About some problems in the transmission of signals in HFC/CATV networks

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Abstract – **In this paper are presented the results of a research into the influence of the change in the parameters of elements of the coaxial part of a HFC/CATV network, as a result of different unfavorable factors. This on its part leads to worsening in the quality of receiving or inability to receive, as well analogue (CSO, CTB < 60 dB) as digital (BER increases, MER and C/N decreases) signals. Thus it is necessary to research and analyze the influence of the parameters of the network and signals, transmitted in it, onto BER, MER, C/N, CSO and CTB and to make the corresponding recommendations to insure a promising and qualitative signal transmission in the HFC/CATV network.**

Keywords – **HFC/CATV, distortions, BER, MER, C/N.**

I. Introduction

Cable television systems are traditionally one-way and distribute mostly television and radio signals to the subscribers. Since the development of Internet and HDTV, cable TV distributors have been interested in distributing those services, too. A good solution is to transmit analog and digital signals together in hybrid communication networks by optical fibers and coaxial cables. It is a fact that the hybrid transmission of the existing AM-VSB and the new digital (M-QAM) signals is essential to the expansion and the increase in efficiency of cable television systems in the future [1], [2].

The architecture of the HFC network is bidirectional communication infrastructure (Fig. 1). Each group of 500 to 2000 subscribers is serviced by two single mode fibers, one for "Downstream" and another for "Upstream" channel, which connects the Head End and the fiber node. Furthermore, signals from the fiber node to the subscribers are transmitted via coaxial cable through few amplifiers and taps/splitters by a frequency division: from 5 MHz to 65 MHz ("Upstream" channel) or from 85 MHz to 862 MHz ("Downstream" channel).

HFC/CATV systems are one of the most attractive, because the M-QAM signals provide high spectral efficiency and purity considering the noise and the nonlinear distortions. However from "clipping" in the laser diode (DFB – distributed feedback) is generated a noise, which causes deterioration (increase) of BER (Bit-Error-Rate) when transmitting simultaneously analog and digital signals [3], [4]. This paper examines the experimental results from the investigation into the influence of the variation of devices' parameters on the coaxial part of the network: increase/decrease of the levels of the analog (AM-VSB, FM) and digital (M-QAM) signals.

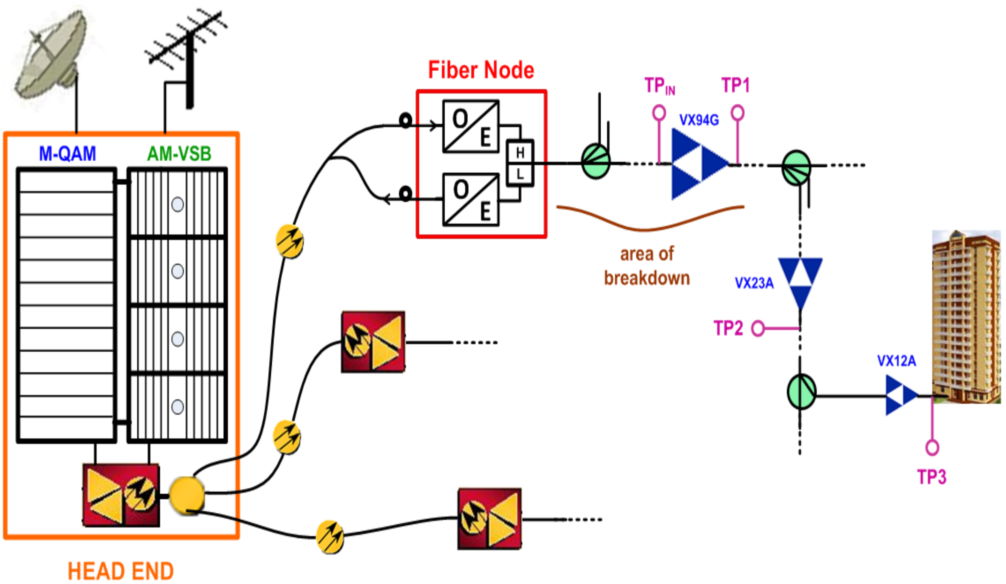

Fig.1. Experimental setup of part of a HFC/CATV network

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Due to disturbances in the integrity of the coaxial cable (trunk, subtrunk, drop), the nominal levels of the signals change. Reasons for that could be: soil consolidation, rodents, construction works, cracking of the outer insulation due to manufacturing defects or such, caused during the installment process into the underground ducts (Fig. 2), [5]. Other causes for the variation in the nominal level of the signals could be: change in the parameters of the taps and splitters; degradation of the contact resistance, in the level regulators, and of the slope of the amplitude-frequency response of the electronic amplifiers; defects in the amplifying elements (monolithic and hybrid integrated circuits, transistors); change of the supply voltage (problems with SMPS); problems in AGC/ALC, NMS modules and others. Effects from such problems (in the present or next element/device) are at first a level change of the signals (linear distortions), but after the signals have entered the input of the next amplifier they can cause non-linear distortions (increased level of the signals compared to the nominal) or degradation of the noiseimmunity (decreased level of the signals compared to the nominal).

Fig.2. Cable fault - two cables

Since the amplifiers are connected in series (Fig. 1), the unfavorable effects multiply, which leads to decrease in the quality of receiving or to the impossibility of receiving both the analog (CSO, CTB < 60 dB) and digital (BER increases, MER and C/N decrease) signals. In this sense it is required to measure and analyze the influence of the parameters of the network and the signals, transmitted through it, over BER, MER, C/N, CSO and CTB.

II. Experimental Setup and Results

A. Initial conditions

In this section are presented the results of the research made in a part of real functioning HFC/CATV system/network, which carries 75 channels (Fig. 3). Part of the analog channels are located between the digital ones (in the range above 470 MHz), and some of them coincide by frequency with broadcasted terrestrial channels (DVB-T, LTE and others) at the place of the experiment.

The studies were carried out for the worst case: when the studied channels coincide by frequency with channels from DVB-T (channels 40 and 52) and when parts of the trunk cable and the subtrunk cable are under the ground – PVC conduit in trench and pit/cable chambers (Fig. 4), and on the power poles (Fig. 5), [6].

Fig.4. Cable chamber

The carrier frequencies of the channels are synchronized in the Head End (Fig. 1), by a PLL, and their levels (Table1) are equalized according to [7], [8], the parameters of the amplifiers and to the ΔU_n (Table2). The equalization of the signals' levels in the composite/group signal is done for channels SR1 and 45 (standard D/K). The difference between the levels of the analog (AM-VSB) and digital (M-QAM) channels is 10÷13dB. The composite nonlinear distortions (CSO, CTB) are measured in channel 22. M=256 for channel 40 and M=64 for channel 52. The electronic amplifiers that were used are by the WISI company: VX94G, VX23A and VX12A (Table3), [9].

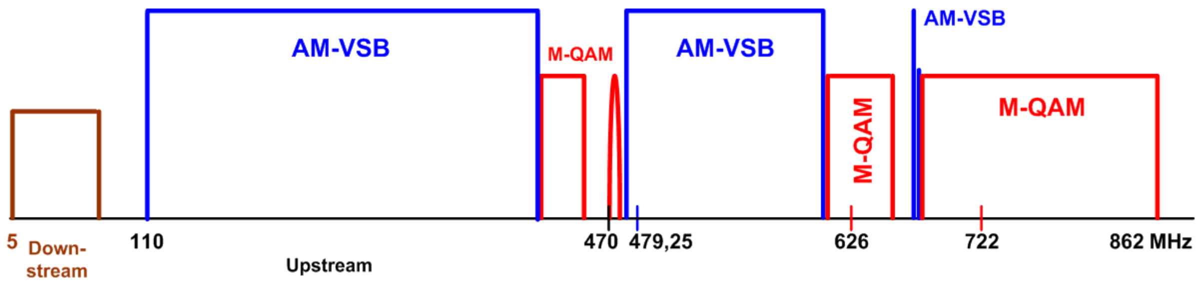


Fig.3. Spectrum of HFC/CATV system

TABLE 1

TP	TP_{in}			TP1			TP2			TP3		
Channel	22	40	52	22	40	52	22	40	52	22	40	52
Parameter / *f*, MHz	479,25	626	722	479,25	626	722	479,25	626	722	479,25	626	722
CSO, dB	64			67			67			67		
CTB, dB	>63			64			64			62		
preBER		1,5E-7	6,2E-8		2,8E-6	1,5E-8		1,8E-9	3,6E-9		1,2E-7	1,3E-8
postBER		9E-10	1,2E-9		9E-10	1,2E-9		9E-10	1,2E-9		9E-10	1,2E-9
MER, dB		37	29		36	29		40	30		37	29
C/N, dB	44	30	31	43	29	30	43	30	33	43	29	30
U, dBμV	69	66	66	91	90	90	102	101	101	89	87	88

Fig.5. Power pole

The measurements are done for 4 test points (TPin, TP1, TP2, TP3) according to Fig.1, with the area of breakdown being close to the fiber node (around the trunk amplifier). The initial state is at normal operating mode of the HFC/CATV system (Table1), after that the levels of the signal increase/decrease to 10 dB. In the first case, the influence of the nonlinear distortion's increase over BER, MER, CSO and CTB is investigated, as well as the alternation of C/N. The second case studies the influence of the decrease in the noiseimmunity due to the impaired shielding and grounding. This leads to the growth of the interferences from other radiocommunication devices and systems/networks (DVB-T, LTE, radio transceivers – used by amateurs, police, fire brigade and etc.) in air mounted coaxial cables and devices.

TABLE 2

Number of channels n	42 CENELEC	55	65	75	85
ΔU_n dB	12,1	12,99	13,55	14,02	14,43

TABLE 3

Parameter / Model amplifier	$U_{out,2}$ dBμV	Gain dB	Attenuator dB	TILT dB
VX94G	121	28	10	20
	109*			
VX23A	122	35	<10	>10
	110*			
VX12A	114	38	18	18
	98*			

Note: * 42 channels CENELEC EN50083

B. Results

The results from the measurements are presented graphically (Fig.6, Fig.7, Fig.8, Fig.9, Fig.10) for three channels - one analog (AM-VSB) 22 and two digital (QAM) - 40 and 52 by D/K standard. The constellation diagrams are also given for the test point TP3 in normal operating mode and in breakdown mode. From the graphics, it is seen that for the analog signals: C/N worsens with 5-10 dB (TP3) in the edges of the investigated range of alternation of U_{out}; CTB with $\Delta U_{out} \geq 6$ dB drops to 50 dB for TP2 and to 48 dB for TP3 and with $\Delta U_{out} \leq -4$ dB its values drop under 60 dB and reach 53 dB for TP3. The change of the nominal level substantially influences the digital signals, as follows: channel 40 MER it worsens with 13-15 dB (TP2, TP3) at the ends of the studied variation range of U_{out} and improves with 4 dB for TP1 with $\Delta U_{out} \geq 6$ dB; for channel 52 MER worsens with 5-8 dB (TP3) in the ends of the studied variation range of U_{out}; C/N_{QAM} drops by around 8 dB (TP2, TP3) with -6 dB $> \Delta U_{out} > 6$ dB - for the two channels; BER increases in the ends of the investigated range of U_{out} up to $3x10^{-3}$, but for values of -4dB $\leq \Delta U_{out} < 0$ dB (channel 52) and -2 dB $\leq \Delta U_{out} < 0$ dB (channel 40) BER decreases with around 0,02 and reaches up to $1,8x10^{-9}$ (40-TP2).

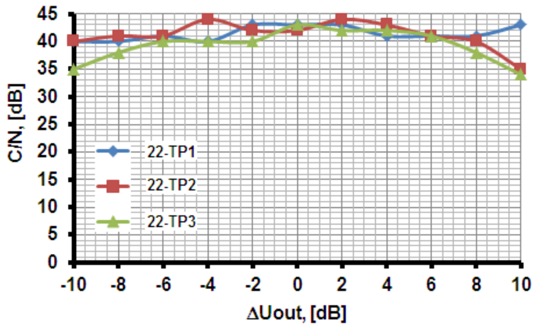


Fig.6. *C/N=func*(ΔU$_{out}$) – AM/VSB

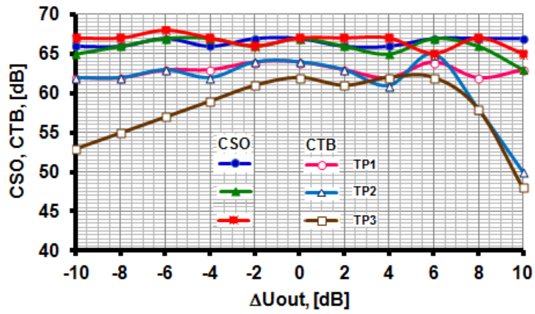


Fig.7. *CSO= func*(ΔU$_{out}$) and *CTB= func*(ΔU$_{out}$)

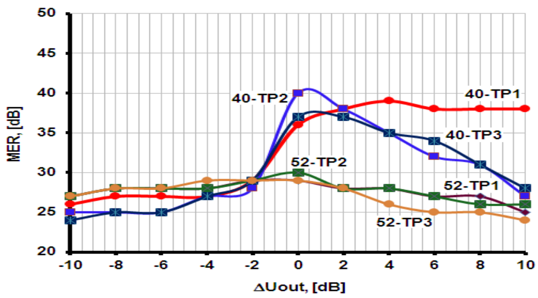


Fig.8. *MER= func(ΔU$_{out}$)*

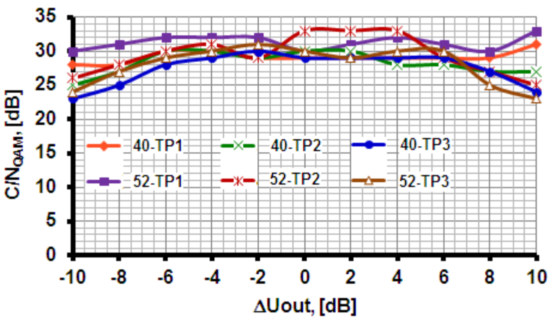


Fig.9. *C/N$_{QAM}$=func*(ΔU$_{out}$)

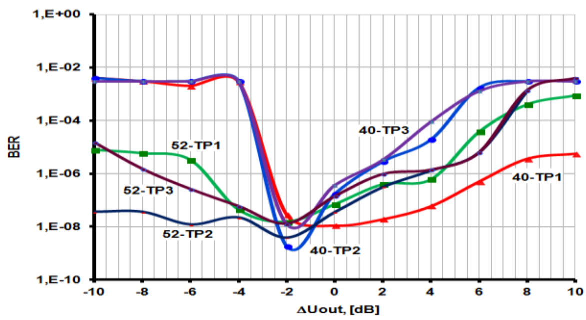
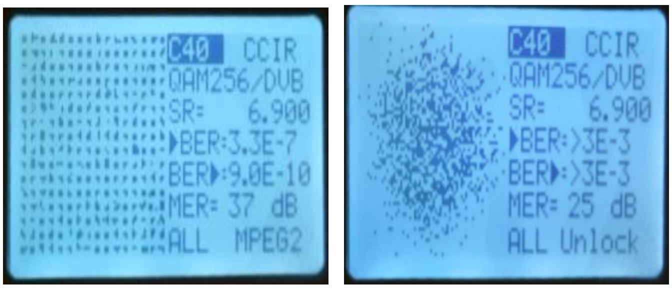


Fig.10. *BER= func(ΔU$_{out}$*



a) ΔU$_{out}$ = 0dB_(TP3) *b)* ΔU$_{out}$ = ±10dB_(TP3)

Fig.11. Constellations: *a)* without and *b)* with breakdown

III. Conclusion

The research, the results and their analysis let us make the following conclusions: a variation with even so much as 2-4 dB of the nominal level in the cable distributing network of the HFC/CATV system can lead to a worsening in the quality of the transmitted signals (QoS) and even to prevent them from being (of M-QAM) received (BER>10^{-6}). Furthermore, in the tests it was found that in the adjacent channels (39, 53) BER, MER, CSO, CTB and C / N do not deteriorate as much as for the channels 40 and 52, which is a result of the lack of influence of the DVB-T channels' (40, 52) broadcast in the area in which the study was conducted. Thus the recommendations, which can be given regarding the attenuation in the nominal level with ± 10 dB are as follow: to be used amplifiers with AGC on the long distances (>2 km); the maximal gain of every amplifier should be ca. 35-40 dB, but the working gain about 5-10 dB lower; all equipment and cables should be placed underground, be well isolated, as well as dampness and rodent proved et al. Taking the necessary measures would considerably improve the reliability and quality of the offered services, including those of the "triple play" – television, telephone and Internet [10].

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