About a Possible Way of Optimizing the Number of Amplifiers in CATVs

Stanimir Sadinov[1], Kiril Koitchev[2]

Abstract - **One of the essential stages in CATV network design or that of larger networks for corporate reception is the proper calculation of voltage level within distribution nets, which must provide good quality of TV signal in the subscriber unit. A major quality factor is the relationship signal/noise as well as signal/required level of retaining of retaining of combination frequencies of the third order in the TV channel at the output of the subscriber's contact (CTB). Level increase at the input (i.e. the first active element) and output of the amplifier will cause a corresponding increase in the signal/noise (S/N) relationship. Voltage level rise at the output will increase the impact of combination frequencies.**

All calculations contribute to the proper determination of input and permissible output levels of voltage in broad band amplifiers so that the required relation-ship signal/noise (S/N) could be ensured along with the influence of combination frequencies (CTB) of the third order in CATV.

By way of programming it is possible to optimise either the number of amplifiers, i.e. the required coefficient of amplification k_{nom}, or the cost of the individual amplifier. Within this procedure the largest possible number of steps is calculated N_{max} by means of comparing noise levels with non-linear deviations (CTB), i.e. the minimum and maximum output level.

Keywords - **CATV network design, signal/noise (S/N), combination frequencies (CTB), non-linear deviations, coefficient of amplification k_{nom}.**

I. INTRODUCTION

Non-linear distortions in the network normally depend on the features of amplifiers which are connected in series in the preliminary tract, the level of their input signals and the number of TV and radio channels which are transmitted along the network. These distortions result in products with new frequencies. The input signal in CATV can be rendered by the following simplified expression:

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$$U_{in} = \sum_{i=1}^{M} U_i \cos\left(\omega_i t + \varphi_i\right) \qquad (1)$$

where M is the number of all bearing oscillations by means of which all TV and radio channels are transferred.

Assume that AF characterization of a particular cable amplifier is approximated by power polynomial of the kind:

$$U_{out} = f\left(U_{in}\right) = \sum_{i=0}^{m} k_i U_{in}^{i} \qquad (2)$$

In such cases heterodyne frequencies are formed at the output which are of the kind $b_1\omega_1 + b_2\omega_2 + ... + b_n\omega_n$, where coefficients $b_1 \ldots b_n$ are positive integers. The levels of nonlinear components obtained at the amplifier output should be low enough to prevent deterioration of picture and sound quality at subscriber's end. The permissible level of each component is determined in relation to the bearing oscillations of desired signals and is defined as a minimum distance whose value, expressed in – 60 dB, is recorded in standard specifications.

Thermal noise is of basic importance to CATV and is defined by means of Niquist's formula:

$$U_{Noise} = \sqrt{4kTR\Delta f}$$

where: k– is Boltzmann constant; T– is absolute thermodynamic temperature, K; R– input amplifier resistance, Ω; Δf– is the frequency band, Hz.

This noise has a uniform frequency range and is referred to as white noise.

Major guiding criterion in building CATVs is reducing of non-linear distortions and the level of noise as well.

These are the conclusions that can be drawn when designing and constructing CATV [1]:

1. Increasing (decreasing) the level of output signal by 1dB will improve (deteriorate) the signal/noise (S/N) ratio by 1dB ; increasing(decreasing) of intermodulation products of the second order (IMD2, CSO) by 1dB and those of third order (IMD3, CTB) by 2 dB.
2. Cumulation of intermodulation products of second order(CSO) along the highway is implemented according to the law of power one(analogous to noise power) whereas the the products of third order (CTB) follow the squared law. Physically this means that when two identical amplifiers are cascade connected and have equal individual values for S/N , CSO , and CTB then there will be lower values of S/N and CSO by 3dB and CTB will be lower by 6dB.

3. In terms of economy the coefficient of amplification will depend on the length of highway. Greater length of trunkline should correspond to a smaller coefficient of amplification. For traditional type of trunklines amplifiers of class not lower than B are to be used (this in accordancewith EN 50083) with amplification coefficient 28÷38dB. For main trunklines or longer ones it is recommendable to use amplifiers of class A with amplification coefficient 20÷27dB. When dimensionong a CATV system it is expedient to leave a margin of 2÷3dB according to the coefficient of amplification

These conclusions can be observed by virtual analysis by means of program application which is the objective of this paper.

II. Development and Implementation of Cable TV Designer Program

Individual Windows application of Delphi has been developed This program is designed to calculate all basic parameters of CATV.

Fig 1. Presents the graphic interface of the related program application

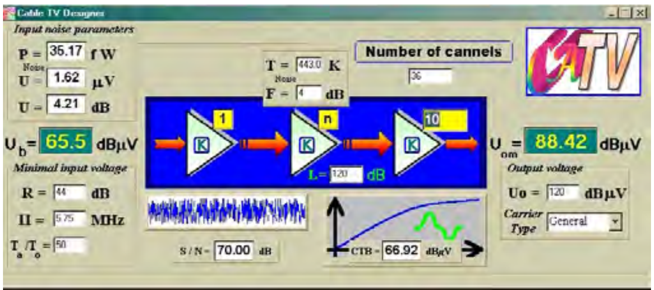


Fig 1. Graphic interface of the Cable TV Designer

Here follows the methodology which underlies Cable TV designer that facilitates computer aided design of cable TV.

It is a well known fact that the relationship between voltages can be expressed in dB by the following:

$$U_{12} = 20.\lg \frac{U_1}{U_2}, \quad dB \tag{4}$$

Engineering practice has adopted measurements of voltages and power of signals to be in dB. Obviously that is possible if a fixed datum for U_2. Is defined. When designing cable networks it is assumed that U_2=1µV i.e. the levels of signals are measured by the unit dBµV. This is the record used in the standard specifications and the service forms and records of communications technology for cable TV

Correlation with the measuring units of SI is expressed by (2):

$$U\,[dB\mu V] = 20.\lg U\,[\mu V] \tag{5}$$

All relationships of two similar values can be expressed in dB unambiguously For example, the signal /noise relationship:

$$S/N = 20.\lg U_S/U_N, \tag{6}$$

where the levels of signal U_S and noise U_N are recorded in random equal units of voltage(normally µV)

A. *Input Parameters:*

F – noise coefficient of individual amplifier, dB

T_{Noise} – noise temperature, K;

R = 44 dBµV – standard protection ratio S/N;

Π – effective noise frequency band of TV channel, MHz;

SECAM --> Π = 5,75 MHz; PAL --> Π = 4,75 MHz

Ta/To <= 50 – relative noise temperature of TV antenna;

M – number of active channels;

N – number of amplifier steps connected in series;

L – losses along the line, dBµV;

U_O – Rated voltage of amplifier with guaranteed CTB ≤ 60 dB (set by the manufacturer), dBµV;

B. *Output Parameters:*

U_b – minimum level of input voltage, dBµV;

U_{Om} - maximum level of output voltage, dBµV;

S/N – signal /noise relationship at the output, dB;

CTB – non-linear distortions (Composite Triple Beat), dBµV;

U_{Noise} – noise voltage at the input, dB;

K_{opt}–optimum coefficient of amplification of particular amplifier, dB.

C. *Methods of Estimation:*

Estimation of input noise parameters

$$T_{Noise} = T_0(F - 1) \tag{7}$$

$$P_{Noise} = k\Pi T_{Noise} \tag{8}$$

$$U_{Noise} = \sqrt{k\Pi T_0 R_0 (F-1)}, \quad \mu V \tag{9}$$

$$U_{Noise[dB]} = 20\lg U_{Noise}, \ dB\mu V \quad , \tag{10}$$

where:

$k = 1{,}38 \times 10^{-23}$ J/K – Boltsmann constant;

T_0 = 293 K – normal noise temperature;

R_0 = 75 Ω – input resistance.

Calculation of input level

$$U_b = R + N_r + 10\lg[(N + 2)10^{0.1F} + T_a/T_0] \tag{11}$$

where:

$N_r = 10lg(kT_0\Pi/P_0) = 2.4$ dBμV–thermal noise of TV channel;

$P_0 = 1/75$ pW, power over 75 Ω, with voltage of 1 μV;

Calculation of non-linear distortions

$$CTB = 31,13 + 23lgM \quad (12)$$

Calculation of output level

$$U_{Om} = U_0 - \Delta U_M - \Delta U_N - (CTB - 60)/2 , \quad (13)$$

where:

$\Delta U_M = x.lg(M - 1)$

x = 10 / synchronous carriers /;

x = 5 / asynchronous carriers /;

x = 7.5 most frequently used value.

$\Delta U_N = y.lgN$

y = 17 /N < 24/;

y = 20 /N ≥ 24/.

Adjustment according to CTB should be applied only for N≥18.

Calculation of signal/noise relationship at line output

$$S/N = U_{Om} - K_{nom} - F - N_r \quad (14)$$

After optimizing the number of used amplification steps the program calculates the required optimum coefficient of transmission.:

$$K_{opt} = L / N \quad (15)$$

This program allows for the optimisation of the number of amplifiers. i.e. the required coefficient of amplification or the cost of individual amplifier. Maximum permissible steps o are calculated N max meanwhile comparing the levels of noise (S/N) and non-linear distortions (CTB) that is, the maximum and minimum output level (see fig 2)

Fig 2 presents signal /noise relationship dependence as well as the dependence of non-linear distortions on the number amplification steps Consequently the optimum number of amplifiers is automatically determined according to a preliminary assigned permissible value of signal/noise relationship. Amplification coefficient of individual amplifier is then optimised by using (15). Also accessible are the dependences of signal/noise relationships and the non-linear distortions on the number channels which are transmitted in the network (see Fig 3) Signal output level is explored as a function of S/N and CTB (see Fig 4). Fig 5 presents the algorithm which is executed by the presented program application.

This program features totally interactive performance and suggests contextual back up information on all input data and estimated parameters of CATV. Application is error protected by continuous control over the values entered by the user. This program application was developed largely with the help of Delphi [3].. Graphic data could be recorded in vector format or raster(bitmap)

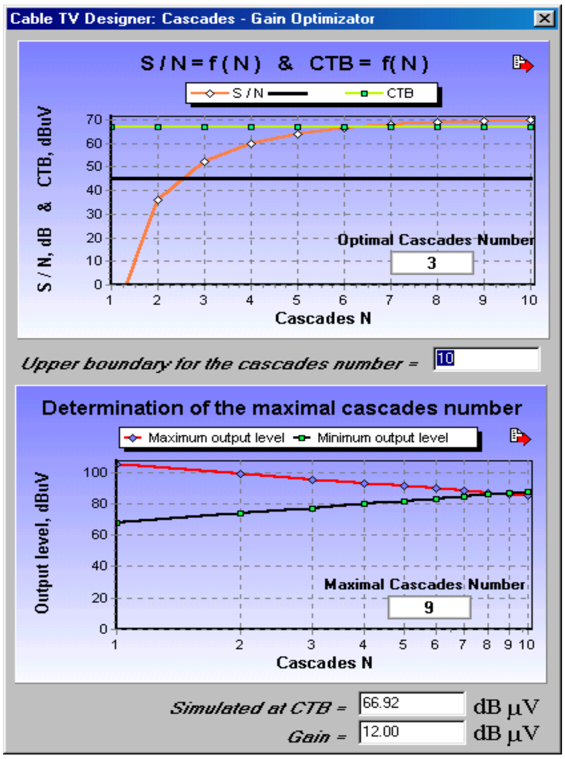
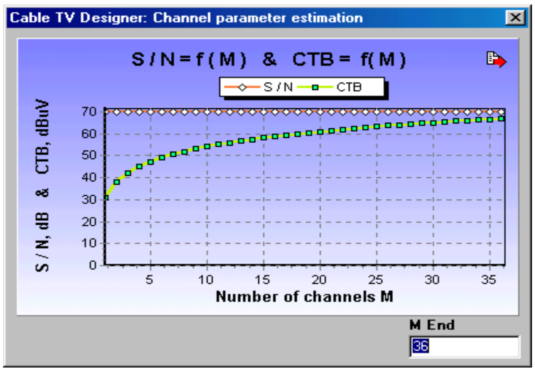


Fig 2 Window of the optimizer for the number of used amplifiers



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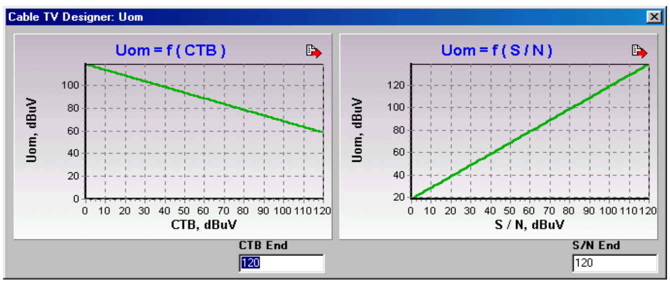

Fig4. Study of the output level dependence on the non-linear distortions and signal/noise relationship

III. CONCLUSIONS

- A special purpose program application has been designed called “Cable TV Designer” which is employed in estimating basic parameters determined by standards, specially applicable in engineering designs of CATV. This program enables computer aided methods of design. [1,2];

- Impact of model parameters has been studied with reference to:

- the impact of the number of employed amplifiers(N) (fig.2)
  - Non-linear distortions remain constant : they are determined solely by the non-regularity of AF characterization (set by the standard as manufacturer’s parameter of amplifiers) and the number of transmitted channels(carriers)
  - Concerning the impact on the signal level as compared to that of noise S/N it should be given a comprehensive regard Optimisation is effected by selecting a pattern with minimum amplification coefficient when output signal is at its peak level[2].
- Concerning the impact of the number of channels(M) (fig 3):
  - The noise level does not change Thermal noise retains the same level throughout the whole frequency range
  - Non-linear distortions grow in number along with the increase in the number of transmitted carriers due to their interaction
- Output level dependence on the S/N relationship and CTB(fig 4)
  - Increase of the non-linear distortions level entails adjustment of output level(decrease) so that the 60dB standard level could be reached.
  - As already noted, the increased output level ensures performance with high signal/noise relationship

The large number of model parameters necessitates the development of computer aided engineering design of CATVs. This program, along with the relevant current standards and manufacturers’ manuals, contributes to a large extent to the solution of such engineering tasks.

REFERENCES

1. Койчев К., С. Садинов. Проектиране на кабелни телевизионни мрежи. “АЛМА МАТЕР Интернационал”, Габрово 2001. ISBN 954 9577 81 3

2. Кабельное ТЕЛЕВИДЕНИЕ справочник. 1999 ÷ 2000

3. Marco Cantu. Mastering™ Delphi™ 5. Vol. I & II“SoftPress”, S. 2000. ISBN 954-685-082-9

4. Koitchev K., S. Nemtsov, S. Sadinov. Studies on The Reliability of Two-way Cable TV Network. 6th International Conference on Telecommunications in Modern Satellite, Cable and Broadcasting Services - TELSIKS 2003

5. Koitchev K., Sadinov St. Maximum Value Determination of Non-linear Products in Cable Television Networks. IEEE Transactions on Broadcasting, March 2003

6. Koitchev K., S. Sadinov, S. Nemtsov, “Suggested Method for Composite Frequencies Allocation”, 5th International Conference on Telecommunications in Modern Satellite, Cable and Broadcasting Services TELSIKS 2001, Proceedings of Papers, volume 2, pp. 541-543.