Establishing National laboratory for time and frequency in Institute of Metrology of Bosnia and Herzegovina and method of distribution and dissemination of accurate time and frequency in Bosnia and Herzegovina

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Abstract – **This paper describes the process of establishing National laboratory for time and frequency (t&f lab) in Institute of Metrology of Bosnia and Herzegovina (IMBIH). According to National Law of Metrology ("Official Gazette of B&H" No. 19/01), main task of IMBIH is forming National laboratories for realization of basic SI units in B&H, as well as assuring international traceability up to the highest metrology level. Few years ago, IMBIH started with activities on building metrology facilities related to measuring accurate time and frequency. Aims of this laboratory are: generating national time scale UTC (IMBIH), distribution and dissemination of accurate time and frequency, calibration of secondary reference standards and other measuring equipment. In this paper complete measuring system of time and frequency, consists of commercial primary time and frequency standard will be presented.**

Keywords - ***Universal Time Coordinated (UTC); National Time Scale; traceability of time and frequency; calibration.***

I. INTRODUCTION

Based on allocation of needs in Bosnia and Herzegovina, IMBIH strongly started with process of establishing large number of national laboratories. Till now, B&H did not have physical realization of local UTC. UTC is base for deriving legal time in B&H. The standard time common to every place in the world is UTC. With t&f lab B&H will become place where UTC standard time is. IMBIH has defined technical specifications for part of equipment which is necessary for work in laboratory for time and frequency, through procjets IPA 2007/2008 financed and supported by European Union and bilateral agreement between Government of the Republic of Slovenia and IMBIH. Specified metrology equipment will ensure full activities of IMBIH in B&H and in the International metrology organizations (EURAMET, BIPM, WELMEC, OIML etc.). Realization of mentioned activities will intensify Technical Infrastrucure in B&H, and makes Bosnia and Herzegovina much closer to European Union. The specified equipment is used by National Metrology Institutes (NMI) all over the world. Activities of mentioned laboratory will be useful for industrial subjects, telecom providers, TV stations, research organizations, calibration laboratories, airports etc.

II. DEFINITION AND REALIZATION OF SI SECOND AND HERTZ

A. *Definition of SI second and Hertz*

Experimental work, however, had already shown that an atomic standard of time, based on a transition between two energy levels of an atom or a molecule, could be realized and reproduced much more accurately. Considering that a very precise definition of the unit of time is indispensable for science and technology, today's definition of SI second is [1]-[2]:

The second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium 133 atom. This definition is valid for a cesium atom at rest at a temperature 0 K.

The SI hertz is derived unit from SI second. Hertz (Hz) is the unit of frequency defined as the number of cycles per second of a periodic phenomenon.

B. *Realization of SI second*

SI second is realized using primary laboratory standards, commercial primary standards with cesium tubes, and hydrogen masers. The most of NMI's use commercial primary standards based on cesium atoms. Primary laboratory standards are the most accurate standards in the world with accuracy better then 1 part to 10^{15}. There are 12 primary standards which contribute to reference UTC. High developed countries as USA (NIST), Germany (PTB), Italy (INRiM), Japan (NMIJ, NICT), France (BNM-SYRTE), UK (NPL) have mentioned standards. Hydrogen maser has $\pm 5\text{x}10^{-13}$ accuracy with good short term stability $\pm 1.5\text{x}10^{-12}$

for average time of one second. Today, atomic clock based on cesium is world wide used for timekeeping. Commercial cesium atomic clock has the same accuracy as hydrogen maser, but lower short term stability. Clocks in national metrology laboratory for time and frequency contribute in process of calculation reference UTC under the supervision of BIPM (Bureau des Piods et Mesures). BIPM issues monthly publication named Circular T where, differences between reference UTC and local realization of UTC in every laboratory (UTC-UTC(k)) for defined time period, is publicated. The largest contribution to calculation of reference UTC time is based on approximately 400 commercial primary cesium standards, i.e. 87.66% of all clocks, see Figure 1. All primary commercial standards are located in 68 t&f laboratories all over the world.

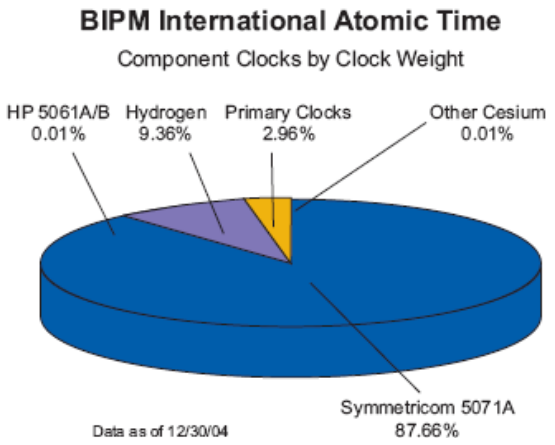

Figure 1. Contribution of all types of clocks in calculation reference UTC [3].

In the Figure 2, laboratories that have contribution for calculation of reference UTC [4], are presented.

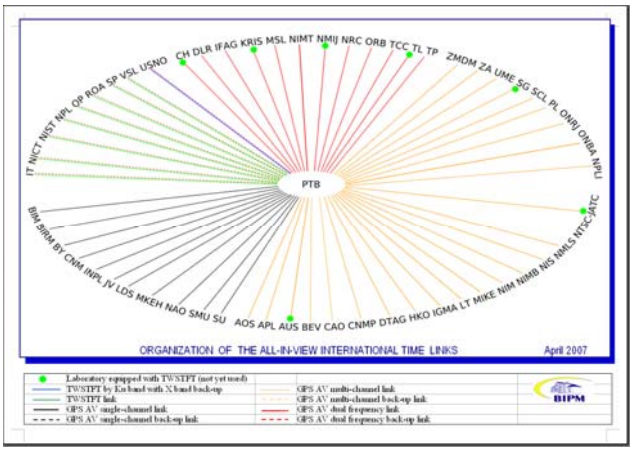

Figure 2. Organization of all in view international time links between labs.

III. NATIONAL STANDARD FOR TIME AND FREQUENCY IN BOSNIA AND HERZEGOVINA

National time scale in B&H will be based on two atomic cesium clocks. One atomic clock will be master clock (national standard), and another clock will work in free running mode and represent backup for countinuous maintaining of national time scale in B&H. Local realization of UTC in the Institute of Metrology of Bosnia and Herzegovina – UTC (IMBIH), will be realized from master clock, in combination with high resolution phase and frequency offset generator.

National standard for time and frequency in B&H is 5071 A with high performance tube, produced by Symmetricom shown in Figure 3. Technical characteristics of national standard are [5]:

- Accuracy : $\pm 5x10^{-13}$
-Long-term stability : $\leq 1.0x10^{-14}$ for 5-day averaging time.

This standard generates following values of frequencies: 100 kHz, 1 MHz, 5 MHz, 10 MHz. One pulse per second (pps) output is also available. Frequency distribution amplifier and pulse distribution amplifier are used for extending capability related to standard time and frequency outputs of atomic clock. Frequency divider is used to convert mentioned standard frequencies in pulses per second.

Figure 3. Primary commercial t&f standard in laboratory of IMBIH.

National time and frequency standard in IMBIH is calibrated by National Institute of Standards and Technology (NIST) in USA. The phase of the 5 - MHz signal from 5071A was compared with the UTC(NIST) timescale, which is an ensemble of hydrogen masers and commercial cesium beam frequency standard steered to track UTC. Some results of Allan deviations for specific average time as results of calibration are shown in table below [6] :

TABLE I. CALIBRATION DATA

Average Time (s)	*Allan Deviation*
10^{-2}	$2.91x10^{-11}$
1	$3.33x10^{-12}$
$1.28x10^{2}$	$4.455x10^{-13}$

IV. MEASUREMENT SYSTEM FOR GENERATION OF NATIONAL TIME SCALE IN B&H

Accurate measurement of time is based on US Global Positioning System (GPS). All laboratories that contribute in calculation of UTC are organized to have measurement system that is compatible with existed GPS system. US GPS consists of 24 satellites. Every satellite is equipped with two rubidium and two cesium clocks. Communication between laboratories and satellites are carried out by Pseudo Random Noise (PRN) codes which modulate carrier signal. PRN code enables recognition of each satellite in GPS constellation. There are several methods for time and frequency transfer via GPS system: one way, common view (CV), all in view (AV) GPS methods. Measurement data is comparing between atomic clocks at the GPS satellites and ground atomic clocks in laboratories.

IMBIH organized its laboratory as a measurement system consists of: two cesium atomic clocks, two dual frequency (geodetic) Global Navigation Satellite Service (GNSS) receivers and two corresponding GPS antennas, time transfer system, NTP server, time interval counter, phase comparator, frequency and pulse distribution units, frequency divider and output offset generator. Conceptual structure of measurement system is shown in Figure 4.

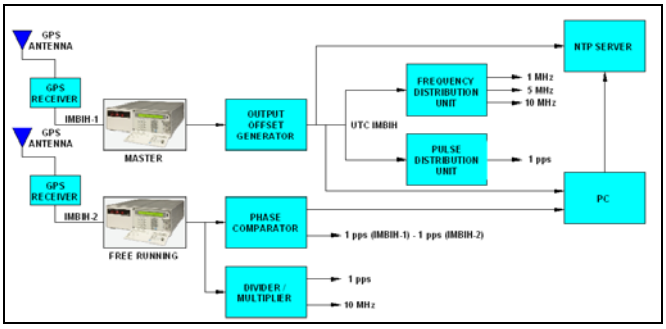

Figure 4. Conceptual structure of measurement t&f system in IMBIH

Laboratory will be connected to US GPS system and one primary laboratory which contributes in calculation of reference UTC. For mentioned purpose, laboratory will use common view GPS method for remote comparisons of atomic clocks.

As shown on Figure 4, measurement system is designed so that one atomic clock is master clock (national standard), and another clock works in free running mode and represents backup for countinuous maintaining of national time scale in B&H. Output offset generator in measurement system is used to achieve extremly high resolution standard frequency and time signals. Function of phase comparator in measurement chain is to compare time and frequency signals between each atomic clock in order to have all information about offsets among each other at any moment. Other elements in measurement chain as divider/multiplier, pulse and frequency distribution unit are mainly used for distribution different values of time and frequency signals.

V. DISSEMINATION AND DISTRIBUTION ACCURATE TIME AND FREQUENCY SIGNALS IN B&H

Dissemination in a strict metrological sense means documented comparison of traceable measurement value with known uncertainty to other measurements which are or consequently become traceable to the original measurement value. The task of dissemination of time/frequency is fundamental to the operation of NMI. US GPS system is the most common way of dissemination time signals. Other methods for dissemination of legal time are [7]-[8]:

- dissemination via radio signals;
- diseemination via telephone signals;
- dissemination using NTP servers (internet);
- dissemination via optical links etc.

When a legal time code is embedded in a transmitted radio signal, the receivers which are within the coverage of the transmitted signal can synchronize their own local clock to the transmitted legal time. The best known radio signal in Europe is DCF77 (Germany).

A legal time code also can be transmitted over the telephone network where modems are used to generate and receive the signal.

NTP servers are the most popular medium for dissemination accurate time all over the world. NTP servers are computer servers that are using the Network Time Protocol to disseminate time codes according to UTC over the Local Area Network (LAN) or Wide Area Network (WAN). Today, all personal computers synchronise their clock using NTP. Legal time dissemination using NTP servers at highest hierarchical lavel in the country, is task of NMI or appointed laboratory for time.

Dissemination of accurate time in IMBIH will be realized via NTP server. IMBIH's NTP server automatically synchronize to GPS and 1 pps and 10 MHz from master clock. Accuracy of server is 50 ns to reference UTC. That server has Stratum 1 operation via US GPS satellites. Stratum 1 means that server is directly linked (not over a network path) to a reliable source of UTC time such as GPS, NIST's radio station Fort Collins-Colorado (WWV) transmissions. In the world of NTP, stratum levels define the distance from the refrence clock. The refrence clock is a Stratum 0 device that is assumed to be accurate and has little or no delay associated with it. The refrence clock tipically synchronizes to the correct time UTC using US GPS transmissions, code division multiple access (CDMA) technology or other time signals such as WWV, DCF77 [8].

Distribution of accurate time and frequency signals will be carried out through optical cable to other interest parties by IMBIH t&f laboratory. Also, t&f laboratory will provide precise time and frequency signals to other national laboratories (laboratories for electrical quantities and length) situated in IMBIH, via optical network.

VI. CONCLUSION

This paper presents strategy of development of national laboratory for time and frequency in B&H. Measurement t&f system will be base for generation national time scale and accurate time and frequency transfer. By purchasing of national t&f standard, B&H finally achieved conditions to take and distribute accurate world time. In this way B&H will become part of world's system of accurate time distribution. Furthermore, by establishing this laboratory, IMBIH will improve metrological infrastructure of its laboratories and help lower metrological levels in B&H.

As final result, Bosnia and Herzegovina will, in soon future, have own local realization of UTC traceable to the reference UTC calculated and maintained by BIPM.

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