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An Uncertainty Investigations for Measurements of Telecommunication Equipment Signals

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Abstract: The research considers the problems that occur during the testing of telecommunication devices. One of these problems is the uniqueness correspondence of the measured parameter of the communication apparatus to normative values in case of various distribution functions of measurement results.

Key words: Testing, normative, apparatus, functions, measurement results, communication

INTRODUCTION

Telecommunication apparatuses are necessarily subject to certification during the passage of certification they undergo various tests and inspections, the results of which in turn undergo processing by processing methods of test results. The results of certificate issuing depends on the objectivity and reliability of the conducted tests. Wherein, true values of measurement results may differ from the actual measured results for various reasons such as: environmental effects instrumental errors of measuring instruments, system errors, etc. As a result, an interval of values is formed in which the true value is also consisted. The determination of such an interval is usually based on the uncertainty calculation (Anonymous, 2018a, b).

The main part: The accuracy assessment of the measurement results is carried out in 3 stages:

1st stage: Measuring problem construction. Wherein:

- The output value of Y is given (unknown, measured value)
- Input values $X_1, \ldots, X_M$, affecting the output value Y are determined
- A measurement model is constructed $Y = f(X_1, \ldots, X_M)$
- The probability distribution type for the input values Xi is determined based on the obtained information

2nd stage: Transformation of input values distributions. In this case, the probability distribution density of the output value Y is determined based on the probability distribution density of the input values X_i and the used measurement model.

3rd stage: Based on the determined probability distribution density of the output value Y, the final measurement result is formed.

For example in case of normal distribution of the input values (Anonymous, 2018a, b), the coverage interval of the input values Y is determined, corresponding to the given probability (probability of coverage). For calculations the following notations are used: x_i-ith measurement result; y-standard deviation of measurement result; $u(x_i)$-standard uncertainties of the corresponding measurement; $u_c(y)$-total standard uncertainty.

There are 2 types of uncertainty assessment $u(x_i)$ for observed values x_{ii}, depending on the type of known distribution functions. These types are A and B.

If the results of multiple measurements or observations are known (statistical data), then the statistical processing methods of data arrays are applied for their processing. Such an assessment of standard uncertainty is a type A. For example the determination of the standard deviation values and the mean value of the multiple measurements results, if they correspond to a Gaussian distribution (Anonymous, 1999). If the distribution does not correspond to the normal, then an example of that is the application of least squares method for curve fitting to the data and for obtaining the appropriate assessment of the approximation parameters and their standard deviations.

If the distribution function is exactly known, then type B is used to assess the standard uncertainties values. As an example, known methods of calculating uncertainty for the normal distribution, triangular, uniform (rectangular), U-shaped or trapezoidal. Standard uncertainty calculations $u(x_i)$ are performed at a known maximum range value ($\pm a_i$) or for normal distribution with standard deviation of observations s_i.

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Thus, to construct a distribution model, the sum of special separate distributions of the normal distribution law with theirs parameters can be used. In a particular case, this might be one normal distribution law.

To use a certain data processing method it is necessary to clarify the belonging of the observation results x_{ik} to the normal distribution. Depending on the number of observations n (Tretyak, 2004), various known criteria might be used. The Pearson χ^2 criteria or ω^2 Mises-Smirnov are the most accurate for n>50. For a smaller number of measurements (50>n>10) it is recommended to use the compound criterion specified in Table 1 of the standard (Anonymous, 2011). In this case, the belonging determination is carried out according to, 2 criteria. By criteria 1, the value $\tilde{d}_i$ (1) is calculated:

$$\tilde{d}_i = \frac{\sum_{k=1}^{n} |x_{ik} - \bar{x}_i|}{n \cdot S_i^*} \quad (1)$$

where, s_i^* -biased assessment of standard deviation Eq. 2:

$$S_i^* = \sqrt{\frac{\sum_{k=1}^{n} (x_{ik} - \bar{x}_i)^2}{n}} \quad (2)$$

The observations results can be considered as a normally distributed, if the condition 3 is fulfilled:

$$d_{1-q_1/2} < \tilde{d}_i \le d_{q_1/2} \quad (3)$$

where, $d_{1-q1}/2$ and $d_{q1/2}$ distribution quantiles (known tabular values).

Criteria 2 it can be assumed that the observations results of the parameter x_i belong to the normal distribution, if there is no more than m of differences $|x_{ik} - \bar{x}_i|$ exceeded the value in Eq. 4:

$$z_{p1/2} . S_i \quad (4)$$

where, $Z_{p1/2}$ the upper distribution quantile of the normalized laplace function corresponding to the Probability $P_1/2$. S_i the standard deviation assessment Eq. 5:

$$S_i = \sqrt{\frac{\sum_{k=1}^{n} (x_{ik} - \bar{x})^2}{n-1}} \quad (5)$$

The value of P_1 is determined from Table 1 (Anonymous, 2011) with a significance level of $q_2 = 0.05$ and the number of observations n.

If any of these 2 criteria is not fulfilled, then it is considered that the presented array with its measurements results does not correspond to the normal distribution law and to determine the type of distribution, other processing methods should be used. For example, the increasing of the coverage coefficient K. This is the simplest method but it has a disadvantage an uncertainty increasing of U.

In the case of the normal distribution of measurement results, the true value of measurement result is included in the confidence interval in Eq. 6:

$$[y\text{-}U,\ y\text{+}U] \quad (6)$$

As it can be seen from Eq. 6 that, the measurement accuracy depends on the uncertainty value U. By its increasing, the uniqueness of the measurement result decreases and at the boundaries of the normative range of values, a situation arises when making a unique conclusion about the correspondence of the measured parameter to the technical requirements is impossible. Therefore, in the case of a normal distribution, the

Table 1: Measurement results

Measurement number	Measurement results (msec)	Measurement number	Measurement results (msec)	Measurement number	Measurement results (msec)
1	101.19	19	102.3	37	101.37
2	101.28	20	102.37	38	102.41
3	102.55	21	101.47	39	102.17
4	102.67	22	100.92	40	101.02
5	102.44	23	101.01	41	101.11
6	102.31	24	101.13	42	102.11
7	102.29	25	100.76	43	102.17
8	101.31	26	101.44	44	102.34
9	101.55	27	100.65	45	102.53
10	100.90	28	101.25	46	101.15
11	100.99	29	100.79	47	100.90
12	100.81	30	101.19	48	100.87
13	102.69	31	102.43	49	102.31
14	101.02	32	102.75	50	100.96
15	101.04	33	100.97	51	101.32
16	101.47	34	101.04	52	101.55
17	101.35	35	100.80	53	101.18
18	102.23	36	101.29	54	102.02

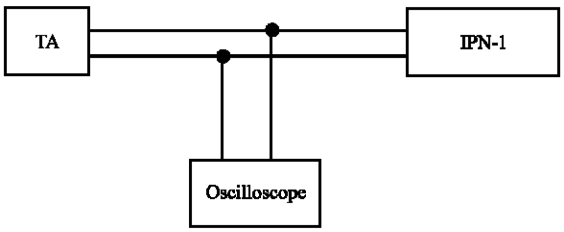

Fig. 1: The measurement scheme of pulse repetition period

Fig. 2: Scheme and external appearance of the measuring equipment of the pulse repetition period

uncertainty U must be minimized as much as possible for these purposes there are a large number of known methods.

Consider the observation results processing for the observed values distribution, different from the Gaussian (normal) Law.

The processing methods of telecommunication equipment parameters for observed values distribution, different from the normal law are not given the enough time and consideration.

We consider the measurement results processing using an example of measuring the pulse repetition period when the telephone number is repeatedly dialed by a pulse dialing device.

Let us consider an example of measuring the pulse repetition period in a series of dialing for a telephone with a pulse method of transmitting dialing signals. The measurement scheme is shown in Fig. 1, the external appearance of the equipment is shown in Fig. 2. The measuring instrument for pulse dialers parameters (IPN-1) stabilized at the contacts of connecting the Telephone Apparatus (TA) to the subscriber line voltage of 60 V. On the TA keyboard, the set of characters "0-9" was consequentially produced in the amount of 54 sets. The sequence of the set was monitored on the IPN-1 display. The parameters of the transmitted pulse were determined from the oscilloscope which has a measurement error of ±0.01 (msec).

MATERIALS AND METHODS

In this research, to obtain the pulse repetition period the Oscilloscope equipment has been used and transfer obtained results on excel sheet and compare these results with Simulink program using MATLAB Software after contacted with telephone to determine the type of distribution, a distribution function histogram of the observation results. That the obtained values have formed a distribution that does not have any symmetry and without further processing it's clear that, the application of the normal distribution law is not possible. This will be confirmed graphically.

RESULTS AND DISCUSSION

Table 1 presents the results of measuring the pulse repetition period in a dialing series for a telephone with a pulsed method of transmitting dialing signals. To determine the type of distribution, a distribution function histogram of the observation results is drawn (Fig. 3). To do this, the whole range of measured values is divided into equal ranges and then the frequency or number of values in each range is calculated.

From the histogram (Fig. 3) it's shown that the obtained values have formed a distribution that does not have any symmetry and without further processing it's clear that, the application of the normal distribution law is not possible. This will be confirmed graphically.

Suppose that the observation results (Table 1) correspond to the normal distribution law. Then for their processing it is possible to use the processing methods of the observation results for a normal distribution function. Then the arithmetic mean (measurement result) (Eq. 7) as:

$$\bar{x} = \frac{\bar{x}_1 - \bar{x}_2}{2} = \frac{101.1157+102.3732}{2} = 101.74444_{MC} \quad (7)$$

The standard deviation assessment of the measurement result s is 0.667. When the coverage coefficient of K is 2, the expanded uncertainty of U = 1.334. Then the total measurement result of Y will be included in the interval from 100.4104-103.0784 (msec).

Another processing method is possible to use. Standard deviation values s_1 and s_2 of separate local

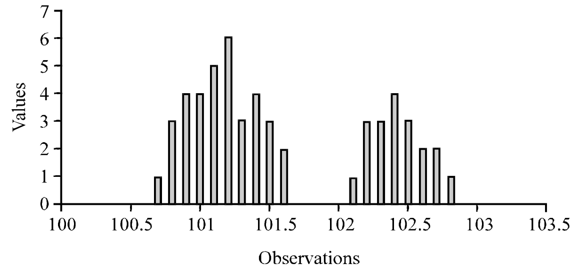

Fig. 3: The distribution function histogram of observation results

distribution functions for the observation results are equal to 0.2367 and 0.1938, respectively. Then, taking into account, the coverage coefficient K = 2, the values of the expanded uncertainty U1 and U2 are 0.4734 and 0.3876. If the total observation result is presented in the form of $\bar{X}_1\text{-}U_1 \le Y \le \bar{X}\text{+}U_2$, then it will be included in the interval from 100.6423-102.7608 (msec).

A sufficient large difference in the measurement results was obtained (ranges in which the true measurement value is included). Studies of methods for processing the multiple measurements results showed that if the normal distribution law cannot be used, the distribution function form has a big influence on the measurement result. Thus in each specific case, the distribution function of the observed values should be analyzed and the range also should be divided into separate distribution functions. This is especially, important in areas which have boundaries with the normative values of the observation results areas.

As a result of the problems analysis of processing the observation results, the following techniques of reducing the uncertainties for the distribution functions of observation results that is different from normal distribution law are proposed:

The determination of the distribution function belonging to a distribution that is different from the normal law. The distribution function analysis to determine the local areas with normal distribution laws and to apply local calculations of standard uncertainties to them. Using mathematical comparison methods with standard uncertainties under the assumption that the function has a normal law.

Processing of observation results with the aim of converting the uncertainties of the form A-B and further using of standard uncertainty calculations $u(x_i)$ according to known expressions of rectangular (uniform), triangular, trapezoidal, U-shaped (arcsine) distributions.

Measurement result presentation in a visual form of distribution functions histograms of the observation results x_i in case of the uncertainty decision existing on whether or not the telecommunication equipment parameter corresponds to normative requirements.

CONCLUSION

The normal distribution law is the main type of measured values distribution used in calculating the results uncertainty. But often, there are situations when the application of the normal distribution is impossible. The research considers one of the techniques of calculating uncertainty when the distribution is different from the normal.

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