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Determination of conditions for equal effect of random and bursty errors on the bandwidth of signalling CCS No7 channel

***Abstract**. In this paper, we give the answer to the question: are there conditions under which the effects of bursty and random errors on the bandwidths of signalling CCS No7 channel are equal? At first, we present the method that determines the characteristics (bandwidth, waiting time on message sending) of signalling CCS No7 channel under the influence of random errors and bursty errors. At the end we specify method that determines the conditions for an equal effect of random and bursty errors on the bandwidth of signalling channel.*

***Streszczenie.** W artykule próbuje się odpowiedzieć na pytanie: czy są warunki kiedy efekty błędów pogrupowania i przypadkowych w kanale komunikacyjnym CCS No7 są jednakowe? Zaproponowano metodę określania charakterystyki – pasma, czasu oczekiwania na wiadomość w zależności od błędów. (**Określanie warunków jednakowego efektu błędów przypadkowych i błędów pogrupowania na pasmo kanału CCS No7**)*

Keywords: bandwidth of signalling CCS No7 channel, random errors, bursty errors, Jensen's inequality.
Słowa kluczowe: pasmo kanału, błędy przypadkowe, CCS Nr.7.

Introduction

The recommendation Q.706 [1], among others, deals with the following characteristics:

- time delay of signalling messages,
- method of determination of the time delay for sending the signalling message by signalling CCS No7 (*Common Channel Signalling Number 7*) channel when the errors are uniformly distributed,
- transmission links for CCS No7 signalling messages sending with a possible correction of errors by primary or preventive cyclic retransmission method,
- the formula for the average waiting time, which is necessary to send the signalling message by signalling CCS No7 channel, in the presence of errors or in the error-free state, for both methods of error correction.

One of the drawbacks of Q.706 recommendation is that it says nothing about the bursty errors and their impact on waiting time for sending the signalling message by signalling CCS No7 channel.

Channel bandwidth is inversely proportional to the time of service, i.e. processing time and waiting time (delay). Therefore, the bandwidth of signalling CCS No7 channel is indirectly determined by the recommendation that determines the delay time, [1]. Bit rate and signal propagation time on the digital channel are processed in this recommendation, and these are important parameters that characterize the digital transmission.

The bit rate penetrates almost all areas of CCS No7. The influence of this parameter on the signalling characteristics of protocol MTP (*Media Transfer Protocol*) can not be neglected. Bit rate is an unavoidable factor in the standardization of certain parts of this protocol. In this paper we shall always mean bit rate of 64 kbit/s and MTP standards related to this bit rate.

The signal propagation time through the data channel, T_p, is the time period that begins when the last bit of signalling unit enters the data channel on the transmitting side, and ends when the last bit of signalling unit, leaves the data channel on the receiving side. This time depends on the length of the transmission channels, through which are signal units transmitted, and on digital media (Table 1/Q.706, [1]).

The importance of this parameter is primarily in the fact that it forms a new parameter called double propagation time, T_L. This parameter indicates the time interval equal to twice the signal propagation time through the digital channel, plus processing time of signalling unit in the signalling point. There is no precise calculation of the signal characteristics of MTP without using this parameter. In the literature [4, 5, 6] it is widely used as a constant parameter. The assigned value is equal to T_L = 30ms, and corresponds to approximately the longest terrestrial connections that are about 2000 km. In further calculations, in this paper, it is considered that the value of this parameter is 30ms.

In order to determine the limits of the mean waiting time for sending signalling messages per signalling CCS No7 channel, where random and bursty errors have a similar impact of the signalling CCS No7 channel, obviously, we should calculate and present the curve Q_t, [1]. As the bandwidth of the signalling CCS No7 channel can be defined as the reciprocal of mean waiting time to send a signalling unit, then it follows that the bandwidth of the signalling CCS No7 channel also has similar values in the same area in the case of random and bursty errors. This is not a precise definition, but for large waiting times the error is negligible.

In this paper, we show that there are some conditions under which the effects of bursty and random errors on the signal bandwidth CCS No7 channels are equal.

Summarily about the signalling CCS No7 channel

Signalling CCS No7 channel is a common channel by which signalling messages are sent, and in the literature can be found also as SS7 (*Signalling System Number 7).* For the first time this channel is recommended to be used by the CCITT 1980th, and revisions were made in 1984, 1988, 1992 and 1996 year. Signalling channel CCS No7 is designed as a standard for common channel signalling, which can be used in various digital networks. This channel (CCS No7) is internationally standardized, and generally speaking, common channel signalling has the following characteristics:

- it is optimized for use in digital telecommunication networks in conjunction with program control which can be modified, using 64 kbit/s channel;
- designed for current and future requirements of information transfer for the telephone network, remote control, operation and maintenance;
- provides reliable transmission of information in the correct sequence without loss and duplication;
- suitable for working with analog channels and at speeds of less than 64 kbit/s;
- used for "point to point" terrestrial and satellite links.

Application area of CCS No7 is large, since the CCS No7 should cover all aspects of signal control in complex digital networks including the reliable control, transfer of control messages and purpose-oriented content of these messages. This digital signalling system is considered to be the best, because it can provide all current needs of the telephone network, as well as the needs of other telecommunication services that are being developed. One of the major imperfections of the common-channel signalling is the possibility of congestion, because the number of users exceeds the number of processing channels.

Bandwidth of signalling CCS No7 channel under the influence of random errors

The signalling units Message Signal Unit (MSU) and Link Status Signal Unit (LSSU) must not be lost. Processing of the signalling channel is arranged as waiting queuing system. The place, where the messages for one channel are waiting to be sent is called transmission and/or retransmission buffer. Retransmission buffer consists of a limited number of waiting places (128). Signalling units are in it as long as the sending party does not receive confirmation of successful receipt of the signalling unit from the receiving side.

The mean waiting time is the main indicator of the traffic bandwidth of the signalling channel, as a waiting queuing system. The waiting time is calculated from the moment of unit content readiness for sending, till the start of sending it to the channel. This statement will be used in this paper.

The problem of bandwidth will be connected with the problem of dimensioning the signalling channel in the sense of its utilization. Signalling channel is dimensioned so that the offered traffic, *a*, in normal operation of the channel do not exceed a specified maximum, a_{max}. The criterion for determining the values of a_{max}, are the conditions of signalling channel. According to the current recommendations, this value varies between 0.2 Erl and 0.4 Erl. Signalling characteristics of the MTP protocol, however, still need to be analyzed for the case of $2 \cdot a_{max}$, because this is the maximum possible traffic load, in the case when the channel takes traffic as an alternative channel.

From Q.706 recommendation [1], we use the expression, which presents the average waiting time to send the signalling message by signalling CCS No7 channel, Q_t, in the presence of uniformly distributed errors. The errors are corrected by the basic method of retransmission. The mentioned expression from [1] is given in the form:

$$Q_t = \frac{T_f}{2} + \frac{a}{T_m} \cdot \frac{\left(m_2 + P_{SU} \cdot T_L \cdot \left(T_L + 2 \cdot T_m\right)\right)}{2 \cdot \left(1 - a \cdot \left(1 - \frac{P_{SU} \cdot T_L}{T_m}\right)\right)} + P_{SU} \cdot T_L \tag{1}$$

where is: Q_t - mean waiting time, T_f – Fill In Signal Unit (FISU) message duration, *a* – traffic of MSU units, T_m - mean duration of MSU message, P_{SU} – probability of incorrectly transmitted signalling unit, T_L - double propagation time from the sending to the receiving side, m_2 – the second moment of the MSU duration, ($m_2 = T_m^2 + \sigma_m^2$, where σ_m^2 is the variance of the MSU duration).

Distribution of the MSU duration and other parameters are as in the examples listed in [1], Model A, table 3/Q.706.

The equation (1) expresses how the mean waiting time for sending the signalling message by signalling CCS No7 channel depends on the probability of incorrectly transmitted signalling units, $Q_t = Q_t(P_{SU})$. In order to consider the error impact on the waiting time to send a signalling message by signalling CCS No7 channel, it is necessary to calculate a function which gives the mean waiting time for sending signalling messages by the signalling channel, depending on the bit error rate (*BER*), $Q_t = Q_t(BER)$. The connection between the probability of incorrectly transmitted signalling unit, P_{SU}, and the *BER*, is given by the following expressions [3]:

$$P_{SU} = 1 - (1 - BER)^n \tag{2}$$

$$BER = 1 - (1 - P_{SU})^{1/n} \tag{3}$$

where n is the number of bits in the signalling unit. From [3] follows $n = 8 \cdot l_{SU}$, where l_{SU} expresses the mean length of signalling units.

The offered traffic of signalling units, *a*, is another parameter in this expression on which we must pay attention. In equation (1), the offered traffic of signalling units will be expressed using effective traffic of signalling units, which is calculated according to the following expression [4, 5]:

$$a_{eff} = a \cdot \frac{1 + P_{MSU} \cdot \frac{T_L}{T_m}}{1 - P_{MSU}} \tag{4}$$

where is: *a* - offered traffic of MSU units; P_{MSU} - the probability of incorrectly transferred MSU units; T_m - the mean duration of MSU messages (which has *m* octets), T_L - double propagation time from the sending to the receiving side.

The effective traffic, a_{eff}, in real conditions of error existence is always greater than the offered traffic, *a*, because the messages are repeated due to the mistakes, and the repeated messages cause an increase in traffic on the CCS No7 channel. Ideally, when there are no transmission errors ($P_{MSU} = 0$, i.e. $BER = 0$), the effective traffic, a_{eff}, would be equal to the offered traffic, *a*.

The curves shown in Fig. 1 are obtained when P_{SU} is expressed by *BER*, (3) is substituted in (1) and (4), and when the offered traffic, *a*, is replaced by the effective traffic a_{eff}, equation (4) is introduced in (1).

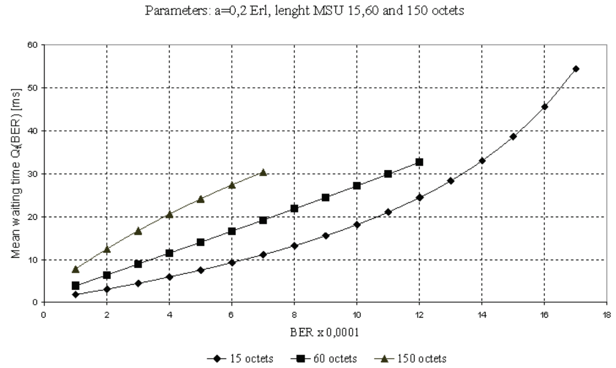

Fig.1. The average waiting time for sending MSU units, a = 0.2 Erl

Bandwidth, $O_t(BER)$, of the signalling CCS No7 channel can be defined as $O_t(BER) = 1/Q_t(BER)$. Upon conversion of the calculated $Q_t(BER)$ for certain values of *BER*, we get the curves presented in Fig. 2. For these curves we use the same parameters as for the curves presented in Fig. 1. From Fig. 1 and Fig. 2 can be seen that as signalling messages are longer, the mean waiting time for sending of messages increases, and therefore the bandwidth of signalling CCS No7 channel decreases. In addition, the mean waiting time on MSU units sending increases with the increase in *BER*, and thus causes a reduction in bandwidth of signalling CCS No7 channels.

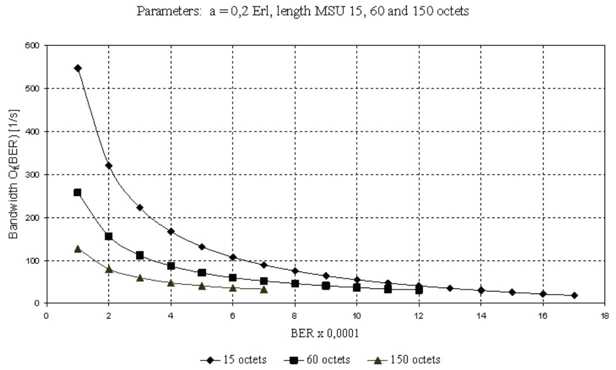

Fig.2. Bandwidth of signalling channel in the function of *BER*, *a* = 0.2 Erl

Determination of the signalling channel bandwidth under the influence of bursty errors

Later in this section, special attention will be paid to the impact of bursty errors on the bandwidth of signalling CCS No7 channel and we shall describe one easy method for determination of the signalling CCS No7 channel properties in the case of bursty errors, which are corrected using the primary method of retransmission. This method is based on the use of Jensen inequality, [6, 7]. According to Jensen inequality, if the function, *f*, is convex downward and *X* is a random variable, the following condition is valid:

$$\text{(5)} \qquad E(f(X)) \geq f(E(X))$$

where E(*X*) is the mean value of the variable *X*, [6]. For strictly convex functions the corresponding condition is:

$$\text{(6)} \qquad E(f(X)) > f(E(X))$$

If the function, *f*, is convex downward (convex upward), this means that it will always be below (above) pulled chord between its furthest points. (If *f*(*x*) is twice differentiable function in the interval (*a, b*), and if the second derivative of *f*(*x*) is, at a certain point, greater than zero, the curve of the function *f*(*x*) is convex downward. If the second derivative of *f*(*x*) is at a certain point less than zero, the curve of *f*(*x*) is convex upward (Section 2.6, Theorem 2.6.1, in [6])). In this paper, we shall always consider functions that are strictly convex downward or strictly convex upward.

Mean waiting time for sending signalling messages by the signalling channel is given as a function of traffic, $Q_t(a)$, (1), and P_{SU} is used as a parameter. In order to obtain mean waiting time for sending signalling messages by the signalling channel in function of *BER*, $Q_t(BER)$, in this section is offered traffic, *a*, taken as a parameter (the traffic, *a*, is converted into a_{eff}, (4)). Probability of incorrectly received message, P_{SU}, is expressed by *BER* (2). So we obtain an expression, which gives the average waiting time to send the signalling messages by the signalling channel as a function of variable *BER*. Based on the calculated values for $Q_t(BER)$ in the function of variable *BER*, the curves in Fig. 3 and Fig. 4 are obtained.

Form of the function $Q_t(BER)$ calculated using equation (1), depends on the used parameters given in Fig. 3 and Fig. 4. On the basis of selected parameters, the curve $Q_t(BER)$ can be convex upward (Fig. 3), or convex downward (Fig. 4), and in special cases can be approximately straight line.

Let us now suppose that the signalling CCS No7 channel is under the influence of bursty errors, so it can be found in state G or state B. In the Fig. 3 and the Fig. 4, left-most points are defined as states with less *BER* (G) and marked by G, and right-most points are defined as states with greater *BER* (B) and marked by B, [8]. It is assumed, that the signalling CCS No7 channel can be found in a state G with probabilities P_G1, P_G2 and P_G3, or in a state B with probabilities P_B1, P_B2 and P_B3, wherein is always $P_Gi + P_Bi = 1$, (i = 1, 2, 3), [8]. After these assumptions, the equivalent *BER*, BER_{eq}, and equivalent mean waiting time, Q_{eq}, can be very easily calculated, according to (7) and (8) for couples of P_Gi and P_Bi, (i = 1, 2, 3):

$$\text{(7)} \qquad BER_{eq}(P_Gi, P_Bi) = P_Gi \cdot BER(\mathrm{G}) + P_Bi \cdot BER(\mathrm{B})$$

$$\text{(8)} \qquad Q_{eq}(P_Gi, P_Bi) = Q_t(\mathrm{G}) \cdot P_Gi + Q_t(\mathrm{B}) \cdot P_Bi$$

where: Q_t(G) - mean waiting time for sending signalling messages in the point G; Q_t(B) - mean waiting time for sending signalling messages in the point B; *BER*(G) - intensity of bit errors at the point G; *BER*(B) - intensity of bit errors at the point B.

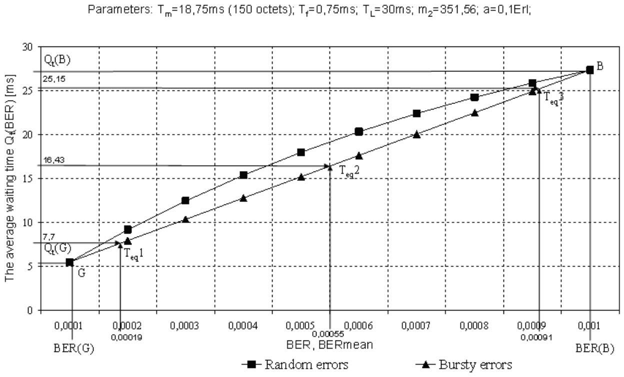

Fig.3. Average waiting time for sending signalling messages by signalling CCS No7 channel for random error (curve convex upward) and for bursty errors

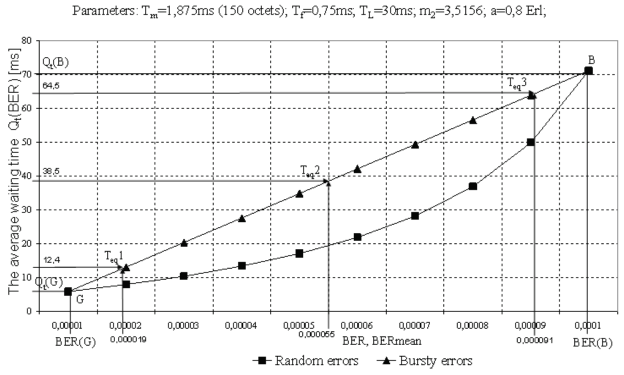

Fig. 4. Average waiting time for sending signalling messages by the signalling channel for random errors (curve convex downward) and bursty errors

Points $T_{eq}1$, $T_{eq}2$ and $T_{eq}3$, which are defined by the pairs $BER_{eq}1$ and $Q_{eq}1$, $BER_{eq}2$ and $Q_{eq}2$, $BER_{eq}3$ and $Q_{eq}3$, [4], are displayed in Fig. 3 and Fig. 4. If we now draw the line, which connects the end points G and B, we shall see that points $T_{eq}1$, $T_{eq}2$ and $T_{eq}3$ lie on the line drawn through the points G and B, (see Fig. 3 and Fig. 4). So, the line drawn through points G and B, is the set of points that represent mathematical expectation for the mean waiting time for sending signalling messages by the signalling channel in the case of bursty distributed errors, because for any pair of values $P_G x$ and $P_B x$, the calculated values $BER_{eq} x$, (7), $Q_{eq} x$, (8), are represented by the point $T_{eq} x$, which is situated on this line, [2, 7].

From aforementioned can be concluded that, if we know the curve of a mean waiting time for sending signalling messages by the signalling channel for the channel model with random errors, $Q_t(BER)$, then the curve of mean waiting time for the channel model with bursty errors can be easily obtained as a line (chord) drawn between the end points of the curve $Q_t(BER)$, [2, 7].

In order to determine the bandwidth of signalling channels under the influence of bursty errors, we shall use the graphs on Fig. 3. and Fig. 4. These graphs present the mean waiting time for sending signalling messages by the signalling channel for bursty errors as a function of *BER*. Bandwidth, O_t, in the function of BER_{eq}, $O_t(BER_{eq})$, will be obtained as the reciprocal of mean waiting time to send a message $Q_t(BER)$, i.e. $O_t(BER) = 1/Q_t(BER_{eq})$. When we recalculate values for the mean waiting time of sending the signalling messages by the signalling channel for bursty errors, we get the curves, which present the bandwidth of the signalling channel as a function of BER_{eq} (Fig. 5 and Fig. 6).

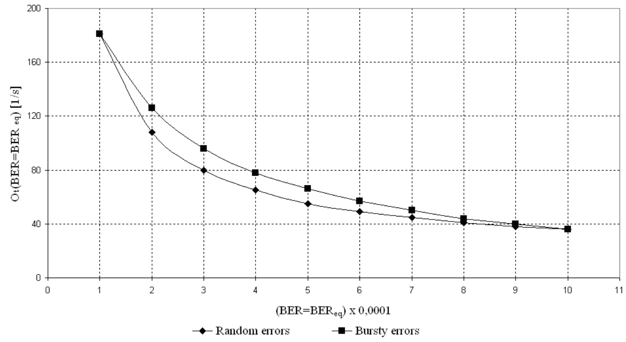

Fig.5. Bandwidth of the signalling channel for random errors (curve $Q_t(BER)$ convex upward) and for bursty errors

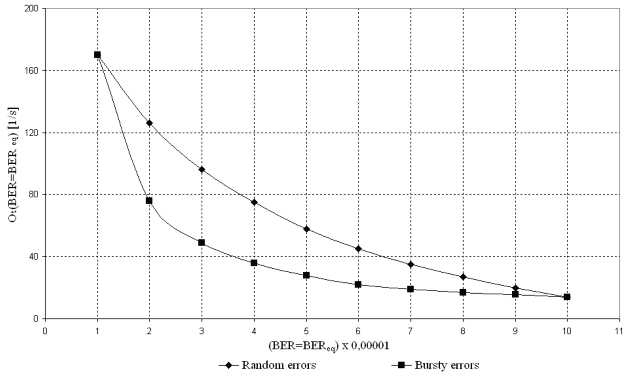

Fig.6. Bandwidth of the signalling channel for random errors (curve $Q_t(BER)$ convex downward) and for bursty errors

Determination of conditions for equal effect of random and bursty errors on the bandwidth signalling CCS No7 channel

Convexity of curves $Q_t(BER)$ defines the relationship between the bandwidth of the signalling CCS No7 channel with random errors and with bursty errors. In this section we want to prove that there are some conditions when the effects of bursty and random errors on the bandwidth of the signalling CCS No7 channel are equal.

In order to determine the limits for the mean waiting time for sending signalling messages per signalling CCS No7 channel, in which $BER = BER_{eq}$, has a similar impact on channel bandwidth for random and bursty errors, we should, obviously, calculate and graph the curves $Q_t(BER)$.

First we present graphically a set of curves $Q_t(BER)$ for constant offered traffic, *a* (Fig. 7). Parameter for the curves in the Fig. 7 is the number of octets, *n*.

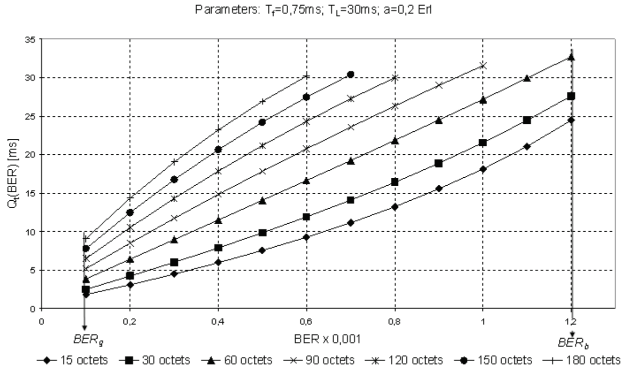

Fig.7. Set of curves $Q_t(BER)$ for different number of octets, *n*, for the constant traffic *a* = 0.2 Erl

Fig. 7 graphically shows the set of curves $Q_t(BER)$ for constant traffic, *a* = 0.2 Erl, depending on the number of bytes *n* ($15 \leq n \leq 180$ octets). Other parameters mentioned in Fig. 7, (T_f, T_L) have the same meaning as in equation (1). In Fig. 7 can be seen that the curves $Q_t(BER)$, for a smaller number of octets (*n* = 15, 30 octets), are convex downward, while the curves $Q_t(BER)$, for a larger number of octets (*n* = 90,120,150,180 octets), are convex upward. It is logical that there is a border between the curves $Q_t(BER)$, that are convex downward and upward, as shown in Fig. 7, and that is approximately the curve for $Q_t(BER)$ of 60 octets. In order to determine, as accurately as possible, the curve $Q_t(BER)$, which is approximately a straight line, we shall find the second derivative of the curve $Q_t(BER)$ for 60 octets, applying the *BER* values that were used in calculating and drawing the graph $Q_t(BER)$ for 60 octets.

The second derivative of the curve $Q_t(BER)$ may have values $Q_t''(BER) > 0$ and $Q_t''(BER) < 0$ on the segment (BER_G, BER_B), where BER_G has a value of $1 \cdot 10^{-4}$, and BER_B the value of $1.2 \cdot 10^{-3}$. The goal is to get approximately a straight line, which means that the second derivative at points that define a straight line must be zero, $Q_t''(BER) = 0$. In order to obtain $Q_t''(BER) = 0$, with the greatest possible accuracy, it is necessary to change the number of octets in points that were used in calculating and drawing the curve $Q_t(BER)$ for 60 octets.

When we connect the calculated points, we get the line as in Fig. 8 which is designated as “calculate octets $Q_t''(BER) = 0$”. As is the number of octets in these points different, $60 \leq n \leq 64$, the curve $Q_t(BER)$ for 62 octets is calculated (Fig. 8, line marked as “62 octets”). From Fig. 8 may be concluded that the line ”calculate octets $Q_t''(BER) = 0$” differs slightly from the line $Q_t(BER)$ for 62 octets in the range BER_G, BER_B.

Therefore, it can be concluded that the message length of 62 octets is approximate boundary at which the impact of random and bursty errors on the signal CCS No7 channel is equal ($BER = BER_{eq}$) for traffic *a* = 0.2 Erl and *BER* in the range of $1 \cdot 10^{-4}$ to $1.2 \cdot 10^{-3}$. It follows that the bandwidth of the signalling CCS No7 channel is equal for random and bursty errors (in this example *n* = 62 octets and *a* = 0.2 Erl).

Fig. 9 gives a set of curves $Q_t(BER)$ for a constant number of octets, *n* = 60 octets, and offered traffic is a parameter that is changing. Other used parameters (T_m, T_f, T_L, m_2), presented in Fig. 9, have the same meaning as in equation (1). It can be seen from Fig. 9 that the curves

$Q_t(BER)$ for the greater traffic (a = 0.2, 0.25, 0.3) are convex downward, while the curves $Q_t(BER)$ for the smaller traffic (a = 0.05, 0.1, 0.15) are convex upward. So, there is a graph of $Q_t(BER)$, which is approximately straight line for a given offered traffic, a, and this line will be between the values of the offered traffic a = 0.15 Erl and a = 0.2 Erl, (Fig. 9). This line is determined by calculating the second derivative of the function $Q_t(BER)$, $Q_t''(BER)$, in the points for which is calculated the set of curves, $Q_t(BER)$, by varying the offered traffic, a, until it is obtained, approximately, $Q_t''(BER) \approx 0$, with the greatest possible accuracy. If these, calculated, points are connected, we get the line for the parameter of the offered traffic, a, for which random and bursty errors have equal influence on the bandwidth of the signalling CCS No7 channel.

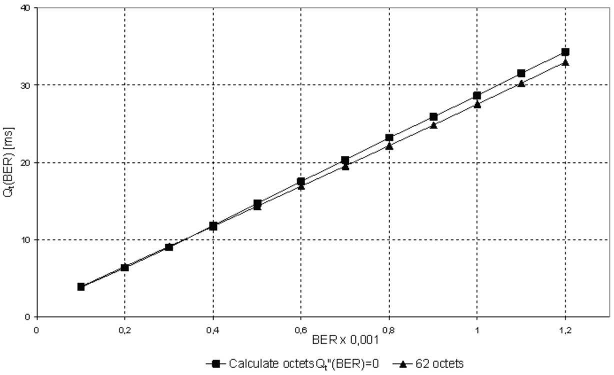

Fig. 8. Determination of the border where is equal the influence of random and bursty errors on the signalling channel, for $BER=BER_{eq}$ and a = 0.2 Erl

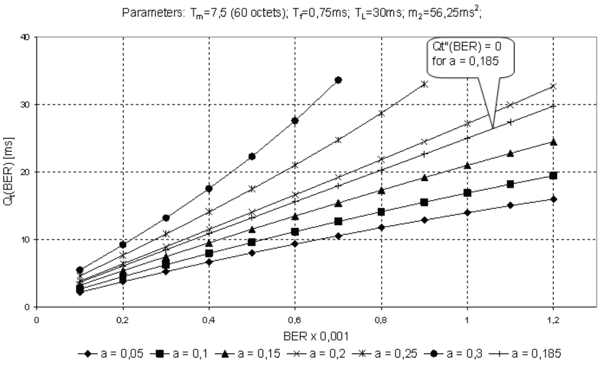

Fig.9. Set of curves $Q_t(BER)$, depending on the offered traffic, a, for a constant number of octets n = 60 octets

Randomly distributed and bursty errors have the similar impact for the value of $a \approx 0.185$ Erl, when the value of $BER = BER_{eq}$ is in the range from $1 \cdot 10^{-4}$ to $1.2 \cdot 10^{-3}$, and when the message length is 60 octets. This means that also the bandwidth of the signalling CCS No7 channel is approximately equal in that case for random and bursty errors.

Conclusion

In this paper, we show that there are some conditions under which the effects of bursty and random errors on the bandwidth of the signalling CCS No7 channel are equal. After all above, the following very important conclusions can now be made:

- bandwidth of the signalling CCS No7 channel for the model with random errors is different from the bandwidth of the same channel under the influence of bursty errors;
- bandwidth of signalling CCS No7 channel with bursty errors is larger than bandwidth of signalling CCS No7 channel with random errors if the function $Q_t(BER)$ is convex upward (small traffic and long MSU) and vice versa;
- differences in bandwidth can be up to 100% (Fig. 6);
- as seen from the examples, the boundaries of equal influence of bursty and random errors on the signalling channel bandwidth can be determined quite accurately (Fig. 7 and Fig. 9);
- this limit is different for each group of parameters.

ACKNOWLEDGEMENTS

The study was carried out within the Project R32007: “Multiservice optical transport platform with OTN/40/100 Gbps DWDM/ROADM and Carrier Ethernet functionality”. The project was financed by the Ministry of Science and Technology, Republic of Serbia.

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