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Return Path Maintenance Plan

A Five Step Approach to Ensuring a Reliable Communications Path

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Overview

Creating and adhering to a return path maintenance plan may appear to be a daunting task. Luckily, by simply using and adhering to the industries basic standard practices you can create a maintenance plan that will reduce your truck rolls and improve your service reliability.

The recommendations in this paper are based on the assumption that you have constructed your HFC plant, properly set your amplifiers for unity gain, aligned your return nodes to be receiving at the same level and have an actively working two-way plant. The maintenance plan that I recommend includes the following steps.

1) Forward & Reverse Sweep – this should be performed once or twice a year and is still the best tool for finding RF problems in the network for troubleshooting
2) Leakage & Ingress – Regular FCC tests prove out the plant, but all technicians should be continuously testing for leakage and ingress to proactively eliminate problems
3) Qualify the Drop – Every install of Basic Video, HSD, VoD, and Telephony should include basic steps to qualify the drop.
4) Monitoring & Prevention – Continuous monitoring of your return path performance allows you to find and fix the problems before the customers complain. This should be done continuously and includes monitoring of the RF and the Data layer to quickly isolate the issue.
5) Training & Coaching – The feet that meet the street are the best asset for maintaining your two-way plant. Proper training of equipment usage and troubleshooting techniques should be an ongoing effort. Providing feedback and coaching will ensure that all technicians are meeting your desired goals.

Step 1: Forward & Reverse Sweep

The initial building block of any return path is a healthy forward path. Forward Sweep is critical in preparing your plant for two-way communications. Without a properly operating forward path, the reverse path becomes irrelevant. Having a good forward path is necessary for DOCSIS® and PacketCable™ telephony. The downstream carrier provides not only the downstream messages but it also includes the vital information to control and setup the transmission channel for the CM and MTA.

With today's short cascades, it is tempting to believe that sweep isn't necessary and by simply balancing and aligning by looking at a high and low carrier, the system will work okay. This isn't true for the forward or the reverse. Sweeping will find network issues that level alone won't. Figure 1 shows a typical distribution system and that by using level measurements, the forward path looks to be in good shape. This simple level and tilt check gives a false sense of security and misses what may really be happening in the network. Figure 2 shows the actual frequency response that is happening in the network as uncovered by sweeping.

Proper sweeping begins with taking a reference at the node, then looking at the differences in RF performance at each amp in the cascade. Since each amplifier should have the same output levels and tilt, as designed for unity gain, the sweep will then compare the reference to the output. Taken at the first amplifier, where the reference was taken, the sweep response should be flat. The leftmost picture in Figure 2 shows the normalized sweep response after taking a reference. Subsequent amplifier sweep responses should also be flat, but if there are network issues, the sweep response will highlight the differences. The middle picture of Figure 2 shows a sweep response with a notch caused by a loose face plate, the third picture of Figure 2 shows a sweep response due to an impedance mismatch causing standing waves. It is possible to use the frequency of the standing wave to calculate the distance to the fault. The formula calculating the distance to the fault is D=492*Vp/Fd, where Vp is the velocity of propagation, approximately 0.87 for hardline cable and Fd is the Frequency Delta between ripples.

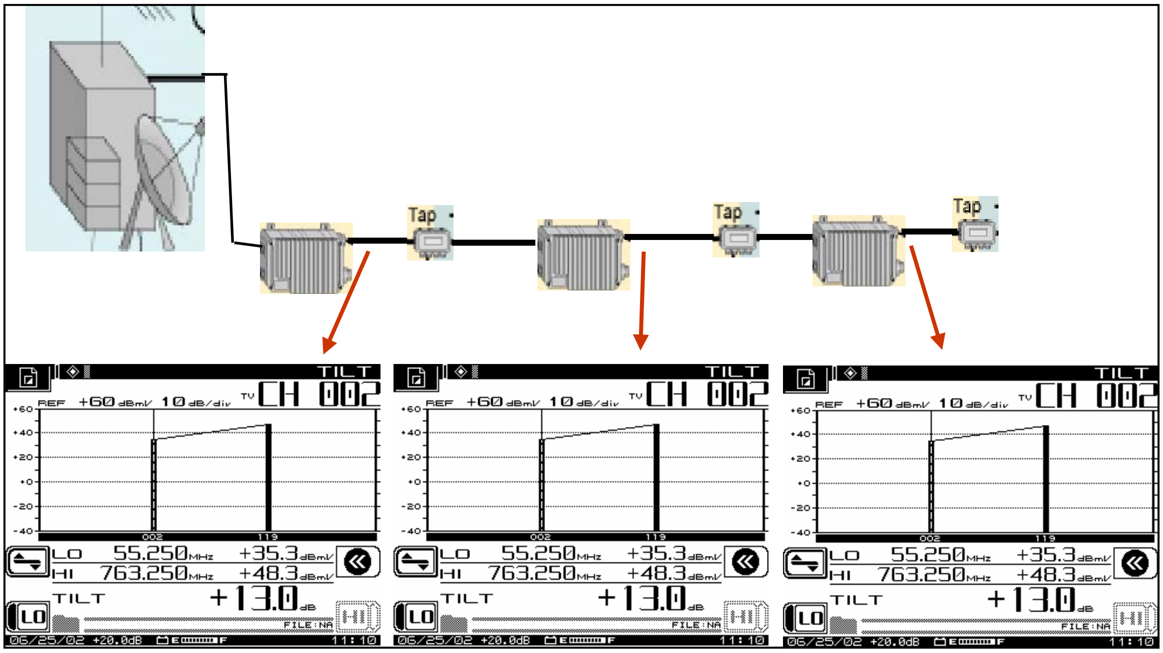

Figure 1: Typical Distribution Network tested using level

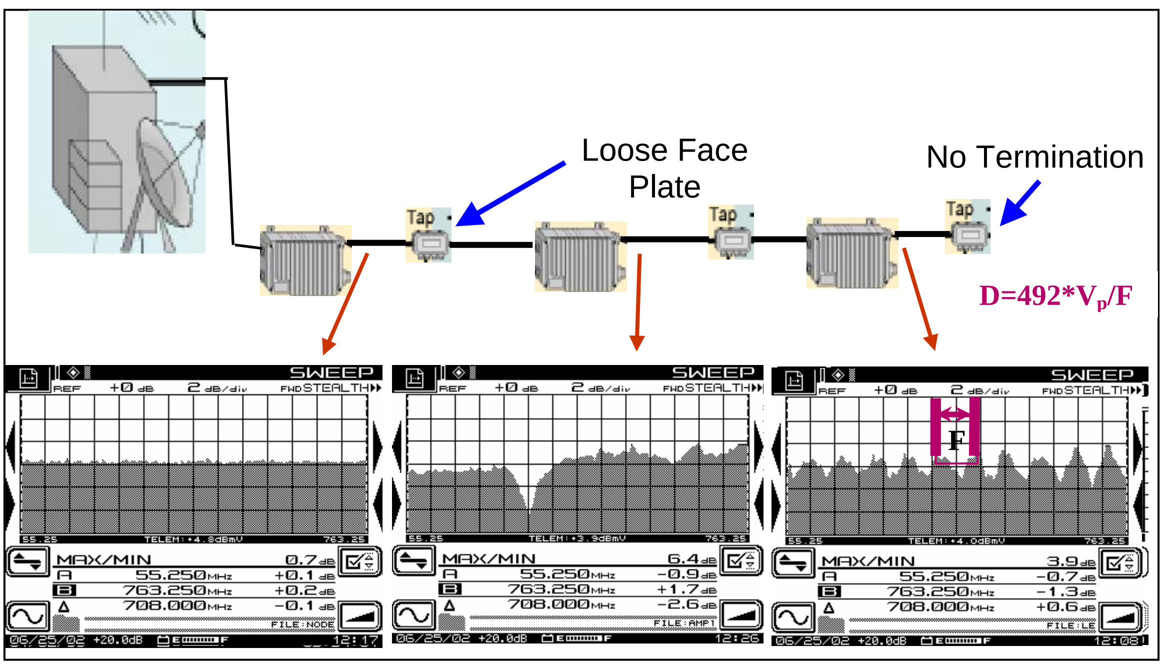

Figure 2: Actual frequency response of Network detected by sweeping

By not sweeping and ensuring good frequency response, you effectively condone putting distortion and C/N problems into your network.

Amplifiers provide a trade off between noise and distortion. If your frequency response is not flat you will be compromising your C/N and your distortion. Figure 3 shows a typical amplifier response curve based on gain and frequency.

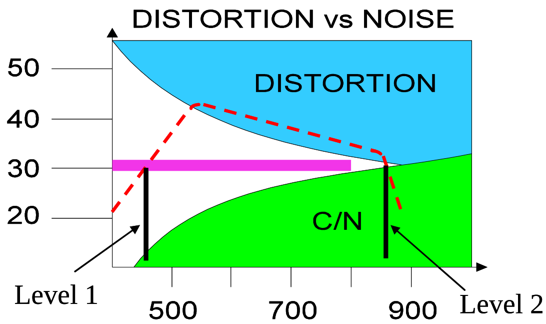

Figure 3: Amplifier Distortion vs. C/N

Sweeping is the quickest and most effective way to optimize your network. A simple sweep can be done in one visit. By simply using level, you might have to visit the test point 100's of times to finally catch the problem.

Using only level measurements you could be driving your amplifiers into distortion or C/N problems. The overlays in Figure 3 show that by looking at two levels, you might believe your amplifier is correctly operating, but when you look at the actual sweep response, shown in red, you can see that you are causing distortion in the mid band and C/N issues in the high band.

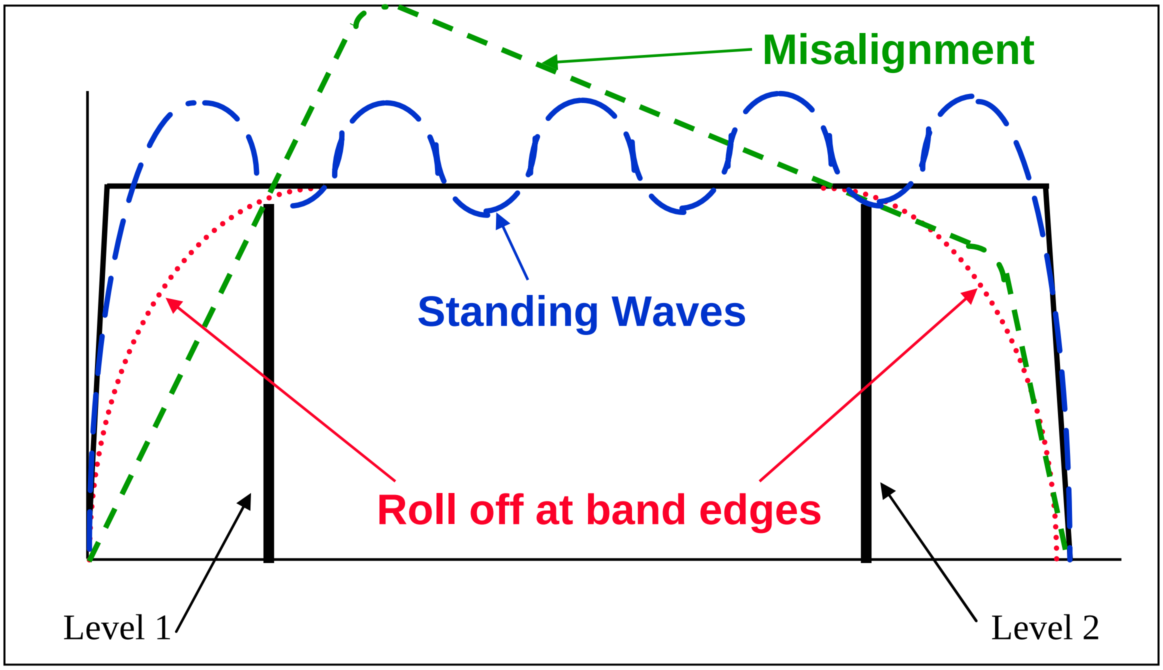

Figure 4: Problems that can be missed by using level instead of sweep

Let's highlight again why you should sweep versus simply using Signal level. Figure 4 shows a theoretical but realistic plot of what can happen in an active HFC system. This plot can apply to either forward or reverse paths.

Referring to Figure 4, in a theoretical system, you could simply take a measurement at a low frequency, Level 1, and a high frequency, Level 2 and interpolate that this would give you the frequency response that you need. But in reality, your frequency response could be drastically different than what a couple of points would show you. You could have misalignment, standing waves or roll-off that would be missed by the level measurements. By using an active sweep system with complete frequency coverage you can ensure proper frequency response and RF performance.

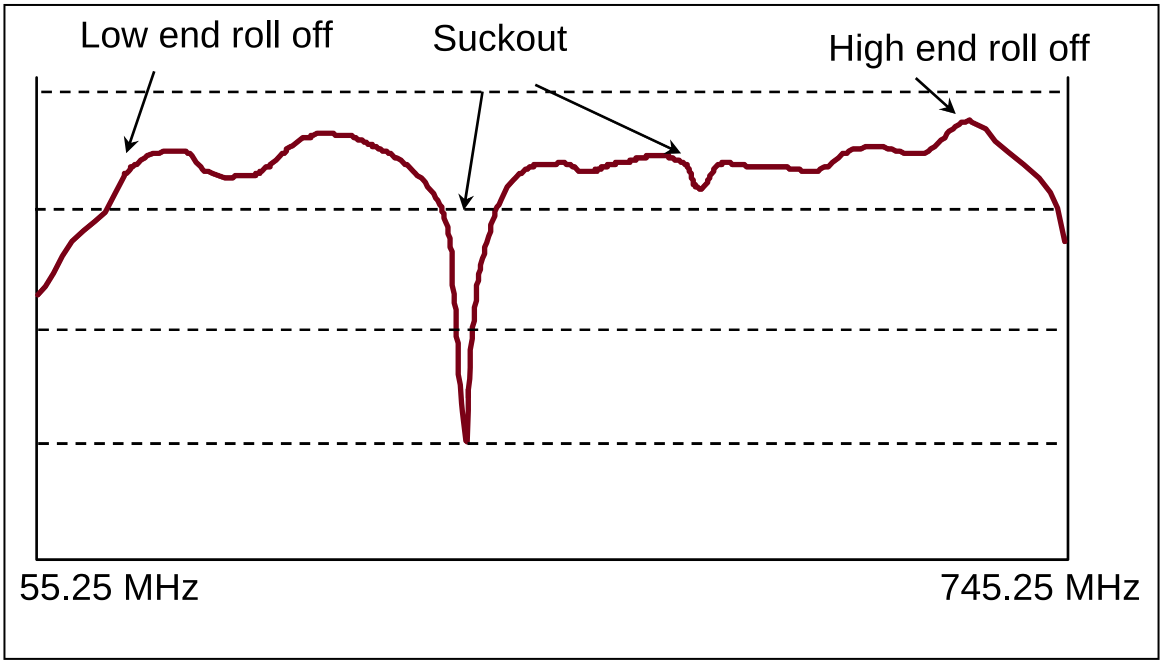

Figure 5: Symptoms identified by sweep that can help diagnose the problem

Once you get in the routine of planned regular sweeping you can use the correct identification of the symptom to aid in problem isolation and location.

- Low-end roll-off is typically caused by a loose connector or screw. An open circuit is like a capacitor. Higher frequencies can cross the gap with no problem where as lower frequencies can not. Low end roll-off is also caused by accessories and diplex filters.
- “Suck-outs” are typically mechanical related and grounding issues. This can also happen from multiple mismatches, which are spaced at even intervals.
- High-end roll-off is typically cable orientated or water in a passive. Water causes a high resistive short to ground which allows higher frequencies to be grounded. This also occurs from diplex filters and accessories.

In the reverse path, reverse sweep with a tightly spaced frequency plan can find issues such as group delay and micro-reflections, which will show up as ripple in the sweep response. Micro-reflections can be detrimental to 16QAM performance. By having a closely spaced frequency sweep plan, e.g. 250 kHz, the amplitude ripple deviations will be shown with better resolution. You can then apply the troubleshooting technique using the frequency delta of the ripples as discussed earlier and determine the fault location.

Step 2: Ingress & Leakage

The biggest enemy for reverse services is noise in the reverse path. The main contributor to this interfering noise is ingress. This ingress is caused by short-wave broadcast transmitters, household and industry type equipment, PC's, TV's, VCR's and other consumer equipment.

Bad, cables, connectors, splitters, taps, etc. in the home or distribution network cause RF-field-strength to leak in. If signals are able to leak in, then signals are also able to leak out. This makes leakage detection an invaluable tool to control ingress. Figure 6 shows graphically that over 95% of the ingress on the return path occurs from the tap through the customers premise. In particular the households are responsible for over 75% of the ingress. Remember, ingress on the return path is summed together. It only takes one bad house to corrupt an entire node!

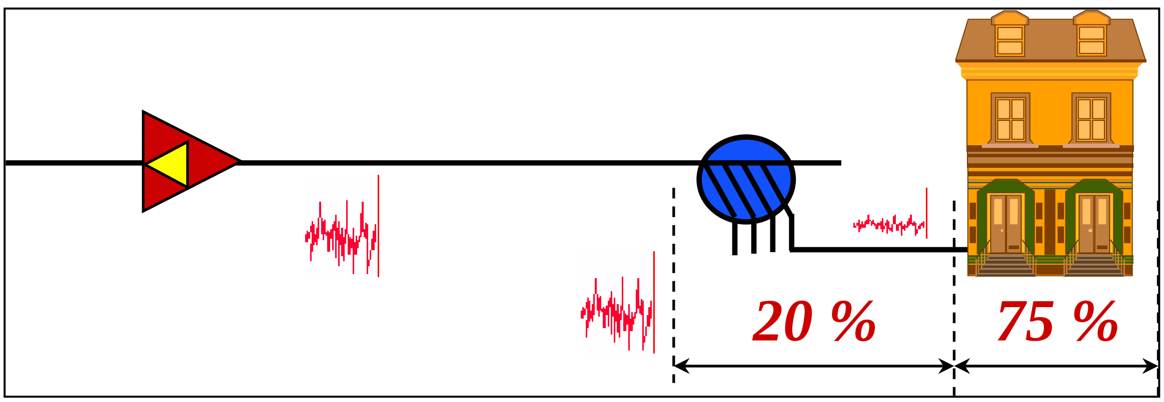

Figure 6: 95% of ingress occurs from the tap through the customer premises

Each home's ingress is combined to accumulate the total ingress noise level of the entire network of homes serviced by a node. Therefore, it is important to keep each individual home under a certain ingress threshold. Because of the low attenuation on tap values of 17dB or less, most of the ingress that is measurable comes from these houses.

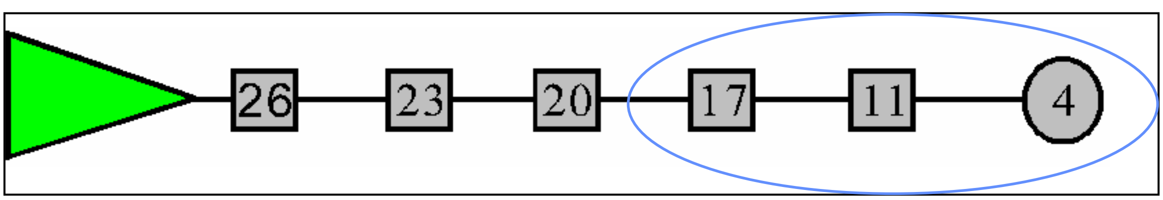

Figure 7: Most ingress occurs in drops with tap values of 17dB or less

Experience has taught us that the required ingress/leakage threshold to make the reverse path work can be more stringent than what is required by the FCC Regulations! Tighten up the plant – beyond FCC specs and your VoIP and HSD customers will run smoother.

To properly maintain the health of the return plant you should include regular leakage monitoring and detection. FCC regulations require regular proof tests but this should be part of every technician's daily routine.

As you are driving to installs and trouble ticket calls use your in-vehicle leakage system. Using a tagging device is highly recommended to eliminate false detection and increase sensitivity. If you find a leak, report it and get it fixed. Figure 8 shows how leaks can be located while driving. Remember leakage means that signals are getting out, therefore signals are getting in.

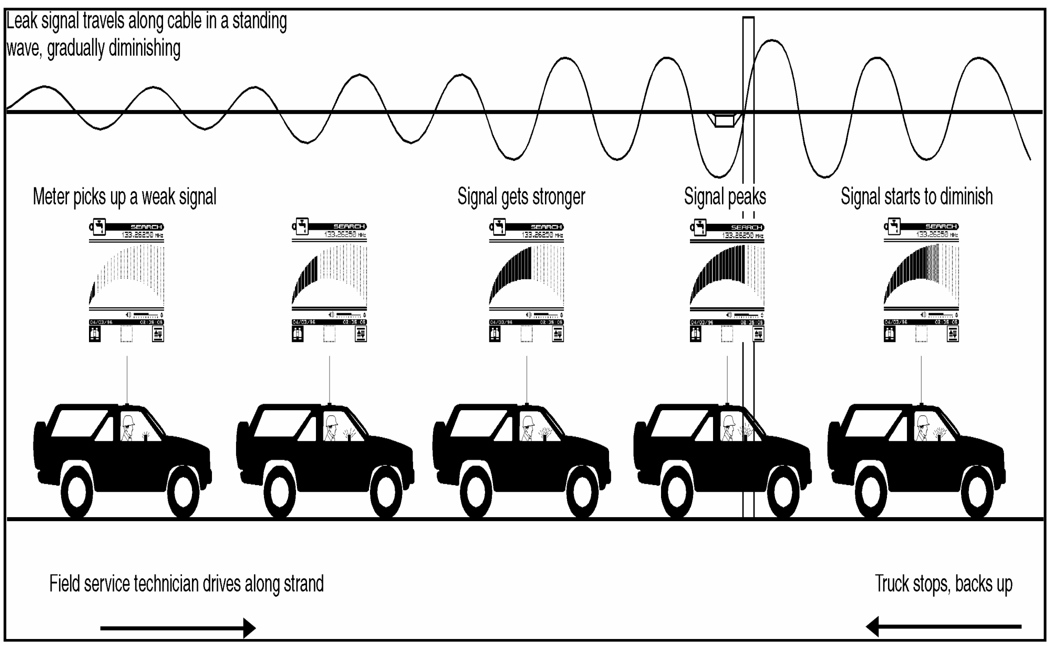

Figure 8: Leakage detection method while in vehicle

Leakage detection at the customers premise is also important since 95% of the ingress comes from the tap through the house. Once you find a leak, you will need a directional antenna to locate it using the triangulation method.

By using a directional antenna, you can pinpoint the direction of the source of the leak. Then by moving to a second point and rotating the directional antenna you can quickly pinpoint the location. Figure 9 provides a suggested triangulation method for identifying the location of a leak.

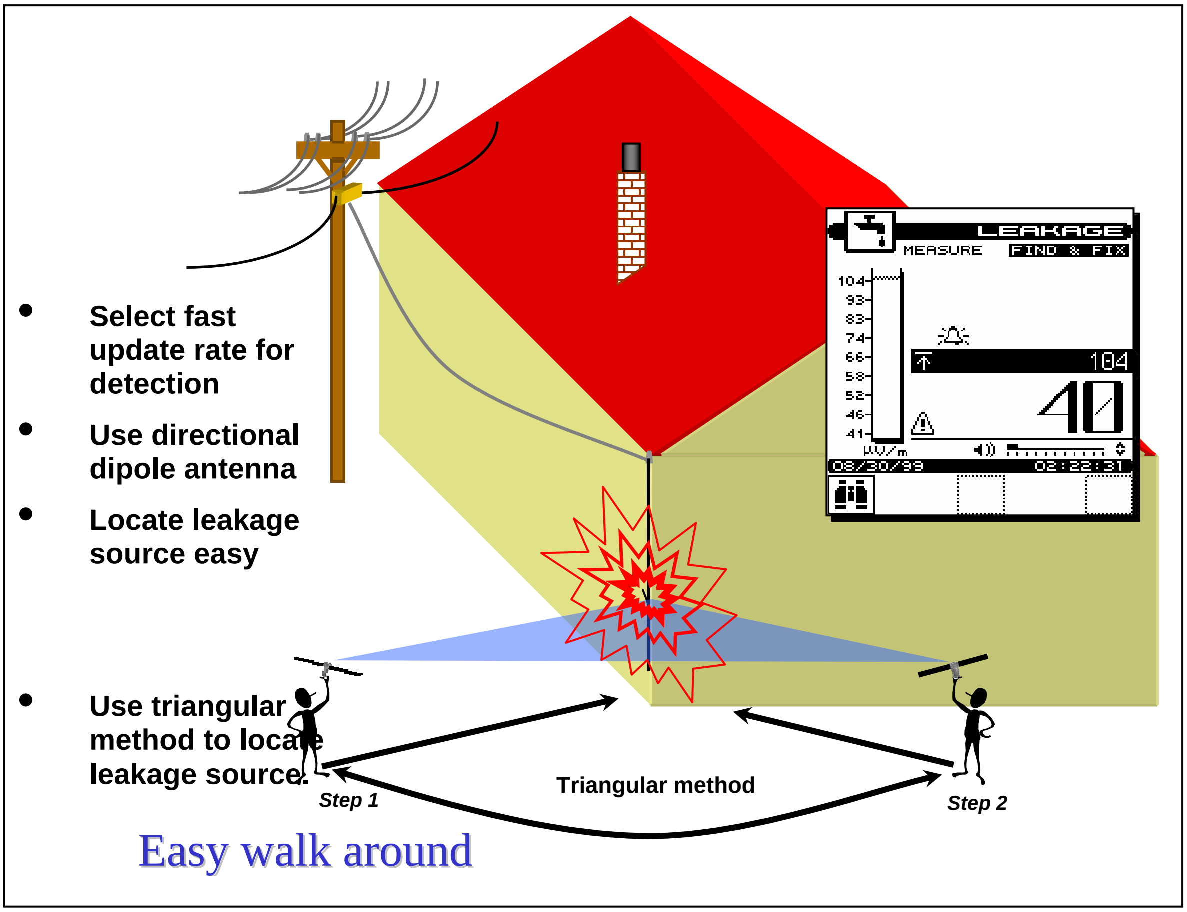

Figure 9: Leakage location using directional antenna

Step 3: Drop Qualification

At installation time, you should follow some basic steps to qualify the drop. The first step is to check the premise for ingress generating sources beginning at the tap with the drop disconnected. Figure 10 shows a typical drop and highlights how to find and fix ingress.

Each home's ingress is combined to accumulate the total ingress noise level of the entire network of homes serviced by a node. Therefore, it is important to keep each individual home under a certain ingress threshold. At the tap (the beginning of the drop cable) you can get the total ingress signature of that home. Moving towards the ingress source (deeper into the home) will eventually zoom in the error.

You can set up limit thresholds to make quick pass-fail status of the ingress levels originating from a drop.

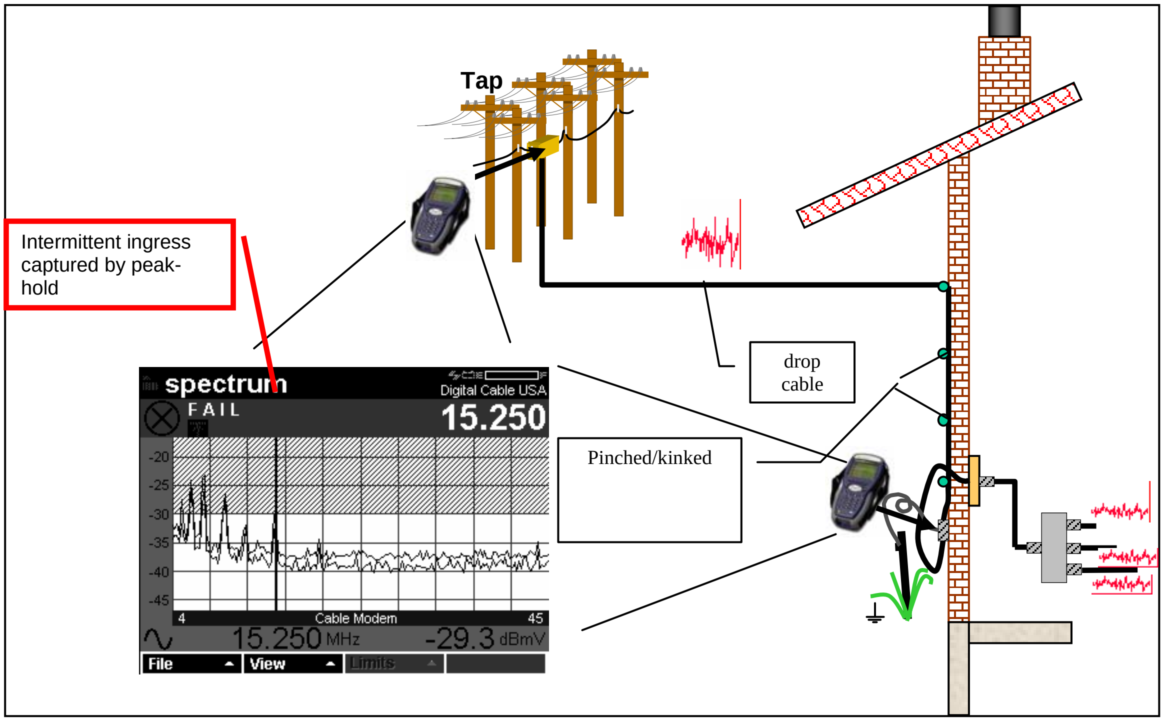

Figure 10: Drop Qualification for Ingress

The second step to qualify the drop is to verify service capability.

Of primary concern is that the DOCSIS® channels are able to operate properly. Verification of ranging provides the necessary information to determine two-way capability. By checking ranging you can verify the following:

1) Downsteam QAM signal is okay and within service margins of Level, MER, and BER.
2) Upstream – the modem is able to range properly and obtain a working upstream channel. One important parameter to look at is the upstream transmit level. It is important to have the upstream transmit level be in the proper range. The nominal transmit level should be between 35dBmV and 45dBmV. This allows enough headroom to allow for system variations but limits the available excess

power of the modem. For example, if the modem settles out with a high transmit level, 56dBmV you are at risk for the modem to drop offline as the system changes. Suppose the modem settles out at a low value, 22dBmV for example because it is on a low value tap. Then the modem is knocked off line and has to range again. Due to too much traffic or noise, the modem doesn't get a response from the CMTS, the modem will continue to ratchet up its output level – potentially all the way up to 58dBmV in an effort to get a response. The result of this excess output level, 36dB higher than nominal, could cause reverse laser clipping. In this situation you can install a frequency selective attenuator that attenuates the reverse path but not the forward path. Figure 12 shows an example of a drop equalizer that can be used to provide selective attenuation. This type of attenuator should be installed at the tap or groundblock to also help minimize ingress.

Figure 11 shows the typical results of a ranging test and highlights the important measurements to look for.

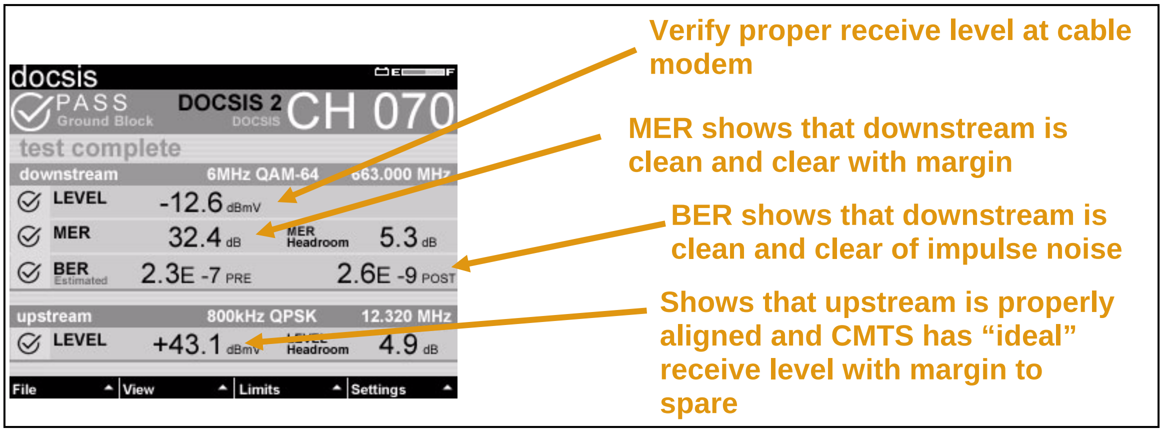

Figure 11: DOCSIS® range result verification

You should also check your service quality for packet loss and throughput. If your upstream or downstream are not at the expected rate, you could be having ingress issues that could be causing re-tries. Re-tries are not allowed in VoIP so this could lead to a bad call quality.

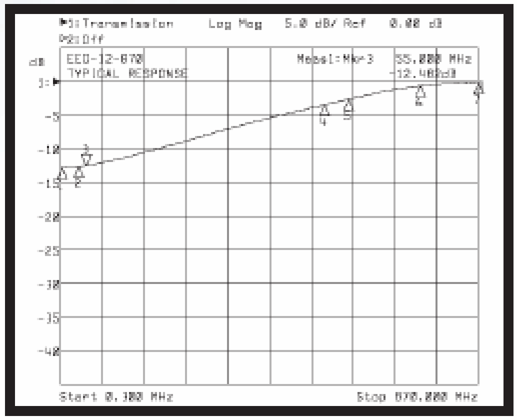

Figure 12: Selective attenuator frequency response of a drop equalizer

By checking for packet loss and having the ability to decipher if the errors are occurring on the downstream or upstream, you can isolate where the problems are occurring. If you are seeing upstream packet loss there is a good chance that you are having an ingress problem that is disrupting the service. Figure 13 shows a typical packet loss test that separates upstream and downstream packet loss. If you are seeing downstream packet loss you could be experiencing ingress, noise or distortion problems that are interfering with your QAM carrier.

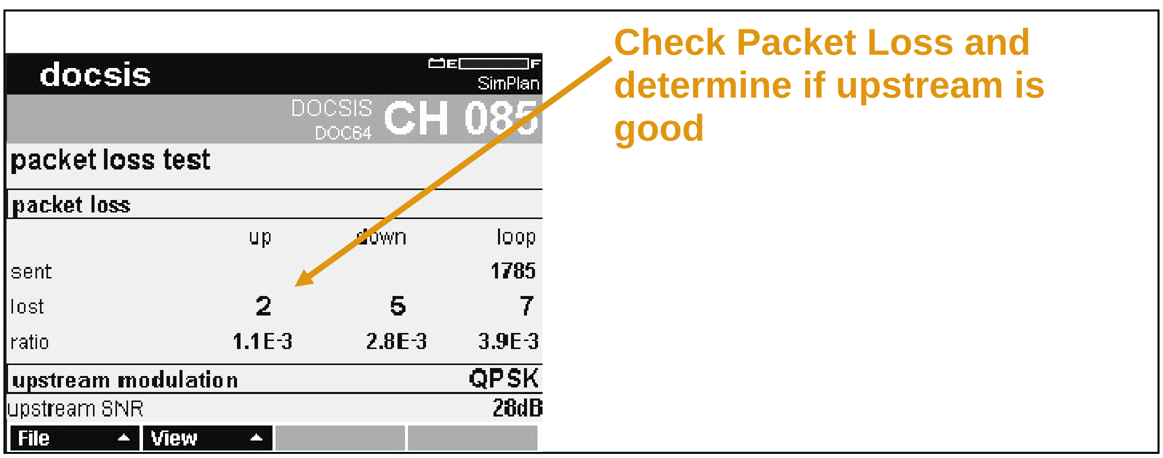

Figure 13: Packet Loss test to prove upstream quality

Similar to packet loss, throughput can also highlight potential reverse path problems. An underperforming upstream throughput may be correlated to lost packets – thereby creating re-tries. Figure 14 shows a typical throughput measurement.

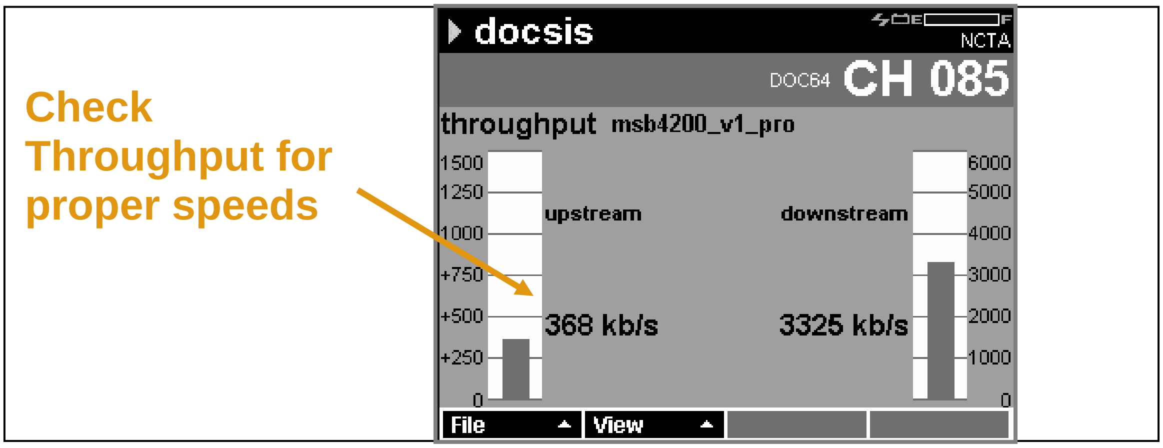

Figure 14: Throughput testing to verify upstream and downstream integrity

Step 4: Monitoring & Prevention

At the system level, reverse path monitoring should be used to proactively maintain your network.

By monitoring each node you can set alarm for issues that would affect your return path performance. CPD, loss of carrier, and average noise floor are typical alarms that can be set with many of the monitoring systems to identify data and voice impairing performance.

By proactively monitoring and recording your return path performance you can find potential issues before they get to the critical state of causing an outage.

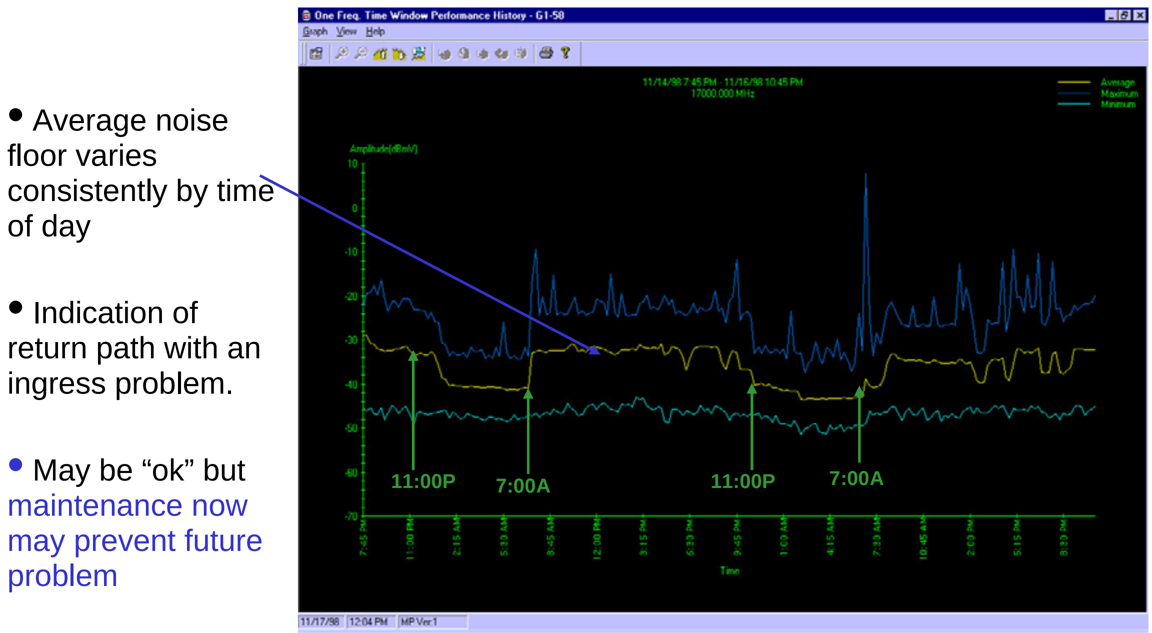

Figure 15: Reverse Path Monitoring and trending identifies marginal nodes

Unfortunately, ingress works 24 hours a day and decides to show up when we are not watching that node. This is why monitoring is important. It helps segregate, and isolate the cause of the problem. Figure 15 shows a marginal node that has a time dependent noise floor. This node may be okay but by performing preventative maintenance now you could prevent a future outage or service disruption.

Monitoring the reverse path can take shape by more than just RF performance monitoring. Many systems are implementing modem status monitoring which will alarm on outages. By using the data tools in conjunction with the RF monitoring tools you can quickly determine the cause of the problem, RF or Data layer. To do this you will need to have history of the RF and Data to compare outages at particular times.

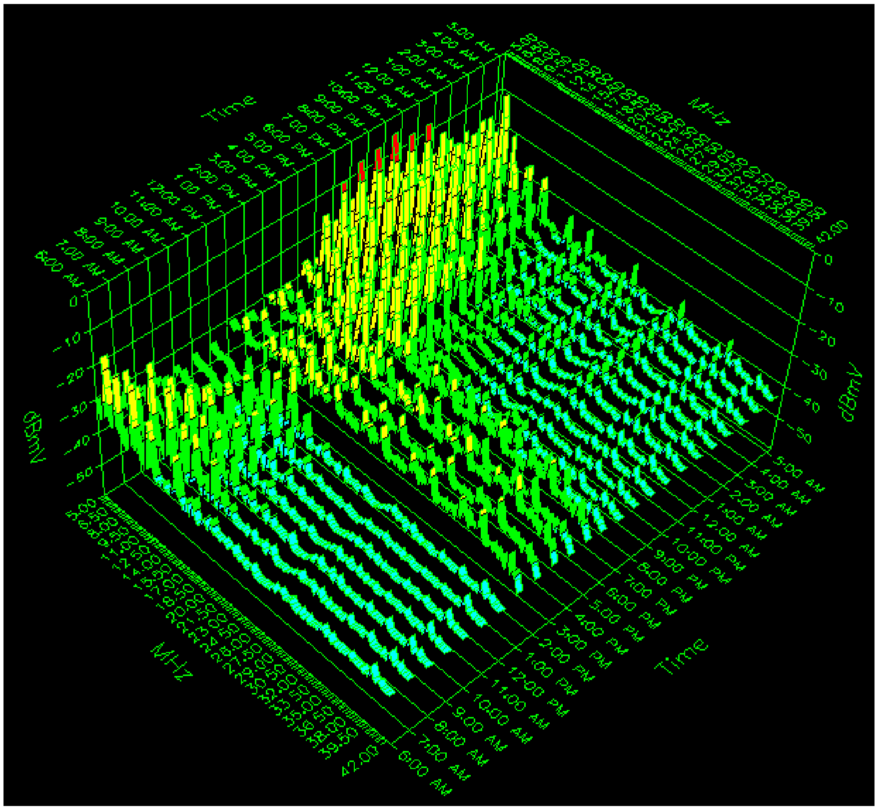

Figure 16: Reverse Path monitoring can uncover intermittent issues

As mentioned before, Ingress always seems to occur when we are not looking for it. You can use your monitoring system to validate an ingress or CPD problem and also to potentially schedule the service call to correct it.

From the graph in Figure 16, you can see that intermittent CPD was occurring on a reverse node. It would consistently get worse from 3:00PM to 9:00PM. By using this data, you can send the technician out at the right time of day to eliminate it. If the technician was going out daily at 9:00 AM they would never be able to isolate and find this problem

Again, this data can be used to correlate with the data monitoring system to determine and fix the cause of the problem.

Step 5: Training & Coaching

The final step to a return path maintenance plan is to ensure proper training and coaching of the technicians.

Proper usage and set up of their field equipment is vital. Many of the available meters have multiple channel plans and limit plans. Proper channel plans are critical to testing the RF network. The analog carriers seem to be daily switching to QAM and the QAM 64 carriers are switching to QAM 256. You need to have a regular and simple process for keeping their tools up to date with the latest information.

Regular training on test methodologies and procedures increases the return on investment of your most important asset, the technicians. By giving them new skills and training they can help meet the demands of an advanced service network.

[redacted]

		Number	Tests Ran		Tests Passed	
Tech ID	Total Jobs	Require Test	Number	%	#	%
128	13	11	11	100%	11	100%
334	11	11	11	100%	11	100%
451	12	8	7	88%	6	86%
567	8	8	8	100%	7	88%
568	9	8	3	38%	3	100%
569	15	11	11	100%	11	100%
702	12	12	11	92%	11	100%
801	4	4	4	100%	4	100%
803	16	12	12	100%	8	67%
880	18	14	13	93%	13	100%
Total	118	99	91	92%	85	93%

Figure 17: Coaching report example used to increase technician efficiency

Creating repeatable and verifiable procedures for qualifying and testing the drop will produce the expected performance for the customers reduce call backs. Once you have established your procedures and metrics, you should create and maintain coaching or performance reports to help maintain the expected level of performance from your technicians. Figure 17 shows an example of a coaching report that could be used to coach a technician on their testing success rate. The purpose isn't to bullwhip the technicians but instead to help coach them into the proper methods to make your network operate properly and your customers satisfied with their services.

Summary

In conclusion, an effective return path maintenance plan involves getting back to the basics and avoids using shortcuts. By adhering to basic principles of RF Sweep, ingress

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

Figure 18: Suggested Test Criteria for optimum performance

and leakage suppression, and doing a complete check of the customers' premises and services, you can adequately ensure a high performance return path system. Figure 18 shows some recommended measurement criteria for creating a well performing HFC communications path.

By monitoring and correlating RF and Data performance, return path issues can be resolved before the customers complain.

By creating standard procedures for drop qualification and having metrics to check the testing results, you can effectively increase your overall efficiency. The extra couple of minutes of drop qualification and service testing will pay for itself many times over by reducing repeat service calls and lost customers. With the competitive landscape that we are in, battling for video, data and voice, we can't afford to loose customers by skipping the basic tests.

Overview of Five Step Approach

Step #	**Step Name**	**Description**
Step 1	Forward & Reverse Sweep	This should be performed once or twice a year and is still the best tool for finding RF problems in the network for troubleshooting
Step 2	Leakage & Ingress	Regular FCC tests prove out the plant, but all technicians should be continuously testing for leakage and ingress to proactively eliminate problems
Step 3	Qualify the Drop	Every install of Basic Video, HSD, VoD, and Telephony should include basic steps to qualify the drop
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Step 5	Training & Coaching	Proper training of equipment usage and troubleshooting techniques should be an ongoing effort. Providing feedback and coaching will ensure that all technicians are meeting your desired goals.