Timing of GSM audio connections by generating UTC(LT) traceable digital time stamps

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Abstract*—Technology for measurement of durations of GSM audio calls has been developed. Call duration was measured by using end-to-end method, making calls between two GSM terminals (Siemens MC35i). One GSM terminal was mobile and equipped with a test signal generator. Pseudo noise DTMF-like signals were used as test signals transmitted through the GSM channel. Receiving GSM terminal was connected to the PIC16F84A type microcontroller, which was used as a generator of digital time stamps at opening and closing of the GSM audio channel. Traceability of generated time stamps with UTC(LT) was assured by supplying the PIC microcontroller with pulse per second pulses (PPS) and 10 MHz clock signal from Cs clock HP5071A keeping UTC(LT) time scale. The uncertainty of generated digital time stamps was 103 µs. The obtained combined uncertainty of call duration measurement was about 100 ms. The technology developed was used for testing and verification of timing systems of GSM operators which are to meet the requirements of legal metrology.

I. INTRODUCTION

Every legal entity selling any goods or services has to measure them. The measuring instrument used for that has to be a subject to legal approval.

The product in the field of telecommunications is a telephone call. So it is necessary to prove the accuracy of the "measuring instrument" - the telecommunication network. According to the ETSI (European Telecommunications Standards Institute) standards [1], charging and billing for GSM/UMTS (Groupe Spécial Mobile / Universal Mobile Telecommunication System) calls are based on CDRs (Call Data Records) generated by MSC (Mobile Switching Centre). Usually voice calls are charged according to the call duration – the time elapsed from the MSC command *Connect* (start of the call) to the command *Release* (stop of the call). Then CDRs are transferred to the billing server which produces the bill applying proper tariff, which may be time-of-day-dependent.

Mobile operators believe their networks are accurate enough: they are synchronized, interconnected, inter-operation- and type-approval- tested; only certified and tested equipment is used. However, some organizations defending customer rights want to have operator-independent instrumentation for assessment of billing accuracy.

In some countries, authorities require independent audit of billing system of telecommunication services, which in turn requires independent (of mobile operator/service provider) assessment of accuracy of call duration metering and accuracy of time stamps of start/stop of call.

This paper presents an end-to-end, network-independent method for measurement of the duration of GSM voice calls as well as time-stamping their start and stop.

II. STRUCTURE OF THE SYSTEM - HARDWARE

The system developed for measurement of GSM calls timing consists of the two parts – mobile and laboratory subsystems (Fig. 1). Mobile subsystem consists of the GSM terminal (Siemens MC35i), the signal generator, and a portable computer (notebook). The function of the mobile subsystem is to initiate a test call. The signal generator connected to the audio input of the GSM terminal generates a pseudo noise DTMF-like (Dual-Tone MultiFrequency) signal used as a test signal to simulate a speech audio signal

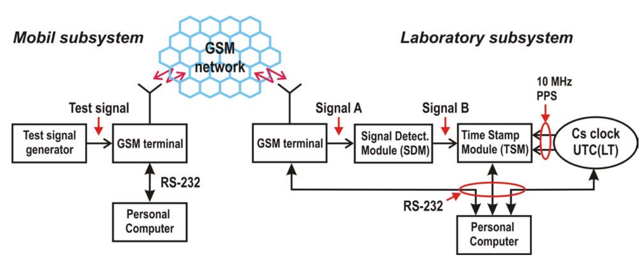

Fig.1 Structure of GSM testing system.

transmitted through the GSM channel. The laboratory subsystem was developed for receiving the test calls and generating UTC-traceable time stamps at the start and the end of the test calls. The structure of the laboratory subsystem is presented in Fig. 1. Signal A is the signal regenerated by the codec of the GSM terminal (Siemens MC35i) when pseudo noise DTMF-like signal has been received. The Signal Detection Module (SDM) transforms the signal A to the form suitable for Time Stamping Module (TSM) – the signal B (Fig. 2).

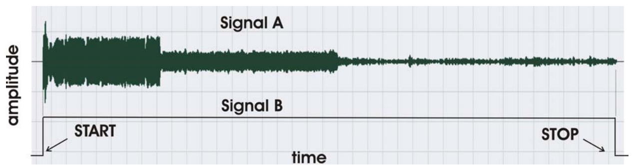

Fig.2. Signals at SDM input (Signal A) and output (Signal B).

The amplitude steps of the signal A are the result of the operation of the GSM terminal codec. The observed amplitude steps depend on the spectrum of signals composing the DTMF-like test signal.

The filter of SDM rejects all spurious signals (signalling, ringing tones) generated by the GSM terminal. The comparator of SDM generates high level (5 V) signal B when the level of the signal A exceeds 1 mV. Comparator was designed using type AD513, SF527N, and 74HC14 integrated circuits. Rise and decay times of the signal B was less than 1,5 µs. Leading and trailing edges of the signal B were used by the Time Stamp Module (TSM) for generation of the START and STOP time stamps, respectively, of the test calls. Basic scheme of the Time Stamp Module is presented in Fig.

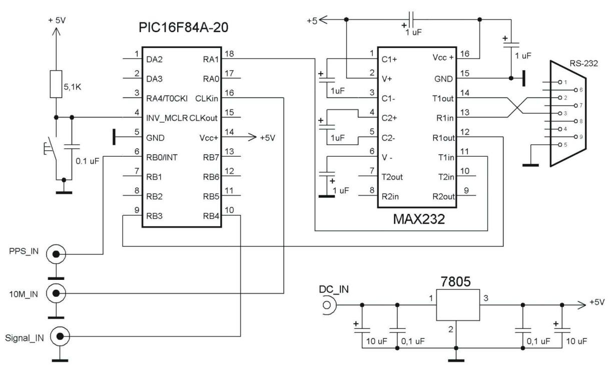

Fig.3. Circuit diagramm of the Time Stamp Module (TSM).

3. Signal B was applied to the input “Signal_IN”. 10 MHz and PPS signals from the Cs clock (HP5071A) of the Lithuanian National Time and Frequency Standard Laboratory were applied to 10M_IN and PPS_IN inputs. Lithuanian National Time and Frequency Standard Laboratory is responsible for maintenance and dissemination of the national time scale UTC(LT) as well as units of time and frequency [2].

III. OPERATION FLOW

General model of the system operation is shown on Fig. 3.

The system is operated as follows:

- all the preparations are made: the devices are connected

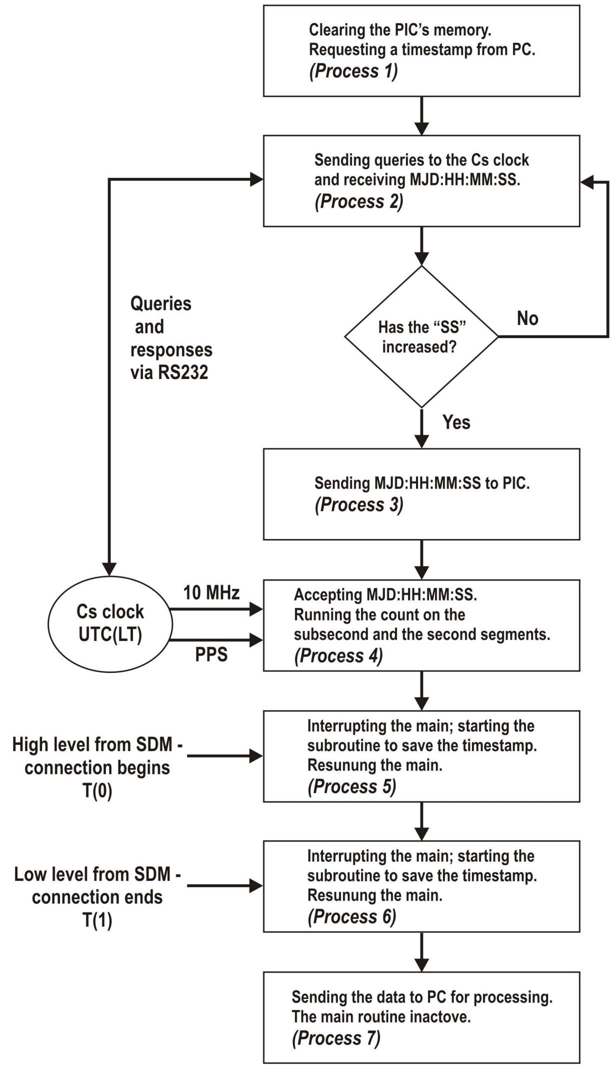

Fig.4. The flowchart of the time stamps generation.

via interface bus RS-232, BNC and other connectors; all the devices are turned on; the Visual Basic 6.0 routine for the control of PIC is started;

- a signal of low level (logical 0) is fed to the pin 4 of the PIC, and PIC is reset. Its memory used in the measurements before is cleared (see flowchart on Fig. 4). Then PIC sends the request for a timestamp to the computer (PC) ***(Process 1)***. The computer, having received the PIC’s request, starts sending its own queries to the cesium (Cs) clock every 100 ms, and the Cs clock responds with a line containing MJD:HH:MM:SS (Modified Julian day: Hours: Minutes: Seconds) ***(Process 2)***. Having received the first timestamp with the number of seconds increased, the computer sends this line in reduced form via the RS-232 bus to the PIC ***(Process 3)***. Interchange of the data is via the pin 18 for the output of the data to the computer and pin 9 for reading;

- when all the action has been performed, PIC starts implementing the cyclic part of the routine, during which it is waiting for the beginning of the test call. Note that the PIC's counter has the segment in which the time stamp as received from the computer is kept, and also the subsecond segment not shown explicitly on the flowchart. Now, with every PPS (pulse per second) coming from the Cs clock through the pin 6, the counter of the PIC nulls the subsecond segment of the time stamp retained and adds unity to the second segment. Then, counting in the subsecond segment starts: with every 256 operations of the PIC (1 operation lasts for 4 cycles of the 10 MHz signal received from the Cs clock), an increment of $4x10^{-7}x256$ s = 0.1024 ms is added ***(Process 4)***. In this way, the accuracy better than 1 ms is attained. To ensure quality of the data, PIC requests a new timestamp from the computer every 60 seconds, i. e., the cycle shown on the flowchart starts once again;
- the GSM terminal of the mobile subsystem (see Fig. 1) makes a call to the laboratory's one. The laboratory's GSM terminal starts ringing; now, both the signal of the calling tone frequency and various spurious signals are present in the laboratory circuitry. Both the calling and spurious signals are filtered out by the filter of the Signal Detection Module (SDM). As no signal (low level of signal B) is fed to the PIC, it is still in the waiting regime;
- the call is responded (the responding button is pressed on the laboratory GSM terminal). However, the filter still transmits no signal until the physical connection in the communication line takes place and the signal A appears. Now, within up to 10 µs, the filter starts feeding high level of signal B (logical 1) to the pin 10 of the PIC. The level remains high until the end of the connection;
- as a reaction to the change of the level in the pin 10 of the PIC, which marks the beginning of the connection, the main routine is interrupted, and the subroutine for the signal processing starts. The subroutine saves the present timestamp (MJD:HH:MM:SS) T(0) together with the value in the subsecond segment augmented since the last PPS received. Then, the main time-counting routine resumes ***(Process 5)***;
- when any of the GSM terminals is hanged up, the connection disrupts, and the test signal is no more transmitted to the SDM. Therefore, the SDM stops feeding high level to PIC;
- with the drop of the voltage in the pin 10, marking the end of the connection, the main routine is once again interrupted, and the subroutine once again saves the present time stamp T(1) (MJD:HH:MM:SS) as well as the value in the subsecond segment augmented since the last PPS received ***(Process 6)***;

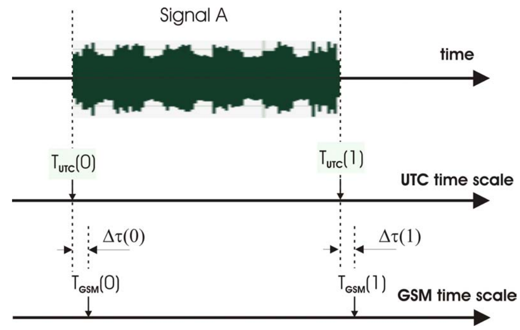

Fig.5. Time stamps generated in UTC(LT) and GSM system time scales.

- the PIC sends all the data fields necessary – the time of the beginning T(0) and the end T(1) of the connection – to the computer via the RS-232 interface bus. The PIC has finished its activity. Since that time, the routine doesn't react to any signals except for resetting ***(Process 7)***;
- the computer processes the data received.

IV. RESULTS

A. Callibration

Callibration of the GSM call testing system was done using a Creative "Sound Blaster Live! 24 bit"- based two channel signal analyzer with timing resolution better than 30 µs. The obtained uncertanty in generation of time stamps with respect to the time scale UTC(LT) was 100 µs.

B. GSM calls timing

Time stamps (T_{UTC}) generated by the system developed and the time stamps (T_{GSM}) obtained from the GSM network operator were compared (see Fig. 5). A few hundred test calls of duration 5÷22 s were made. Some results of comparison are

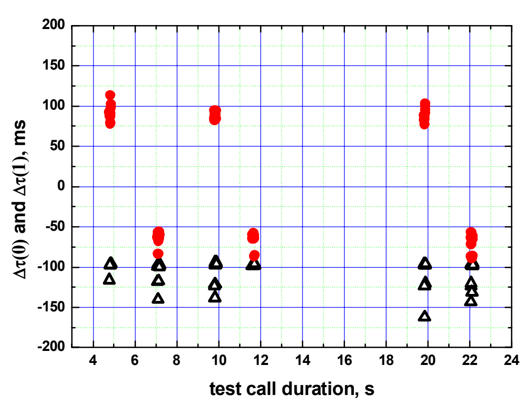

Fig.6. Differences of time stamps generated in UTC(LT) and GSM time scales. **Δ**, ● – time stamps generated at the START and STOP of the GSM calls respectively.

presented in Fig. 6. Positive $\Delta\tau$ values correspond to the delay of GSM time stamps with respect to UTC time stamps. That GSM time stamps ware generated by call STOPs initiated by laboratory GSM terminal.

Standard deviations of $\Delta\tau(0)$ and $\Delta\tau(1)$ are in the range of 2÷22 ms. The differences of mean values of generated time stamps are caused partially by the specifics of the synchronization of the GSM network timing system to the UTC(LT) time scale.

The results show good accuracy of the method and instrumentation. The system developed could be used as a GSM call timing assessment instrument.

REFERENCES

[1] ETSI TS 132 005. Universal Mobile Telecommunications System (UMTS); Telecommunication Management; Charging and billing; 3G call and event data for the Circuit Switched (CS) domain (3GPP TS 32.005 version 3.6.0 Release 1999).

[2] R. Miškinis, “Lithuanian National Time and Frequency Standard”, Proceedings of the Annual Precise Time and Time Interval (PTTI) Meeting , vol. 36, pp. 191-194, December 2004.