A computerized-measurement approach is described that allows measuring circuits with specified functional properties to be designed.

The use of modern computers to solve measurement problems has not only stimulated the development of new measurement methods but also required the reexamination of traditional methods. In measurements of passive complex quantities, an example is the quasibalancing method [1]. It consists of putting the measuring circuit (MC) in a state, which is called the quasiequilibrium state, in which information about one of the measured parameters is easily obtained. This state is set by adjusting some parameter of the MC. The quasibalancing method assumes the presence of quasiequilibrium conditions that are convenient for indication that the state has been attained and the possibility of reading the measured parameter from the dial or the presence in the MC of a signal that uniquely determines the measured parameter. This method simplifies both the MC and the process of its balancing. It is successfully used to measure the parameters of two-element two-terminal networks, and corresponding theoretical approaches have been developed.

Attempts to employ these approaches to measure the parameters of multielement two-terminal networks (MTP) have shown that their effectiveness is limited to measurement of the parameters of three-element two-terminal networks [2]. Use of the quasibalancing method to measure the parameters of two-terminal networks with a larger number of elements has led to solutions that are cumbersome and difficult to implement. This situation is partly explained by the fact that, as a rule, these approaches analyze the vector diagram of the MC and represent the immitance of a two-terminal network as a vector on a complex plane whose components are functions of the desired parameters. In the case of a two-element two-terminal network, each component is a function of only one parameter, but in the multielement case, each component is a function of several parameters, the vector diagram loses clarity, and its analysis is greatly complicated with an increase in the number of elements. The quasiequilibrium conditions are also complicated, and indication of the quasiequilibrium state requires function generators, which are difficult to implement without computers. The possibility of using the latter in MTP transducers and meters has allowed a qualitative step to be taken – the possibility in principle of using the quasibalancing method to measure the parameters of two-terminal networks with any number of elements [3, 4].

According to [3], the quasiequilibrium conditions are found by analysis of locations of the zeros and poles of a rational function of the measuring circuit on a complex plane. The quasiequilibrium state is attained by adjustment of a measuring-circuit parameter regardless of the frequency of the computed values of the coefficients of the function. The order in which the unknown parameters of the two-terminal network are found is strictly specified and is determined by its structure. This approach permits measurement of the parameters of a limited class of series-parallel two-terminal networks and is in many cases unsuitable when only one informative parameter is to be measured independently of others.

The approach proposed in [4] is based on representation of the hodograph of the MC function in the form of a circular curve. A quasiequilibrium state is attained when the order of the circular curve changes. This approach has the same function-
al possibilities as that proposed in [3]; moreover, in some special cases it permits an informative parameter to be measured independently of others.

Let us consider a general approach to the problem of MTP measurement by the quasibalancing method [5]. We have an MC to be balanced and formulate a rational operator function of that circuit:

\[ W(p) = \frac{a_0 p^n + a_{n-1} p^{n-1} + \ldots + a_1 p + a_0}{b_m p^m + b_{m-1} p^{m-1} + \ldots + b_1 p + 1}, \quad (1) \]

where the coefficients \( a_i \) and \( b_j \) are functions of the parameters of the two-terminal network \( x_i \) (where \( i = 1, L \); \( L \) is the number of network parameters) and the adjustable parameters of the network \( q_k \) (where \( k = 1, K \); \( 1 < K < L \)) and \( p \) is the Laplace transform variable.

From the results of measurements in the frequency or time domain, we can put together a system of equations that directly relate the measured quantities \( a_i \) for various values of a parameter \( s_i \) to the coefficients \( \{a_i, b_j\} \) (in other words, "expand" Eq. (1) in the parameter \( s_i \) into a system of equations):

\[ \Phi_r[W(a_0, \ldots, a_n, b_1, \ldots, b_m, s_i)] = a_i, \quad i = 1, 2, \ldots, r = 1, 2, \ldots, (2) \]

from which the variables \( \{a_i, b_j\} \) can be uniquely determined [2]. The symbol \( \Phi_r \) indicates functional transformations — for example, separation of the real or imaginary part of the function \( W(j\omega) \), calculation of its absolute value and phase, determination of discrete signal values, etc. Frequency, time, or a parameter of the measuring circuit can be selected as the parameter \( s_i \).

We note that the equations of system (2) can also differ in the form of their functional transformations \( \Phi_r \). Let it be required to measure the parameter \( x_j \) first and to read its controllable parameter \( q_k \) (note that \( l \) and \( k \) can have any values, i.e., any of the parameters of the two-terminal network can be measured in the first cycle). For this it is necessary to satisfy the relation (we call it the quasiequilibrium equation)

\[ x_j = cq_k, \quad (3) \]

where \( c \) is a constant coefficient.

Since the coefficients of function (1), \( \{a_i, b_j\} \), are functions of \( x_j \) and \( q_k \), satisfaction of relation (3) indicates the presence of a functional relationship between these coefficients:

\[ F(a_0, a_1, \ldots, a_n, b_1, \ldots, b_m) = 0, \quad (4) \]

We can find this dependence by solving system (2) jointly with Eq. (3). Note that relation (4) in [3] means that the coefficients of function (1) are independent of frequency; in [4], that the order of the circular curve has been reduced.

Equation (4) can be used as the quasiequilibrium condition, i.e., the parameter \( q_k \) should be adjusted until equality (4) is satisfied. In quasiequilibrium position \( F = 0 \), relation (3) is satisfied, and from the parameter \( q_k \) we can read the value of the parameter \( s_j \). After parameter \( x_j \) has been measured, any other parameter of the two-terminal network can be measured in a similar manner. This reduces the order of system (2) by one.

We illustrate the proposed approach by the comparatively simple example of determining the parameters of the three-element two-terminal network shown in Fig. 1.