The Correlation of CER to BER:

Typically, when we look at errors on modems in ServAssure, we are looking at Codeword Error Rate (CER) but when looking at errors on digital cable boxes in iGlass or Unified, we are looking at Bit Error Rate (BER). Is there a relationship between the two?

It almost goes without saying that if a device receives an errored codeword of data, there must have been a number of bits within the codeword which were errored to cause this. Moving beyond the obvious though, what is the exact relation?

While a discussion of bit error rate can get quite lengthy and complicated, at this point it is best just to realize that if a codeword of data is unable to be corrected it therefore means that the correction algorithm was unable to determine which bits were bad and therefore how many were bad. Given this, the only way for the BER of this errored codeword to be given is to use a mathematical formula to estimate how many bits within the codeword were in fact errored.

Above is shown a marginal BER on a cable box. What would the equivalent CER be?

The main difficulty with this though is that different manufacturers can use different formulas to calculate this value. Therefore for a given codeword error rate, iGlass can report one BER and a DSAM meter another. Further complicating this is Pre-BER and Post-BER. These just state the BER before Forward Error Correction (FEC) attempts to fix the errored bits and the BER after the FEC fixes as many broken bits as it can (essentially pre-correction errors and post-correction errors). While DSAM meters will report both pre and post correction, iGlass reports Pre-BER (in addition to corrected bytes and uncorrected codewords).

Because of the different methods used to calculate BER, there is no definite conversion to CER. However, we can come up with a rough correlation through no less authoritative a source than the DOCSIS Specification. While the DOCSIS 1.1 specification that our network currently works under only gives threshold limits for BER, the DOCSIS 3.0 Specification gives both BER and CER threshold limits. Since the specification for BER is the same for both, 1.0E-08, CER specifications should be equivalent for both as well. Below is the page from the DOCSIS 3.0 specification:

6.3.3.2 256 QAM

6.3.3.2.1 256 QAM CM BER Performance

Implementation loss of the CM MUST be such that the CM achieves a post-FEC BER less than or equal to 10^{-8} when operating at a carrier to noise ratio (E_s/N_o) as shown below. If it is not possible to measure post-FEC BER directly, Codeword Error Rate, R_C (as defined in Section 6.3.3.1.1) may be used. In this case, the CM MUST achieve a Codeword Error Rate of less than or equal to 9×10^{-7} when operating at a carrier to noise ratio (E_s/N_o), as shown in the following:

Input Receive Signal Level	E_s/N_o
-6 dBmV to +15 dBmV	30 dB or greater
Less than -6 dBmV down to -15 dBmV	33 dB or greater

Per the above specification then, the CER should be less than or equal to 9E-07. Converting this from scientific notation to decimal gives us a value of 0.0000009. Converting this to a percentage will give us 0.00009%.

Given the above, the CER on a modem should stay below 0.0001% to stay within specification.

This is a pretty low error rate as far as an Internet connection goes. In fact it could probably go significantly higher and still maintain a connection that will not be noticeably degraded for the customer. This is because most traffic across the Internet uses TCP packets, which if errors in the data stream occur, the protocol will simply request the data be resent. Therefore, since all the data will eventually get across the connection, there ultimately won't be any data loss, just slowdown from the multiple retries to send the same data. Keep in mind though, this is not the case for streaming audio and video as these are UDP packets and are degraded by packet loss.

Digital phone is a different situation, being similar to streaming audio and video. Since the voice data is sent across as a continuous stream, there is no ability to resend errored data. Any errors that aren't corrected through Forward Error Correction (FEC) will introduce a gap in the voice which will cause choppiness to be heard in the audio. At what point this degradation will be noticeable to the customer is purely subjective though. Below is information from Motorola regarding this.

Motorola VOIP Testing

Overall voice quality is subjective. Lab tests have shown that the human ear can detect degradation at a CER of 1xE-4 level - Occasional pops and minor disturbances, but you can still make and complete calls.
CER 1 x E-3 - Voice quality is noticeably impacted with pops and portions of some words dropped, but can still make and complete calls. Calls are typically not dropped until the modem almost loses DS lock.

***Good level** = 9 x E-7 CER or 1 x E-8 BER is the DOCSIS spec.*
***Yellow level** = CER of 1 x E-5*
***Red level** = CER of 1 x E-4 or greater*

Any drop in CER below the DOCSIS spec could impact voice quality.

Given the above parameters from Motorola, a good CER to maintain for digital phone is the DOCSIS specification of less than or equal to 0.00009% (or less than .0001%). The marginal level (yellow) is 0.001% and the threshold (red level) is 0.01% CER.

Video, like voice, is more critical as well. Video data is also a continuous stream and any errors that aren't corrected through FEC will mean the data is gone forever. Therefore, the specifications are equally tight: good 1E-8, marginal 1E-7 and bad 1E-6.

CER to BER Correlation:

Since the DOCSIS 3.0 specification says that 0.0001% CER is roughly equivalent to 1.0E-8 BER, if we see uncorrected errors on a modem downstream channel above this level, will we also see pixilation on video services? Most likely yes.

The modem downstream channel is on a frequency of 711MHz. There are video QAM's close to this at 687MHZ, 693MHz, 717MHz, 723MHz, etc. While you will hear the argument that CER on a modem won't cause high BER on a cable box, this really isn't the issue.

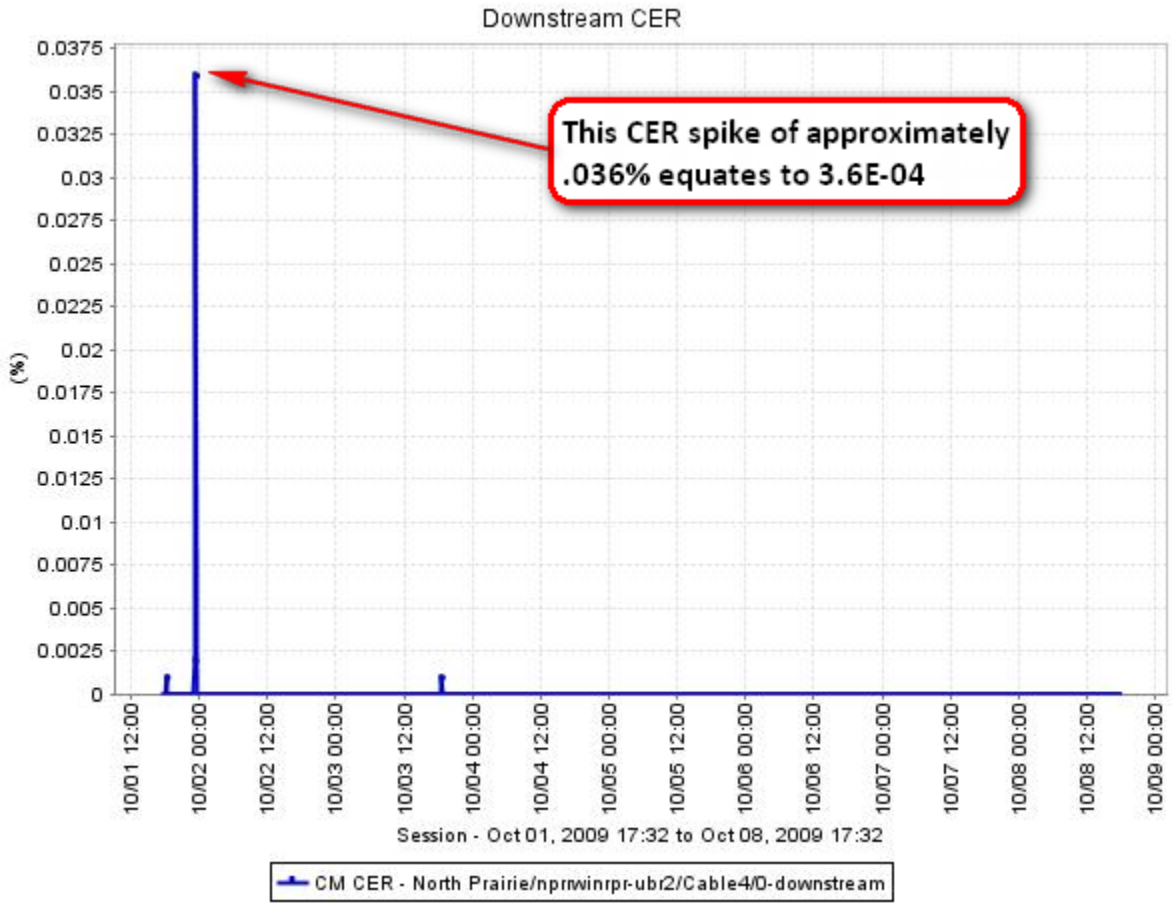
High CER on a modem and high BER on a cable box are not the root problems in and of themselves. These errors are symptoms of a problem. The question then becomes what issue is causing these symptoms?

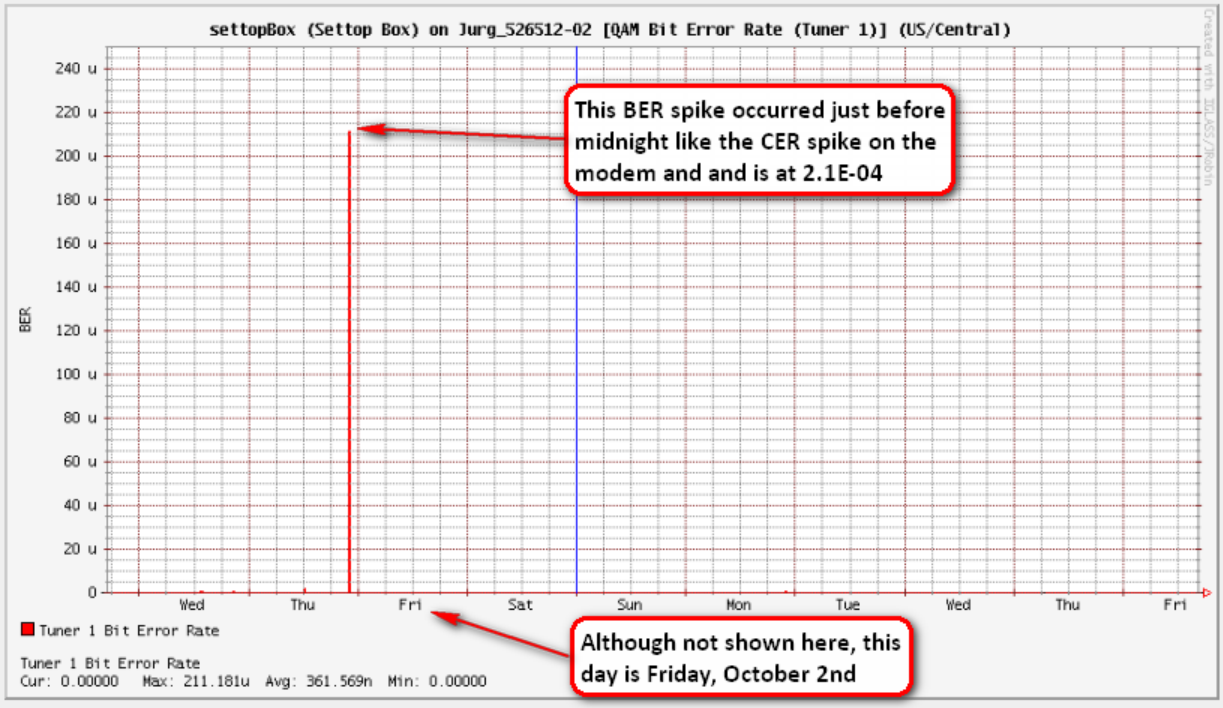
Is it a corroded connector (either hardline or soft cable); is it a degraded cable (again hardline or soft cable); is it a cracked hardline; is it a drop amplifier that's overdriving the equipment; is

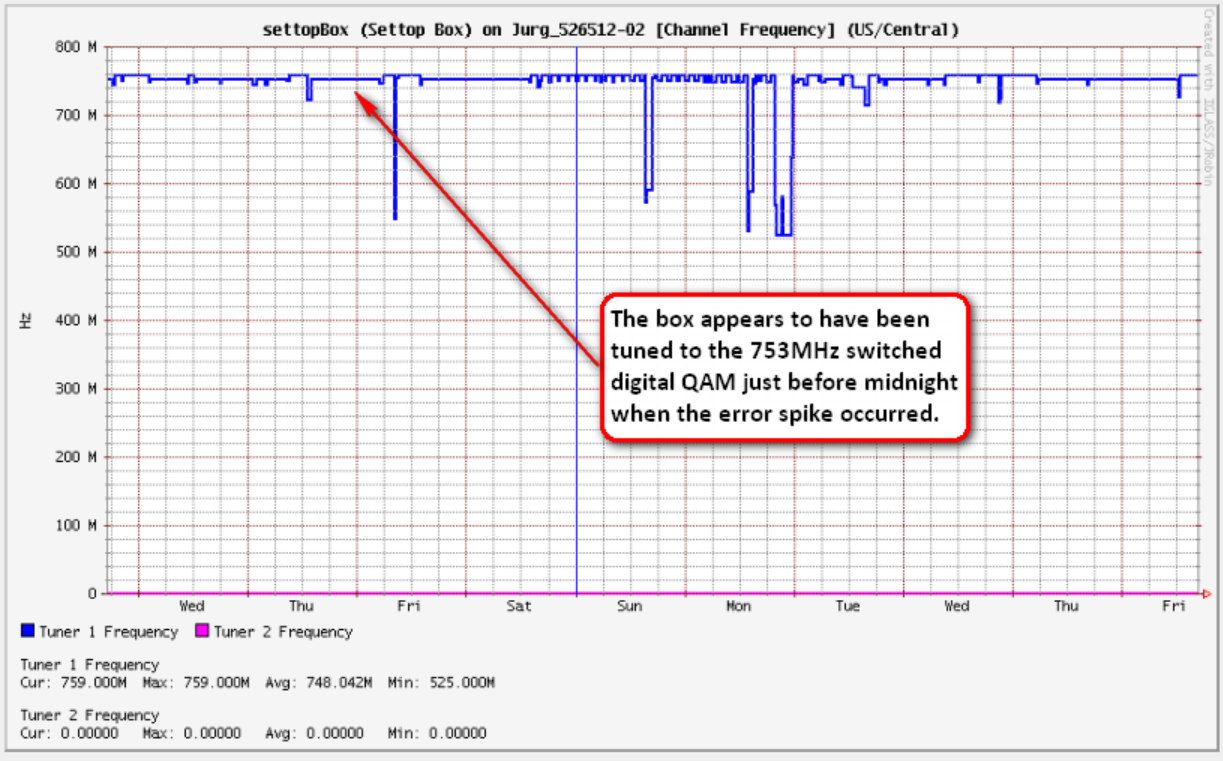
it an active not balanced properly thus causing a non-linearity in the signal? These are just some of the problems which may cause the symptoms of high BER and High CER.

While it is conceivable that the corrosion on a hardline connector is degraded in such a manner that it will only affect a very narrow portion of the frequency spectrum around 711MHz, this is probably only a one in a million chance. It is far more likely that this corrosion will affect the entire upper frequency spectrum and thus affect both the modem downstream channel and all higher frequency video QAM's as well. Thus if we are seeing high CER spikes on modem down streams throughout a certain leg of the node, there is a great deal of certainty the issue causing these errors will equally be affecting cable boxes as well.

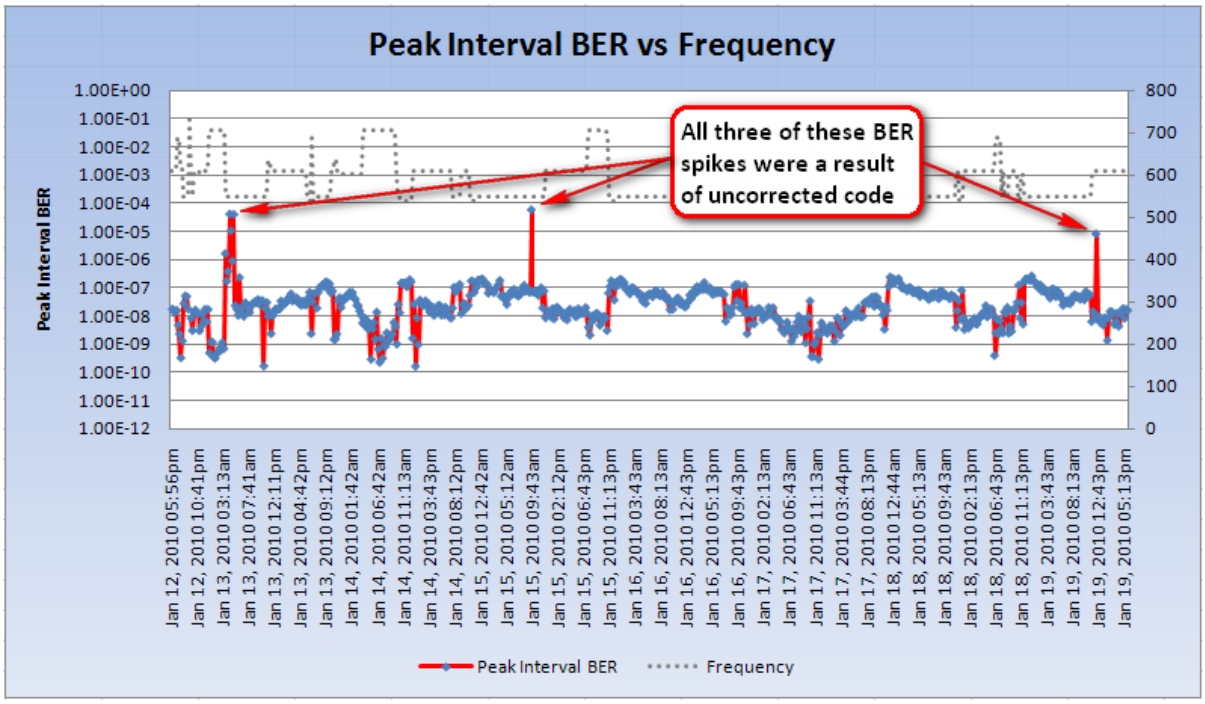
To demonstrate this, below are monitoring graphs for a modem and cable box at the same customer premises. As can be seen, there was a CER spike on the modem and a BER spike on the cable box which occurred during the same timeframe.

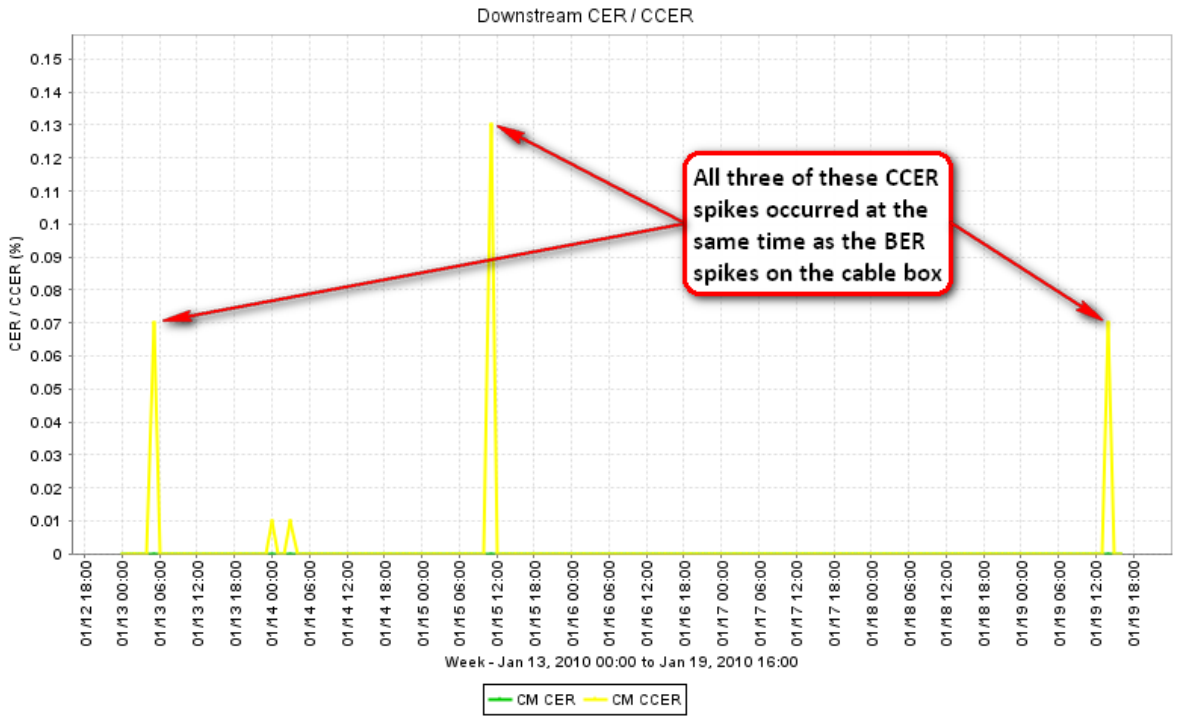



settopBox (Settop Box) on Jurg_526512-02 [QAM Bit Error Rate (Tuner 1)] (US/Central)
BER
240 u
220 u
200 u
180 u
160 u
140 u
120 u
100 u
80 u
60 u
40 u
20 u
0
Wed
Thu
Fri
Sat
Sun
Mon
Tue
Wed
Thu
Fri
This BER spike occurred just before midnight like the CER spike on the modem and and is at 2.1E-04
Although not shown here, this day is Friday, October 2nd
Tuner 1 Bit Error Rate
Tuner 1 Bit Error Rate
Cur: 0.00000 Max: 211.181u Avg: 361.569n Min: 0.00000


settopBox (Settop Box) on Jurg_526512-02 [Channel Frequency] (US/Central)
Hz
800 M
700 M
600 M
500 M
400 M
300 M
200 M
100 M
0
Wed
Thu
Fri
Sat
Sun
Mon
Tue
Wed
Thu
Fri
The box appears to have been tuned to the 753MHz switched digital QAM just before midnight when the error spike occurred.
Tuner 1 Frequency
Tuner 2 Frequency
Tuner 1 Frequency
Cur: 759.000M Max: 759.000M Avg: 748.042M Min: 525.000M
Tuner 2 Frequency
Cur: 0.00000 Max: 0.00000 Avg: 0.00000 Min: 0.00000

The following set of graphs is also from the same customer premises (although different from the account above). The cable box was being monitored in Unified and the modem in ServAssure.





As can be seen by these two graphs, even if we have only CCER (Corrected Codeword Error) spikes on the modems and MTA's, there will be uncorrected BER spikes on the cable boxes.

Beyond these two examples above though, we have many other examples of repeat trouble call customers we have worked with who were complaining of pixilation of their video service and were resolved through tracing down plant issues using modems with high CER spikes.

Essentially what we have done when initially investigating a pixilation issue for a customer, is to first check the customer's modem or MTA to see if there is any fluctuation on the modem signal levels (both upstream and downstream), check for SNR fluctuation or below specification parameters and of course downstream CER and CCER. If the customer doesn't have a modem or MTA, a same tap or downstream neighbor's can be checked instead.

If there is any signal fluctuation or out of spec SNR issues, this is obviously a problem and should then be checked against neighboring accounts. On numerous occasions, we have had accounts which show no fluctuation or other out of specification conditions but are showing downstream CER and/or CCER spikes. These error spikes can then be traced up the node the same as a signal issue and the area where the issue starts identified.

In all cases where the above has been done, once Network Performance has eliminated the issue causing the CER spikes on the modems, the customer's pixilation issue has either been resolved completely or reduced drastically.

With the experience of these investigations, it can be stated with some certainty that if all the modems or MTA's in an area are showing any error spikes in a similar pattern, the cable boxes in that area will likewise have BER spikes occurring and pixilation issues. The opposite does not appear to be true though. We have come across accounts which monitoring in iGlass or Unified shows BER spikes for all boxes in an area but when monitoring the modems in ServAssure Voice Sessions the modems show no errors.

Although most BER issues are noted on the upper QAM's, issues also arise where only lower QAM's are affected. When this happens, it would be natural for us not to see CER spikes on the modems. Again though, these seem to be the exceptions and not the rule as most issues affect higher QAM's rather than the lower. However, we have seen issues where upper QAM's are showing BER spikes on the cable boxes but no CER spikes on the modems. The main reason for this is unclear at this time and further investigation and testing will need to be done. However, one point of speculation is that due to the nature of the wider bandwidths that the cable boxes are required to operate in, their receivers are more susceptible to anomalies in the cable signal than are the narrower bandwidth modems and MTA's.

Another interesting phenomenon which warrants further testing is variability within different equipment manufacturers and models. This variability of equipment type with respect to how

well they are able to receive an error-free cable signal is demonstrated by the table below:

Account #	Street Address	Grid ID	Equipment Type	MAC Address	CER Value	CCER Value
56698304	7801 88TH AVE 80	3H314A02	TM402G	00:13:11:61:42:6e	0.08%	3.25%
56701502	7801 88TH AVE 115	3H314A02	TM502G	00:15:ce:4b:83:06	4%	1%
56701402	7801 88TH AVE 114	3H314A02	TM502G	00:15:a3:fc:25:3f	4%	1%
56702606	7801 88TH AVE 126	3H314A02	DP2203N	00:0f:21:d7:02:c7	0.30%	0.19%
56702903	7801 88TH AVE 129	3H314A02	DP2203N	00:14:f8:42:4c:a6	0.43%	0.55%
56703003	7801 88TH AVE 130	3H314A04	GSB4100	00:20:40:5a:57:f8	0.60%	0.28%
56703702	7801 88TH AVE 131	3H314A04	GSB4100	00:20:40:45:2f:16	0.60%	0.28%
56703204	7801 88TH AVE 132	3H314A04	DP2203	00:18:68:7e:0c:a8	0.28%	0.07%
56703502	7801 88TH AVE 136	3H314A04	DP2203N	00:18:68:c4:29:70	0.70%	0.70%
58836201	7801 88TH AVE 138	3H314A04	DP2203	00:18:68:83:cb:26	0.28%	0.07%
56703801	7801 88TH AVE 139	3H314A04	TM502G	00:15:a3:c7:3a:f5	4%	1%
56703903	7801 88TH AVE 140	3H314A05	DP2203N	00:0f:21:e2:71:e3	0.30%	0.48%
56704004	7801 88TH AVE 141	3H314A05	TM502G	00:15:a4:34:a1:f9	4%	1%
56704207	7801 88TH AVE 143	3H314A05	SB5101	00:1a:66:6f:97:9e	0.75%	0.70%
56705002	7801 88TH AVE 151	3H314A05	DP2203N	00:14:f8:e9:be:1f	0.45%	0.55%
57171203	7801 88TH AVE 164	3H314A09	SB5101	00:1a:66:5c:52:5c	0.30%	0.45%

The table was compiled from a single neighborhood, which had six customers scheduled for pixilation trouble calls. The table notes the CER and CCER on modems and MTA's throughout this run. As can be seen by the data, most equipment was experiencing between 0.2% and 0.75% CER. However, looking at the MTA's highlighted in yellow, we can see all Arris TM502G MTA's showed a much higher 4% CER. The CCER on the devices was similarly high at 1% for all devices.

It should be noted that this discrepancy doesn't seem to have anything to do with the Arris devices being less able to correct for errors than the other devices though. If this was the case, the CCER would be high on the other devices because they would have done more corrections. What this seems to indicate is that for whatever condition was present on the cable system to cause these errors, the receivers in the Arris MTA's were less able to handle this condition.

Before we write off the Arris device as inferior though, it should be noted that I have had other similar situations where Motorola 4100, 4200, and Arris 402 devices were showing high CER spikes on the same run where Motorola 5100, 5101 and SA2203 devices were showing much lower CER spikes. What this indicates is that certain devices are better able to handle different error causing conditions on the cable system. So while Modem A may be better able to handle low SNR on the cable plant than Modem B, Modem B may be able to handle micro-reflections better than Modem A.

This same scenario seems to hold true for cable boxes verse modems and MTA's The receivers in the modems and MTA's are able to handle error causing conditions better than the cable box receivers; thereby resulting in the situation where when we see CER spikes on modems we will

see BER on cable boxes but when we see BER on cable boxes we may or may not see CER spikes on modems.

With the cable box monitoring ability in iGlass and Unified being limited, the ability to use ServAssure to trace some of these plant issues becomes even more important. All pixilation issues should first be looked at as modem issues if possible. While there is no guarantee that this will produce usable data to track down a plant issue, it is at least one method which has proven to be very effective.