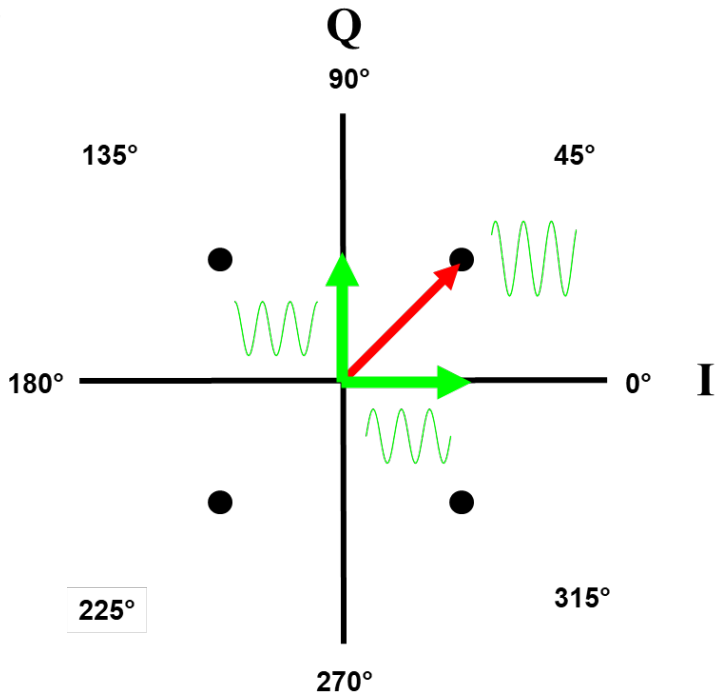
Troubleshooting SC-QAM Channels with a QAM Analyzer

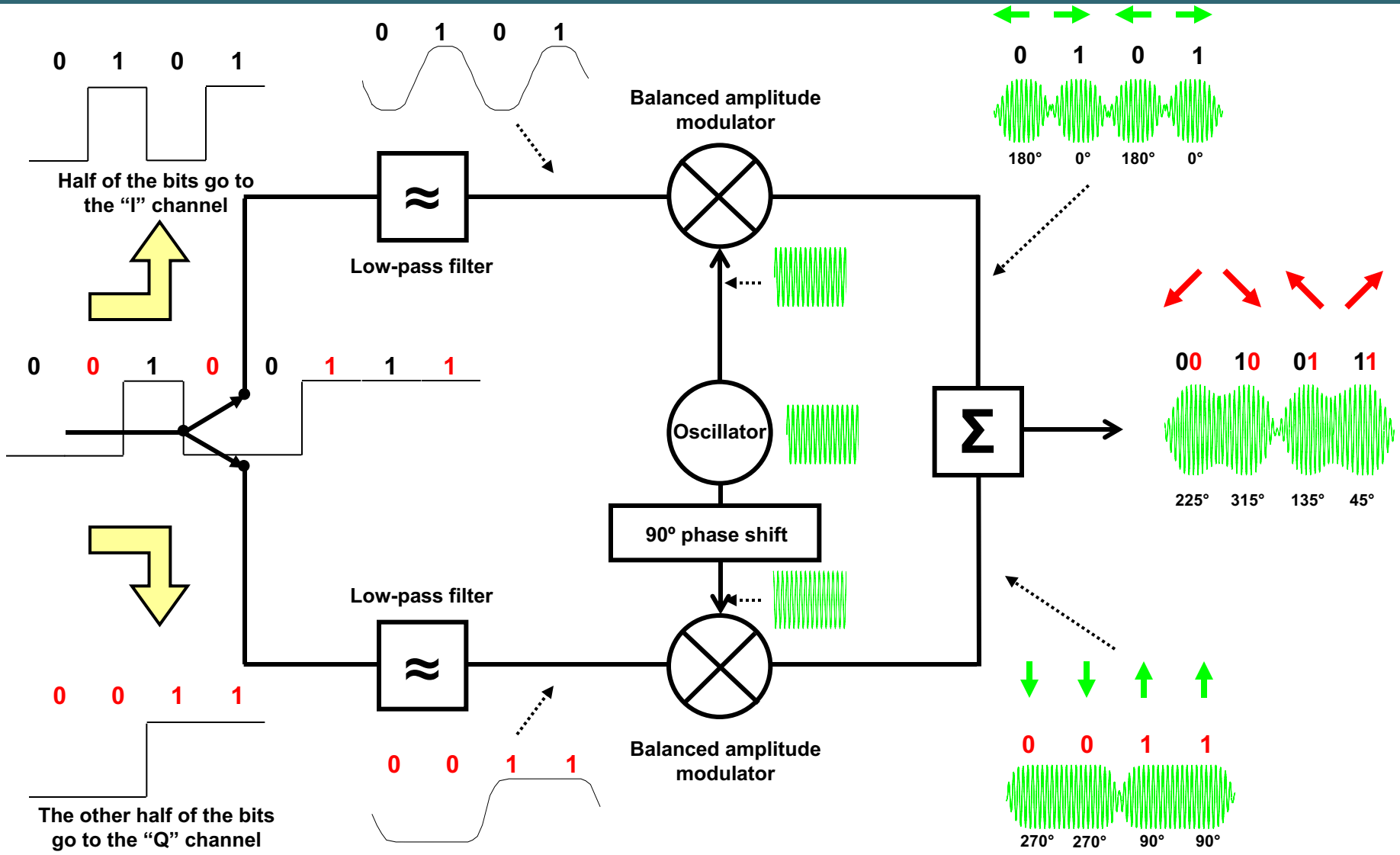
Ron Hranac

Before we Begin

- **SC-QAM: single carrier quadrature amplitude modulation.**
- **Originates in a QAM modulator or edge-QAM modulator, which can be standalone or part of a cable modem termination system (CMTS) or a cable modem.**
- **What is an SC-QAM signal or channel? A double-sideband, suppressed carrier RF signal, in which amplitude and phase variations represent the data being transmitted.**



A Closer Look at a QPSK (4-QAM) Modulator



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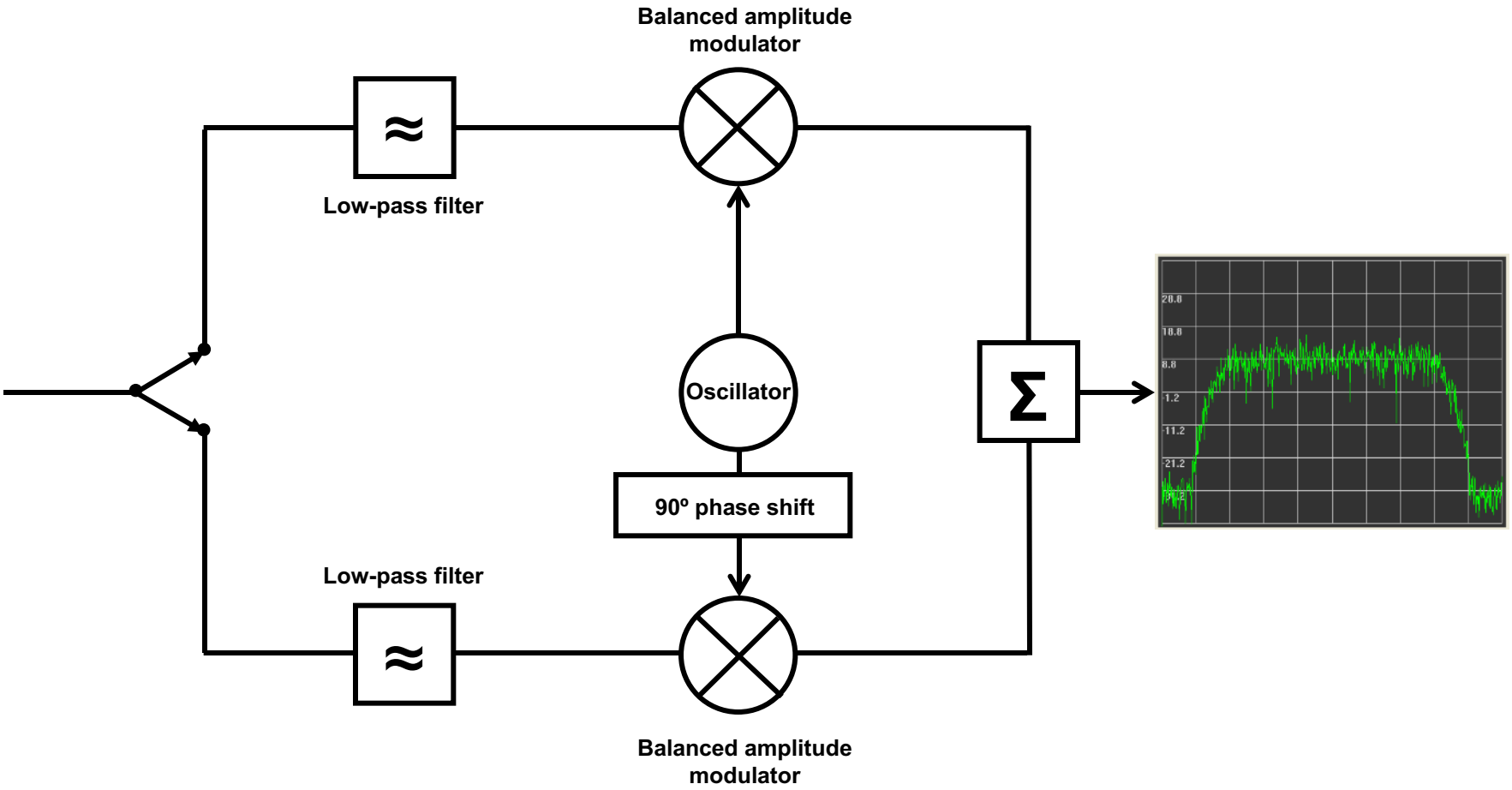
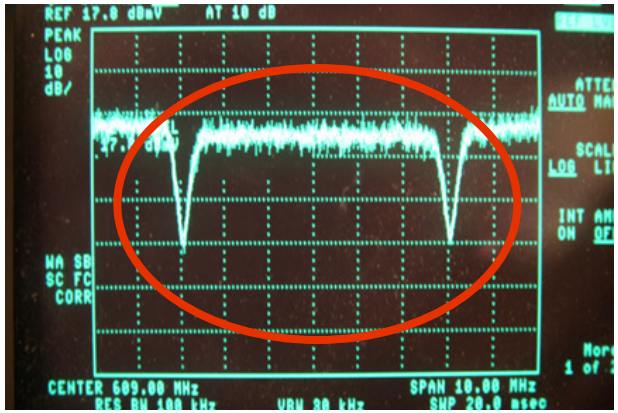


Where's the Problem?

Symptom: Intermittent tiling in digital video services carried on CTA Ch. 88 (609 MHz).



- **What do our signal level meter and spectrum analyzer tell us about the SC-QAM channel?**
  - ✓ **Its digital channel power (signal level) is +6.3 dBmV**
  - ✓ **The "haystack" looks okay**
  - ☞ **Hmmm, must be the STB!**

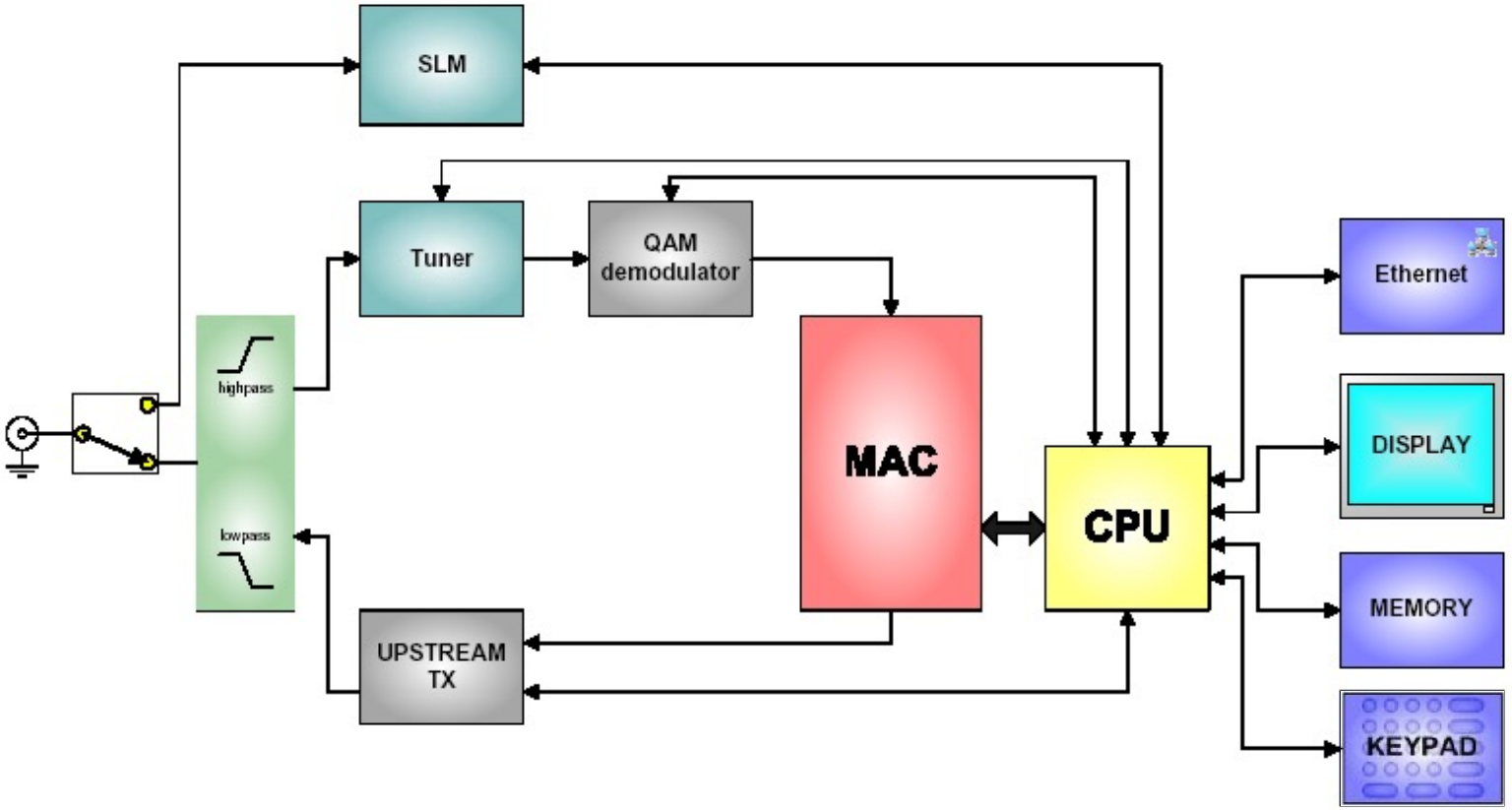
What's Missing?

- **While a signal level meter and conventional spectrum analyzer are valuable tools, they don't tell the whole story about the health of downstream and upstream SC-QAM channels.**
- **How, then, can one "look inside" the haystack to see what's going on?**
- **Use a QAM analyzer (a.k.a. digital signal analyzer)! These instruments support a suite of measurements:**

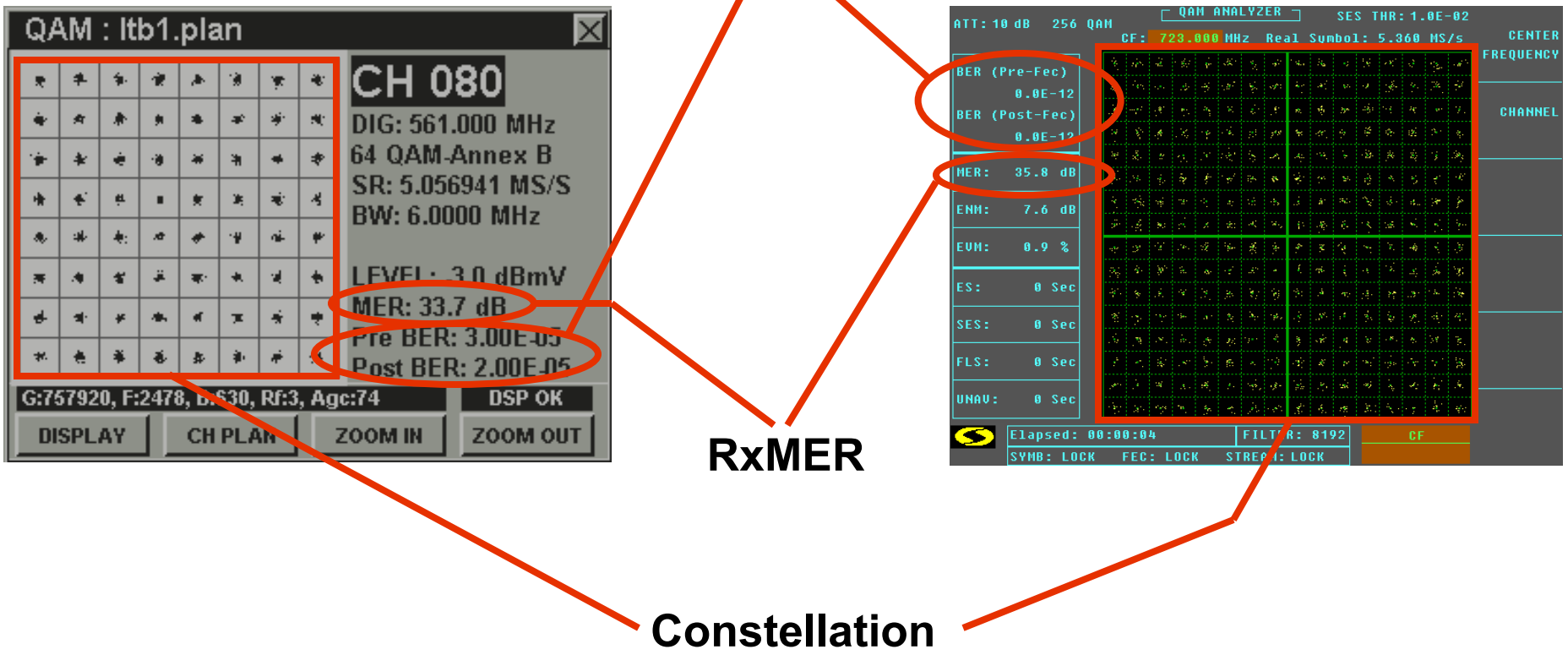
- Analog channel signal level
- Digital channel power (signal level)
- Constellation display
- Receive modulation error ratio (RxMER)
- Pre- and post-FEC bit error ratio
- Adaptive equalizer graph

- Some instruments support other measurements such as frequency response, group delay variation, ingress or interference under the carrier, upstream transmit level, upstream packet loss, ping, throughput, latency and jitter

QAM Analyzer Block Diagram

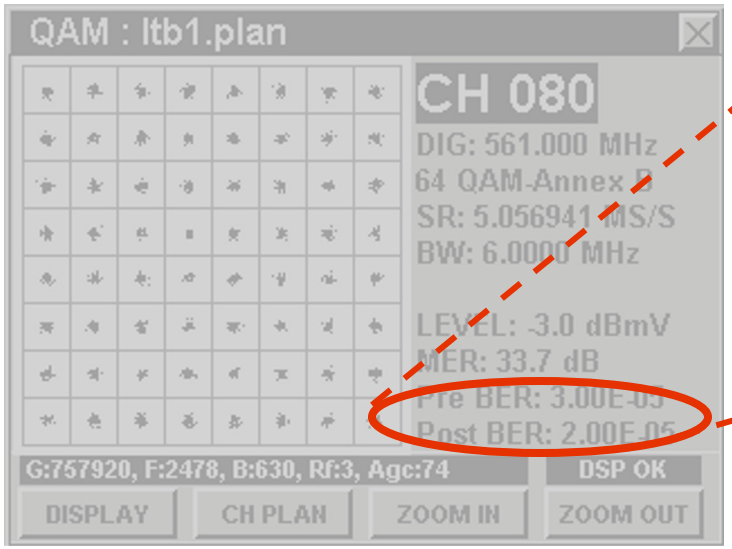


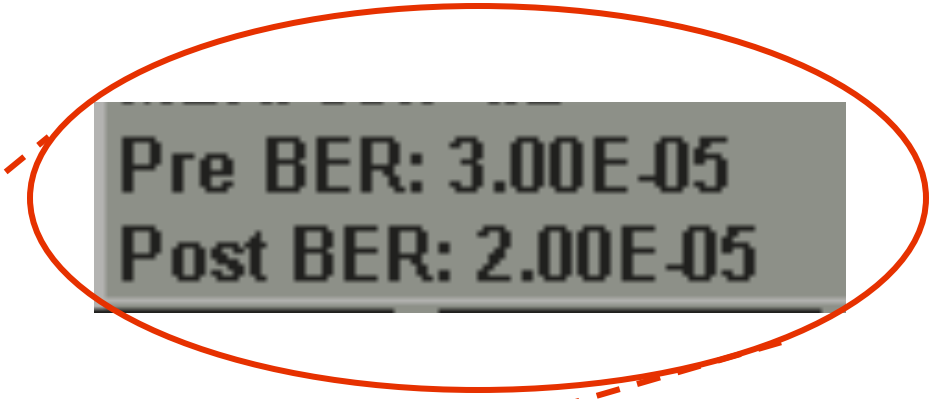
Downstream Performance: QAM Analyzer



Graphics courtesy of Sunrise Telecom and Trilithic

Pre- and Post-FEC BER



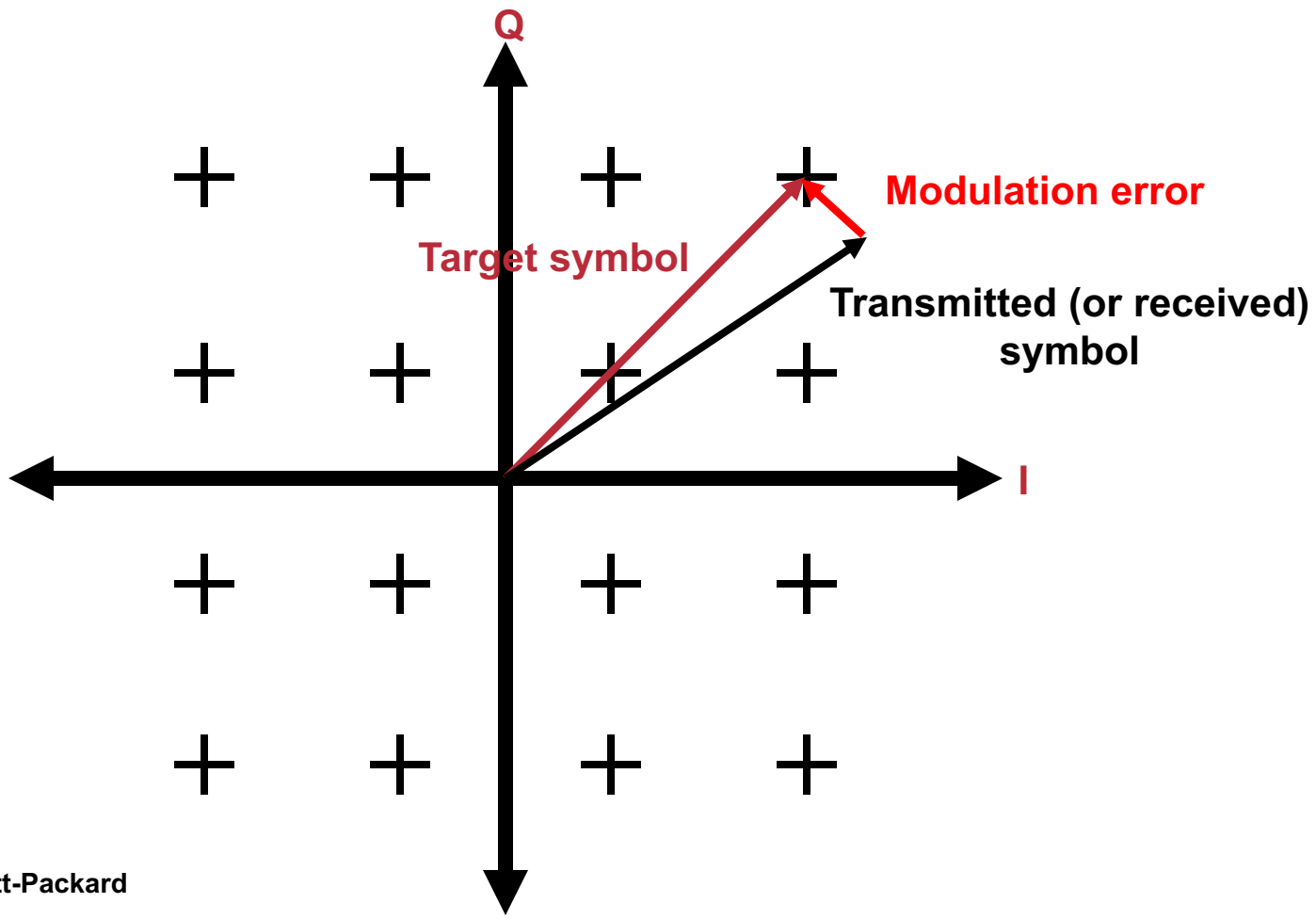


In this example, digital channel power, RxMER and the constellation are fine, but pre- and post-FEC BER indicate a problem—perhaps sweep transmitter interference, downstream laser clipping, a QAM modulator problem, or a loose connection.

Graphic courtesy of Trilithic

Modulation Quality: RxMER

Modulation error = **Transmitted symbol** – **Target symbol**

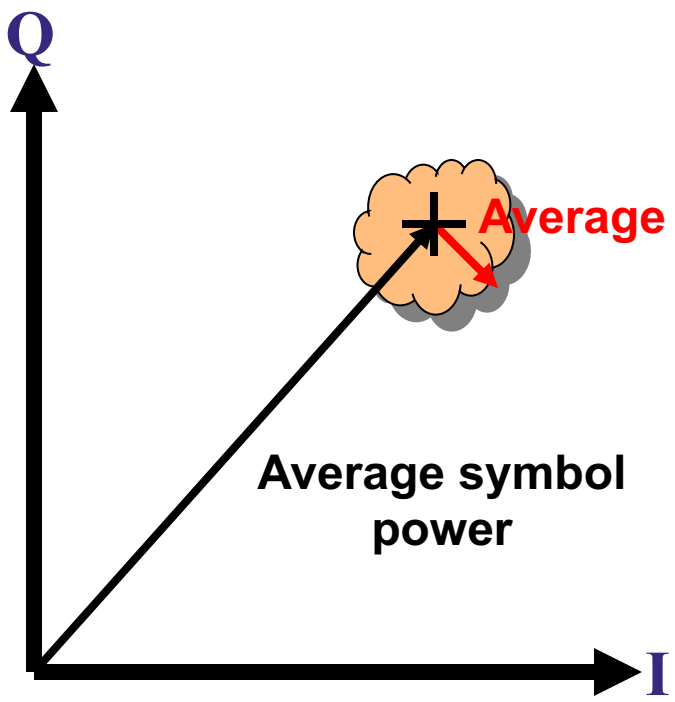


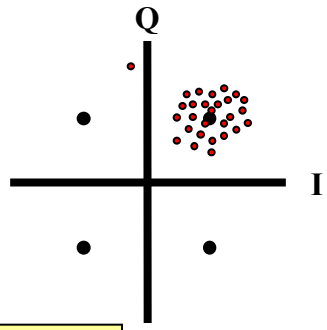
Source: Hewlett-Packard

RxMER

$$MER = 10\log_{10}\left[\frac{\sum_{j=1}^{N}\left(I_j^2 + Q_j^2\right)}{\sum_{j=1}^{N}\left(\delta I_j^2 + \delta Q_j^2\right)}\right]$$

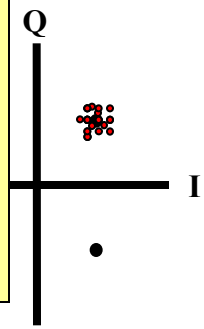
RxMER = 10log(average symbol power/average error power)





A large "cloud" of symbol points means low RxMER—this is not good!

In effect, RxMER is a measure of how "fuzzy" or spread out the symbol points in a constellation are.

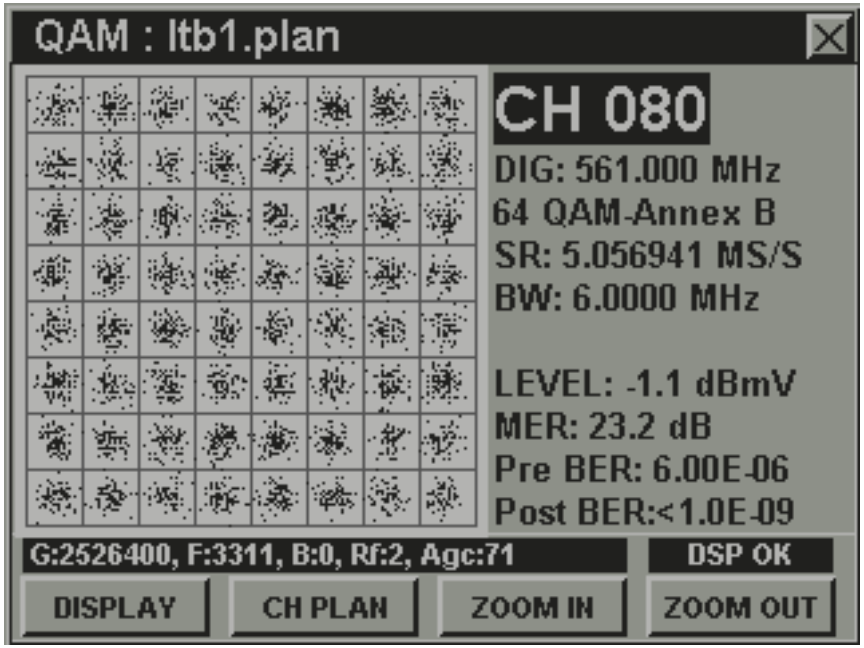


A small "cloud" of symbol points means high RxMER—this is good!

Source: Hewlett-Packard

Constellation Display

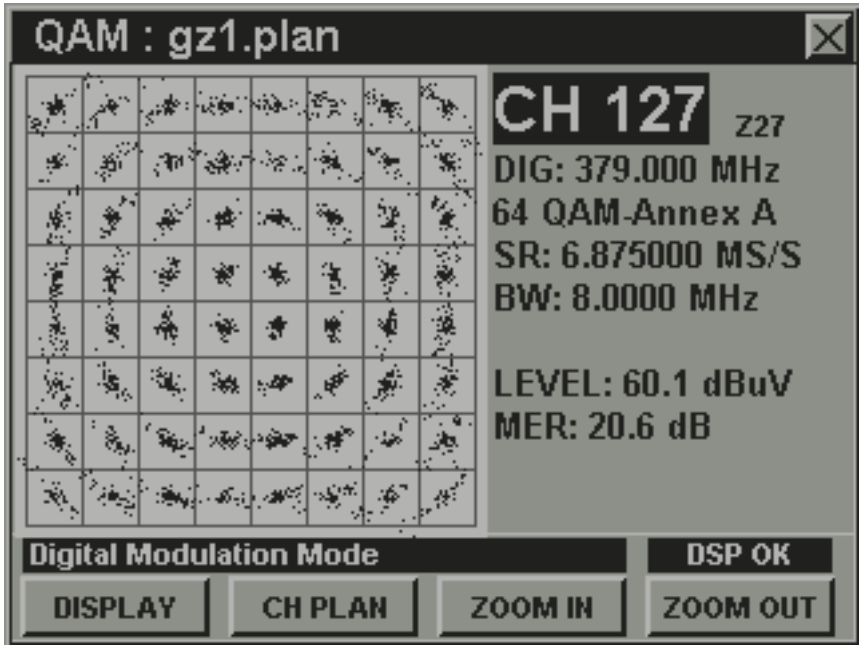
This display shows low RxMER, which could be caused by poor CNR, low signal level, excessive noise-like distortions, ingress, improperly set up amplifier, linear distortions, etc.



Graphic courtesy of Trilithic

Constellation Display

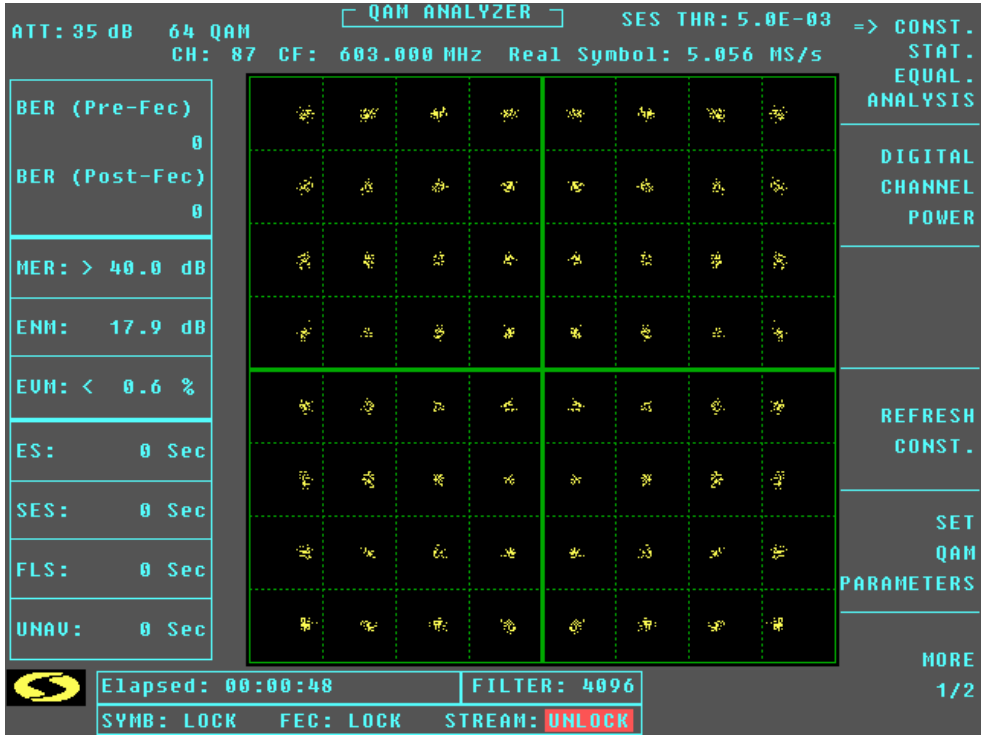
Phase noise – this occurs in the signal source (transmitter or modulator), upconverter, downconverter, or receiver.



Graphic courtesy of Trilithic

Constellation Display

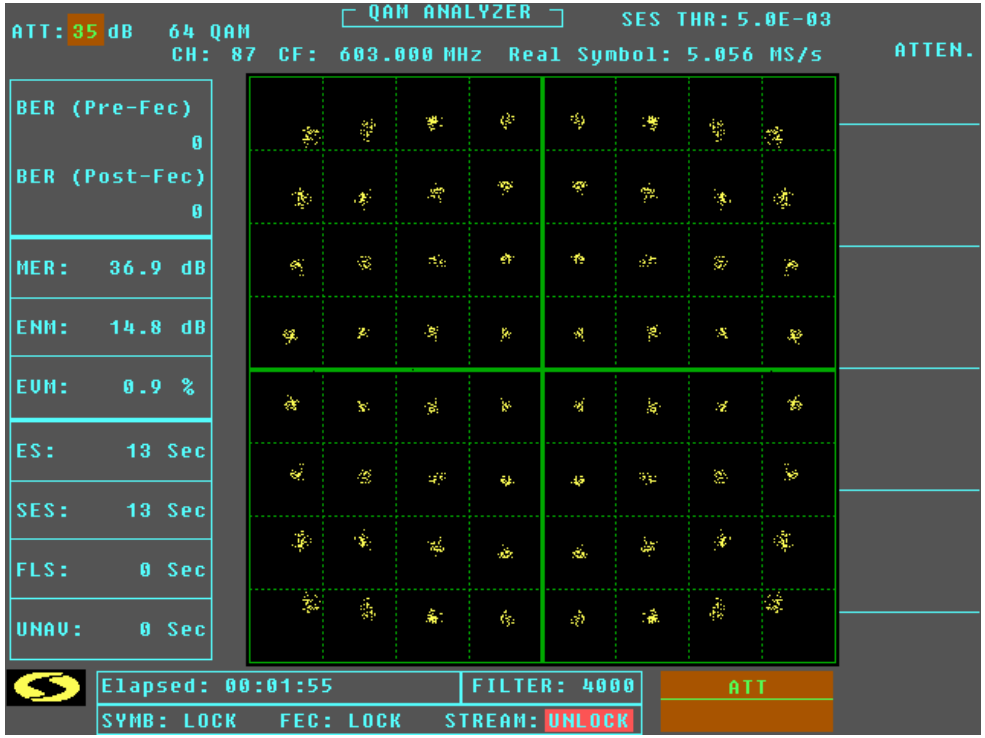
I-Q imbalance – this occurs in the signal source (transmitter or modulator)



Graphic courtesy of Sunrise Telecom

Constellation Display

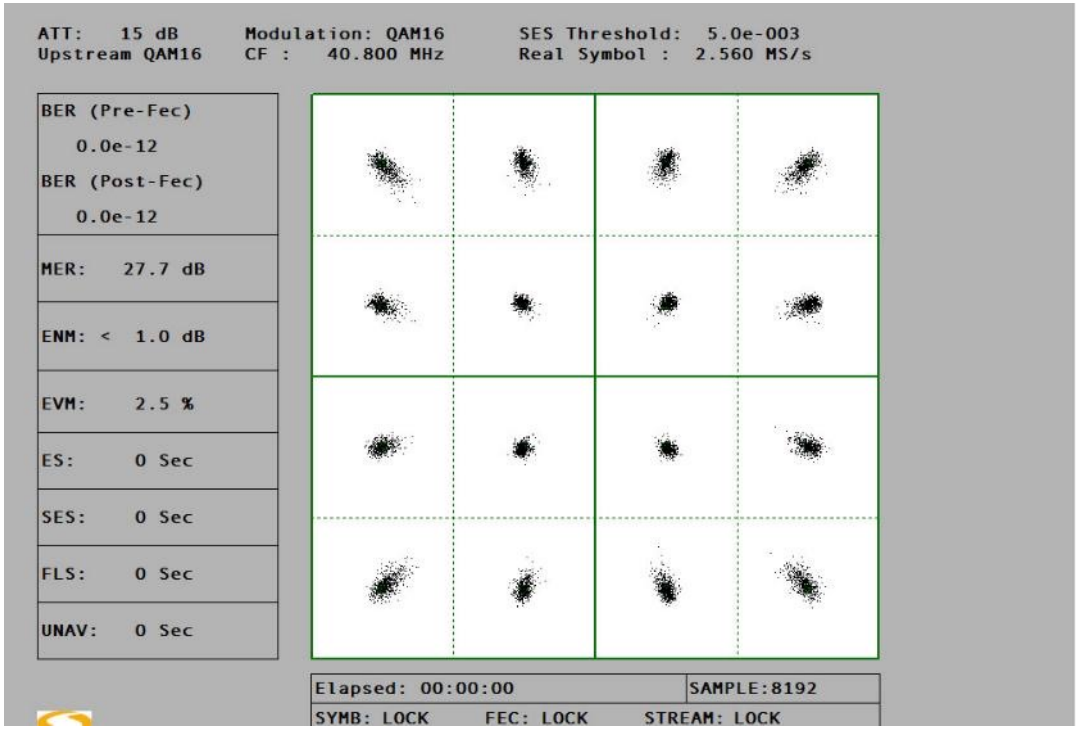
Gain compression – an indication of the onset of clipping (laser, amplifier, or other active device)



Graphic courtesy of Sunrise Telecom

Constellation Display

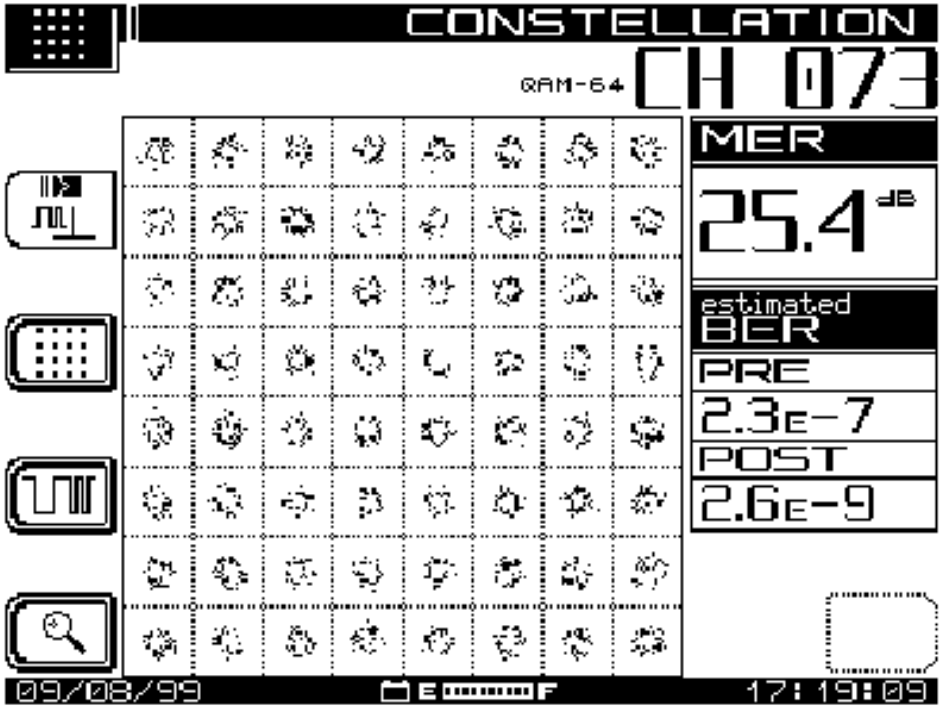
Gain compression: Upstream Laser Clipping



Graphic courtesy of Sunrise Telecom

Constellation Display

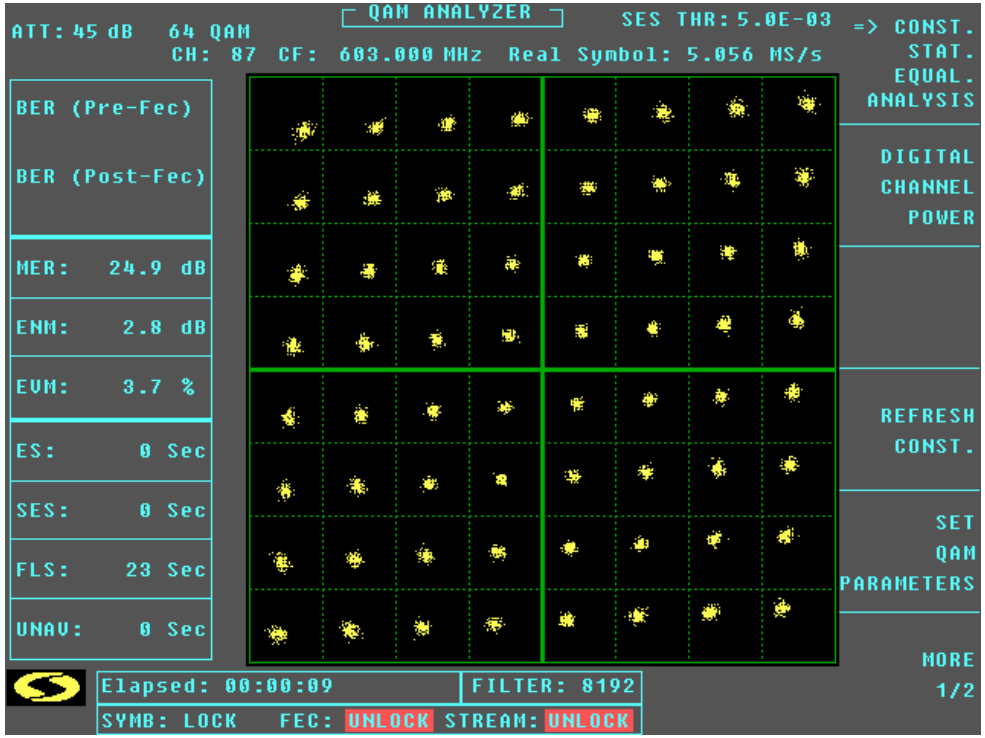
Coherent interference



Graphic courtesy of JDSU (Acterna)

Constellation Display

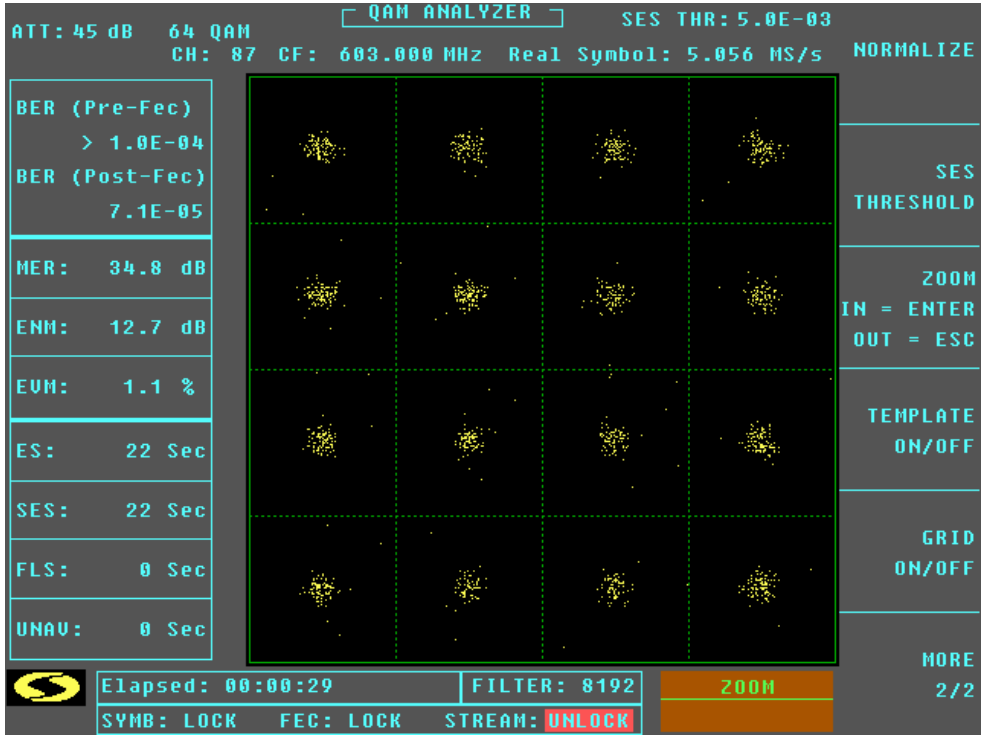
Quadrature distortion – this occurs in the signal source (transmitter or modulator)



Graphic courtesy of Sunrise Telecom

Constellation Display

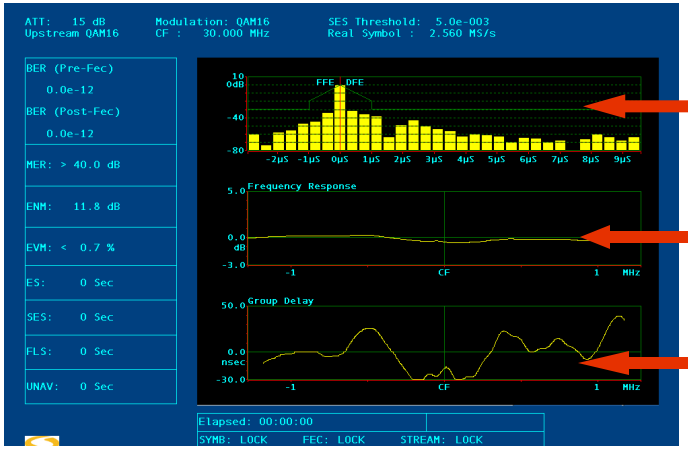
Zoom function

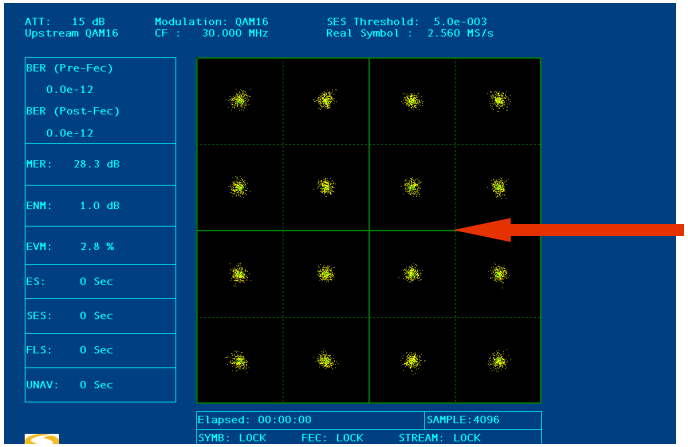


Graphic courtesy of Sunrise Telecom

Linear Distortions

Good…





Graphics courtesy of Sunrise Telecom

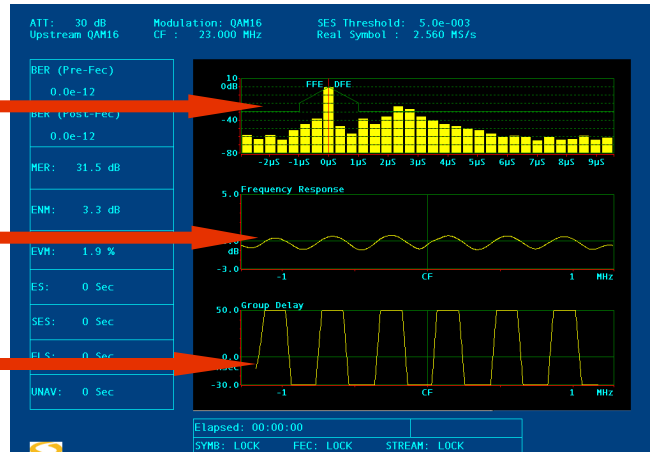
Equalizer graph

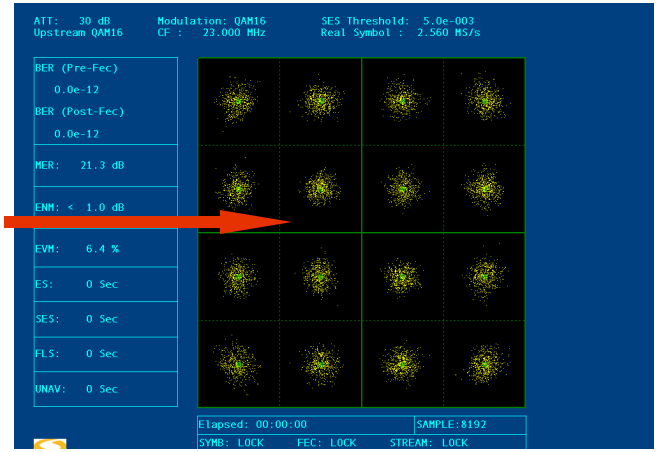
Equalizer frequency response

Group delay variation

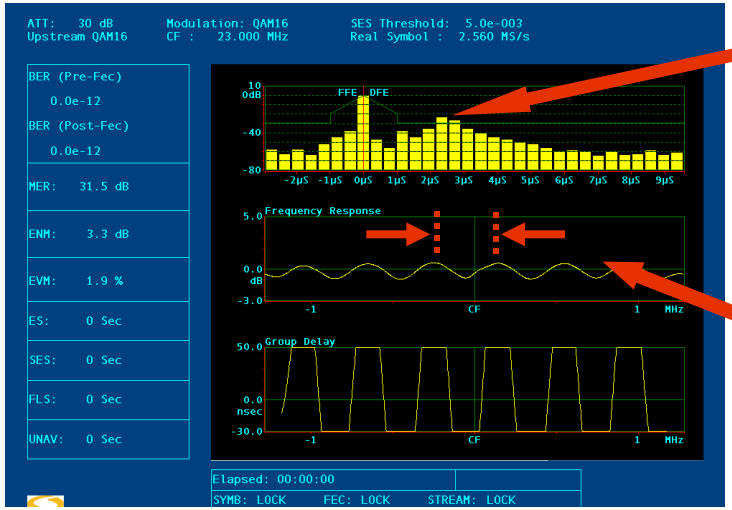
Constellation and RxMER

Not so good…





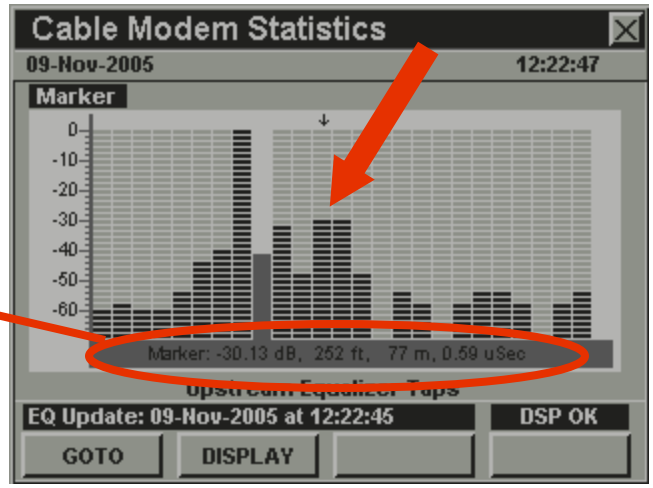
Linear Distortions



Reflection at about 2.5 µs (2500 ns): Assume ~1 ns per ft., (2500/1)/2 = 1250 ft (actual is 1.17 ns per ft for 87% VoP: (2500/1.17)/2 = 1068 ft echo cavity length)

Amplitude ripple spacing ~400 kHz: Echo cavity length = 492 x (.87/.400) = 1070 ft.

Some QAM analyzers calculate the echo cavity length (distance between two impedance mismatches)



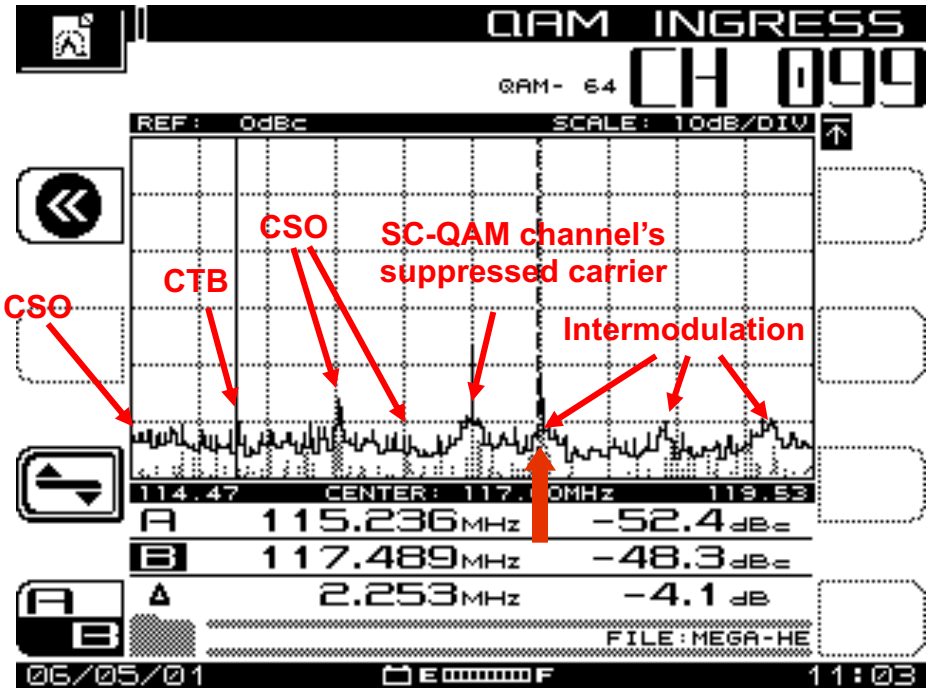
Graphics courtesy of Sunrise Telecom and Trilithic

Operational RF Levels

- **In years past operators set SC-QAM channel signal level 6 dB (256-QAM) to 10 dB (64-QAM) below what the visual carrier level of an analog TV channel on the same frequency would be**
- **This ratio should be maintained throughout the entire cable network**

Distortion or Interference Under the Carrier

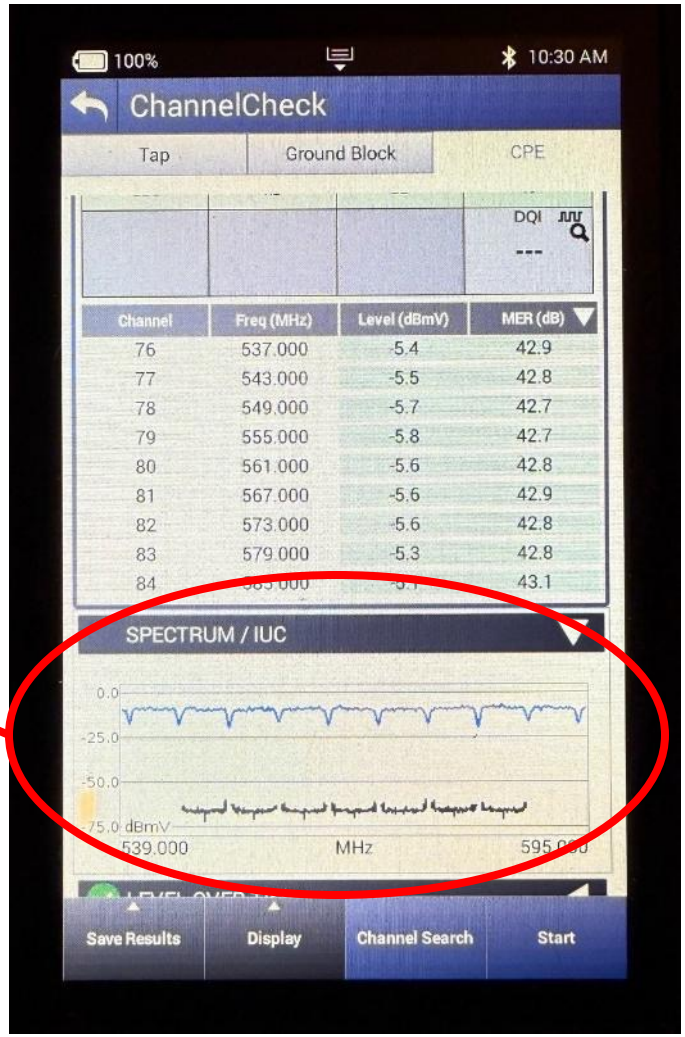
Using this meter's "QAM Ingress" mode, one can see an in-channel carrier-to-interference ratio of 48.3 dB about 0.5 MHz above center frequency



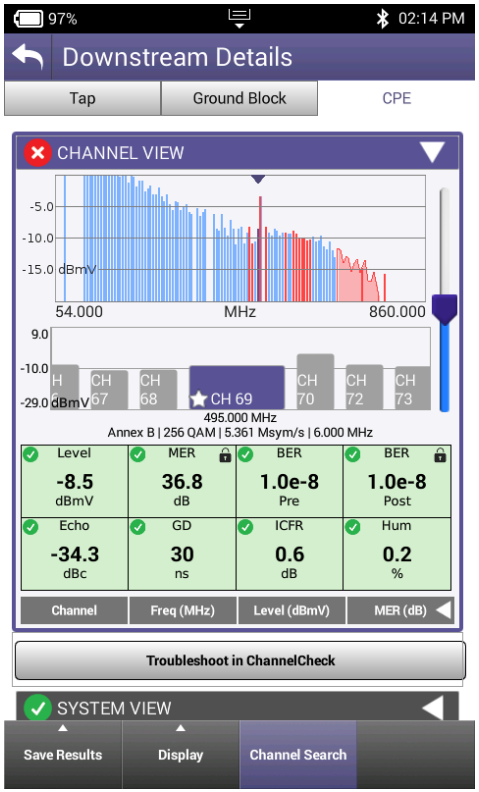
Graphic courtesy of JDSU (Acterna)

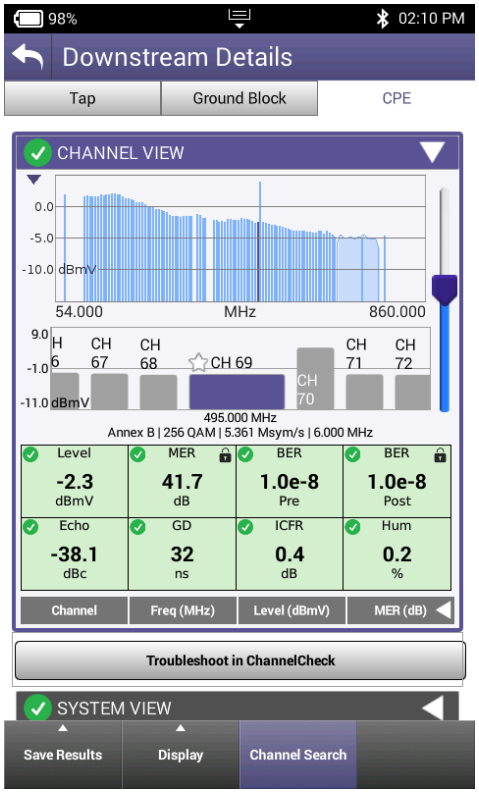
Distortion or Interference Under the Carrier

Using this meter's "Spectrum/IUC" mode, the noise floor under the group of SC-QAM channels is free from visible interference.



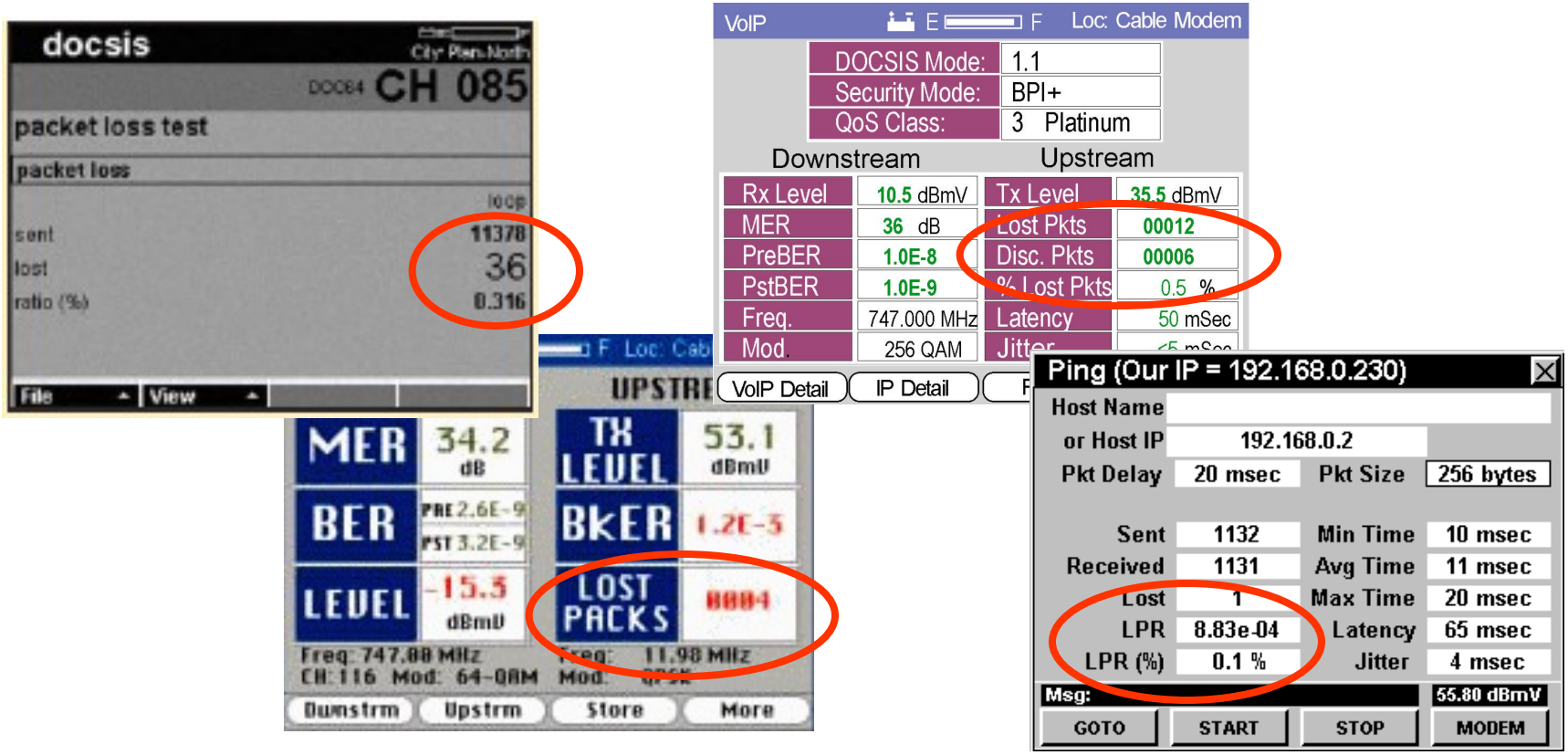
Checking SC-QAM Channel Performance





Upstream Performance: Packet Loss

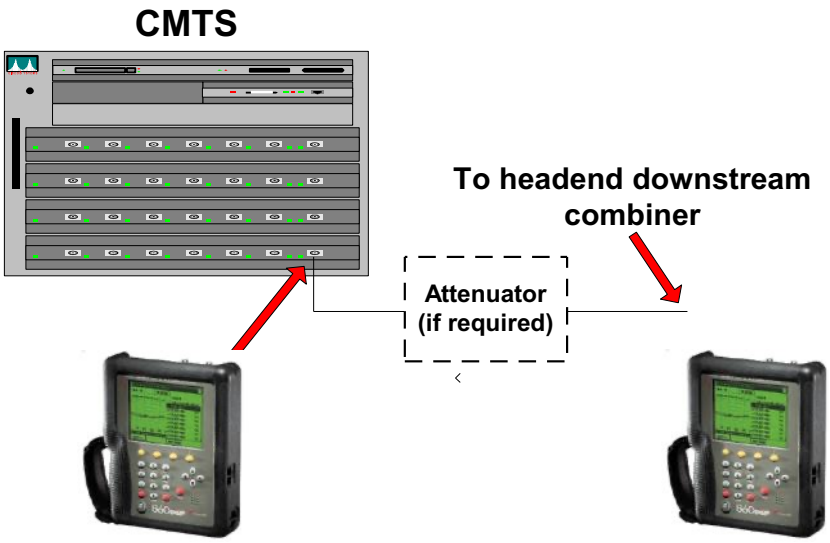
Some QAM analyzers support upstream packet loss measurements



Graphics courtesy of JDSU (Acterna), Sunrise Telecom and Trilithic

Troubleshooting—CMTS Output

- **Verify correct digital channel power (per channel)**
- **Also check BER, RxMER and constellation**

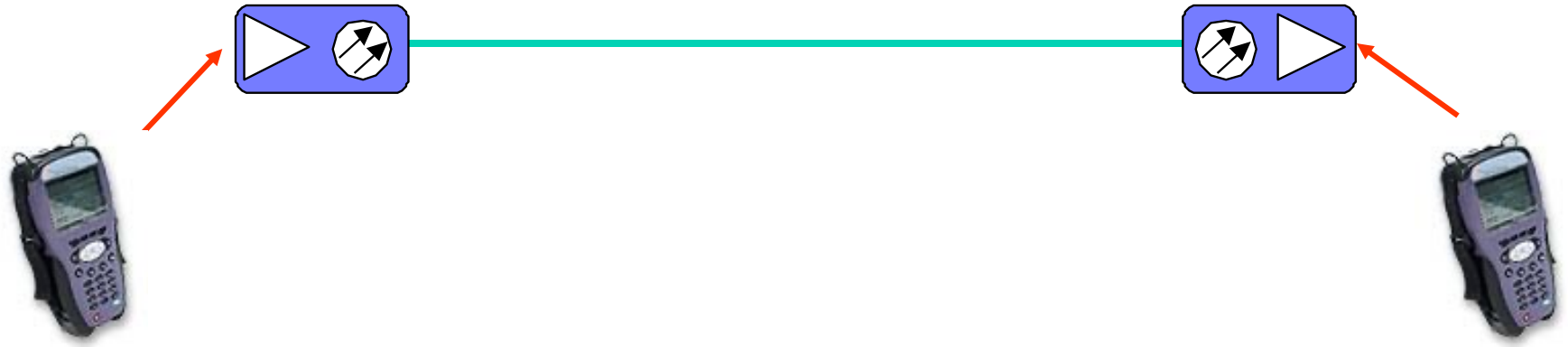


Combiner Output and Fiber Link

- **Check signal levels and BER at downstream laser input and node output**

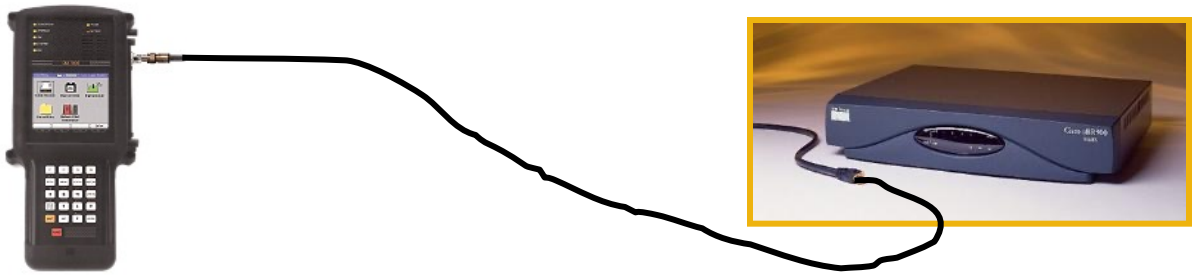
  Bit errors at downstream laser input but not at the CMTS output may indicate sweep transmitter interference, loose connections or combiner problems

  Bit errors at node output but not at laser input are most likely caused by downstream laser clipping



Out in the Field…

- If everything checks out okay at the node, go to an affected subscriber's premises (or a nearby tap).
- Measure downstream RF levels, RxMER and BER, and evaluate the constellation for impairments. Look at the adaptive equalizer graph, equalizer frequency response and group delay variation. If your QAM analyzer supports it, repeat these measurements in the upstream.
- Measure upstream transmit level and packet loss.
- Use the "divide-and-conquer" technique to locate the problem.



Measurement & Troubleshooting Summary

- **Constellation display**
  - Low RxMER or CNR
  - Phase noise
  - I-Q imbalance
  - Coherent interference (ingress, beats)
  - Gain compression
  - Laser clipping
  - Sweep transmitter interference
- **Pre- and post-FEC BER**
  - Sweep transmitter interference
  - Laser clipping
  - Loose connections
  - Low RxMER or CNR
- **Equalizer graph**
  - Reflections

- **Linear distortions**
  - Adaptive equalizer graph
  - Equalizer's frequency response
  - Group delay variation
  - Constellation display
  - RxMER
- **Transient impairments**
  - Pre- and post-FEC BER
  - Constellation display zoom function
  - Upstream packet loss
- **Signal level problems**
  - Analog TV channel signal level
  - Digital channel power
  - Upstream transmit level
  - Constellation display

Q & A