Reduction of Nonlinear Products from Composite Distortions of the Signals in Optical Link

Oleg Borisov Panagiev[1] and Galya Veselinova Raicheva[2]

***Abstract* - Nowadays application of hybrid fiber coaxial (HFC) networks in cable communication systems is a key technology for two-way transmission of information between users. In spite of that, common transfer of AM-VSB and M-QAM signals is attended with unfavorable effects that analogue channels have on digital ones: arise of composite distortions of second and third order, increase of BER, decrease of noiseimmunity etc. Methods for supporting minimal levels of distortions in HFC networks conformed to network topology and parameters of optic transmitter, receivers and amplifiers are offered.**

***Keywords* – HFC, composite distortions, HUB, BER, M-QAM**

I. Introduction

With the increasing demands of interactive services, existing coaxial TV systems with its inherent problems and limitations can not be used for large and very large distances (> 10 km), [1], [2].

Solution of the problems and elimination of limitations are possible with building up of hybrid fiber coaxial (HFC) networks, which application nowadays in cable communication system is a key technology for two-way transmission of information between users. Better quality of video services could be achieved by applying of subcarrier multiplexing (SCM) in the HFC systems that use M-ary quadrature modulation (M-QAM) for transmission of compressed digital video signal (MPEG) together with ordinary amplitude modulation of analogue signals (AM-VSB). Frequency diagram of one HFC network is shown on Fig.1. Using MPEG compression and QAM modulation is possible to transfer some digital video programs or some narrow-band channels with data, telephone signals etc. in one channel with frequency band 8 MHz instead of one analogue TV program with AM/VSB modulation. Internet access request from the subscriber is transmitted via Upstream services, and the receipt of requested information from the WEB by in the Downstream services.

In really operation of HFC networks with common transmission of AM/VSB and M-QAM signals in determined conditions could be observed unfavorable effect from analogue on digital channels [3], [4], [5]. As a result nonlinear products are obtained (composite distortions – CSO, CTB and CXM). The most important factors for their origin are: laser “clipping”, Rayleigh backscattering and reflection noises.

In general case complex distortion are regarded as a noise, because their adverse effect is accompanied by increase of binary error rate BER.

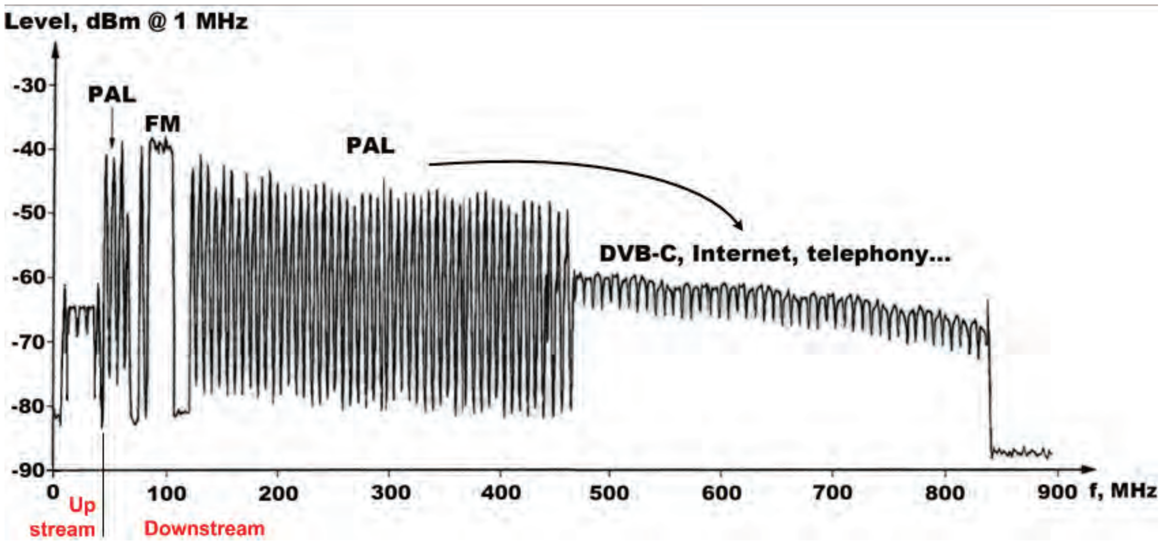

Fig.1. Frequency diagram of HFC network

II. Determination of optical power in HUB/FN

In HFC networks are established a lot of distortion factors, lowering the quality of digital channels, some of them are related to network topology [6] and others – with way of

[1]Oleg B. Panagiev is with the Technical University of Sofia, Bulgaria, E-mail: olcomol@yahoo.com

[2]Galya V. Raicheva is with the Technical University of Sofia, Bulgaria, E-mail: raicheva@tu-sofia.bg

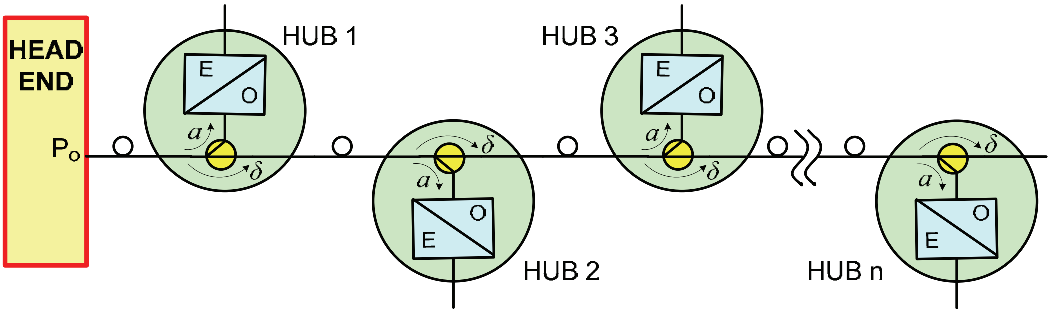

Fig.2. Bus topology

mixing of AM-VSB and M-QAM signals [4] and parameters of optical devices [7], [8] – optical receivers, optical transmitters and optical amplifiers.

Topology of a HFC network usually is tree type (branched), but for large networks it is non-effective and expensive, that is why recently star topology is used, BUS - is already used in local networks (LAN) and ring topology.

In many cases, the three types topology are used together (for large cable TV systems) in order to combine their advantages in particular application.

A. Bus topology (Fig.2)

In Bus topology one more parameter appears in expression for determination of optical power in particular HUB, this is the loss of power *a* (tap-off attenuation in dB) by derivation of light signal:

$$P_{n,b}[dBm] = P_o - a - (n-1).\delta\,, \tag{1}$$

where $n \le 60$. On Fig.3 is shown diagram of $P_{n,b} = func\,(P_o, n)$, where P_o= (4÷16) dBm, n = 1÷60, δ =1,8 dB and a =5,6 dB, (WISI LK06).

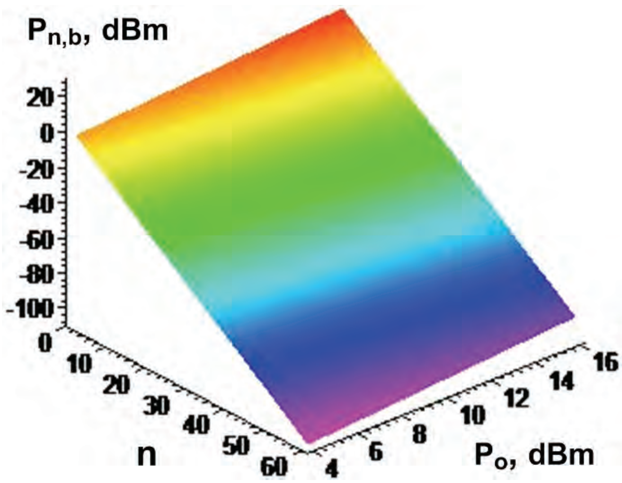

Fig.3. Diagram of $P_{n,b} = func\,(P_o, n)$

B. Star topology (Fig.4)

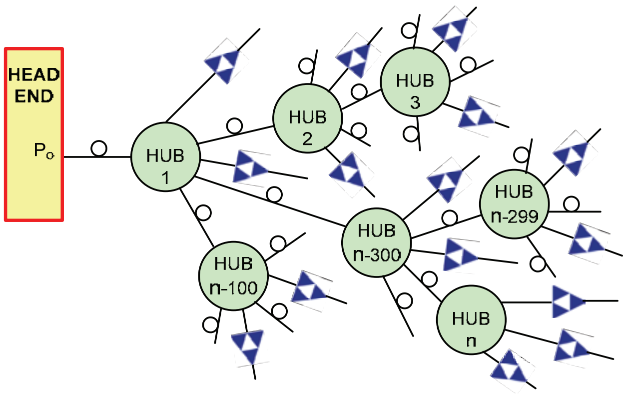

Fig.4. Star topology

For star topology, optical power in any HUB depending on output power of optical transmitter could be determined by:

$$P_{n,s}[dBm] = P_o - \delta - 10.[1 + 3{,}322.\lg(1 - 10^{-\frac{\delta}{10}})].\lg n\,, \tag{2}$$

where

P_o is output power of optical transmitter in dBm;

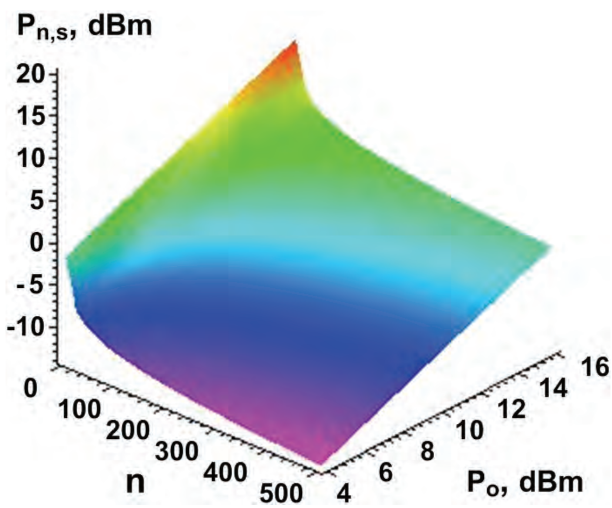

Fig.5. Diagram of $P_{n,s} = func\,(P_o, n)$,

n – HUB number, $n \leq 500$;

$P_{n,s}$ – power available at n-th fiber node (FN/HUB) in dBm;

δ - HUB losses (insertion losses, throughpass attenuation) in dB.

On Fig.5 is shown diagram of $P_{n,s} = func\,(P_o, n)$, where Po= (4÷16) dBm, n = 1÷500 and δ = 5,7 dB, (WISI LK13).

III. Reduction of Composite Distortions in Optical Link

Every main trunk in HFC systems consists of fibers and branching – of coaxial cables. In optical part except the thermal noise and non-linear distortions there are created impulse noises from laser "clipping". [3], [4], [5]. The impulse noise inherent to multiplexed signal by frequency division causes a drop of output power of laser diode near zero and its input control current is lower than current setting its work point. [3], [5]. As a result, nonlinear products appear that cause increase BER. It is necessary to analyze carefully this product in order to determine requirement not only to the system, but also to its components: optical transmitters/receivers, bridge and linear amplifiers.

For determination of composite distortions it is necessary to use simplified expressions to obtain values for CTB, CSO and CXM.

Maintaining minimum levels of complex distortions in HFC networks is an essential task that must be solved depending on the network topology and parameters of active devices into it. It should be noted that in optical systems of different manufacturers exploitation parameters are with similar values (Table 1) as regards to laser diodes used in transmitter as well as photodiode used in the receiver. Significant impact on output parameters have the index of optical modulation m. Increase of this index causes deterioration of CTB, CSO and CXM (they are ratio carrier/interference according to CENELEC EN 50083-6) and improvement of ratio carrier /noise (CNR), (Fig.6).

The main reasons leading to the need to recalculate the composite distortions of the system are:

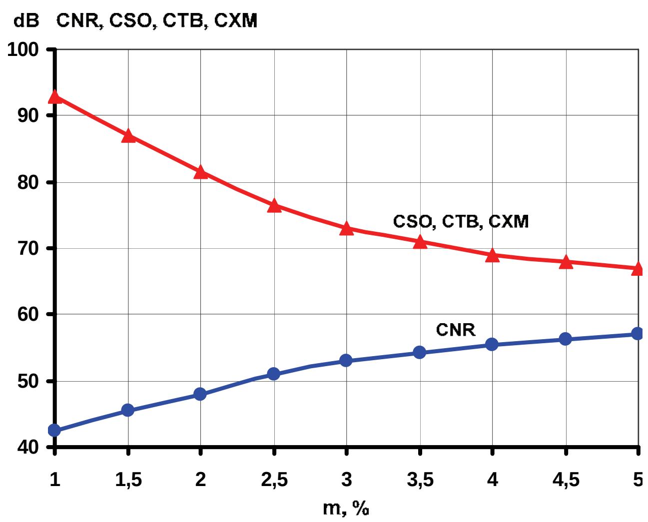

Fig.6. Influence of m on CSO, CTB, CXM and CNR

Table 1

	Optical Tx			Optical Rx		
Type	LT61S	OTXS06	CHP GQTX	LR 82	ORB901	CHP GFRX
Optical (input) output level, dBm	6	8	10	(-8...0) 0	(-8...+3) 0	(-3...+3)
RF – (input) output level, dBμV	(79...88)	(85)	(97)	(77...95) 90	(85) 104	101
CNR,dB	>50	>50	51	50	52	62
CSO,dB	>60	>60	55	≥ 60	35*	>65
CTB,dB	>60	>65	60	≥ 60	35*	>85
CXM,dB	60	60	63	60	55*	80
Producer	WISI	Triax	C-COR	WISI	Triax	C-COR

A). Reducing the level of modulating signal P_{in} (respectively of output optical power P_o) for one (any/unspecified) channel.

Expressions for determination of complex distortions are:

$$CSO_{new}\,[dB] = CSO + \Delta CSO, \quad (3)$$

$$CTB_{new}\,[dB] = CTB + \Delta CTB, \quad (4)$$

$$CXM_{new}\,[dB] = CXM + \Delta CXM, \text{ where} \quad (5)$$

$$\Delta CSO\,[dB] = -\Delta Po, \quad (6)$$

$$\Delta CTB\,[dB] = -2.\Delta Po, \quad (7)$$

$$\Delta CXM\,[dB] = -2.\Delta Po, \text{ a} \quad (8)$$

$$\Delta P_o\,[dB] = (P_o - P_{o,nom}), \text{ for a channel.} \quad (9)$$

***B). Change of optical modulation index* (OMI, *m*).**

$$m = \Delta P_o\,[mW] / P_o\,[mW] \text{ или} \quad (10a)$$

$$m = 10^{\frac{\Delta P_o\,[dBm] - P_o\,[dBm]}{10}} \quad (10b)$$

In logarithmic units

$$m\,[dB] = \Delta P_o\,[dBm] - P_o\,[dBm] = 10\lg m. \quad (10c)$$

Change of optical modulation index in dB is

$$\Delta m\,[dB] = 20lg(m_1 / m_2), \quad (11)$$

m_1 and m_2 in practice is difficult to be measured that is why according to [9]:

$$\Delta m\,[dB] = \Delta P_o. \quad \text{Then} \quad (12)$$

$$m_{new}\,[dB] = m + \Delta m. \quad (13)$$

Influence of m on CSO, CTB, CXM and CNR is shown on Fig.6.

***C*). Reduction of the level of output optical power P_o** of the transmitter depending on number of transfer channels N.

$$\Delta P_{in}\ [dB] = 10\lg N, \tag{14}$$

$$P_{in,new}\ [dBm] = P_{in} - \Delta P_{in}, \tag{15}$$

$$P_{o,new}\ [dBm] = G_p + P_{in,new}, \tag{16}$$

where G_p is gain of power amplification.

D*). *Cascade connection of optical systems

Total complex distortions in conformity with these of n-th system and Table 2 are:

$$CSO_{\Sigma}\ [dB] = CSO_n + \Delta^{'}CSO, \tag{17}$$

$$CTB_{\Sigma}\ [dB] = CTB_n + \Delta^{'}CTB, \tag{18}$$

$$CXM_{\Sigma}\ [dB] = CXM_n + \Delta^{'}CXM, \tag{19}$$

TABLE 2

Δ' , dB	Reduction, dB		
	Δ'CSO	Δ'CTB	Δ'CXM
0	3,61	4,52	6,0
1	3,14	4,03	5,53
2	2,71	3,59	5,08
3	2,33	3,19	4,65
4	1,99	2,82	4,25
5	1,69	2,48	3,88
6	1,43	2,18	3,53
7	1,21	1,91	3,21
8	1,02	1,67	2,91
9	0,85	1,46	2,64
10	0,71	1,27	2,39
11	0,60	1,10	2,16
12	0,50	0,96	1,95
13	0,41	0,83	1,75
14	0,34	0,72	1,58
15	0,29	0,62	1,42
16	0,24	0,54	1,28
17	0,20	0,46	1,15
18	0,16	0,40	1,03
19	0,13	0,34	0,92
20	0,11	0,30	0,83

where $\Delta^{'}\ [dB] = Cxx_{n-1} - Cxx_n$, and *xx* takes the symbol: *SO*, *TB* or *XM*.

IV. CONCLUSION

When the parameters of optical devices in both topologies are equal, the optical power could be determined in respective HUB and could be made the following conclusions:

- in star topology it is possible to connect at last five times more HUB than Bus topology;
- in star topology when the number of HUB is increased, for example twice (from 16 to 32), the optical power in the last HUB is twice less ($P_{32} \leq P_{16}/2$);
- in Bus topology the twice increase of HUB leads to fivefold decrease of optical power in the last HUB ($P_{32} \leq P_{16}/5$).

REFERENCES

[1] C. Cox III, “*Analog optical links theory and practice*,” Cambridge University press, 2004.

[2] K. Angelov, K. Koitchev, S. Sadinov. “An investigation of noise influences in optical transmitters and receivers in cable TV networks”, ICEST, Proc. of Papers, Sofia, pp. 102-105, 29 June – 01 July 2006.

[3] R. Howald. “HFC-Reloaded: The service capabilities being unleashed by hybrid fiber coax make a further examination mandatory”, Comm. systems design, pp. 7-10, June 2003.

[4] S. Bette, V. Moeyaert, M. Lhoir and etc. “Temporal Binary Error Distribution of QAM Transmission Impaired by Clipping-Induced Noise in CATV Lightwave Subcarrier Multiplex Systems”, Proc. Symposium IEEE/LEOS Benelux, pp.167-170, 2004.

[5] O.B. Panagiev, “Some Capabilities of the Optical Technologies in the Cable Television Systems”, IX NSASC "Electronics'2000, Sozopol 20-22 sept. 2000, pp. 163-170.

[6] S. Patela. “CATV and other fiber-optic networks”, 2001.

[7] Triax: Main Catalogue 2009.

[8] http://www.wisi.de/

[9] Hirshmann. Vortrag Optische AM-CATV-Ubertragung. 1996.