AN ANALOG-DIGITAL METHOD FOR MEASURING PARAMETERS AND PROBABILITY DISTRIBUTIONS OF THE TELEPHONE TRAFFIC

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ABSTRACT

The development of teletraffic theory and the needs of maintenance as well as the growth of telephone networks make it necessary to increase the range of telephone traffic measurements.

In the paper an analog-digital method of measurements of such parameters is presented.

The main idea of the paper is to show that the method, based on measurements of electrical charge is convenient alternative to increase the range of telephone traffic measurements.

This method is especially suitable for use in the existing electromechanically controlled /e.g. step-by-step, crossbar systems etc./ telephone exchanges, since traffic measuring circuits provided in such exchanges can be directly used without any modification.

INTRODUCTION

Traffic measurements are usually meant to denote all methods used for observing and collecting data of interest for the traffic being handled [5].

The importance of real traffic measurement for rational maintenance, extension of exchanges and telephone networks as well as the progress of telephone traffic theory have been discussed in numerous papers e.g. [4], [5], [6].

The extension of the scope of real traffic measurement has been suggested for several years. This extension does not only concern the increase of observation period for traditional traffic intensity measurements, but including in systematic measurements the order parameters characteristic of this traffic.

The electronic exchanges, having the storage program control, as a rule, meet this requirement.

On the other hand the extension of the traffic measurement scope in electromechanical exchanges in operation, needs the use of such methods and measuring equipments, which would meet at a low cost the following requirements:

- gathering data concerning various parameters by means of similar /preferably the same/ measuring equipments,

- obtaining output data in the form directly ready for further treatment by a computer,

- limiting the output data number by means of preliminary treatment, performed during the gathering,

- simplicity of installation in already operating electromechanical exchanges,

- the possibility of adaptation of the measuring equipment to the capacity of given exchange and measurement needs for various parameters, by means of modular construction.

As to the latter one, it is to be emphasized, that the introduction of new methods and equipments to already operating exchanges is possible when considering the one of two assumptions:

- the adaptation of the exchange to the properties of the measuring equipment, or

- the adaptation of the measuring methods and measurement equipment to already existing measurements circuit in exchanges.

The first assumption usually provides us with a bigger scope of measuring possibilities, however it usually needs extra cabling which may be troublesome and involve higher costs.

Following the other assumption, we avoid higher costs of installation and the measuring possibilities prove to be satisfactory in the aspect of routine traffic measurement.

One of the directions in the traffic measurement modernization is the use of mini-computers /or microcomputers/ for gathering the traffic data in electro-mechanical exchanges [6]. This method characterizes with cyclic scanning of measuring points /i.e. trunk, switching devices etc./ and differentiating one of their two states /free "0" or busy "1"/.

Counting the number of events is performed by registration of each change of the state 0→1 or 1→0. The measurement of time section during which the given device was in busy state needs the storage of the actual time at the transfer moment of this device from 0→1. The transfer from 1→0 denotes the freeing of this device, hence the time of the latter is stored.

The time of device occupation is defined on the basis of times difference, which passed from the moment of occupation and freeing of this device.

This data make it possible, among the other, to determine the average value of traffic intensity. Apart from the defining of this value, it is possible, of course, to determine other parameters and distributions of probability of certain quantities which characterize the telephone traffic.

The use of computer methods for traffic measurement permitted the accurate analysis of the traffic phenomenon, and that is why, they are irreplaceable in research works.

However these methods, as a rule, need the adaptation of the exchanges equipment.

Here the question is raised, whether at a mass, routine traffic measurements it is not recommendable to use simpler and cheaper methods and equipments adapted to the existing ones in many
MEASURING POSSIBILITIES OF THE ANALOG-DIGITAL METHODS

The suggested method of parameters measurement of traffic allow for the observation of any parameter which can be allotted to the one of the three following classes:

- Class I - number of predetermined traffic events during the observation period /e.g. number of calls originated, number of calls encountering congestion etc./.
- Class II - charge of the telephone traffic flowing by the group of trunks or switching devices during the observation period /e.g. charge of carried traffic, charge of the effective traffic etc./.
- Class III - the time of duration of predetermined states in the observation period /e.g. total time of the congestion in the Busy Hour/.

The analog-digital methods are to be used in exchanges in which the measuring circuits /Fig. 1 ± 3/ already exist, or can be easily prepared.

Fig. 1 Circuits for measuring the number of traffic events

The circuit shown in Fig 1 is used for counting the traffic in many exchange systems and cooperates with electro-mechanical counter.

Fig. 2 Circuit for measuring the average value of traffic intensity

The circuit for measuring the average of traffic intensity is typical of many systems adapted for measuring by means of e.g. erlangmeter /Ah-meter/. The equivalent resistance of parallelly connected resistors is inversely proportional to the number of simultaneously busy devices in the trunk group.

The circuit shown in Fig 3 is used in some systems of exchanges /e.g. Pentaconta 1000 C/ for informing the translator about the occupation of all trunks of a given direction. This circuit can be utilised for the measuring the time of congestion.

Fig. 3 Circuit for measuring of congestion time

THE METHOD OF REGISTRATION OF TRAFFIC EVENTS

The analog-digital method of measuring the electrical charge, used for observing the number of traffic events, assumes that the occurrence of a definite traffic event is accompanied by a single electrical impulse.

The method of measuring the number of definite traffic events during the observation period T allows for the registration under each impulse, the fixed, unit charge \( \Delta q \). The real duration time of that impulse and its amplitude. The registered values of the charge \( \Delta q \) are summed up. The charge \( Q_T \) defining the total number of events during the observation period T is expressed as following:

\[
Q_T = \sum_{n=1}^{N} \Delta q
\]

Reading of the registered charge value \( Q_T \) is made by the digital method of time measurement at the fixed value of electrical current selected in this way that the obtained result expressed in time units will directly define the number of events n or its multiplicity.

THE METHOD OF MEASURING THE AVERAGE VALUE OF TRAFFIC INTENSITY

Let us assume that by means of a device M the electrical charge flowing in the circuit is measured as in Fig 2.

The dependence allowing for defining the average value of traffic intensity by means of measuring the electrical charge flowing through the circuit, during the observation period, in the configuration shown in Fig 2 has been known for many years [10]. It can be expressed in the form of:

\[
\bar{A}_T = \frac{Q_T}{U \cdot R \cdot T}
\]

where \( \bar{A}_T \) is average value of traffic intensity, \( Q_T \) - electrical charge flowing through the circuit under measurement, \( U \) - voltage feeding the circuit under measurement, \( R \) - the resistance of a single resistor in measuring circuit, \( T \) - observation period.

This dependence express the essence of the method of traffic intensity measurement by means of previously used erlangmeter /Ah-meter/ i.e. electromagnetic device for measuring the electrical charge with the visual reading. A well known analogy between the charge of telephonic traffic and electrical one has been utilised here.

The suggested here method is also based on the dependence, however only for the description of registration process of the traffic charge.
A different characteristic of that method is the fact that previously registered traffic charge during the observation period, is read by means of digital method of time \( t \) measurement, which passed from the moment of starting the reading, to the moment of ascertainment that the "reading out" of the previously registered charge value of \( Q_n \) has been finished incidentally, the reading of this charge is performed at the fixed current value \( I_c = \text{const} \), hence:

\[
Q_n = I_c \int_{t_0}^{t_f} t \, dt
\]

Substituting \( I_c \) to \( I \) we obtain the formula for the average value of traffic intensity expressing the essence of the discussed method:

\[
A_T = \frac{I_c \int_{t_0}^{t_f} t \, dt}{U \cdot R}
\]

Since \( I \), \( U \) and \( R \) are constant parameters, for the fixed observation period \( T \):

\[
\frac{I_c}{T} = k
\]

the formula \( /2/ \) will take the form:

\[
A_T = k t_r
\]

According to the above formula the charge registered by the analog method can be read by means of digital method and hence, the average value of traffic intensity during the observation period \( T \) can be easily found.

THE METHOD OF MEASURING OF CONGESTION TIME

Assuming that measuring circuit is available, as in Fig 3, the registration and summing up of time sections during the observation when congestion occurred, is possible.

Each occurrence of congestion brings about in the circuit, as shown in Fig 3, the flow of current through the device registering the charge.

Hence, the registration process can be described by a formula:

\[
Q_T = \sum_{i=1}^{k} I_r \int_{t_1}^{t_i} t \, dt
\]

\( Q_T \) - charge registered during the observation, \( I_r \) - fixed value of the current in a measurement circuit, \( i = 1 \ldots k \) the number of time sections during which the congestion occurred, \( t_i \) - duration time of \( i \) section.

The reading out of a registered charge \( Q_n \) is made as formerly by means of digital method time measurement, at \( I_c = \text{const} \), selected in the way that the output data will be expressed in time units.

THE MANNER OF PRACTICAL UTILIZATION OF ANALOG-DIGITAL METHODS

The practical use of the idea of observing the traffic parameters on the way of electrical charge measurements, needs the element disposal which would make the following possible:

- storing during the observation time \( T \) of electrical charge defining the number of events, the traffic charge, or congestion time,
- reading out of the stored charge in the way providing the output result in the form appropriate for computing,
- providing the satisfactory accuracy at the record /storage/ and reading of this charge

Apart from the above, this element should be cheap and small in size. At the present day technical possibilities, the available element meeting the requirements, is the electrochemical integrator with the discreet reading.

The electrochemical integrator, so called \( E \)-cell made by the Inc. Flessey[12] is a miniature electrolytic cell which accurately measures the quantity /coulombs/ of electricity passing through it by the application of well known Faraday's Law of Electrolysis.

The standard previously known instrument for measuring quantity of electricity is the silver coulometer, involving the weighing of silver deposited onto platinum cathode.

The \( E \)-cell component is a special type of silver coulometer which does not require any weighing, and which is thus more convenient to use.

The \( E \)-cell component consists of a gold electrode in contact with an acidified aqueous silver phosphate solution. Fig 4 shows construction of the standard \( E \)-cell component.
registered charge values can be easily read-out at the constant value of the current by the method of digital time measurement; the following dependence is used:

$$q \frac{t}{e} /10/$$

To read the registered charge the polarity of the applied voltage across the cell is now reversed, so that the silver-plated gold electrode is made the anode and the silver cup the cathode, the silver will be stripped from the gold electrode and deposited onto the cup. This mode of operation is referred to as read-out or as a clearing the E-cell device. At the start of clearing, simultaneously, the electronic counter of time is started.

When all the silver has been completely stripped from the gold electrode the cell is said to be read out. If sufficient voltage is available in the external circuit, the applied voltage across the E-cell unit will then abruptly rise to approximately 1.0 volt (see Fig 5).

Fig.5 Electrochemical integrator /E-cell/ operating curve

The sharp voltage change, which occurs when stripping is complete is a quantitative signal that the cell is read-out. It can be used to accurate the threshold circuit and to stop electronic counter.

The read out, in this way, value of electrical charge is easy to be processed by digital methods into an appropriate code and registered by the means of a punch or a magnetic tape.

EXPERIMENTAL MEASURING EQUIPMENT

On the basis of discussed here analogue-digital methods of measuring the traffic parameters, at the Telecommunication Institute of Warsaw Techni­cal University, the measurement device called WMR /Polish abbreviation: multiparameter mea­surer of traffic/ has been elaborated.

This device consists of separate measuring channels and common equipment (Fig 6). The measuring channels containing 2 electro-chemical integrators each, are appropriately adapted to the registration of the traffic charge, /channels of A type/, number of events /channels of B type/ or the time of congestion /channels B too/.

The device has the module design, which allows for the adaptation of total number of channels and their division into channels of A and B type to the needs of a given exchange. The common device of relatively simple design performs read­ing out of the registered charge in the integrators of measurement channels. The integrators are successively connected to the reading circuits /10 integrators simultaneously/ by means of the

![Commutator](https://example.com/commutator)

Fig.6 Block diagram of the WMR equipment

To provide the continuation of measurement, each measurement channel is equipped into two integrators. In the successive quarters, these in­tegrators are connected alternately to the mea­surement circuit and to the device reading out the registered in previous quarter charge.

THE USE OF ANALOG-DIGITAL METHODS FOR DETERMI­NATION OF PROBABILITY DISTRIBUTION OF QUANTITIES CHARACTERISTIC OF TELEPHONE TRAFFIC

The analog-digital methods can be used not only for observing the parameters of telephonic traffic but for the data storage as well, permitting the defining of probability distribution of quantities characteristic for that traffic.

The exhaustive presentation and reasoning of the idea of the above mentioned methods would need the introduction of numerous definitions. Here I will only confine myself to presenting the simple example of the above idea.

Let us assume that the purpose of the observation is obtaining the probability distribution of instant values of the telephonic traffic intensity. The sample history record of the traffic process being analysed has been presented in Fig 7.

As we know, the probability distribution of this process can be assessed basing on the formula:

$$P\left[ x/\tau = x \right] = \frac{1}{\mu} /11/$$

where: $T$ - observation period, $T = \sum_{i=1}^{n}$ is combined /summed up/ time, during which the time history record of process $x/\tau$ assumed adequacy the value $x = 0, 1, 2, ..., n$

Thus, using the classic analog method of defining $P\left[ x/\tau = x \right]$ it is necessary to discover the state during which the process has assumed adequately value $x = 0, 1, 2, ..., n$ and to measure
of time sections \( t \), corresponding this state respectively. This simple principle of defining \( p [x/t = x] \) is rather troublesome in technical realization, among others, because it needs the use of window discrimination for discovering the state of a process /see [1]/,

\[
T_{\text{ref}} = \frac{A_t}{\Delta t_i}
\]

Fig. 7 Probability measurement—present method /see [1]/

In differentiation from the above described classic method, the suggested one of defining the distribution of the traffic process, needs only the defining in the result, of measuring the field value of geometrical figures \( S_2, S_3 \ldots S_{-1} / \text{see Fig 8} / \), which can be determined by means of measuring adequate values of electrical charge by means of analog digital method.

Fig. 8 Probability measurement—suggested method

It is easy to show that if the variability scope \( x/t \) is divided into \( n-1 \) of the same intervals \( \Delta x_i \) at the length chosen in the way within each of the intervals can a change \( x/t \) occur "up" or "down" only about one state /one unit/, then \( p [x/t = x] \) can be defined by means of formula:

\[
p [x/t = x] = \frac{S_{x-1} - S_x + S_{x+1}}{\Delta x_1^2}
\]

/12/

It is worth noticing that in case of a suggested method the record /diagram/ of the \( x/t \) is not necessary. It is enough to know the value of the fields \( S_x \) where \( x = 0, 1, 2 \ldots n-1 / \text{see Fig 9} / \).

\[
x_1, x_2, \ldots, x_n
\]

\[
\Delta x_i = \frac{T_{x/t} \Delta x_i}{(S_0 - S_1) - (S_1 - S_2)}
\]

\[
S_{x+1} = S_0 - 2S_1 + S_2
\]

Fig. 9 Principle of determination \( p [x/t = x] \)

Thus, at the simplified assumption, that the scope of variability \( x/t \) is divided into the same intervals \( \Delta x_i \) for determination \( p [x/t = x] \) it is enough to define the fields value \( S_x \) contained between the time axis and "field" values \( S_1, S_2 \ldots S_{-1} \) contained between the straight lines carried from the points \( x = 1, 2 \ldots n-1 / \) and an adequate part of a diagram \( x/t \). Of course the values \( \Delta x_i \) and \( T \) ought to be also known.

The above mentioned simplified assumption is not rigorous. It can be shown that the method can be used for definition of \( p [x/A] \) for the case in which the division of the variability scope \( x/t \) is made in relatively free way. In a case like that, however, the formula /12/ cannot be used, and solution of a problem needs solving of an adequate system of linear equations, but the idea is similar.

FINAL REMARKS

The analog-digital methods presented in this paper, based on the measurements of electrical charge guarantee:

- observation of different traffic parameters at the use of approximate procedure; which makes the use of relatively cheap, universal measuring equipment possible;
- adaptation of measuring equipment to the measurement circuits of numerous presently exploited telephonic systems;
- primary treatment /reduction/ of data during the storage, right through the properties of the method /summing up, integration/

- performing the observation continuously, eliminating in this way the influence of sampling interval over the statistic accuracy of obtained results.

As to the last point, it is worth remembering that the problem of sampling interval influence over the accuracy of traffic measurements was the subject of numerous publications among others [2],[3],[6],[7].

It is to be emphasized that the discussed here methods, which provide the continuity of observation allow for entire elimination of the error of which the source is measurement discontinuity/sampling interval/ inherent for other methods.

On the other hand, the disadvantage of the discussed methods is a certain influence of the resistors tolerance in measurement circuits over the technical accuracy.

The electrochemical integrator itself, in the process of registration /storage/ and reading out the charge introduces an error. The research works showed, however, that the use of adequate circuit solution in the measurement equipment, allows for a remarkable reduction of this error.

Thus, the analysed here methods in some cases are profitable for measurement practice.

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