CATV Systems – Parameter's Optimization

Oleg Borisov Panagiev[1]

Abstract – **This paper aims to provide an exact expressions for the BER performance of the HFC (Hybrid Fiber Coaxial)/CATV (CAble TeleVision) systems in the presence of an additive mixture of infrequent clipping impulse and Gaussian background noise. The clipping noise model employed here is presented as Weibull distributions.**

Keywords – *CATV* (**cable television), optimization, HFC networks, BER.**

I. Introduction

CATV systems are traditionally one-way and broadcasting infrastructure for residential area TV distribution. Whit the population of Internet services, cable services providers are interested in providing these Internet services. Such a good solution is a hybrid transmission on analogue and digital signals by means optical fibers and coaxial cables. In fact, the hybrid transmission of existing AM/VSB and new digital signals is essential for developing future expandable and cost-effective CATV systems. The HFC topology is considered as a bi-directional broadband communication infrastructure. A group of 500 to 2000 subscribers are served by a fiber that comes from the HEADEND to a fiber node (FN), as shown in Fig.1. Moreover, signals are transmitted electrically from FN to home by coaxial cable through some amplifiers and splitters. Stations attached to the cable transmit and receive signals over different frequencies, named as upstream and downstream channels.

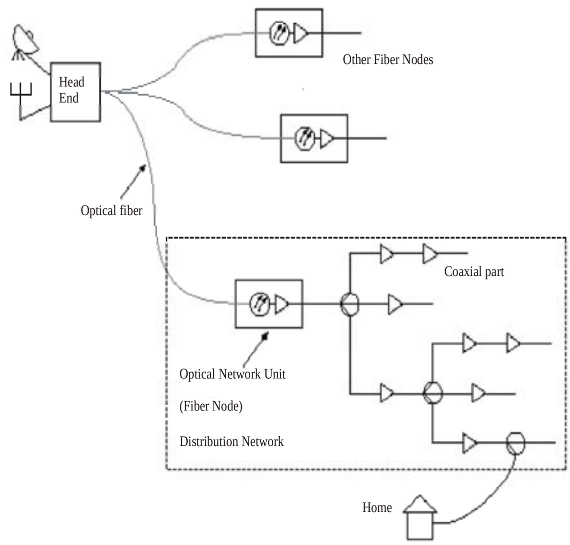

Fig.1. HFC/CATV system

[1]O. B. Panagiev is a system engineer at the Technical University of Sofia, e-mail: olcomol@yahoo.com

HFC/CATV systems are ones of the attractive systems, since M-QAM is expected to be able to offer both high spectral efficiency and robustness to noise and non-linearity. But, the clipping noise generated by the laser diode (DFB – distributed feedback) threshold results in a severe BER (Bit Error Rate) performance degradation in the transmission of digital signals because of its impulsive nature, although the impact on the analogue video transmission is much more tolerable.

II. HFC systems – features, advantages and parameters

The topology of HFC/CATV system (Fig.1) presents some inherent problems and limitations. For instance, a large number of broadband amplifiers are required to operate in cascade. Each amplifier adds noise and intermodulation distortions to the signal, the number of cascaded trunk amplifiers in the primary lines is thus limited to 40 to 45, in order to ensure a good reliability of the network and a good quality of the signal delivered to the subscribers. In order to provide other services such as digital television, it is necessary to increase the capacity of existing networks.

Large bandwidth, low losses and lightweight make optical fibre a unique candidate for designing CATV systems. One constraint, which has to be taken into account, is the considerable investment, which has been needed to build the existing coaxial CATV networks. It thus seems obvious that one has to search for ways to apply the fibre technology to an hybrid optical fiber-coaxial cable system which makes use of the existing plant structures, at the same time, uses the optical fibre advantages for suppressing the most serious weaknesses of current networks.

Features and advantages

- Remote location light-source for easy maintenance.
- Heat – free light: cold light emission points, Infrared spectrum are not transmitted.
- Color control/change: certain light sources use color or dimming programs with local or remote control lines.
- Focusable light: directional lighting / high contrast ratio: control of beam size by selection of suitable end-fittings for high object contrast ratio.
- Dimmable light.
- Moving and colored light.
- Conservation lighting: UV-filtered light.
- Intrinsic safety: Electricity- free lighting: no electric or electromagnetic interference.
- Low maintenance.
- Low running costs.
- Ecologically desirable.

- Providing designers with great flexibility and versatility in meeting the growing challenges.

B. Fiber optic link: transmissions-system parameters

- Direct laser modulation
- OMI - optical modulation index
- RIN - relative intensity noise
- Optical signal parameters
- Signal quality
- Carrier to noise ratio (CNR)
- Signal to noise ratio (SNR)
- Bit error rate (BER)
- CSO (Composite Second Order)
- CTB (Composite Triple Beat)
- Interference of audio-video channels
- Average transmitter life-time
- External modulation

III. Parameter's Optimization

A. General principles

In this part we described four cases for optimizations on parameters HFC network. These parameters define her reliability and quality transmitting signals – analog (AM/VSB) and digital (M-QAM).

The nonlinear distortions, as with thermal noise, are inevitable impairments in CATV systems; therefore, it is necessary to specify levels of distortions that can guarantee desirable picture quality for in-service programs. Many efforts to clarify the impact of these distortions on the AM/VSB signal have been made, and the required distortion levels for the AM signal have been established. Furthermore, composite distortions are ones of the most important narrow-band interferences when considering the digital channel quality of CATV systems. Accordingly, should be taking into account to it in order to specify not only system performance but also the requirements for system components, such as optical transmitters/receivers, trunk amplifiers, brides and etc.

B. Essences and algorithms

The averaged BER of the digital channel (M-QAM signal) must be specified to guarantee the picture quality of digital channels when discussing composite distortion levels. The PDF (probability density function) of the distortions is necessary in evaluating the BER of the M – QAM signal; accordingly, the required composite distortion levels in the digital channel can be determined by using a BER analysis method that takes into account this PDF.

The Weibull distribution has been used in [5,6] in order to examine the composite distortions' statistical features, where PDF [6] is

$$P_e = \frac{1}{2} K_1^M \cdot \exp[-\frac{3}{2}\cdot\frac{CNR}{M-1} + \gamma] \quad (1)$$

The BER of M - ary QAM is evaluated in terms of optical modulation indexes of M - QAM and AM/VSB signals which in turn specify CNR, impulsive index γ (clipping index) of the clipping noise, and power ratio of the Gaussian noise to the clipping noise.

K_1^M is a ratio depending on the M-ary quadrature amplitude modulation and the Gray's code:

$$K_1^M = (2/\log_2 M)\cdot(1-1/\sqrt{M}) \quad (2)$$

$$\gamma = \lambda/B \quad (3)$$

$$\lambda = \sqrt{\frac{f_H^2 + f_H.f_K + f_K^2}{3}} . \exp\left[-\frac{1}{N.m_{AM}^2}\right] \quad (4)$$

We should be optimizing CATV system by following primary data:

$f_H = 47$ MHz; $f_K = 470$ MHz; F = 0,69mA;

RIN = -150dB/Hz; $i_n = 24.10^{-12}$ A/$\sqrt{Hz}$.

1. **First case P_e = func (CNR, M):**

$$P_e = 1{,}002.((1-1/\sqrt[5]{M}).\exp(-1{,}5.10^{0{,}1CNR}/(M-1)) /\log_2 M)) \quad (5)$$

where B = 10 MHz is channel bandwidth;
N = 42 - number of channels (AM/VSB);
m_{AM} = 5% is modulation index of AM/VSB signals;
M = 16 to 256;
CNR = 30 to 50 dB.

In fig.2 is given a graphic of the dependence $P_e = func(CNR, M)$ in the three-dimensional space.

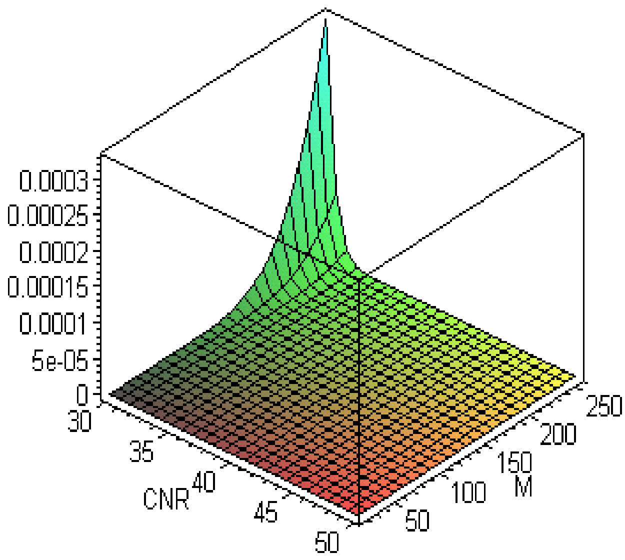

Fig.2. P_e = func (CNR, M)

2. Second case P_e = func (CNR, N):

$$P_e = 0,1875.\exp(-0,1.10^{0,1CNR}).\exp(28,6.\exp(-400/N)) \quad (6)$$

In fig.3 is given a graphic of the dependence $P_e = func(CNR, N)$ in the three-dimensional space for the following values of:

B =10 MHz; m_{AM} = 5%; M = 16; N = 1 to 50;
CNR = 21 to 30 dB.

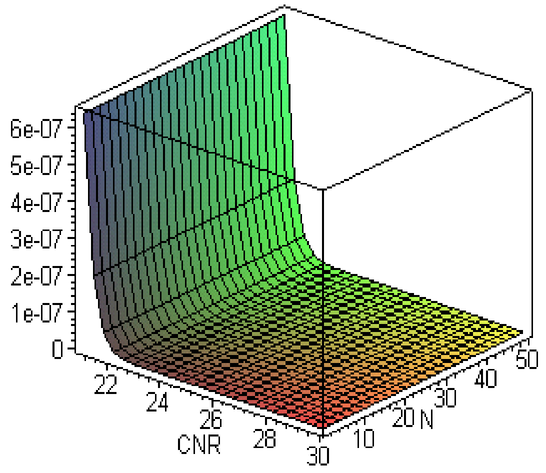

Fig.3. P_e = func (CNR, N)

3. Third case P_e = func (CNR, m_{AM}):

$$P_e = 0,1875.\exp(-0,1.10^{0,1CNR} + 28,6.\exp(-0,0238/m_{AM}^2)) \quad (7)$$

In fig.4 is given a graphic of the dependence $P_e = func(CNR, m_{AM})$ in the three-dimensional space for the following values of:

B =10 MHz; M = 16; N = 42; CNR = 21 to 30 dB; m_{AM} = 1 to 10%.

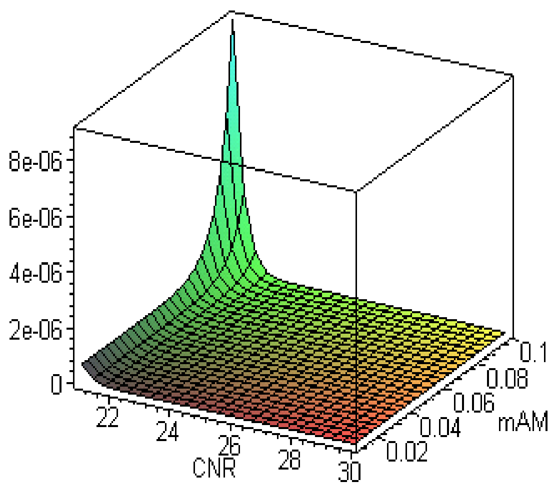

Fig.4. P_e = func (CNR, m_{AM})

4. Fourth case P_e = func (CNR, B):

$$P_e = 0,1875.\exp(-0,1.10^{0,1CNR}).\exp(20903,938/B) \quad (8)$$

In fig.5 is given a graphic of the dependence $P_e = func(CNR, B)$ in the three-dimensional space for the following values of:

M = 16; N = 42; m_{AM} = 5%; CNR = 21 to 30 dB; B = 5 to 12 MHz.

The calculation of P_e and the drawing of the graphics is done by the program product MAPLE.

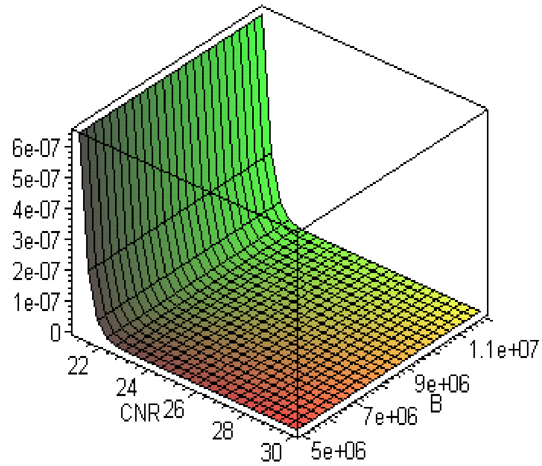

Fig.5. P_e = func (CNR, B)

IV. Conclusion

We have presented results of investigation of M-ary QAM (BER) performances in a HFC/CATV system. The results show that the BER performance of the M-QAM signals in such environments can be significantly degraded in the presence of the clipping noise distortion generated by occasional laser clipping of the AM signals. By modeling the clipping noise as a Weibull distributions, we have obtained the asymptotic distribution of the clipping noise plus the additive Gaussian noise and evaluated the BER`s of the M - QAM signals, under various clipping conditions (CNR, m_{AM}) and the parameters B, N and M. The results show a significant increase in BER by lower value on CNR and higher values on m_{AM} and M. The results also show, that BER independed from B and N for high values on CNR.

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