Максимальная эффективность обнаружения ИИ наблюдается при расположении ИСП к обследуемому объекту на расстоянии не более 10 см при скорости его перемещения (трассирования) вдоль объекта не более 10 см/с. По мере приближения к ИИ частота следования сигналов возрастает.

Литература

1. Уроки аварий на промышленных облучательных установках / Международное агентство по атомной энергии. – Вена, 1997.

2. Wheatley J., Ortiz-Lopez P. IAEA Radiation Events Database (RADEV), Radiological Protection of Patients in Diagnostic and Interventional Radiology / J. Wheatley, P. Ortiz-Lopez // Nuclear Medicine and Radiotherapy: Proc. Int. Conf. Malaga, 2001 / IAEA-CN-85-268. – Vienna, 2001.

3. Lessons Learned from Accidents in Industrial Radiography: Safety Reports Series No. 7 / International Atomic Energy Agency. – Vienna, 1998.

4. Lessons Learned from Accidental Exposures in Radiotherapy: Safety Reports Series No. 17 / International Atomic Energy Agency. – Vienna, 2000.

5. ТУ BY 100345122.091-2017 «Измерители-сигнализаторы поисковые ИСП-РМ1703GNA-II».

6. Mobile Intel® Pentium® Processor–M. Datasheet / Intel Corporation.

UDC 535.3

UNCERTAINTY ESTIMATING OF THE COMPLEX VALUES IN ELECTROMAGNETIC MEASUREMENTS

Saukova Y.N., Malashonak S.V.

Belarusian National Technical University
Minsk, Belarus

Electromagnetic quantities, for example, electric voltage, current, power, resistance, magnetic flux etc are of interest from the point of view of the concept of uncertainty, since most of them are complex in alternating current circuits containing capacitance or inductance.

Models of mathematical expectations of these quantities have three forms of notation – rectangular, polar and exponential. The rectangular form is [3]:

$$Z=a+bi, \quad (1)$$

where z -complex number; a – real part; b – imaginary part; i – imaginary unit, $i^2=-1$.

The polar form of notation involves the transition from Cartesian coordinates (x,y) to polar ones (r,φ) where r is the distance of the point from the origin and φ is the angle, in radians, from the positive x-axis to the ray connecting the origin of the point [3]:

$$Z = r(\cos\varphi + i\sin\varphi), \quad (2)$$

where r – modulus of complex number:

$$r = |z| = |a + bi| = \sqrt{a^2 + b^2}, \quad (3)$$

φ – argument of complex number,

$$\varphi = \mathrm{arctg}\frac{b}{a}. \quad (4)$$

The exponential form of a complex quantity is [3]:

$$Z = r*e^{i\varphi}, \quad (5)$$

where $e^{i\varphi}$ – complex number from Euler's formula.

The graphical interpretation of mathematical expectations of a complex quantity is a vector on a plane, as shown in Figure 1 (the real part of the number is plotted along the abscissa – the active component of the quantity, along the ordinate – the imaginary part (or reactive component)

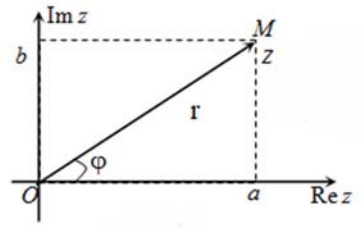


Figure 1 – Graphical representation of a complex quantity

Nowadays, there are guidelines [1–3] for estimating the uncertainty of complex quantities, given in rectangular form. For example, the author of [2] work offers several approaches to describing the uncertainty of a complex quantity: 1) using the Jacobi matrix; 2) based on alternative expressions of the law of propagation of uncertainty: a) through the correlation coefficients, б) using submatrix.

The Jacobi matrix has a block structure that can be related to the derivatives of f with respect to the individual 2D inputs [2].

$$J(y)=[J_1(y)\ J_2(y)\ \dots\ J_m(y)], \quad (6)$$

where

$$J_i(y) = \begin{bmatrix} \frac{\partial f_1}{\partial x_{1j}} & \frac{\partial f_1}{\partial x_{2j}} \\ \frac{\partial f_2}{\partial x_{1j}} & \frac{\partial f_2}{\partial x_{2j}} \end{bmatrix}. \quad (7)$$

These blocks represent 2D sensitivity coefficients. They can be related to complex partial derivatives of the function using "simple and elegant matrix". For a complex number (1), the mathematical expectation model is as follows [2]:

$$M(z) \equiv \begin{bmatrix} a & -b \\ b & a \end{bmatrix}. \quad (8)$$

Such matrices behave like complex numbers in the usual matrix operations for arithmetic: division corresponds to multiplication by the inverse matrix and taking a transposition matrix corresponds to a complex conjugation operation. In addition, if the complex function f (z) is analytic in the region of interest, then the Cauchy-Riemann relations will be applied to its partial derivatives [4]:

$$\frac{\partial f_1}{\partial a} = \frac{\partial f_2}{\partial b}, \frac{\partial f_1}{\partial b} = -\frac{\partial f_2}{\partial a}. \quad (9)$$

Equations (8) and (9) show that the complete Jacobi Matrix can be written in the form [2]:

$$J(y)=\left[M\left(\frac{\partial f}{\partial x_1}\right) M\left(\frac{\partial f}{\partial x_2}\right) \dots M\left(\frac{\partial f}{\partial x_m}\right)\right]. \quad (10)$$

An alternative expression of the law of propagation of uncertainty using the correlation coefficients assumes that the covariance matrix is symmetric and positive definite. It can always be considered in the matrix of correlation coefficients and matrix of standard deviations [2]:

$$V(X) = S(X)R(X)S(X)', \quad (11)$$

where R (X) is a matrix of correlation coefficients; S (X) is the diagonal matrix of standard uncertainties of the individual input signal of the component (i.e. the square root of the diagonal elements of V (X)).

The propagation law can be expressed in terms of R (X) by substituting (11) in (6) [2, 3]:

$$U(y) = J(y)S(X). \quad (12)$$

This gives an alternative form of the law

$$V(y) = U(y)R(X)U(y)' \quad (13)$$

An alternative submatrix approach uses formulas (6) and (13) to sum by explicitly recognizing (2x2) the internal structure of the matrices U (y), V (X), and R (X). There are m sub-matrices associated with the input quantities in U (y) [2]:

$$U_j(y) = \begin{bmatrix} u_{11j} & u_{12j} \\ u_{21j} & u_{22j} \end{bmatrix}. \quad (14)$$

In this case, the uncertainty is the product of a two-dimensional matrix of sensitivity coefficients $J_i(y)$ and a submatrix of standard uncertainties from the diagonal matrix S(X) corresponding to input j:

$$U_j(y) = \begin{bmatrix} \frac{\partial f_1}{\partial x_{1j}} & \frac{\partial f_1}{\partial x_{2j}} \\ \frac{\partial f_2}{\partial x_{1j}} & \frac{\partial f_2}{\partial x_{2j}} \end{bmatrix} \begin{bmatrix} u(x_{1j}) & 0 \\ 0 & u(x_{2j}) \end{bmatrix}. \quad (15)$$

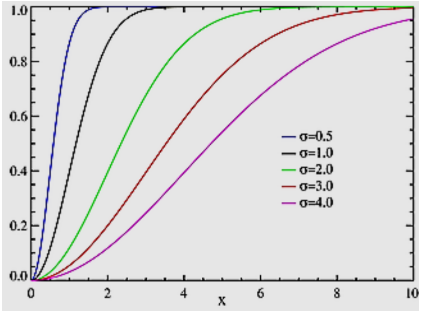
Thus, $U_j(y)$ is a two-dimensional analogue of the “scalar uncertainty component”.

The “chain rule” of uncertainty estimation, set forth in [2, 3], is based on chains of intermediate calculations considering the correlation between their results. In addition, authors assume, firstly, the rectangular form of notation of complex quantities should be replaced with an exponential one, since this form of notation allows us to directly work with both degrees of freedom that any complex quantity has. It is convenient to represent these degrees of freedom as uncertainty when measuring the vector length of a complex quantity and the angle of inclination of this vector, through which this value is set in the exponential form of the record. After all, it is these values that we obtain when measuring complex quantities, for example, electromagnetic quantities in alternating current circuit. Thus, the region of permissible values of the measured quantity will be obtained as a region in the Cartesian coordinate system (the dimensions of which are determined by the permissible error or target uncertainty for each degree of freedom) and the measured value itself can be represented as a set of vectors starting at the origin and forming the region values, which should be included in the range of permissible values of this quantity. Secondly, in some cases, it is necessary to consider different laws of probability distribution for the real and imaginary parts of a complex quantity, which can cause difficulties in assessing the range of permissible values of the quantity and verification of compliance of measurement results with requirements.

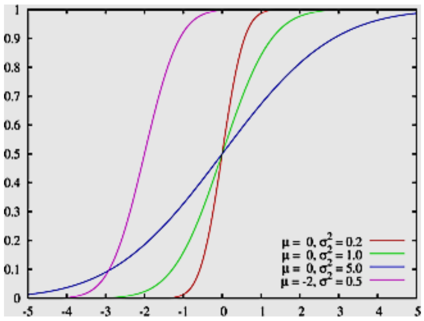
Third, if, when considering a scalar quantity, we could unambiguously set the tolerance interval on the value axis and then simply compare the measured values with it, assessing whether it falls within the tolerance field. For vector quantities, this is extremely difficult, since we do not have the means to unambiguously compare vectors with each other.

When trying to evaluate and simulate the results of measurements of a complex quantity, we are faced with the need to construct the range of values of the desired quantity based on two degrees of freedom with different distribution laws for each of them. For example, the distribution of the angle of inclination will have the form of the Rayleigh distribution (Figure 2, *a*) and the modulus of the vector of most physical quantities will have the form of the Gaussian distribution (Figure 2, *b*).

It may be difficult to combine the uncertainties of the Gauss and Rayleigh probability distributions during the estimating ofuncertainty. The range of acceptable values can be represented as a rectangle or ellipse, as shown in the figure 3 [3]. In addition, questions arise about the possible choice of priority between degrees of freedom and requirements for them. The areas of acceptable values for a continuous value are shown in the figure. Obviously, for discrete quantities, they will be described by finite sets of the geometric location of points using the mathematical apparatus of discrete geometry and set theory.



a



b

Figure 2 – Probability distribution functions of a complex quantity: *a* – Rayleigh; *b* – Gauss

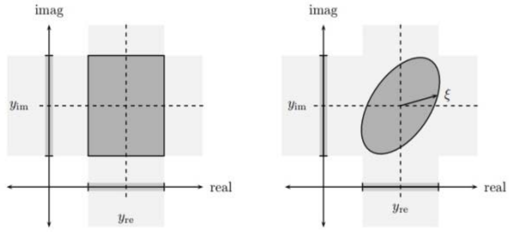


Figure 3 – Representation of the range of acceptable values:
a – with all possible outcomes, *b* – without the least likely

References

1. Dailys Arronde Pérez, Hubert Zangl, «Introducing uncertainty of complex valued quantities in measurement science education», Proc. SPIE 11144, Photonics and Education in Measurement Science 2019, 1114410 (17 September 2019). DOI: 10.1117/12.2531840.

2. Hall B.D. A computational technique for evaluating and propagating the uncertainty of complex valued quantities, Proceedings of 60th ARFTG Washington DC, USA, Dec. 5–6, 2002, 19–28.

3. Parsonson (1971). Pure Mathematics, Vol. 2, Cambridge University Press, June 2nd, 1971, ISBN13: 9780521080323.

4. Spiegel M. R., Complex variables, Schaum's Outline Series, McGraw-Hill, Great Britian, 1974.

УДК 004.056

АНАЛИЗ ТЕНДЕНЦИЙ ОБЕСПЕЧЕНИЯ ИНФОРМАЦИОННОЙ БЕЗОПАСНОСТИ В ПИЩЕВОЙ ОТРАСЛИ

Попов А.В., Серенков П.С.

Белорусский национальный технический университет,
Минск, Республика Беларусь

Постоянно изменяющиеся отраслевые технические нормативные правовые акты в сфере систем менеджмента безопасности пищевых продуктов свидетельствуют о повышении заинтересованности в управлении информацией на всех стадиях жизненного цикла продукции.

В настоящее время системы менеджмента информационной безопасности рассматриваются, как одна из важнейших составляющих процесса обеспечения безопасности пищевых продуктов. Стабильный, адекватный, надежный процесс прослеживаемости информации о качестве и безопасности пищевой продукции на всех этапах жизненного цикла продукции не возможен, если не обеспечены надлежащие условия получения, передачи и хранения этой информации. По тем же причинам невозможно обеспечить быстрый обмен информации о возможных проблемах с безопасностью продукции по звеньям жизненного цикла продукции, что, например, важно в случаях обнаружения несоответствия продукции и необходимости быстрого принятия мер по изъятию (отзыву) продукции с рынка.

В настоящее время в пищевой отрасли наблюдается динамическое развитие автоматизированных производств, компьютеризированных технологий. Налицо так называемая цифровизация пищевой отрасли. Повышение степени автоматизации на всех стадиях производства и контроля качества продукции, только повышает риски потерь информации со всеми возможными последствиями. Проблема, идентифицированная в докладе, связана с тем, что используемые технологии поддержания определенной практики документирования стали не применимы для управления электронными данными. Многие предприятия продолжают вести бумажный документооборот, получая и храня данные на бумаге даже там, где есть возможность полного использования электронной информации.

Невзирая на то, что потребность в более новых методах управления информацией (а в особенности, в управлении электронными данными) в промышленности есть, требования к целостности и доступности информации прописаны, как обязательные, при этом в отрас-