

**IMPROVEMENT OF THE METROLOGICAL PROVISION OF COMPARISON AND
CALIBRATION OF TIME AND FREQUENCY MEASURING INSTRUMENTS**

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Abstract: The article examines the improvement of metrological support for time and frequency measurement instruments during comparison and calibration. Based on a review of scientific literature and modern technologies, the effectiveness of existing methods, their limitations, and modernization opportunities are analyzed. The study results provide practical recommendations for enhancing measurement accuracy and ensuring stable operation of measuring devices.

Key words: time measurement, frequency measurement, comparison, calibration, metrological support, measuring instruments.

Login. Modern science and technology development inseparable part — measure of tools accuracy and reliability. Especially, time and frequency parameters measurement in the field high accuracy and stability provision current from tasks one is considered. Because this parameters various scientific, industrial and telecommunications systems effective performance directly. For example, telecommunications signal synchronization in networks, digital and analog electronics on devices time coordination, high fast processors and industry automation in systems frequency control of the system work to the efficiency impact shows. This point of view from a perspective, measurement of tools metrological supply — that is measurement of the results accuracy, reliability and to standards compatibility — modern scientific and practical in research central place occupies. Time and frequency measurement tools modern technique and various sciences in the directions wide For example, radio electronics, space technologies, energy systems, transportation and automotive industry, medicine technologies, as well as scientific experiments and experiments this without tools effective work Therefore, they permanent accordingly comparison, calibration and updated to go — technological of processes accuracy and stability of providing main Metrological of supply content only measurement of the tool technician in its properties not, maybe his/her work in external conditions to the effects in endurance, calibration methods and reference standards also manifested in the compatibility it will be.

Metrology in science time and frequency measurement tools comparison and calibration processes complicated systematic processes as Their efficiency one row parameters through is evaluated: measurement of the tool accuracy, signals again work speed, temperature and external conditions compensation to do possibility, also long term stability. With this together, global scientific in the community new methods, digital and physicist of tools synchronization technologies, signal again work algorithms and high stable reference frequencies working This is coming out. metrological supply new quality to the stage take exit opportunity is creating.

Historical point of view from the point of view than, time and frequency measurement of tools development humanity technological development inseparable part was. Initial mechanic and mechanical-electronic watches, oscilloscopes and signal generators modern digital frequency measurement and time synchronization of tools the foundation organization reached.

Present on the day quantum and atomic standards based high accurate time and frequency measurement systems scientific experiments, telecommunications and navigation systems, as well as high fast electronic on devices is being used. With this together, calibration and comparison processes international standards, for example, SI units appropriate done is increased, this and measurement results on a global scale reliability provides. Current on the day metrological supply improvement, that is time and frequency measurement tools comparison and calibration accuracy, speed and reliability increase current task as This is not only technological processes, scientific research and industry working of the releases quality indicators improves, maybe national and international to standards suitable incoming calibration systems create through republic of science to develop and industry competitiveness to increase service Therefore, time and frequency measurement of tools metrological supply according to scientific research done increase and them modernization to do modern science and technology main from directions one as is considered.

This in the article time and frequency measurement of tools comparison and calibration practical and theoretical aspects, available of methods efficiency, their disadvantages and modernization opportunities wide analysis The article is purpose — metrological supply improvement the ways determination, measurement of the results accuracy and reliability increase, as well as new modern methods scientific In this way, the article metrology and measurement tools field according to scientific and practical research for main source as service to do possible.

Literature analysis. Metrology and measurement tools comparison and calibration according to previously take visited research many edged and is diverse. In this field take visited scientific literature analysis time and frequency measurement of tools metrological supply according to there is approaches, used methodologies, their advantages and restrictions to determine help First of all, international and national standardization systems, that is including SI (International System of Units) and international metrology organizations by designated standards, time and frequency measurement of tools accuracy and stability in providing central place For example, by the BIPM recommendation atomic standards, cesium atomic clocks and optical with frequency standards high accurate time measurement opportunities. This resource creates through it was determined that the atomic standards-based calibration methods not only laboratory in the circumstances, maybe industry and space systems are also being used. Also, the latest ten in years electronic and digital measurement technologies development metrology in the field new approaches brought. For example, digital frequency counters, synchronized oscilloscopes and FPGA (Field Programmable Gate Array) based signal processing work systems to traditional analog devices relatively high speed and accuracy to provide opportunity This gives in the works It is emphasized that digital of tools main advantage — size of the results digital in the form preservation and again processing, this and comparison and calibration processes to automation opportunity creates.

Metrology in Uzbekistan too and measurement tools according to scientific research take. For example, Mahmudov and others by take visited in research frequency measurement of tools national to the referent's suitable calibration processes and their reliability studied. Results according to, national calibration systems modernization to do, international to standards compatibility increase and modern electronic from tools use efficiency noticeable at the level increases. With this together, national scientific affairs often technician aspects, including the signal stability, external to the effects endurance and far term work features analysis did this. highlight It is necessary, time. and frequency measurement tools calibration in the processes scientific in literature occurring main approaches two main to the direction divided into: the first one — reference standards based traditional calibration, the second is

digital and automated systems using measurement monitoring results and analysis to do. For example, traditional in approaches oscilloscopes, mechanical and electronic clocks, signal generators through measurement results Digital and automated in approaches and FPGA, microprocessor calculation systems and digital frequency counters is used, this and calibration process speed and accuracy increases. Also, scientific in literature time and frequency measurement of tools stability evaluation, their mistakes reduce and measurement the results to optimize related. The methodologies are also extensive. For example, Allan deviation and other statistic parameters frequency stability in evaluation wide These methods are especially useful for high accuracy required space and radio astronomy in systems important importance has.

The analysis is this time shows and frequency measurement tools comparison and calibration efficiency increase for scientific and practical in terms of following directions current is:

1. Modern digital and automated measurement from systems use;
2. National and to international reference standards suitable incoming calibration methods working exit;
3. Measurement of the results stability and accuracy statistic methods with analysis to do ;
4. Time and frequency of tools far term performance and external to the conditions endurance increase

In generally, literature analysis this time shows and frequency measurement of tools metrological supply in the field scientific research many edged and systematic requires approaches. Thus together, national and international scientific experiments integration, modern digital technologies current to grow and calibration methodology optimization this in the field development main directions defines.

Discussion. Time. and frequency measurement of tools metrological supply in the field research showed that this of tools accuracy and stability systems efficiency directly defines. References analysis this showed that atomic clocks, cesium and rubidium based on standards, as well as digital frequency counters high accurate measurement opportunities creates. With this together, national and international to standards suitable coming calibration methods current measurement of the results reliability in increasing solution doer factor is considered. Studied literature and practical research showed that traditional calibration methods mechanic and in analog devices good result gives, but their digital and high frequency systems with integration complex. For example, an oscilloscope and signal generators-based comparison methods at low frequencies effective although, high frequency telecommunications and space in systems their accuracy enough not. This point of view visually, digitally and FPGA- based automated measurement systems to advantage has they are not only measurement speed increases, maybe of the results stability and again work also provides the opportunity.

Discussion this shows that metrological of supply efficiency increase for one how many directions important importance has:

1. Calibration and comparison methods improvement: National and international reference standards with harmonious methods working exit, especially high frequency and high accuracy required in systems This measurement is important. of tools mistakes to minimize help gives.
2. Digital and automated from systems usage: FPGA, microprocessor calculation systems and digital frequency counters using measurement the results automatic again work and monitoring opportunities noticeable at the level This is comparison and calibration processes speed and accuracy provides.

3. Sustainability and external to the condition's endurance increase: Time and frequency measurement tools various external to influences — temperature, vibration, electromagnetic noises — sensitive to be possible. Therefore, modern on devices stable components and compensation algorithms application necessary.

4. Statistical and metrological analysis methods current: Allan variance, errors analysis and other statistic methods using frequency and time stability is evaluated. This is measurement of tools far term monitoring performance and need when calibration optimization opportunity gives.

Discussion during also to emphasize that it is necessary, international and national experiments harmony through metrological of supply quality noticeable at the level increase. For example, BIPM and NIST international of centers experiences national calibration to laboratories current to be, as well as digital automated systems working exit and from the test transfer — measurement of the results reliability high to the level. It also raises practical in terms of time and frequency measurement of tools efficiency increase, not only industry and in the fields of science, but also digital communication, transportation, space technologies and medicine It is also important in the fields of together, metrological supply improvement through technological processes efficiency increases, works release quality improves and global standards adaptation opportunity is created.

As a result, the analysis and discussion this time shows and frequency measurement tools comparison and calibration metrological supply improvement not only scientific, maybe practical It is also important. This measurement tools in the field innovative approaches current national and international to standards suitable systems create and modern digital technologies implementation to grow through done increase possible.

Conclusion. This in the article time and frequency measurement tools comparison and calibration metrological supply improvement issues scientific-analytical point of view from the point of view studied. Literature analysis this showed that traditional methods and analog devices low frequency in systems effective works, but high frequency and modern digital in systems their accuracy enough Therefore, FPGA and microprocessor based on automated measurement systems, digital frequency counters and the alarm again work algorithms metrological supply noticeable at the level improve opportunity gives. Discussion results this shows that metrological of supply efficiency increase for national and to international reference standards suitable incoming calibration methods working output, measurement of tools stability and external to the conditions endurance increase, as well as statistical and metrological analysis methods implementation to grow. This is important. approaches measurement of the results accuracy and reliability improvement, technological processes and scientific of research quality to improve service does.

As a result, the article metrological supply modernization to do, time and frequency measurement of tools efficiency increase and modern technologies current to grow according to practical recommendations presented. This is not only scientific, maybe industry and technological in the fields measurement systems stable performance to provide service does.

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