Plant Maintenance

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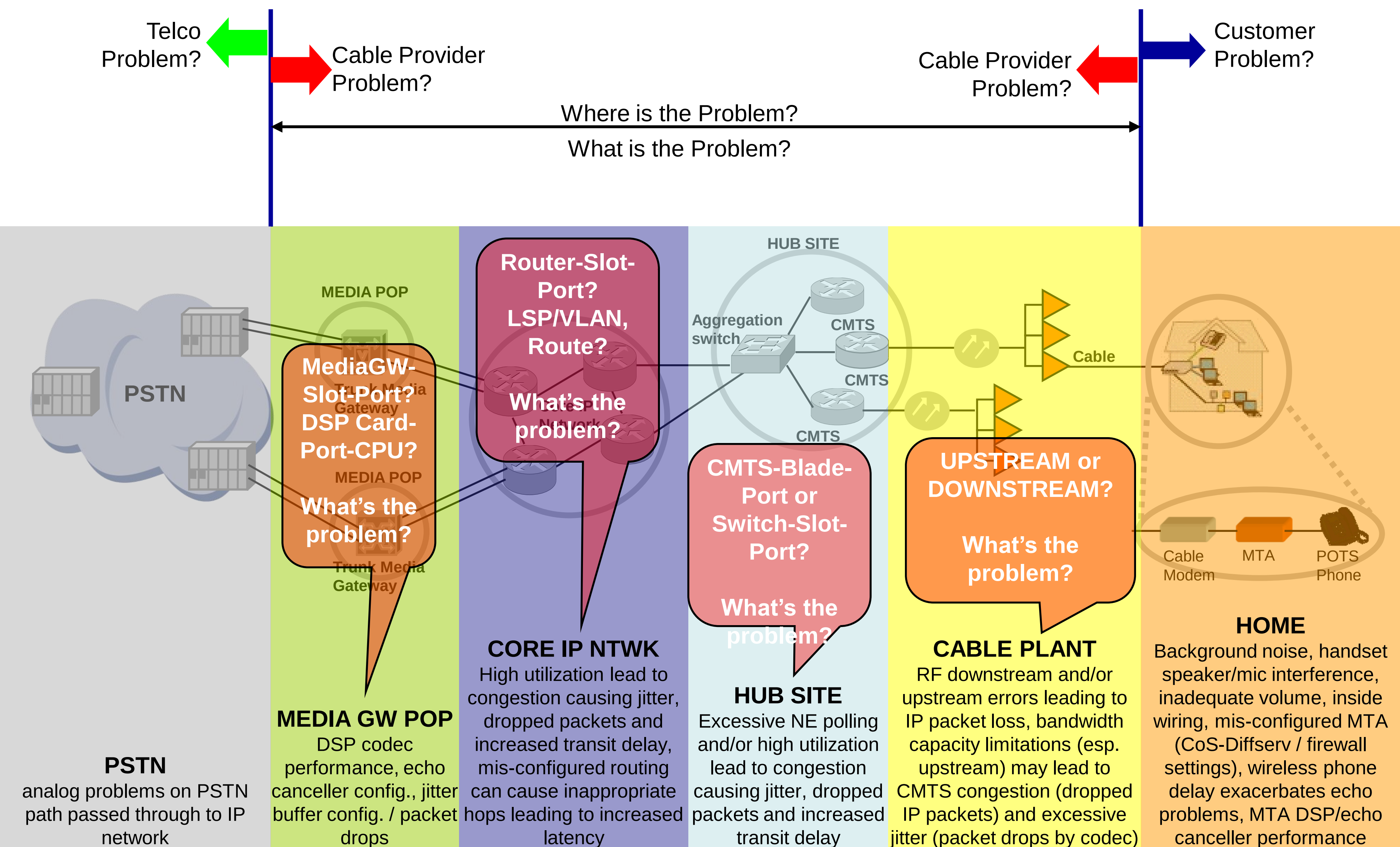
Voice Quality Impairments – it's not always the plant!



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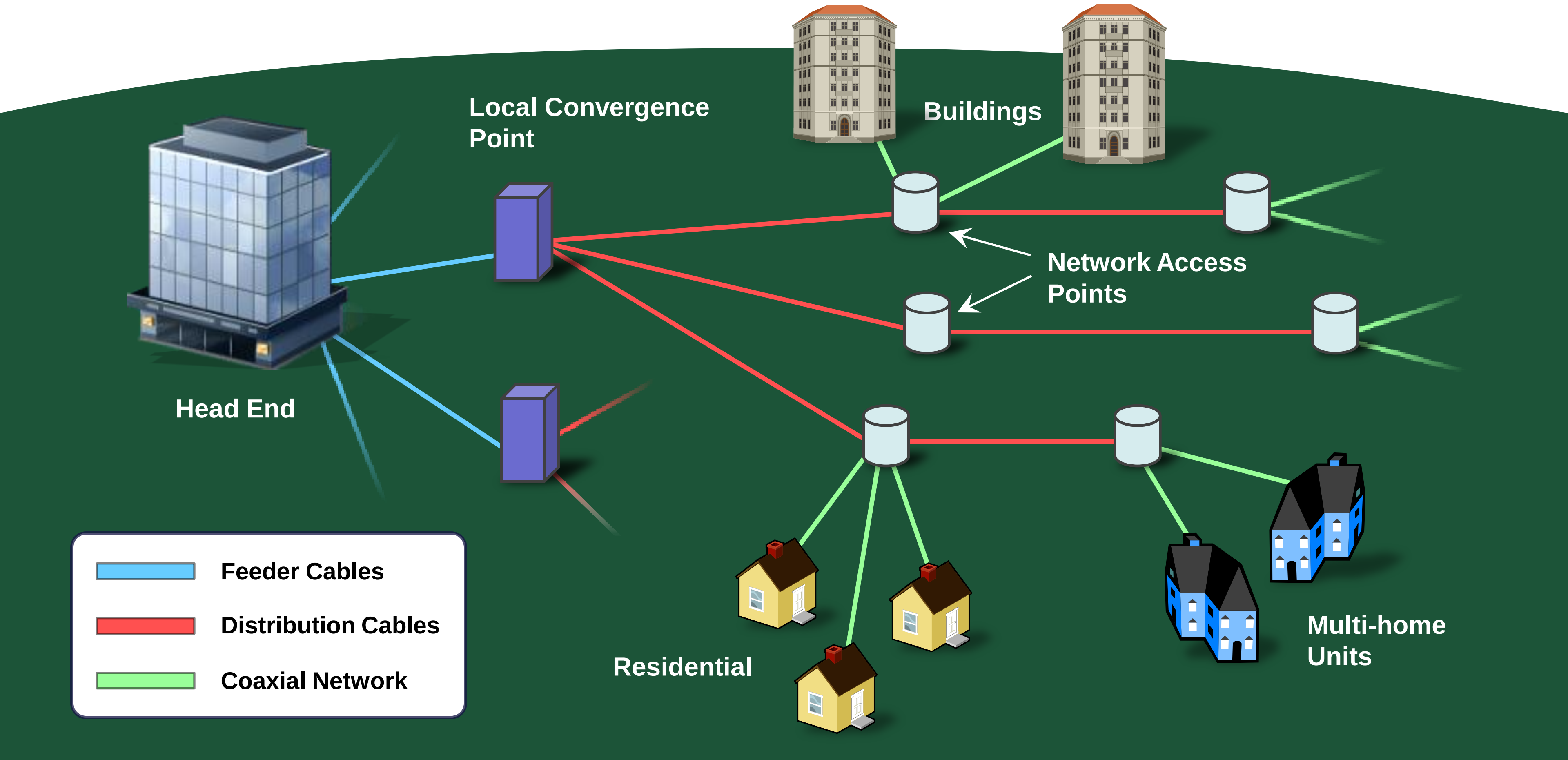
Fiber Connectors Are Everywhere

Fiber optic connectors are common throughout the network, and they give you the power to add, drop, move and change the network.

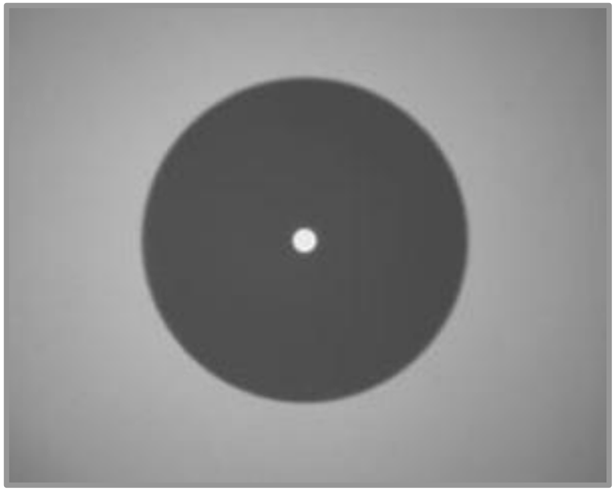


Sources of
Fiber Contamination

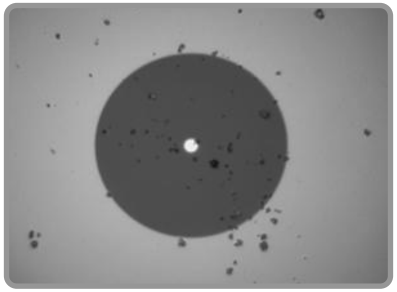
Types of Contamination

A fiber end face **should be free of any contamination or defects,** as shown below:

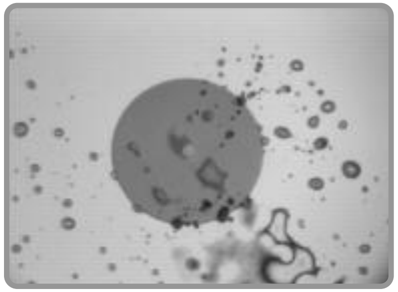
SINGLEMODE FIBER



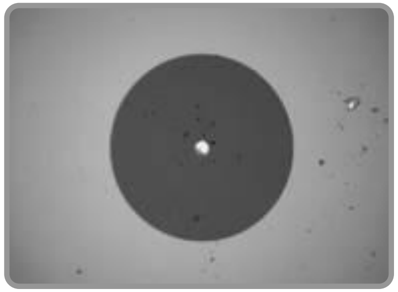
Common types of contamination and defects include the following:



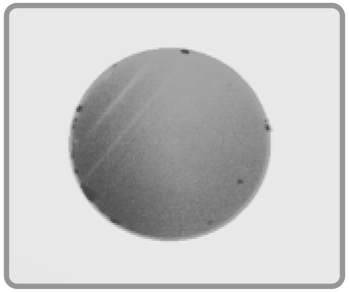
Dirt



Oil



Pits & Chips



Scratches

Where is it? – Everywhere

Your biggest problem is right in front of you… you just can't see it!

DIRT IS EVERYWHERE!

- Airborne, hands, clothing, bulkhead adapter, dust caps, test equipment, etc.
- **The average dust particle is 2–5µ, which is not visible to the human eye.**
- A single spec of dust can be a major problem when embedded on or near the fiber core.
- **Even a brand new connector can be dirty.** Dust caps protect the fiber end face, but can also be a source of contamination.
- Fiber inspection microscopes give you a clear picture of the problems you are facing.

Where is it? – Proliferation of Dirt

There are a number of different sources where dirt and other particles can contaminate the fiber.

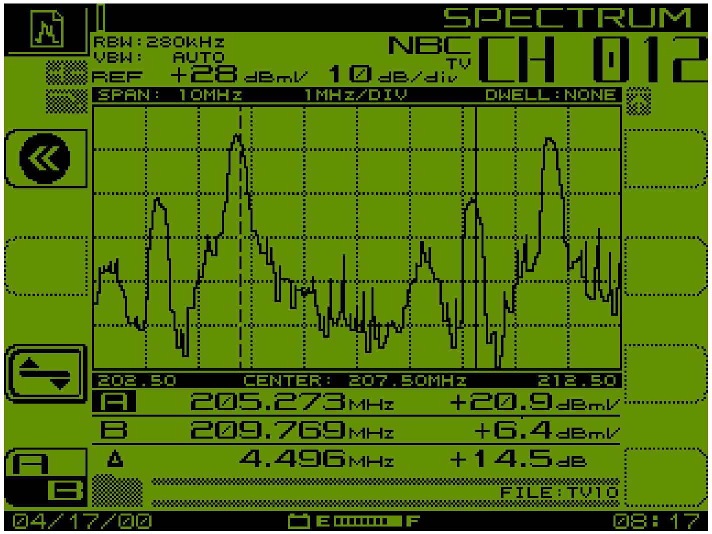
- **Test Equipment**
- **Dust Caps**
- **Bulkheads**
- **People**
- **Environment**

Connectors and ports on test equipment are mated frequently and are highly likely to become contaminated. Once contaminated, this equipment will often cross-contaminate the network connectors and ports being tested.

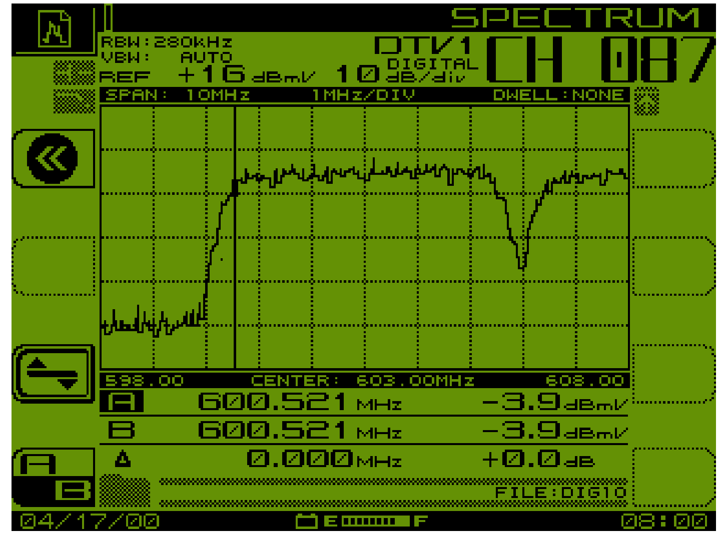
Inspecting and cleaning test ports and leads before testing network connectors prevents cross-contamination.

HFC Network

Analog vs. Digital

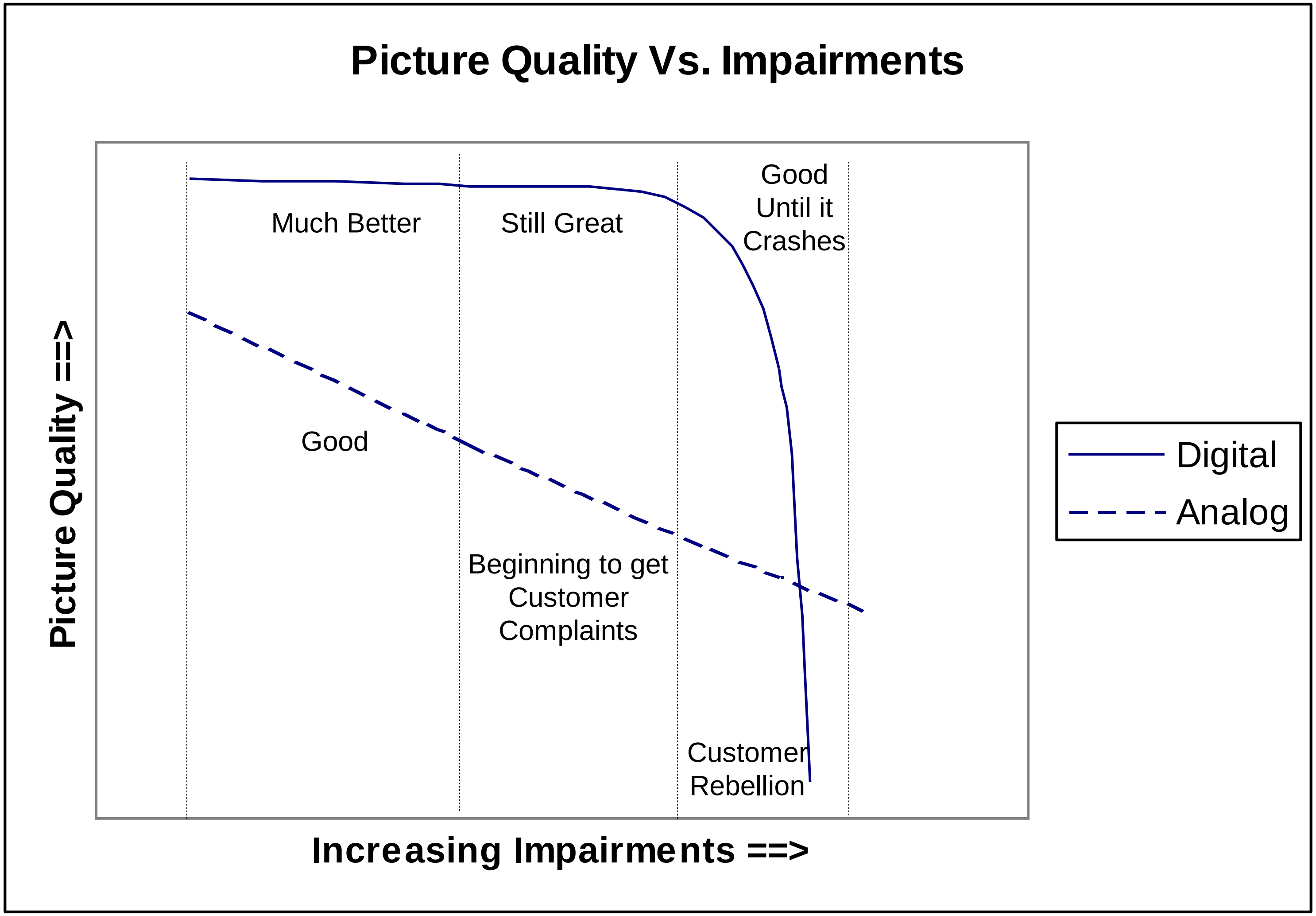


- Analog signal components are visibly discernable using a spectrum analyzer

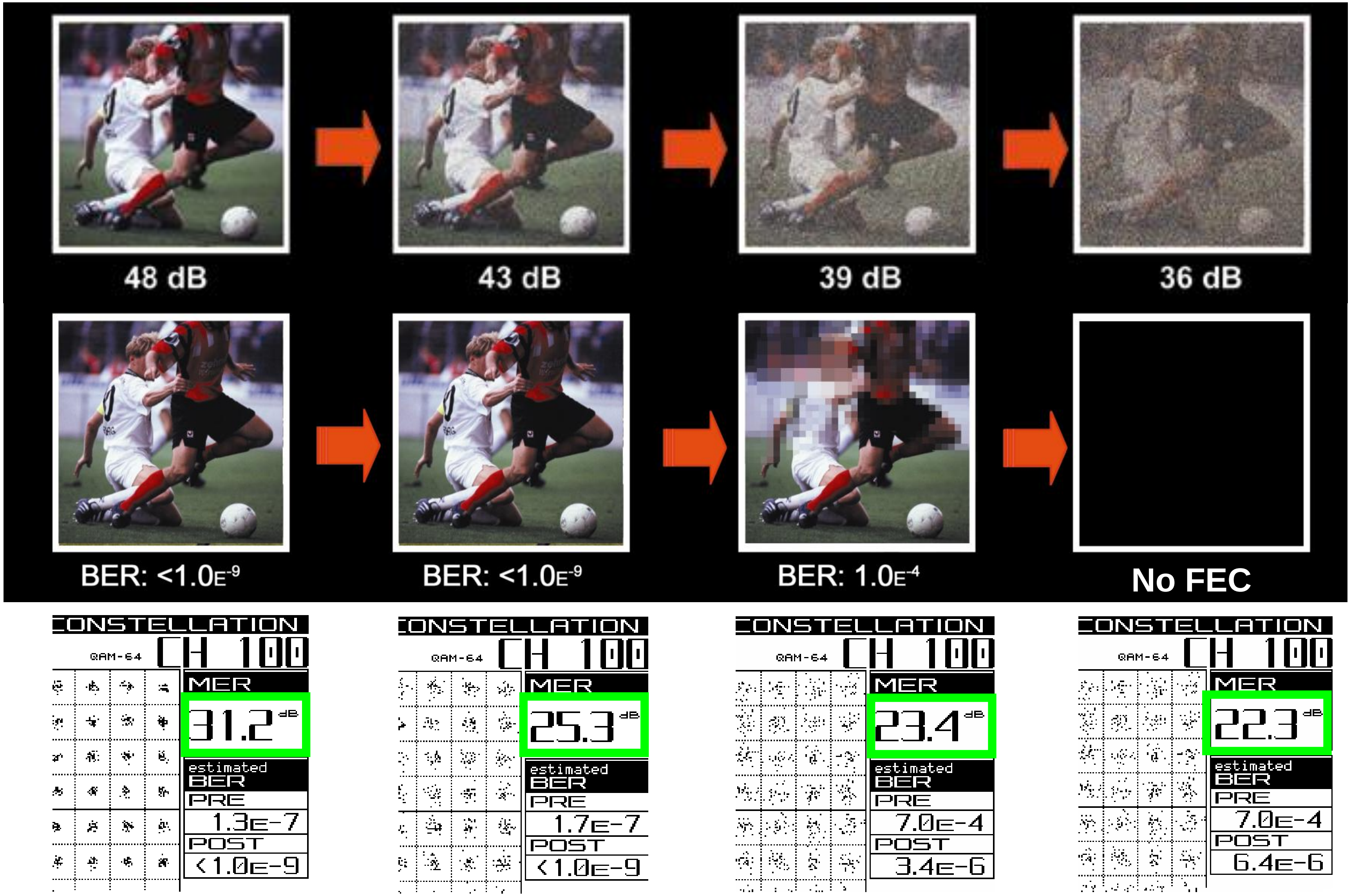


- Digitally modulated signals only show a “haystack” on a spectrum analyzer regardless of modulation or content – (more tools needed)

Digital TV Waterfall Graph



Analog vs. Digital Measurements



BER Example

- A 256QAM channel transmits at a symbol rate of 5M symbols per second
- Bit rate = 8 bits per symbol X 5M symbol per second =40M bits per second
- Error Incident = Bit rate X BER = Errors Per Second

BER	Error Frequency	Error Incident
10^{-12}	1 in 1 Trillion bits	25000 secs between errs (6.94 hrs)
10^{-11}	1 in 100 Billion bits	2500 secs between errs (41.67 mins)
10^{-10}	1 in 10 Billion bits	250 secs between errs (4.167 mins)
10^{-9}	1 in 1 Billion bits	25 seconds between errors
10^{-8}	1 in 100 Million bits	2.5 seconds between errors
10^{-7}	1 in 10 Million bits	4 errors per second
10^{-6}	1 in 1 Million bits	40 errors per second
10^{-5}	1 in 100 Thousand bits	400 errors per second
10^{-4}	1 in 10 Thousand Bits	4000 errors per second
10^{-3}	1 in 1 Thousand bits	40000 errors per second

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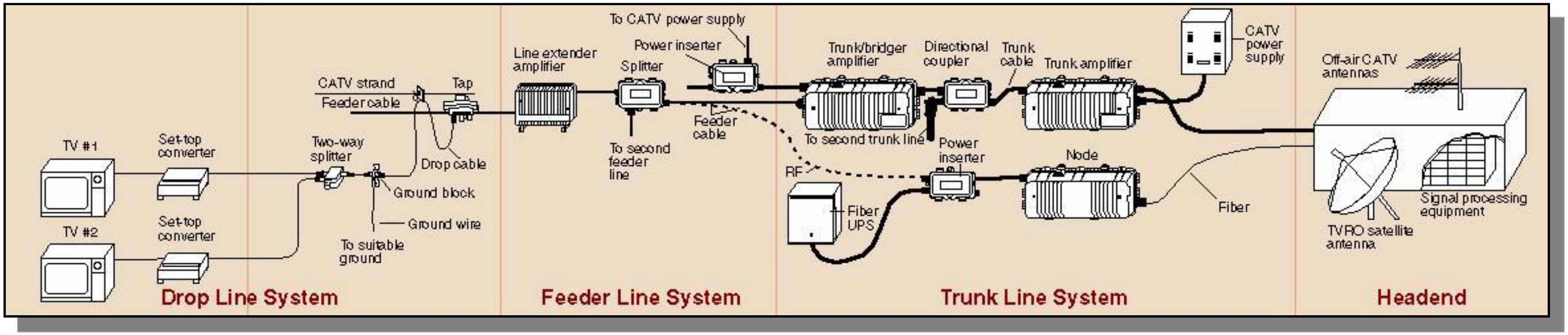
Expected MER & BER Results

Digital video		MER 64 QAM	MER 256 QAM	Pre FEC BER	Post FEC BER
Headend	Excellent	35 dB	35 dB	0.0 E-00	0.0 E-00
	Acceptable	33 dB	35 dB	1.0E-08	0.0E+00
	Marginal	30 dB	32 dB	1.0E-07	1.0E-08
Node	Excellent	34 dB	35 dB	0.0 E-00	0.0 E-00
	Acceptable	31 dB	34 dB	1.0E-08	0.0 E-00
	Marginal	28 dB	30 dB	1.0E-07	1.0E-08
Amp	Excellent	33 dB	35 dB	1.0E-09	0.0 E-00
	Acceptable	30 dB	32 dB	1.0E-08	1.0E-09
	Marginal	25 dB	29 dB	1.0E-07	1.0E-08
Tap	Excellent	32 dB	35 dB	1.0E-08	0.0 E-00
	Acceptable	28 dB	31 dB	1.0E-07	1.0E-09
	Marginal	24 dB	28 dB	1.0E-06	1.0E-08
Set-top	Excellent	32 dB	35 dB	1.0E-08	0.0 E-0
	Acceptable	27 dB	31 dB	1.0E-07	1.0E-08
	Marginal	23 dB	27 dB	1.0E-06	1.0E-07

Segmented Error Budgets

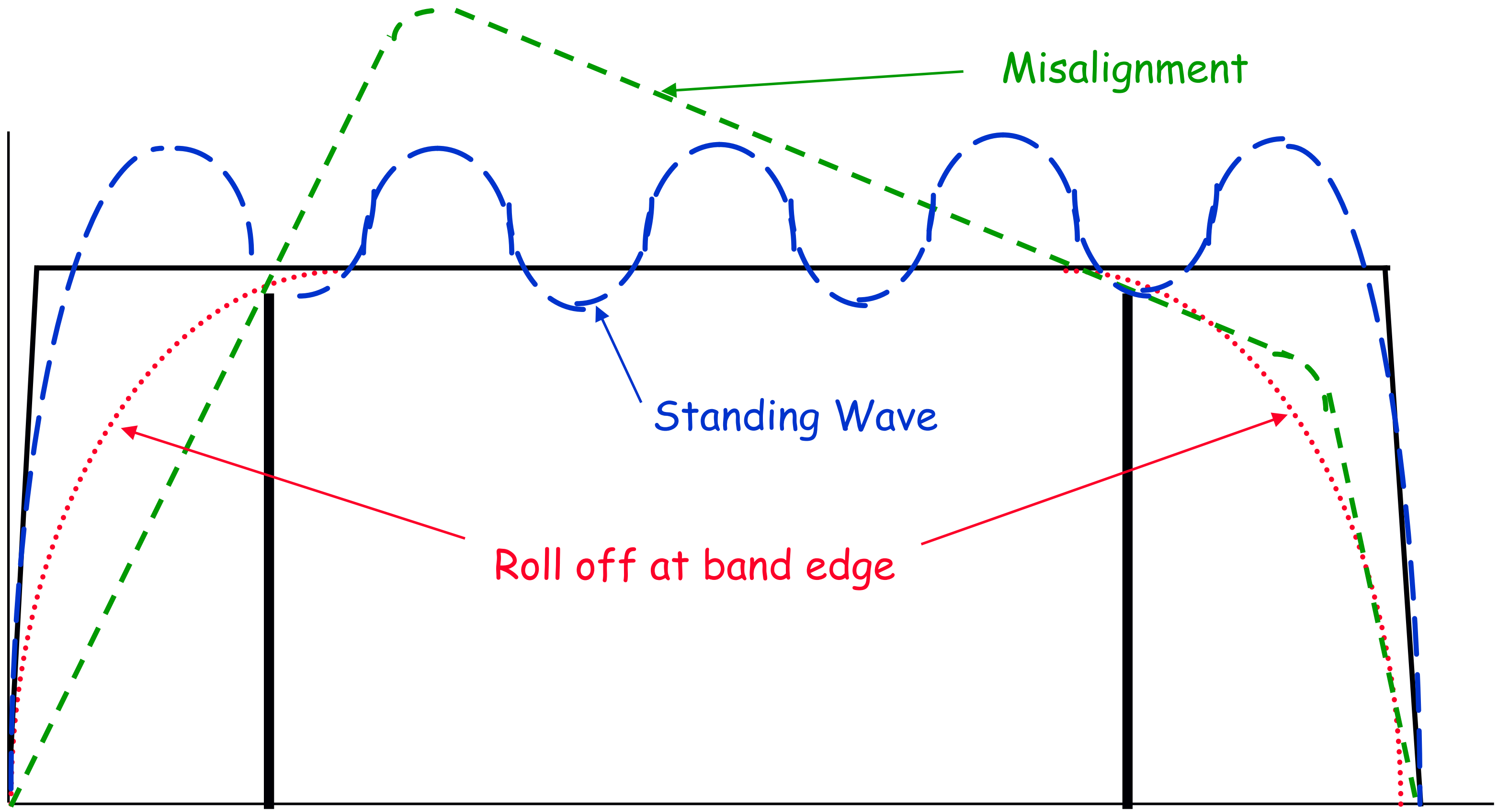
Test Critaria	Measurement	Goal	Start Seeing Degradation on Call Quality
	Delay (1-way)	< 100 ms	> 150 ms
	Jitter	< 5 ms	> 15 ms
Service Level Test	Packet Loss	< 0.5%	> 2%
	R-Value	> 80	< 70
	MOS	> 4	< 3
	MER	30dB(64), 33dB (256)	25dB(64), 28dB(256)
RF	PRE-FEC BER	1.00E-09	1.00E-07
At Home	Rx - Level	-5~+5 dBmV	<-10dBmV or >+10dBmV
	Tx - Level	35 ~45 dBmV	< 30dBmV or >50dBmV
	MER	32dB(64), 35dB (256)	28 dB(64), 31dB(256)
RF	PRE-FEC BER	1.00E-09	1.00E-07
At Node	Freq Response	< 4dB	> 5dB
	Upstream SNR	>35dB	<25dB
CMTS	CMTS Loading	<50%	>80%

Sweep vs. Signal Level Meter Measurements



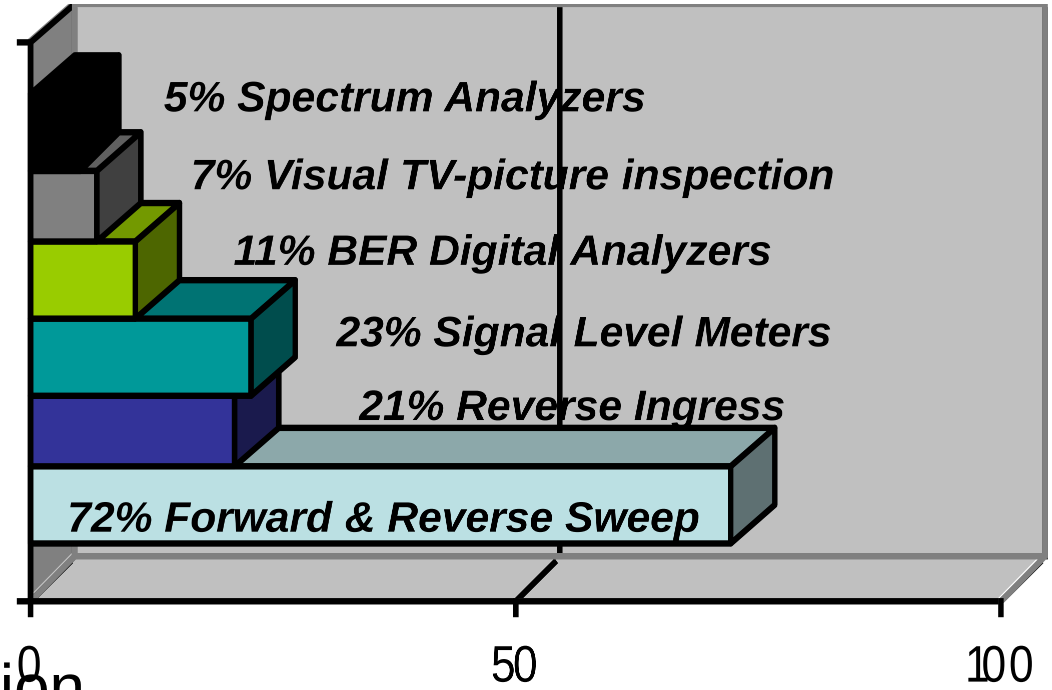
- References: Sweep systems allow a reference to be stored eliminating the effect of headend level error or headend level drift.
- Sweep Segments: Stealth makes it possible to divide the HFC plant into network sections and test its performance against individual specifications.
- Non-Invasive: Sweep systems can measure in unused frequencies. This is most important during construction and system overbuilding.
- BEST Solution to align: Sweep systems are more accurate and faster.

A Sweep Finds Problems That Signal Level Measurements Miss



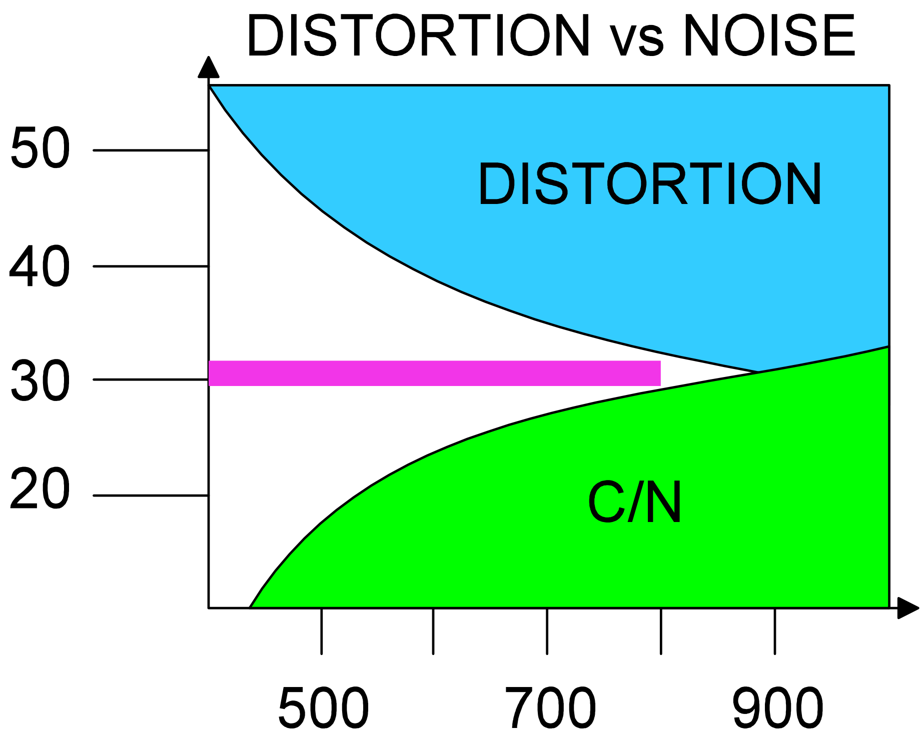
What faults cause CATV signals to fail ?
(80-90% of the time, the same faults…)

- Success rate of finding and fixing the following problems using:
  - Signal Levels
  - TILT
  - Gain / Loss
  - Suck-outs (notches)
  - C/N
  - HUM
  - CTB/CSO Intermodulation
  - CPD - Forward and Reverse
  - Reverse Ingress
  - BER / MER
  - Reflections / Standing waves



Source: Research 11/97-2/98 Market survey with 200 US and European CATV operators

WHY SWEEP? Sweep 1 or 2 times/year *or* visit cascade



- CATV amplifiers have a trade-off between noise and distortion performance
- Tightly controlling frequency response provides the best compromise between noise and distortion.

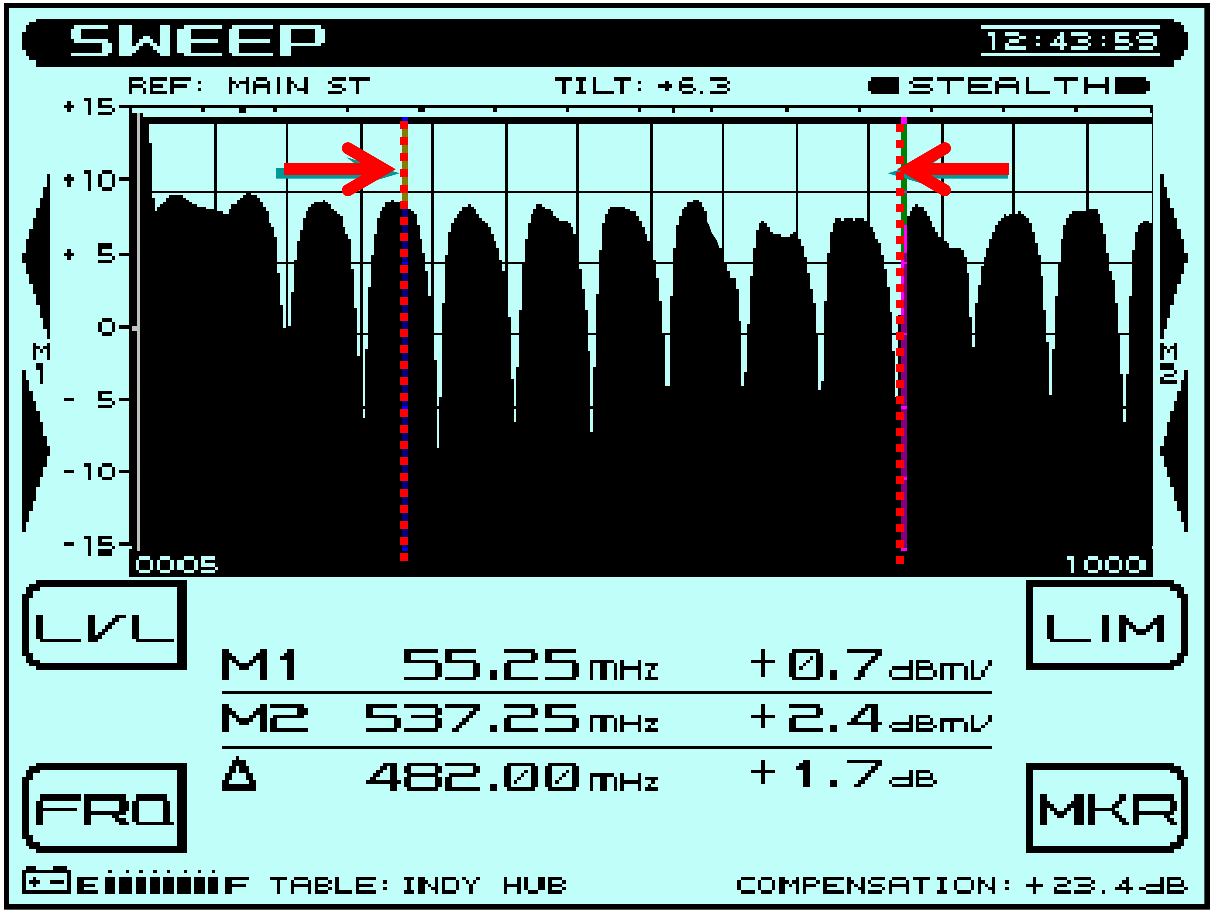
Standing waves

One Cycle = 18 MHz

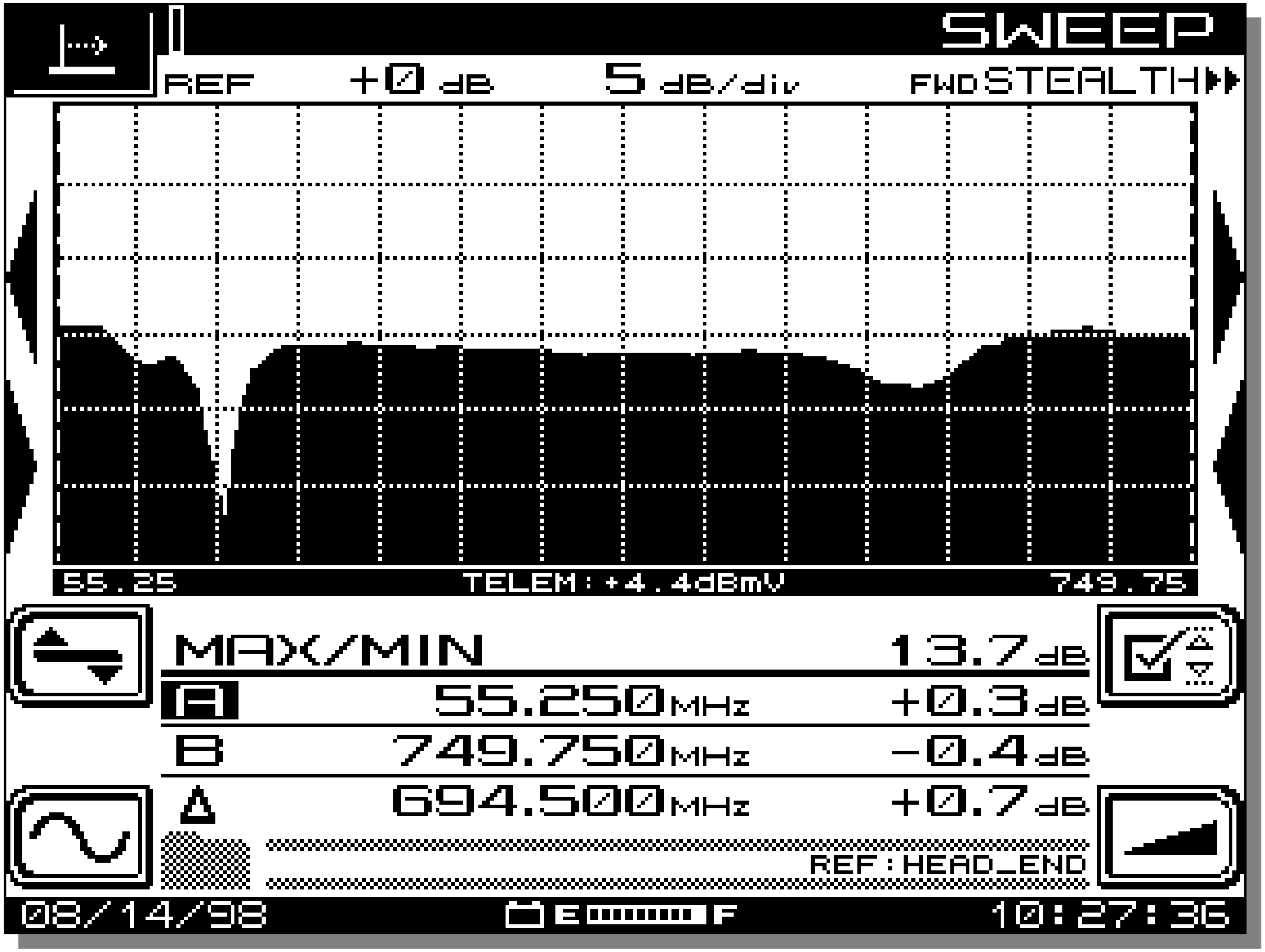
VP = 0.93

492 x 0.93
-------------- = 25.42 feet
18

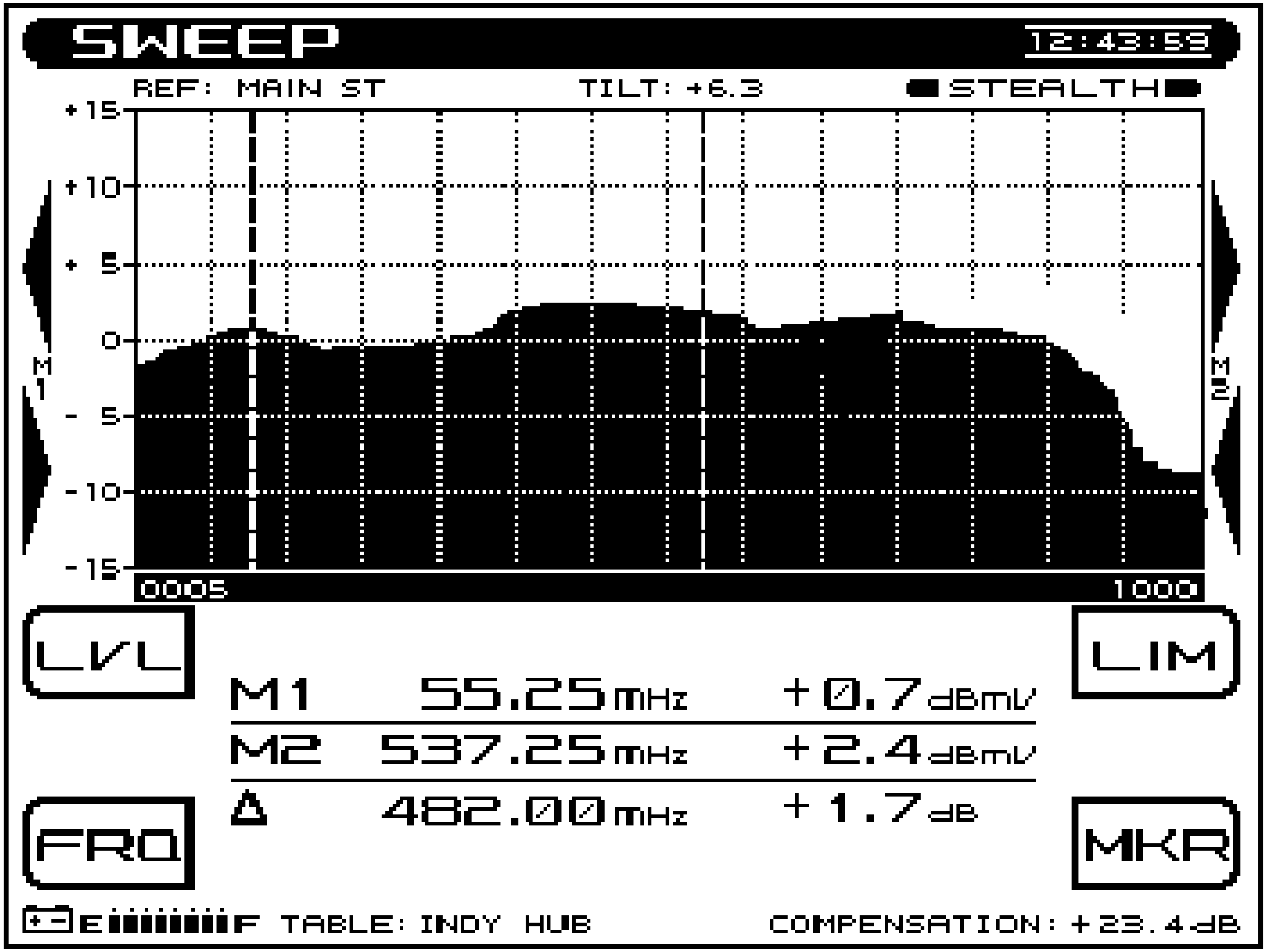
/ 3.33 = 7.63 meter



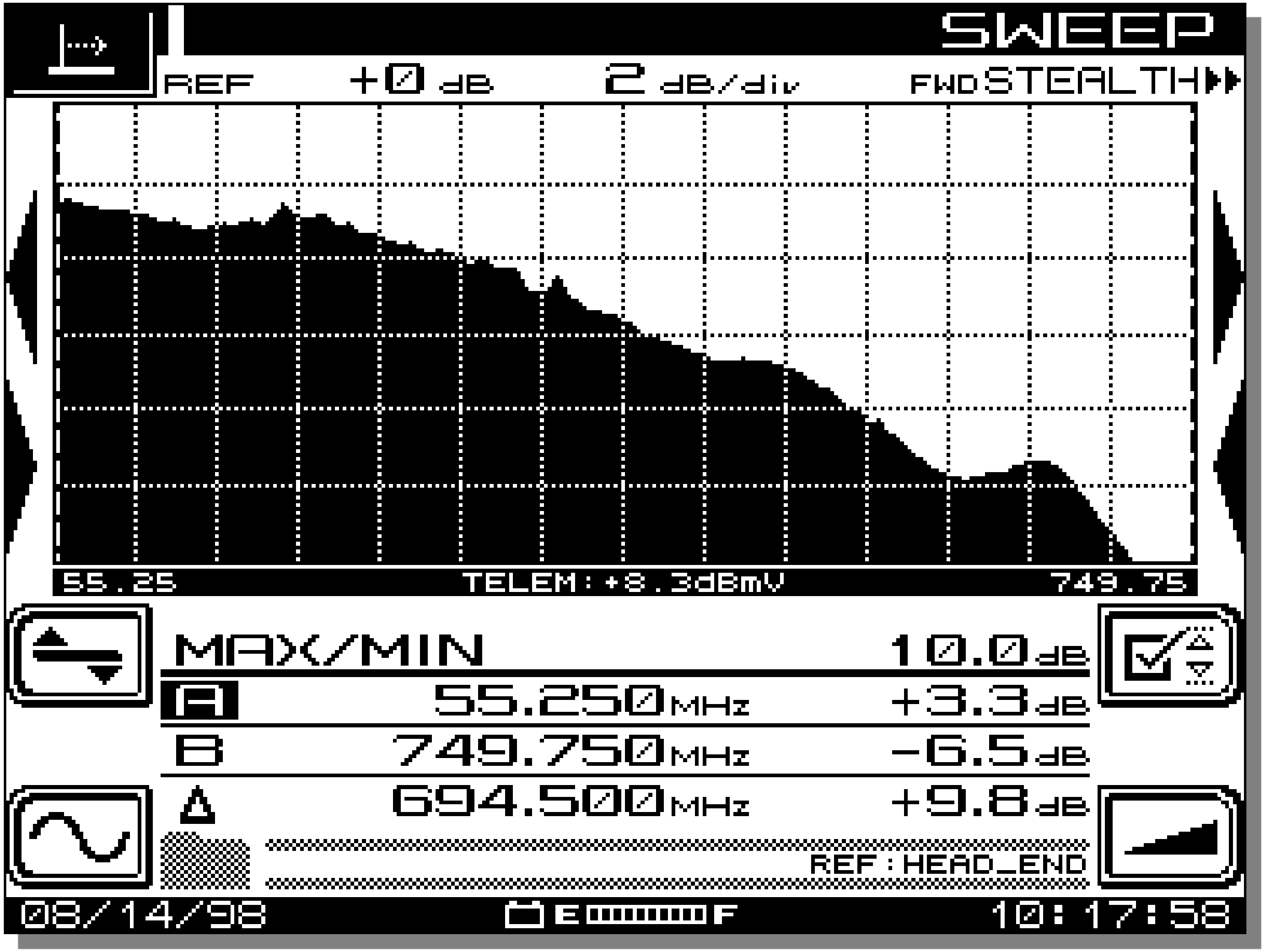
Suck-out (Notch)



High end roll-off



Wrong Tilt Compensation



VoIP Testing

Why is it important?

What can be done?

VoIP Call Quality

Echo

Packet Loss

Codec Selection

Network Delay

Jitter

Network Congestion

What is VoIP?

Codec

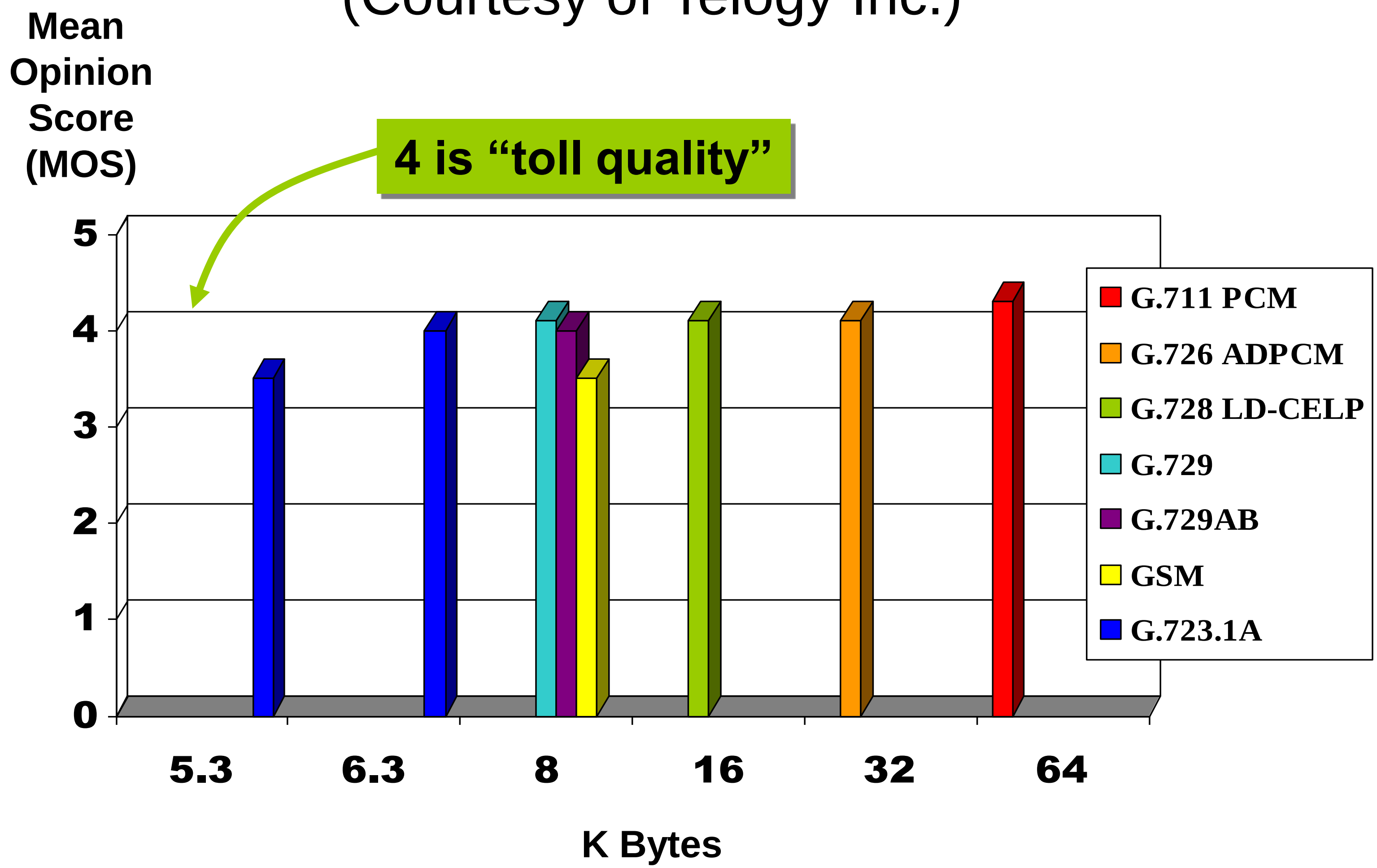
The choice of the codec is a direct determinant of the quality achievable for the system. The codec is responsible for coding the transmission (analog to digital) and decoding to the user (digital to analog). Each codec has a specific sampling rate and compression algorithms that offers a bandwidth advantage at the expense of conversion speed, or delay. PacketCable™ specifies the use of three codecs[iii]. G.711 (both u-law and A-law versions) is mandatory, G.728 and G.729E (Annex E) are recommended.

These MTAs may also utilize Voice Activity Detection (VAD) {e.g. G729B} and Packet Loss Concealment (PLC).The utilization of VAD will reduce bandwidth as it effectively shuts down transmission until there is active traffic. However, this comes at the risk of clipping speech. PLC is used to substitute lost packets and will be discussed further when discussing packet loss in general.

The codec sets the baseline for the calculation of I_e of the E-Model, R-Value and also affects the delay characteristics.

How Well Do the Codecs Work?

(Courtesy of Telogy Inc.)



What is VoIP?

Jitter

In a perfect system, all packets would be received at the same time and presented to the receiving device. This is not the case in a real system. The time difference that packets arrive, or transit time difference is referred to as jitter. This has an effect on quality as it manifests in garbled speech. To compensate, jitter buffers are used at the expense of delay. If the buffer is sized too high, there will be excessive delay, too small, and the buffer may be overrun resulting in lost packets.

What is VoIP?

Delay

Delay is measured as a 'mouth to ear' measurement, which, by definition, implies a one-way delay. This is measured using parameters within the RTCP. PacketCable™ specifies that this must be turned on under most cases. There are primarily four components of delay:

The summation of all delays is referred to as the absolute delay (Ta) used in the calculation of I_d of the E-Model, R-Value. This has a drastic effect quality, particularly after the delay reaches 150ms as there is a sharp knee around the calculation.

What is VoIP?

Transport Delay
This is the delay for the packets to transverse the network components (routers, gateways, etc.). It is controlled via the system architecture.

Propagation Delay
This is the physical time it takes the signal to travel. It is composed of the time between satellite hops, or transmission lines. This is a function of the type of call made and the architecture. ITU-T G.114, 'One-way transmission time', page 10 describes the different elements contributing to propagation delay with recommended formulas for calculation. This delay can be substantial.

Packetization Delay
This is the delay caused by the packetization of data from the codecs.

Jitter Buffer Delay
This is the delay introduced by buffering data to reduce variations in arrival times. For PLANNING PURPOSES, IT IS RECOMMENDED to assume that, a de-jitter buffer adds one half of its peak delay to the mean network delay[iv].

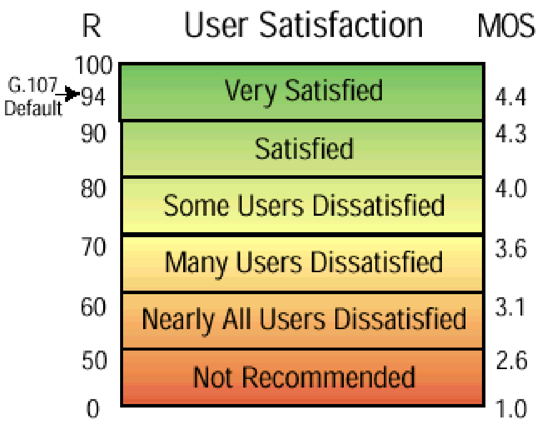
What is VoIP?

Packet Loss

Packet loss occurs either from queues in the system overrun due to traffic congestion or the physical transmission is corrupting the data. This has a drastic affect on the quality of the voice transmission because it directly results in losing the data, i.e. the words in a conversation. This is also worse when the loss is bursty in nature. Over a conversation, listeners may not notice few lost packets, but a burst with consecutive loss of data will be noticeable. This phenomenon is taken into account by weighting of the I_e factor of the E-Model, R-Value.

Voice Quality - E-Model

- E-Model → R-Value
  - Most complete, objective test

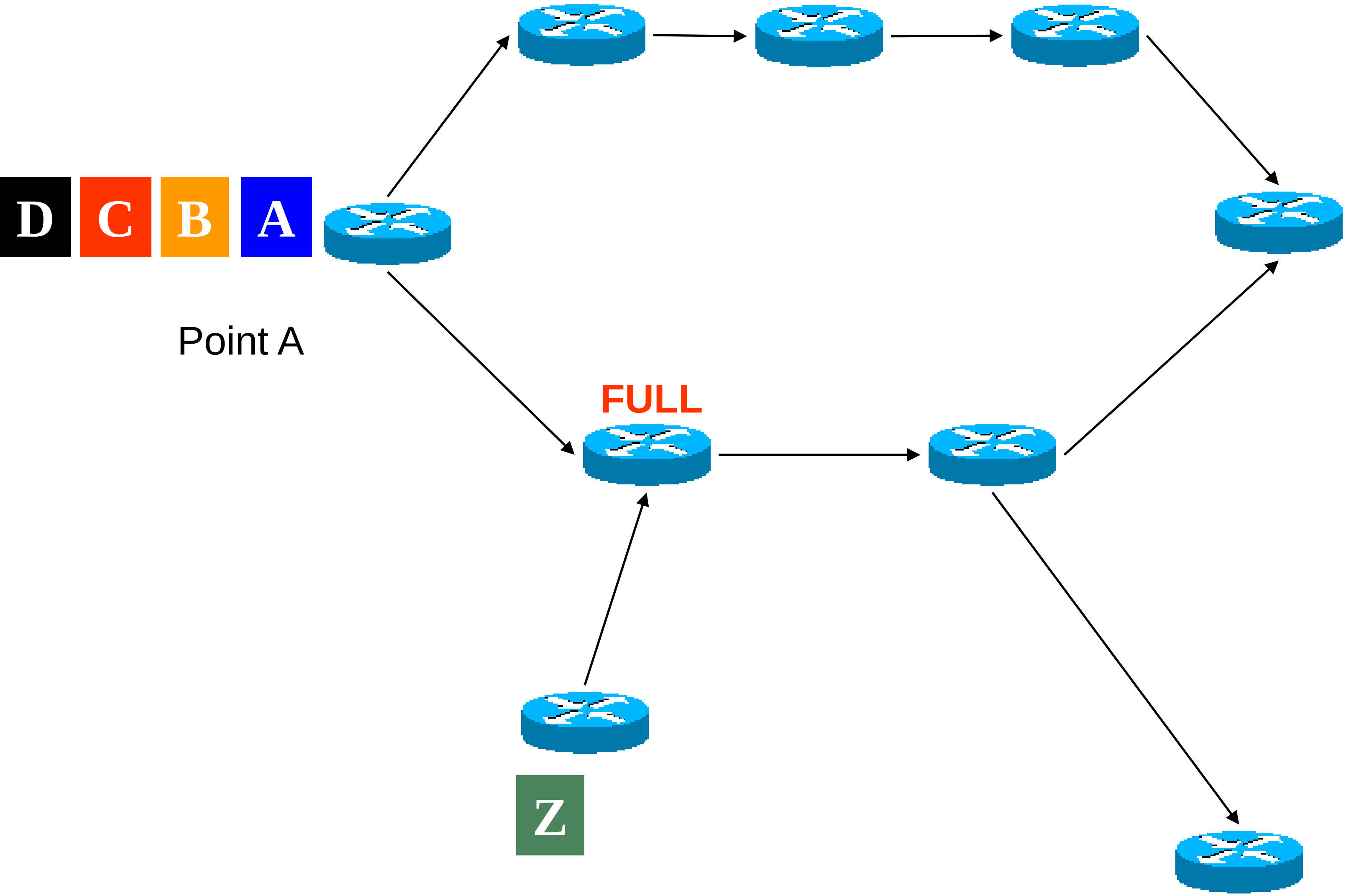


R = Ro + A – Ls – Ld – Le

- Ro: Basic SNR or circuits – handsets, environment
- A: Advantage Factor – GSM poor service, example.
- Ls: Simultaneous impairment factor – loudness/volume, hissing, sidetone, quantization distortion
- Ld: Talker/listener echo, **Overall Delay**
- **Le: Equipment impairment factor – Packet loss, Jitter**

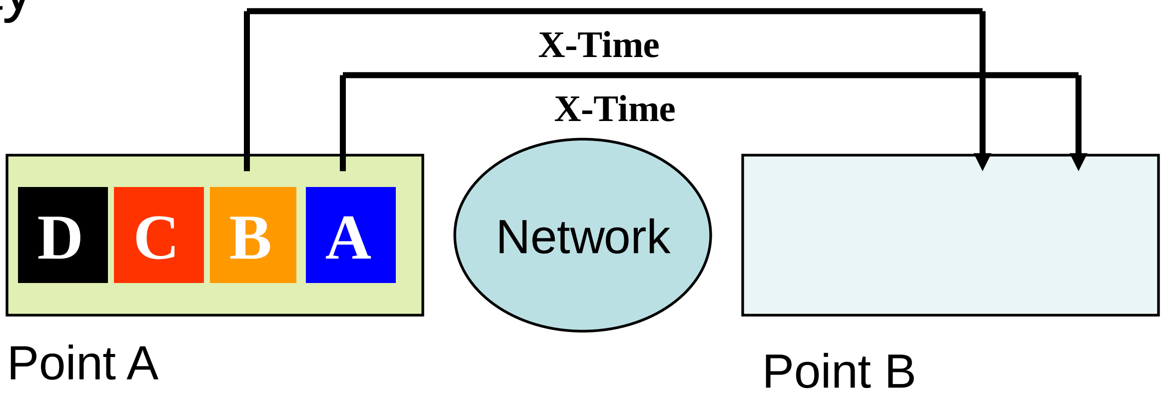
Things you will take action on!

Packet Knowledge



Delay, Packet Loss and Jitter- What is it?

- Delay



  - Time it takes a packet to 'transverse' the network
    - Point A to Point B
  - Time it takes is shown here as 'X'
  - Too much delay affects the quality of a call
    - See this on PSTN with international calls (Over-talk)
    - (More delay = more potential echo)
  - Usually an architecture (traffic/capacity) issue
    - Longer distances and more routers add delay
    - Too many calls/downloads add delay (slows routers)
    - Generally not a HFC issue with equipment such as amplifiers

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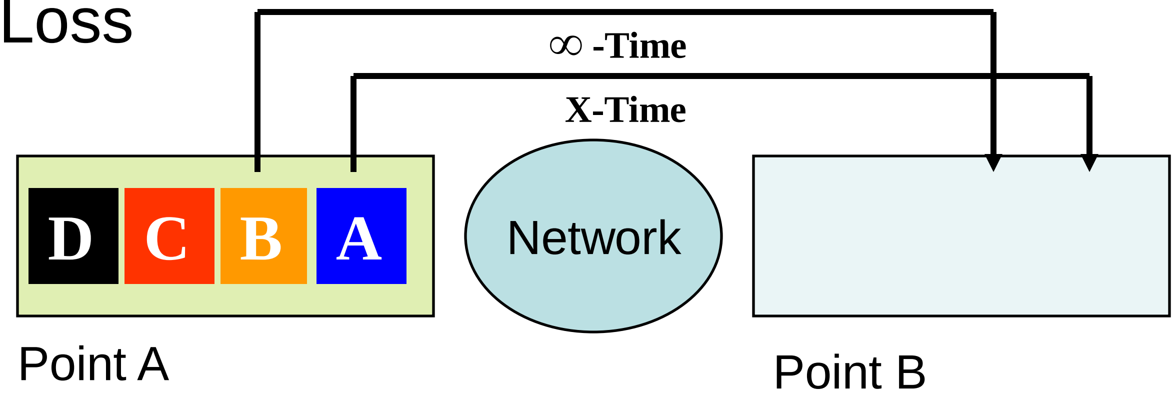
Delay, Packet Loss and Jitter- What is it?

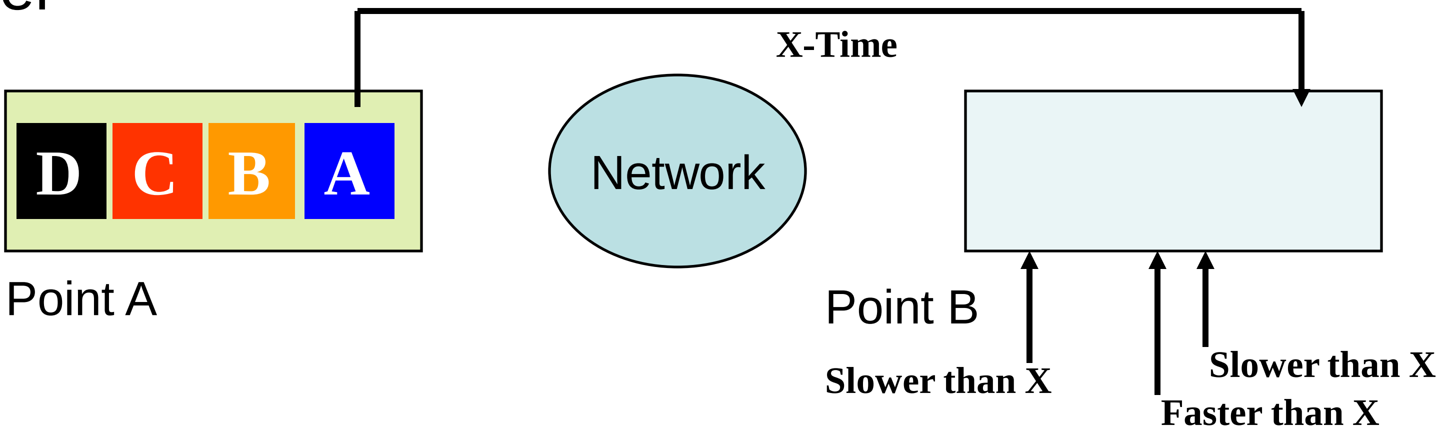
- Packet Loss



  - Packet did not arrive (Point B) or out of sequence
    - VoIP telephony is different than data
      - If it was out of order, computer reorders for data
      - If lost, just retransmit data
  - Shown here as infinite time – did not show up
  - Worse if it is ‘bursty’, many lost in a row – “lossy”
  - Can be architecture or physical layer
    - Ingress (especially upstream)
    - Routers over capacity (too full to hold any more)

Delay, Packet Loss and Jitter- What is it?

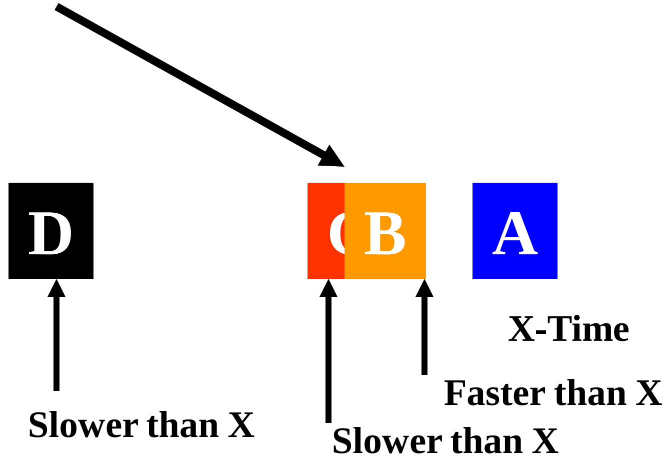
- Jitter



  – Packets not arriving with the same timing (different from X-Time) – time between packets is different
    - **Different than data**
      – You never notice with Data, doesn't matter how the information arrives, just care that it shows up
      – VoIP is Real-Time
    - **Key Causes**
      – IP based equipment having packet routing issues

Jitter – A problem?

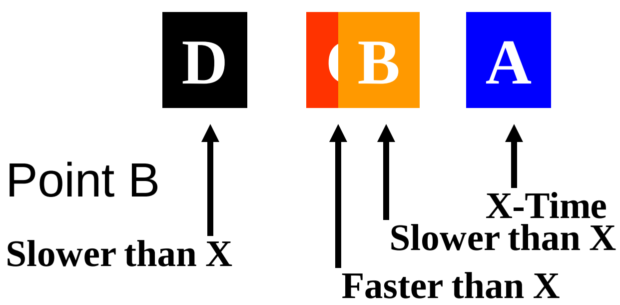
- Creates two problems
  - Direct speech quality
    - Part is FF, part is normal, part is 'Slow'
  - Could result in Packet Loss
    - Walk on top of packets if some are slow and consecutive ones are fast.



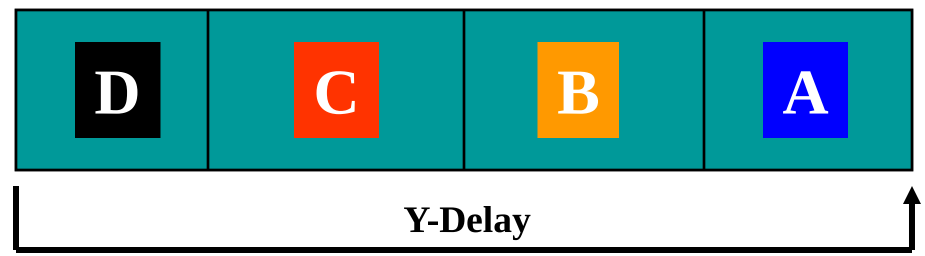
  - Could be capacity, physical or core architecture
    - Routers spitting out packets at varying intervals
    - Packets take different routes to destination

Jitter – Solution?

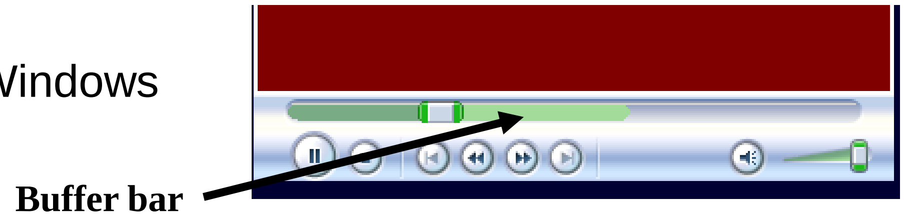
- Jitter Buffer
  - Add a place to store the data, and ‘spit’ it out at a constant rate
    - If packets come in fast – slow them down
    - Packets are slow – OK, we have added time to allow for this



Jitter Buffer

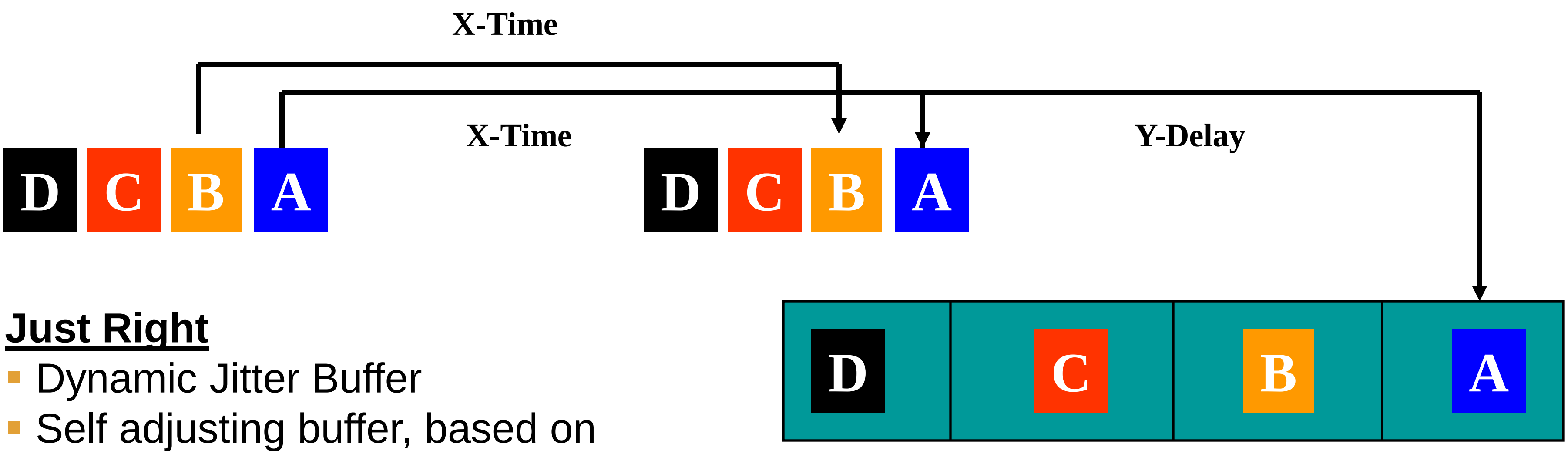


- Very similar to Windows Media Player



Jitter Buffer – Problem Solved?

- Yes and No
  - We have taken care of jitter (that isn't extreme), but have added delay: Y (buffer size)
    - If packets come in fast – *slow them down*
    - Packets are slow – OK, *we have added time to allow for this*

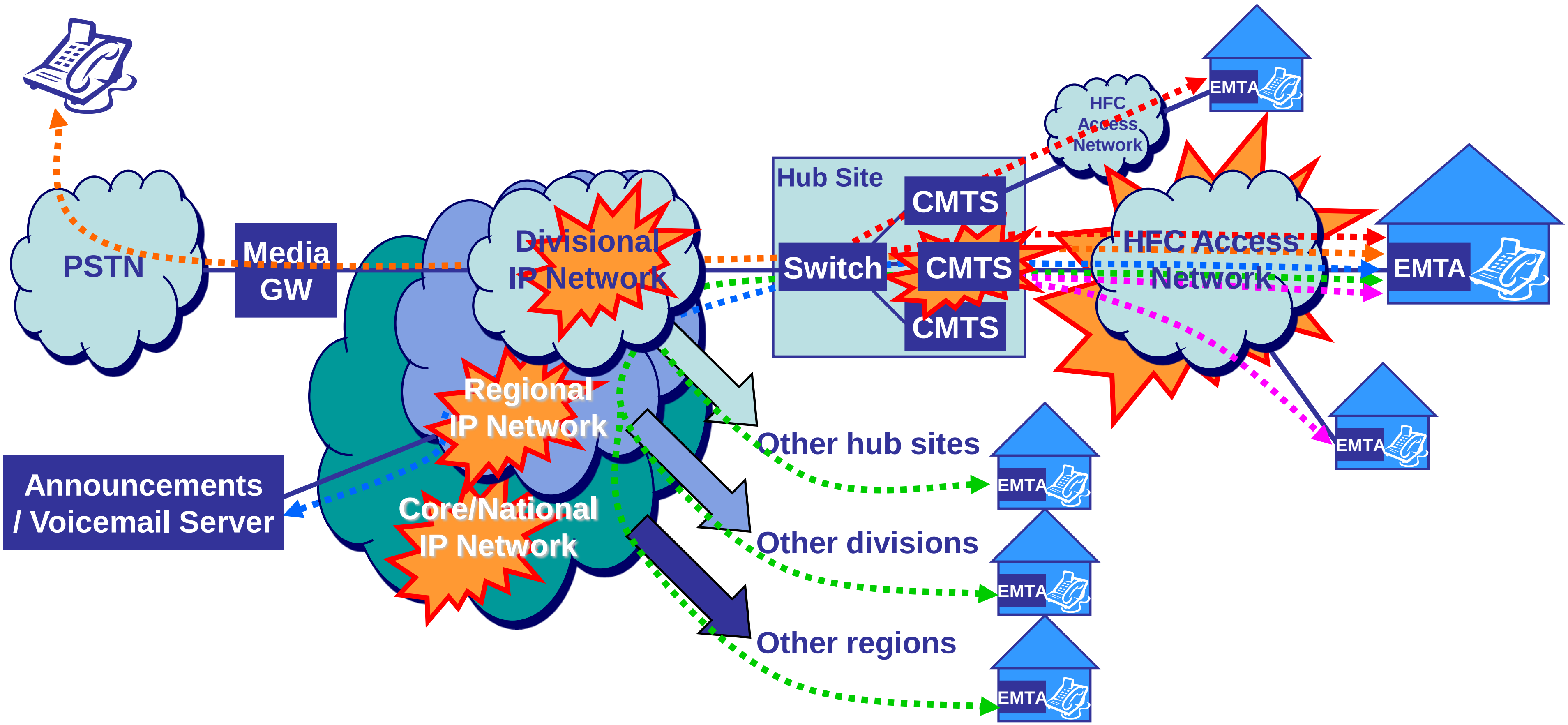


Just Right

- Dynamic Jitter Buffer
- Self adjusting buffer, based on system conditions which optimizes the jitter buffer

Variable IP call paths

- IP packet loss and jitter can occur at several points
- Longer IP call path = higher probability of IP impairments



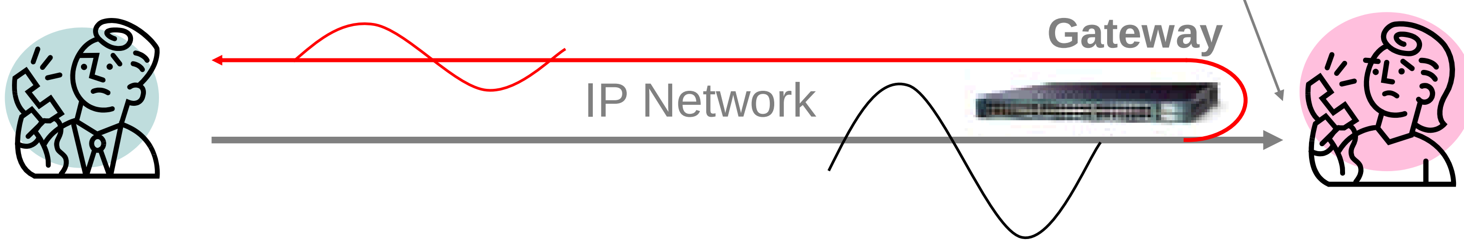
What is VoIP?

you hear echo then the source of the echo is either the far end or somewhere in the PSTN network.

Echo

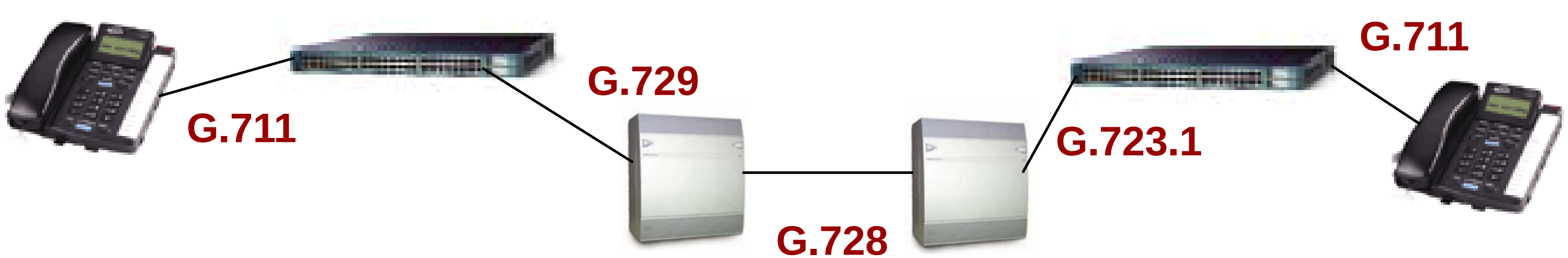
If the far end hears echo then you generate the Echo

- Reflection of speakers voice to speakers ear
  - Not a true digital or VoIP problem
  - Aggravated by network latency

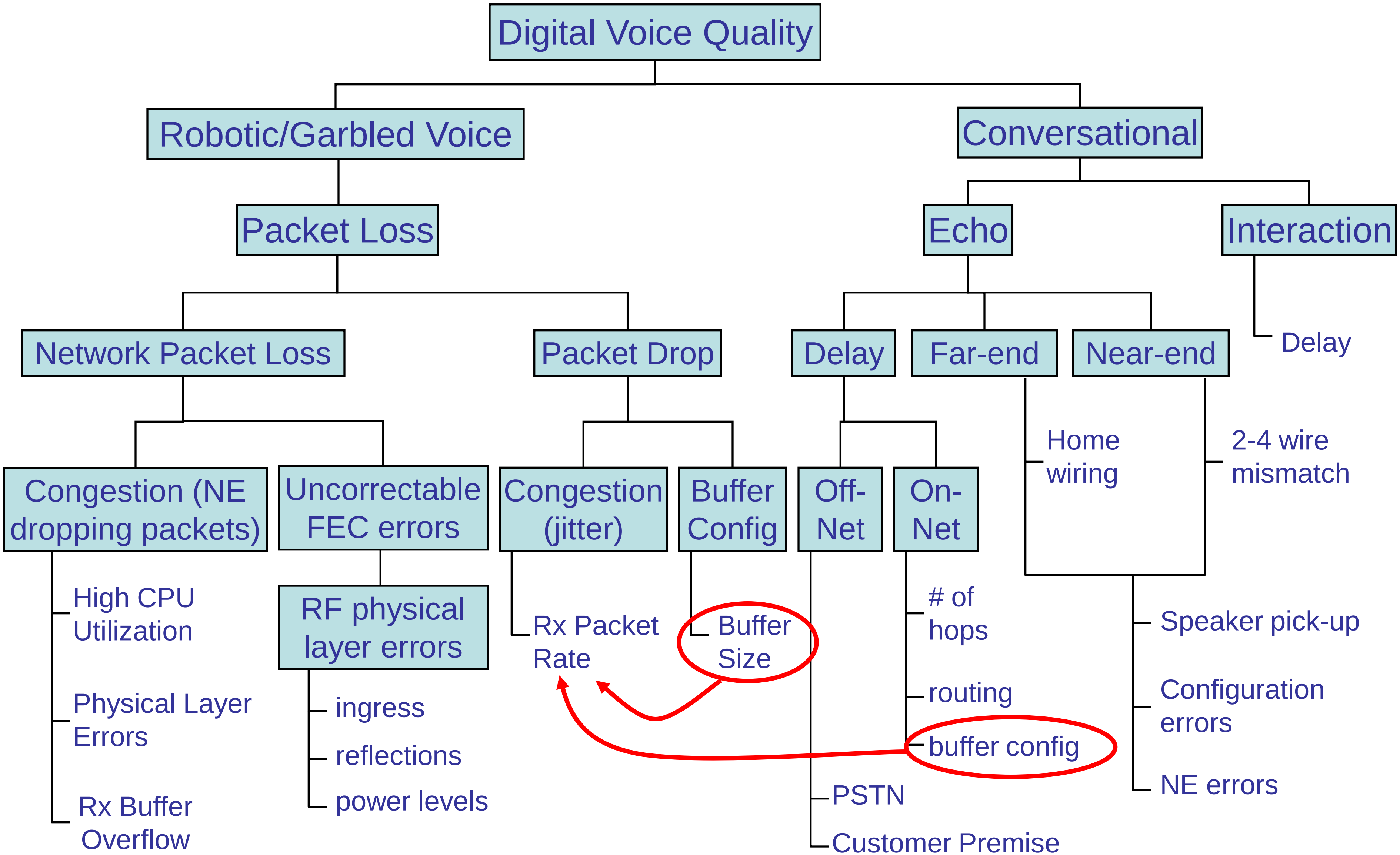


Multi-tandem distortion

- Multiple transitions between CODECS
- Each transition adds distortion



Interdependency between technological issues



DOCSIS and VoIP specific field tests

- Packet Loss
- Throughput
- Upstream transmit levels
- Provisioning files
- Ping tests
- Jitter
- Delay
- VoIP – MOS and R-Value

VoIP – Bullet Train Analogy

- Ideal World:
  - – Packets like train Cars through a station – 1 at a time, evenly spaced, and Fast
    - Bullet Train…

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VoIP – Train Analogy

- Real World
  - – VoIP Packets don't always do what you want…
    - Multiple railcars taking different directions, uneven spacing
    - Missing railcars… all = TRAIN WRECK!

Plant Problems

Why is it important?

What can be done?

Reverse Path Impairments

- Ingress and electrical noise
- Common Path Distortion (CPD)
- Thermal (intrinsic) noise
- Laser clipping noise
- Micro-Reflections

Reverse Path Impairments

There are a variety of impairments that can affect two-way operation.

They are classified in three main categories: ***stationary impairments***, which include thermal noise, intermodulation distortion,and frequency response problems; ***transient impairments***, which include RF ingress, impulse noise, and signal clipping; and ***multiplicative impairments***, which include transient hum modulation and intermittent connections.

Reverse Path Impairments

Thermal noise —The majority of thermal noise is generated in active components. Besides choosing active equipment with a relatively low noise figure, there is little else that you can do about the thermal noise in active devices, other than ensure proper network alignment.

Reverse Path Impairments

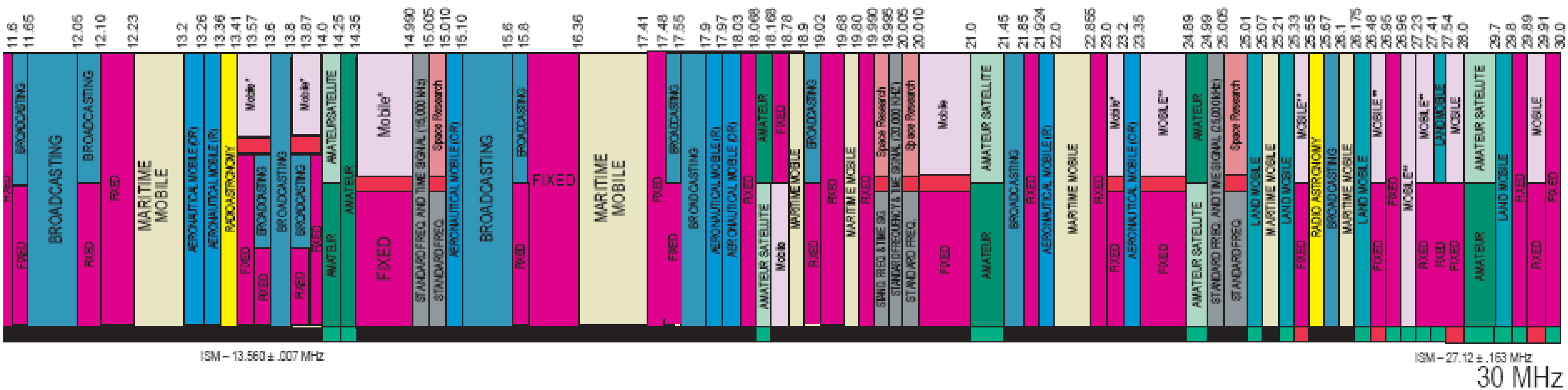
Intermodulation distortion—The most common types of intermodulation distortion affecting the reverse path are second and third order distortions. These can be generated in amplifiers and reverse lasers. A more troubling type of intermodulation can occur in some passive components. It is known as common path distortion (CPD), and usually occurs at a dissimilar metals interface where a thin oxide layer has formed.

Reverse Path Impairments

Frequency response— Frequency response problems are due to improper network alignment, unterminated lines, or damaged components. When reverse frequency response and equipment alignment have been done incorrectly or not at all, the result can be excessive thermal noise, distortions, and group delay errors.

Reverse Path Impairments

RF ingress — The 5-40 MHz reverse spectrum is shared with numerous over-the-air users.



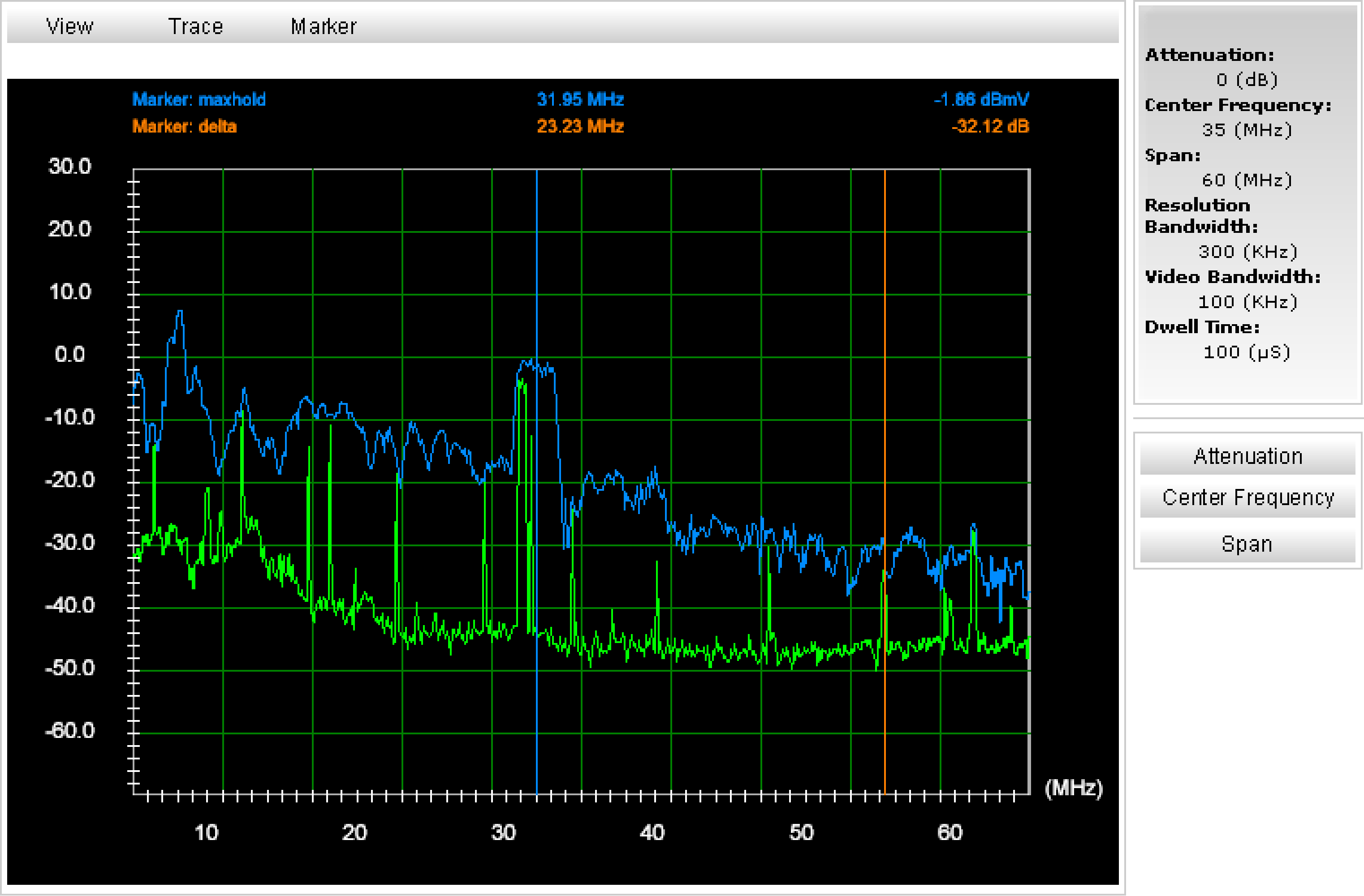
Signals in the over-the-air environment include high power shortwave broadcasts, amateur radio, citizens band, government, and other two-way radio communications.

Reverse Path Impairments

Impulse noise —Most reverse data transmission errors have been found to be caused by bursts of impulse noise. Impulse noise is characterized by its fast risetime and short duration.

Common sources include vehicle ignitions, neon signs, static from lightning, power line switching transients, electric motors, electronic switches, and household appliances.

Impulse Noise in the Upstream



Reverse Path Impairments

Signal clipping —RF ingress and impulse noise can cause signal clipping, or compression, in reverse plant active components. Excessive levels from in-home devices such as pay-per-view converters also can cause clipping. Clipping occurs in reverse amplifiers and optical equipment.

Reverse Path Impairments

Transient hum modulation — Transient hum modulation manifests itself as a low frequency disturbance to carriers on the network, and is thought to be generated when high current in a network passive device causes the device's ferrite materials to saturate.

Ingress

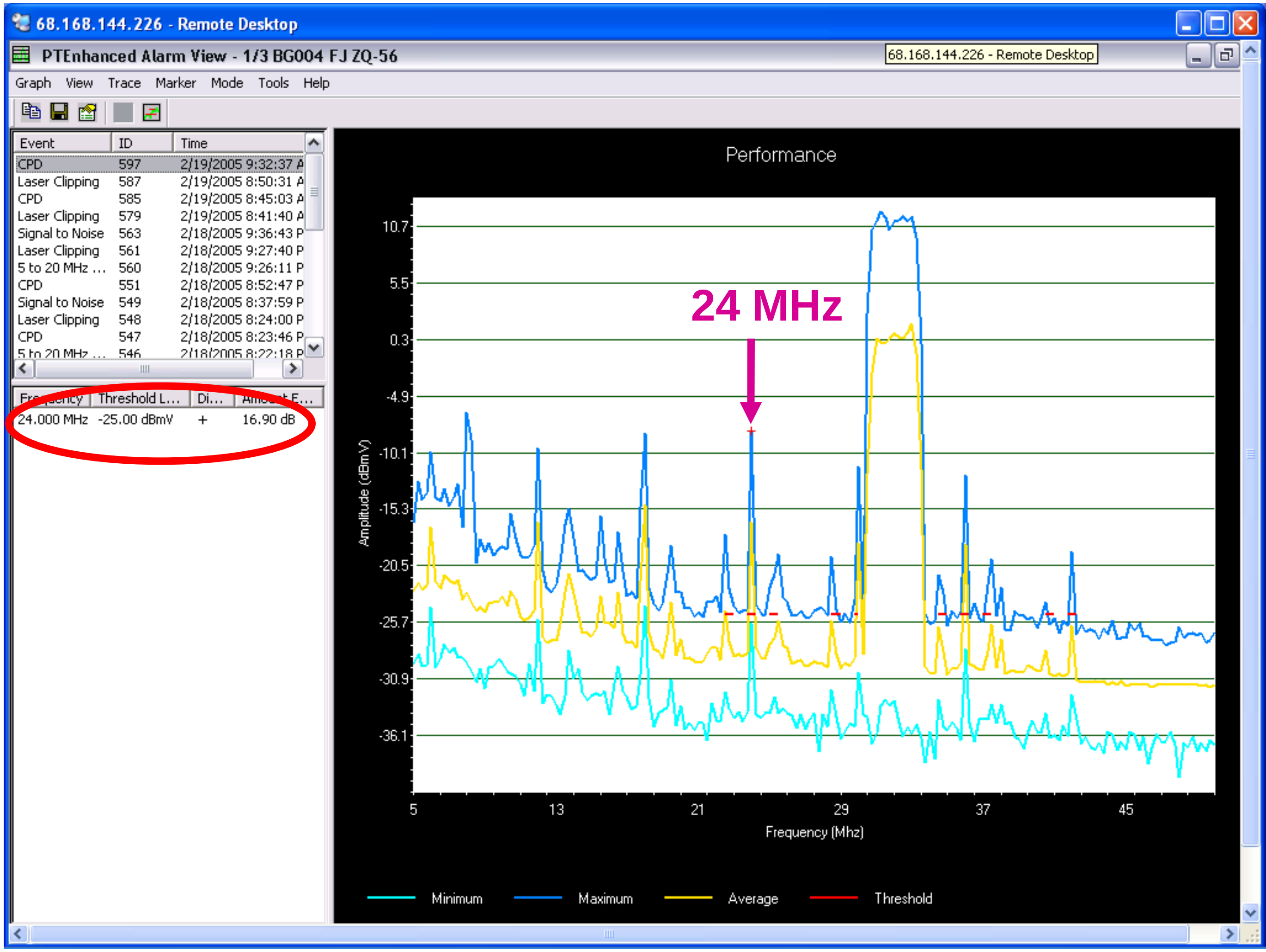
- 75 – 90% of ingress originates in the subscriber's home
- To minimize the effects of ingress, operate the subscriber terminals (modems & set-tops) near maximum transmit level

Common Path Distortion (A.K.A. CPD)

- Non-linear mixing from a diode junction
  - Corrosion (metal oxide build-up) in the coaxial portion of the HFC network
  - Dissimilar metal contacts
  - 4 main groups of metals
    - Magnesium and its alloys
    - Cadmium, Zinc, Aluminum and its alloys
    - Iron, Lead, Tin, & alloys (except stainless steel)
    - Copper, Chromium, Nickel, Silver, Gold, Platinum, Titanium, Cobalt, Stainless Steel, and Graphite
- Second and third order distortions

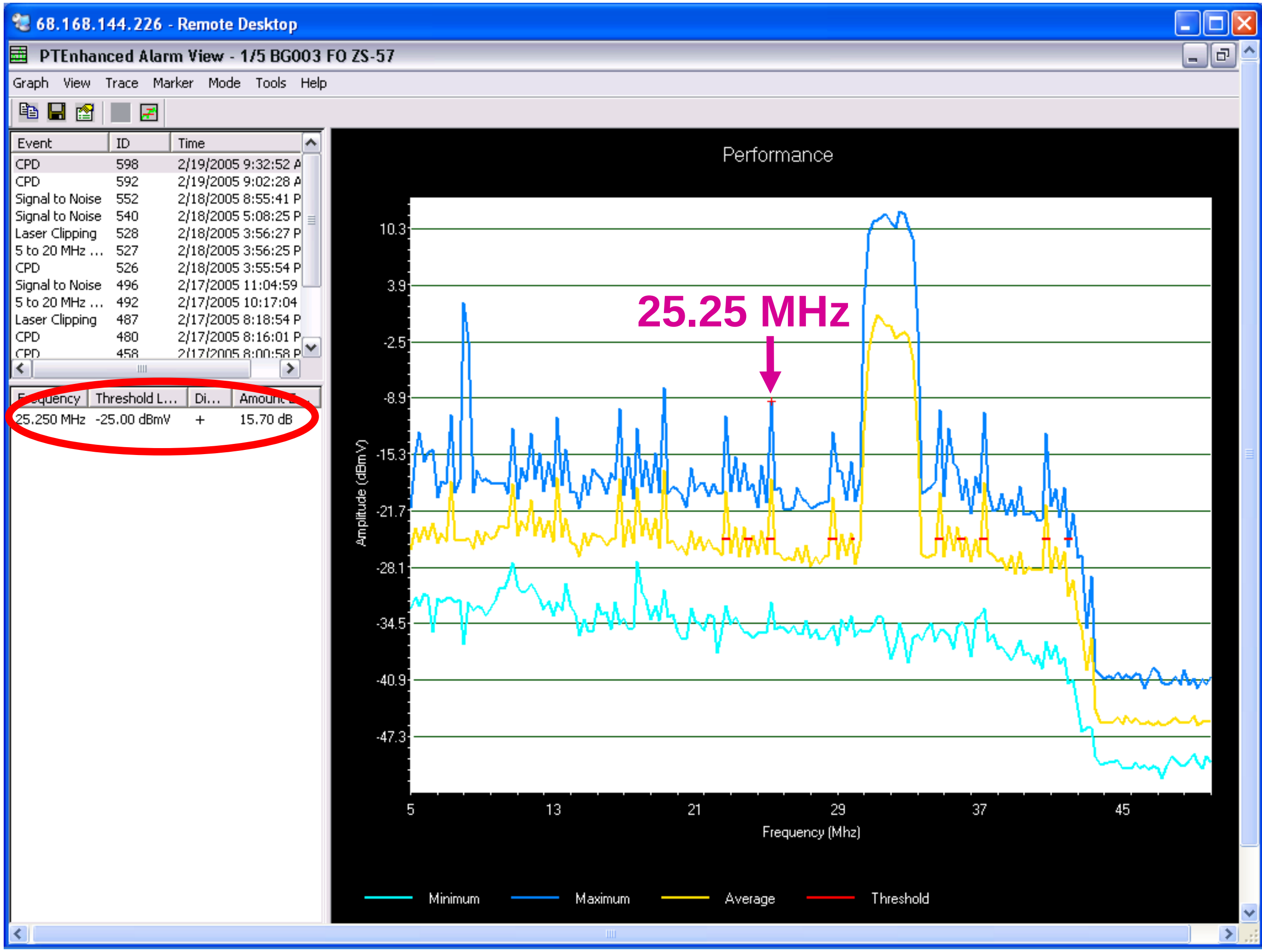
Common Path Distortion (A.K.A. CPD)

CPD distortions are spaced at 6 MHz apart from each other starting at 6 MHz



Common Path Distortion (A.K.A. CPD)

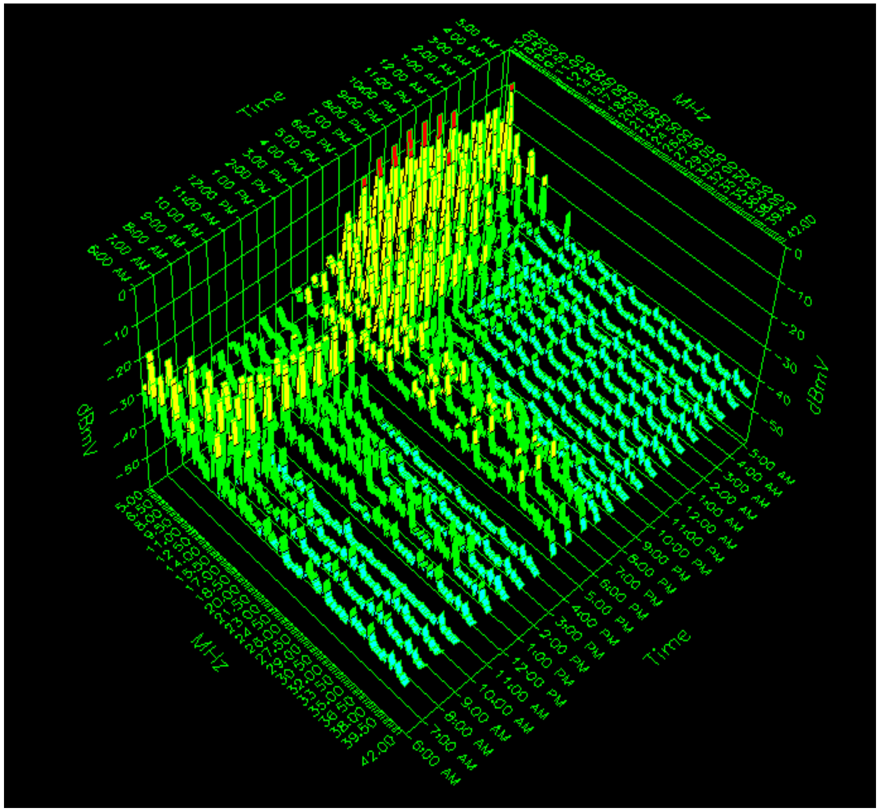
CPD can be higher in level at +/- 1.25 MHz above and below the primary CPD frequencies



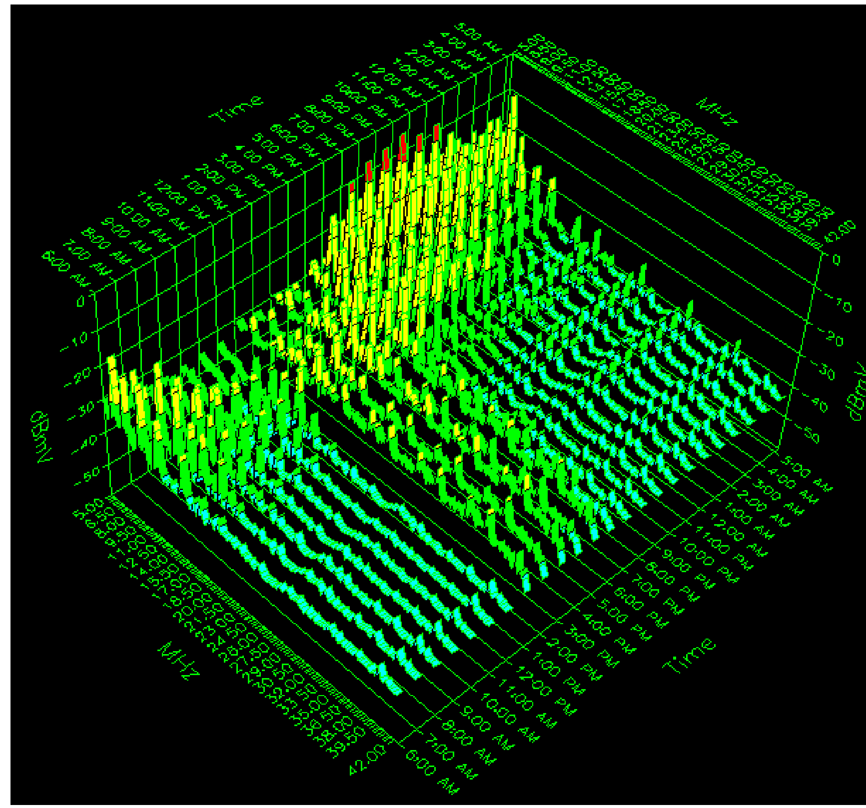
CPD Changes Over Time and Temperature

Average Noise by Hour

Day 1



Day 2



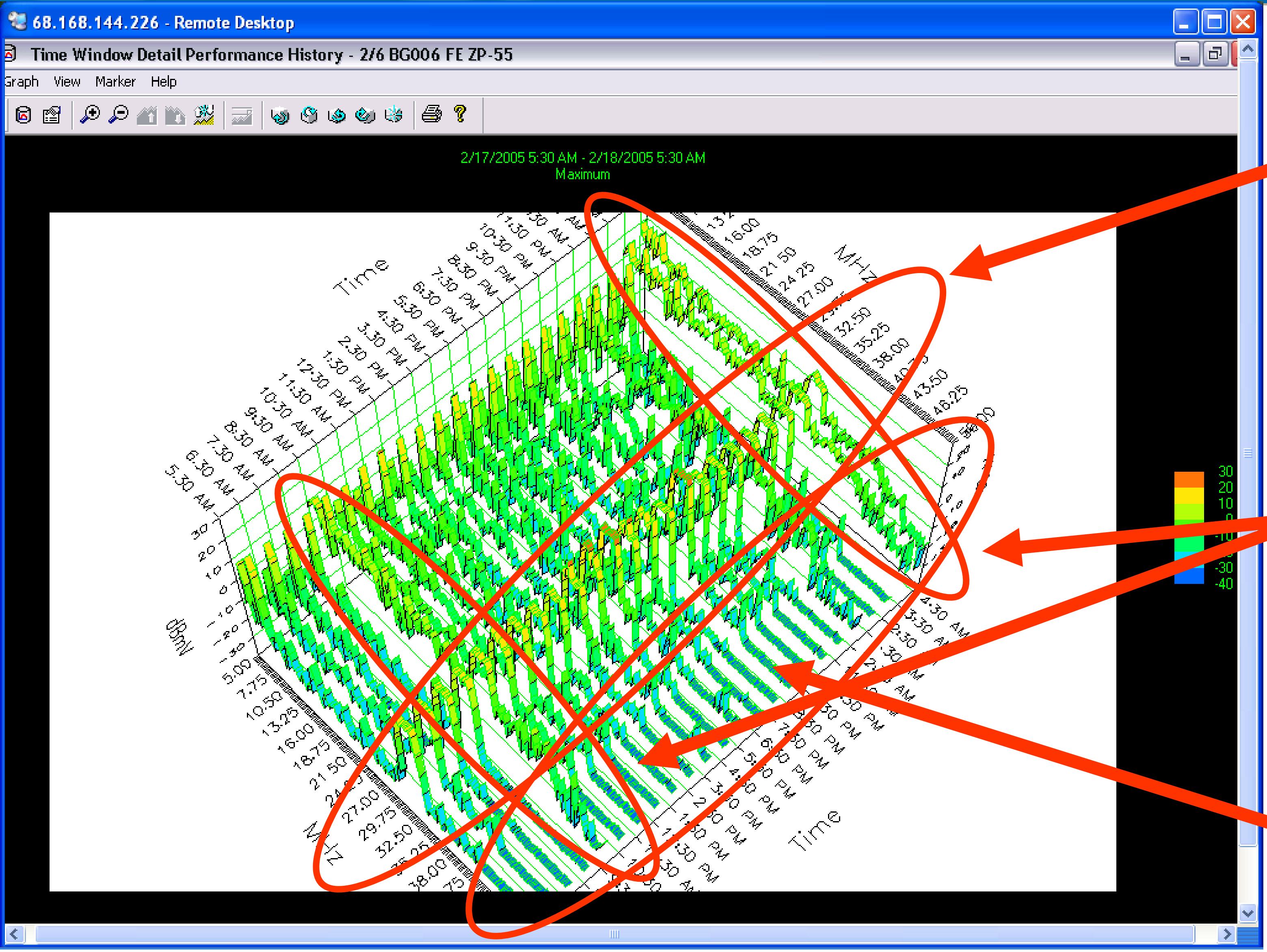
Reverse Path Performance History shows intermittent CPD that varies by time of day. If you only look at snapshot of performance during day you would miss what would affect customer service at night.

Thermal Noise and Laser Noise

- Maintain a tight control of reverse RF signal levels
  - Laser drive level too high
    - *causes excessive laser clipping*
  - Laser drive level too low
    - *reduces C/N and C/I ratios*

Reverse levels must be held to a relatively narrow 'window' in order to guarantee that they fall comfortably between a lower limit (imposed by the noise floor) and a higher limit (set by laser clipping noise)

24 Hour Performance History Max Hold Detail Graph



DOCSIS® Modem Carrier

Wide band noise beyond 42 MHz diplex roll-off

Diplex roll-off above 42 MHz

JDSU

Micro-reflections

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, but *all* unused tap ports should be terminated with 75-ohm terminations (locking terminators *without* resistors or stingers do not terminate the tap port)
- Poor isolation in splitters, taps and directional couplers
- Unused customer premises splitter and directional coupler ports not terminated
- Use of so-called self-terminating taps at feeder ends-of-line; these are the equivalent of splitters, and do not terminate the feeder cable unless *all* tap ports are terminated
- 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

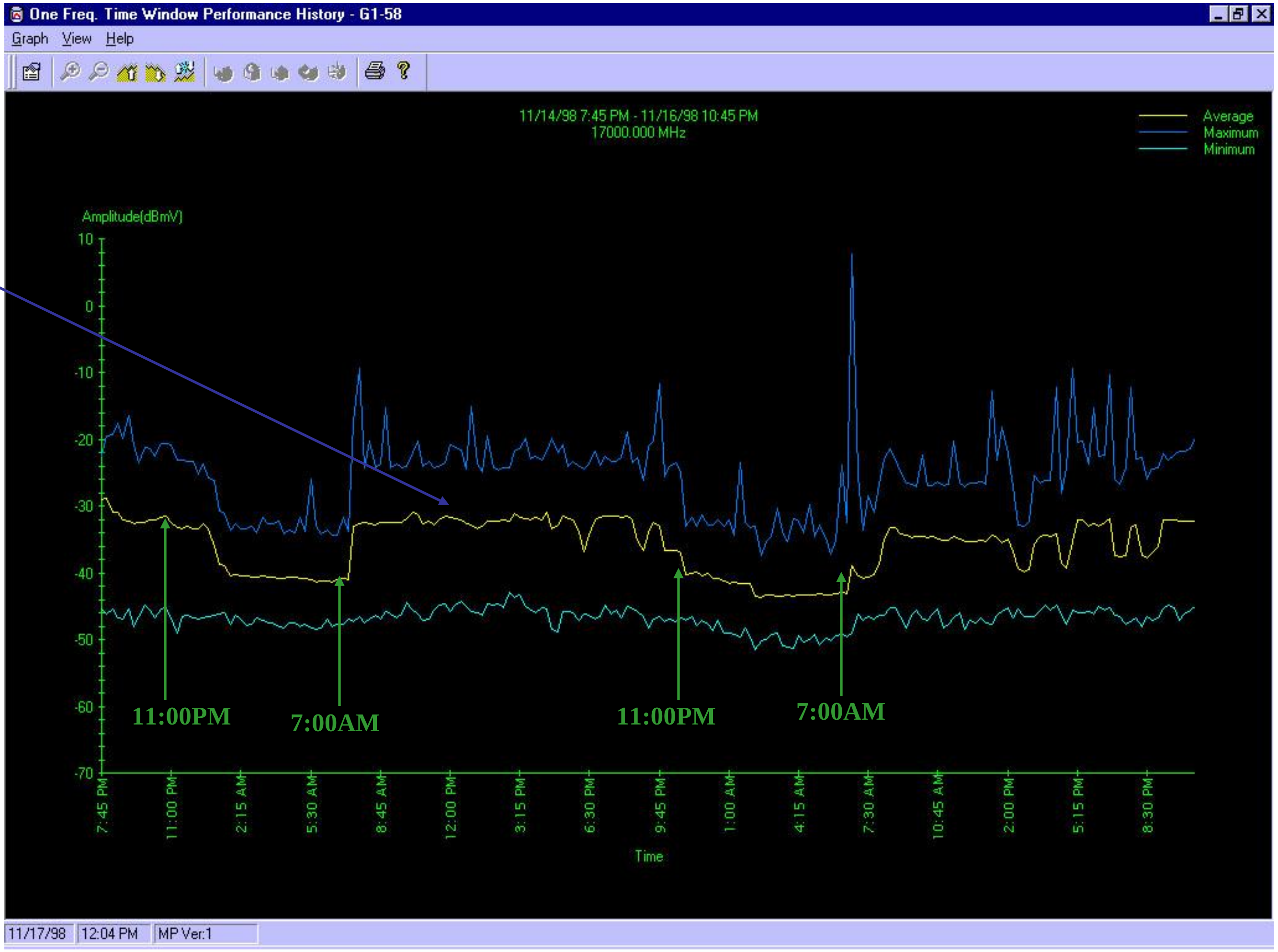
Cisco Systems

RON HRANAC
rhranacj@cisco.com

JDSU

Sample: "Loose Plant" Performance History

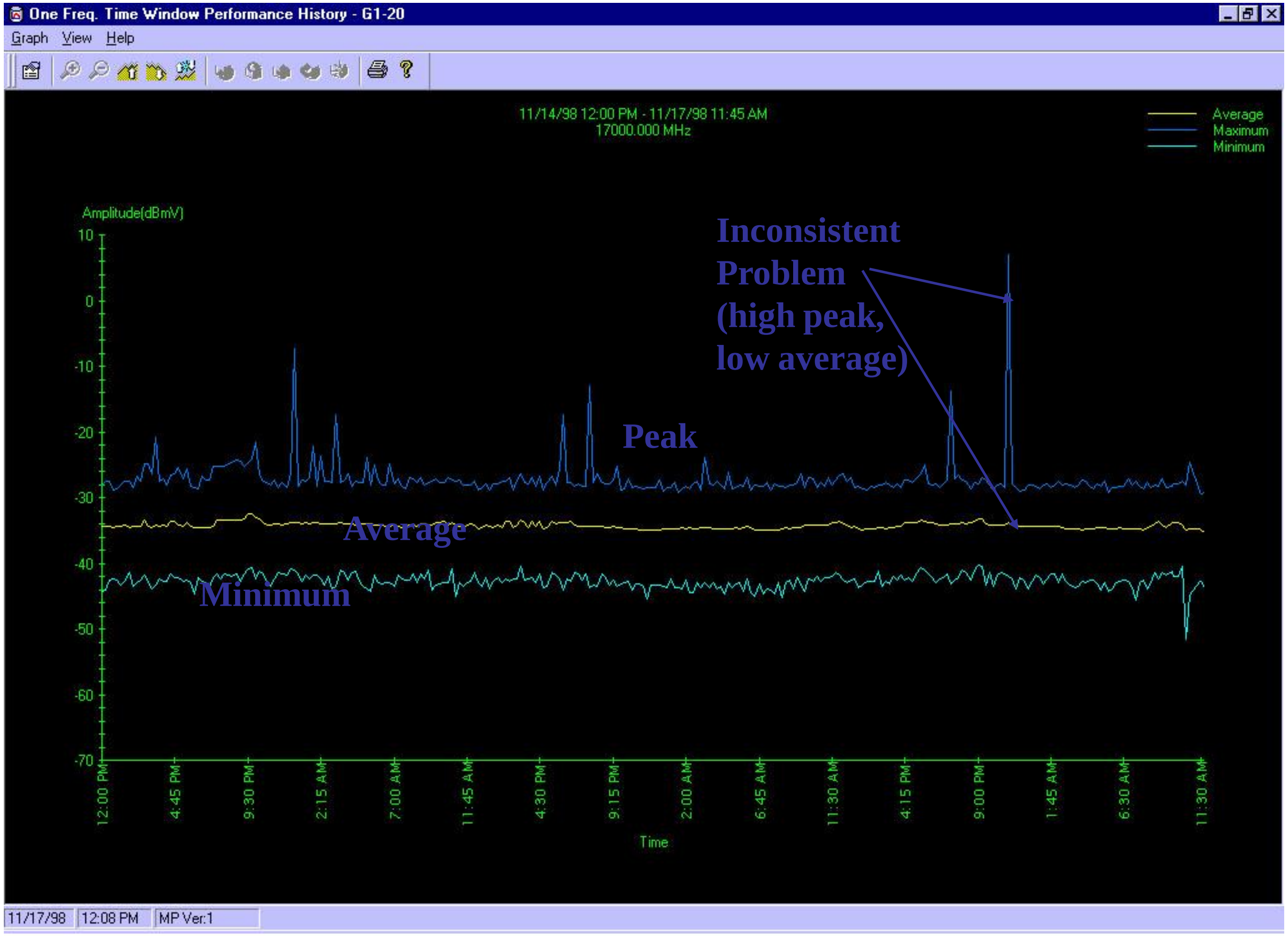
- **Average noise floor at 17 MHz varies consistently by time of day**
- **Indication of return path with an ingress problem.**
- **Maintenance now will prevent future problems**



Single Frequency Time Window for 72 Hours from one return path

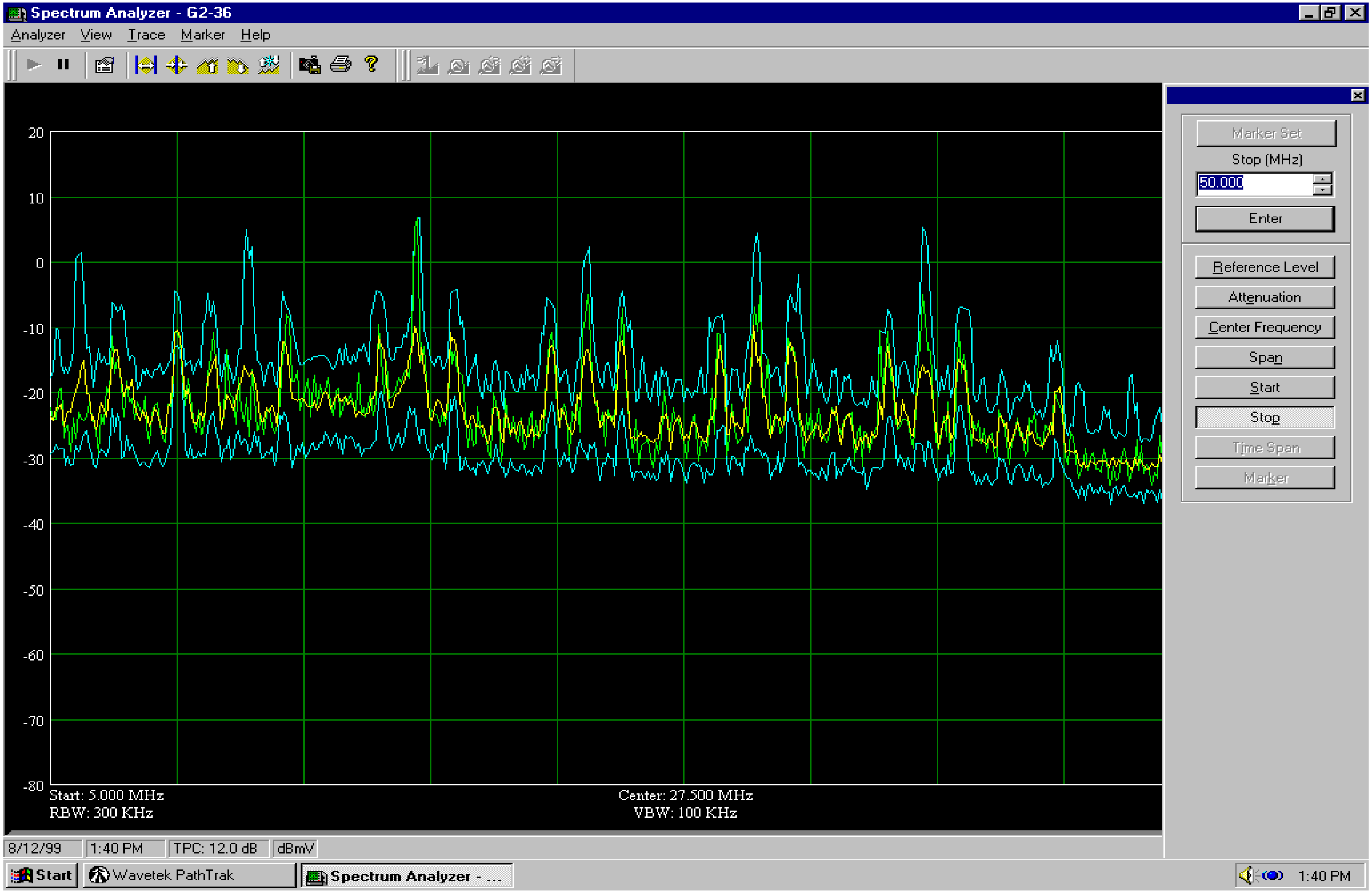
Sample: 'Tight' Performance History

- 17 MHz noise floor tracked over time
- Average noise floor stays fairly flat and consistent over the 3 day period



Single Frequency Time Window for 72 Hours from one return path

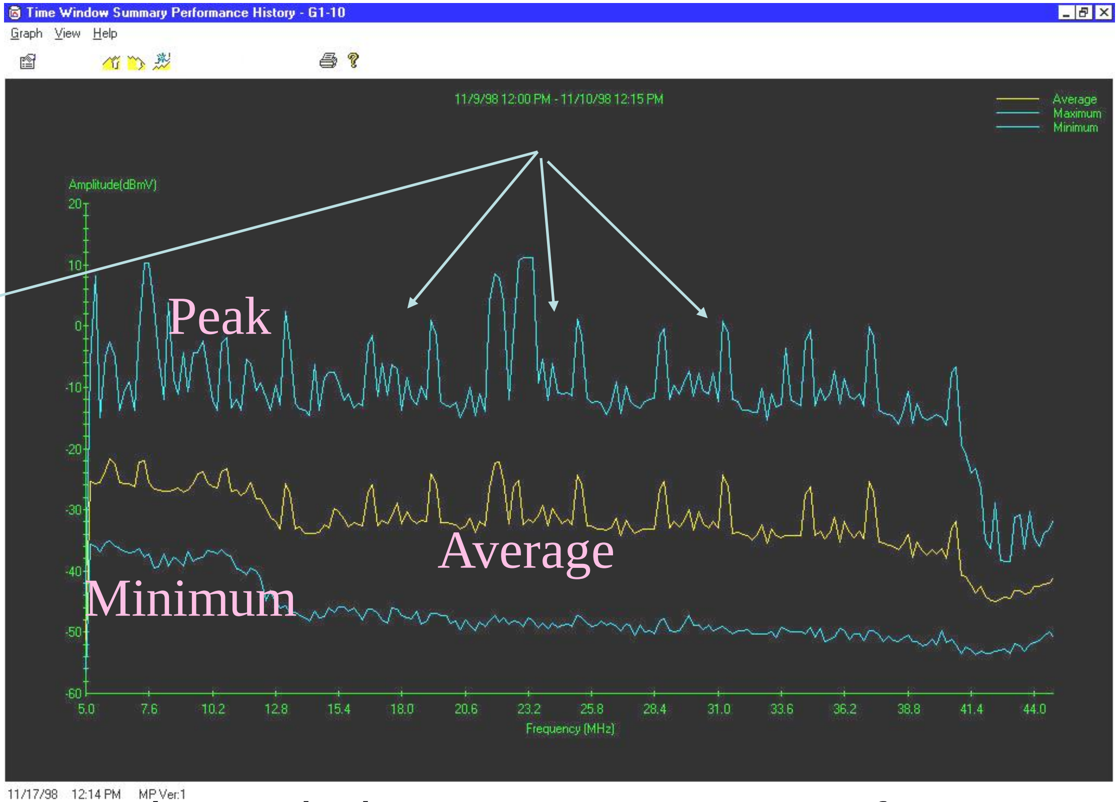
6MHz CPD



Spectrum Analyzer - G2-36
Analyzer View Trace Marker Help
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
Start: 5.000 MHz
RBW: 300 KHz
Center: 27.500 MHz
VBW: 100 KHz
Marker Set
Stop (MHz)
50.000
Enter
Reference Level
Attenuation
Center Frequency
Span
Start
Stop
Time Span
Marker
8/12/99
1:40 PM
TPC: 12.0 dB
dBmV
Start
Wavetek PathTrak
Spectrum Analyzer - ...
1:40 PM

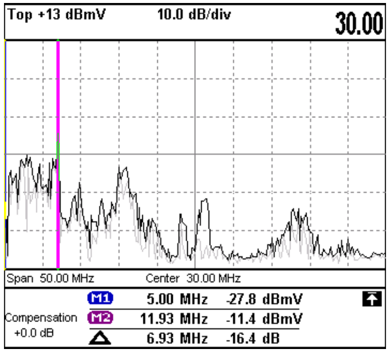
Sample CPD Performance History Report

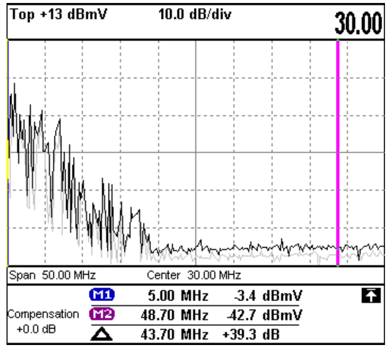
- Peak distortion repeated at 6 MHz intervals
- The Average is lower in level
  - May have stopped or intermittent throughout the day

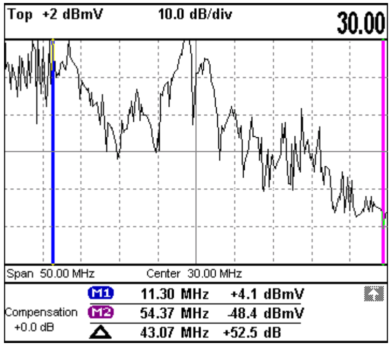


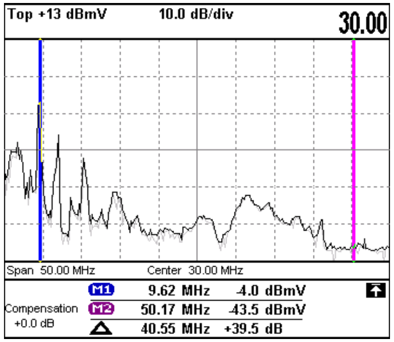
Time Window Summary Report for 24 hours from a single return path

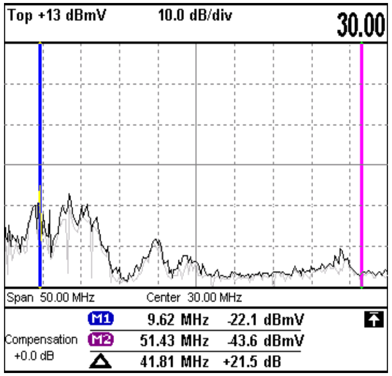
Local Drop Reverse Spectrum Samples

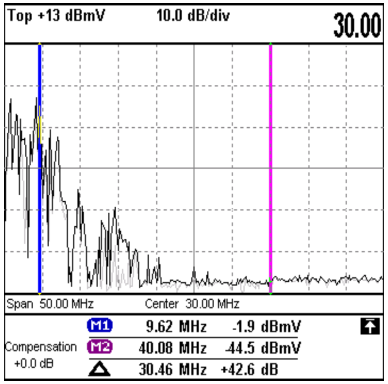


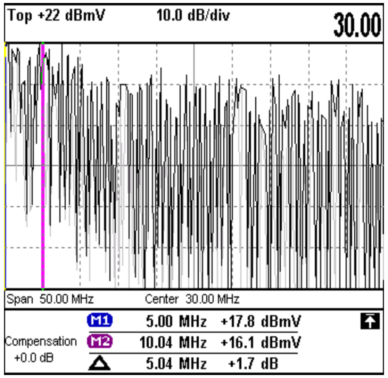


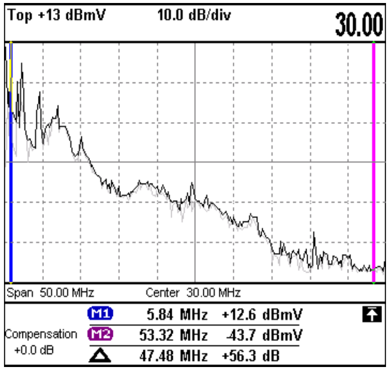


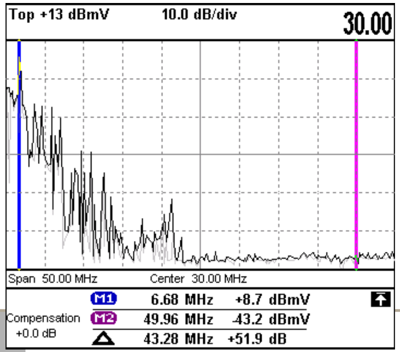


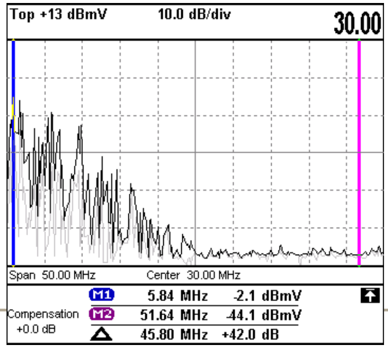


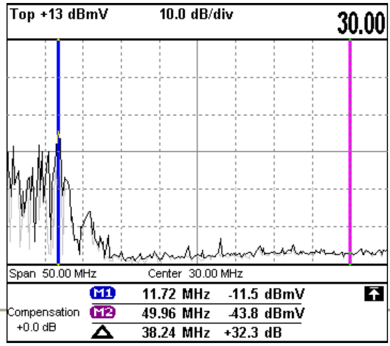


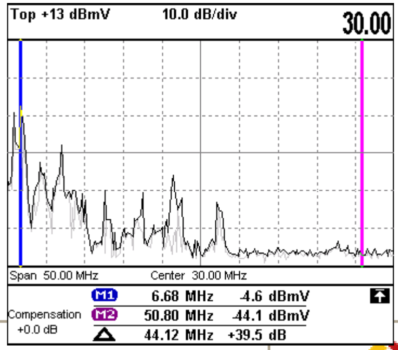




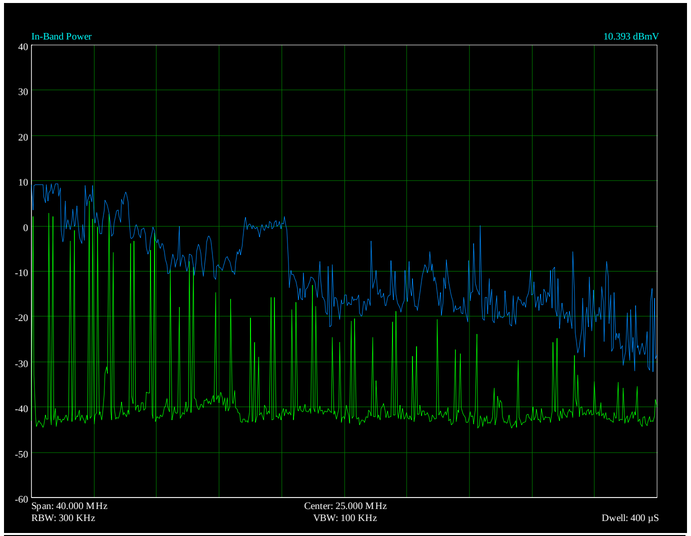


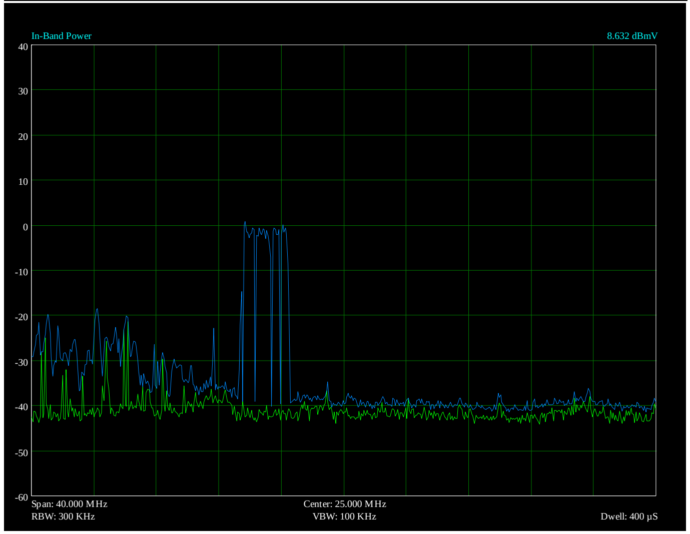


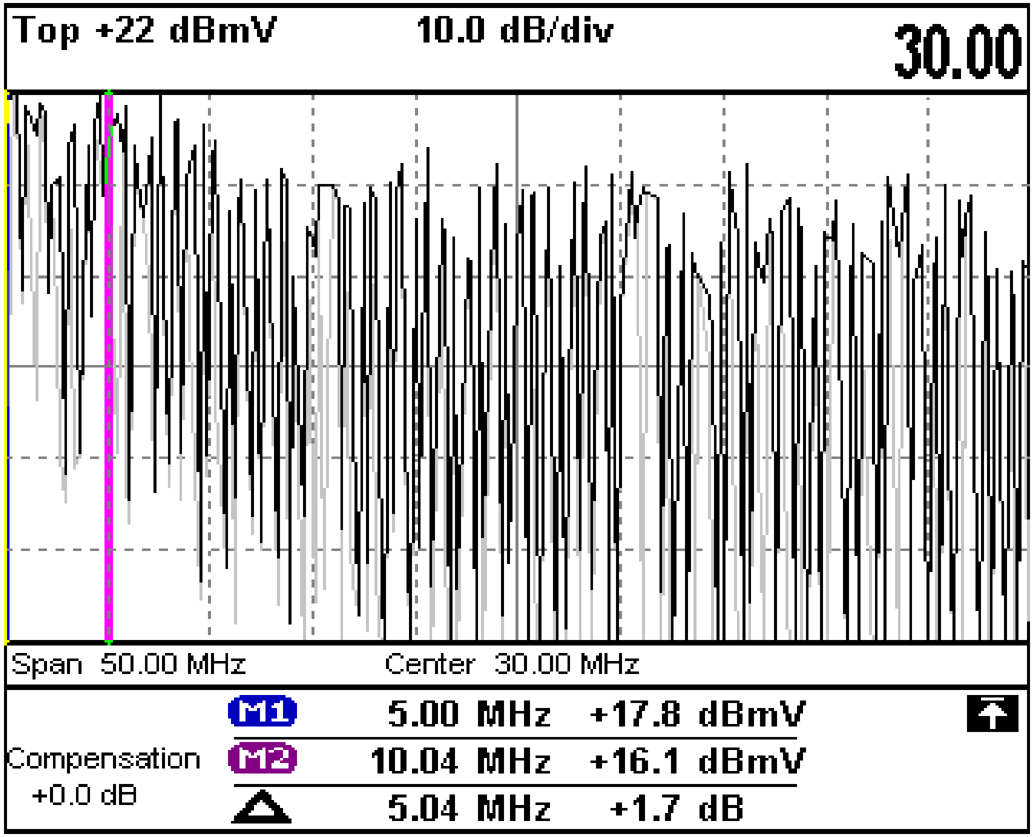




1 Drop – 1 Node – DO NOT NEGLECT DROP INGRESS MITIGATION!!







- **Reverse Spectrum shot at customer's drop**

Troubleshooting is "Back to the Basics"

- Majority of problems are basic physical layer issues
- Most of the tests remain the same
- Check power
- Check forward levels, analog and digital
- Check forward / reverse ingress
- Do a visual check of connectors / passives
- Replace questionable connectors / passives
- Tighten F-connectors per your company's installation policy
  - Be very careful not to over tighten connectors on CPE (TVs, VCRs, converters etc.) and crack or damage input RFI integrity

Thank You !

Mark Ortel

Support Engineer

JDSU

Cable Networks Division

www.jdsu.com

SCTE Chapter