Upstream Design Considerations in HFC/CATV Systems

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***Abstract* – In this paper are proposed circuit solutions and methodology to balance the Upstream channel, as well as expressions for determining the output signals of cable modems, the total noise in the channel and the signal to noise ratio. The results are shown in block diagrams, graphs and tables.**

***Keywords* – HFC/CATV, cable modems, C/N.**

I. INTRODUCTION

Today a typical HFC/CATV network allocates a large amount of capacity to Downstream transmission with the spectrum ranging between 47(85)–862 MHz. With most of the spectrum is dedicated to TV channels (analog, digital, VoD and maybe HDTV), only a small amount of unallocated bandwidth remains [1].

The Upstream spectrum, too, is limited - available bandwidth is 5–30(65) MHz, out of which the lower frequencies cannot be used due to noise. This bandwidth is required to service network monitoring, interactive TV (digital), VoD, cable telephony and cable modems [2], [3].

II. STRUCTURAL SCHEME AND MATHEMATICAL RELATIONSHIPS

Subject of the present development are the design considerations for the Upstream (return path) in HFC/CATV networks and in particular the part of the fiber node (FN) to the subscribers' equipments (Fig.1). The cable amplifiers (CA) are two-way and some of them are with active, another with passive return channel. This is defined out of the results received for the parameters of transmitted signals by sizing the return path. The passive Taps and Splitters have a different attenuations and a number of tap/split outputs. In supertrunk lines are used single optical fibers, in trunk lines – trunk coaxial cables, in subtrunk lines - drop (distribution) coaxial cables from the F11/RG11 series and in subscriber lines – drop (distribution) coaxial cables from the F6/RG6 series. Subscriber equipments are: TV receiver, cable modem, phone/Fax and set-top-box. For noise reduction in return channel between the respective output of the passive devices (directional coupler or splitter) and the subscriber equipments is installed a Return Step Attenuator (RSA). RSA suppresses the signals in return path (including the noise).

The value of RSA is defined according to the level of output signal from the cable modem, the distance to the home amplifier and tap loss of the passive device to the subscriber. This way the signals in return path for every subscriber, served from this amplifier, are evened. If there are subscribers, which do not use services from the return path, instead of RSA is installed a high frequency filter (HPF) with a frequency band 85-862MHz. This reduces the penetration of noises and ingress of the subscribers' equipments, which do not use interactive services [4].

All reviews and analysis are made for a frequency band of return path from 5-65MHz. The proposed mathematical expressions are universal for both cable distribution networks, built in the apartment buildings and between family houses.

A. Calculation of the output level of cable modem

To be reduced the noise and ingress in return path is

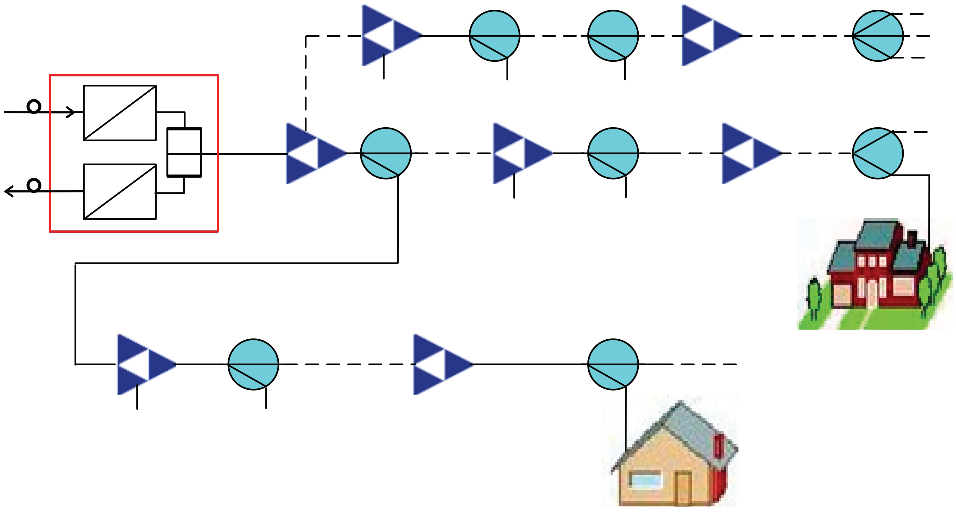

Fig.1. HFC/CATV cable distribution network

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necessary the level of signal at the input points of the amplifiers and the fiber node to be equal (80dBμV) – points 1 to 12 from Fig.1. For this purpose are calculated the cable modems' output levels U_{CM} in a way that, by indicating every source of attenuation in the line between subscriber and amplifier/fiber node, on its input (for return path) will be received the necessary level 80dBμV. The common formula for making the calculations is:

$$U_{CM,k} = U_{in,i} + \sum_{i=1}^{M} G_{Up,i} - U_{in,FN} - \sum_{j=1}^{J} a_{PD,j}$$

$$- \ell_{TK}.a_{TK} - \ell_{STK}.a_{STK} - \ell_{SSK}.a_{SSK}, \qquad (1)$$

where $U_{CM,k}$ is the output level of k-th cable modem (k=1, 2, 3, 4, 5 …) in dBμV; $U_{in,i}$ is the input level of i-th cable amplifier mounted nearest to k-th cable modem, [dBμV]; $U_{in,FN}$ is the input level of fiber node, [dBμV]; $G_{Up,i}$ is the gain of upstream path components in i-th cable amplifier, [dB]; $a_{PD,j}$ - attenuation of passive devices in the line between cable modem and fiber node (tap and through loss), j is the number of passive component, [dB]; ℓ_{TK}-full length of trunk coaxial cable [m]; ℓ_{STK}- full length of subtrunk coaxial cable [m]; ℓ_{SSK}-full length of subscriber coaxial cable [m]; a_{TK} – attenuation of trunk coaxial cable for 1m at 65MHz, [dB/m]; a_{STK} – attenuation of subtrunk coaxial cable for 1m at 65MHz, [dB/m]; a_{SSK} – attenuation of subscriber coaxial cable for 1m at 65MHz, [dB/m].

On Fig.1 with a dotted line is marked the possibility of existence of other amplifiers and passive devices, as 1, 2, 3…12 are input points of the amplifiers and fiber node.

B. Calculation of the aggregate noise

Main passive devices in the cable distributive network, which are used for tap/splitting of the signals transmitted in downstream (forward) path, are directional couplers (Taps) and Splitters (Fig.1). Through them is realized also the transmitting of signals in upstream (return) path, as in this case they take the functions of sumators. There is a correlation between the Tap/Splitter value and the susceptibility of a subscriber location introducing noise and ingress to the network. Conceptually it can be illustrated by focusing on the isolation between the subscriber and the network provided by the Tap/Splitter. For example: the 4 dB Tap/Splitter provides only 4 dB of isolation between the subscriber and the network - whereas the 30dB Tap provides 30dB of isolation. The smaller value Tap will inherently allow more noise and ingress into the network.

On Fig.2 are given the graphical symbols of Tap and Splitter, as well the ports, their parameters and the levels of signals and noises. Based on those, below are presented mathematical relationships for calculating of the aggregate noise at every point of the cable distribution network.

1. **1.** Calculation of the signal at the output of the passive component:

a) when the signal at the output of the Tap comes from the direct line:

$$C_{0,out}^{(T)} = C_{0,in} - a_{thru}, \text{ [dBμV]}; \qquad (2)$$

b) when the signal at the output of the Tap comes from the side/drop/tap lines (i=1÷ 4):

$$C_{i,out}^{(T)} = C_{tap,i} - a_{tap,i}, \text{ [dBμV]}; \qquad (3)$$

c) when the signal at the output of the Splitter comes from the direct lines (i=1÷ 4):

$$C_{i,out}^{(S)} = C_{in,i} - a_{thru}, \text{ [dBμV]}. \qquad (4)$$

2. Calculation of the noise at the output of the passive component:

a) when the noise at the output of the Tap comes from the direct line:

$$N_{0,out}^{(T)} = N_{0,in} - a_{thru}, \text{ [dBμV]}; \qquad (5)$$

b) when the noise at the output of the Tap comes from the side/drop/tap lines (i=1÷ 4):

$$N_{i,out}^{(T)} = N_{tap,i} - a_{tap,i}, \text{ [dBμV]}; \qquad (6)$$

c) when the noise at the output of the Splitter comes from the direct lines (i=1÷ 4):

$$N_{i,out}^{(S)} = N_{in,i} - a_{thru}, \text{ [dBμV]}. \qquad (7)$$

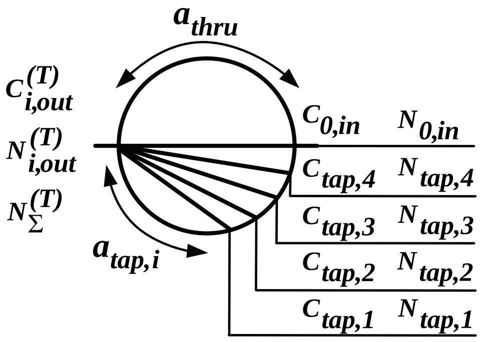
3. Calculation of the aggregate noise at the output of the passive component:

a) for Tap:

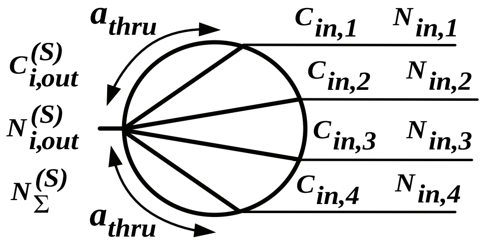
$$N_{\Sigma}^{(T)} = 20\lg[\sum_{i=0}^{4} 10^{(N_{i,out}^{(T)}/20)}], \text{ [dBμV]}; \qquad (8)$$

b) for Splitter:

$$N_{\Sigma}^{(S)} = 20\lg[\sum_{i=1}^{4} 10^{(N_{i,out}^{(S)}/20)}], \text{ [dBμV]}. \qquad (9)$$



a) Tap



b) Splitter

Fig.2. Graphic symbols of passive devices

III. CALCULATION OF U_{CM}, C/N AND C/N_{Σ}

The practical application of the above shown mathematical relationships is described below for cases in which are used different passive devices for branching of the signal to the subscribers (Figs.3 and 4). Considered are cable distribution networks for subscribers, which live in family houses. Proposed are different options, for making a comparison of the network quality and recommendations for their application.

Cable amplifiers are with built amplifier for return path in order to be provided a level of signal 80dBμV in the input of every one of them. This way are compensated the losses in the coaxial cables and the passive devices between every two amplifiers. The distances from the subscriber equipment (set-top-box) to the respective directional coupler (Tap) are equal. This will allow the comparison of the respective parameters of signals not only for the subscribers from one branch, but also for those from both branches (upper and lower), Figs.3 and 4.

The maximal distance in the upper branch between CA and subscriber (test point 24 and test point 1/2/3) is 185m, and in the lower one it is 140m. The proposed example architecture of the cable distribution network allows the number of subscribers to increase from 13 to 100, if Taps with four tap ports and four port Splitters are used.

On Figs.3 and 4 are presented the architectures of a cable distribution network with and without Return Step Attenuator (RSA). RSA are wrapped directly to port “tap” of a Tap and to port “out” of a Splitter. The value of RSA by balancing of return path must be chosen so, that the level of noise (N, N_{Σ}) in direction to the amplifier reduces itself. If at any test point this level is higher from the noise level at a previous test point, it is necessary the value of the attenuation at the step attenuator to be increased. The results of the analysis for the signal’s level alternation, carrier-to-noise ratio and carrier-to-aggregate noise at different test points are given in Table 1, Figs.5 and 6.

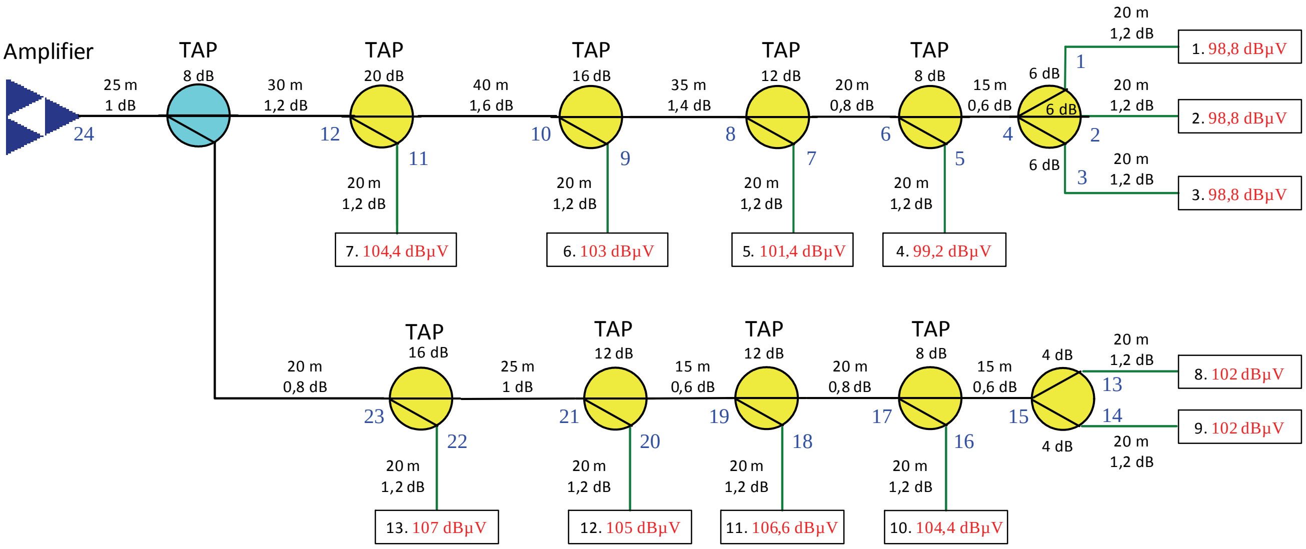


Fig.3. Architecture of cable distribution network without Return Step Attenuator

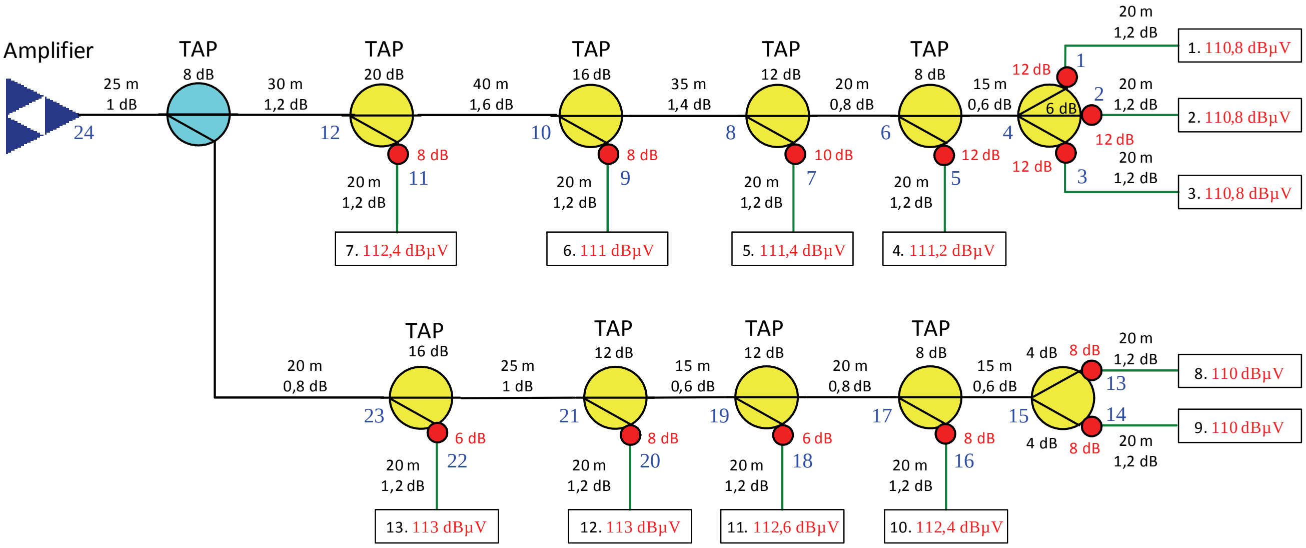


Fig.4. Architecture of cable distribution network with Return Step Attenuator

TABLE 1

Test point №	without RSA			with RSA ●		
	C dBμV	C/N dB	C/N_{Σ} dB	C dBμV	C/N dB	C/N_{Σ} dB
1	97,6	67,6	-	109,6	79,6	-
2	97,6	67,6	-	109,6	79,6	-
3	97,6	67,6	-	109,6	79,6	-
4	91,6	-	58,06	91,6	-	70,6
5	98	68	-	110	80	-
6	90	-	55,66	90	-	67,66
7	100,2	70,2	-	110,2	80,2	-
8	88,2	-	54,17	88,2	-	65,82
9	101,8	71,8	-	109,8	79,2	-
10	85,8	-	53,1	85,8	-	64,24
11	103,2	73,2	-	111,2	81,2	-
12	83,2	-	52,3	83,2	-	63,09
13	100,8	70,8	-	108,8	78,8	-
14	100,8	70,8	-	108,8	78,8	-
15	96,8	-	64,8	96,8	-	72,78
16	103,2	73,2	-	111,2	81,2	-
17	95,2	-	62	95,2	-	69,99
18	105,4	75,4	-	111,4	81,4	-
19	93,4	-	60,32	93,4	-	67,92
20	103,8	73,8	-	111,8	81,8	-
21	91,8	-	58,65	91,8	-	66,32
22	105,8	75,8	-	111,8	81,8	-
23	89,8	-	57,52	89,8	-	64,97
24	80	-	48,5	80	-	57,96

In the defining of signal levels at the test points in the drop lines is used equation:

$$C_i = U_{CM,k} - \ell_{SSK} . a_{SSK}, \text{ [dBμV], where} \qquad (10)$$

i= 1, 2, 3, 5, 7, 9, 11, 13, 14, 16, 18, 20 and 22 or for our case:

$$C_i = U_{CM,k} - 1{,}2, \text{ [dBμV].} \qquad (10a)$$

IV. CONCLUSION

From Fig.5 is to be seen, that the levels of signal for a specific test point in the direct line with and without RSA are the same. The levels of signal in the drop line for a specific test point are different (the level of signal at a given test point by using a RSA is higher from this one at the same point but without RSA and with the value of the attenuation of a RSA).

From Fig.6 is to be seen, that the values of C/N and C/N_{Σ} are increasing by using of RSA, as for test point 24 it is C/N_{Σ}=57,96dB. This value is with around 9,5dB higher from the value of C/N_{Σ}=48,5dB in an architecture, in which is not used a step attenuator.

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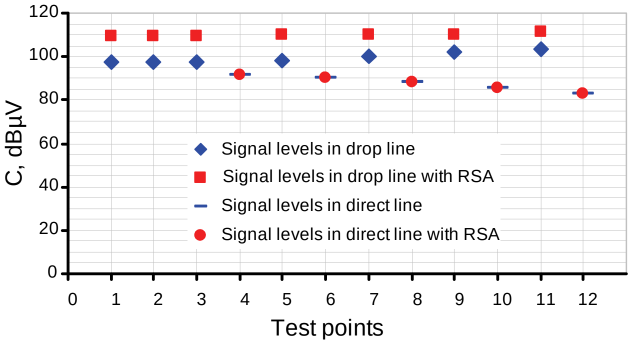
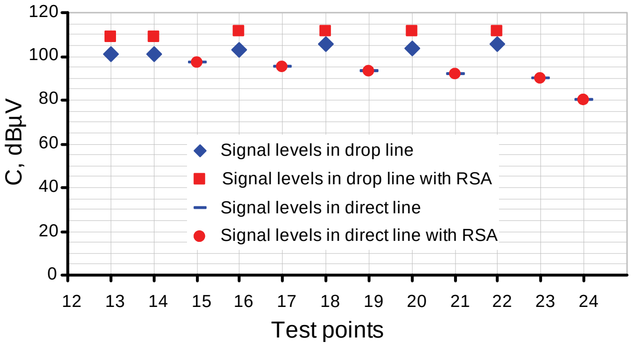
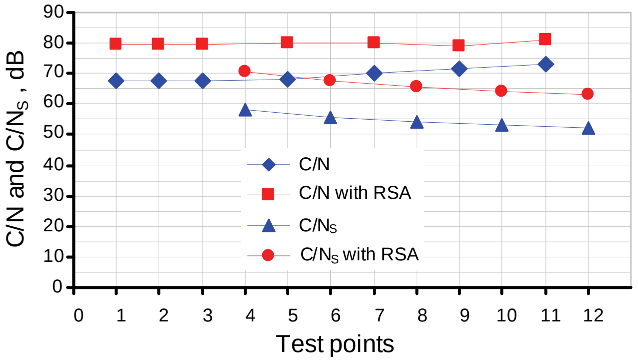


a) Upper branch

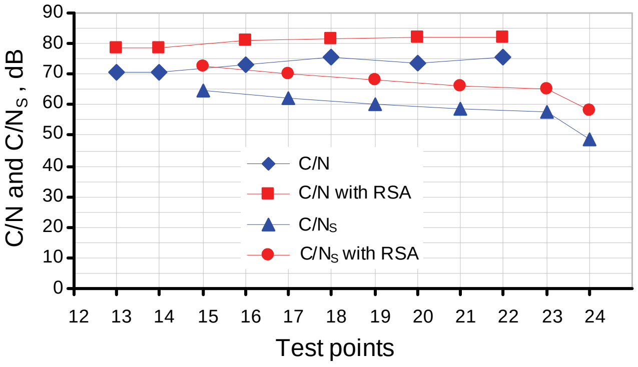


b) Lower branch

Fig.5. Signal levels



a) Upper branch



b) Lower branch

Fig.6. C/N and C/N_{Σ}

[4] Product Application Note: ARSA Return Step Attenuator. Arcom Labs, Syracuse, NY, 2008.