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**LABORATORY EXERCISE  
ON COMPLEX MEASUREMENT TASK:  
VOICE TRANSMISSION QUALITY MEASUREMENT**

The laboratory exercise dealing with voice transmission quality of service measurement in mobile networks that is being designed in Czech Technical University in Prague is described in the paper. The final experiment that is made during the exercise is based on measurement of voice quality of the GSM connection established between student's GSM terminal and remote GSM station of measuring system. The measurement is performed by means of measurement system that has been developed at the University. The remote station can work either in fully automatic mode or can be controlled via web interface. Deeper understanding of exercised topic is expected in comparison with plain simulations. On the other hand, all the exercise takes less time in comparison with excursion to telecommunication switch where similar measurement systems can be found and tested.

*Key words: voice transmission quality measurement, laboratory exercise.*

## 1. INTRODUCTION

Today's industrial measurements are far away from simple tasks when the amount of the measured quantity is transformed by almost linear or at least monotonic conversion into electrical signal that is displayed using suitable analogue or digital meter. Most of today's measurement tasks cover acquisition and processing of many input quantities that creates the result by linear or non-linear combination. Moreover, these quantities are usually not directly accessible and have to be measured indirectly. Sometimes it is necessary to monitor not only actual state of particular quantities but also their history. Algorithms that are being used for data post-processing are more and more often not purely straight-forward but contains blocks that introduce modern

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approaches of signal processing like fuzzy logic, iterative processes or predictive algorithms. Nevertheless, as exact and reliable error analysis as possible and guaranteed stability and accuracy are required for the output result.

The more complex the measurement tasks are, the more difficult is to design an effective laboratory exercise on them. There is not enough time during one exercise to introduce, in detail describe and explain, and finally measure and exercise. On the other hand, many principles and methods are to be covered by one subject that means only few or even none of tasks can be distributed over more than one exercise.

There are many approaches to solve this problem ranging from pure software demonstrations using preprogrammed tools to excursions to the field [5]. In the following text, our approach will be shown on example of complex measurement task - intrusive measurement of voice transmission quality of service in modern mobile telecommunication network.

## 2. VOICE TRANSMISSION QUALITY MEASUREMENT: COMPLEX MEASUREMENT TASK

Voice Transmission Quality of Service (VTQOS) measurement becomes an emerging task that is widely required by network operators, state and regulation authorities, technology vendors and system integrators. There are many standards and methods for VTQOS measurement [4]. The mostly used two methods are stated in ITU-T Recommendation P.861 (Perceptual Speech Quality Measurement – PSQM) [2] and in recent Recommendation P.862 (Perceptual Evaluation of Speech Quality PESQ) [3]. The measurement is performed by comparisons between original and transmitted speech sample. The speech samples have to fulfill special requirements dealing with frequency content etc. and are usually built from several male and female voices of given language. The measured impairments [1] are such as echo, overall loudness ratio, clipping, impulsive noise, psophometric noise etc. The resulting parameter is the PESQ score that is usually mapped to Mean Opinion Score (M.O.S.) reaching values between 1 (=worst) and 5 (=best). To correctly interpret results, it is recommended to acquire during measurement also additional parameters like overall transmission delay in speech channel. For mobile networks, also parameters of radio channel that is usually considered as the weakest part of the communication chain RxLev (electromagnetic field intensity) and RxQual (Bit Error Ratio for digitally modulated signals used e.g. in GSM or DECT) are acquired. This enables to find easily the reason of VTQOS decrease when it appears. From the above-mentioned short description should follow the complexity of VTQOS measurement task.

### 3. LABORATORY EXERCISE CONCEPT

The laboratory exercise on the above mentioned topic belongs to the subject “Selected Chapters of Advanced Measurements” that runs at the 5<sup>th</sup> year (9<sup>th</sup> or 10<sup>th</sup> semester). The laboratory exercise is composed of three parts: short theoretical background explanation, speech samples preparation, and practical measurements.

#### 3.1. THEORETICAL BACKGROUND EXPLANATION

The first part of the exercise is devoted to short theoretical introduction. Short tutorial text describing the needs and methods for VTQOS measurements is available for student. At the end of this text there is a short and simple quiz attached so each student can verify if he has understood the topic. The filled quiz is a mandatory item of the final report, however, it is not necessary to achieve any particular quiz results to continue in the exercise. We think that the opposite way (blocking questions in the quiz) could affect some students in a stressy way.

The complete tutorial text (except of quiz) is available on web pages of the subject. Eventually, this theoretical introduction can be performed remotely in advance.

#### 3.2. SPEECH SAMPLES PREPARATION

The next step of the exercise is preparation of speech samples. Original speech samples are available as digitally recorded files in \*.wav format. Currently used library of speech sample includes English recordings delivered by ITU together with related recommendations [2],[3] and some Czech samples acquired in audio recording studio with respect of P.830. Developed software tool (Matlab toolbox) is available to introduce a well-defined distortion of given speech sample (either default or recorded by student). The distortion types cover (multiple) echo, amplitude clipping, packet delay jitter simulation, noise introduction, frequency digital filtering etc. (See Fig.1). This is useful for verification of VTQOS standards performance: Students can generate “output” (transmitted) sample by virtue of original recording having exact knowledge about type and amount of distortion introduced. Then, influence of this distortion on the result of VTQOS algorithm can be evaluated.

We consider as a big advantage the opportunity to listen immediately to the distorted result using SoundBlaster and headphones. It enables students to evaluate speech quality perceptually in a subjective way before objective assessment by means of VTQOS methods. Some known insufficiencies of currently used VTQOS standards can be verified easily in this way.

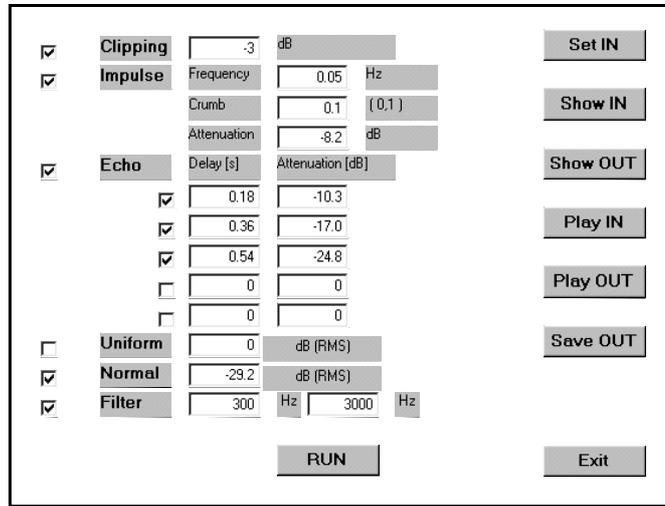


Fig. 1. The developed toolbox for defined distortion of speech samples. Impairments like clipping, impulse noise, multiple echo, uniform and/or normal noise and frequency filtering can be introduced to the input speech sample at well defined levels

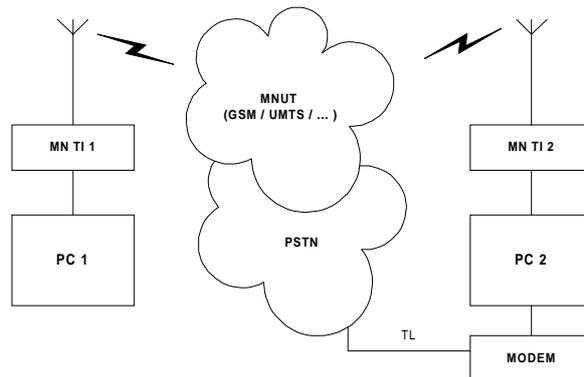


Fig. 2. Block schematics of Voice Transmission Quality of Service measurement system developed at CTU Prague. Legend: MN TI: Mobile network testing interface, PC – personal (portable) computer, PSTN – Public Switched Telephone Network, MNUT – Mobile Network under Test

### 3.3. PRACTICAL MEASUREMENTS

The final part of the exercise is the practical usage of VTQOS measurement system. The measurement is performed on the system that has been developed at the University. It is based on PC with mobile terminal attached by mean of serial line (RS232) and audio bi-directional connections. The system allows to enter input speech sample, to establish the connection between two station of the system, to transmit the sample

and acquire its received version. Finally, the transmitted and received versions are compared according to current VTQOS standards. The standards are implemented in Matlab that enables the user to experiment easily with internal algorithm settings.

The developed system is a simplified version of professional measuring systems that are commonly used by network operators. The commercially available systems offer wider range of features and also higher computing power but they are very expensive.

On the other hand, we believe that slightly simplified system is an advantage for exercise: users does not need to learn a difficult user interface of commercial system with its various settings and currently useless additional features.

Students can perform several types of measurements. The basic measurement is an intrusive measurement with standard original speech sample. The principle is to establish a connection between two (local and remote) stations of measuring system and to transmit and evaluate predefined speech sample. The evaluation is performed by remote station (called party) and only results are transmitted back to the laboratory. This procedure has to be repeated for more GSM operators (by changing the SIM modules of GSM terminal) and for more speech samples for each operator. The results are statistically processed and simple example of competitive analysis is evaluated. The results obtained by previously exercising group can be compared with the current one and the differences can be discussed (networks system improvements, different network load for different times etc.)

Another measurement is a semi-intrusive case when student uses its own speech as the original speech sample. The measurement is performed in the following way: The system establishes the connection as before but human operator (student) speaks to the microphone of local GSM terminal. This speech is both locally recorded (as wav file) and transmitted to another (remote) station, acquired there and send back as data file (either by means of data transmission via modem or via Internet). The local station then compares the transmitted and received versions.

Students are asked to prepare a final report about the exercise. It should comprise the following items:

- Exercise title, date, name of other students in the group etc.,
- Types of measurement equipment used,
- Filled in quiz (as mentioned above),
- Short description of tasks performed during speech sample preparations, subjective observations and insufficiencies of VTQOS algorithms found during this, part of the exercise,
- Measurement result of intrusive measurement of 3 GSM operators. It should include original data, statistically processed results and final comparison,
- Measurement result of semi-intrusive measurement for one call. The frequency and temporal structure of own original speech sample has to be evaluated to confirm its applicability,

- Error analysis. Based on introductory tutorial notes and on statistical analysis of the measured data, possible measurement error sources have to be estimated and the overall error should be evaluated. Tolerance ranges (non-enhanced A-uncertainty) should be found for all measurement results,
- Conclusion. It should comprise (also negative) notes about any irregularities during the measurement process, failed devices, eventual SW mistakes etc.

#### 4. FURTHER POSSIBLE IMPROVEMENTS

Several improvements should be done in the future. Our intention is to enable students to perform as many measurement tasks as possible remotely via Internet. Virtually, the complete measurement (except of own speech sample on-line transmission) could be performed remotely. This would enable students to perform tests of real network even in evening or nighttime on-line and to see how the quality is improved when the network usage/load is minimal. Unfortunately, this can not be allowed until the laboratory is equipped with test SIM modules for these purposes. In present, we have to use common SIM modules and keep their usage under control.

#### 5. CONCLUSION

Concept of complex measurement task exercise is presented. The exercise has been designed according to our previous experience that admonishes to avoid pure software demonstrations and, on the contrary, too complicated professional measurement system usage.

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