# Balancing the Reverse Path in CATV Systems

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*Abstract* – **The paper deals with some problems in balancing the reverse path of HFC CATV systems and the methods to solve them. Criteria are given to determine the parameters of the reference signal fed to the input of each optical node and amplifier in the reverse path. The sequence of balancing operations is described. A special attention is drawn to the design of the subscribers' distribution network and to the equalization of the signal levels in the subscribers' cable modems at the drop amplifier input in particular. Two methods to set and maintain the balance of the reverse path are described that make it possible for some of the signal characteristics to be monitored.**

*Keywords* – **HFC CATV, Reverse Path, Unity Gain, BER, laser clipping, drop equalizer.**

## I. Introduction

CATV systems make it possible for unlimited number of subscribers to access different services that cab be divided into two general groups: commonly provided and additional. Cable television and broadcasting are associated with the first one, while the second one includes high-speed Internet, on-demand multimedia, voice and phone communications, domestic and office alarm systems etc. Modern CATV systems are of the hybrid type: they implement fiber optics for the trunk rings and sub-trunk lines and coaxial cables for the peripheral branches.

One of the main causes to worsen communication quality over the reverse path of CATV systems is the funnel effect due to the tree-and-branch topology of the cable distribution networks. As a result, noise and inter-modulation products from all the network branches interfere with the signal in the subscribers' cable modems. Thus, the value of the bit error ratio (BER) at the receiver output of the cable modem terminal system (CMTS) is increased and communications over the reverse path get worse or cut-off. The influence of the funnel effect can be reduced significantly through optimization of the cable distribution network's topology and of the RF signals' dynamic range at the modulation input of the reverse path lasers or through appropriate filtering [1]. Another way to estimate the operability of the reverse path is to check the level of the digitally modulated RF carrier at the receiver input of the CMTS. As referred in CMTS specifications, a typical value for the cable modems is 0 dBmV. Reverse path balancing can be applied to provide that level, thus avoiding any undesirable worsening of BER in the optical transmitters of the reverse path.

When balancing the reverse path some difficulties can be met because of the different level of the signals that come from the subscribers' cable modems and are passed to the input of the reverse path amplifiers. This is due to the unequal paths passed by the signals, i.e. to the different attenuation along the coaxial cable and the passive devices included (splitters and taps). Though the level of the radio pulse transmitted by the cable modem is automatically controlled in the CMTS (within the limits of 92 dBμV to 112 dBμV) no alignment of the signals' levels is possible, so variations within 6 dB are quite admissible. Hence, when designing the reverse path it is of great importance to achieve a level equalization of the subscribers' signals at the input of the drop amplifier.

## II. The Concept of Unity Gain

The idea is based on the requirement that the loss between each amplifier section equals the gain in that section, i.e. a gain of 0 dB. Not meeting the requirement means that the signals of some sections when passed to the optical transmitter input of the reverse path will differ in level from the necessary one. This will cause an inadmissible drop in the carrier-to-signal noise ratio (CNR) and in the ratios of the carrier-to-aggregate distortion signals such as composite second order (CSO) and composite triple bit (CTB) at the receiver input of the CMTS which will result in an increase of BER.

Balancing the forward path causes no problems because all the signals are of the same level as aligned in the headend. The aim is to obtain one and the same signal level at the cable amplifiers' inputs of the coaxial line. To this aim an attenuator and an equalizer are used in the amplifiers' input to compensate for temperature and frequency effect on the coaxial cable attenuation. The optimal signal level in the forward path amplifiers can be calculated when given the necessary values of the following parameters: CNR, CSO and CTB at the subscriber's outlet, number of RF channels transferred, parameters of the amplifier chosen, number of amplifiers implied in each coaxial line [2].

The input of each amplifier and optical node in the upstream direction is used as a check point to measure signals' levels of the reverse path. Alignment begins at the return path transmitter/amplifier closest to the headend – typically a fiber optic node – and aims at obtaining a reference signal level that is preliminary set. To this aim either the transmission coefficient of the preceding optical node or the attenuation of the attenuator and the slope of the equalizer characteristics is adjusted at the output of the preceding amplifier.

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When choosing the reference input level a consideration must be made for optical and RF noise floors as well as clipping due to overdrive. A typical manufacturer's specification for optimum video input level to the return laser is 20 dBmV. Modern sweep systems are designed to operate 10 dB (or more) below the optimum carrier level, i.e. at a reference level of 10 dBmV. CATV systems are designed to operate at a reference level of 15 dBmV (75 dBμV), that must be set both in the input of each optical node and cable amplifier of the reverse path and in the headend [3]. Level variations within ± 2 dB (i.e. variations from 73 dBμV to 77 dBμV) are admissible.

The test signal frequency must correspond to the operation frequency of the cable modems, a frequency of 23 MHz to 25 MHz being the ideal one. In systems that employ a very wide reverse path (5… 65 MHz) it may be better to utilize two test frequencies, one at 25 MHz and the other at 50 MHz to properly correct for even the reverse path slope.

## III. LEVEL EQUALIZATION OF THE UPSTREAM SIGNALS AT THE DROP AMPLIFIER INPUT

High quality of the received CATV signals requires a level of 70 ± 5 dBμV at the subscriber's tap. Appropriate values of the tap attenuation in each subscriber's tap must be chosen as shown on fig. 1. As far as the reverse path is concerned losses in both the coaxial cable and passive devices of the subscribers' distribution network are much less than those of the forward path. On the diagram one can see two digits, the first one referring to signals in the reverse path and the second one referring to signals in the forward path. It is evident that with tap attenuation thus distributed the signals of the subscribers' modems will be of different level at the subscriber's amplifier input the highest value corresponding to the most-distant homes. This would make balancing the reverse path quite difficult.

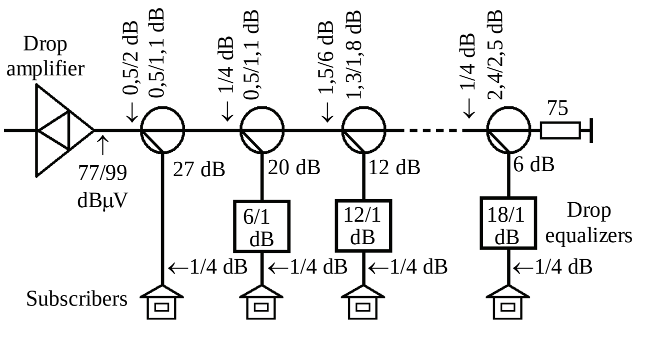


Fig. 1.

To compensate for signal level differences in the upstream direction drop equalizers of chosen characteristics must be implemented in the subscribers' taps. When choosing the value of attenuation some considerations must be made referring to the subscribers' distribution network, attenuation in the coaxial cable and in passive devices, the level of signals transmitted to home terminals etc. The aim is to make all signal levels coming to the subscriber's amplifier from all the subscribers' cable modems equal to the reference value (75 ± 2 dBμV). In the case a reference level of 77 dBμV is applied and drop equalizers of attenuation of 6, 12 and 18 dB are used.

Drop equalizers provide selectivity of attenuation at a chosen step within the frequency band of the reverse paths thus making possible the inter-active optimization of the system design. They help suppressing the ingress within the reverse path. Another advantage is that they enable the subscribers' cable modems to transmit signals of higher levels, hence to improve the CNR. Drop equalizers compress the dynamic range of the signals passed to the drop amplifier for the reverse path. As a result signal limiting is avoided and isolation between subscribers is improved.

## IV. ALGORITHM FOR BALANCING THE REVERSE PATH

The algorithm for balancing the reverse path can be explained by means of fig. 2 where a section of the cable distribution network of a CATV system is shown. Its optical part has a tree-and-branch topology, where signals at some points of the optical trunk line branch out towards optical nodes to feed the local area coaxial distribution networks.

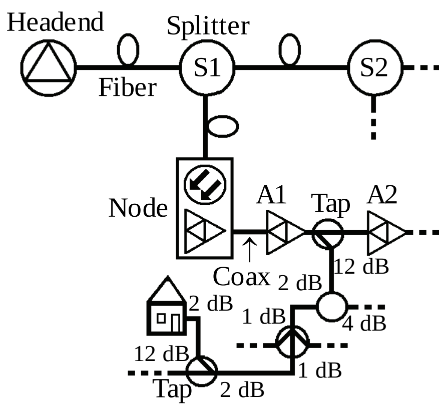


Fig. 2.

The procedure of balancing starts from the optical node that is closest to the headend. A test signal (75 dBμV and frequency about 25 MHz) is fed to the modulation input of the return laser module. Its gain is adjusted in a way to make the level of the RF signal at the headend input equal to the reference level. A spectrum analyzer or a sweep receiver in the range of 5 MHz to 65 MHz can be used to monitor the test signal in the headend. After balancing the reverse path section of the first optical node the test generator is injected into the next optical node input port and the procedure is repeated.

Balancing the coaxial sections of the reverse path can not start before gain of all optical nodes is set to the desirable value. Initially the test signal is fed to the input of amplifier A1 in the first local coaxial network that is closest to the optical node. The test signal level at the headend input is made equal to the reference one (75 dBμV), the attenuator and the equalizer connected in its output being properly adjusted. After balancing the section of the first amplifier the test generator is injected into the next amplifier input port A2 and the procedure is repeated, etc.

## V. METHODS TO SET AND SUPPORT BALANCE IN THE REVERSE PATH OF A CATV SYSTEM

The above algorithm for balancing the reverse path requires co-operation of two operators: one to adjust the corresponding optical node or amplifier and the other to monitor the signal level in the headend and to communicate with the first operator (over radio or wire channel). This makes it necessary for more effective methods of balancing to be applied during the whole lifetime of the system. In the paper two methods are considered as illustrated in fig. 3 and fig. 4.

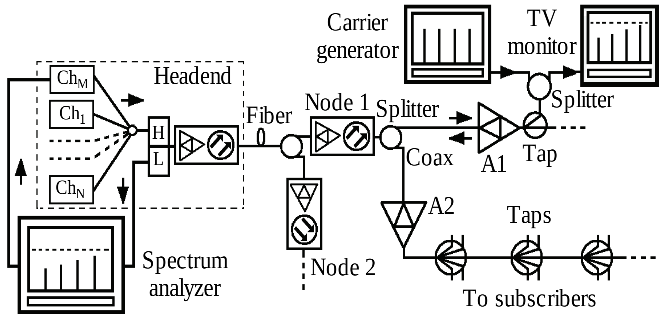


Fig. 3.

With the first method a spectrum analyzer, a TV monitor and a 2- or 4-carrier generator (from 5 to 65 MHz) are needed. The spectrum analyzer is connected at a test point of the headend to control setting the necessary reference level of the reverse path signal. A video modulator and an up converter are used to transfer the produced video signal to a given (unused) TV channel and to add it to the other signals in the forward path of the cable system. Then all optical nodes and amplifiers in the reverse path are adjusted one after the other, 2 or 4 carriers from the signal generator being fed to their inputs. The TV monitor is connected at the same points after being adjusted for the forward path by means of an image from the spectrum analyzer in the headend. The signal generator is connected at the input of the next-to-come optical node or amplifier in the reverse path and its gain is adjusted by means of the TV monitor with the aim to equalize the head up signals' level with the reference level.

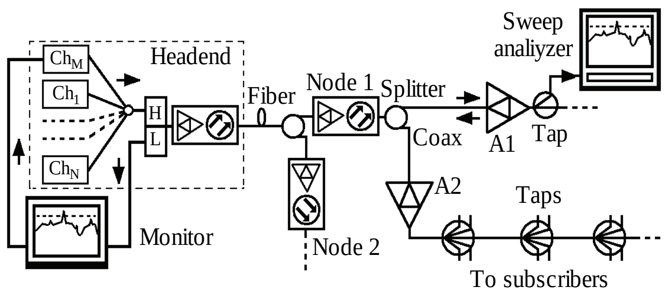


Fig. 4.

The second method makes use of a sweep analyzer and a return monitor. The sweep analyzer is connected at the input of the reverse path amplifier to be adjusted and the return monitor is in the headend, its image being transmitted over a separate forward TV channel. Thus a direct connection is established between the 2 sets of instruments. This method is more effective because it provides possibilities to monitor the frequency-response curve of the whole reverse path and to evaluate ingress, reflection and frequency-dependent attenuation in all the units.

## VI. CONCLUSION

Balancing the reverse path of HFC CATV can cause troubles to the operators due to random factors that can not be considered at the design phase. Thus the balancing procedure requests all requirements here considered to be strictly observed. The proposed methods for balancing the reverse path are rather easy to implement. It makes it possible for the received signals' level in the headend to be monitored on the very spot where each amplifier or optical node is connected. They make operators' activities easier, besides they provide facilities to build up a fully automated system for maintaining the desired quality of communications over the reverse path of CATV systems.

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