METHODOLOGY FOR CHECK OF DIGITAL FREQUENCY METERS

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Abstract: This report describes the methodology for metrological check of digital frequency meters – method, technical equipment for metrological check and method of processing and presenting the results from the check of measuring digital frequency meters owned by Kozloduy NPP.

Key words: Metrological check, digital frequency meters, high-frequency signal generator type SMA 100A, rubidium frequency standard Symmetricom 8040, frequency of quartz oscillator.

Introduction

This methodology provides for condition, technique, technical means for metrological check and method of processing and presenting the results from the check of digital frequency meters owned by Kozloduy NPP, as well as period meters of the digital period meter type, frequency meters embedded in other devices and pulse counters. The methodology covers also the check of the embedded quartz oscillator of the checked frequency meter.

The digital frequency meter in general is a multi-functional device which measures the frequency, period (time intervals), relationship between two frequencies and is also a pulse counter. The check consist of direct measurement of frequency and amplitude with a frequency meter stabilized with frequency standard /hereinafter referred to as frequency meter/ and with an oscilloscope.

The methodology is designed for digital frequency meters which:

• measure signal in frequency range up to 2,4 GHz with relative error $\leq \pm 2*10^{-6}$;

• range of the measuring period from 10 ns to 10 s with relative error $\leq \pm 3*10^{-4}$;

• frequency of quartz oscillator: 1, 5, 10 MHz with allowable relative error $\leq \pm 3.10^{-6}$

• Minimum level of input signal to 10 mV_{rms};

• Ratio between frequencies measured by the two signals in the range of the measuring results from 10^{-10} to 10^{11}.

2. Background

The digital frequency meters measure the periodic signals with different frequency and period for the needs of radiotechnical measurements.

The frequency meters can be analogue or digital, portable or stationary. The metrological check of digital frequency meters includes the calculation of the following:

• the main relative error by the frequency of the reference quartz oscillator of the frequency meter;

• instability of quartz oscillator;

• the main relative error during frequency measurement;

• the main relative error during period measurement;

• the main error of the frequency meter when presenting ratio between two frequencies – "Ratio" function.

2.1. Applied reference equipment

The reference equipment used during the check should comply with the following requirements:

• SMA 100A high frequency signal generator with frequency range 9 kHz ÷ 3 GHz, with accuracy $1*10^{-8}$ by frequency and level -145 dBm ÷ +30 dBm, with accuracy < 0,5 dB.

• Digital frequency meter Agilent 53220A, with frequency range from 1 Hz to 350 MHz, with accuracy $\pm 1*10^{-10}$.

• Rubidum frequency standard Symmetricom 8040 with annual stability of frequency $1*10^{-11}$;

• Scopemeter OX7104-C with frequency range 10 Hz ÷ 100 MHz, with accuracy $\leq \pm 1$ %.

and auxiliary means:

• thermal moisture meter.

2.2. Safety measures and requirements to the personnel

The specialists from the Metrology Assurance Department who performs the check shall:

• have been trained and passed successfully the exam for technical operation;

• have the qualification class 4 for Industrial Safety;

• have passed industrial safety briefing;

• be familiar with this methodology;

• inspect the electrical connections of the measuring diagram prior to the check and in case of any visible nonconformities on electrical connections or any doubts about potential danger of electric shock, to stop the check until the problem is solved.

2.3. Performance of the check

2.3.1. Administrative check

It will detect the following:

• the availability of technical description and operating procedure, designation signs on the checked frequency meter, presence of conductors and connection terminals;

• if any component from the listed parts from the set of the checked frequency meter is missing, the check will be terminated and in the report from metrological check (hereinafter referred to as the report), in item 5 it will be written down "non-compliance with the requirements" and the frequency meter is declared unfit, which will be included in the report conclusion.

• Technical check

During the technical check of the digital frequency meter, the following is identified through a visual inspection:

• there are no damaged or unfixed parts;

• there are no constant impurities.

Through testing:

• functional check of the frequency meter's operability;

• operability check of digital indication;

• determination of minimum level of the input signal (sensitivity) of the frequency meter;

• functional check of the device operability in "time intervals measuring" mode.

When non-conformity to the requirements indicated in item 5 of the relevant report is identified, it will be put down "non-compliance with the requirements" and the frequency meter will be declared unfit, which is included in the report conclusion and the check will be terminated.

When compliance with the indicated requirements is identified, the frequency meter is considered functionally fit and it will be written down "compliance with the requirements" in item 5 of the report.

2.3.3. Metrological check

For metrological check a number of actions are performed, which should define the compliance of the checked digital frequency meter with the requirements for measurement accuracy indicated in the technical description and operating procedure by following their rules and consequence:

• Calculation of the main relative error by the frequency of the reference quartz oscillator of the frequency meter: through a direct measurement of the frequency of the quartz oscillator of the checked digital frequency meter performed with a standard digital frequency meter. The standard frequency meter is connected to the output for the frequency of the reference quartz oscillator (on the back panel of the digital frequency meter). Not less than 10 consequent indications of the standard frequency meter are recorded.

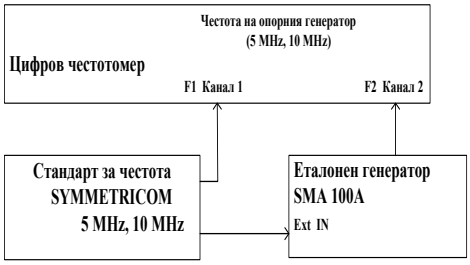
• Calculation of quartz oscillator instability: The instability of quartz oscillator is calculated as a difference between two values of the relative error of its frequency for a time interval specified in technical documentation of the manufacturer of the frequency meter. 10 consequent measurements per hour are performed for a period of not less than 6 h. In order to obtain 24-hour instability, the maximum value of instability for 6-hour period should be multiplied 4 times. Frequency adjustment of the quartz oscillator is not allowed during the check.

• Calculation of the main relative error during frequency measurement. This error is calculated for each frequency meter channel through direct measurement of the frequency in not less than four points of the frequency range. Reading of the measured frequency is in direct relation with the resolution of the measuring equipment. The resolution could be improved by selecting longer gate time, for ex. 10 s. The input of the checked frequency meter is connected to the corresponding output of the chosen standard, and depending of the requirements in the manufacturer's technical documentation, external load resistance is added or selected embedded from the working menu (50 Ω or 1 MΩ) to the checked channel. Function "Frequency" is selected from the frequency meter menu by buttons for switch-over of the front panel or back panel in case the frequency meter is a measuring unit from a standard measuring system. The measured frequency is written with two limit values **Fд.гр.** and **Fг.гр.** in the report. The standard frequency meter is synchronized with the frequency standard Symmetricom 8040. The synchronization of the digital frequency meter is performed in order to establish the deviation of the measured frequency, which depends on element basis of the frequency meter only without being influenced by the characteristics of the internal oscillator. The checked frequency meter will measure the set characteristics (amplitude and frequency) of the

signal set by the oscillator.

• Calculation of main relative error during period measurement. It is calculated for each frequency meter channel through direct measurement of the period in not less than four points of the frequency range. A measuring diagram is implemented similar to the previous check. Function "Period" is selected from the frequency meter by buttons for switch-over of the front panel.

• Calculation of the main error of the frequency meter when measuring the ratio between two frequencies – "Ratio" function. The standard oscillator is stabilized with SYMMETRICOM 8040C frequency standard. The both frequency meter inputs measure simultaneously the sent frequencies F1 and F2, its display shows the ratio F1/F2. F1 is the frequency sent to channel 1 (CH1, or channel A) of the frequency standard, F2 is the frequency sent to channel 2 (CH2, or channel B) of the standard generator SMA 100A.



The ratios of standard frequencies are measured in two points of the frequency range.

• During metrological check of the pulse counters the absolute error is calculated for recorded number of pulses. The metrological check of the pulse counters is performed through comparison of pulses formed by input measuring signal (pulse voltage with positive polarity) for a certain time period. From the corresponding output of the selected standard a pulse signal is sent with amplitude values recommended by pulse counter's manufacturer and frequency according to the table. Measuring time (1s, 10s or 100 s) is selected by a button on the front panel of the checked counter. 5 measurements are performed for each of the measured values in order to identify recurrence of the results.

2.3.4. Processing of the results from the check

• The main relative error of the frequency of the reference quartz oscillator is obtained from the data obtained from the measurements, and their arithmetical mean value is calculated according to the formula:

$$f_{cp} = \frac{\sum_{i=1}^{n} f_i}{n} \qquad (1)$$

where f_i is the value of reference frequency measured by the standard frequency meter, Hz;

n – number of measurements.

The relative error of the frequency of the quartz oscillator $\delta_{кв}$, %, is calculated according to the formula:

$$\delta_{кв} = \frac{f_{cp} - f_{ном}}{f_{ном}} \cdot 100, \% \qquad (2)$$

where: $f_{ном}$ – nominal value of the quartz oscillator frequency, Hz.

$\delta_{кб}$ and $\delta_{доп}$ are compared according to the formula:

$$\delta_{кб} \le \delta_{доп}, \qquad (3)$$

where $\delta_{доп}$ is the relative allowable error according to the technical description and operating procedure.

• From the data obtained during the check of the quartz oscillator instability γ, the relative value of the instability of the quartz oscillator frequency is calculated according to the formula:

$$\gamma = \delta_{oi} - \delta_{oi-1} \qquad (4)$$

where: δ_{oi} is the relative error of the quartz oscillator frequency at the end of the i^{th} interval;

δ_{oi-1} is the relative error of the quartz oscillator frequency at the beginning of the i^{th} interval.

The checked device corresponds to the requirements from the manufacturer's technical specification if the highest instability value from the obtained ones γ_{max} does not exceed the value specified in the technical description.

$$\gamma_{\max} \le \gamma_{доп} \qquad (5)$$

• From the data obtained during the measurements, the relative error of the frequency, %, is calculated according to the formula:

$$\delta_f = \frac{f_{ср.пр} - f_д}{f_д} \cdot 100 \qquad (6)$$

where: $f_{ср.пр}$ – arithmetical mean value of the two recorded indications , $f_{с.ср.}$ and $f_{д.ср}$ of the checked frequency meter; $f_д$ – the actual value of the frequency set by the standard oscillator. The checked device

corresponds to the requirements of the manufacturer's technical specification if the following requirement is fulfilled:

$$\delta_f \le \delta_{доп} \quad (7)$$

where: $\delta_{доп}$ – allowable error, in %, specified in the manufacturer's technical specifications.

• From the data obtained during the measurements, the relative error of the frequency meter, %, during measurement of the frequency periods set by standard oscillator, is calculated according to the formula:

$$\boldsymbol{\delta_т = \frac{T_{пр} - T_д}{T_д} . 100, \%} \quad (8)$$

where:

$T_{ПР}$ – period value, measured by checked measuring equipment;

$T_Д$ – period value, measured by standard generator.

The checked device corresponds to the requirements of the manufacturer's technical specification if the following requirement is fulfilled:

$$\delta_T \le \delta_{доп} \quad (9)$$

When calculating the main error during presenting the ratio between two frequencies – "Ratio" function. From the data obtained during measurements in compliance with item 6.3.1.5, the absolute error is calculated according to formula:

$$\Delta = \left(\frac{F_1}{F_2}\right) np - \left(\frac{F_1}{F_2}\right) д \quad (10)$$

where:

$$\left|\Delta_{пр}\right| \le \left|\Delta_{доп}\right| \quad (11)$$

$\left(\frac{F_1}{F_2}\right) np$ – ratio (nondimensional number) between two frequencies measured by the checked frequency meter;

$\left(\frac{F_1}{F_2}\right) д$ – calculated ratio (nondimensional number) between two frequencies set by the standard generator.

The checked device corresponds to the requirements of the manufacturer's technical specification if the following requirement is fulfilled:

$$\left|\Delta_{пр}\right| \le \left|\Delta_{доп}\right| \quad (11)$$

• For pulse counters: From the data obtained during measurements, the measured value of the number of pulses is calculated, which has maximum deviation from the actual value $N_{max,изм.}$.

The absolute error is calculated according to the formula:

$$\Delta_N = N_{max,изм.} - N_д \quad (12)$$

where:

$N_{max,изм.}$ – the highest measured value of the number of pulses recorded by the pulse counter;

$N_д$ – the actual value of the number of pulses recorded by the standard frequency meter.

The checked pulse counter corresponds to the requirements of the manufacturer's technical specification if the following requirement is fulfilled:

$$\Delta_{Nдоп.} \le 0,01\% \pm 1dig \quad (13)$$

In case of non-compliance with the requirements of any of the checked metrological characteristics of the digital frequency meter, it is written down "non-compliance with the requirements" in item 5 of the report, and in conclusion the checked frequency meter is declared unfit.

3. Conclusion and presenting the check results

The data from the performed check of the digital frequency meter are put down in a metrological check report.

For frequency meters which comply with the requirements of the current methods, a metrological check certificate is issued according to the requirements and they are labelled for validity.

For frequency meters which do not comply with the requirements of the current methods, a notice for unfitness is issued and they are labelled with a prohibition sign.

References

[1] Agilent 53200 Series 350 MHz Universal Frequency Counters/ Timers;

[2] BK Precision Instruction Manual Model 1823A 2,4 GHz Universal Frequency Counter

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