System Sweeping RF Portion of the HFC Network

System Sweeping Application Overview

Effective, efficient preventive maintenance for the RF portion of the HFC network requires skill and application specific tools. One of the most useful tools for alignment and troubleshooting is system sweeping.

Maintaining the RF portion of the HFC network requires certain types of tests to characterize the transmission properties. This portion of the network is made up of both active devices (optical to RF conversion at the node, amplification to extend the range of the RF distribution section of the plant) and passive components (coaxial cable, connectors, splitters, taps, etc.).

The potential for natural or man-made damage to the plant is clear and present. Catastrophic damage that causes an outage can typically be located relatively quickly and repaired (depending on the extent of the damage) while non-catastrophic damage can be harder to locate and may cause subscriber irritation, or bring signal/service quality dangerously close to the edge of failure.

Various RF transmission tests are commonly used to verify that the plant is working according to design specifications as a matter of routine - called preventive maintenance. One of the most helpful and reliable tests is system sweeping.

Sweep testing is a way to examine the transmission characteristics of the network, typically by injecting a signal of known and constant amplitude and sweeping it through the network's frequency range. Cable systems are designed for unity gain so variations from a flat response, called the "peak-to-valley" of the response, are optimally minimized. This does not take into account tilt that is induced at the amplifier to pre-compensate for cable loss and minimize the impact of intermodulation distortions.

This predictable and expected response variation is eliminated from the displayed response by "normalizing" to a stored reference. This normalization process is a direct comparison of the currently measured response to a stored reference response, and is practical because the system is designed for unity gain, meaning that the output of every amplifier (downstream, forward test point) will be theoretically identical. Typically the technician will store a reference response at the node output test point at the beginning of every shift.

As cable systems evolve to a higher concentration of digital signals, the need for sweeping may actually become greater. While analog signals tend to show a gradual degradation in service (picture) quality as the carrier-to-noise or intermodulation distortion ratio decrease, digital service quality remains constant until these factors cause a complete outage. (Granted there is some blocking or pixilation at the edge, but the edge is narrow between good quality and outage.) This means that there will be no visible indicator (canary in the coal mine) that there is a network performance problem that is shrinking the buffer between good and bad service without a diligent preventive maintenance program in place.

Shortening amplifier cascades minimizes response signature build-up, but the increased presence of passives in the swept portion of the network adds a significant contribution to response variation.

There are various techniques used in system sweeping.

Sweepless sweep - this sweep method, which compares system signal levels measured at a reference test point to levels at subsequent test points farther downstream, was developed to eliminate interference from an injected sweep signal, and banks on the spectrum being fully occupied with service signals.

Low level sweep - this sweep method also typically uses a reference measurement, but uses an injected sweep signal with specific frequency designation in attempt to avoid interference. This sweep provides good information about what is happening in "empty" spectrum areas, but has a tendency to cause interference.

Combined sweep - this sweep uses a combination of injected sweep and service carrier reference levels. This method is very effective, but in some cases where up to 3 data points within a 6 MHz digital channel are sampled, the response update is irritatingly slow. Newer technology enables the sweep update rate to remain consistently fast even with higher resolution.

What constitutes a good frequency response?
Traditionally the "peak-to-valley" response variation pass/fail limit was determined by a formula that takes into account the number of amplifiers in cascade. The formula was n/10 + 1, where n is the number of amplifiers in cascade. Recently, based on the much diminished cascade length, this formula has changed at least according to some manufacturers' recommendation to n/2 + 1.

When I get a bad response, how do I find the source of the problem?
Wouldn't it be great if you could look at a response anomaly and know right away what the cause was, and where it was coming from?

In the case of response variations like suck-outs (a response where a portion of the swept band is not passing signal) and roll-offs (the response is dropping off at the low or high end of the spectrum) the "divide and conquer" troubleshooting technique is used to locate the source of the problem.
To locate the source of the problem, bisect the plant between the current test point and the reference test point and see if the problem is there. Keep bisecting until the source is found.

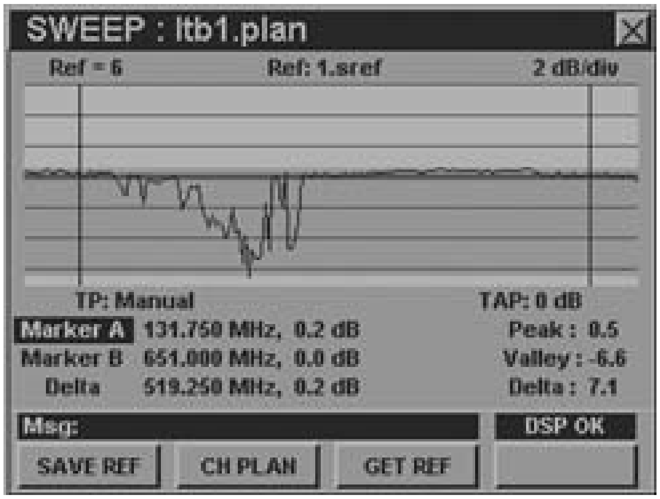


Figure 1. Sweep response showing a "suck-out."

Standing waves caused by reflections from an impedance mismatch can be analyzed to determine the distance to the fault, and some sweep receivers provide some calculation assistance with this. Here's how the standing wave can be analyzed. Place one marker on one of the standing wave peaks, and the other marker on another standing wave peak (see illustration). The distance to the fault can be determined using the formula:

$$d = \frac{492 \times VP}{f}$$

Where, d = distance to the fault in feet; VP = velocity of propagation factor of the cable; and f = the frequency spanned by one cycle of the standing wave.

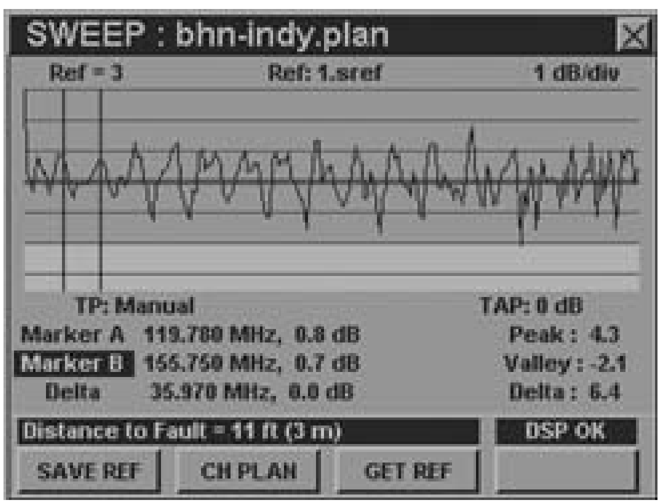


Figure 2. Sweep response showing standing wave analysis with calculated distance to fault.

Sometimes the standing wave is a bit more complex, composed of multiple reflections from multiple faults, and in these cases the most prominent and obvious cycle should be analyzed first.

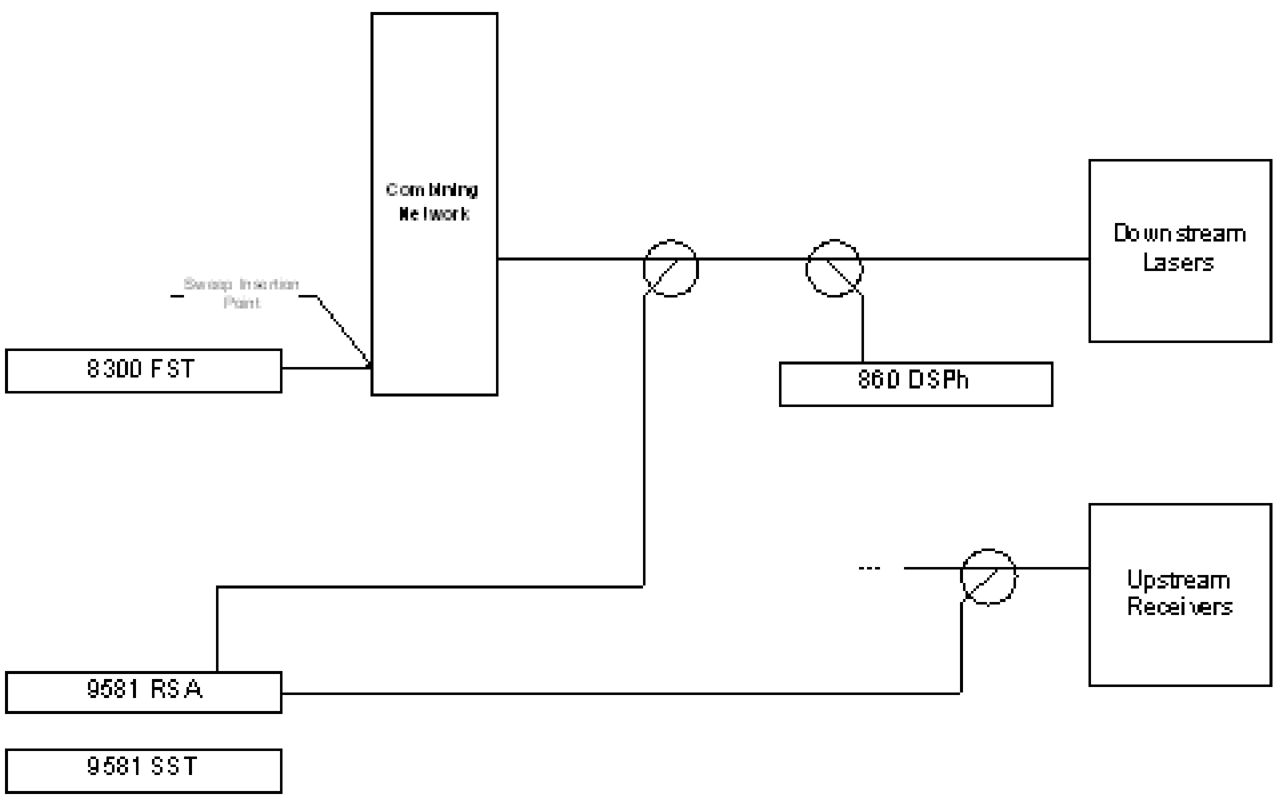
The sweep signal that enables testing the response in vacant spectrum areas is typically inserted at a designated sweep insertion point in the combining network.

This test point has some associated loss, and this should be taken into account when inserting the signal. The signal can be inserted at or below the levels of cable service signals, and configured so it doesn't "step on" those signals. The technician stores a reference sweep with the receiver at the node prior to testing the response on that node.

While the downstream network is designed for unity gain, where the output of every amplifier should be the same as the output of the amplifier before it, the upstream plant is designed to have the same input levels at every amplifier.

The upstream amplifier is aligned such that the signals arrive at the input to the next amplifier at the proper levels. This is done by injecting a sweep signal of known level (at non-interfering frequencies) and measuring at the hub site or headend. At the node (and at each return amplifier) a certain amount of amplification is required to compensate for cable loss behind the amplifier.

The amplifier is adjusted while monitoring the signals received in the hub or headend, to receive the proper levels at the headend, hub, or input to next upstream amplifier. While network technology advances, the outside plant design has remained relatively constant. Preventive maintenance is a critical requirement for HFC networks, and the "ancient art" of system sweeping is a fundamental analytical/diagnostic tool, that has maintained its value, standing the test of time.



Sweep System Configuration Diagram