Using Linear Equalizers to Shape HFC Network Frequency Response Application Note

Overview

This application note addresses the selective replacement of cable equalizers with linear equalizers for frequency response shaping in hybrid fiber-coax (HFC) transmission networks.

This application note:

- Reviews the traditional roles of cable equalizers and linear equalizers in HFC networks
- Identifies factors that can affect overall network frequency response
- Describes an alternative use for linear equalizers that can improve overall network frequency response in certain applications
- Provides implementation guidelines for this alternative use with 1 GHz GainMaker® linear equalizers

Scope

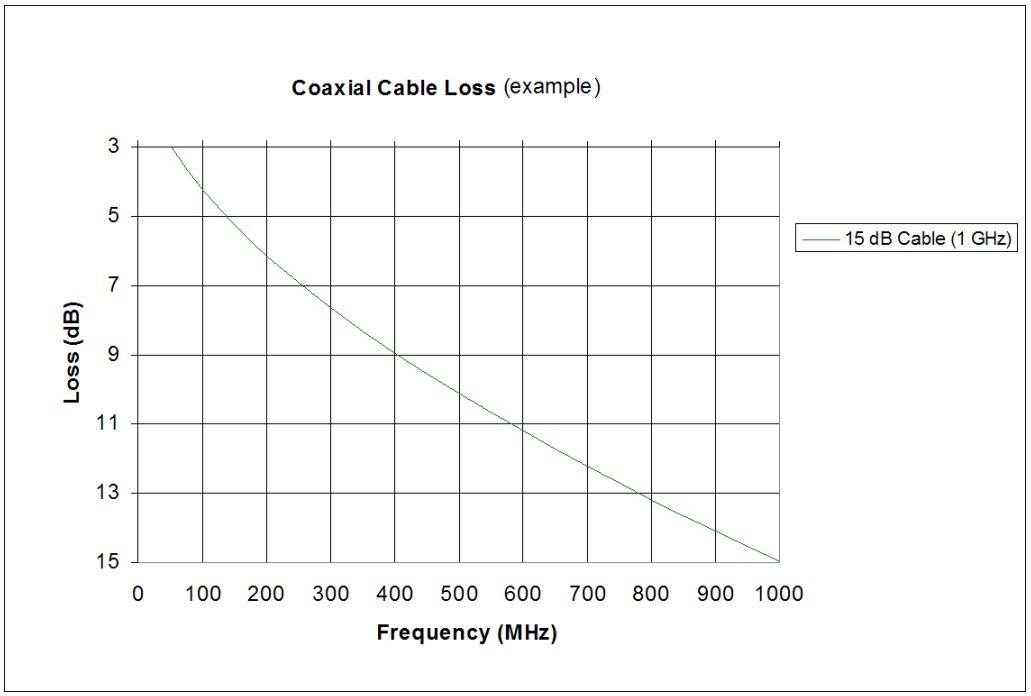
The concepts presented in this document apply to HFC transmission networks in general. Guidelines are provided for applying these concepts to 1 GHz GainMaker system amplifiers and line extenders.

Traditional Equalizer Usage

Cable Equalizer Usage

The coaxial cables used in HFC networks have greater signal loss at higher frequencies. A plot of coaxial cable loss versus frequency has a curved, down-tilted shape (provided that the frequency axis uses a linear scale).

The following illustration shows a sample plot of cable loss versus frequency.



The curved shape associated with the plot is sometimes referred to as a *smile shape*.

Cable equalizers are designed to offset both the tilt and the shape associated with coaxial cable loss. Thus, a plot of cable equalizer loss versus frequency is the opposite of the coaxial cable plot, with greater loss at lower frequencies and a *frown shape*.

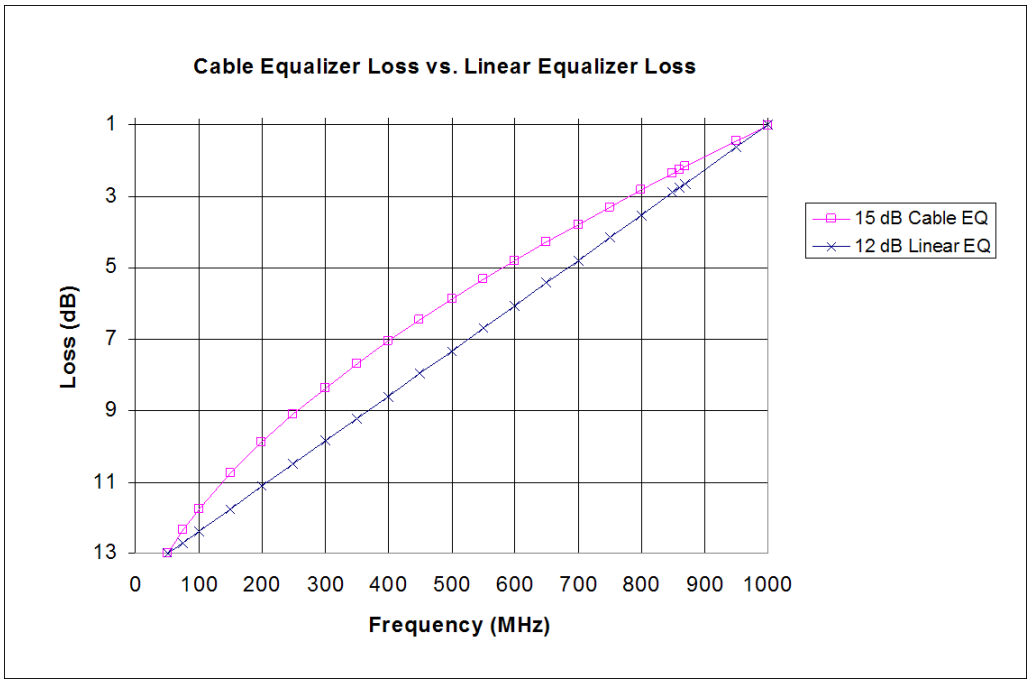
A sample plot of cable equalizer loss versus frequency can be seen in the illustration on the next page.

The *dB value* of a cable equalizer indicates the equivalent amount of cable loss that the equalizer is designed to compensate for in terms of both tilt and shape. Plug-in cable equalizers are typically available in a wide range of fixed dB values. Typically, most cable equalization is accomplished at the input of the amplifier station (input equalization), with additional equalization between amplifier gain stages (interstage equalization).

Linear Equalizer Usage

Most HFC networks use up-tilted RF amplifier output levels, meaning that their RF output levels increase at higher frequencies. Today's networks typically employ a linear output tilt, so that a plot of output level versus frequency is a straight line that tilts upward from low to high frequency. This linear output tilt is produced at the node using a passive network called a *linear equalizer*.

The following illustration compares the straight-line loss characteristic of a linear equalizer with the frown-shaped characteristic of the cable equalizer described earlier.



As shown above, both the linear equalizer and the cable equalizer introduce greater signal loss at lower frequencies. However, whereas the cable equalizer response is curved, the linear equalizer response is a straight line, indicating equal loss per unit of frequency.

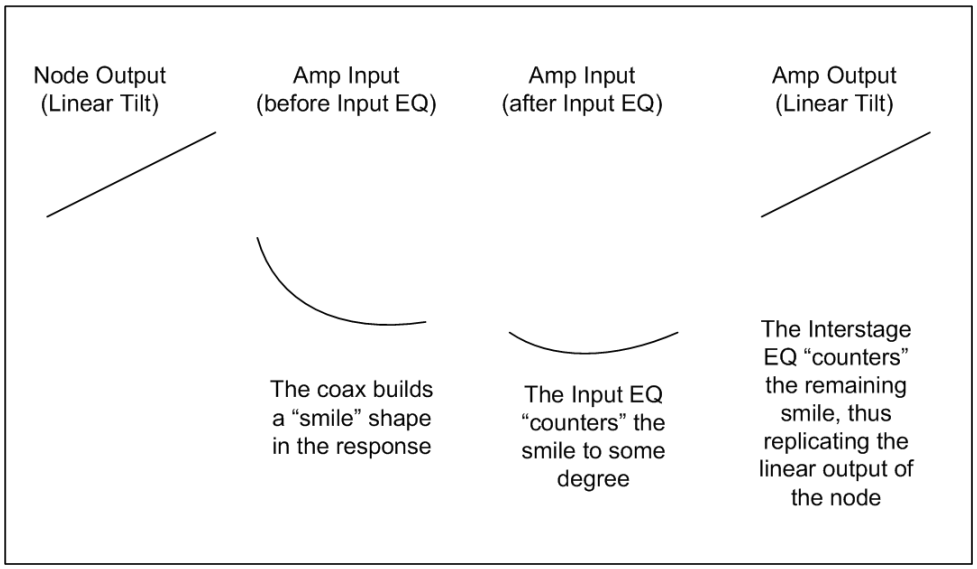
The dB value of a linear equalizer indicates the amount of tilt it produces, where the tilt is equal to its loss at lowest rated frequency subtracted from its loss at highest rated frequency. As with cable equalizers, plug-in linear equalizers are typically available in a wide range of fixed dB values.

Both Equalizers Working Together

Traditional HFC network implementations combine the use of cable equalizers and linear equalizers to help achieve optimum overall frequency response. A linear equalizer at the node is used to provide the desired linear output tilt, while cable equalizers in the amplifiers are used to offset the down-tilt and shape introduced by the coaxial cable.

In principle, this scheme allows for the replication of the original linear output tilt at all amplifier stations. If all of the down-tilt produced between amplifier stations has the smile shape associated with coaxial cable, the cable equalizers offset both the down-tilt and the shape, and the net result is a linear tilt at the amplifier outputs.

The following illustration shows the idealized result of combined linear and cable equalization.



Factors Affecting Network Frequency Response

In an HFC network, a variety of factors can affect the overall frequency response. The amplifiers, connectors, cables, and other passives in the network each have inherent frequency response characteristics, or *signatures*, that contribute to the overall response.

Additionally, undesired conditions such as loose connectors, loose seizure screws, and water-damaged components can produce abnormal frequency response. The effects of these undesired conditions can be seen during a frequency-response sweep as sharp dips in response, commonly referred to as suck-outs, or excessive low- or high-frequency losses. The conditions creating such abnormal frequency response should be tracked down and corrected.

The magnitude of the cumulative frequency response resulting from the characteristic signatures of all of the plant components may become great enough to be considered excessive. To address this, many amplifier vendors, including Cisco, have produced optional plug-in trim networks that can be selectively deployed in amplifier stations to shape and improve the overall network frequency response.

In some cases, the overall shape of the cumulative frequency response may be found to be more or less frown-shaped. This shape may have various causes, including some degree of low- and high-frequency rolloff in plant components. Additionally, the frown shape may be accentuated if there is down-tilt produced between amplifiers that does not have the same smile shape as that of coaxial cable.

For example, most HFC network taps and passives have down-tilted frequency response characteristics. Their down-tilt may not have the characteristic smile shape associated with coaxial cable, and may instead be more linear or have some degree of frown shape. The cumulative down-tilt produced by the passives must be counteracted by the equalizers in the network.

Because cable equalizers are designed to fully offset only the smile shape associated with cable, they do not typically offset any non-smile shape that might be associated with the passives. In this example, some degree of frown-shaped response may become apparent as a result. This frown-shaped response may become more pronounced in the deeper sections of the network which contain the greatest quantities of taps and passives.

Alternative Use of Linear Equalizers

Frequency Response Shaping via Selective Linear Equalization

If the network is experiencing a build-up of frown-shaped frequency response, selectively replacing some amplifier cable equalizers with linear equalizers may reduce the magnitude of the frequency response frown.

Since there will always be cable induced down-tilt, replacing all of the cable equalizers with linear equalizers is not recommended, as this would likely produce an excessive amount of smile shape in the network response. Instead, selective replacement of cable equalizers should be limited to interstage equalizers, as further explained below.

Implementation in GainMaker Amplifiers

The interstage cable equalizers in GainMaker amplifiers may be selectively replaced with linear equalizers to implement a gradual, controlled degree of alternative frequency response shaping.

By limiting the change to the interstage, the quantity of linear equalizer values required is minimized. Additionally, the potential for an excessive degree of linear equalization is reduced, as the amount of equalization used in the interstage is typically less than that used in the input equalizer location.

Whether it is desirable to replace the interstage equalizers in all of the amplifiers in the network, just those in the feeder portion, or on a more limited basis will depend upon the net effect achieved in practice in any particular network.

Note that optional plug-in trim networks are also available to shape and improve frequency response in netowrks deploying GainMaker amplifiers. Such trim networks may be used alone or in combination with the selective use of linear equalizers to help improve overall frequency response.

Equalizer Replacement Table

If this alternative approach is used in systems deploying 1 GHz GainMaker amplifiers, the following table lists the cable equalizer values that come pre-populated in the interstage equalizer (ISEQ) position from the factory, and the recommended alternate linear equalizer ISEQ values. Their associated losses in dB are also shown.

1 GHz Amplifiers	**System Amplifiers (All)**		**AGC and Manual Line Extenders**		**Thermal Line Extenders**	
Frequency (MHz)	**Factory ISEQ** **10.5 dB Cable EQ**	**Alternate ISEQ** **9 dB Linear EQ**	**Factory ISEQ** **9 dB Cable EQ**	**Alternate ISEQ** **7.5 dB Linear EQ**	**Factory ISEQ** **7.5 dB Cable EQ**	**Alternate ISEQ** **6.0 dB Linear EQ**
	Loss (dB)					
52	9.4	10.0	8.2	8.5	7.0	7.0
150	7.8	9.1	6.8	7.7	5.9	6.4
250	6.7	8.1	5.9	6.9	5.0	5.7
350	5.7	7.2	5.0	6.1	4.3	5.1
450	4.8	6.2	4.3	5.4	3.7	4.5
550	4.0	5.3	3.6	4.6	3.2	3.8
650	3.3	4.3	3.0	3.8	2.6	3.2
750	2.6	3.4	2.4	3.0	2.1	2.6
870	1.8	2.2	1.7	2.0	1.6	1.8
950	1.3	1.5	1.3	1.4	1.2	1.3
1000	1.0	1.0	1.0	1.0	1.0	1.0

Notes:

- The total loss at 1000 MHz and the total tilt from 52 to 1000 MHz are kept very similar to keep the gain characteristic of the amplifier from being adversely affected by the change.
- Some cases may require a slight adjustment of the input cable equalizer value. The process for selecting the optimum input cable equalizer value is not affected by the change, and involves selecting the equalizer value that achieves a result closest to the desired output tilt.

Summary

The selective use of linear equalizers in GainMaker amplifiers can improve overall frequency response in networks that experience an excessive degree of frown-shaped response. Operators may wish to consider this approach as one of the tools available to them for improving response in networks deploying GainMaker amplifiers.

Optional plug-in trim networks with adjustable frequency response shaping are also available for GainMaker amplifiers. Trim networks may be used alone or in combination with selective replacement of cable equalizers with linear equalizers to help improve frequency response, in cases where such improvement is desirable.

For Information

If You Have Questions

If you have technical questions, call Cisco Services for assistance. Follow the menu options to speak with a service engineer.

Cisco Systems, Inc.
5030 Sugarloaf Parkway, Box 465447
Lawrenceville, GA 30042

678 277-1120
800 722-2009
www.cisco.com

September 2012 Printed in USA Part Number 4022872 Rev C