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Notes on Cable Equalizers

Coaxial and twisted-pair cables have the frequency-dependent behavior of increasing loss with increasing frequency. The primary mechanism for this characteristic is skin effect, which progressively reduces the effective cross-section of the current-carrying portion of the cable's conductors at higher frequencies.

In channelized broadband systems such as cable television, the problem is handled with equalized line amplifiers. These amplifiers have a highpass response that is approximately the opposite of the cable loss characteristic. These amplifiers do not need to be particularly accurate in their correction factor because each channel occupies a small portion of the total spectrum and will have little gain deviation. The main purpose of the equalizers is to maintain signal levels at the highest frequency channels—which eventually are limited by the increased noise, which is amplified along with the signals.

Another common analog system is video, where the maximum bandwidth may be 40 MHz. This modest bandwidth can be adequately flattened with a low-order equalizer network. The only difficulty is that every cable run of significant length must be equalized. This is typically done with an adjustment at each port of the central routing switcher. It's a tedious job, but only needed at initial construction and when changes are implemented.

Equalizers and High Speed Digital Signals

Amplitude errors are a serious problem with digital signals. Rise and fall transitions are the highest frequency components of the approximately square wave of a digital signal. High frequency loss due to cable attenuation reduces the rise time and eventually closes the "eye" of the observed waveform. The result is increased bit-error rate, and eventually, total communications failure.

The Primary Equalizer Problems: Flatness and Adaptability

Figure 1 shows a typical bridged tee equalizer section and a plot showing cable frequency response, equalizer frequency response and the total system response. This equalizer has attenuation equal to the amount of amplitude correction and will require an amplifier to restore the signal level. Because this type of equalizer has a "hump" in the response, cascaded sections are needed to obtain good flatness over a wider bandwidth.

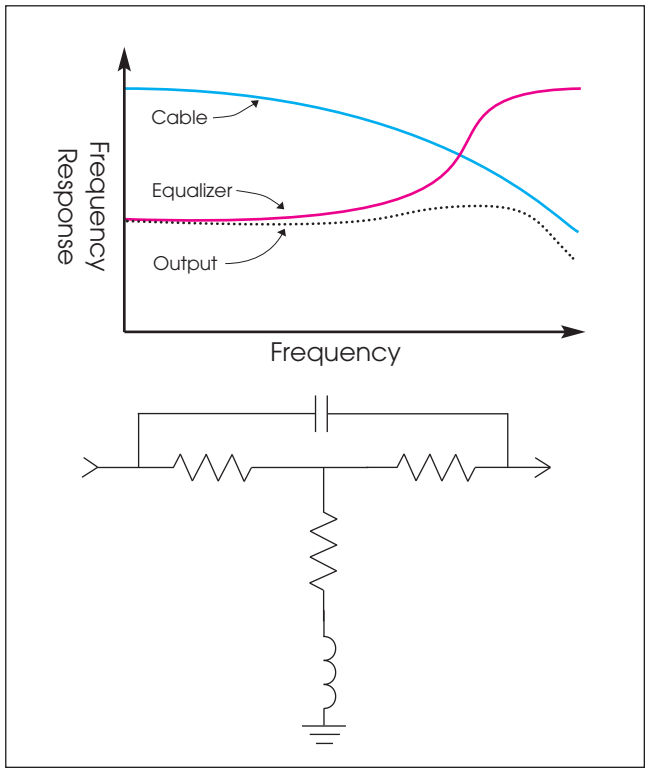

Figure 1 · A bridged tee equalizer can provide a boost for the high frequency loss of a cable, with a practical limitation set by the attenuation it adds at low frequencies. The resistors determine low frequency attenuation, while the capacitor and inductor establish the "turnover" frequency and the slope of the attenuation curve.

Different lengths and types of cable will have varying amounts of loss. The need to adjust an equalizer for every different situation can be impractical in systems such as a large computer network where new users are regularly added or relocated. Also, any system with switched circuits will have the problem of changing equalization requirements. An automated system is the only practical answer.

Fortunately, this has been addressed commercially. Many products are offered for this type of frequency compensation of long cables, as well as for time/phase equalization that may be introduced by other elements in the system.

In the digital realm, 1000 feet of CAT-5 twisted-pair cable can be equalized to about 25 MHz, sufficient for video services. Approximately 25 feet can be equalized to 1 GHz for high-speed data.