Saw Filter
  - 6MHz
- Set the Roll-off Factor accordingly
  - Annex B
    - 64 QAM – 18%
    - 256 QAM – 12%
  - Annex C
    - 64 QAM – 13%
    - 256 QAM – 13%
- Adaptive Equalizer
  - On
- Center frequency tuned to the channel under test

5.3.10 Set the QAM analyzer for a 1 minute averaged BER test. Enable the modulator forward error correction (Annex B or Annex C).

5.3.11 Per the test equipment manual, reset the BER results and begin the 1 minute averaged BER test. Ensure that both the post-FEC and pre-FEC BER are error free.

5.3.12 If the test fails to meet error free performance, verify the setup connections, the tuning of the Bandpass filter, proper RF levels, modulator/demodulator settings, as well as the QAM Analyzer settings. If pre-FEC error free performance is unobtainable, ensure that the setup has sufficient performance margin (at least two orders of magnitude) such that it will not impact the measurement of the DUT. Refer to the equipment manufacturers manuals as needed.

6.0 PROCEDURE

6.1 Connect the DUT into the test setup as indicated in Figure 1. Verify that the DUT input is per specification.

6.2 Adjust the levels of the DUT {optical link and/or RF amplifier(s)} as specified.

6.3 Ensure that the input of the QAM analyzer is at the proper RF level. Refer to the manufacturer's specification sheet.

6.4 Set the QAM analyzer, for a 1 minute averaged BER test. Enable the modulator forward error correction (Annex B or Annex C).

Note: A sequential grouping of the individual 1-minute tests will be performed in order to complete the overall test. See Appendix A for a detailed explanation as to the overall integration time.

6.4.1 Per the test equipment manual, reset the BER results and begin the 1 minute averaged BER test.

6.4.2 At the conclusion of the 1-minute test, record the pre-FEC BER results and immediately reset the BER measurement in order to begin the next series of the data compilation.

Note: The accuracy of the pre-FEC BER results have been compromised once any post-FEC bit errors have occurred. If any post-FEC errors are recorded, disregard the pre-FEC BER results.

6.4.3 Repeat 6.4.2 until the entire data set is completed. The final results must clearly indicate whether Annex B or Annex C FEC encoding was utilized.

Note: Some test instruments can be set up to achieve minute by minute average BER results during a multiple minute test. Provided the BER test sample period is less than or equal to one minute, any 'sub-minute' test period BER results can be averaged in order to determine the average BER per each one minute time period. For example, if BER is measured in one second samples, the average of 60 contiguous samples would equal the average BER for a one minute period. In this case, the analyzer test duration is set for the total, desired test time. The one second samples are extracted and the individual 1-minute results are created at the conclusion of the entire test.

Consult the test equipment manufacturer's procedures for information on setting up the instrument.

APPENDIX A: TEST INTEGRATION TIME

The BER test integration time is merely the length of time that the test is allowed to run before taking a measurement or considering the test complete.

Determining the test integration time (length of the test) involves a couple of parameters. First, the length of the test is directly related to how small of a BER value is attempting to be measured. For example:

Assuming that the desired measurement is 1e-12 with a 256 QAM signal
1 / (1e-12) = 1e12 bits
1e12 bits / 42.8843Mbps *(transmitted bit rate)* = 23.3186e3 seconds
23.3186e3 seconds = 6.4774 hours

Assuming that the desired measurement is 1e-9 with a 256 QAM signal
1 / (1e-9) = 1e9 bits
1e9 bits / 42.8843Mbps = 23.3186 seconds

The next parameter to consider is an averaged BER measurement over 15 minutes, or longer, can mask a short duration anomaly by averaging its affects across the entire 15+ minute test. Linking several shorter tests together in order to complete one whole test can overcome this issue. For example:

Transmitted bit rate = 42.8843Mbps (256 QAM)

Assuming a 1-minute test in which 100 randomly dispersed errors occur.
42.8843Mbps * 60seconds = 2.5731e9 bits
100 errors / 2.5731e9 bits = 3.8864e-8 BER

Assuming a 15-minute test in which each 1-minute block yields the same 3.8864e-8 result, the end result would of course be identical. In this case the 15-minute test would not produce any issues.

Now assume that one of the 1-minute blocks has an additional burst of 3000 errors.

<u>Averaging all errors across 15 minutes:</u>
42.8843Mbps * 60seconds * 15minutes = 38.5959e9 bits
(1400+3100 errors) / 38.5959e9 bits = 1.1659e-7 BER

<u>Using individual 1 minute tests:</u>
42.8843Mbps * 60seconds = 2.5731e9 bits
3100 errors / 2.5731e9 bits = 1.2048e-6 BER
This particular 1-minute block would indicate a BER of 1.2048e-6, while the remaining 14 blocks would each show 3.8864e-8

The end result of the averaged, 15-minute test produces a result which can lead to a misconception of an acceptable margin. By looking at 15 separate 1-minute blocks, the potential issue of less BER margin is identified.

In determining the total test integration time or the time to complete the entire test, it is suggested that the test be allowed to run such that at least 100 errored seconds are incurred.

APPENDIX B: ERRORED AND ERROR-FREE SECONDS

In addition to Bit Error Rate, another important parameter, which can be recorded during the BER test, is Errored and Error-Free Seconds. By comparing the ratio of Errored and Error-Free Seconds to the total test time, the clustering/distribution of errors can be identified. The clustering/distribution of the errors will illustrate whether the errors are most likely the result of clipping/compression or noise.

Errors caused by laser clipping tend to be bursty in nature and will not be evenly distributed across the entire test. Conversely, errors produced as a result of Gaussian noise will be more uniformly dispersed and of a shorter duration.

Typically the overall Bit Error Rate result will be comprised of both types of errors (Burst and Non-Burst). By establishing the dominant error type during the total peak BER, the main contributor can be identified.

The importance of identifying Burst Errors vs. Non-Burst Errors further manifests itself into determining the amount of performance margin that is available. In an AWGN channel, the ratio between pre-FEC and post-FEC BER will be much greater than that of a laser clipped channel. In other words, a change to the pre-FEC BER within a laser clipped channel will have a larger impact to the post-FEC BER than it would in an AWGN channel.