INFLUENCE OF MICROWAVE MULTIPROBE MULTIMETERS RECURSIVE ALGORITHMS ON ACCURACY
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Abstract – There was developed algorithm that reduces error of multiprobe microwave multimeter. When estimating the total error the largest contribution makes mismatch error residue, the error is also appears from mutual reflections between adjacent sensors. Multiprobe multimeter measurement is indirect measurement which involves the calculation of the required parameters from sensor signals that performed with the use of stochastic approximation Robbins-Monro procedure.

I. INTRODUCTIONS
Development of VHF electronics makes economically useful introduction of energy-saving heat processing in the wide domain of technological processes. It is necessary take into account a change of object characteristics during processing and guarantees stable operation of a microwave generator, if load mismatched and non-stable. One of problems of high-powered microwave technology that appears during the use of high-power microwave systems is to limit level of reflected wave, which can damage generator. The range of load variation can be wide and the rate of change may be different. Therefore, the power supply of microwave generator is equipped with protection system. The protection allows, in millisecond time intervals reducing the generator power to a level at which the reflected power does not lead to the destruction of the generator and tuning off power supply. However, such protection interrupts the process, which in most cases is unacceptable. The solution to this problem involves the use of automated microwave tuners that compensate change in the complex load impedance over a wide range. To create such combined system it is necessary to have microwave measurement device that measures incident and reflected power, the modulus and the phase of the reflection coefficient. A multiprobe microwave multimeter places in the main waveguide between generator and termination. Such unit with the microcontroller system provides the continuous processing of the primary signal of probes with high accuracy and maximum efficiency and controls mode of generator operation.

Simulation in the microwave domain is useful in terms of reproducibility of the experimental conditions, allows to select from a variety of influencing factors, the most significant and has less than a full-scale experiment cost.

II. MAIN PART
The object of the research and simulation is the algorithm and the sensor signals error processing in the microwave multiprobe multimeter. Multiprobe microwave multimeter is a measurement device that allows characterizing simultaneously microwave signal and tract parameters. It works by restoring the standing wave pattern in the waveguide, for what used signal processing of sensors located in the tract. Multimeter model is linearized system of algebraic equations. There was proposed signal processing by Robbins-Monro procedures.

In such measurement the largest errors are almost always caused by sensor and sources mismatch.
Mismatch error appears due to unknown termination parameters, i.e. instead of incident power $P_{in}$ the measurement result is passing power, $P_{pass} = P_{in} (1 - \Gamma^2)$, $\Gamma$ reflection coefficient.

Mismatch error by definition

$$\delta_{\text{mismatch}} = \frac{P_{\text{pass}} - P_{\text{in}} (1 - \Gamma^2)}{P_{\text{in}} (1 - \Gamma^2)} \times 100\%,$$ (1)

The biggest mismatch error appears at measurement with one sensor. On the basis of its usually one estimates correction factor and define mismatch error residue. However, there are substantially lower mismatch error when two or more sensors was used. From number of sensor increasing much more use can be withdrawn in reducing the mismatch error, if not simply summarize the sensor signals, but combine the signals from the sensors in the passing power by definition

$$P_{\text{pass}} = P_{\text{in}} (1 - \Gamma^2) = \sqrt{b_0^2 - b_1^2 - b_2^2},$$ (2)

$b_0, b_1, b_2$ – intermediate variables which are functions of the sensor signals. When using this algorithm, the error at a fixed frequency is completely absent, but not in the frequency range, on the other hand sensors' addition leads to adjacent sensors mutual reflection, reflection error should be considered in the total error calculation.

Error may be significantly reduced by employing sensor signal processing with procedure of Robbins-Monro. The condition of applicability them is redundant system of linear equations , i.e., when there are more equations than independent variables. Recursive algorithms allows to improve accuracy due to using simultaneously of current measurement results and results get from previous steps [2]. Robbins-Monro procedure at $k + 1$ step is

$$\hat{x}(k+1) = \hat{x}(k) + K(k) \left[ y(k) - H(k) \hat{x}(k) \right],$$ (3)

where $y(k) = H(k) x(k) + \xi(k)$ – equation of observation. $K(k)$ – gain coefficient, $y(k)$– vector of sensor measurement results, $\hat{x}(k)$– vector of unknown parameters, $k$ – step number.

There was proposed estimation of multiprobe microwave multimeter error, consisting of four stages. First of all estimates the error of sensor. It consists of a number of systematic and random errors, which united with accounting on their distribution. Random error presumable arises from unpredictable or stochastic temporal or spatial variation of influence quantities. Method of combining errors is the root-sum of squares (RSS) method.

Since multiprobe measurement method is indirect measurements, the expression for errors of intermediate variables through the sensor error from equation (2) is

$$\Delta b = K \Delta P,$$ (4)

The third stage is an error transformation for the unknown variables. Accuracy of indirect measurement is defined by the accumulation of errors. The transition from the errors of intermediate variables to the desired variable error performs with account on the sensitivity coefficients as partial derivatives. If passing power is calculated by the formula (1) error for passing power is

$$\Delta P_{\text{pass}} = \left( \frac{1}{2P_{\text{pass}}} - 2b_0 \right) \Delta b_0 + \left( \frac{1}{2P_{\text{pass}}} - 2b_1 \right) \Delta b_1 + \left( \frac{1}{2P_{\text{pass}}} - 2b_2 \right) \Delta b_2,$$ (5)

where $\Delta b_i$ – column vector coefficients from (3), $i=0,1,2$.

When passing power is calculated, the mismatch error is added. And, depending on its relationship with the rest of error is summed with different coefficients.

The novelty of the approach lies in the fact that if the sensor signal errors become larger due to sensor signal processing them became comparable with the remainder of the mismatch error, so they could be taken into account with less coefficient. This leads to that the total error is less.

Figure 1 shows that the behavior of the iterative algorithms with filtering errors in the frequency band is not always has an advantage over algorithms without filtering. So for phase distance less than 1.75 radians (fig 1) algorithm with filtering error is more. This is because the calculated signal, which is used in equation (3), is received for a phase distance of 2.14 radians. Hence, the closer real phase distance to 2.14 radians, the accuracy is higher. To repair this shortcoming a first approximation of the phase distance can be to calculate from four sensors signals, and then on its basis to calculate the rest of computation.

![Figure 1 – Dependence of total error from phase distance for two processing algorithms with \textbf{X} filtration by Robbins-Monro procedure and without \textbf{X}.](image)

III. CONCLUSIONS

The application of Robbins-Monro procedure in the microwave multiprobe algorithm decreases measurement error. Total errors consist from mismatch residue error, mutual sensor reflection error and sensor signal processing error and due to processing became less.

REFERENCES
