Investigation of the Impact of Disturbances in Transmitting Digital Data Along the Return Channel in CATVs

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Abstract: **In CATVs the range between 0-47 MHz is used to create interactive systems fir transmission of data and is revered to as reverse channel or return channel.**

Cable lines, which are used to transmit data along the return channel of CATVs, undergo a certain amount of disturbances, which causes the quality of transmitted data to deteriorate. The quality of transmitted digital signals is characterized by error coefficient within a certain section of cable track. This coefficient could be expressed as a ratio of the number of error characters received at the end of a certain cable section versus the total number of transmitted characters-BER.

Calculation of BER for most frequently used modulations M-PSK and M-QAM is performed either by estimating the probability for character error or by means of evaluating upper and lower limits of noise level. Precise analysis of BER system is often difficult to achieve and, usually, the results should be processed further.

This paper proves that the signal/noise ratio *R* is a function of probability *P* and is numerically equal to the error coefficient BER. In this way it is possible to calculate the required ratio signal/noise *R* by analytical estimation, which used a preset error coefficient BER.

Further it is proved that heat noises appear to be a key factor that limits the length between two cable amplifiers. The paper also contains deduced relationships, which allow to determine the permissible length between two highway amplifiers *l* depending on the noise arising in the line. Graphic presentations show relationships between the length of individual cable sections and the rate of transmission of digital signals along different types of coaxial cable lines; the permissible error coefficient for particular section being 10^{-9} and kilometer attenuation in coaxial lines for frequency of 1 MHz.

Keywords **- CATV network design, return channel; M-PSK and M-QAM), BER coefficient**

I. Introduction

CATV networks allow for two-way transmission of signals; from the main station to a large number of subscribers and , conversely, from subscribers to the main station via a narrower channel. Frequency range from 80 to 862 MHz is used for the straight channel whereas the reverse channel will use from 5 to 47 MHz. Cable lines which are used to transfer digital information along the reverse channel are impacted by disturbances which lower the quality of transferred data.

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Transferred digital signals' quality is characterized by error coefficient at a certain section of the cable track. This coefficient could be expressed as a ratio between the number of erroneously received characters at a certain section of the cable track and the total number of transferred symbols – BER

Calculation of BER for most frequently used modulations M-PSK and M-QAM is performed either by estimating the probability for character error or by means of evaluating upper and lower limits of noise level. The precise analysis of BER for any particular system is often difficult to achieve which usually entails further processing of results[4, 5, 6].

The reason for errors in digital signals is found in noise and disturbances whose instantaneous voltages exceed permissible limits thus causing the occurrence of redundant pulses or disappearance of pulses. To avoid errors it is necessary to keep a correct signal/noise ratio at the amplifier input which is hooked up to the CATV reverse channel [1].

Permissible values of noise voltage are determined by the magnitude of the "lowest possible eye-opening of the diagram" B_0 and should not exceed the value $0{,}5B_0$ [2]. Error coefficients of individual amplifiers are determined by the probability of exceeding that value.

II. Exposition

Noises which occur in the communication channel, as well as the heat and those which are caused by mutual impact, have normal (Gauss) distribution. Therefore, the probability of exceeding the permissible noise voltage value will be determined by the integral of probabilities. In this particular case the character 0 should not exceed any absolute voltage value($B_0/2$). The probability for bilateral excess over P_2 of this value . (i.e. $B_0/2$ и + $B_0/2$) will be equal to

$$P_2 = 1 - \frac{1}{\sqrt{2\pi}} \int_{-b_0}^{+b_0} l^{-b^2/2} db = \frac{2}{\sqrt{2\pi}} \int_{+b_0}^{\infty} l^{-b^2/2} db, \quad (1)$$

where $b=u/Us$; u-instantaneous voltage value of the noise (random variable); U_s - effective value of noise voltage; $b_0=B_0/2U_s$.The probability for unilateral excess over values $+B_0/2$ (or - $B_0/2$), which occur in case of character –1 (or +1)will be equal to the half of values determined in (1), i.e.

$$P_1=P_2/2 \quad (2)$$

Since in dual signal characters 0 and 1 occur with equal probability, which equals ½, then it follows that when using bipolar signal the probability for occurrence of 0 will be

$$P_0=1/2 \quad (3)$$

Then the probability for the occurrence of characters –1 and +1 will be

$$P_{-1}=P_{+1}=1/4 \tag{4}$$

Error occurrence probability will be expressed by the following relationship

$$P=P_0P_2+P_{-1}P_1+P_{+1}P_1=P_2[P_0+(P_{-1}+P_{+1})/2]$$

So after taking account of (1) it will be

$$P=[P_0+\frac{1}{2}(P_{-1}+P_{+1})].\frac{2}{\sqrt{2\pi}}\int_{+b_0}^{\infty} l^{-b^2/2}db=$$
$$=\frac{3}{4}\frac{2}{\sqrt{2\pi}}\int_{+b_0}^{\infty} l^{-b^2/2}db \tag{5}$$

In (5) the value P determines the probability of noise voltage u to exceed the value $B_0/2$ at a point of solution which, consequently, will cause an error. In order for the error probability to be lower the effective value of noise voltage U_s should be lower,too, and consequently there should be lower probability of occurrence of noise whose instant value of b_0 exceeds U_s with a number of times thus reaching a permissible value $B_0/2$, i.e.

$$b_0\,U_s=B_0/2$$

hence

$$b_0=B_0/2\,U_s \tag{6}$$

occurs as the boundary of integration which is indicated above in (1). Assuming that the permissible amplitude of the $B_0/2$ pulse may obtain various values, then the probability expressed in (5) will occur as function of the value B_0.

$$P(b_0)=\frac{3}{4}\frac{2}{\sqrt{2\pi}}\int_{+b_0}^{\infty} l^{-b^2/2}db \tag{7}$$

Signal/noise relationship occurs as a unit of measuring amplifier's noise resistance

$$R=20\lg B_0/U_s,\ [dB] \tag{8}$$

By taking (6) into account we get

$$R=20\lg 2.b_0 \tag{9}$$

In this way the signal/noise relationship determined by (9) occurs as a function of probability P which is expressed through (7) and numerically equal to the error coefficient BER By using expressions (7) and (9) it is possible to calculate the required signal/noise relationship R by employing a preset error coefficient P.

The results are presented in a table 1.

In coaxial cables operating cable temperature appears to be the main source of noise. Hence temperature generated noises are the reason for limiting interamplifier sections l depending on the noise occurring within the line. In [1] we have the deduced formula of the power of heat noises N:

$$N=R.T_0\int_0^{f_T}F_\omega(f)g_\omega(f)df \quad , \tag{10}$$

where $F_\omega(f)$ is the resultant noise coefficient of sequentially started amplifiers and adjusters; $g_\omega(f)$- is the total coefficient of transfer of both amplifier and adjuster; f_T- is thepulse frequency.

Tabl. 1

P	R_p[dB]	P	R_p[dB]	P	R_p [dB]
10^{-3}	16,1	10^{-7}	20,5	10^{-11}	22,6
10^{-4}	17,7	10^{-8}	21,1	10^{-12}	23,0
10^{-5}	18,8	10^{-9}	21,7	10^{-13}	23,4
10^{-6}	19,7	10^{-10}	22,2	10^{-14}	23,7

From (10) it is possible to determine the permissible length of amplifiers' sections l for dual signals

$$\frac{e^x}{x}=\frac{P_u}{2kT_0F_1Q\Phi} \tag{11}$$

and

$$x=2\alpha_0 l\sqrt{\Phi/f_0} \quad , \tag{12}$$

where P_u-stands for the maximum signal power, [W]; $k=1,38.10^{-23}$ W.*C/K*-Boltzmann constant; $T_0=290$ K-absolute temperature, at which noise parameters are determined; $F_1=3,162$-coefficient of amplifier's noise; Q-relationship between signal maximum power and the power of heat noise upon the same load; Φ-rate of transmission *[bit/s]*; α_0-kilometre attenuation of cable *[Np/km]* with frequency of f_0 *[Hz]*; l-length of regenerating section *[km]*.

To simplify calculations, it is assumed that the transmission coefficient of power amplifier does not depend on frequency

$$g_u=e^{\alpha_0 l\sqrt{f_T/f_0}}$$

and the adjuster's transmission coefficient is frequency dependent:

$$g_k=e^{\alpha_0 l\sqrt{f/f_0}}e^{-\alpha_0 l\sqrt{f_T/f}}$$

After integrating above expressions we obtain the expression for heat noises power of amplifiers and adjusters which are connected in series.

$$N=2kT_0F_1f_T\frac{e^x}{x}\ .$$

By introducing new parameters $Q=P_u/N$ and $\Phi=f_T$ we get simpler expressions for (11) and (12) and by assuming that the maximum voltage of signal (character l) U_{max} is 3V over the wave resistance of line $z=75\Omega$

Then the maximum power of signal in [*m*W] will be.l:

$$P_u=U^2_{max}/z=3^2.1000/75=120$$

And the signal/noise relationship

$$R=10.lgQ$$

hence

$$Q=10^{R/10}$$

Rate of transmission of dual signals

$$\Phi=f_T=2f_0$$

- kilometer attenuation of cable for frequency f_0 [*MHz*] is $\alpha_0 = \alpha_1\sqrt{f_0}$, where α_1 is kilometer attenuation for frequency of 1 *MHz*.

a) For normal coaxial cable(Bulgarian make) type PK 75 with pairs 1,37/9,0 mm

$$\alpha_1 = 2{,}34\ dB/km$$

b)For coaxial cable with pairs 0,68/4,6 mm

$$\alpha_1 = 5{,}31\ dB/km$$

c) For coaxial cable with pairs 0,68/2,2 mm

$$\alpha_1 = 8{,}86\ dB/km$$

where f_T and f_0 are in *MHz*.

Relationships (11) and (12) appear as (rate of transmission Φ is expressed in *kbit/s*).

$$\frac{e^x}{x} = \frac{4{,}74.10^{12}}{10^{R/10}\Phi}$$

$$x = 2\alpha_1 l\sqrt{\Phi} \quad [Np]$$

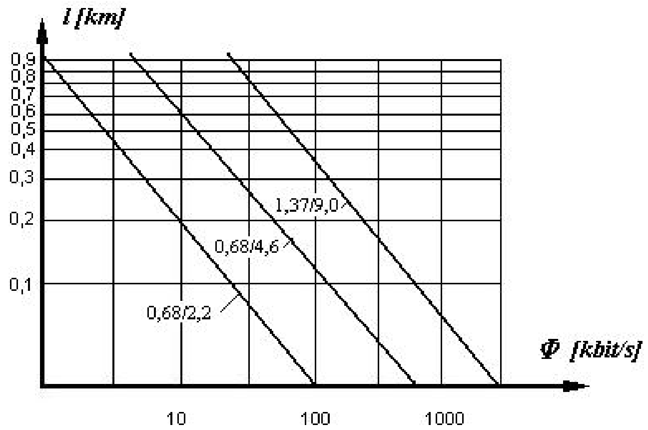

Fig.1. Amplified section length related to the rate of transmission of digital signal with permissible error coefficient 10^{-9} and kilometer attenuation for three types of coaxial cables at frequency of 1*MHz*.

Fig 1 presents the dependences for the length of regeneration section *l* on the rate of digital signal transmission which are abstained by means of the expressions that have been analyzed so. The permissible value of error coefficient 10^{-9} corresponds to *R=21,7 dB*. Taking margined from the tolerance of the regenerator 3 dB and , also, taking in consideration the level of disturbances from previous impacts and heat noises, R is to be increased to *4,8 dB* (*10*.lg *3*) and then

$$R=21{,}7+3+4{,}8=29{,}5\ dB$$

III. CONCLUSIONS

Drawing upon Fig. 1 it follows that for a particular rate of transmission Φ_I the length of the regenerating section l_I for the corresponding coaxial cable is to be selected in such a way so that the point with coordinates (Φ_I, l_I) is located below the the straight line that corresponds to the type of coaxial cable used. Accordingly, the error coefficient of the regeneration section with length of *l* does not exceed the value 10^{-9}. For example, if the rate of transmission of digital data is 500 *kbit/s* the length of cable section should be 300*m* if coaxial cable with pair of 1.37/9.0 *mm* is used and with pairs of 0,68/4,60 *mm* and rate of Φ =200 *kbit/s* the length should not exceed 250 *m*. Since the length of regeneration section is about 600 *m* when highway amplifiers are used ,the optimum rate of transmission is reached at 300 *kbit/s* for trunk cables with pair of 1,37/9,0 *mm*.

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