Measuring and Qualifying the Docsis Upstream Path

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My Business Card

Tom Scanlin
Regional Sales Engineer
Sunrise Telecom Broadband
708-751-7510
tscanlin@sunrisetelecom.com
www.sunrisetelecom.com
Better understand how to make upstream signals and measurements
What are the signal impairments on the reverse path
Agenda

- Return Path Measurements
  - Spectrum Analysis
  - Constellation
  - MER and BER
  - Adaptive Equalizer
  - Case Study

- Return Path Alignment
  - Node Optimization
    - Laser link optimization
    - Return receiver optimization
  - Coaxial Plant Alignment and sweep

- Troubleshooting Hints
Why 64-QAM?

- Higher upstream data throughput required for:
  - Voice
  - Peer to Peer
  - Up to 120 Mbs for 4 bonded channels for DOCSIS 3 in the upstream
  - Competition
  - Business Services
Upstream 64 QAM Challenges

- Once interference occurs in voice the data cannot be retransmitted.
- Measurements are more difficult because the signals are bursty.
- 64 QAM loses 3 dB of headroom because the maximum modem output is 52 dBmV as opposed to 58 dBmV for QPSK.
More Upstream Challenges with 64 QAM

- 64 QAM is less robust than 16 QAM
  - Requires better SNR and MER

- QAM means that the carrier is amplitude modulated and therefore more susceptible to amplitude based impairments such as:
  - Ingress
  - Micro-reflections
  - Compression
Recommended Network Specifications

- Part 76 of the FCC Rules
- DOCSIS for upstream and downstream
- NCTA Recommended Practices for upstream carriers
Spectrum Analyzer and QAM Upstream Measurements at the headend

- Upstream Carrier Levels
- Spectrum Analysis
- Constellation Measurements and Diagnosis
  - MER, BER, and Constellation Analysis
- Upstream Linear Distortion Measurements
  - Group Delay
  - Amplitude Response
Upstream Signal Measurements
Upstream Level Measurement
The First Step

- Verify the upstream carrier amplitude at the input to the CMTS upstream port is within spec.

- Usually 0 dBmV at the input, some systems may vary.
  - Can be measured using peak power on the preamble of the carrier

- An average power measurement could also be made on a constant carrier injected at the correct level.

- Measure total power at the input to the CMTS (<35dBmV, TP)
Spectrum Analysis
-CNR
-C/I
# DOCSIS Upstream RF Channel Transmission Characteristics

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<td>Amplitude ripple</td>
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<td>Seasonal and diurnal signal level variation</td>
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Upstream CNR

- Check the upstream carrier-to-noise, carrier-to-ingress, and carrier-to-interference ratios
  - DOCSIS assumes a *minimum* of 25 dB for all three parameters
  - This is measured at the CMTS upstream port
- Remember that we lose 3 dB of dynamic range with 64 QAM at 6.4 MHz.
- CNR and SNR are different measurements!
CNR or SNR

- **CNR** is a measurement performed on **RF signals**
  - Raw carrier power to raw noise power in the RF transport path only
  - Ideal for characterizing network impairments

- **SNR** is a pre-modulation or post-detection measurement performed on **baseband signals**
  - Includes noise in original signal, transmitter or modulator, transport path, and receiver & demodulator
  - Ideal for characterizing end-to-end performance—the overall signal quality seen by the end user
Upstream Spectrum Analysis

- Make sure noise floor of system is being displayed 10 db out of the spectrum analyzer noise floor

- Use peak hold to capture transients

- Use Averaging to capture CPD
Good CNR and C/I

3.2MHz
Upstream Carrier-to-Interference
Upstream Spectrum Display Showing Laser Clipping
Upstream Spectrum Analysis

- Make sure noise floor of system is being displayed 10 db out of the spectrum analyzer noise floor

- Use peak hold to capture transients

- Use Averaging to capture CPD
Impulse Noise

- Narrowband interference
- High pk-avg, impulsive
- Possible laser overload (wideband components)
- Likely supports 16-QAM
- Insufficient for 64-QAM
Upstream Spectrum Display Showing Laser Clipping
Return Path Constellation Analysis
Upstream Path

AT2500RQv / CM2000E-USG

TYPICAL APPLICATION

- Frequency response alignment or diplex filter roll-off
- Quantify linear distortions between two points
- QAM16/QAM64
- Micro-reflections caused by impedance mismatches
- Group delay
- Non Linear operation of the Return laser
- Bit transmission errors
- Random Non Linear network events detected by Pre-Post BER
A Good 16 QAM Constellation

Zero Bit Errors
CPD and Noise

QAM Analyzer

ATT: 25 dB  16 QAM

CF: 33.000 MHz  Real Symbol: 2.560 MS/s

BER (Pre-Fec): 0
BER (Post-Fec): 0
MER: 30.9 dB
ENM: 2.7 dB
EVM: 1.7%
ES: 0 Sec
SES: 0 Sec
FLS: 0 Sec
UNAV: 0 Sec

Elapsed: 00:26:00  FILTER: 8192
SYMB: LOCK  FEC: LOCK  STREAM: LOCK
Laser Clipping

**QAM Analyzer**

- **ATT:** 15 dB
- **QAM:** 16 QAM
- **CF:** 40.800 MHz
- **Real Symbol:** 2.560 MS/s

**Metrics:**

- **BER (Pre-Fec):** 0
- **BER (Post-Fec):** 0
- **MER:** 26.5 dB
- **ENM:** < 1.0 dB
- **EVM:** 2.9%
- **ES:** 0 Sec
- **SES:** 0 Sec
- **FLS:** 0 Sec
- **UNAV:** 0 Sec

**Status:**

- **Elapsed:** 00:12:00
- **Filter:** 8192
- **Symb:** Lock
- **FEC:** Lock
- **Stream:** Lock
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Adaptive Equalizers

- Corrects for Frequency Response imperfections
- Corrects for Group Delay
- Show impedance mismatches
Adaptive Equalizers

BER (Pre-Fec) = 0
BER (Post-Fec) = 0
MER: > 40.0 dB
ENM: 11.8 dB
EVM: < 0.6 %
ES: 0 Sec
SES: 0 Sec
FLS: 0 Sec
UNAV: 0 Sec

Elapsed: 00:00:04
SYMB: LOCK  FEC: LOCK  STREAM: LOCK
Micro-reflections are **impedance mismatches**

- In the real world of cable networks, 75 Ω impedance is at best considered nominal
- Micro-reflections cause group delay and frequency response problems.
- Impedance mismatches are **everywhere**: connectors, amplifiers inputs and outputs, passive device inputs and outputs, and even the cable itself
- Upstream cable attenuation is lower than downstream cable attenuation, so upstream micro-reflections **tend to be worse.**
- Anywhere an impedance mismatch exists, some of the incident energy is **reflected** back toward the source
Micro-reflections

- Higher orders of modulation are affected by micro-reflections to a much greater degree so **64 QAM is affected more than 16 QAM**

- Upstream micro-reflections and group delay are minimized by using **adaptive equalizers**. This feature is available in DOCSIS 1.1 and 2.0 & 3.0 CMTSs, but not 1.0.
Microreflections

Causes:

- Damaged or **missing** end-of-line terminators
- Damaged or missing chassis terminators on directional coupler, splitter, or multiple-output amplifier unused ports
- **Loose** center conductor seizure screws
- Unused tap ports not **terminated**—this is especially critical on low value taps
- Unused drop passive ports not terminated
- Use of so-called **self-terminating taps** at feeder ends-of-line
Microreflections

Causes (cont’d):

- **Kinked** or damaged cable (includes cracked cable, which causes a reflection *and* ingress)
- Defective or damaged actives or passives (*water-damaged*, water-filled, cold solder joint, corrosion, loose circuit board screws, etc.)
- Cable-ready TVs and VCRs connected directly to the drop (return loss on most cable-ready devices is poor)
- Some traps and **filters** have been found to have poor return loss in the upstream, especially those used for **data-only** service
## Microreflections

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## Amplitude Ripple
( Frequency Response)

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Frequency Response of an Upstream Carrier

ATT: 5 dB  
Modulation: QAM256  
CF: 10.500 MHz  
SES Threshold: 5.0e-003  
Real Symbol: 5.120 MS/s

BER (Pre-Fec)
0.0e-12

BER (Post-Fec)
0.0e-12

MER: 31.5 dB

ENM: 3.3 dB

EVM: 1.6 %

ES: 0 Sec

SES: 0 Sec

FLS: 31 Sec

UNAV: 0 Sec

Frequency Response

Elapsed: 00:00:00

SYMP: LOCK  
FEC: UNLOCK  STREAM: UNLOCK
Group Delay

- Different data travels through the same medium at different speeds. This is Group Delay.
- Group delay is defined in units of time, typically nanoseconds (ns) over frequency. In other words how much GD per each MHz.
- In a system, network or component with no group delay, all frequencies are transmitted through the system, network or component with equal time delay.
- Frequency response problems in a CATV network will cause group delay problems.
- Group delay is worse near band edges and diplex filter roll-off areas.
Upstream frequency

- Keep the upstream QAM digitally modulated carrier well away from diplex filter roll-off areas (typically above about 35~38 MHz), where group delay can be a major problem.

- Choose an operating frequency that will minimize the likelihood of group delay.
  - Frequencies in the 20~35 MHz range generally work well.

- Group delay may still be a problem when the frequency response is flat.
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Group Delay Measurement

- BER (Pre-Fec): 0.0e-12
- BER (Post-Fec): 0.0e-12
- MER: 31.6 dB
- ENM: 3.4 dB
- EVM: 1.6 %
- ES: 0 Sec
- SES: 0 Sec
- FLS: 94 Sec
- UNAV: 0 Sec

Group Delay

- Elapsed: 00:00:00
- TXNR: LOCK
- FEC: UNLOCK
- STREAM: UNLOCK

ATT: 5 dB, Modulation: QAM256, SES Threshold: 5.0e-003, Real Symbol: 5.120 MS/s
Statistics Mode

- ATT: 60 dB
- QAM
- PL: 0.0000%

- BER (Pre-Fec)
  - AVG: 4.0E-08

- BER (Post-Fec)
  - AVG: 0

- MER: 38.1 dB
- ENM: 9.9 dB
- EVM: 0.7%

- ES: 0 Sec
- SES: 0 Sec
- FLS: 0 Sec
- UNAV: 0 Sec

- Elapsed: 01:00 of 1 (Min)

- SYMB: LOCK
- FEC: LOCK
- STREAM: LOCK

- QAM ANALYZER
- SES THR: 5.0E-03
- CONST. => STAT.
- EQUAL. ANALYSIS
- DIGITAL CHANNEL POWER
- STAT. PERIOD
- START => STOP STAT.
- SET QAM PARAMETERS
- MORE
- 1/2

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Some things to check out!

- Before adding a 64 QAM carrier the following should be checked
  - Compression of the return laser due to added carrier or a carrier with added bandwidth
  - MER and BER over a period of time
  - Group Delay of a new carrier
  - MER and BER of the new carrier.
  - Amplitude Ripple
  - Microreflections
A Case Study
Upstream Spectrum

Tech Name: Unavailable
Site Id: Unavailable
Comments: DOCSIS CARRIER 32MHZ
Mode: SA
Date: December 02, 2004 05:13:27 AM
Temperature: 23 °C

A1T: 26 dB  OFS: 0 dB
VSW: 100 kHz
CF: 50.000 MHz
SPAN: 100.0 MHz

Marker V1: 32.750 MHz
Marker V2: 27.500 MHz
Delta: 5.250 MHz

No Average
ATT: 30 dB  
Modulation: QAM16  
Upstream QAM16  
CF: 23.000 MHz  
SES Threshold: 5.0e-003  
Real Symbol: 2.560 MS/s

BER (Pre-Fec): 0.0e-12
BER (Post-Fec): 0.0e-12
MER: 31.5 dB
ENM: 3.3 dB
EVM: 1.9 %
ES: 0 Sec
SES: 0 Sec
FCS: 0 Sec
UNAV: 0 Sec

Oops!

Elapsed: 00:00:00
SYMB: LOCK  
FEC: LOCK  
STREAM: LOCK
D = 492(\text{VP/F}) = 492(87\%\div0.4\text{MHz}) \approx 1100 \text{ feet}
Peak to Valley Group Delay ≈ 270 nSeconds
Bit Errors

AT:  20 dB  Modulation: QAM16  SES Threshold: 5.0e-003
Upstream QAM16  CF:  23.000 MHz  Real Symbol: 2.560 Ms/s

BER (Pre-Fec)
AVG  7.8e-008
BER (Post-Fec)
AVG  0.0e-12

MER:  23.1 dB
ENM:  < 1.0 dB
EVM:  5.2 %

ES:  0 Sec
SES:  0 Sec
FLS:  0 Sec
UNAV:  0 Sec

Elapsed: 00:03:00 of 3 (Min)
SYMB: LOCK  FEC: LOCK  STREAM: LOCK
Effects of Over-Driving a Laser
Moral of the Story?

- CNR and Distortion measurements from a spectrum analyzer are great but, don’t tell the whole story.
- Other digital measurements are advised using a vector analyzer to ensure QAM reliability
  - MER and BER
  - Group Delay and other Equalizer measurements
  - Constellation
  - Statistic Measurement
Measurement Summary

- Check for laser clipping
- Measure over time
- Measure for frequency response of the carrier
- Measure group delay of the carrier
- Measure MER and BER of upstream carrier
- Can be accomplished by inserting a QAM carrier at the EOL and using a digital analyzer in the headend.
64 QAM Pre-Launch Checklist

- CMTS modulation profile optimized for 64-QAM
- Vector Analysis, not just spectrum analysis
- Entire cable network—headend, distribution network and subscriber drops—DOCSIS-compliant
- Select upstream frequency that avoids diplex filter roll-off area
- Forward and reverse properly aligned
- Signal leakage and ingress management
- Good installation practices
Ron Hranac wrote the book

- Hranac R., “CNR versus SNR” March 2003 *Communications Technology*
- Hranac R., “Spectrum analyzer CNR versus CMTS SNR” September 2003 *Communications Technology*
- Hranac R., “16 QAM Plant Preparation”
- Hranac R., “Deploying VOIP on the Outside Plant”
- Hranac R., “Linear Distortions,” Last 2 issues of CT Magazine
References

- “RF Impairments in the Return Path and their impact on DOCSIS performance”, by Jack Moran, Motorola
- “Modern Cable Television Technology”, by Walter Cicora, James Farmer and David Large
- Return Path Familiarization and Node Return Laser Setup,” by Frank Eichenlaub, Cisco Systems
- Characterizing and Aligning the HFC return path for Successful DOCSIS 3.0 Rollouts, Dr. Robert L. Howald et all, Motorola, SCTE Cable Tech Expo 2009
More References

- “Seek Balance in All Things” A Look at Unity Gain in the Upstream Coax Plant, by Ron Hranac, Communications Technology, June 2000
- “A Primer on Common Path Distortion”, by Nick Romanick, Communications Technology, April 2001
- “
Thank You!
The return optical link
Return Optics

- We discuss this first because it has the greater impact on the MER at the CMTS input because it has the lowest dynamic range.
- Optimized by measuring NPR at the input to the CMTS by injecting different total power at the input to laser.
- Carriers should be derated according to bandwidth using power per hertz.
- Not part of the unity gain portion of the HFC plant.
- Set up is laser and node specific.
Power per Hertz Calculation

Power per Hertz

\[ \text{dBmV/Hz} = \text{Total Power} - 10 \log (\text{BW}) \]
\[ \text{dBmV/Hz} = 45 - 10 \log (37,000,000) \]
\[ \text{dBmV/Hz} = 45 - 10 (7.57) \]
\[ \text{dBmV/Hz} = 45 - 75.7 \]
\[ \text{dBmV/Hz} = -29.3 \]

Total Power Input for 6.4 MHz 64 QAM

\[ \text{dBmV} = -29.3 + 10 \log (\text{BW}) \]
\[ \text{dBmV} = -29.3 + 10 \log (6,400,000) \]
\[ \text{dBmV} = -29.3 + 10 (6.8) \]
\[ \text{dBmV} = -29.3 + 68 \]
\[ \text{dBmV} = 38.7 \]
Total Power

25 dBmV

5 MHz

500 MHz
Several Carriers:

- Total Power = Carrier Level + 10 log (# of carriers)
  - Total Power = 25 dBmV + 10 log (6)
  - Total Power = 25 + 7.78 = 32.78 dBmV
Minimum CNR requirements to get 1E-7 BER (not good enough)

- QPSK 15 dB
- 16 QAM 22 dB
- 64 QAM 28 dB plus a window
Finding the “X” value in the headend

To return receiving equipment

X

4.1 dB

3.7 dB

3.5 dB

4.3 dB
Headend combining and splitting

Other Return Services

CMTS

Telephony

Set top converter
The outside plant
Why do we need Unity Gain?

If Unity Gain is not observed distortions and or noise build up quickly!
Unity Gain in the forward path

Each amplifier compensates for the loss in the cable and passives before the amplifier under test. The system is aligned so that the levels at each green arrow are exactly the same.
If the return amplifiers were balanced with constant outputs, the levels would vary widely by the time they got back to the headend. This is due to return amplifiers having several inputs.
In the return path, amplifier outputs are balanced for a constant input to the next amplifier upstream. This maintains Unity Gain, but makes the measurement more difficult.
How is a reference level determined?

From trunk return

52 dBmv modem output
23db tap
2 dB drop loss
7 dB directional coupler

20dBmV at the reference point

23
Advantages of return sweep over the older methods

- Not as labor intensive as the older methods.
- Align forward and reverse with the same stop at the amplifier.
- No cumbersome equipment in the field or the headend.
- Minimum use of bandwidth for test equipment.
- Control over the measurements.
- We are aligning the entire spectrum in both directions, not just 2 carriers!
5 steps to set up your return path correctly

- Know your equipment
- Determine reference levels
- Determine reference points
- Optimize return lasers portion first
- Sweep coaxial portion of the plant
Know your equipment, know your system

- Block diagrams of amplifiers, nodes, receivers, etc.
- Test Equipment
- What are the return design levels
- What are the injection points
Injection levels

21 dBmV at the reference points means an injection level of 41 dBmV
Upstream Impairments

- RF Ingress
- Intermodulation Distortions
- Laser Clipping
- Group Delay
- Amplitude Response
Common Path Distortion

- A series of beats easily seen in the return spectrum at repetitive 6 MHz spacings
- Ingress does not cause repeatable patterns
- Usually caused by corrosion at a dissimilar metals interface acting as a diode
- Actually caused by the forward carriers and also increases distortions in the forward path
- The higher in level the forward carrier levels are at the source of the problem, the worse CPD will be
Crystallization occurs and the corrosion creates thousands of small diodes between the two metals.

Diodes are non-linear devices that can act as frequency “mixers” in a CATV plant.
Frequency Mixing

Mixing two frequencies (F1 & F2) will yield four results:

- F1: 55.25 MHz
- F2: 61.25 MHz
- F1 + F2: 116.50 MHz
- F2 – F1: 6.00 MHz
Common Path Distortion

- A corroded connection causes mixing
- The resulting impedance mismatch also causes reflections
- The mixing products are reflected right back into the return amplifier.

Downstream Signals

(~6, 12, 18, 24…)

Difference frequencies reflected upstream
Because the channels in the forward system are 6 MHz apart, the sum and difference frequencies occur at 6 MHz intervals as well.
CPD common sources

- Loose or over-tightened seizure screws
- **Loose** hold down screws on modules and circuit boards
- Feed through connectors
- **Loose** and corroded terminators on taps
- Bad line terminators on taps
- Anything that allows *moisture* to enter a device
CPD troubleshooting tips

- When return sweeping, set up sweep from 5-50 MHz
- Check distortions on the forward path above your highest channel
- Once the feeder leg is found, troubleshoot from the termination and work back toward the amplifier
Ingress

- Ingress is a combination of random and periodic noise and discrete signals leaking into the cable
- Usually generated in the customer’s home
- Excessive ingress can cause the return laser to clip, but not usually
- Ingress from anywhere affects the entire system
- One bad egg takes down the node
Where does Ingress come from?

Upstream Over-The-Air Spectrum, 5-30 MHz

Source: NTIA (http://www.ntia.doc.gov/osmhome/allochrt.pdf)
Impulse Noise

- Short duration usually less than 100 micro seconds.
- Use peak hold
- Sources:
  - Ignitions
  - Arc Welders
  - Vacuum Cleaners
  - Electric Motors
Ingress is always worse from the lower value taps!

Forward Losses

Reverse Losses

45 dBmV output at design frequency
How can we minimize ingress?

- Quality cable and connectors
- Good installation practices
- Better than mandatory leakage program
- Taps with equalizers
Troubleshooting Goals

- To be able to localize problems without taking the system down!
- Identify problems from the field without a trip to the hub or headend first.
  - Visibility into at the hub or headend the return path from the field
Troubleshooting

- Isolate the node
- Isolate the feeder
- Isolate the tap
Troubleshooting Hints and Tools

- Know your test equipment
- Know your amplifier configurations
- Low pass filter on the spectrum analyzer
- AC blocking seizure screw probe
- Tap jumpers
- Return Path problems have relative levels depending on where they are being measured
Using a Low Pass Filter

Without a low pass filter

With a low pass filter
3010R Return Spectrum

Current Node
Typical Node RF Block Diagram

Fwd Signal from Optical Rcvr.

Return Signal to Optical Transmitter

Port 3 Output TP

Port 4 Output TP

Port 5 Output TP

Port 6 Output TP

STATION

FWD EQ

FWD PAD

LOW PASS FILTER

Diplex Filter

Diplex Filter

Diplex Filter

Diplex Filter

REV Switch

REV Switch

REV Switch
(1) Test Points are Bi-Directional
Notes: ALL test points can be -20 or -25dB
Difference Between Ports on an Amplifier

Ingress on port 4 test point

Ingress on port 3 test point
Troubleshooting to the tap

Tap Isolation
20dB down
Ingress at the input and output seizure

Ingress on the output seizure screw

Ingress on the input seizure screw
CPD and a carrier

- Shortwave Interferer (high level)
- Evidence of CPD tones – tolerable but can degrade and associate with a microreflection
- Noise floor of FP return, stable
- Adequate for 16-QAM, poor conditions for 64-QAM
Constellation Analysis

Patterns in the Constellation
A better parameter than SNR is modulation error ratio (MER) or error vector magnitude (EVM).

MER takes into account:
- CNR
- Phase Noise (jitter of phase of QAM modulator’s carrier)
- Intermod Distortions
- Compression of Lasers and Amplifiers
- Frequency Response
- THE SUM OF ALL EVILS

MER is a single figure of merit for the quality of an RF QAM modulated signal.

MER and EVM are the same thing. MER is expressed in dB; EVM is expressed in %.

Can be directly linked to BER.
Vectors and QAM

I 180°  Q 90°  I 0°

1011

Q 270°

I 0°
Vectors and QAM

The diagram illustrates QAM (Quadrature Amplitude Modulation) with vectors representing different data points. The axes are labeled with I (in-phase) and Q (quadrature) phases, with angles of 0°, 90°, 180°, and 270°. The data points are marked with binary sequences, showing how modulation is applied in different quadrants of the I-Q plane.
Introduction to BER

- Bit Error Rate (BER) is an important concept to understand in any digital transmission system since it is a major indicator of the quality of the digital system.
- As data is transmitted some of the bits may not be reproduced at the receiver correctly. The more bits that are incorrect, the more the signal will be affected.
- BER is a ratio of incorrect bits to the total number of bits measured.
- It's important to know what portion of the bits are in error so you can determine how much margin the system has before failure.
What is BER?

- BER is defined as the ratio of the number of wrong bits over the number of total bits.
- BER is measured by sending a known string of bits and then counting the errored bits vs. the total number of bits sent.
- This is technically an out of service measurement.

\[
\text{Sent Bits} \quad 1101101101 \\
\text{Received Bits} \quad 1100101101
\]

\[
\text{BER} = \frac{\# \text{ of Wrong Bits}}{\# \text{ of Total Bits}} = \frac{1}{10} = 0.1
\]
### What is BER?

- BER is normally displayed in Scientific Notation.
- The more negative the exponent, the better the BER.
- Better than 1.0E-6 is needed after the FEC for the system to operate.
- The only thing you need to remember is the higher the negative exponent the better.

#### Decimal vs. Scientific Notation

<table>
<thead>
<tr>
<th>Decimal</th>
<th>Scientific Notation</th>
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<tbody>
<tr>
<td>1</td>
<td>1.0E+00</td>
</tr>
<tr>
<td>0.1</td>
<td>1.0E-01</td>
</tr>
<tr>
<td>0.01</td>
<td>1.0E-02</td>
</tr>
<tr>
<td>0.001</td>
<td>1.0E-03</td>
</tr>
<tr>
<td>0.0001</td>
<td>1.0E-04</td>
</tr>
<tr>
<td>0.00001</td>
<td>1.0E-05</td>
</tr>
<tr>
<td>0.000001</td>
<td>1.0E-06</td>
</tr>
<tr>
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<td>1.0E-08</td>
</tr>
<tr>
<td>0.000000001</td>
<td>1.0E-09</td>
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#### Lower and Better BER

<table>
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<td>2.0E-06</td>
</tr>
<tr>
<td>0.000001</td>
<td>1.0E-06</td>
</tr>
</tbody>
</table>
Noise and Intermittents

- Errors caused by noise or intermittent causes can have the same BER, but very different effects.
- Errors that are spread out are due to noise problems.
- Errors that are grouped are due to intermittent problems such as ingress or loose connectors.

Spaced Errors: 1101101011010011100

Burst Errors: 1111101011101101101

This Example Shows the Same Error Rate But the Burst Errors are More Difficult to Correct