CALIBRATION OF ANALYZERS OF THE MOBILE COMMUNICATION SYSTEM PARAMETERS

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Abstract. The creation and operation of mobile communication systems is impossible without determining the parameters of base stations and mobile communication systems. For these purposes, appropriate devices are used that optimally combine testing capabilities in a single portable solution, which eliminates the need for several separate control and measuring devices. One of the main types of measurements of such devices is the measurement of the power of ultra-high and extremely high frequency signals. The article presents the method of calibrating meters of directional and absorbed power of ultra-high and extremely high frequency signals using the Bird 5000-EX mobile communication system parameter analyzers complete with the Power Sensor 5010V sensor and measuring sensors, Anritsu CellMaster MT8212EA and Arnitsu SiteMaster S331E spectrum analyzers. Calibration schemes for analyzers of parameters of mobile communication systems and analyzers of mobile communication base stations (hereinafter referred to as analyzers) have been developed. A measurement model of the analyzers based on the parameters of the directional and absorbed power of ultra-high and extremely high frequency signals based on the developed calibration schemes was created. The contribution of each component of the measurement model to the calibration result and the corresponding uncertainties of the model components were determined. The measurement uncertainty budget was made based on the proposed analyzer calibration model. The influence of the most significant influential values on the accuracy of measurement results was analyzed. The content of quantitative and qualitative indicators of corrections, which must be taken into account during calibration to achieve the highest accuracy of measurements, is revealed. The practical results of studies of measurement instability are given. The analyzer calibration method described in the article can be used in calibration laboratories that have the appropriate equipment and standards.

Key words: Directional power, Absorbed power, Parameter analyzer, Calibration, Measurement uncertainty.

1. Introduction

The relentless development of mobile communications is taking place all over the world and Ukraine. New broadband communication technologies such as 4G and 5G are being created and developed. Landline phones and even landline Internet are gradually becoming a thing of the past. For the creation and operation of mobile communication systems, regulatory documents are developed and implemented by relevant industry specialists; for example, such as the recommendations of the ITU Telecommunication Standardization Sector of the International Telecommunication Union (ITU-T) [1–3], which are essentially detailed instructions for creating such systems. The frequency bands are defined by the ITU, and mobile communication systems use two main frequency bands, ultra-high (300-3000 MHz) and extremely high (3-30 GHz) frequencies. 3G technologies use frequencies in the range of 400 MHz–2.6 GHz, 4G – 600 MHz–6 GHz, 5G – 600 MHz–24 GHz.

It is impossible to create and ensure the operation of mobile communication systems without conducting the necessary measurements. Such measurements are characterized by extensive automation, great variety, high accuracy and rapid development. Together with the development of measurements, the assortment of measuring devices and even their generation changes. The devices must be functional and deviate in their readings within acceptable limits. The main quantities that are measured by devices applicable in the field of mobile communication are frequency, time and related parameters of instability, power levels of ultra-high and extremely high frequency (UEHF) signals, amplification (attenuation) coefficients of UEHF signal power, reflection coefficients of UEHF power, etc. To control device parameters, mobile communication providers usually use the most common procedure in the world, namely, calibration according to requirements [4].

An urgent issue is the application of existing and the development of new procedures for calibrating parameter analyzers of mobile communication systems in accordance with the requirements [4] according to one of the most common parameters in the field of mobile communication – measurements of the power of UEHF signals. As calibration objects, one of the most common devices in the field of mobile communication (hereinafter referred to as analyzers) was selected: parameter analyzers of mobile communication systems (Bird 5000-EX complete with Power Sensor 5010V and measuring heads, manufactured by Bird Electronic Corporation , USA), analyzers of mobile communication base stations (spectrum analyzers Anritsu CellMaster MT8212EA, Arnitsu SiteMaster S331E, produced by the transnational corporation Anritsu, Japan).

2. Drawbacks

Calibration of UEHF power sensors is not a new issue and has been repeatedly considered in editions of document EA-04/02, at different frequencies, in the latest edition [5] – at a frequency of 19 GHz. A separate application devoted to this issue, for calculating the calibration error of UEHF signal power sensors, is given in [6].

UEHF power measurement tools are used to calibrate various measuring tools in the frequency range from 30 MHz to 18 GHz [7–11]. Typical UEHF power sensor calibration schemes are known, in particular, they are given in [9–11]. For directional and absorbed power meters, the direct comparison method and the comparator comparison method are used.

The above examples are only basic, devoted only to the calibration of absorbed power sensors, and may be adjusted depending on the available calibration equipment and the characteristics of the measuring devices being calibrated.

The article discusses the issues of analyzer calibration for measurements of directional and absorbed power of UHF signals, which differ from the absorbed power sensors given in [5], the components of the budget and the uncertainty budget itself are specified, based on the calibration scheme proposed in the study.

3. Goal

The purpose of the study is to improve the calibration method of parameter analyzers, in particular, to develop a calibration scheme, create a measurement model, and determine the contribution of each component to the calibration result and measurement uncertainty.

4. Calibration Schemes of Analyzers for Measuring the Power

Calibrating the analyzers is performed by comparing the analyzer readings with the readings of the reference UEHF absorbed power meter. Since analyzers can measure both directional and absorbed power, the calibration scheme is chosen taking into account the type of analyzer being calibrated (Fig. 1, 2). The dashed lines show additional instruments that can be used for measurements, if necessary.

Let's consider the calibration method of analyzers for measurements of directional and absorbed of UEHF power signals using the example of parameter analyzers of mobile communication systems such as Bird 5000-EX complete with Power Sensor 5010V and measuring sensor, analyzers of mobile communication base stations such as Anritsu spectrum analyzers CellMaster MT8212EA and Arnitsu SiteMaster S331E. As a reference meter, the R&S NRP UEHF power meter with the NRP Z22 power converter (hereinafter referred to as R&S NRP) is used, the frequency range of which is from 10 MHz to 18 GHz, the main absolute error of the UEHF power measurement is ± 0.1 dB.

The list of measuring equipment and auxiliary equipment for the implementation of the calibration scheme is as follows: Aaronia BPSG6 OEM signal generator (frequency range from 23.5 MHz to 6 GHz, output signal level range from minus 45 dBm to +18 dBm, basic absolute error ± 1 dB); high-frequency power amplifier U3-33 (frequency range from 0.05 to 400 MHz, amplification factor – up to 25 dB); CNT-90 electronic counter frequency meter (frequency range – up to 3 GHz, main relative frequency measurement error 10^{-8}); digital multimeter Agilent 34410A (the main absolute error of measuring the frequency and voltage of the AC power supply network ± 0.5%); thermohygrometer Testo 608-H1 (temperature measurement range from 0 to 50 °C with absolute error limits of ± 0.2°C, humidity measurement range from 10 to 95% with absolute error limits of ± 3%).

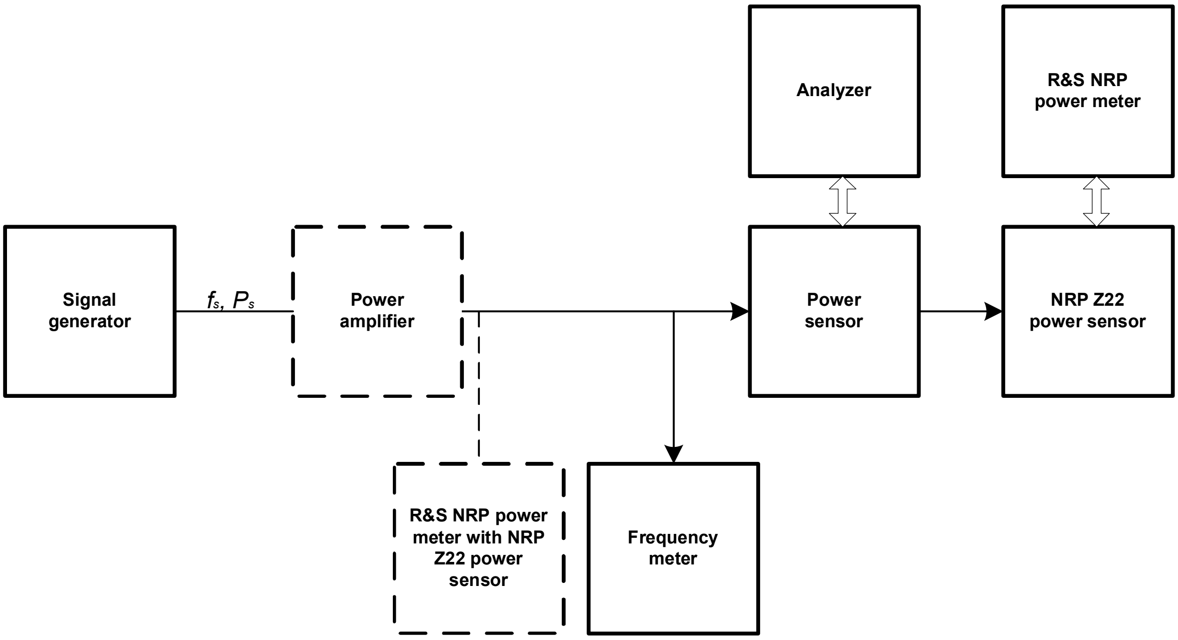
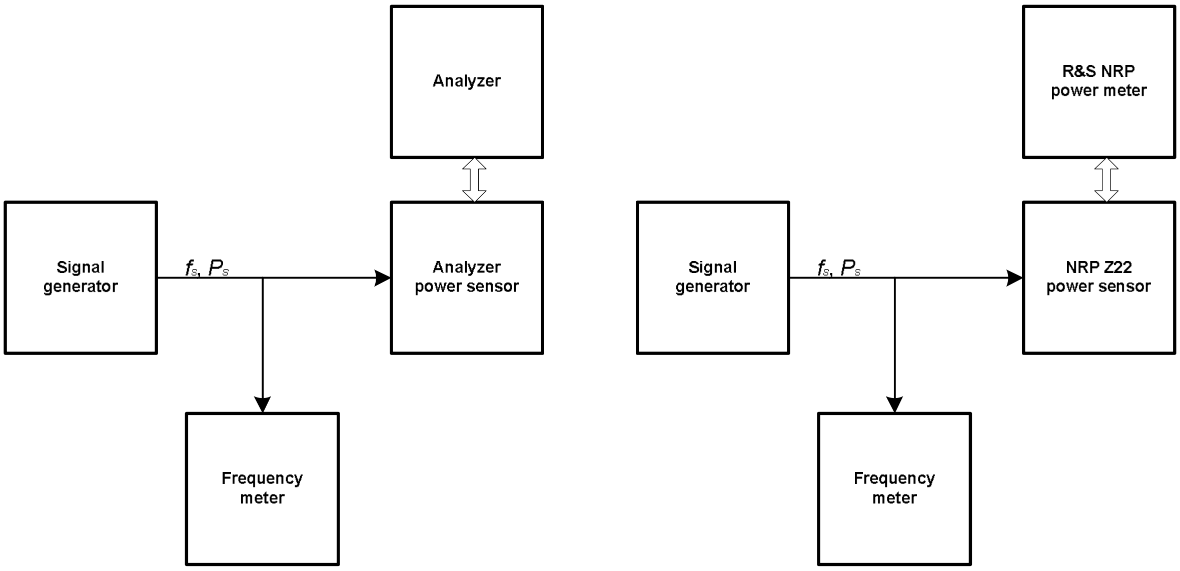


Fig. 1. Calibration scheme of analyzers for measurements of directional power



a *б*

Fig. 2. Calibration scheme of analyzers for measurements of absorbed power: a – measurement of absorbed power by the analyzer; b – measurement of the absorbed power with a reference meter

For calibration, other working standards or measuring equipment can be applied ensuring the required accuracy of measurements. Analyzer calibration operations are performed under the following environmental conditions: temperature – from 15 °C to 25 °C, relative humidity – from 30% to 80%, network frequency – from 49 Hz to 51 Hz, AC network voltage - from 198 V to 242 V. At the request of the customer, calibration can be performed under other conditions allowed by the operating documentation for working standards, HRT and analyzers being calibrated. If necessary, the analyzer to be calibrated can be placed in a thermostatic chamber.

The presence of operating documentation is checked for preparing of calibration, environmental conditions are ensured in the room where the calibration will be carried out. At the same time, the temperature and humidity of the environment are measured a Testo 608-H1 hygrometer. They conduct an external inspection of the analyzer, connect blocks and nodes of working standards and measuring equipment in accordance with the calibration scheme and according to operational documentation, turn them on and warm them up. The analyzer is prepared for operation in accordance with the operational documentation. The analyzer has the automatic test function and adjustment of its internal units and nodes. On the R&S NRP, the automatic calibration function is started, after its completion, the required value of the signal frequency is set.

If all operations of preparation for calibration are completed successfully, then proceed to the execution of calibration operations, otherwise calibration is stopped. While calibrating, dBm measurement units are set on the analyzer and R&S NRP. An Aaronia BPSG6 OEM high-frequency signal generator is fed to the analyzer sensor with a frequency of 400 MHz and a level of 10.0 dBm. The signal strength measured values with the analyzer and the R&S NRP reference power meter are indicated into the calibration report. The same signal strength measurements are carried out for levels of 13.5, 15, and 18 dBm. Repeat the operations for the following signal frequency values: 600, 900, 1700, 1800, 1900, 2100, and 2600 MHz and the measurements, if necessary, replace the measuring sensors. Calibration can be carried out at other points. If necessary, a power amplifier is deployed, and the output power of which is controlled by the R&S NRP.

5. Evaluation of Uncertainty of Measurement Results

The assessment of the measurement uncertainty of the results according to the requirements [2, 5, 12] is carried out after the completion of experimental studies. The measurement model looks like:

$$\delta P_x = P_{xs} + \delta P_{ps} + \delta P_{\gamma s} + \delta P_{crs} + \delta P_{\beta cable} + \\ + \delta P_{ts} + \delta P_{tx} + \delta P_{ds} + \delta P_{dx}, \quad (1)$$

here: δP_x is deviation of the power value measured by the analyzer from the actual value; $P_{xs} = P_x - P_s$ is difference between readings in dB; P_x is displays of the measured power value of the signal by the analyzer in dBm; P_s is displays the measured R&S NRP signal power value in dBm; δP_{ps} is correction for deviation of R&S NRP readings (from calibration certificate); $\delta P_{\gamma s}$ is R&S NRP drift correction since its last calibration (from the R&S NRP passport and can be refined if statistical data is available); δP_{crs} is R&S NRP reflected power correction (from calibration certificate); $\delta P_{\beta cable}$ is correction for attenuation in the cable providing the signal from the signal generator to the analyzer sensor (from the calibration certificate); δP_{ts} is temperature dependence correction R&S NRP (from the working standard passport); δP_{tx} is correction for temperature dependence of the analyzer (from the analyzer passport); δP_{ds} is correction for the discreteness of the R&S NRP indicator readings (from the working standard passport); δP_{dx} is correction for the discreteness of the analyzer indicator readings (from the analyzer passport).

Table. **Bird 5000-EX analyzer measurement uncertainty budget at 400 MHz**

Quantity, x_i	Estimation of the input value x_i, dB	Standard uncertainty, $u(x_i)$, dB	Probability distribution	Divider	Uncertainty contribution, $u_i(y)$, dB
P_{xs}	1.144	0.128	normal	1	0.128
δP_{ps}	0.010	0.062	normal	1	0.062
$\delta P_{\gamma s}$	0	0.030	uniform	$\sqrt{3}$	0.017
δP_{crs}	0	0.010	U-shaped	$\sqrt{2}$	0.007
$\delta P_{\beta cable}$	-0.009	0.012	uniform	$\sqrt{3}$	0.007
δP_{ts}	0	0.081	uniform	$\sqrt{3}$	0.047
δP_{tx}	0	0	uniform	$\sqrt{3}$	0.000
δP_{ds}	0	0.005	uniform	$\sqrt{3}$	0.003
δP_{dx}	0	0.005	uniform	$\sqrt{3}$	0.003
δP_x	1.145				0.151

Based on the measurement model, the uncertainty budget for the Bird 5000-EX mobile communication system parameters analyzer is presented in the Table.

The standard uncertainty of type A of the difference between the readings of the analyzer and the R&S NRP for the number of measurements performed in the calibration of the analyzer equal to n = 5 is given by the formula:

$$u_A(P_{xs}) = \sqrt{\frac{1}{n(n-1)}\sum_{i=1}^{n}\left(P_{xsi} - \overline{P_{xs}}\right)^2}, \tag{2}$$

here $\overline{P_{xs}}$ is the arithmetic mean of the differences between the readings of the analyzer and the R&S NRP. Standard uncertainty $u(x_i)$ of type B is as follows: $u(\delta P_s)$ is R&S NRP standard uncertainty from calibration certificate); $u(\delta P_{ys})$ is standard uncertainty of the R&S NRP drift correction (from the R&S NRP passport and can be refined if statistical data is available); $u(\delta P_{crs})$ is standard uncertainty of R&S NRP reflected power (from calibration certificate); $u(\delta P_{\beta cable})$ is standard uncertainty of cable attenuation correction (from calibration certificate); $u(\delta P_{ts})$ is standard uncertainty of temperature dependence correction R&S NRP (from standard passport); $u(\delta P_{ts})$ is standard uncertainty of the correction for the temperature dependence of the analyzer (from the analyzer passport); $u(\delta P_{ds})$ is standard uncertainty of the R&S NRP discreteness correction (from the reference passport); $u(\delta P_{ds})$ is standard uncertainty of the correction for the discreteness of the analyzer readings (from the analyzer passport).

The total standard uncertainty $u_c(\delta P_x)$ is determined by the formula:

$$u_c(\delta P_x) = \sqrt{u_A^2 + \sum_{i=1}^{m} u_i(y)^2}, \tag{3}$$

here m is the total number of components of type B $u_i(y)$. The expanded uncertainty is calculated:

$$U = k \cdot u_c(\delta P_x), \tag{4}$$

here $u_c(\delta P_x)$ is the value of the standard uncertainty of the signal power measurement; k is coverage factor, $k = 2$. According to the Table 1 data, the expanded uncertainty U is 0.3 dB. The results of analyzer calibration are issued with a calibration certificate in accordance with the requirements [4]. The proposed measurement model and measurement uncertainty budget provide for obtaining results in relative units - dB.

6. Conclusions

The presented method makes it possible to calibrate the UEHF directional analyzers with sufficient accuracy. The proposed uncertainty budget considers the significant components of uncertainty. The calibration scheme for UEHF directional analyzers can become the basis for accredited calibration laboratories. The proposed calibration method can become the foundation for calibrating UEHF reflected power analyzers.

7. Gratitude

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8. Conflict of interest

The authors state that there are no financial or other potential conflicts regarding this work.

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