Software for CATV Design and Frequency Plan Optimization

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Abstract. *The paper deals with the structure of a software medium used for design and sub-optimization of frequency plan in CATV networks, their description and design method. The software performance is described and a simple design example of energy balance of a simplified CATV network is given. The software was created in programming environment called Delphi and local optimization was made in Matlab.*

Keywords

CATV, CSO, CTB, software, optimization, ACO, Cable Television, Net, styles.

1. Introduction

CATV networks support the distribution of television, radio, data, etc. signals from a service provider to a great number of subscribers. The main requirement for CATV networks is the attainment of high-quality television picture and soundtrack for receivers of end-user subscribers. Problems related to the broadcast of these signals are resolved by network design. This network includes passive and active elements.

The characteristic feature of analog television signal is its relatively broad frequency band and significant signal sensitivity to most of distortion and the disturbance in real transmission channel (linear and nonlinear distortion, amplitude and phase distortion, reflection in impedance mismatching points, interference signals, noise etc.). These facts make great demands on technical parameters of CATV, especially for synchronous transmission of a great number of television and radio signals.

The technical requirements or parameter file and measurement methods for CATV networks are defined for example by European Standard EN 500 83 Cable Distribution Systems for Television and Sound Signals. The compliance of these parameters warrants the quality of output television signal and corresponding picture "level 4" (noticeable but noise free) by end-user subscribers.

The created software makes it possible to design a desired structure of CATV networks with regard to a compliance of television signal parameters values, which are standardized. Especially these parameters comprise (represent) signal to noise ratio (C/N), signal to nonlinear distortion ratio (CSO and CTB) and dynamic range in particular. Subsequently the software makes it possible to sub-optimize CATV network for a known structure and specific components.

2. Software

The interactive software for energy balance and design of broadband cable transmission networks with specific structure and with the possibility of sub-optimization makes it possible to find an appropriate technical solution of CATV network for a specific structure and parameters of required network components. It is possible to re-count, optimize or find a preferable option for by other forms designed projects. The software was created in programming environment DELPHI 7 and it was created on the basis of a fact that some software media for design CATV networks are existing, but they are focused on a special network structure and especially this software medium comprises strictly of confidential know-how of some companies.

The main advantages of the designed software are:

- simplified data entry of CATV network topology,
- database of network structure elements usage and possibilities of database upgrade,
- makes it possible to calculate signal level in all downstream and upstream points of CATV network,
- values of system parameters calculation – values of signal to noise ratio and values of nonlinear distortion CSO and CTB, a comparison of calculated values with standard values makes it possible to propose better solution,
- network optimization for specific structure and specific components with the orientation on minimum distortion and degradation of transmission signal,
- optimization of TV channel distribution in an assigned frequency range,
- display of design results in an output technical report form, display of network topology in a technical

drawing form with all signal level values and system parameters values.

The software flowchart is displayed in Fig. 1.

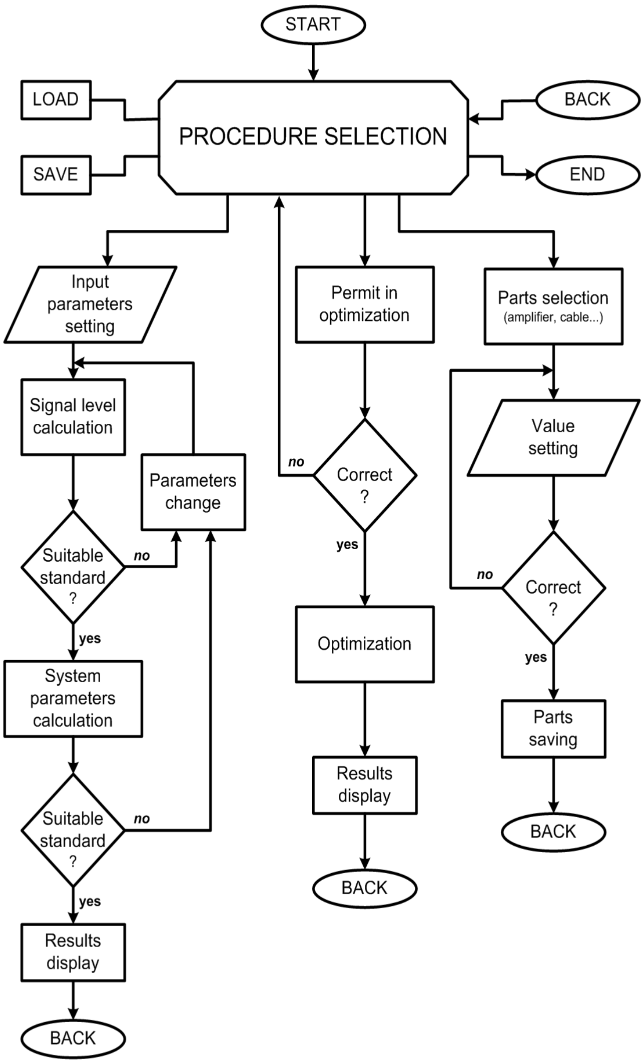

Fig. 1. The software flowchart for design and optimization of CATV.

2.1 Input Parameters for the Computing Design

The following input parameters were selected for CATV design:

- input signal levels (3 frequencies for downstream: 75 MHz, 606 MHz and 862 MHz and upstream frequencies 5 MHz and 55 MHz – the software allows CATV network design for TV frequency band up to 862 MHz),
- values of system parameters in an output master station and in a transfer point (house station): C/N, CTB and CSO,
- a structure of primary and secondary lines and detailed design of lines, represented by:
  - cable parameters: attenuation of the cable used, for length 1 m and for 5 frequencies (5 MHz, 55 MHz, 75 MHz, 606 MHz and 862 MHz) and in dependence on the type of the cable used,
  - active components parameters (broadband amplifiers): gain *G* [dB], noise number *F* [dB], maximal value of output signal level for the guarantee to demand signal to nonlinear distortion ratio 60 dB for CSO and CTB - L_{CSO} [dBμV] for CSO = 60 dB, L_{CTB} [dBμV] for CTB = 60 dB and operation level of amplifier L_o [dBμV] and eventually parameters of tilt elements,
  - passive components parameters: attenuation of used components for 5 frequencies (5 MHz, 55 MHz, 75 MHz, 606 MHz and 862 MHz) and the number of sockets,
- frequency plan (the number of transmission channels and position of channels in frequency band).

3. Optimization of Frequency Plan

A nonlinear distortion is caused by a nonlinear dependence of the output signal on the input signal of the active equipments (channel amplifiers, band amplifiers, modulators of the master station, broadband amplifiers) and increases with the input signal level. The amplitude of a nonlinear distortion depends on the lay-out of TV channels in transmission frequency band - the frequency plan.

The largest part of TV signal power is situated in the narrow frequency band of the picture carrier frequency. If more harmonic frequencies are transmitted into the broadband active equipment, a lot of intermodulation products arise as a result of nonlinear distortion. The parameter for representation of accumulation of intermodulation products effect was introduced as the ratio of the carrier frequency of the picture level to intermodulation products accumulation of the second order – C/CSO (CSO - *Composite Second Order*) and as the ratio of the carrier frequency of the picture level to intermodulation products accumulation of the third order – C/CTB (CTB - *Composite Triple Beat*) [1].

3.1 System Model

It is possible to assess the influence of nonlinear transmission characteristic for synchronous broadcasting of more TV signals by means of transmission of more harmonic signals, which correspond with carrier frequencies and active equipment with universal transmission characteristic. Then the output signal will have infinite number of members, which are created by a single harmonic signal or by interaction of more harmonic signals. The transmission characteristic of the system is given by [1]:

$$e_{out} = A \cdot e_{in} + B \cdot e_{in}^2 + C \cdot e_{in}^3 + \ldots, \quad (1)$$

$$e_{in} = \sum_{i=1}^{n} E_i \cdot \cos(2\pi \cdot f_i t) \quad (2)$$

where A, B, C, D… are the coefficients of the transmission function, f_i are the frequencies of individual harmonic signals (the carrier frequencies of pictures), $f_i < f_{i+1} < f_{i+n}$, and n is the number of input harmonic signals.

It is possible to simplify the formula for transmission characteristic of active equipment according to the formula

$$e_{out} = k_1 \cdot e_{in} + k_2 \cdot e_{in}^2 + k_3 \cdot e_{in}^3 \quad (3)$$

where k is a real positive or negative constant after simplification.

A multispectral component arises at the amplifier output with transmission characteristic according to equation (3) after substitution of equation (2) in equation (3) and mathematical modifications.

A model of broadband amplifier and its influence on transmission of more TV channels, clustering in one broadband direct channel, was made in Matlab. Saleh's model of amplifier [7] and a simplified transmission characteristic of active equipment were used for the broadband amplifier model in Matlab. The simplified transmission characteristic of active equipment is given by formulas (3) and (2).

3.2 ACO Optimization

To solve the optimization problem, ant colony algorithm (ACO) was used. In principle, discrete problem is concerned – location of optimal sequence of numbers. Then this sequence designates the lay-out of single TV channels in the whole transmission broadband spectrum of television signals.

The optimization can be compared with so-called commercial traveler problem, where the shortest track (way) between cities is picking out, so that all cities are visited. Then for the optimization of frequency plan, single television channels represent cities and the shortest track represents the lowest resulting nonlinear distortion CSO (CTB).

In the start-up phase of the algorithm, ants are located in different cities and initial values $\tau_{ij}(0)$ determine intensity of a trail. Every ant shifts from city i into city j with probability according to equation (4), [9]. $\tau_{ij}(t)$ determine information on number of ants, which pick out, in former times, the same trip (track) between cities i and j and visibility η_{ij} determines, that the closer is the city, the higher probability it has to be chosen.

$$p_{ij}^{k}(t) = \begin{cases} \dfrac{[\tau_{ij}(t)]^{\alpha} \cdot [\eta_{ij}]^{\beta}}{\sum\limits_{l \in allowed_k} [\tau_{il}(t)]^{\alpha} \cdot [\eta_{il}]^{\beta}} & if \quad j \in allowed_k \\ 0 & else \end{cases} \quad (4)$$

After n iterations, all ants finish trip. In this point, for every ant the value L_k (ant trip length k) is calculated and values $\Delta\tau^k_{ij}$ are updated according to equation (5), [9]. The shortest trip the ants find, is saved (min L_k, $k = 1, \ldots, m$). This procedure is repeated until the maximum number of cycles NC_{MAX} is reached.

$$\Delta\tau_{ij}^{k} = \begin{cases} \dfrac{Q}{L_k} & if \ k^{th} \ ant \ went \ from \ city \ i \ to \ j \ along \ the \ path \\ 0 & else \end{cases} \quad (5)$$

The flowchart of the described algorithm ACO is displayed in Fig. 2.

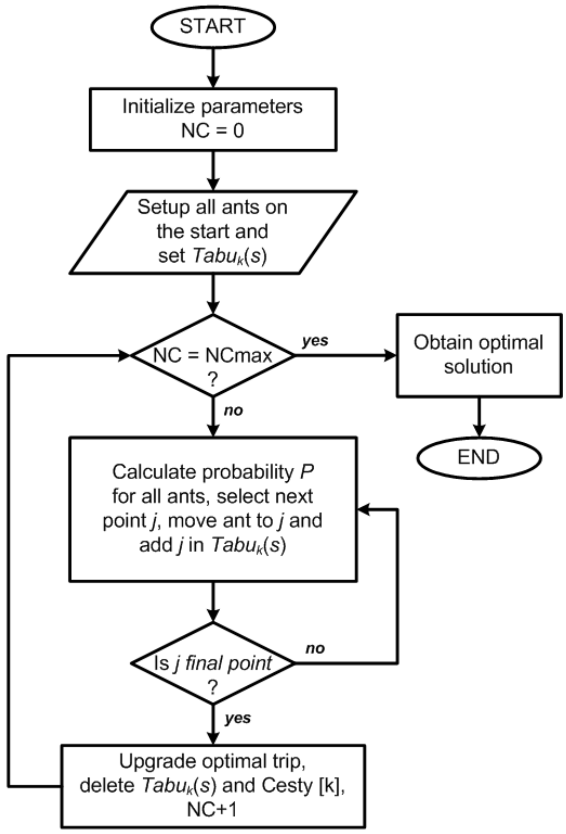

Fig. 2. The flowchart of the described algorithm ACO.

3.3 ACO Optimization Results

These input parameters were chosen for the frequency plan optimization:

- the level of input signal E_1 = 84 dBμV,
- the gain of amplifier G = 30 dB,
- 12 TV signals in frequency system CCIR B/G – system for cable television (band USB, OSB and part of frequency band ESB).

The optimization was implemented according to the flowchart in Fig. 2 and the number of cycles value was set to NCmax = 200. For a broadband amplifier model, the simplified transmission characteristic of active equipment was used, which is given by (3) and (2).

The run of the optimization procedure is displayed in Fig. 3. The resulting minimum value of the 3rd order intermodulation products accumulation is *CTB*min = 35,5 dB, compared to 39,7 dB without optimization. The improvement is thus 4,2 dB. The process of CTBmin value optimization is displayed in Fig. 4. The ratio of the carrier frequency of the picture level to intermodulation products accumulation of the third order is *C/CTB* = 72,5 dB with *CTB*min = 35,5 dB.

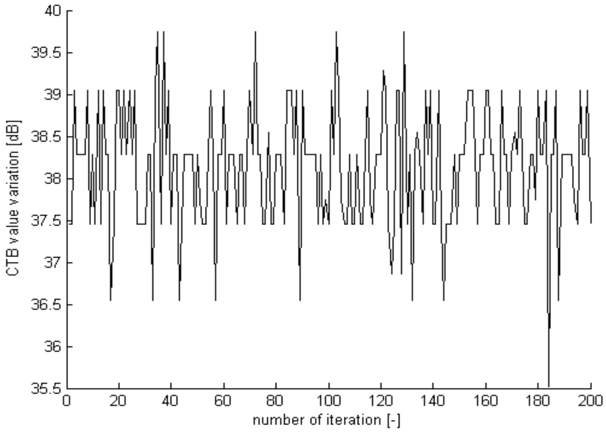

Fig. 3. CTB value variation.

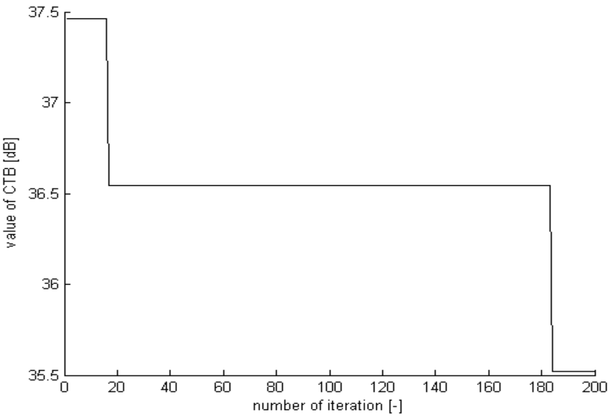

Fig. 4. ACO optimization.

The resulting values of frequency plan optimization are given in Tab. 1. The lay-out of transmission channels in frequency spectrum is displayed in Fig. 5.

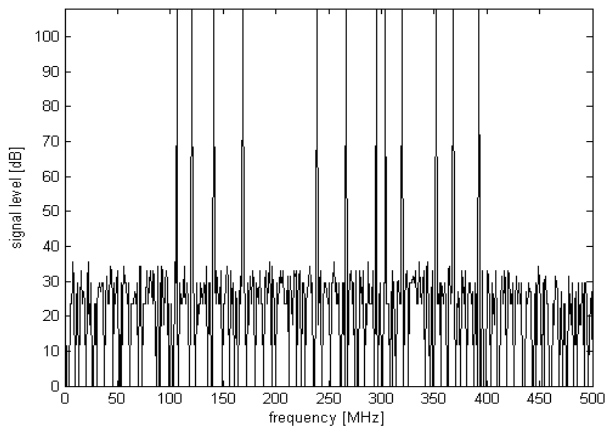

Fig. 5. Output signal of broadband amplifier.

f [MHz]					
105.25	119.25	140.25	168.25	238.25	266.25
294.25	303.25	319.25	351.25	367.25	391.25

Tab. 1. Optimized frequencies of TV channels.

4. Results of CATV Design Example

The design example of energy balance of a simplified CATV network was done with the software. This CATV network corresponds to the area with the length of approx. 500 m and considers the connection of 5 panel buildings. The CATV network parameters are given in Tab. 2.

Component	Parameters
Network topology	See Fig.5
Primary amplifier ARL 839PG	G = 39 dB, F = 7 dB, CSO = 60 dB - L_{CSO} = 109 dBμV, CTB = 60 dB - L_{CTB} = 110.5 dBμV
Secondary amplifier ARL 834PG	G = 34.5 dB, F = 7 dB, CSO = 60 dB - L_{CSO} = 109 dBμV, CTB = 60 dB - L_{CTB} = 110.5 dBμV
Tertiary amplifier AKL 832B5	G = 32 dB, F = 7 dB, CSO = 60 dB - L_{CSO} = 104 dBμV, CTB = 60 dB - L_{CTB} = 103.5 dBμV
Hubs SA03 and SE02	Attenuation [dB]
Cable C3, C6, C12, PRG7	Attenuation [dB]
Input signal level	105 dBμV
Input system parameters	C/N = 55 dB, CSO = 80 dB, CTB = 80 dB
Number of channels	42

Tab. 2. Input parameters of CATV network.

The example of network topology setting in the created software is displayed in Fig. 6. The resulting values of levels and the resulting network topology are displayed in Fig. 7 and the resulting values of system parameters are given in Tab. 3.

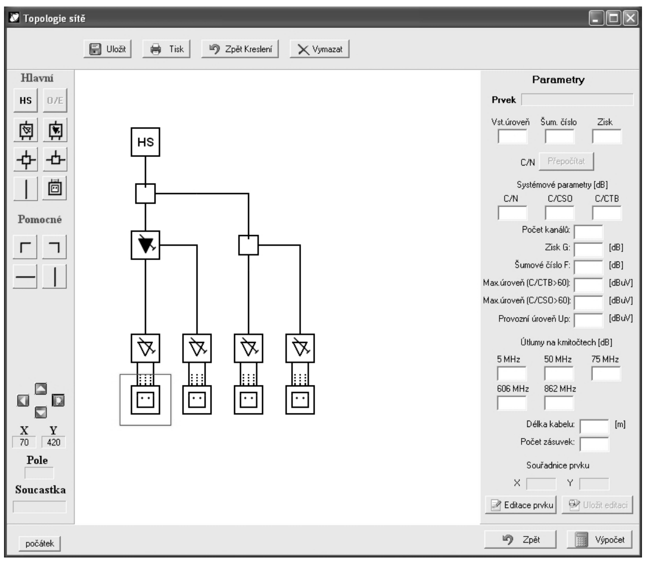

Fig. 6. Parameters CATV network entry.

When comparing the system parameters values in Tab. 3. with standard and maximal and minimal signal level values in Fig. 7, it is obvious the CATV network design is right for standard EN 500 83.

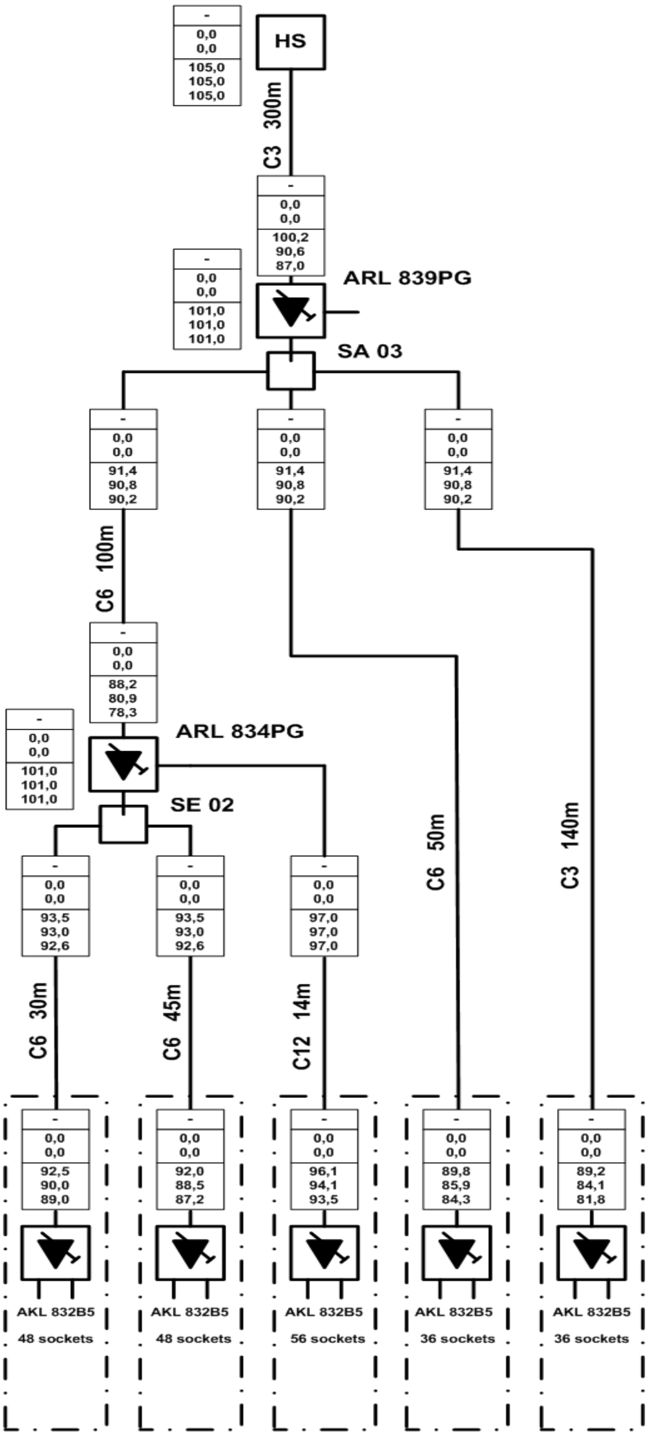

Fig. 7. The result of topology network design example.

Parameters	Calculated value [dB]	Value of EN 500 83 [dB]
C/N	50.1	45
CSO	58.8	57
CTB	57.4	57

Tab. 3. Calculated system parameters.

5. Conclusions

The interactive software for energy balance and design of broadband cable transmission networks with specific structure and with the possibility of sub-optimization was introduced. The software properties and software utilization possibilities were described and the software main input parameters were defined. Further the design example of energy balance of simplified CATV network was introduced. This CATV network corresponds to the area with the length of approx. 500 m and calculated with a connection of 5 panel buildings.

The optimization problem of nonlinear distortion and frequency plan in CATV networks was introduced and simulations of this optimization were shown. The optimization will be completed with other optimization possibilities and will be integrated into the software for energy balance and design of CATV networks.

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Ondřej HÁLA (*1981 Brno) received his M.Sc. degree from the Brno University of Technology, Czech Republic, in 2004. He is a Ph.D. student at the Dept. of Radio Electronics. His research activities include selected topics of Cable Television, CATV testing and optimization, Digital Video Broadcasting.